BEFORE THE
ILLINOIS POLLUTION CONTROL BOARD

DYNEGY MIDWEST GENERATION, LLC

Petitioner

v.

ILLINOIS ENVIRONMENTAL PROTECTION AGENCY

Respondent.

PCB 2024-________

NOTICE OF FILING

To:

Pollution Control Board, Attn: Clerk
100 West Randolph Street
James R. Thompson Center
Suite 11-500
Chicago, Illinois 60601-3218
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Division of Legal Counsel
Illinois Environmental Protection Agency
1021 N. Grand Avenue East
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Springfield, Illinois 62794-9276
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PLEASE TAKE NOTICE that I have today filed with the Office of the Clerk of the Pollution Control Board the attached **PETITION FOR REVIEW OF ILLINOIS ENVIRONMENTAL PROTECTION AGENCY'S NON-CONCURRENCE WITH ALTERNATIVE SOURCE DEMONSTRATION UNDER 35 ILL. ADM. CODE PART 845 AND MOTION FOR STAY**; **APPEARANCES OF JOSHUA MORE, BINA JOSHI, AND SAMUEL RASCHE**; and a **CERTIFICATE OF SERVICE**, copies of which are herewith served upon you.

/s/ *Samuel A. Rasche*
Dated: February 2, 2024

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BEFORE THE
ILLINOIS POLLUTION CONTROL BOARD

DYNEGY MIDWEST GENERATION, LLC Petitioner **v.** **ILLINOIS ENVIRONMENTAL PROTECTION AGENCY** Respondent.	**PCB 2024-________**

APPEARANCE OF JOSHUA R. MORE AND CONSENT TO E-MAIL SERVICE

I, Joshua R. More, hereby enter my appearance on behalf of DYNEGY MIDWEST GENERATION, LLC and authorize the service of documents on me by email in lieu of receiving paper documents in the above-captioned proceeding. My email address to receive service is as follows:

Joshua.More@afslaw.com

/s/ *Joshua R. More*
Joshua R. More

Dated: February 2, 2024

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BEFORE THE
ILLINOIS POLLUTION CONTROL BOARD

DYNEGY MIDWEST GENERATION, LLC Petitioner **v.** **ILLINOIS ENVIRONMENTAL PROTECTION AGENCY** Respondent.	**PCB 2024-________**

APPEARANCE OF BINA JOSHI AND CONSENT TO E-MAIL SERVICE

I, Bina Joshi, hereby enter my appearance on behalf of DYNEGY MIDWEST GENERATION, LLC and authorize the service of documents on me by email in lieu of receiving paper documents in the above-captioned proceeding. My email address to receive service is as follows:

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/s/ *Bina Joshi*
Bina Joshi

Dated: February 2, 2024

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BEFORE THE
ILLINOIS POLLUTION CONTROL BOARD

DYNEGY MIDWEST GENERATION, LLC Petitioner **v.** **ILLINOIS ENVIRONMENTAL PROTECTION AGENCY** Respondent.	**PCB 2024-________**

APPEARANCE OF SAMUEL A. RASCHE AND CONSENT TO E-MAIL SERVICE

I, Samuel A. Rasche, hereby enter my appearance on behalf of DYNEGY MIDWEST GENERATION, LLC and authorize the service of documents on me by email in lieu of receiving paper documents in the above-captioned proceeding. My email address to receive service is as follows:

Sam.Rasche@afslaw.com

/s/ *Samuel A. Rasche*
Samuel A. Rasche

Dated: February, 2024

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BEFORE THE
ILLINOIS POLLUTION CONTROL BOARD

DYNEGY MIDWEST GENERATION, LLC Petitioner **v.** **ILLINOIS ENVIRONMENTAL PROTECTION AGENCY** Respondent.	**PCB 2024-________**

PETITION FOR REVIEW OF ILLINOIS ENVIRONMENTAL PROTECTION AGENCY'S NON-CONCURRENCE WITH ALTERNATIVE SOURCE DEMONSTRATION UNDER 35 ILL. ADM. CODE PART 845 AND MOTION FOR STAY

Petitioner Dynegy Midwest Generation, LLC ("DMG" or "Petitioner"), pursuant to Sections 105.200 *et seq.* and 845.650(e) of Title 35 of the Illinois Administrative Code, 35 Ill. Adm. Code §§ 105.200 *et seq.* and § 845.650(e), appeals the final decision of the Illinois Environmental Protection Agency ("IEPA" or the "Agency") that did not concur with the Alternative Source Demonstration for the Vermilion Power Plant New East Ash Pond submitted to the Agency on December 1, 2023 (the "Vermilion ASD"). IEPA's non-concurrence is stated in a letter from IEPA Bureau of Water Groundwater Section Manager Michael Summers to DMG dated December 28, 2023, and served upon DMG on January 2, 2024, via U.S. Mail, which is attached as **Exhibit A** (the "IEPA Denial"). As detailed in Section II below, IEPA's Denial is contrary to the applicable regulations and arbitrary and capricious. For the reasons set forth in Section III below, Petitioner also requests a partial stay of Part 845 requirements as they apply to the exceedances at issue in this Petition.

In support of this Petition and Motion for Stay, DMG states as follows:

I. BACKGROUND

A. Regulatory Background

1. IEPA regulates coal combustion residuals ("CCR") surface impoundments under 35 Ill. Adm. Code. Part 845 ("Part 845").[1] Part 845 includes requirements for regular groundwater monitoring. 35 Ill. Adm. Code § 845.650.

2. If, during groundwater monitoring, one or more constituents are detected and confirmed to be in exceedance of the groundwater protection standards in Section 845.600 ("GWPS"), a series of additional steps are triggered.

3. Within 60 days after detecting an exceedance of a GWPS, an owner or operator may submit an Alternative Source Demonstration ("ASD") to IEPA demonstrating "that a source other than the CCR surface impoundment caused the contamination and the CCR surface impoundment did not contribute to the contamination, or that the exceedance of the GWPS resulted from error in sampling, analysis, statistical evaluation, natural variation in groundwater quality, or a change in the potentiometric surface and groundwater flow direction." 35 Ill. Adm. Code § 845.650(e).

4. The ASD must "include a report that contains the factual or evidentiary basis for any conclusions and a certification of accuracy by a qualified professional engineer." *Id.*

5. IEPA must send a public notice of the ASD, and members of the public may submit written comments to IEPA within 14 days of the notice. *Id.*

6. Within 30 days after receiving an ASD, IEPA must provide a written response to the owner or operator of the CCR surface impoundment either concurring or not with the ASD. If

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[1] Subsequent references in this petition to "Section 845.xxx" or "§ 845.xxx" shall be to 35 Ill. Adm. Code, Part 845, unless otherwise specified.

IEPA concurs, the owner or operator must continue groundwater monitoring, but is not required to take additional actions in connection with the identified exceedance, including initiating an assessment of corrective measures. If IEPA does not concur, the owner or operator may petition the Board for review of the non-concurrence. *Id.*

7. Other requirements are prompted in the absence of an ASD, or in the event an ASD is denied and a stay is not granted. For example, within 90 days after detecting an exceedance of a GWPS, the owner or operator of the CCR surface impoundment must initiate an assessment of corrective measures. 35 Ill. Adm. Code § 845.660(a). The owner or operator must, within 90 days of initiating its assessment of corrective measures (or up to 60 days longer if an extension is requested and granted), submit to the Agency an assessment of corrective measures. *Id.* at § 845.660(a)(2). Within a year of completing the assessment of corrective measures, an owner or operator must submit a construction permit application and corrective action plan to IEPA identifying the selected remedy. *Id* at § 845.670(b).

B. DMG's Alternative Source Demonstration

8. DMG owns and operated the now retired Vermilion Power Plant ("Vermilion") located in Vermilion County, Illinois, approximately 4 miles northeast of the Village of Oakwood. Vermilion includes the New East Ash Pond ("NEAP"), a CCR surface impoundment regulated under Part 845.

9. On October 2, 2023, groundwater monitoring at Vermilion identified the following GWPS exceedances at multiple wells (collectively, the "Vermilion Exceedances"):

a. Chloride at wells 35D and 70D (the "Chloride Exceedances");

b. Lithium at wells 35D and 70D (the "Lithium Exceedances");

c. Sulfate at well 35D (the "Sulfate Exceedance"); and

d. Total dissolved solids at well 35D (the "TDS Exceedance").[2]

10. DMG notified IEPA of its groundwater monitoring results, including the Vermilion Exceedances, placed the information in its operating record, and contracted with an environmental consultant to further investigate the cause of the GWPS exceedances. Vermilion Power Plant New East Ash Pond (NEAP); IEPA ID # W1838000002-04, Groundwater Monitoring Data and Detected Exceedances 2023 Quarter 2 (October 2, 2023), available at https://www.luminant.com/documents/ccr/il-ccr/Vermilion/2023/2023-Vermilion%20NEAP%202023%202nd%20qtr%2035%20IAC%20845%20GW%20rpt-Vermilion-New%20East%20Ash%20Pond-W1838000002%E2%80%9004.pdf.

11. On December 1, 2023, DMG submitted the Vermilion ASD to IEPA. The Vermilion ASD concluded that sources other than the NEAP were responsible for the Vermilion Exceedances. The Vermilion ASD is attached as **Exhibit B**.

12. The Vermilion ASD identified five lines of evidence to demonstrate that a source other than the NEAP caused the contamination and the NEAP is not the cause of or contributing to the Vermilion Exceedances. First, the Vermilion ASD demonstrated that the ionic composition of bedrock groundwater in the affected wells is consistent with published observations for Pennsylvanian Bedrock in the area and different from the ionic composition of NEAP porewater. **Exhibit B** at 8-10. The Vermilion ASD explained that NEAP porewater has a calcium-sulfate dominant hydrochemical composition, whereas wells 35D and 70D are sodium-chloride dominant.

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[2] DMG also detected GWPS exceedances for sulfate and TDS at a separate well. DMG concluded the NEAP may have caused or contributed to these exceedances and, therefore, did not address these exceedances in the Vermilion ASD. DMG is addressing these exceedances by taking additional steps in accordance with Part 845, including 35 Ill. Adm. Code § 845.660.

Id. at 10. Additionally, wells 35D and 70D are screened at lower elevations, and “[g]roundwater from deeper in Pennsylvanian aquifers tends to be more dominant in chloride.” *Id.* The Vermilion ASD concluded that “compliance groundwater samples have a different ionic composition than porewater and a composition relative to background that is consistent with expected changes due to screen depth, indicating that the NEAP porewater is not the source of CCR constituents detected in wells 35D or 70D.” *Id.*

13. Second, regarding the Chloride Exceedances, the Vermilion ASD demonstrated that “[c]oncentrations of chloride in the NEAP porewater are lower than those observed in the groundwater.” *Id.* at 15. Because the “maximum concentration of chloride detected in NEAP porewater . . . is lower than the minimum concentration of chloride in 35D . . . or 70D” and “median concentrations of chloride in wells 35D and 70D are 15 and 27 times greater, respectively, than the median chloride . . . in NEAP porewater[,]” the Vermilion ASD concluded that “the NEAP cannot be the source of the elevated chloride concentrations in 35D and 70D.” *Id.* at 11.

14. Third, regarding the Lithium and Chloride Exceedances, the Vermilion ASD included evidence from a bedrock solids and geochemical evaluation, described in a technical memorandum included with the ASD, which identified naturally occurring shale bedrock as the source of lithium and chloride exceedances at 35D and 70D. *Id.* at 15, Appendix A. The technical memorandum included an “evaluation of site-specific solid phase compositions and geochemical conditions, multivariate statistical analyses, and literature review of Pennsylvanian-aged shale bedrock groundwaters . . .” *Id.* at 11. For lithium, the technical memorandum explained that “[s]olid phase samples collected near compliance wells 35D and 70D contained lithium[.]” *Id.* at Appendix A, p. 9. Additional “sequential extraction procedure” analyses (which are “used to infer associations between constituents and different classes of solids”) demonstrated that “much of the

lithium in the solid phase" is associated with mica and clay minerals and x-ray diffraction "identified abundant micas and clay minerals hosted in the shale bedrock that are the source of the Lithium in Site groundwater." *Id.* at Appendix A, pp. 4,9. Regarding chloride, the technical memorandum explained that "[e]levated chloride concentrations in groundwater are observed in the region that originate from Pennsylvanian-aged shale bedrock and brine migration over time" and that advanced statistical methods, including principal component analysis, "demonstrate that groundwater geochemical signatures" from the bedrock confining unit is "distinctly different from that of the [CCR] porewater based on a combination of parameters." *Id.* at Appendix A, p. 9. Accordingly, the technical memorandum concluded that the "alternative source of lithium and chloride observed in wells 35D and 70D is the shale bedrock." *Id.*

15. Fourth, regarding the Sulfate Exceedance, the technical memorandum further demonstrated that "elevated sulfate concentrations at 35D are the result of influence from a major coal seam in the bedrock . . ." *Id.* at 12. The technical memorandum explains that the bedrock confining unit "contains a major coal seam that has been mined in the vicinity of the NEAP" and that samples of the coal previously analyzed by the Illinois State Geological Survey ("ISGS") and other parties, as well as x-ray diffraction all "indicate that the coal contains up to 10% iron sulfide." *Id.* at Appendix A, p.8. Additionally, "strong upward vertical hydraulic gradients are present within the [bedrock confining unit]" that "would cause sulfate generated from sulfide oxidation in the coal to influence the groundwater composition at 35D." *Id.* The upward hydraulic gradient is powerful enough that when the "fractured shale was penetrated" for soil boring purposes it resulted in "water geysering more than 30 feet above ground surface at an estimated flow rate of greater than 100 gallons per minute[.]" *Id.* Accordingly, the technical memorandum concluded that the

"alternative source of sulfate observed in well 35D is the coal seams within the [bedrock confining unit]." *Id.* at Appendix A, p. 9.

16. Finally, the Vermilion ASD provided evidence from isotopic analysis demonstrating that there is little to no communication between the bedrock aquifer and the overlaying Quaternary deposits (i.e. the layers on top of the bedrock). *Id.* at 14. This is further evidence that the NEAP is not the source of the exceedances in bedrock compliance wells 35D and 70D. *Id.* Prior sampling and isotopic analysis conducted by ISGS and DMG in 2002 indicated that "[g]roundwater collected from wells screened in shallow bedrock in the vicinity of the NEAP . . . had estimated ages ranging from 13,920 to 34,610 years . . . in contrast to groundwater collected [from the Quaternary deposits] which had estimated ages of less than 210 years." *Id.* at 13.. Accordingly, the Vermilion ASD concluded that "bedrock groundwater is between 13,000 and 35,000 years older than groundwater in the Quaternary deposits; and, bedrock groundwater is isolated from the groundwater in the quaternary deposits." *Id.* at 15.

17. Additionally, the Vermilion ASD explained that because "the major contributors to TDS are chloride and sulfate, [lines of evidence] that apply to chloride and sulfate also apply to TDS." *Id.*

18. For the above reasons, the Vermilion ASD concluded that the evidence demonstrated "that the [Vermilion Exceedances] were not due to the NEAP and are attributable to natural groundwater interactions with bedrock and historic coal mining." *Id.*

C. The IEPA Denial

19. On December 28, 2023, IEPA sent a letter notifying DMG of IEPA's non-concurrence with the Vermilion ASD (the "IEPA Denial"). The IEPA Denial states that IEPA "does not concur" due to three "data gaps." **Exhibit A**. The three listed data gaps according to IEPA are:

20. First, "[c]haracterization that the draw water from the bedrock is completely isolated from local groundwater flow system." ("Data Gap 1"). *Id.*

21. Second, "[n]o assessment of the interaction between bedrock groundwater and the old east pond." ("Data Gap 2"). *Id.*

22. Third, "[l]ack of analysis of the leachable metals from the CCR in the New East Ash Pond." ("Data Gap 3"). *Id.*

23. The IEPA Denial did not include any additional explanation or analysis. *Id.*

II. Discussion

24. IEPA's bases for its non-concurrence, the three "Data Gaps," are each arbitrary and capricious and not supported by IEPA's regulatory authority or the requirement set forth under Section 845.650.

A. There are no data gaps in the Vermilion ASD

25. IEPA's Denial unreasonably demands data and analysis that is not required by Section 845.650. The regulation requires only that DMG submit a "demonstration . . . that a source other than the CCR surface impoundment caused the contamination and the CCR surface impoundment did not contribute to the contamination." 35 Ill. Adm. Code § 845.650(e). In support of the demonstration, the regulations require that an ASD "include a report that contains the factual or evidentiary basis for any conclusions and a certification of accuracy by a qualified professional engineer." *Id.* The Vermilion ASD report does just that through a scientifically supported analysis that contains multiple lines of evidence and is certified by a qualified professional engineer. **Exhibit B.** *See also*, Declaration of Mindy Hahn at 2-3 (February 2, 2024), attached as **Exhibit C**.

26. Significantly, the IEPA Denial ignores a large amount of relevant data included and referenced within the Vermilion ASD that render the data referenced in the alleged "Data Gaps" unnecessary. This includes information contained in the 2021 Hydrogeologic Site Characterization

Reports. It also includes information contained within in a 2003 report by Kelron regarding regional and local hydrogeology and geochemistry in the vicinity of Vermilion (the "Kelron Report"). **Exhibit B** at 16. The Kelron Report, for example, included information regarding historical mining activity, a review of regional groundwater quality, field investigation, and an evaluation of data (including but not limited to the preparation of cross sections, the evaluation of summary statistics for the site and background wells, geochemical analysis and multivariate analysis to compare geochemical signatures). As explained further below, this existing data provides a thorough picture of the site and demonstrates that IEPA's alleged "Data Gaps" are unsupported, arbitrary, and capricious.

27. The information identified by IEPA's "Data Gaps" is not necessary to form a "factual and evidentiary basis" for the conclusions reached in an ASD. The information would not lead to a different result, and the fact the data was not submitted is inadequate to support the Agency's nonconcurrence with the Vermilion ASD.

1. "Data Gap 1"

28. "Data Gap 1" demands a "characterization that the draw water from the bedrock is completely isolated from local groundwater flow system." **Exhibit A**. On its face, it is not clear what information IEPA is seeking with "Data Gap 1," and IEPA does not provide any further explanation or specificity as to what additional data it is requesting. "Draw water from the bedrock" is itself local groundwater, and thus necessarily part of a "local groundwater flow system." **Exhibit C** at 14. Logically, the draw water then cannot be "completely isolated" from the local groundwater of which it is a part.

29. DMG assumes IEPA intended to require a characterization that the bedrock draw water is completely isolated from the geological units compromising the NEAP. Regardless, there

is no legal or technical basis for the requested characterization, nor would it change the conclusions of the Vermilion ASD.

30. The multiple lines of evidence analysis in the Vermilion ASD, discussed in detail above, provided the "factual and evidentiary basis" for the ASD's conclusions that a source other than the NEAP caused the Vermilion Exceedances and that the NEAP did not cause or contribute to the Vermilion Exceedances, as required by Section 845.650(e). **Exhibit B** at 5, 8; **Exhibit C** at 9-14. Following this approach, the Vermilion ASD reviewed and analyzed not only the hydraulic connection between groundwater containing units, but also the comparative ionic composition, chemical constituents, and age (using isotopic analysis) of NEAP porewater and groundwater in the affected wells. **Exhibit B** at 8-15. Moreover, the Vermilion ASD included additional analysis demonstrating that the Vermilion Exceedances are "attributable to natural groundwater interactions with bedrock and historical coal mining." *Id.* at 8.

31. From a technical basis, the information requested in "Data Gap 1" is both illogical and unnecessary given available information regarding site geology and groundwater flow. The NEAP is located above the bedrock. The Vermilion ASD, including a technical memorandum attached as an Appendix to the ASD, explained that groundwater within the bedrock is significantly older than the shallower groundwater that may be influenced by the NEAP, which "provides further evidence that [the bedrock groundwater system] is isolated from shallow groundwater." **Exhibit B** at Appendix A, p.8. Moreover, the technical memorandum included extensive documentation of the hydrogeologic conditions within the local bedrock. The technical memorandum cites to separate hydrogeologic reports, conducted nearly two decades apart, confirming that "strong upward vertical hydraulic gradients are present within the [bedrock confining unit]. *Id.* That is, the evidence demonstrates that groundwater flows upward from the

bedrock and that groundwater from the NEAP does not flow towards and, therefore would not influence, groundwater in the bedrock unit (including, e.g., the groundwater sampled in wells MW35D and MW70D). **Exhibit C** at 10-15. Given this existing evidence, the characterization requested in this "Data Gap" is entirely unnecessary. *Id***.** at 14-15. Were a new characterization conducted as requested through this "Data Gap" it would not change the results or conclusions of the Vermilion ASD. *Id*. at 15.

32. Thus "Data Gap 1" as written does not make logical sense, requests unnecessary information, is not required under § 845.650(e), and would not be expected change the conclusions reached in the Vermilion ASD. **Exhibit C** at 14-15. Accordingly, IEPA's use of "Data Gap 1" to support its nonconcurrence is arbitrary and capricious.

2. "Data Gap 2"

33. "Data Gap 2" demands that the Vermilion ASD should have included an "assessment of the interaction between bedrock groundwater and the old east pond." **Exhibit A**. Again, this assessment is not required by § 845.650(e). As explained above in Section II.A.1., the Vermilion ASD presented multiple lines of evidence that are more than sufficient to demonstrate that the Vermilion Exceedances "were not due to the NEAP and are attributable to natural groundwater interactions with bedrock and historic coal mining." **Exhibit B** at 15; **Exhibit C** at 13-14. This demonstration supports the Vermilion ASD's conclusions, and any additional assessment regarding the "old east pond" ("OEAP") would not alter those conclusions. **Exhibit C** at XX.

34. Moreover, available data indicated such an analysis was unnecessary and would add no value to (or change the conclusions in) the ASD. **Exhibit C** at 17. IEPA's Denial indicates that it believes this assessment was necessary because of the Agency's conclusion, based on the presentation of horizontal hydrologic gradients in a figure contained in the Vermilion ASD report,

that the OEAP is “upgradient” of the NEAP. **Exhibit A.** However, the IEPA Denial ignores the voluminous other data included in and referenced by the Vermilion ASD that provide a more complete picture of the hydrogeologic conditions at Vermilion and demonstrate that the OEAP is not “upgradient of” and would not be expected to interact with or influence the bedrock groundwater. The Vermilion ASD cites to 2021 Hydrogeologic Site Characterization Reports for both the NEAP *and* the OEAP, both of which were previously provided to IEPA through various permit applications. **Exhibit B** at 16-17. These reports plainly show that, due to significant variability in the topography of local bedrock (which is lower at the OEAP and higher at the NEAP), the upward hydraulic gradient of groundwater from the local bedrock, and the presence of wells with no exceedances between the OEAP and the wells with the Vermilion Exceedances, the NEAP and the bedrock groundwater in the monitoring wells containing the Vermilion Exceedances are not hydraulically downgradient from the OEAP. **Exhibit C** at 15-16.

35. The information requested by “Data Gap 2” is not required by Part 845, would not change the conclusions of the Vermilion ASD, and is premised on an incomplete and inaccurate review of the data presented in the Vermilion ASD. Accordingly, IEPA’s use of “Data Gap 2” to justify its nonconcurrence is arbitrary and capricious.

3. <u>“Data Gap 3”</u>

36. “Data Gap 3” demands that the Vermilion ASD should have included an “analysis of the leachable metals from the CCR in the New East Ash Pond.” **Exhibit A.** IEPA does not specify what “analysis” should be performed. However, there is no requirement in Part 845 that source characterization of CCR for an ASD include such a leachable metals analysis and IEPA’s Denial provides no justification for its demand.[3] Further, from a technical basis, the porewater

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[3] To the extent IEPA is suggesting a leach test methodology described in SW846 is required, the plain language of the rules does not require the utilization of SW846 for purposes of an ASD. While SW846 is

analysis conducted in the Vermilion ASD is a more appropriate and accurate method to characterize the NEAP source material's impact on groundwater than a leachable metals analysis. **Exhibit C** at 17-19.

37. Source characterization of the NEAP was conducted using the best scientifically available procedure. CCR porewater most accurately represents the mobile constituents associated with waste management activity within the NEAP, and is representative of the waters that could be potential contributors to groundwater observed in compliance monitoring wells. **Exhibit C** at 18-19. A leachable metals analysis would require laboratory simulations that are less direct and less appropriate for understanding the potential impact of a release because, unlike porewater, they are not representative of the actual water quality from a CCR surface impoundment that would mix with groundwater. **Exhibit C** at 17-18.

38. The IEPA Denial is not clear regarding what specific leachable metals analysis IEPA believes should have been utilized for source characterization. **Exhibit A**. However, no method would have been preferable to or provide more appropriate information than the source characterization methodology utilized for Vermilion ASD. **Exhibit C** at 17. A leachable metals analyses would have necessarily consisted of a laboratory simulation of potential leachate from material in the NEAP, while the methodology utilized for the Vermilion ASD included an analysis of actual and direct measurements of field porewater and leachate quality at the NEAP. *Id.* at 17-19.

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incorporated by reference into Part 845 by Section 845.150, the only substantive provision of Part 845 requiring analysis using SW846 is Section 845.640(e), which applies to analyzing groundwater monitoring samples under a groundwater monitoring program and is not at issue here. 35 Ill. Adm. Code § 845.640(e). The text of SW846 itself makes clear that methods in that document are not "mandatory" unless specifically specified as such by regulation. United States Environmental Protection Agency ("USEPA"), SW-846 Update V, (July 2014) at 1.

39. If source characterization of CCR at the NEAP did include a leachable metals analysis, it would not be expected to change the results of the Vermilion ASD. *Id.* at 19.

40. IEPA's denial of the Vermilion ASD based on "Data Gap 3" is accordingly arbitrary and capricious.

B. IEPA's Denial imposes practically infeasible requirements.

41. IEPA's interpretation of Section 845.650(e) is further unreasonable because the alleged "Data Gaps" demand complex sampling and analysis that cannot feasibly be completed within the timeframes contemplated by the regulations, if at all.[4] Section 845.650(e) requires owners and operators to submit an ASD within 60 days after detecting a GWPS exceedance. The regulations further require IEPA to reach a final decision within 30 days after receiving an ASD. 35 Ill Adm. Code § 845.650(e)(4).

42. "Data Gap 1" requests that DMG provide a demonstration that bedrock groundwater is "completely isolated from local groundwater flow system." **Exhibit A**. As discussed above, the Vermilion ASD already includes an evaluation of and references to analyses demonstrating the limited communication between the bedrock unit and overlaying units, as well as the upward flow of groundwater from the bedrock. To the extent IEPA is requesting that DMG provide yet another demonstration regarding the flow of groundwater to or from the bedrock, doing so is technically infeasible, particularly within the 60-day period DMG had to assemble the Vermilion ASD. To begin with, bedrock wells sampled to monitor the NEAP generally have a slow recharge/recovery rate after sampling and DMG is required to sample bedrock groundwater every 3 months under Part 845. **Exhibit D** at 1. Thus, there is no opportunity to sample the

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[4] Meanwhile, as discussed above, the IEPA Denial ignores the significant and complex sampling and analysis referenced within the Vermilion ASD that *was* conducted at the site historically and provides a fulsome understanding for hydrogeology and geochemistry at the site. **Exhibit C** at 4-9.

groundwater under the "normal" conditions that would be required to analyze its natural flow conditions. *Id*. Compiling the data necessary for such a demonstration, if even possible, would take approximately 64 weeks to complete. **Exhibit D**, Declaration of Cynthia Vodopivec at 1. There would be no reason for an owner or operator to begin such a characterization until after a GWPS exceedance is detected. Thus, even if DMG anticipated IEPA's request for this data and began a new characterization of bedrock groundwater flow at the exact moment the GWPS exceedance was detected, the characterization could not reasonably be completed until over a year *after* IEPA's deadline to reach a final decision on the Vermilion ASD (let alone DMG's deadline to submit an ASD).

43. "Data Gap 2" requests a full "assessment of the interaction between bedrock groundwater and the old east pond." **Exhibit A.** IEPA does not identify exactly what it believes this assessment should entail (as explained above in Section II.A.2., the Vermilion ASD already includes signification information regarding this issue). However, assuming such an assessment would include the installation of three new bedrock wells followed by sampling and analysis activities, this would likely take at least 54 weeks. **Exhibit D** at 1. Once again, even, if DMG initiated the assessment on the same day it detected an exceedance, it would not be completed in time to include in an ASD.

44. "Data Gap 3" requires an analysis of leachable metals from the CCR in the NEAP. **Exhibit A.** Such a demonstration, which contains scientific limitations, could take approximately 20 weeks. **Exhibit D** at 1. [5] Again, there is no ongoing regulatory requirement that DMG conduct

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[5] Undertaking the steps required to provide the information IEPA seeks through "Data Gaps" 1-3 would also be costly: collecting the information requested by "Data Gap 1" would likely cost approximately $315,000, "Data Gap 2" would cost approximately $320,000, and "Data Gap 3" would cost approximately $195,000. **Exhibit D** at 1. While cost is not a driver of actions taken for completing an ASD, as Dr. Hahn explains, accepted scientific practice is to not develop costly

such analysis, and thus there would have been no reason for DMG to begin any such assessment until a GWPS exceedance is detected. Once again, even if DMG had fully anticipated IEPA's request, it would not have been able to complete the analysis until months past the deadline to submit an ASD.

45. The data collection the IEPA Denial categorizes as "gaps" in the Vermilion ASD could not feasibly be completed before the prescribed deadline for submitting an ASD, if at all. IEPA's interpretation that Section 845.650 requires these characterizations would thus make the entire ASD provision meaningless, as it would be impossible for any owner or operator to submit a sufficient ASD.

46. Accordingly, IEPA's Denial is arbitrary and capricious and also ignores reality.

47. Furthermore, even if the data requested was required to be collected elsewhere under Part 845, there is no requirement in Section 845.650 that such data be used in connection with an ASD. Here, qualified professionals used best available information to develop an ASD within the regulatory deadline and in conformance with regulatory requirements. Certainly, additional lines of evidence could be added to the ASD analysis; however, professional judgment and practicality dictate that every possible line of evidence need not and cannot be developed. **Exhibit C** at 2-3. Doing so would take an unreasonable amount of time. Additionally, doing so is unnecessary when existing information is sufficient to support the conclusion that an alternative source caused the contamination detected and that the CCR surface impoundment at issue did not contribute to that contamination. *Id.*

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additional lines of evidence when sufficient evidence exists from other, better lines of evidence to support a conclusion. **Exhibit C** at 2-3.

III. MOTION FOR PARTIAL STAY

48. Because Part 845 does not authorize an automatic stay, DMG asks the Board to stay the requirements of Sections 845.650(d), 845.660, 845.670, and 845.680 for the Vermilion Exceedances at issue in this Petition until the later of (a) the Board's final resolution of this Petition, or (b) if this Petition is granted, IEPA's issuance of a concurrence.

A. The Board has authority to issue a stay.

49. The Board has long recognized its authority under Illinois law to issue discretionary stays. *See Community Landfill Co. and City of Morris v. IEPA*, PCB 01-48, PCB 01-49 (consol.), slip op. at 4 (Oct. 19, 2000); *see also, e.g., Ill. Power Generating Co. v. IEPA*, PCB 16-60, slip op. at 1 (Dec. 17, 2015). Section 845.650(e)(7), which authorizes a petition for review of an IEPA nonconcurrence with an ASD, "would be rendered meaningless" if the Board had no authority to stay the associated regulations. *See Id.* An IEPA nonconcurrence with an ASD triggers corrective measure requirements that must be initiated within a short timeframe, likely far before the Board reaches a final resolution of this petition.[6]

50. Further, the rules specifically contemplate that the Board may stay certain regulatory requirements pending resolution of a petition for review: "The filing of a petition for review under subsection (e)(7) does not automatically stay any requirements of this Part as to the owner or operator, including the 90-day deadline to initiate an assessment of corrective measures (see Section 845.660(a)(1))." Section 845.650(e)(7). If the Board had no authority to stay the corrective measure requirements, there would have been no need for the rules to specify that the stay is not automatic.

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[6] Section 845.660(a) requires: "The assessment of corrective measures must be initiated within 90 days after finding [of any GWPS exceedance]" and the "assessment of corrective measures must be completed and submitted to the Agency within 90 days after initiation of assessment of corrective measures . . ."

B. A partial stay is appropriate under Illinois law.

51. The Board considers four factors[7] when determining whether to grant a discretionary stay of a final Agency decision:

a. a certain and clearly ascertainable right needs protection;
b. irreparable injury will occur without injunction;
c. adequate remedy at law exists;
d. a probability of success on the merits.

PCB 16-60, slip op. at 2 (Dec. 17, 2015), citing *Community Landfill Co. and City of Morris v. IEPA*, PCB 01-48, PCB 01-49 (consol.), slip op. at 4 (Oct. 19, 2000). The Board need not find that all of these factors exist in order to grant a discretionary stay. *Id.* The Board will also consider the likelihood of environmental harm should a stay be granted. *Id.*, citing *Motor Oils Refining Co. v. IEPA*, PCB 89-116, slip op. at 2 (Aug. 31, 1989).

52. For the reasons stated in this Petition, a stay is necessary to protect DMG's right to appeal the IEPA Denial and to prevent DMG from being unlawfully and unreasonably required to comply with costly and potentially unnecessary corrective measure requirements before it is able to exercise its right to appeal and be heard by the Board. Accordingly, DMG has an ascertainable right that needs protection.

53. DMG will suffer irreparable injury if it is subject to the corrective measure requirements of Sections 845.650(d), 845.660, 845.670, and 845.680 for the Vermilion Exceedances at issue in this Petition. Compliance with these requirements would require DMG to

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[7] When reviewing a request for a discretionary stay in the context of a permit appeal or appeal of final agency decision, the Board has held that "although there are no specific standards set by the Board for issuing stays, Illinois law provides for standards under which such equitable relief is appropriate." *Motor Oils Refining Co. v. IEPA*, PCB 89-116, slip op. at 1 (Aug. 31, 1989), *citing Junkunc v. S.J. Advanced Technology & Mfg.*, 101 Ill. Dec. 671, 498 N.E.2d 1179 (Ill. App. 1 Dist. 1986).

expend resources to complete assessments of corrective measures, prepare corrective action plans and take other steps under Part 845 for alleged discharges that, as explained in detail in the Vermilion ASD and this Petition, likely never occurred. The assessments of corrective measures alone would likely cost approximately $35,000. **Exhibit D** at 1. Selecting an appropriate remedy and developing a corrective action plan could cost approximately an additional $225,000. *Id*. If DMG complied with the corrective measure requirements for the Vermilion Exceedances at the NEAP and then succeeded on the merits of this Petition, costs, as well as time and other resources, would be lost. *Id*. Thus, DMG would suffer irreparable injury.

54. DMG has no other adequate remedy at law to prevent these injuries or to contest the IEPA Denial.

55. It is also likely that DMG will succeed on the merits of this Petition. DMG has demonstrated by a preponderance of the evidence that an alternative source other than the NEAP is responsible for the Vermilion Exceedances and that the NEAP did not contribute to that contamination as evidenced through the thorough analysis of a qualified professional engineer, and DMG is prepared to demonstrate that IEPA's nonconcurrence was arbitrary and capricious and/or inconsistent with applicable laws and regulations. *See, e.g.*, **Exhibit B**; **Exhibit C**.

56. Finally, no harm to human health or the environment will result from a stay of these requirements. The Vermilion Exceedances are limited to two monitoring wells. As demonstrated in the Vermilion ASD and this Petition, the Vermilion NEAP is not the source of or contributing to the Vermilion Exceedances. Notably, the IEPA Denial does not suggest that IEPA believes the NEAP is the cause of or is contributing to the GWPS exceedances – rather, the IEPA Denial is based on alleged "data gaps." **Exhibit A**. Moreover, the corrective measure requirements of Sections 845.650(d), 845.660, 845.670, and 845.680 include an assumption that the impoundment

under assessment is at least a partial cause of the exceedances.[8] It is impossible to complete a corrective action assessment or to determine the optimal corrective action for a source that is not the cause of the exceedances, and to do so would provide no benefit to human health and the environment. Further, DMG has conducted a human health and risk assessment for the NEAP demonstrating that the "effect of the NEAP on groundwater quality in the unlithified materials and bedrock is either negligible or not present as a result of limited or no hydraulic connections." Human Health and Ecological Risk Assessment, Vermilion Generating Station, Oakwood, Illinois at ES-2 (Feb. 27, 2020), available at https://www.luminant.com/documents/ccr/il-ccr/Vermilion/2022/Vermilion%20NEAP%20Closure%20Construction%20Permit%20Application-W1838000002-04%20revised.pdf. The risk assessment further demonstrated that "[g]roundwater as a source of drinking water and/or irrigation water is not a complete exposure pathway for CCR-related constituents originating from the OEAP . . . or the NEAP.". *Id.* at 8. Lastly, DMG has been and will continue to be subject to the groundwater monitoring requirements of Section 845.650, which ensures that any changes in circumstances during the stay that could pose a risk to human health or the environment will be quickly identified and responded to in accordance with Part 845.

IV. CONCLUSION

57. For the above reasons, DMG respectfully requests that the Board stay the requirements of Sections 845.650(d), 845.660, 845.670, and 845.680 relating to the Vermilion Exceedances at issue in this Petition until the later of (a) the Board's final resolution of this Petition, or (b) if this Petition is granted, IEPA's issuance of a concurrence. Moreover, DMG

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[8] *See, e.g.*, Section 845.660(a) (". . .the owner or operator must initiate an assessment of corrective measures to prevent further releases, to remediate any releases, and to restore the affected area.").

respectfully requests that the Board grant this Petition for Review and remand to IEPA to issue a new final written response concurring with the Vermilion ASD.

Respectfully submitted,

/s/ Joshua R. More
Joshua R. More

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Attorneys for Dynegy Midwest Generating, LLC

BEFORE THE
ILLINOIS POLLUTION CONTROL BOARD

DYNEGY MIDWEST GENERATION, LLC

Petitioner

v.

ILLINOIS ENVIRONMENTAL PROTECTION AGENCY

Respondent.

PCB 2024-________

CERTIFICATE OF SERVICE

I, the undersigned, certify that on this 2nd day of February, 2024:

I have electronically served a true and correct copy of the attached Petition for Review of Illinois Environmental Protection Agency's Non-Concurrence with Alternative Source Demonstration Under 35 Ill. Admin. Code Part 845 and Motion for Stay and Appearances of Joshua R. More, Bina Joshi, and Samuel A. Rasche by electronically filing with the Clerk of the Illinois Pollution Control Board and by e-mail upon the following persons:

Pollution Control Board, Attn: Clerk
100 West Randolph Street
James R. Thompson Center
Suite 11-500
Chicago, Illinois 60601-3218
PCB.Clerks@illinois.gov

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

My e-mail address is sam.rasche@afslaw.com

The number of pages in the e-mail transmission is 370.

The e-mail transmission took place before 5:00 p.m.

/s/ Samuel A. Rasche
Samuel A. Rasche

Dated: February 2, 2024

ARENTFOX SCHIFF LLP
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Attorneys for Dynegy Midwest Generating, LLC

BEFORE THE
ILLINOIS POLLUTION CONTROL BOARD

DYNEGY MIDWEST GENERATING, LLC

Petitioner

v.

ILLINOIS ENVIRONMENTAL PROTECTION AGENCY

Respondent.

PCB 2024-________

INDEX OF EXHIBITS

Exhibit A	Letter from Michael Summers, P.G., Manager, Groundwater Section, Division of Public Water Supplies, Bureau of Water, Illinois Environmental Protection Agency to Dianna Tickner, Dynegy Midwest Generation (December 28, 2023)
Exhibit B	Ramboll, 35 I.A.C. § 845.650(e): Alternative Source Demonstration, New East Ash Pond, Vermilion Power Plant, Vermilion Illinois, IEPA ID: W1838000002-04 (December 1, 2023).
Exhibit C	Declaration of Melinda W. Hahn, PhD (February 2, 2024)
Exhibit D	Declaration of Cynthia Vodopivec on behalf of Dynegy Midwest Generation, LLC (February 2, 2024)

Exhibit A

ILLINOIS ENVIRONMENTAL PROTECTION AGENCY
1021 NORTH GRAND AVENUE EAST, P.O. BOX 19276, SPRINGFIELD, ILLINOIS 62794-9276 · (217) 782-3397
JB PRITZKER, GOVERNOR **JOHN J. KIM**, DIRECTOR

217-782-1020

December 28, 2023

Dianna Tickner
Dynegy Midwest Generation, LLC
1500 Eastport Plaza Drive
Collinsville, Illinois 62234

Re: Vermilion Power Plant East Power Plant New East Ash Pond; W1838000002-4
Alternate Source Demonstration (ASD) Submittal

Dear Mrs. Tickner:

The purpose of this correspondence is to notify you that the Illinois Environmental Protection Agency (Illinois EPA) does not concur with the Vermilion New East Ash Pond System Alternative Source Demonstration (ASD) dated December 1, 2023. The Illinois EPA does not concur due to the following data gaps:

- Characterization that the draw water from the bedrock is completely isolated from local groundwater flow system.
- No assessment of the interaction between bedrock groundwater and the old east pond. Based on Fig.1 shows to be upgradient of the New East Ash Pond.
- Lack of analysis of the leachable metals from the CCR in the New East Ash Pond.

If you have any questions, please contact: **Justin Bierwagen** Illinois EPA, Bureau of Water, Groundwater Section DPWS #13, P.O. Box 19276, Springfield, Illinois 62794-9276. If you have any questions concerning the investigation described above, please call 217-782-1020.

Sincerely,

Michael Summers, P.G.
Manager, Groundwater Section
Division of Public Water Supplies
Bureau of Water

cc: Justin Bierwagen
Lynn Dunaway
Keegan MacDonna
Records 06M

2125 S. First Street, Champaign, IL 61820 (217) 278-5800
1101 Eastport Plaza Dr., Suite 100, Collinsville, IL 62234 (618) 346-5120
9511 Harrison Street, Des Plaines, IL 60016 (847) 294-4000
595 S. State Street, Elgin, IL 60123 (847) 608-3131
2309 W. Main Street, Suite 116, Marion, IL 62959 (618) 993-7200
412 SW Washington Street, Suite D, Peoria, IL 61602 (309) 671-3022
4302 N. Main Street, Rockford, IL 61103 (815) 987-7760

Exhibit B

Luminant

Dynegy Midwest Generation, LLC
1500 Eastport Plaza Drive
Collinsville, IL 62234

December 1, 2023

Illinois Environmental Protection Agency
DWPC – Permits MC#15
Attn: 35 I.A.C. § 845.650(e) Alternative Source Demonstration Submittal
1021 North Grand Avenue East
P.O. Box 19276
Springfield, IL 62794-9276

Re: Vermilion Power Plant New East Ash Pond; IEPA ID # W1838000002-04

Dear Mr. LeCrone:

In accordance with Title 35 of the Illinois Administrative Code (35 I.A.C.) Section (§) 845.650(e), Dynegy Midwest Generation, LLC (DMG) is submitting this Alternative Source Demonstration (ASD) for exceedances observed from the Quarter 2 2023 sampling event at the Vermilion Power Plant New East Ash Pond, identified by Illinois Environmental Protection Agency (IEPA) ID No. W1838000002-04.

This ASD is being submitted within 60 days from the date of determination of an exceedance of a groundwater protection standard (GWPS) for constituents listed in 35 I.A.C. § 845.600. As required by 35 I.A.C. § 845.650 (e)(1), the ASD was placed on the facility's website within 24 hours of submittal to the agency.

One hard copy is provided with this submittal.

Sincerely,

Dianna Tickner

Dianna Tickner
Sr. Director – Decommission and Demolition

Enclosures
Alternate Source Demonstration, Quarter 2 2023, New East Ash Pond Vermilion Power Plant

Intended for
Dynegy Midwest Generation, LLC

Date
December 1, 2023

Project No.
1940103649-014

35 I.A.C. § 845.650(E): ALTERNATIVE SOURCE DEMONSTRATION

NEW EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS
IEPA ID: W1838000002-04

RAMBOLL Bright ideas. Sustainable change.

CERTIFICATIONS

I, Eric J. Tlachac, a qualified professional engineer in good standing in the State of Illinois, certify that the information in this report is accurate as of the date of my signature below. The content of this report is not to be used other than for its intended purpose and meaning, or for extrapolations beyond the interpretations contained herein.

Eric J. Tlachac

Eric J. Tlachac
Qualified Professional Engineer
062-063091
Illinois
Ramboll Americas Engineering Solutions, Inc.
Date: December 1, 2023

ERIC J. TLACHAC
062-063091

I, Brian G. Hennings, a professional geologist in good standing in the State of Illinois, certify that the information in this report is accurate as of the date of my signature below. The content of this report is not to be used other than for its intended purpose and meaning, or for extrapolations beyond the interpretations contained herein.

Brian G. Hennings
Professional Geologist
196-001482
Illinois
Ramboll Americas Engineering Solutions, Inc.
Date: December 1, 2023

BRIAN G. HENNINGS
196.001482

CONTENTS

TABLES (IN TEXT)

FIGURES (IN TEXT)

FIGURES (ATTACHED)

APPENDICES

ACRONYMS AND ABBREVIATIONS

35 I.A.C.	Title 35 of the Illinois Administrative Code
ASD	Alternative Source Demonstration
BCU	Bedrock Confining Unit
CCR	coal combustion residuals
DMG	Dynegy Midwest Generation, LLC
E001	Event 1
EPRI	Electric Power Research Institute
GMP	Groundwater Monitoring Plan
GWPS	groundwater protection standard
HCR	Hydrogeologic Site Characterization Report
ISGS	Illinois State Geological Survey
IQR	interquartile range
LOE(s)	line(s) of evidence
mg/L	milligrams per liter
Middle Fork	Middle Fork of the Vermilion River
NAVD88	North American Vertical Datum of 1988
NEAP	New East Ash Pond
PCA	principal component analysis
Ramboll	Ramboll Americas Engineering Solutions, Inc.
SEP	sequential extraction procedure
SI	surface impoundment
SSL	statistically significant level
TDS	total dissolved solids
TU	tritium units
UCU	Upper Confining Unit
UU	Upper Unit
VPP	Vermilion Power Plant

1. INTRODUCTION

Under Title 35 of the Illinois Administrative Code (35 I.A.C.) § 845.650(e), within 60 days from the date of determination of an exceedance of a groundwater protection standard (GWPS) for constituents listed in 35 I.A.C. § 845.600, an owner or operator of a coal combustion residuals (CCR) surface impoundment (SI) may complete a written demonstration that a source other than the CCR SI caused the contamination and the CCR SI did not contribute to the contamination, or that the exceedance of the GWPS resulted from error in sampling, analysis, statistical evaluation, natural variation in groundwater quality, or a change in the potentiometric surface and groundwater flow direction (Alternative Source Demonstration [ASD]).

This ASD has been prepared on behalf of Dynegy Midwest Generation, LLC (DMG) by Ramboll Americas Engineering Solutions, Inc (Ramboll), to provide pertinent information pursuant to 35 I.A.C. § 845.650(e) for the Vermilion Power Plant (VPP) New East Ash Pond (NEAP) (*i.e.,* Site) located near Oakwood, Illinois.

The most recent quarterly sampling event (Event 1 [E001]) was completed on June 29, 2023, and analytical data were received on August 3, 2023. In accordance with 35 I.A.C. § 845.610(b)(3)(C), comparison of statistically derived values with the GWPSs described in 35 I.A.C. § 845.600 to determine exceedances of the GWPS was completed by October 2, 2023, within 60 days of receipt of the analytical data (Ramboll, 2023). The statistical comparison identified the following GWPS exceedances at compliance groundwater monitoring wells:

- Chloride at wells 35D and 70D
- Lithium at wells 35D and 70D
- Sulfate at wells 35D and 70S
- Total dissolved solids (TDS) at wells 35D and 70S

Pursuant to 35 I.A.C. § 845.650(e), the lines of evidence (LOE) presented in Section 3 demonstrate that <u>sources other than the NEAP are the cause of the chloride, lithium, sulfate, and TDS GWPS exceedances at wells 35D and 70D</u> listed above and the NEAP has not contributed to the exceedances.

This ASD was completed by December 1, 2023, within 60 days of determination of the exceedances (October 2, 2023), as required by 35 I.A.C. § 845.650(e). This ASD has been completed in conformance with guidance provided in the Electric Power Research Institute (EPRI) guidance for development of ASDs at CCR sites (EPRI, 2017), and the United States Environmental Protection Agency (USEPA)'s Solid Waste Disposal Facility Criteria: Technical Manual (USEPA, 1993).

<u>Sulfate and TDS GWPS exceedances at well 70S</u> will be addressed in accordance with 35 I.A.C. § 845.660.

2. BACKGROUND

2.1 Site Location and Description

The former VPP is located four miles northeast of the Village of Oakwood in Vermilion County. The NEAP lies in the bottomlands of the Middle Fork of the Vermilion River (Middle Fork) and is bordered to the west by bluffs, to the south by unimproved DMG land, and to the north and east by the Middle Fork. Several underground coal mines and one surface mine were historically operated both beneath the NEAP and in the vicinity of the VPP.

2.2 Description of New East Ash Pond CCR Unit

The NEAP is a 29-acre inactive, unlined CCR SI constructed overtop a thick shale formation using berms constructed with a low-permeability clay core and cutoff walls keyed into the underlying shale formation.

The original East Ash Pond (1989 pond footprint) was constructed in 1989 and expanded in 2002 to form the present-day NEAP. The 1989 pond footprint was built overtop a thick shale formation which is greater than 80 feet thick in the vicinity of the ash ponds. The earthen berms on the north, east, and south sides of the 1989 pond footprint were constructed with a low-permeability clay core and cutoff walls keyed into the underlying shale formation. The cutoff walls extended approximately 8 feet into the underlying shale. A natural earthen bluff composed of low-permeability native clays formed the west side of the 1989 pond footprint.

New berms were constructed to expand the capacity of the 1989 pond footprint in 2002, forming the footprint of the present-day NEAP. The new berms raised the height of the original berms and were constructed with clay liners keyed into the underlying clay core. A cutoff trench backfilled with low permeability fill was placed along the western side slope of the enlarged NEAP. The low-permeability materials surrounding the footprint of the present-day NEAP form the existing containment system. The secondary pond was not expanded or modified as part of the 2002 NEAP expansion. The VPP ceased operations in 2011 when the power plant was retired.

2.3 Geology and Hydrogeology

2.3.1 Site Hydrogeology

Significant site investigation has been completed at the VPP to fully characterize the geology, hydrogeology, and groundwater quality as provided in the October 2021 operating permit application (Geosyntec, 2021), the January 2022 construction permit application (Geosyntec, 2022), and the Hydrogeologic Site Characterization Report (HCR; Ramboll, 2021a). These materials are incorporated herein. A site conceptual model has been developed and is discussed below.

In addition to the CCRs present in the NEAP, there are three different types of unlithified material present above the bedrock, which were categorized into hydrostratigraphic units in this report as follows:

- Upper Unit (UU): includes mixed Quaternary alluvial deposits of the Cahokia Alluvium described as sand with occasional layers of silty clay. The alluvial sand is generally a fine to medium sand that contains silts, clays, and gravels in varying amounts. This unit is present outside of the NEAP and in the bottomlands of the Middle Fork.

- Upper Confining Unit (UCU): consists of predominantly low permeability silty and clayey diamictons (glacial till) of the Wedron Formation with intermittent sand layers and lenses. This unit is present outside of the NEAP and along the western bluff of the Middle Fork.
- Bedrock Confining Unit (BCU): lowermost unit identified at the site and underlies all unlithified deposits. This unit occurs within Pennsylvanian shale which is the uppermost lithified unit at the Site.

None of the hydrostratigraphic units described above have been identified as an aquifer. However, the Upper Unit and BCU have been identified as potential migration pathways (PMPs).

Groundwater flow direction and gradients toward the Middle Fork have not changed significantly since the hydrogeologic study of the NEAP was completed in 2003 (Ramboll, 2021a; Kelron, 2003), and recent data supports the existing conceptual site model. A bedrock potentiometric surface map for June 19, 2023, is presented in Figure 1.

2.3.2 Regional Bedrock Geology

Regional investigations of the Illinois Basin have identified bedrock (specifically brines within the bedrock formations) as a source of chloride in groundwater (Kelley et al, 2012; Panno et al, 2018). Studies by Cartwright (1970) and Siegel (1989) indicate that groundwater migrates toward the center of the Illinois Basin and discharges upward through overlying confining units. The "Saline groundwater and brines can be brought near or to the land surface by natural conditions, such as migrating up prominent fractures and/or faults in bedrock, or by anthropogenic activities, such as exploration for and exploitation of petroleum. The mixing of upward-migrating saline groundwater with fresh groundwater from shallow aquifers can make groundwater from private wells undrinkable and can present a very expensive problem for municipalities (Panno and Hackley, 2010). Illinois State Geological Survey reporting includes 31 chloride results from available water samples (including some samples from VPP) which range from 2.1 to 30,269 milligrams per liter (mg/L) with mean value of 1,689 mg/L and median of 13 mg/L (Illinois State Geological Survey [ISGS] 2002). The report also concludes that water from the wells completed in shale contained higher concentrations of aluminum, barium, bromide, boron, chloride, fluoride, iron, lithium, potassium, sodium, and strontium. Tritium and carbon-14 age dating has demonstrated that groundwater from the bedrock is significantly older than that from the shallow Quaternary deposits (Kelron, 2003; ISGS, 2002).

2.4 Groundwater and NEAP Monitoring

The monitoring system for the NEAP was established in the Groundwater Monitoring Plan (GMP; Ramboll, 2021b) and consists of monitoring wells installed in the UU, UCU, and BCU, including background monitoring wells 10 and 22, located west of the NEAP, and compliance monitoring wells 16A, 16B, 35S, 35D, 70S, 70D, 71S and 71D (Figure 1). NED1 (installed in CCR) is used to collect porewater samples and monitor water levels within the NEAP.

3. LINES OF EVIDENCE THAT POTENTIAL GROUNDWATER PROTECTION STANDARD EXCEEDANCES ARE NOT RELATED TO THE NEAP

As allowed by 35 I.A.C. § 845.650(e), this ASD demonstrates that sources other than the NEAP (the CCR unit) caused the exceedances at 35D (chloride, lithium, sulfate, and TDS) and 70D (chloride and lithium) and the NEAP did not contribute to the exceedances. Specifically, the following LOEs conclude that the chloride and lithium exceedances at 35D and 70D are due to groundwater interactions with the bedrock, and that the sulfate exceedance at 35D is due to influence from historic coal mining activities. LOEs supporting this ASD include the following:

1. The ionic composition of bedrock groundwater is different than the ionic composition of porewater and consistent with published observations for Pennsylvanian Bedrock.
2. Concentrations of chloride in the NEAP porewater are lower than those observed in the groundwater.
3. A bedrock solids and geochemical evaluation identified naturally occurring shales as the source of lithium and chloride exceedances at 35D and 70D.
4. A bedrock solids and geochemical evaluation identified naturally occurring coal seams as the source of the sulfate exceedance at 35D due to regional upward vertical hydraulic gradients in the shale bedrock.
5. Isotopic analysis of groundwater from the bedrock and overlying Quaternary deposits indicate that bedrock groundwater is between 13,000 and 35,000 years older than groundwater in the Quaternary deposits; and bedrock groundwater is isolated from the groundwater in the quaternary deposits.

These LOEs are described and supported in greater detail below.

Since the major contributors to TDS are chloride and sulfate at 70D and 35D (respectively), the LOEs that apply to chloride and sulfate also apply to TDS. Figure A (on the following page) shows boxplots summarizing the relative contribution of each major ion to TDS in groundwater from wells 35D and 70D since 2021. Box plots graphically represent the range of a given dataset using lines to construct a box where the lower line, midline, and upper line of the box represent the values of the first quartile, median, and third quartile values, respectively. The minimum and maximum values of the dataset (excluding outliers) are illustrated by whisker lines extending beyond the first and third quartiles of (*i.e.,* below and above) the box plot. The interquartile range (IQR) is the distance between the first and third quartiles. Outliers (values that are at least 1.5 times the IQR away from the edges of the box) are represented by single points plotted outside of the range of the whiskers. Figure A shows that chloride has the greatest contribution to TDS concentrations at 70D (median of 42 percent) and sulfate has the greatest contribution to TDS at 35D (median of 42 percent).

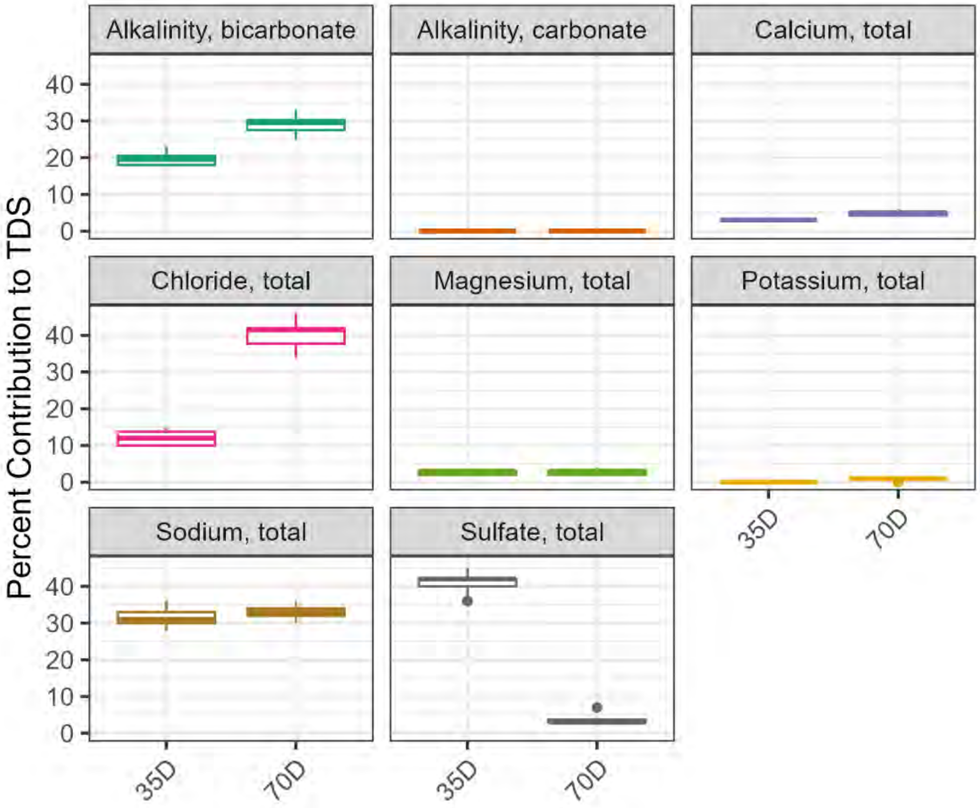

Figure A. Contribution of each major ion to TDS at wells 35D and 70D.

3.1 LOE #1: The Ionic Composition of Bedrock Groundwater is Different Than the Ionic Composition of Porewater and Consistent with Published Observations for Pennsylvanian Bedrock

Piper diagrams graphically represent ionic composition of aqueous solutions. A Piper diagram displays the position of water samples with respect to their major cation and anion content on the two lower triangular portions of the diagram, providing the information which, when combined on the central, diamond-shaped portion of the diagram, identify composition categories or groupings (hydrochemical facies). Figure B below is a Piper diagram that displays the ionic composition of samples collected from the bedrock background and bedrock compliance wells associated with the NEAP (sampled June 20 and 29, 2023), and porewater sampling location associated with the NEAP (sampled August 17, 2021).

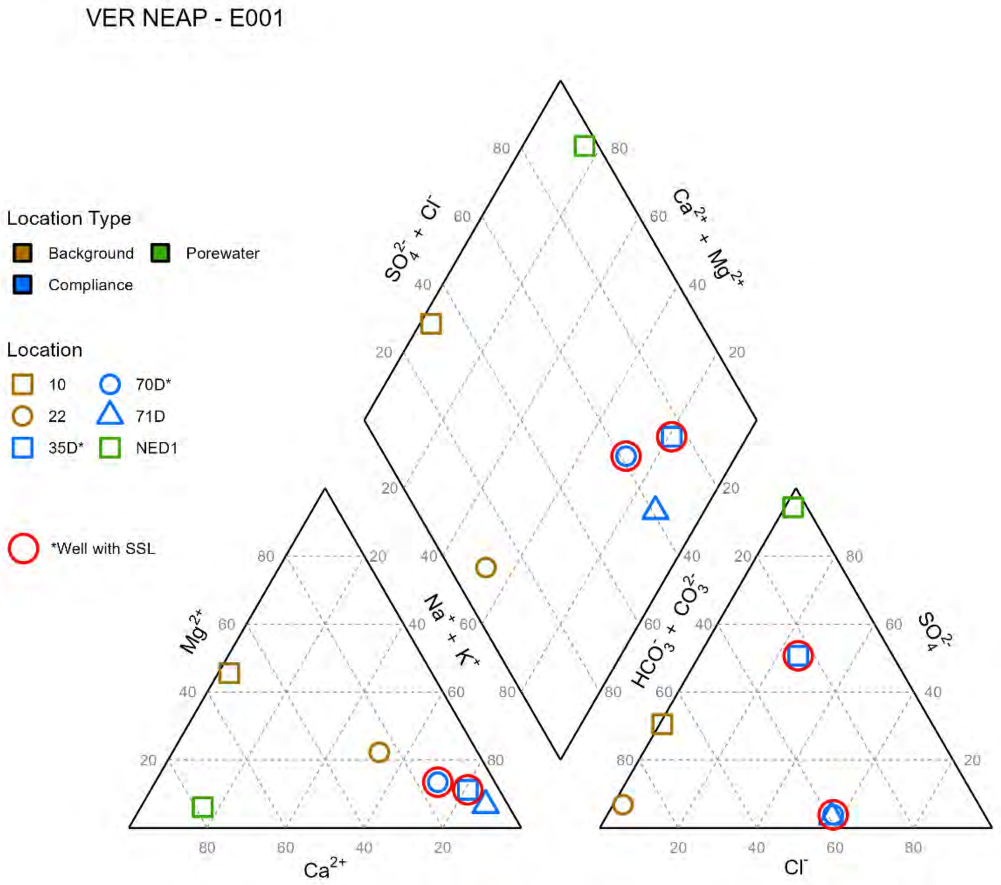

Figure B. Piper Diagram. Shows ionic composition of samples of bedrock groundwater (collected June 20 and 29, 2023) and porewater associated with the NEAP (collected on August 17, 2021).

It is evident from the piper diagram (Figure B) that porewater from the NEAP (green symbol) is primarily in the calcium-sulfate hydrochemical facies, while the bedrock groundwater samples (blue symbols) are in the sodium-chloride hydrochemical facies. The background BCU sample (brown symbol) is in the sodium-bicarbonate hydrochemical facies. The background BCU sample is collected from well 22, which is screened at from 556 to 576 feet North American Vertical Datum 1988 (NAVD88), and wells 35D and 70D are screened at lower elevations (536 to 546 feet NAVD88 and 541 to 551 feet NAVD88, respectively). Groundwater from deeper in Pennsylvanian aquifers tends to be more dominant in chloride, and groundwater may change from a sodium-bicarbonate to a sodium-chloride facies over small changes in depth (Lloyd and Lyke 1995). Therefore, compliance groundwater samples have a different ionic composition than porewater and a composition relative to background that is consistent with expected changes due to screen depth, indicating that NEAP porewater is not the source of CCR constituents detected in wells 35D or 70D.

3.2 LOE #2: Concentrations of Chloride in the NEAP Porewater are Lower than Those Observed in the Groundwater

A box plot of chloride concentrations in compliance monitoring wells 35D and 70D and porewater well NED1 is provided in Figure C on the following page. Chloride concentrations are lower in

NEAP porewater samples[1] collected during 2021 than in compliance groundwater samples collected from wells 35D and 70D from 2021 to 2023. The maximum concentration of chloride detected in NEAP porewater (44 mg/L) is lower than the minimum concentration of chloride in 35D (199 mg/L) or 70D (317 mg/L). In addition, median concentrations of chloride in wells 35D and 70D are 15 and 27 times greater, respectively, than the median chloride of 25 mg/L in NEAP porewater. Therefore, the NEAP cannot be the source of the elevated chloride concentrations observed in 35D and 70D.

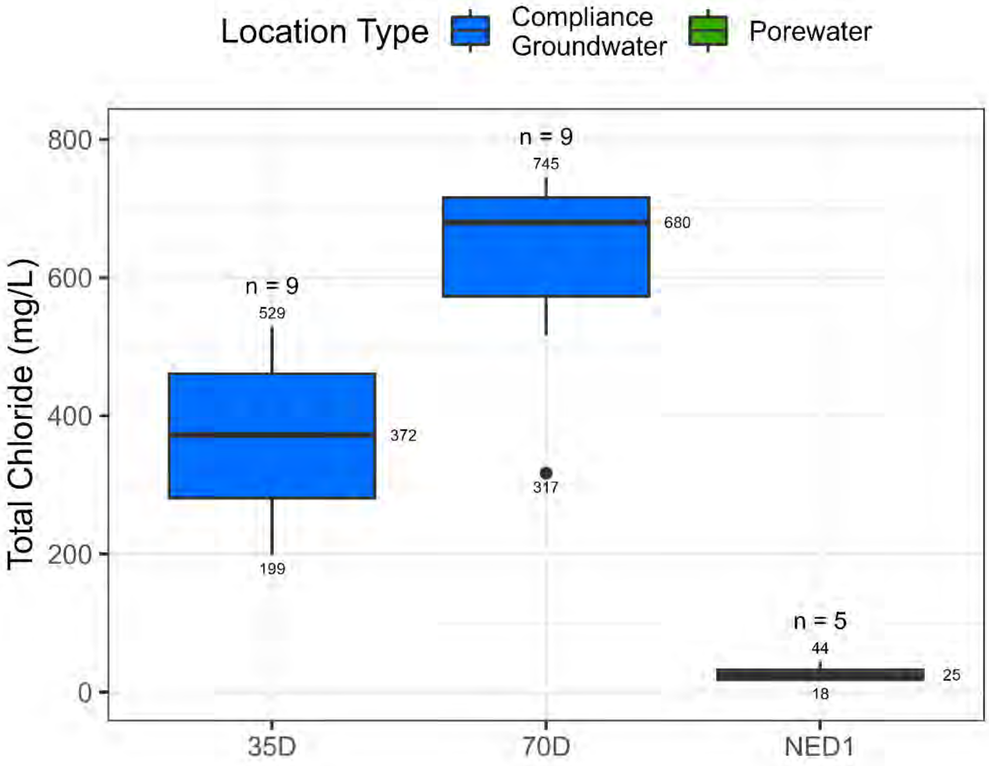

Figure C. Chloride Box Plot. The sample size (n), maximum, median, and minimum values are noted.

3.3 LOE #3: A Bedrock Solids and Geochemical Evaluation Identified Naturally Occurring Shales as the Source of Lithium and Chloride Exceedances at 35D and 70D

Appendix A presents the results of additional analysis performed in 2023 by Geosyntec. Their evaluation of site-specific solid phase compositions and geochemical conditions, multivariate statistical analyses, and literature review of Pennsylvanian-aged shale bedrock groundwaters identified naturally occurring lithium and chloride associated with shales as the alternative source of these constituents to the groundwater at 35D and 70D based on the following observations:

---

[1] CCR porewater most accurately represents the mobile constituents associated with the waste management activity within the CCR SI (EPRI, 2017). The composition of CCR porewater accumulated at the base of the CCR unit, which is derived from, and represents contact with, CCR material above and around the well screen, is the truest representation of mobile constituents throughout the CCR SI.

- Sequential extraction procedure (SEP) analyses demonstrated that much of the lithium in the solid phase is associated with the fractions which correlate to primary minerals such as micas and clay minerals, as well as the fractions associated with sulfides and oxide minerals.
- Geochemical conditions in the groundwater support desorption or dissolution of the sulfide and iron oxide mineral phases that host lithium.
- X-ray diffraction confirmed the presence of abundant micas and clay minerals, which host native lithium, in the shale bedrock.
- Groundwater chloride concentrations observed in Pennsylvanian-age shale bedrock aquifers are comparable to or higher than those observed at wells 35D and 70D.
- Principal component analysis (PCA) shows that BCU well groundwater is distinct from CCR porewater.

3.4 LOE #4: A Bedrock Solids and Geochemical Evaluation Identified Naturally Occurring Coal Seams as the Source of the Sulfate Exceedance at 35D Due to Regional Upward Vertical Hydraulic Gradients in the Shale Bedrock

Appendix A presents an evaluation of the geochemistry at 35D in the context of previously reported site conditions. This data demonstrates that elevated sulfate concentrations at 35D are the result of influence from a major coal seam in the bedrock based on the following observations:

- The coal seam mined near the site has been previously characterized and contains both iron sulfide minerals and siderite (FeCO3), which is evidence of rapid oxidation of the iron sulfide minerals.
- The groundwater chemistry at 35D suggests that siderite and the iron oxide mineral ferrihydrite are in a state of dynamic equilibrium, consistent with weathering of pyrite to siderite to ferrihydrite.
- Oxidation of sulfide minerals releases sulfate to the groundwater.
- Strong upward groundwater hydraulic gradients are present within the bedrock that provide hydraulic connection between the coal seam the bedrock that well 35D is screened.

3.5 LOE #5: Isotopic Analysis of Groundwater from the Bedrock and Overlying Quaternary Deposits Indicate that Bedrock Groundwater is Between 13,000 and 35,000 years Older Than Groundwater in the Quaternary Deposits; and, Bedrock Groundwater is Isolated from the Groundwater in the Quaternary Deposits

In 2002 ISGS and Dynegy collected groundwater samples from 8 monitoring wells and tested the samples for carbon-14 and hydrogen-3 (tritium) (ISGS, 2002). Six of the monitoring wells (25, 26, 27, 28, 29, and 30) were located adjacent to the NEAP (Figure 2). Wells 26 and 28 had well screens that intersected Quaternary deposits of the UU and the remaining wells were screened in shallow shale bedrock. Results of the testing are presented in Table 11 of the ISGS report included below as Table A and on Figure 2.

Table A. Isotopic Data from ISGS Sampled Wells (Table 11 from ISGS, 2002)

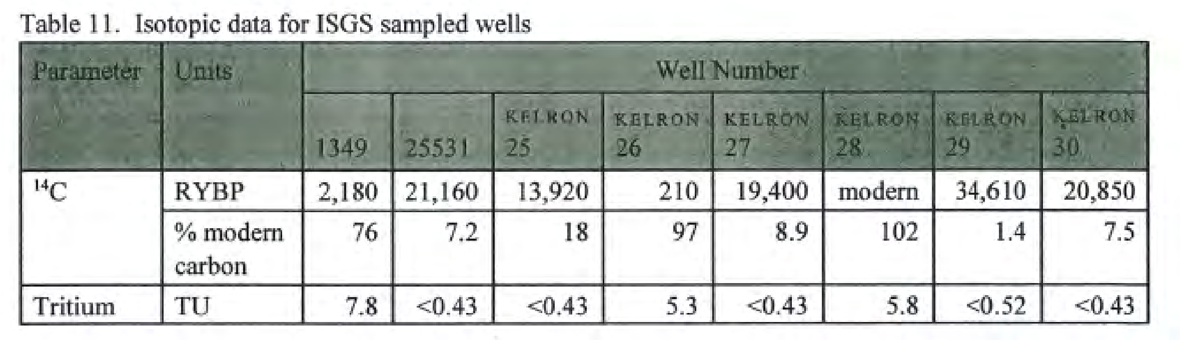

Table 11. Isotopic data for ISGS sampled wells

Parameter	Units	Well Number							
		1349	25531	KELRON 25	KELRON 26	KELRON 27	KELRON 28	KELRON 29	KELRON 30
^{14}C	RYBP	2,180	21,160	13,920	210	19,400	modern	34,610	20,850
	% modern carbon	76	7.2	18	97	8.9	102	1.4	7.5
Tritium	TU	7.8	<0.43	<0.43	5.3	<0.43	5.8	<0.52	<0.43

^{14}C = carbon-14

RYBP = Radiocarbon Years Before Present

TU = tritium units

Tritium is generated in the atmosphere and decays in the isolated subsurface. Water with tritium concentrations greater than 5 tritium units (TU) is considered to be recent, while water with nondetectable tritium concentrations is considered to be greater than 50 years old (ISGS, 2002). Groundwater collected from shallow Quaternary deposits is recent (TU>5), while groundwater from the shallow bedrock is older (no tritium detected). The tritium results are consistent with the carbon-14 results, which indicate that the shallow bedrock wells contain an inorganic carbon signature substantially older than that from wells screened in the Quaternary deposits. Groundwater collected from wells screened in shallow bedrock in the vicinity of the NEAP (wells 25, 27, 29, and 30) had estimated ages ranging from 13,920 to 34,610 years based on carbon-14 age dating. This is in contrast to groundwater collected from wells 26 and 28 (screened in the Quaternary deposits) which had estimated ages of less than 210 years. These results indicated to ISGS that the wells that "draw water from the bedrock are either only slightly connected to or completely isolated from the local groundwater flow system [overlying Quaternary deposits]".

In addition to the spatial location of the wells tested for carbon-14 and tritium relative to the NEAP, the elevations of the well screens and lithology of the age dated wells overlap with the well screen elevations and lithology of wells 35D and 70D which contain the GWPS exceedances (Table B) with the exception of MW30, which is screened at a lower elevation than all of the other wells.

Table B. Summary of Bedrock Well Screen Elevations and Lithology

Well ID	Screen Elevation (feet NAVD88)	Lithology
MW35D – exceedance well	546 to 536	shale bedrock
MW70D – exceedance well	550 to 540	shale bedrock
MW25	560 to 540	shale bedrock
MW27	557 to 537	shale bedrock
MW29	558 to 538	shale bedrock
MW30	519 to 499	shale bedrock

This data demonstrates that bedrock groundwater in the vicinity of the NEAP is isolated from the overlying Quaternary deposits and the NEAP is not the source of exceedances to the GWPS in bedrock compliance wells 35D and 70D.

4. CONCLUSIONS

Based on these five LOEs, it has been demonstrated that the NEAP is not the source of the chloride, lithium, sulfate, and TDS GWPS exceedances in wells 35D and 70D and has not contributed to exceedances identified during the first quarterly sampling event. The chloride and lithium exceedances are due to groundwater interactions with the bedrock, and the sulfate exceedance is due to influence from historic coal mining activities. Because the major contributors to TDS are chloride and sulfate, LOEs that apply to chloride and sulfate also apply to TDS.

1. The ionic composition of bedrock groundwater is different than the ionic composition of porewater and consistent with published observations for Pennsylvanian Bedrock.
2. Concentrations of chloride in the NEAP porewater are lower than those observed in the groundwater.
3. A bedrock solids and geochemical evaluation identified naturally occurring shales as the source of lithium and chloride exceedances at 35D and 70D.
4. A bedrock solids and geochemical evaluation identified naturally occurring coal seams as the source of the sulfate exceedance at 35D due to regional upward vertical hydraulic gradients in the shale bedrock.
5. Isotopic analysis of groundwater from the bedrock and overlying Quaternary deposits indicate that bedrock groundwater is between 13,000 and 35,000 years older than groundwater in the Quaternary deposits; and, bedrock groundwater is isolated from the groundwater in the quaternary deposits.

This information serves as the written ASD prepared in accordance with 35 I.A.C. § 845.650(e), demonstrating that the chloride, lithium, sulfate, and TDS exceedances observed at wells 35D and 70D during the first quarterly sampling event were not due to the NEAP and are attributable to natural groundwater interactions with bedrock and historic coal mining. Therefore, assessment of corrective measures is not required for these constituents at the NEAP.

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FIGURES

Electronic Filing: Received, Clerk's Office 02/02/2024 **PCB 2024-053**

COMPLIANCE MONITORING WELL

BACKGROUND MONITORING WELL

PORE WATER WELL

MONITORING WELL

GROUNDWATER ELEVATION CONTOUR (10-FT CONTOUR INTERVAL, NAVD88)

INFERRED GROUNDWATER ELEVATION CONTOUR

GROUNDWATER FLOW DIRECTION

REGULATED UNIT (SUBJECT UNIT)

SITE FEATURE

PROPERTY BOUNDARY

NOTES:
1. ELEVATIONS IN PARENTHESES WERE NOT USED FOR CONTOURING.
2. ELEVATIONS IN BRACKETS WERE OBTAINED OUTSIDE OF THE 24 HOUR PERIOD FROM INITIATION OF DEPTH TO GROUNDWATER MEASUREMENTS BUT WITHIN THE SAME SAMPLING EVENT.
3. ELEVATION CONTOURS SHOWN IN FEET, NORTH AMERICAN VERTICAL DATUM OF 1988

0 150 300
Feet

POTENTIOMETRIC SURFACE MAP
JUNE 19, 2023

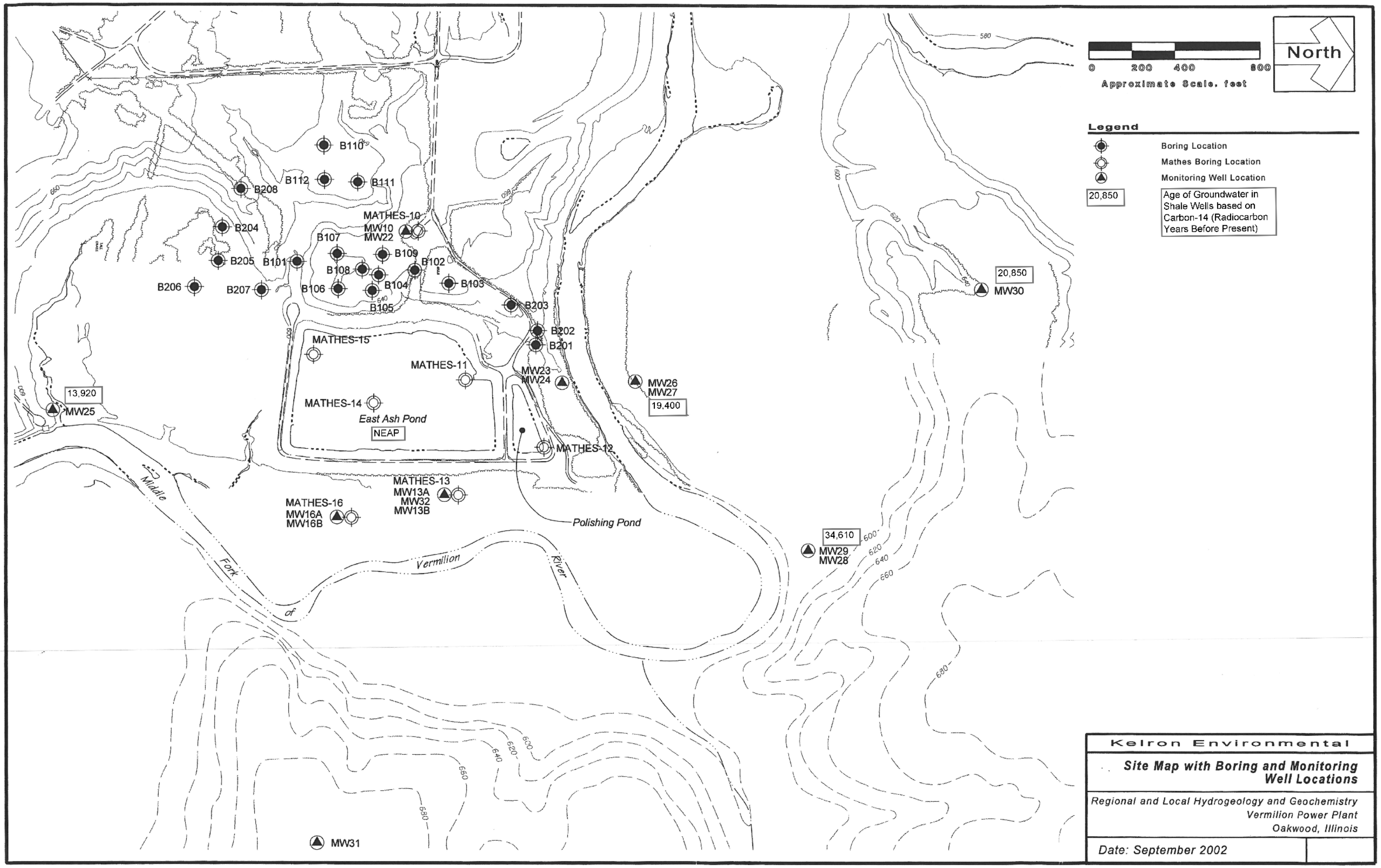
ALTERNATIVE SOURCE DEMONSTRATION
NEW EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

FIGURE 1

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

Y:\Mapping\Projects\22\2285\MXD\Alt_Source_Dem\Vermilion\NEAP_912\E001\Figure 1_VER 912 NEAP Pot Surface 20230619.mxd

PROJECT: 169000XXXX | DATED: 11/28/2023 | DESIGNER: GALARNMC



MONITORING WELL LOCATION MAP WITH RESULTS OF CARBON-14 AGE DATING

ALTERNATIVE SOURCE DEMONSTRATION
NEW EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

FIGURE 2

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

Service Layer Credits:

Y:\Mapping\Projects\22\2285\MXD\Alt_Source_Dem\Vermilion\NEAP_912\E001\Figure 2. Monitoring Well Location Map Carbon14.mxd

PROJECT: 169000XXXX | DATED: 11/28/2023 | DESIGNER: GALARNMC

APPENDICES

APPENDIX A

GEOSYNTEC CONSULTANTS, 2023. TECHNICAL MEMORANDUM: EVALUATION OF ALTERNATIVE SOURCES WITHIN AQUIFER SOLIDS, VERMILION POWER PLANT - NEW EAST ASH POND. OCTOBER 26, 2023.

Geosyntec consultants

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Worthington, Ohio 43085
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TECHNICAL MEMORANDUM

Date: November 30, 2023

To: Brian Voelker, Dynegy Midwest Generation, LLC

Copies to: Stu Cravens and Phil Morris, Dynegy Midwest Generation, LLC
Eric Tlachac and Brian Hennings, Ramboll

From: Allison Kreinberg and Ryan Fimmen, PhD, Geosyntec Consultants

Subject: Evaluation of Alternative Sources within Bedrock Solids
Vermilion Power Plant – New East Ash Pond

This document serves as an Appendix to the December 1, 2023, Alternative Source Demonstration (ASD) for the Vermilion Power Plant New East Ash Pond (NEAP) (Site) for the Quarter 2 2023 sampling event completed to fulfill the requirements of Title 35 of the Illinois Administrative Code (35 I.A.C.) § 845.650(e) (VER NEAP E001 ASD). A previous Evaluation of Potential Groundwater Protection Standard (GWPS) Exceedances prepared by Ramboll Americas Engineering Solutions, Inc. (Ramboll) in January 2022 concluded that the potential GWPS exceedances of chloride, lithium, and total dissolved solids (TDS) at downgradient monitoring wells 35D and 70D could be attributed to sources other than the NEAP (Ramboll 2022). Geosyntec Consultants, Inc. (Geosyntec) has completed a review of geochemical and site conditions at the Site to evaluate the influence of the solid-phase mineralogy and geochemistry of the bedrock confining unit potential migration pathway (“bedrock") on groundwater composition. Using additional evidence from laboratory analyses and statistical evaluations, this technical memorandum demonstrates that naturally occurring lithium and chloride associated with bedrock underlying the Site is a source of lithium, chloride, and total dissolved solids (TDS) to Site groundwater. Additionally, this memorandum provides evidence that sulfate concentrations at well 35D can be attributed to the weathering of sulfur-bearing minerals within the coal seams in the Site lithology.

SITE CONDITIONS

Site geology consists primarily of unlithified alluvial and glacial deposits overlying shale bedrock that contains a major coal seam mined in the region. The alluvial deposits consist of the Cahokia Alluvium composed primarily of sand with occasional layers of silty clay and the Upper Till Unit (Wedron Formation and Glasford Formation Till) consisting of clay and silty clay with occasional sand lenses. The Cahokia Alluvium comprises the Upper Unit (UU) at the NEAP and is generally 10 to 25 feet thick. Below this unit is the Upper Confining Unit (UCU) that is comprised of the lower permeability Wedron and Glasford Formations. The UCU is of variable thickness, ranging from up to 100 feet west of the NEAP and absent east of the NEAP (Ramboll 2021).

The Bedrock Confining Unit (BCU), typically greater than 80 feet thick, consists of the Pennsylvanian-age Shelburn Formation, which is primarily a low permeability shale with thin limestone, sandstone, and coal beds. The top of the shale unit in the vicinity of the NEAP is described as highly weathered and decomposed. This unit contains the Danville (No. 7) Coal, which was encountered near the NEAP at approximately 80 to 100 feet below ground surface (ft bgs). Wells 35D and 70D are both screened within the BCU.

Groundwater within the BCU exhibits an upward hydraulic gradient and high dissolved mineral content (Ramboll 2021). Previous isotopic analyses by Kelron Environmental (Kelron) suggest that groundwater in the BCU is significantly older than the recent groundwater in the overlying unlithified deposits by approximately 13,000 to 35,000 radiocarbon years before present (Kelron 2003). Additional information regarding Site hydrogeology and stratigraphy is provided in the ASD prepared by Ramboll.

BEDROCK SOLIDS EVALUATION

Geosyntec reviewed the results of analyses completed on solid phase samples collected from the Site to evaluate if lithium and chloride concentrations in groundwater at wells 35D and 70D in excess of the GWPS could be derived from the native weathered shale bedrock lithology.

Samples were collected from soil borings advanced in June 2023 near two locations: compliance well 35D and compliance well 70D (**Figure 1**). Due to access limitations and health and safety considerations at the Site, the boring locations were adjusted in the field and are approximately 200-250 feet offset from the original well locations. Differences in ground surface elevations and bedrock dip were considered during drilling and sample selection so that the sampled intervals correspond with the well screen interval. Boring locations and well screen intervals are shown in the cross sections provided in **Attachment 2**. The material sampled for geochemical characterization is consistent with the material present in the well screens (gray weathered shale).

The field boring log for these soil borings are provided as **Attachment 2**. Soil boring logs and well construction logs for 35D and 70D are also included in **Attachment 2**. Two samples were collected from the boring near well 35D (VER-35), and three samples were collected from the boring near well 70D (VER-70) at various depths.

All samples were submitted for analysis of mineralogy via X-ray diffraction (XRD), and two samples from VER-35 (55-60 ft bgs and 60-63 ft bgs) and one sample from well VER-70[1] (75-80 ft bgs) were submitted for analyses of total lithium and lithium distribution within the bedrock using sequential extraction procedure (SEP). SEP is an analytical technique that uses progressively stronger reagents to solubilize metals from specific phases within the solid matrix and is used to infer associations between constituents and different classes of solids (Tessier et al. 1979). These classes of solids are identified based on their solubility under different reagents; the reagents are provided in **Attachment 3**. Analysis of chloride by SEP was not performed due to the high solubility of the chloride ion in solution.

Results for total and SEP analyses of lithium in these samples are presented in **Table 1** and the analytical laboratory reports are provided as **Attachment 3**. As a first step to evaluate data quality in an SEP analysis, the sum of individual extraction steps from the SEP was compared to the total lithium concentration. The sum of the SEP procedure is not expected to be exactly equal to the total metals analysis but should generally be consistent with the total metals analysis. The total lithium concentrations ranged from 39 micrograms per gram of material (µg/g) to 42 µg/g in the shale samples. The summed concentrations of lithium from the SEP analyses ranged from 45.3 to 50.8 µg/g. The results were generally consistent between the total metals analyses and the summed SEP steps, indicating good metals recovery and data quality. These results are also consistent with previous samples collected at the Site (31.1-33.3 mg/kg, Ramboll 2021) and within the Danville coal (5.5-89 mg/kg, USGS 2002).

The results presented in **Table 1** demonstrate that lithium is associated with multiple solid phase components. The majority of the lithium was released via leaching steps associated with two reactive solid phase components: metal oxides (between 24 and 28%) and sulfides (between 28 and 31%). Lithium associated with oxides and sulfides may be mobilized via desorption or dissolution of these phases in the event of geochemical changes to the system due to the relative instability of oxide and sulfide minerals.

---

[1] Two samples from the unlithified units from VER-70 (30-40 ft bgs) and (41-42 ft bgs) are excluded from subsequent results tables and discussion to emphasize findings associated with shale lithologies in support of an assessment of naturally occurring lithium in bedrock.

Eh-pH diagrams were generated using groundwater data for well 35D (**Figure 2**) and well 70D (**Figure 3**) to evaluate groundwater conditions at these wells relative to the thermodynamic stability of iron oxide and iron sulfide minerals. As indicated on **Figures 2** and **3**, groundwater chemistry at both monitoring wells generally favor thermodynamic stability of the iron oxide phase. However, multiple samples from well 35D plot within the three-phase stability boundary between amorphous iron oxide $Fe(OH)_3$(ppd), the iron carbonate mineral siderite, and aqueous Fe^{2+} (**Figure 2**), indicating that groundwater at this well is experiencing dynamic equilibrium conditions in which chemical reactions between these phases may occur. Groundwater from well 70D indicates a preference for iron oxide phases ($Fe(OH)_3$(ppd)), although groundwater chemistry at this well may be trending towards iron carbonate (siderite) stability (**Figure 3**). Iron sulfide minerals such as pyrite are not predicted to be in a stable phase at either well; therefore, any existing sulfidic minerals within the bedrock would be expected to undergo oxidative dissolution. Lithium associated with the sulfide solid phase component (**Table 1)** would then become mobilized due to dissolution/desorption processes and resulting in an increase in aqueous lithium in groundwater. Similarly, dissolution of iron oxides would occur under variable equilibrium conditions and result in an increase in aqueous lithium in groundwater.

Notable abundances (31 to 37%) of lithium were also found to be associated with the final extraction of the analysis, which is typically considered to be associated with residual metals which are immobile and not readily soluble. The abundance of lithium within this residual fraction indicates association with inseparable primary mineral phases such as clay minerals (Tessier et al., 1979). Clay minerals are known to be common sorbents for naturally occurring lithium (Starkey 1982). Lithium is known to leach from lithium-hosting igneous rocks and micas through weathering processes. Mineral weathering reactions occurring in micas may result in lithium-rich micas transforming directly to illitic clays, and then to mixed-layer and smectite clays. The lithium within these primary minerals either becomes incorporated directly into the crystal structures of the clay minerals or is transported in water and later concentrated in brines through evaporation (Ronov et al. 1970). Lithium-enriched brines constitute a common origin of lithium in clay minerals, as eroded fine-grained materials (i.e., detrital clays) deposited in these brines are capable of hosting lithium within vacant sites in the octahedral layers comprising part of their crystal structures (Schultz 1969). Field lithologic descriptions of the samples from VER-35 and VER-70 indicate that the samples collected from these two locations consist of weathered shale, which is comprised primarily of mica and clay minerals that are known to be hosts of natural lithium.

Mineralogical analyses were completed using XRD to evaluate whole rock mineralogy and determine the abundance of iron oxide minerals, iron sulfide minerals, clay minerals, and micas within the bedrock solids. Whole rock mineralogy results are provided in **Table 2**. Sample mineralogy consists predominantly of quartz, mica (muscovite), feldspars (albite and microcline), and clay minerals (illite, chlorite, and kaolinite) (**Table 2**). Of these minerals, muscovite and clays are known hosts of natural lithium within their crystal structures and comprise natural sources of lithium in the system (Zawidzki 1976; Starkey 1982). As indicated in **Table 2**, these minerals are present at large abundances in samples from well 35D and well 70D (between 43.0 to 47.4%), indicating that these lithium-host minerals occur in the BCU and constitute a natural source of aqueous lithium to groundwater.

While iron oxides were not identified via XRD, they are likely present in the system. Amorphous $Fe(OH)_3$(ppd), which is thermodynamically favored to form at the Eh and pH measured in groundwater (**Figures 2 and 3**), cannot be identified via XRD due to its lack of crystalline structure. However, the SEP results identified an abundance of iron in the leaching step associated with non-crystalline oxides (step 3; **Attachment 3**), and iron oxides are often present on clay surfaces due to the relationship between their surface charges (Ohtsubo 1989). As discussed above, the XRD analysis identified the presence of clay minerals within the shale (**Table 2**, **Attachment 4**). Thus, weathering reactions involving iron oxides likely constitute an additional natural source of aqueous lithium to groundwater.

As discussed above, the shale bedrock material consists predominantly of micas and clays which are known hosts of lithium within their crystal structures. The weathered nature of the shale bedrock material suggests that chemical weathering processes are likely occurring, the result of which supports the occurrence of weathering reactions involving metal oxide and sulfide minerals, as well as alteration reactions between mica and clay minerals and between different types of clay minerals. These reactions all represent processes by which lithium associated with the native geologic materials may become mobilized, contributing aqueous lithium to groundwater.

Similar to lithium, chloride occurs naturally within shale bedrock, which likely contributes to elevated chloride in groundwater. Because of the high solubility of chloride, it is not feasible to determine phase associations through SEP; however, studies within the region have found that groundwater chloride concentrations comparable to or higher than those observed at wells 35D and 70D are often found within the Pennsylvanian-aged shale bedrock. The mean chloride concentration in Pennsylvanian bedrock aquifers in the area reported by the Illinois State Geological Survey (ISGS) is 1,689 mg/L and a chloride maximum concentration of 30,269 mg/L was reported (ISGS 2002). Chloride concentrations observed in wells 35D and 70D are 251 mg/L and 492 mg/L, respectively. A USGS summary found that water within the upper parts of the Pennsylvanian-aged bedrock is generally similar throughout the Illinois and Indiana basins. This water is influenced by the interaction with the variable interbedded rock types present in the bedrock; it can vary from a sodium bicarbonate to a sodium chloride type within a few feet of change in depth (Lloyd and Lyke 1995).

Furthermore, seeps with high naturally occurring salinity (i.e., brines) are known to occur in southern Illinois. Samples of seeps and shallow wells affected by brine in Illinois had highly variable chloride concentrations ranging from ~100 mg/L up to more than 15,000 mg/L (Panno, et al. 2005). These results suggest that contact with Pennsylvanian-aged bedrock can result in natural variability in the reported chloride concentrations in groundwater at ranges consistent with those observed at the site.

STATISTICAL EVALUATION OF GROUNDWATER COMPOSITION

Advanced statistical analyses were employed to evaluate the similarity or dissimilarity among different groundwater samples or groups based on a broad suite of analytes. Dimensional reduction techniques, such as principal component analysis (PCA), are especially effective in identifying the analytes responsible for statistical differences between samples and revealing underlying patterns related to environmental factors, contamination sources, or other natural characteristics of the Site. Clustering methods were further utilized to group samples based on their combined chemical composition through maximizing intra-group similarity and minimizing inter-group similarity.

PCA is often used to simplify large datasets with multiple variables by creating new uncorrelated variables known as principal components (PCs). The PCs are linear combinations of the original variables; the first few PCs typically capture most of the variation within the dataset. Factor loadings are calculated based on the correlation between PCs and the original variables. As such, variables with notably higher positive or negative factor loadings are main drivers of similarity or dissimilarity and clustering of samples. Factor scores are calculated based on the correlation between the combined chemical composition of each sample and the PCs. Samples with similar chemical compositions show similar factor scores and tend to cluster together on a PCA plot.

In this study, the dataset used for PCA included 62 groundwater samples collected in 2021 and 2023 from upgradient wells (10 and 22), downgradient wells (70S, 71S, 70D, 71D, 16A, and 35D) and a porewater well (NED1).[2] PCA requires that input variables have similar scales of measurement and variances. As such, data were standardized by mean-centering and scaling to unit variance prior to performing PCA. Data were further square transformed to reduce the skewness of dataset. The fraction of total variation explained by each PC is shown in **Figure 4a**, with the first two PCs accounting for approximately 80 percent [%] of the total variation in the datasets. Additionally, the quality of representation of each variable is presented in **Figure 4b**. As

---

[2] Analytes included in the PCA include alkalinity, boron, calcium, pH, barium, chloride, and fluoride. The complete dataset used for PCA analysis is provided with this submission as **Attachment 5**.

illustrated in the figure, the first dimension is dominated by alkalinity, boron, and calcium, while the second dimension is dominated by fluoride, chloride, and barium.

PCA results are often visualized using biplots where samples are projected on to the first two PCs (i.e., factor scores), and factor loadings are represented as vectors. The closer the data points are on the graph, the greater the similarity in their chemical composition. The result from this study is shown on **Figure 5**, where the samples acquired from BCU are orange, UCU and UU are shades of blue, and the porewater samples are gray. The biplot suggests that porewater samples cluster relatively separately from the BCU, UCU, and UU samples. Additionally, the chemical signatures of groundwater samples from the BCU are different than combined group of UCU and UU samples, whereas the composition of upgradient samples from the UCU are similar to those from downgradient UU locations. Upgradient well 22 clusters more closely with the shallower UCU and UU wells. The PCA results indicate that the composition of the BCU groundwater samples is statistically different than that from the porewater, suggesting that the porewater is not the source of elevated lithium, chloride, and TDS to Site groundwater.

Furthermore, the factor loadings, represented as vectors on the biplot, suggest that constituents such as boron and carbonate alkalinity are responsible for the chemical signature of the porewater cluster. In contrast, chloride is one of the drivers for the distinct chemical composition of the BCU cluster.

Clustering was further explored using Ward’s hierarchical clustering method, a distance measure employed in agglomerative algorithms and commonly applied in hydrogeochemical studies. The analysis was performed on a scaled and centered dataset. The results from clustering (**Figure 6**), align with findings from the PCA (**Figure 5**) and supported the distinction between porewater samples from downgradient and upgradient groundwater samples from BCU, UCU and UU. Furthermore, the distinct clustering of the BCU samples relative to the clustering of the UCU/UU samples suggests that chemical composition of groundwater samples is primarily influenced by their lithography rather than their relative locations to the CCR unit (i.e., upgradient or downgradient). These results support the conclusion that downgradient locations with lithium and chloride exceedances are not affected by the CCR unit, and their geochemistry is instead influenced by the native lithology.

SULFATE EVALUATION

Elevated sulfate concentrations have been observed in well 35D that are inconsistent with other BCU wells at the Site, as indicated by exceedances of the GWPS for sulfate at well 35D and not at other BCU wells. The PCA results shown in **Figure 5** indicate that for parameters other than sulfate (which was not included in the parameters evaluated in the PCA), the groundwater chemistry from well 35D is similar to overall bedrock groundwater chemistry. As described above and in greater detail in the Site Hydrogeologic Characterization Report (Ramboll 2021), the BCU contains a major coal seam that has been mined in the vicinity of the NEAP. Samples of this coal were collected and analyzed by Kelron and the ISGS, and XRD results indicate that the coal contains up to 10% iron sulfide, primarily pyrite and marcasite (FeS_2) (Mehnert 2002). Pyrite and especially marcasite are unstable under oxidizing conditions and will readily undergo oxidative dissolution to form dissolved iron and sulfate. This mechanism of sulfate mobilization is further supported by the observation of the iron carbonate mineral siderite ($FeCO_3$), which was described as a "needle-like white precipitate above the coal in the core" which "is undoubtedly the result of this rapid oxidation" (Mehnert 2002). Siderite is also identified in the bedrock samples collected from borings VER-35 and VER-70 at concentrations ranging from 4.9 to 5.4 weight percent (**Table 2**).

Figure 2 shows the iron thermodynamic stability diagram for the well 35D groundwater. Groundwater pH and ORP data are plotted within the iron stability field, which illustrates that under these conditions, siderite and ferrihydrite are in a state of dynamic equilibrium. The weathering of pyrite to siderite to ferrihydrite would result in an increase in aqueous sulfate concentrations.

Furthermore, strong upward vertical hydraulic gradients are present within the BCU (Kelron 2003; Ramboll 2021). While it is estimated that the coal seam is deeper than the screened interval at well 35D, an upward vertical gradient would cause sulfate generated from sulfide oxidation in the coal to influence the groundwater composition at 35D. **Figure 7** shows the locations where coal and void space were observed during exploratory drilling for the historic coal mine (Kelron 2003). In boring locations B201 and B202, artesian conditions were observed, with water geysering more than 30 feet above ground surface at an estimated flow rate of greater than 100 gallons per minute when the fractured shale was penetrated as the borings were advanced (Kelron 2003). These field observations indicate that the high hydraulic head within the coal seam can influence overlying formations.

As noted above, isotopic analyses of tritium (^3H) and radiocarbon (^{14}C) suggest that the bedrock groundwater is significantly older than the shallower groundwater at the Site (Kelron 2003). Tritium concentrations in the groundwater from the overlying unlithified deposits are between 5.3 and 5.8 tritium units and can be classified as "recent water". Tritium concentrations in the bedrock were non-detect. The age of the bedrock groundwater ranges from approximately 13,000 to 35,000 years before present as determined by radiocarbon dating. The lack of influence from recent water within the bedrock groundwater system provides further evidence that it is isolated from the shallow groundwater and that the elevated sulfate observed in 35D is due to natural variations in sulfur-bearing minerals in the bedrock.

CONCLUSION

Naturally occurring lithium, chloride, and sulfate associated with minerals in the BCU and the coal seam in the vicinity of the NEAP at the Site were identified as alternative sources of these constituents to Site groundwater. Solid-phase samples collected near compliance wells 35D and 70D contained lithium, and SEP analyses demonstrated that much of the lithium in the solid phase is associated with the fractions which correlate to primary minerals such as micas and clay minerals, as well as the fractions associated with sulfides and oxide minerals. XRD identified abundant micas and clay minerals hosted in the shale bedrock that are the source of lithium in Site groundwater. Elevated chloride concentrations in groundwater are observed in the region that originate from Pennsylvanian-aged shale bedrock and brine migration over time. Elevated sulfate concentrations at 35D are associated with the oxidative dissolution of iron sulfide minerals present in coal seams within the bedrock and transported through upward hydraulic gradients within the BCU. Advanced statistical methods demonstrate that groundwater geochemical signatures from the BCU, the UCU, and the UU are distinctly different from that of the porewater based on a combination of parameters.

The alternative source of lithium and chloride observed in wells 35D and 70D is the shale bedrock. The alternative source of sulfate observed in well 35D is the coal seams within the BCU. These elevated chloride and sulfate concentrations are the dominant contributors of elevated TDS values at 70D and 35D, respectively (VER NEAP E001 ASD). This information serves as the written ASD demonstrating that the GWPS exceedances for lithium, chloride, and TDS at well 70D and for lithium, chloride, sulfate, and TDS at 35D were not due to the NEAP CCR unit.

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TABLES

Table 1 - Lithium SEP Results Summary
Vermilion Power Plant - New East Ash Pond

Soil Boring Location		**VER-35**		**VER-35**		**VER-70**	
Sample Depth (ft bgs)		**(55-60)**		**(60-63)**		**(75-80)**	
Location		**Downgradient**		**Downgradient**		**Downgradient**	
Field Boring Log Description		**Weathered Shale**		**Highly Weathered Shale**		**Highly Weathered Shale**	
Total Lithium		42		39		42	
SEP Results							
SEP Fraction	**SEP Reagent**	**Concentration**	**% of Total**	**Concentration**	**% of Total**	**Concentration**	**% of Total**
Exchangeable Metals Fraction	$MgSO_4$	<10	--	<10	--	<11	--
Metals Bound to Carbonates Fraction	Sodium acetate, acetic acid	0.56 J	1%	0.62 J	1%	<8.3	--
Non-crystalline Materials Fraction	Ammonium oxalate (pH 3)	0.52 J	1%	0.74 J	2%	0.41 J	1%
Metals Bound to Metal Hydroxide Fraction	Hydroxylamine HCl and acetic acid	13	28%	12	27%	12	24%
Bound to Organic Material Fraction	5% sodium hypochlorite (pH 9.5)	4.1 J	9%	3.9 J	9%	4.4 J	9%
Metals Bound to Acid/Sulfide Fraction	HNO_3, HCl, and H_2O	13	28%	14	31%	15	30%
Residual Metals Fraction	HF, HNO_3, HCL, and H_3BO_3	15	33%	14	31%	19	37%
SEP Total		46.2	100%	45.3	100%	50.8	100%

Notes:
SEP - sequential extraction procedure
ft bgs - feet below ground surface
All results shown in microgram of lithium per gram of soil (µg/g).
Total lithium was analyzed using aqua regia digest, ICP-MS
Non-detect values are shown as less than the reporting limit.
The lithium fraction associated with each SEP phase is shown.
% of total lithium is calculated from the sum of the SEP fractions.

Table 2-1. Summary of X-Ray Diffraction Analysis
Vermillion Power Plant - New East Ash Pond

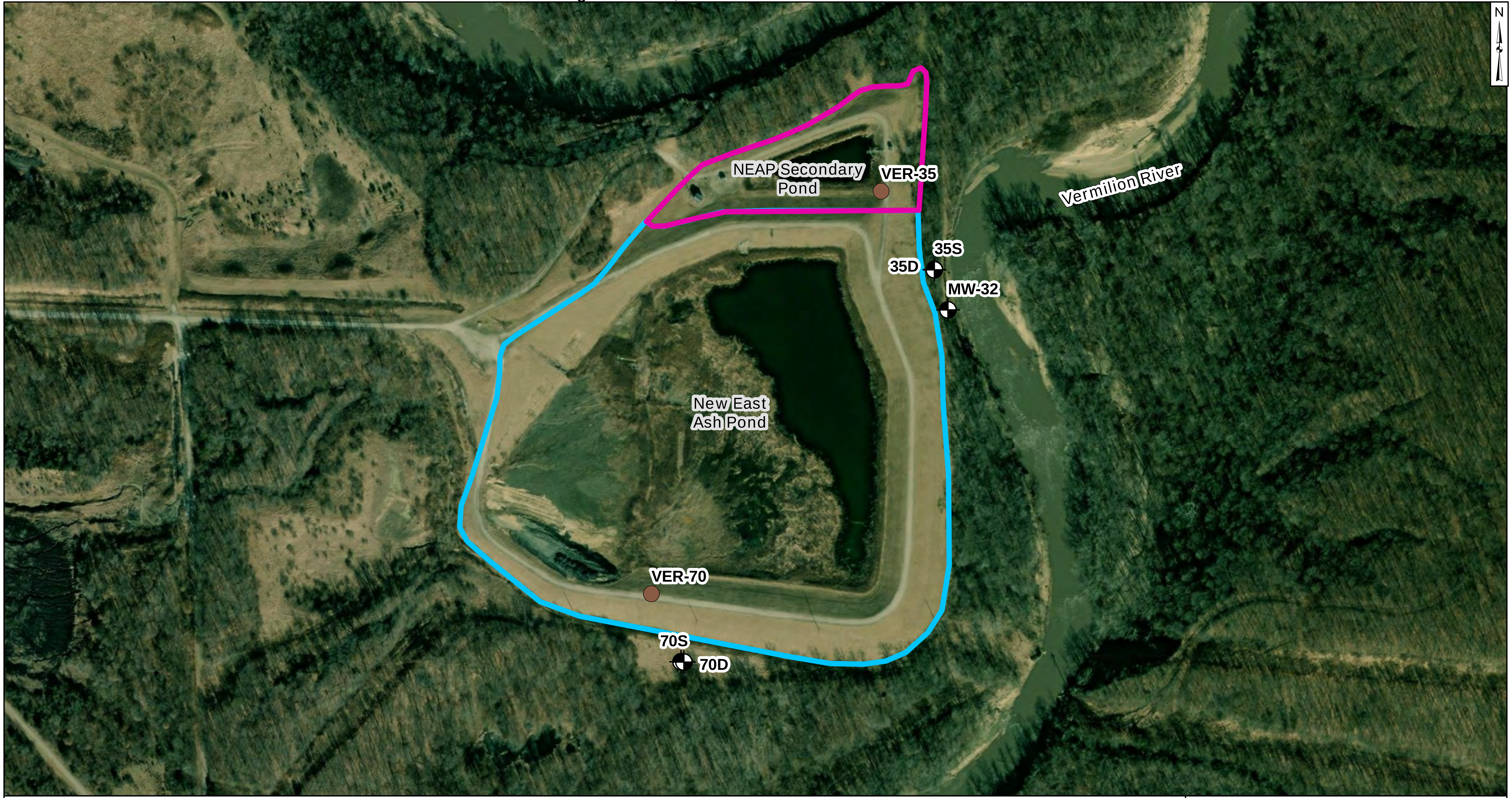
Field Boring Location			**VER-35**	**VER-35**	**VER-70**
Sample Depth (ft bgs)			**(55-60)**	**(60-63)**	**(75-80)**
Location			**Downgradient**	**Downgradient**	**Downgradient**
Field Boring Log Description			**Weathered Shale**	**Highly Weathered Shale**	**Highly Weathered Shale**
Mineral/Compound	**Formula**	**Mineral Type**	**(wt %)**	**(wt %)**	**(wt %)**
Quartz	SiO_2	Silicate	38.5	38.1	35.0
Muscovite	$KAl_2(AlSi_3O_{10})(OH)_2$	Mica	23.4	23.0	27.0
Albite	$NaAlSi_3O_8$	Feldspar	12.6	12.6	11.5
Illite	$K(Al,Mg,Fe)_2(Si,Al)_4O_{10}(OH)_2$	Clay	7.1	8.0	5.2
Chlorite	$(Fe,(Mg,Mn)_5,Al)(Si_3Al)O_{10}(OH)_8$	Clay	6.9	6.8	7.7
Kaolinite	$Al_2Si_2O_5(OH)_4$	Clay	5.6	5.4	7.5
Siderite	$FeCO_3$	Carbonate	4.9	5.0	5.4
Microcline	$KAlSi_3O_8$	Feldspar	1.0	1.1	0.70
Clay Minerals Total			19.6	20.2	20.4
Clays + Muscovite Total			43.0	43.2	47.4

Notes

Sample depth is shown in feet below ground surface (ft bgs).

wt %: percentage by weight

FIGURES



Legend

- ⊕ Monitoring Well
- ● Boring Location
- 🟦 New East Ash Pond (NEAP)
- 🟪 NEAP Secondary Pond

Notes

- Soil boring locations are approximate.
- Only select monitoring well locations are shown.
- Ash pond boundaries are approximate.

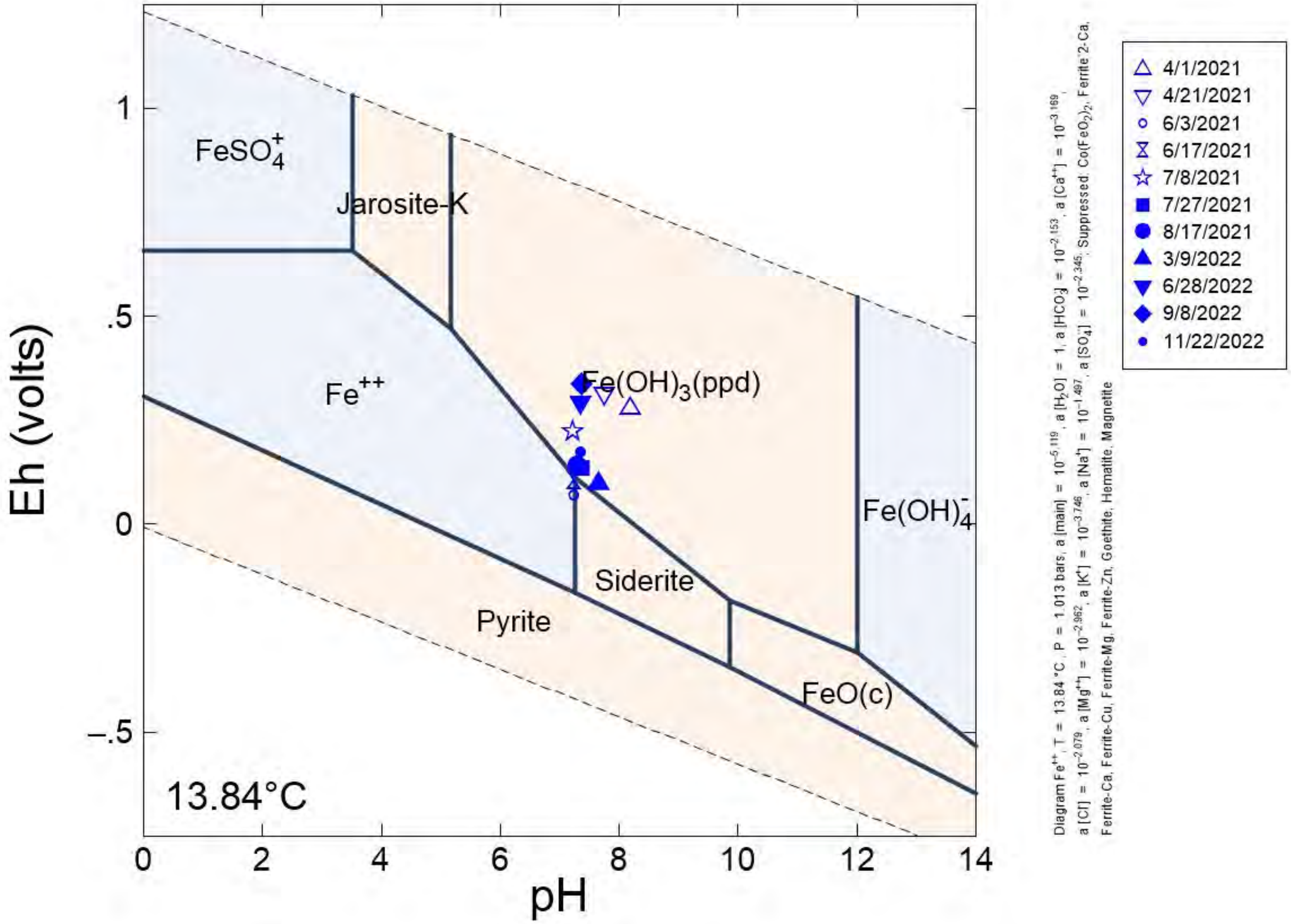
Boring Locations

Dynegy Midwest Generation
Vermilion Site
Oakwood, Illinois

Geosyntec
consultants

Columbus, Ohio
October 2023

Figure
1



Notes:
1. Iron stability diagram with groundwater sampling results from well 35D.
2. Activities of constituents were calculated from average values for well 35D groundwater.
Fe – iron, pyrite – FeS$_2$, siderite – FeCO$_3$, Fe(OH)$_3$(ppd) – precipitated ferrihydrite, Eh – oxidation reduction potential (converted from field measurements using + 0.2 volts)

Well 35D Iron Stability Diagram

Vermilion Power Plant – New East Ash Pond

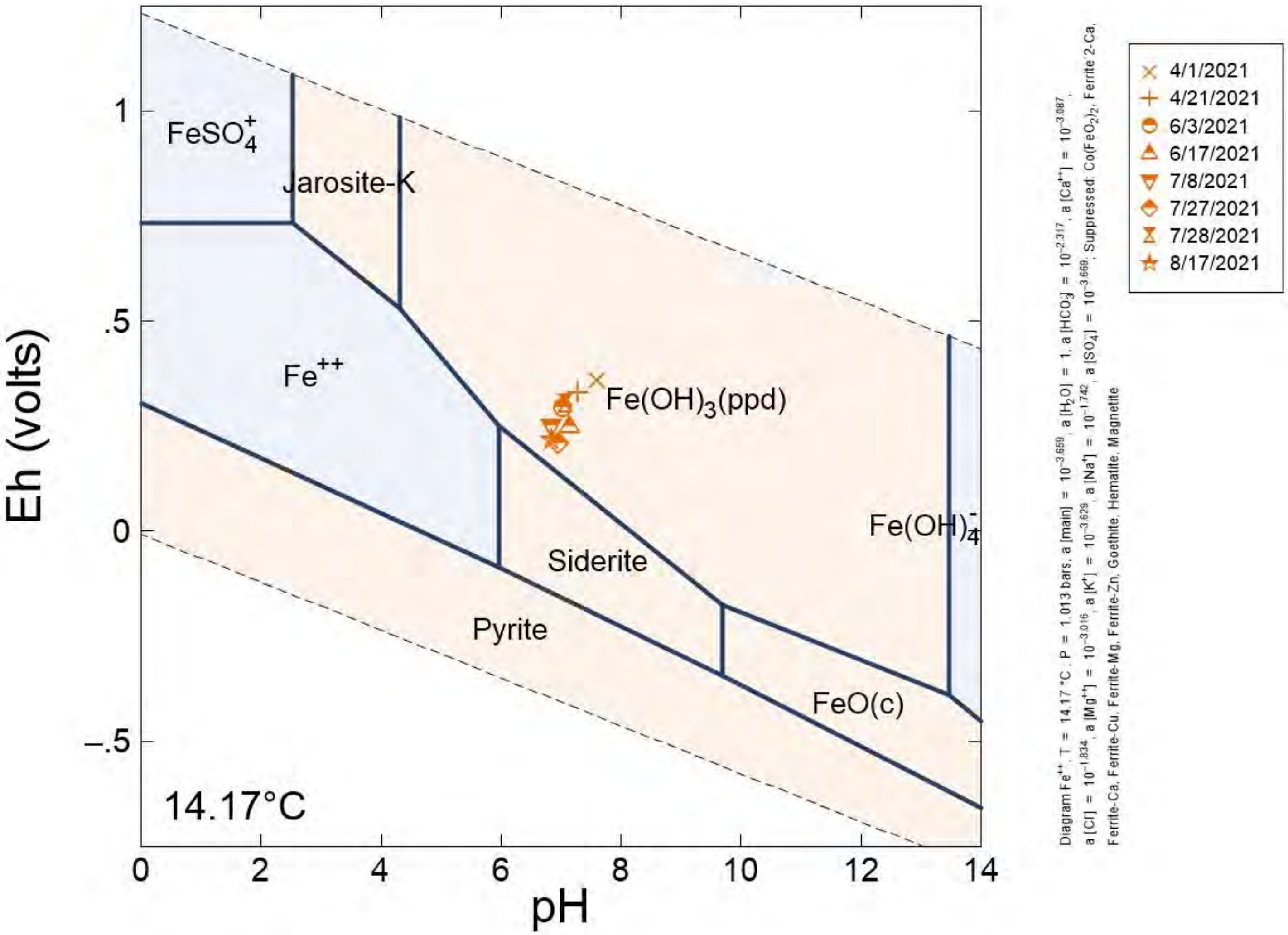
Geosyntec consultants

Figure

2

Columbus, Ohio

October 2023



Well 70D Iron Stability Diagram

Vermilion Power Plant – New East Ash Pond

Geosyntec consultants

Columbus, Ohio

October 2023

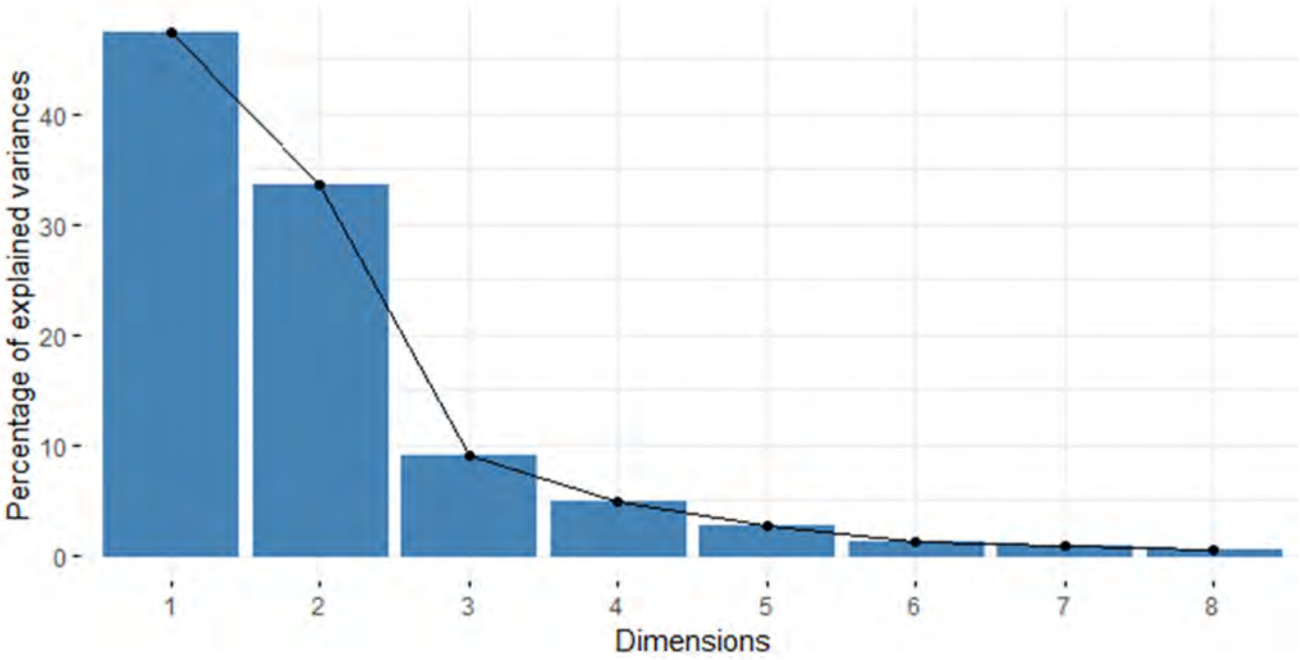
Figure

3

Notes:

1. Iron stability diagram with groundwater sampling results from well 70D.
2. Activities of constituents were calculated from average values for well 70D groundwater.

Fe – iron, pyrite – FeS_2, siderite – $FeCO_3$, $Fe(OH)_3$(ppd) – precipitated ferrihydrite, Eh – oxidation reduction potential (converted from field measurements using + 0.2 volts)



Notes:

1. Samples collected from upgradient wells 10 and 22, downgradient wells 70S, 71S, 16, 35D, 70D, and 71D, and porewater well NED1 were included in the evaluation.

PCA Analysis - Quality of Representation of Principal Components

Vermilion Power Plant – New East Ash Pond

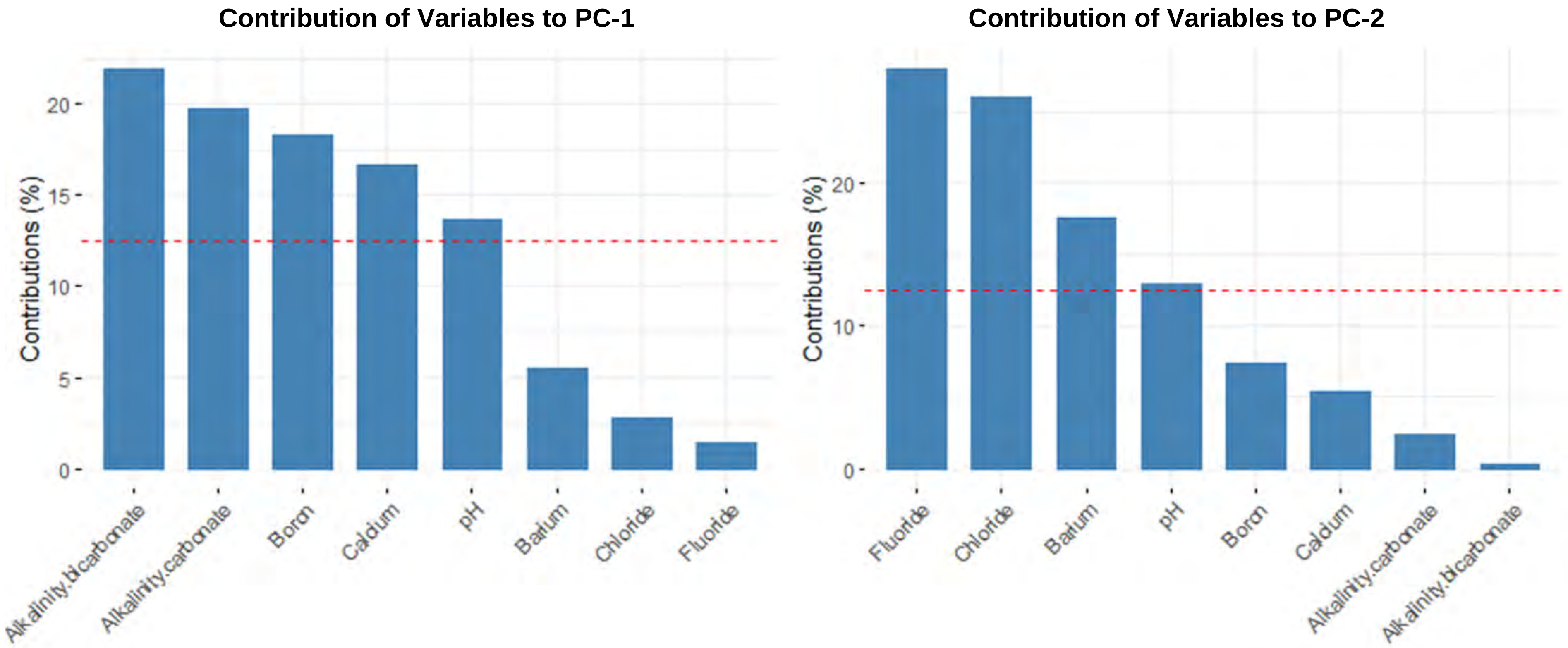
Geosyntec consultants

Columbus, Ohio

October 2023

Figure

4a



Notes:

1. The dashed red line represents the anticipated value for uniform contribution. The constituents with a contribution exceeding the reference line are considered significant in its contribution to each PC (principal component).

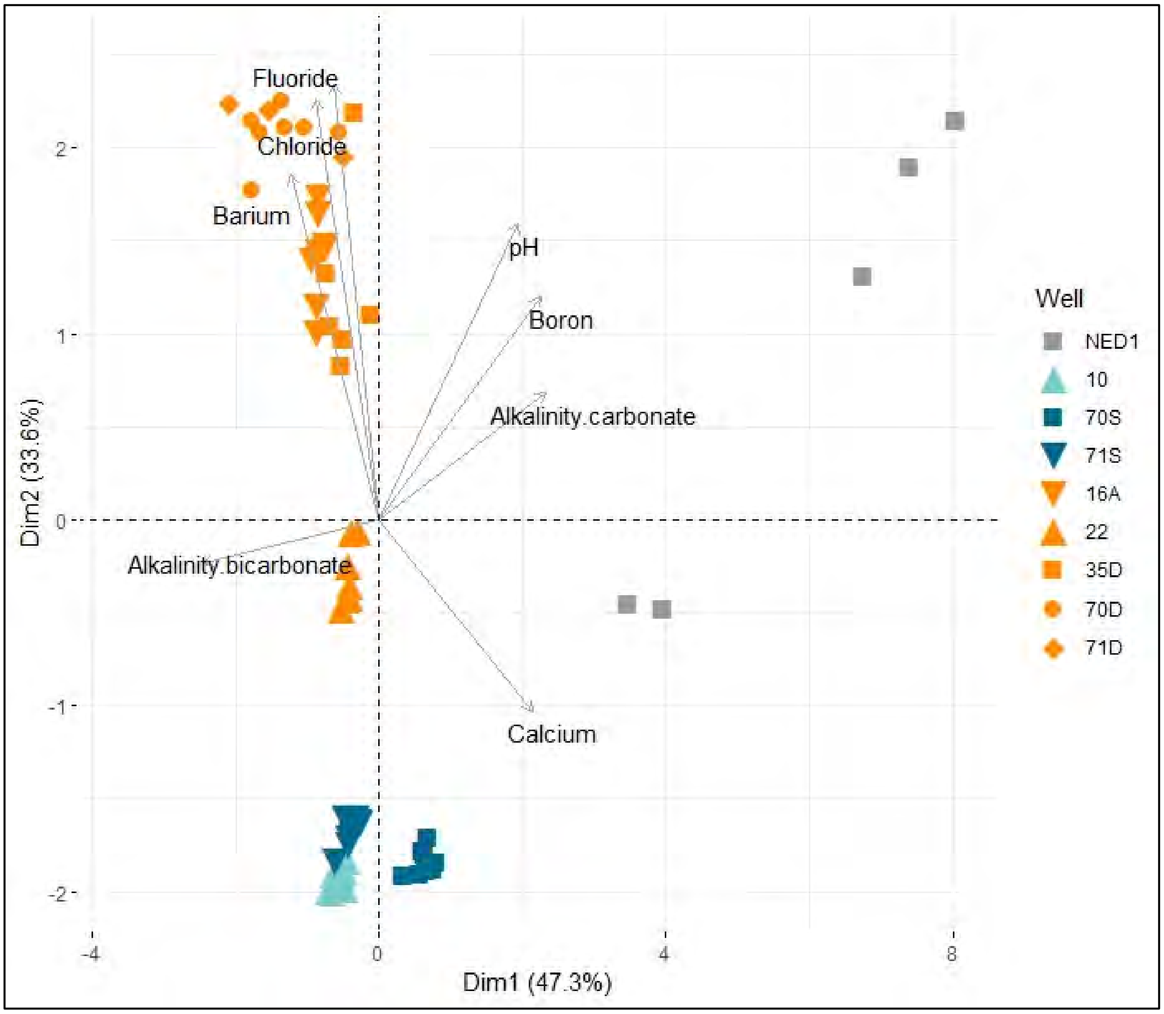
Contribution of Variables to First Two Principal Components

Vermilion Power Plant – New East Ash Pond

Geosyntec consultants

Figure **4b**

Columbus, Ohio | October 2023



Notes:

1. The arrows signify the correlations between the constituents and the principal components.
2. Datapoints are colored based on hydrostratigraphic unit of sampling locations as follows:
   -Bedrock Confining Unit (BCU) wells: 16A, 22, 35D, 70D, 71D,
   -Upper Confining Unit (UCU) well: 10
   -Upper Unit (UU) wells: 70S, 71S
   -Coal Combustion Residual (CCR) well: NED

Principal Component Analysis Biplot

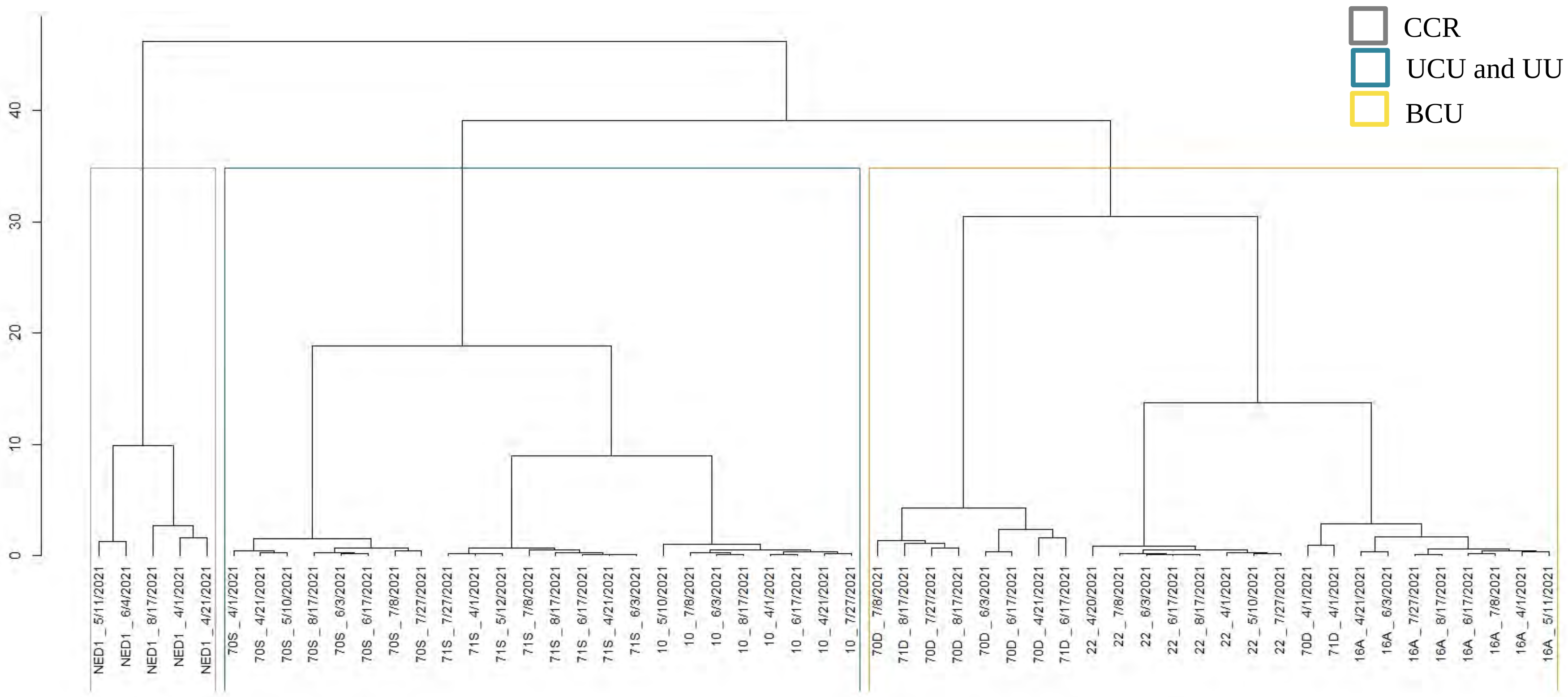
Vermilion Power Plant – New East Ash Pond

Geosyntec consultants

Columbus, Ohio

October 2023

Figure 5



Notes:

1. The cluster analysis used Euclidean distances as the similarity measure and Ward’s method as the clustering algorithm.

2. BCU, CCR, UCU and UU refer to Bedrock Confining Unit, Coal Combustion Residual, Upper Confining Unit, and Upper Unit, respectively.

Dendrogram Graph from Cluster Analysis

Vermilion Power Plant – New East Ash Pond

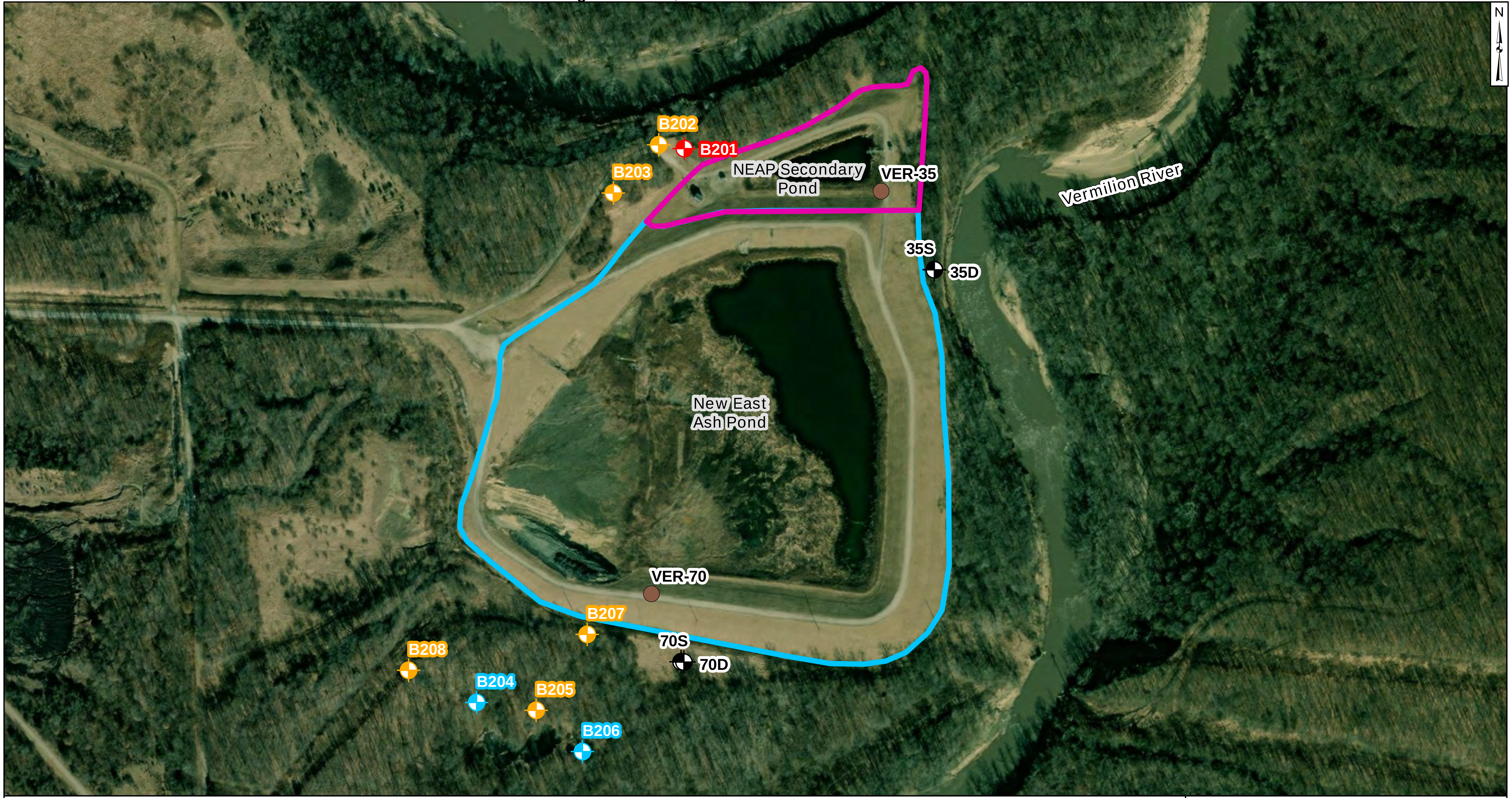
Geosyntec consultants

Columbus, Ohio

October 2023

Figure

6



Legend

2001 borings which identified:

⊕ Coal

⊕ Void Space

⊕ Coal & Void Space

⊕ Monitoring Well

● Boring Location

▭ New East Ash Pond (NEAP)

▭ NEAP Secondary Pond

Notes

- Soil boring locations are approximate.
- Ash pond boundaries are approximate.

250 125 0 250 Feet

Coal and Void Locations

Dynegy Midwest Generation
Vermilion Site
Oakwood, Illinois

Geosyntec consultants

Columbus, Ohio

October 2023

Figure 7

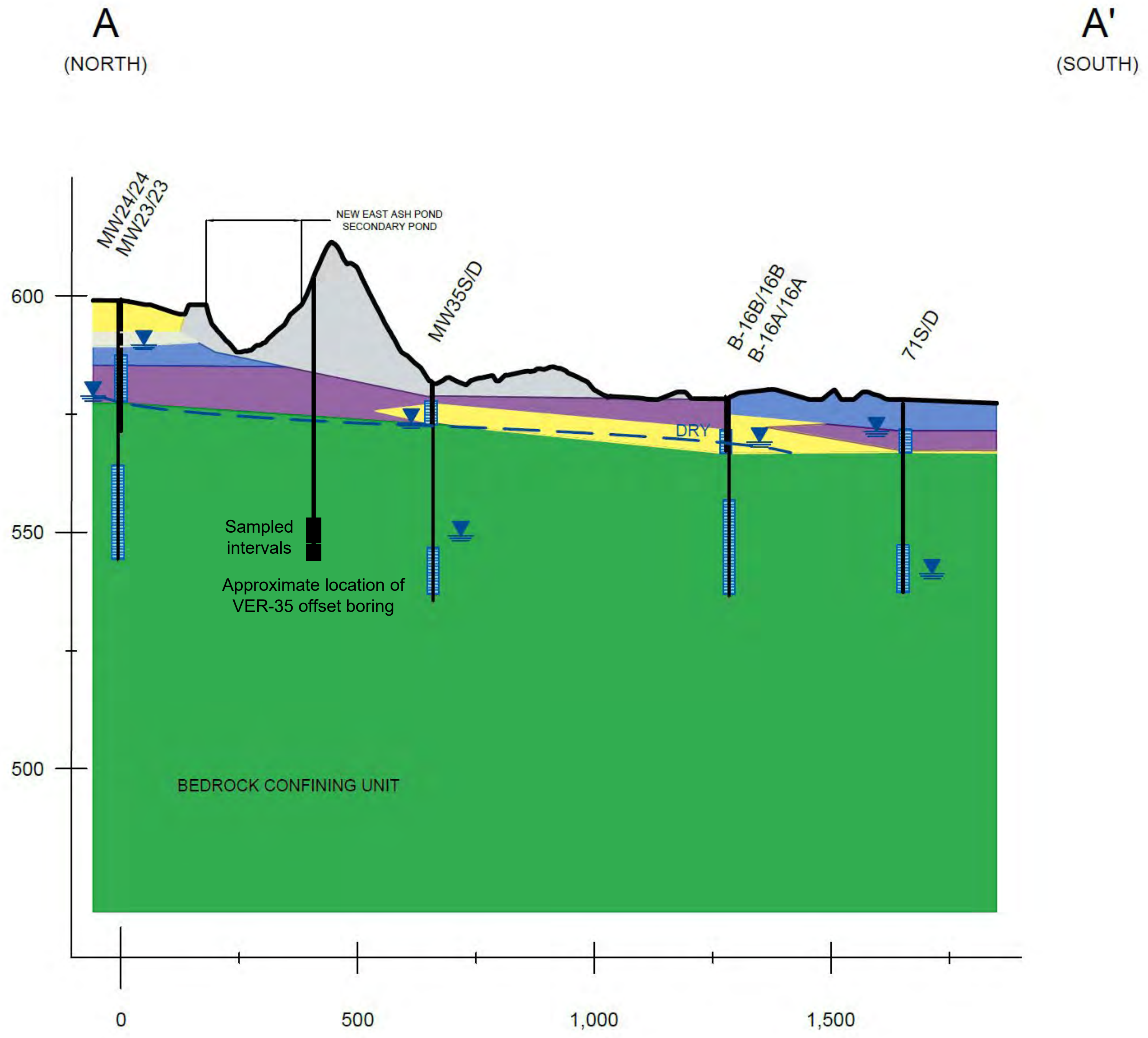
Y:\Company\Projects_post_2014\CHE8404_VPS_Closure_RIA_Sprt\500 - Technical\572 - MNA and GSI Evaluation\GIS\MXDs\20231020_Figure 1-Coal_Locations.mxd. ASoltero. 10/20/2023. Project/Phase/Task.

ATTACHMENT 1

Cross Sections

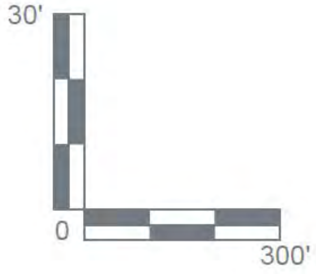
Electronic Filing: Received, Clerk's Office 02/02/2024 **PCB 2024-053**

\\ramboll.sharepoint.com@SSL\DavWWWRoot\sites\vistra\Shared Documents\CCR GW\Deliverables\Part 845 Operating Permits\Sites\Vermilion\Hydrogeo Report\NEAP HCR\Figures\working files\CAD\Cross Sections\Vermilion-NEAP-Cross Sections.dwg PROJECT: 1940100806 | DATED: 10/12/2021 | DESIGNER: ENGELHSA



NOTES

1. This profile was developed by interpolation between widely spaced boreholes. Only at the borehole location should it be considered as an approximately accurate representation and then only to the degree implied by the notes on the borehole logs.
2. Scale is approximate.
3. Vertical scale is exaggerated 10X.
4. Groundwater elevations measured on March 29, 2021.
5. PMP = Potential Migration Pathway



LEGEND

⬜	FILL
🟪	CLAY (CL/CH)
⬜	TILL (CL/CH)
🟦	SILT (ML)
🟨	SAND (SP/SM/SW)
⬜	GRAVEL (GP/GW)
🟩	BEDROCK / WEATHERED BEDROCK (INTERBEDDED SHALE, LIMESTONE, SANDSTONE, V. LITTLE SS)
▤	WELL SCREEN INTERVAL
- -	BEDROCK CONFINING UNT POTENTIOMETRIC SURFACE
▼	BEDROCK CONFINING UNIT / PMP GROUNDWATER / OTHER GROUNDWATER / SURFACE WATER ELEVATION(S)

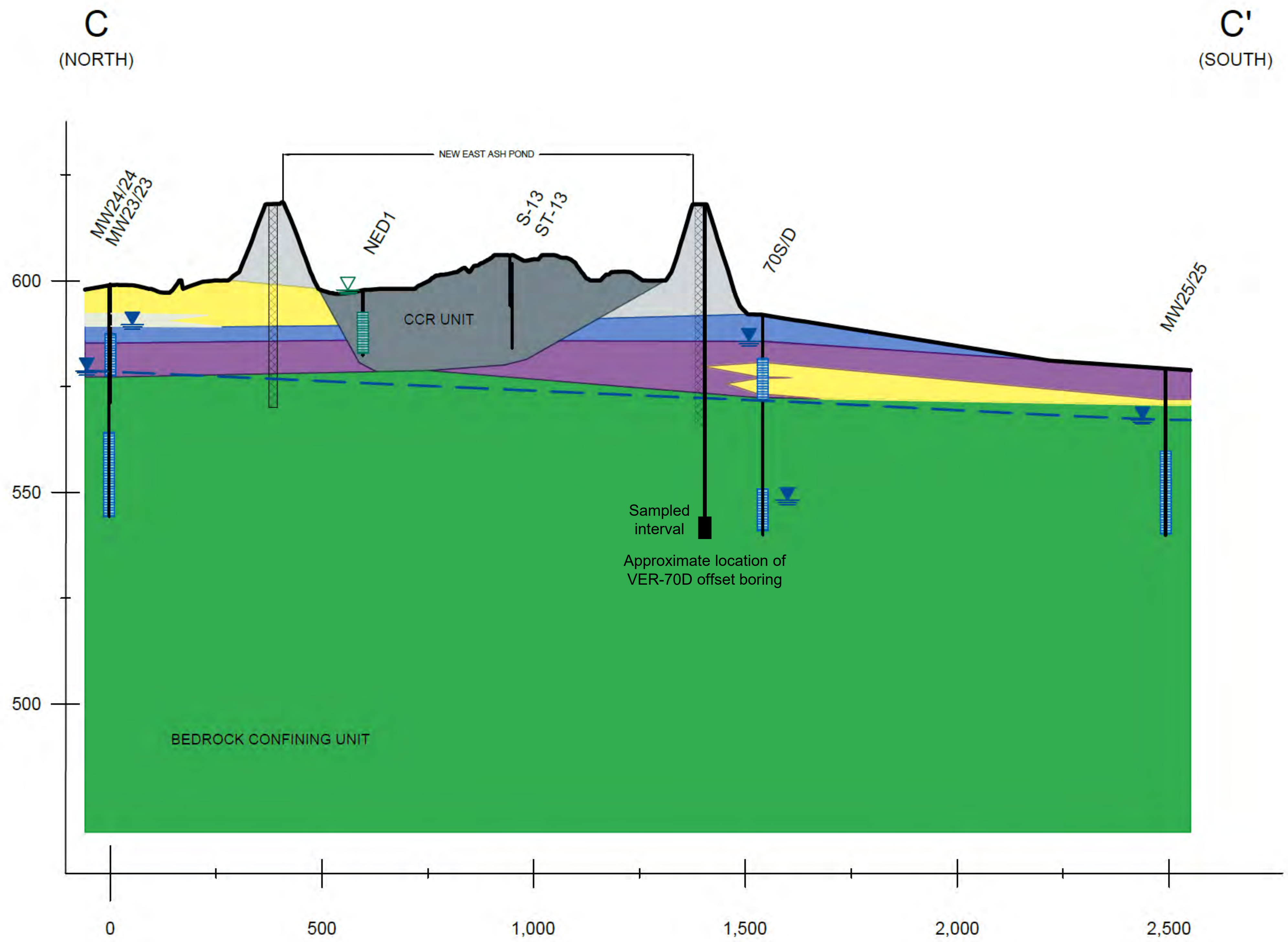
GEOLOGIC CROSS SECTION
A-A'

HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
NEW EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

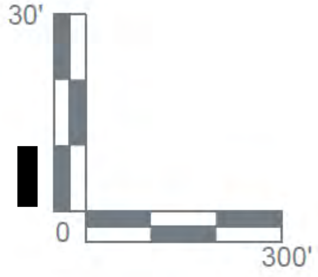
FIGURE 2-9

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

RAMBOLL



NOTES
1. This profile was developed by interpolation between widely spaced boreholes. Only at the borehole location should it be considered as an approximately accurate representation and then only to the degree implied by the notes on the borehole logs.
2. Scale is approximate.
3. Vertical scale is exaggerated 10X.
4. Groundwater elevations measured on March 29, 2021.
5. PMP = Potential Migration Pathway



\\ramboll.sharepoint.com@SSL\DavWWWRoot\sites\vistra\Shared Documents\CCR GW\Deliverables\Part 845 Operating Permits\Sites\Vermilion\Hydrogeo Report\NEAP HCR\Figures\working files\CAD\Cross Sections\Vermilion-NEAP-Cross Sections.dwg

PROJECT: 1940100806 | DATED: 10/12/2021 | DESIGNER: ENGELHSA

LEGEND

- ▩ COAL COMBUSTION RESIDUALS (CCR)
- ▩ FILL
- ▩ CLAY (CL/CH)
- ▩ TILL (CL/CH)
- ▩ SILT (ML)
- ▩ SAND (SP/SM/SW)
- ▩ GRAVEL (GP/GW)
- 🟩 BEDROCK / WEATHERED BEDROCK (INTERBEDDED SHALE, LIMESTONE, SANDSTONE, V. LITTLE SS)
- ▤ WELL SCREEN INTERVAL
- ‐ ‐ BEDROCK CONFINING UNT POTENTIOMETRIC SURFACE
- ▽ POREWATER ELEVATION
- ▼ BEDROCK CONFINING UNIT / PMP GROUNDWATER / OTHER GROUNDWATER / SURFACE WATER ELEVATION(S)
- ▨ CLAY CORE KEYED 8-FT INTO BEDROCK

GEOLOGIC CROSS SECTION
C-C'

HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
NEW EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

FIGURE 2-11

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

RAMBOLL

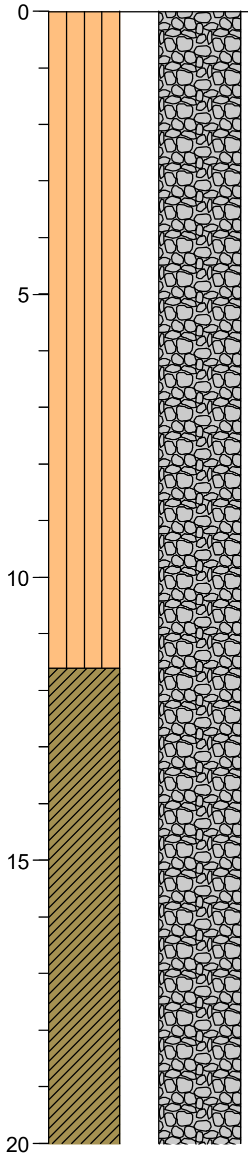
ATTACHMENT 2

Boring Logs - VER-35 and VER-70
Soil Boring and Well Construction Logs - 35D and 70D

Geosyntec consultants
engineers | scientists | innovators

Client:	**Vistra**	**BORING LOG**
Project:	**Vermilion Power Plant New East Ash Pond**	**Boring No. VER-35**
Address:	**10188 East 2150 North Road, Oakwood, IL**	**Page: 1 of 4**

Drilling Start Date:	**06/24/2023**	Boring Depth (ft):	**63**
Drilling End Date:	**06/24/2023**	Boring Diameter (in):	**6**
Drilling Company:	**Cascade Drilling**	Ground Surface Elev. (ft):	**Not surveyed**
Drilling Method:	**Sonic**	Boring was advanced adjacent to well 35D. Samples collected from 55-60 ft bgs and 60-63 ft bgs	
Drilling Equipment:	**Geoprobe**		
Driller:	**Jeff Jehn**		
Logged By:	**Andrew Kelley**		



DEPTH (ft)	LITHOLOGY	WATER LEVEL	BORING COMPLETION	COLLECT Sample Type	COLLECT Date & Time	COLLECT Blow Counts	COLLECT Recovery (ft)	SOIL/ROCK VISUAL DESCRIPTION
0					10:35	NA	5.1/ 10	(0') GRAVELLY SILT (ML); light gray to brown (darkens downward), dry, loose, little sand, minor concretions.
								(3') CLAYEY SILT (ML); dark reddish brown, moist, firm, some black organics staining, few gravel, minor iron oxide stains.
10					10:45		2.5/ 10	(10') As above.
								(10.6') GRAVELLY SILT (ML); light gray to brown, moist, loose, fine to coarse gravel, little sand.
								(11.6') SILTY CLAY (CL); dark grayish brown, moist, stiff, medium plasticity.

NOTES:

Geosyntec consultants
engineers | scientists | innovators

Client: **Vistra**
Project: **Vermilion Power Plant New East Ash Pond**
Address: **10188 East 2150 North Road, Oakwood, IL**

BORING LOG

Boring No. **VER-35**
Page: **2 of 4**

Drilling Start Date:	**06/24/2023**
Drilling End Date:	**06/24/2023**
Drilling Company:	**Cascade Drilling**
Drilling Method:	**Sonic**
Drilling Equipment:	**Geoprobe**
Driller:	**Jeff Jehn**
Logged By:	**Andrew Kelley**

Boring Depth (ft):	**63**
Boring Diameter (in):	**6**
Ground Surface Elev. (ft):	**Not surveyed**

Boring was advanced adjacent to well 35D.
Samples collected from 55-60 ft bgs and 60-63 ft bgs

DEPTH (ft)	Sample Type	Date & Time	Blow Counts	Recovery (ft)	SOIL/ROCK VISUAL DESCRIPTION
20		10:55	NA	8/8	(20') CLAY (CL); gray to light brown, moist, very soft, trace coarse gravel, high plasticity.
					(22.3') WEATHERED SHALE, gray, moist, highly decomposed, moderately disintegrated.
25					
				2/2	(28') As above.
30		11:55		8/10	(30') SHALE, gray, wet, highly decomposed, slightly disintegrated.
35					(35.3') WEATHERED SHALE, gray, moist, highly decomposed, highly disintegrated.
40					

NOTES:

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Client: **Vistra**
Project: **Vermilion Power Plant New East Ash Pond**
Address: **10188 East 2150 North Road, Oakwood, IL**

BORING LOG

Boring No. **VER-35**
Page: **3 of 4**

Drilling Start Date:	**06/24/2023**
Drilling End Date:	**06/24/2023**
Drilling Company:	**Cascade Drilling**
Drilling Method:	**Sonic**
Drilling Equipment:	**Geoprobe**
Driller:	**Jeff Jehn**
Logged By:	**Andrew Kelley**

Boring Depth (ft):	**63**
Boring Diameter (in):	**6**
Ground Surface Elev. (ft):	**Not surveyed**

Boring was advanced adjacent to well 35D.
Samples collected from 55-60 ft bgs and 60-63 ft bgs

DEPTH (ft)	LITHOLOGY	WATER LEVEL	BORING COMPLETION	COLLECT				SOIL/ROCK VISUAL DESCRIPTION
				Sample Type	Date & Time	Blow Counts	Recovery (ft)	
40					12:10	NA	2/2	(40') As above.
					13:20		4/5	(42') WEATHERED SHALE, gray, moist, highly decomposed, highly disintegrated.
45								
					13:40		3.3/4	(47') As above.
50								
					14:05		3/4	(51') As above: slightly decomposed, competent at 1.5-1.6 ft.
55					14:20		4/5	(55') As above: slightly less weathered.
60								

NOTES:

Client:	**Vistra**	**BORING LOG**
Project:	**Vermilion Power Plant New East Ash Pond**	**Boring No.** **VER-35**
Address:	**10188 East 2150 North Road, Oakwood, IL**	**Page:** **4 of 4**

Drilling Start Date:	**06/24/2023**	Boring Depth (ft):	**63**
Drilling End Date:	**06/24/2023**	Boring Diameter (in):	**6**
Drilling Company:	**Cascade Drilling**	Ground Surface Elev. (ft):	**Not surveyed**
Drilling Method:	**Sonic**	Boring was advanced adjacent to well 35D. Samples collected from 55-60 ft bgs and 60-63 ft bgs	
Drilling Equipment:	**Geoprobe**		
Driller:	**Jeff Jehn**		
Logged By:	**Andrew Kelley**		

DEPTH (ft)	LITHOLOGY	WATER LEVEL	BORING COMPLETION	COLLECT				SOIL/ROCK VISUAL DESCRIPTION
				Sample Type	Date & Time	Blow Counts	Recovery (ft)	
60	▤		▨		14:50	NA	2/3	(60') As above: gray, moist, highly decomposed, highly disintegrated, few fragments are slightly more competent.
								(63') End of Boring.
65								

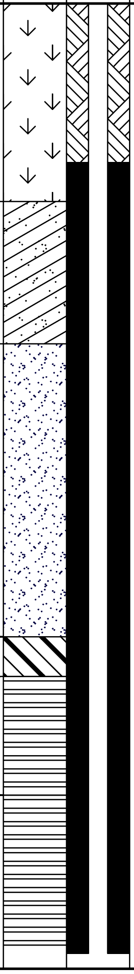
NOTES:

SOIL BORING LOG INFORMATION

NATURAL RESOURCE TECHNOLOGY

Page 1 of 3

Facility/Project Name Vermilion Power Station	License/Permit/Monitoring Number	Boring Number MW35D	
Boring Drilled By: Name of crew chief (first, last) and Firm Bruno Williamson Ramsey Geotechnical Engineering	Date Drilling Started 3/1/2017	Date Drilling Completed 3/3/2017	Drilling Method rotary/auger
Common Well Name MW35D	Final Static Water Level Feet (NAVD88)	Surface Elevation 581.25 Feet (NAVD88)	Borehole Diameter 7.3 inches
Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒ State Plane 1,279,955.58 N, 1,151,276.17 E [✓ E]/W 1/4 of 1/4 of Section , T N, R	Lat 40° 10' 47.14212" Long 87° 44' 8.06652"	Local Grid Location Feet ☐ N ☐ S Feet ☐ E ☐ W	
Facility ID	County Vermilion	State IL	Civil Town/City/ or Village Danville

Sample Number and Type	Sample Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram		Soil Properties Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 SS	24 16.5	2 2 3 3	1	0 - 2.5' **FILL, SILT:** ML, very dark grayish brown (10YR 3/2), 15-30% silt, trace wood and roots, cohesive, low plasticity, moist.	(FILL) ML									
2 SS	24 19	1 3 3 3	2 3	2.5 - 4.3' **SANDY LEAN CLAY:** s(CL), weak red (2.5YR 4/2), 5-15% fine sand, sand content increasing with depth, low plasticity, moist.	s(CL)									
3 SS	24 21	2 3 4 3	4 5	4.3 - 8' **POORLY-GRADED SAND:** SP, yellowish brown (10YR 5/6), fine sand, 15-30% clay, moist. 5.1' trace clay.	SP									
4 SS	24 18	3 3 3 3	6 7	7.5' trace gravel and cobbles.										Auger bringing up cobbles on flights.
5 SS	24 10	3 4 4 22	8 9	8 - 8.5' **FAT CLAY:** CH, very dark grayish brown (10YR 3/2), trace silt, high plasticity, moist. 8.5 - 10' **Weathered SHALE Bedrock** BDX (SH), very dark grayish brown (10YR 3/2) to very dark greenish gray (GLEY 1 3/10Y), highly weathered, red (7.5YR 4/6) discoloration, fissile, moist.	CH BDX (SH)				0.5					
6 SS	15 15	20 34 50 for 3"	10 11 12	10 - 15.6' **Weathered SHALE Bedrock** to **SHALE:** BDX (SH), gray (GLEY 1 6/N), weak, fissile, intensely fractured, red (7.5YR 4/6) discoloration, dry.	BDX (SH)									

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm Natural Resource Technology 234 W. Florida St., Fifth Floor, Milwaukee, WI 53204	Tel: (414) 837-3607 Fax: (414) 837-3608

SOIL BORING LOG INFORMATION SUPPLEMENT

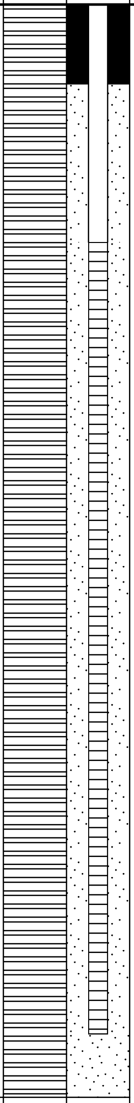
Boring Number MW35D

Sample								Soil Properties					
Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
7 SS	8 9	45 50 for 2"	13	10 - 15.6' **Weathered SHALE Bedrock** to **SHALE:** BDX (SH), gray (GLEY 1 6/N), weak, fissile, intensely fractured, red (7.5YR 4/6) discoloration, dry. *(continued)*									
8 SS	9 7	31 50 for 3"	14		BDX (SH)								
			15										
9 CORE	120 120		16 17 18 19 20 21 22 23	15.6 - 45.8' **SHALE:** BDX (SH), dark reddish gray (10YR 4/1) to gray (2.5Y 5/1), microcrystalline, thinly bedded to laminated, weak, slightly decomposed (very dark gray (10YR 3/1) to black (10YR 2/1) discoloration in partly healed fractures), competent, dry to moist in fractures.									Core 9, RQD = 89%. Light brown gray return water. 4" diameter outer casing set from 0-16 ft bgs.
			24 25		BDX (SH)								
10 CORE	131.3 120		26 27 28 29 30 31 32	25.6' partly to totally healed fractures.									Core 10, RQD = 89%. Light gray return water.

SOIL BORING LOG INFORMATION SUPPLEMENT

NATURAL RESOURCE TECHNOLOGY

Boring Number MW35D

Sample									Soil Properties					
Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram		Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
11 CORE	111.1 120		33 34 35 36 37 38 39 40 41 42 43 44 45	15.6 - 45.8' **SHALE:** BDX (SH), dark reddish gray (10YR 4/1) to gray (2.5Y 5/1), microcrystalline, thinly bedded to laminated, weak, slightly decomposed (very dark gray (10YR 3/1) to black (10YR 2/1) discoloration in partly healed fractures), competent, dry to moist in fractures. *(continued)* 41.9' - 43' crossbedding.	BDX (SH)									Core 11, RQD = 93%. Gray return water.
				45.8' End of Boring.										

NATURAL RESOURCE TECHNOLOGY

Electronic Filing: Received, Clerk's Office 02/02/2024 **PCB 2024-053**

MONITORING WELL CONSTRUCTION

Facility/Project Name: Vermilion Power Station

Local Grid Location of Well: ____ ft. ☐ N. ☐ S. ____ ft. ☐ E. ☐ W.

Well Name: MW35D

Facility License, Permit or Monitoring No.:

Local Grid Origin ☐ (estimated: ☐) or Well Location ☒

Lat. 40° 10' 47.142" Long. 87° 44' 8.067" or

St. Plane 1,279,955.58 ft. N, 1,151,276.17 ft. E. [✓ E]/W

Facility ID:

Date Well Installed: 03/03/2017

Section Location of Waste/Source: ____ 1/4 of ____ 1/4 of Sec. ____, T. ____ N, R. ____ ☐ E ☐ W

Type of Well: mw

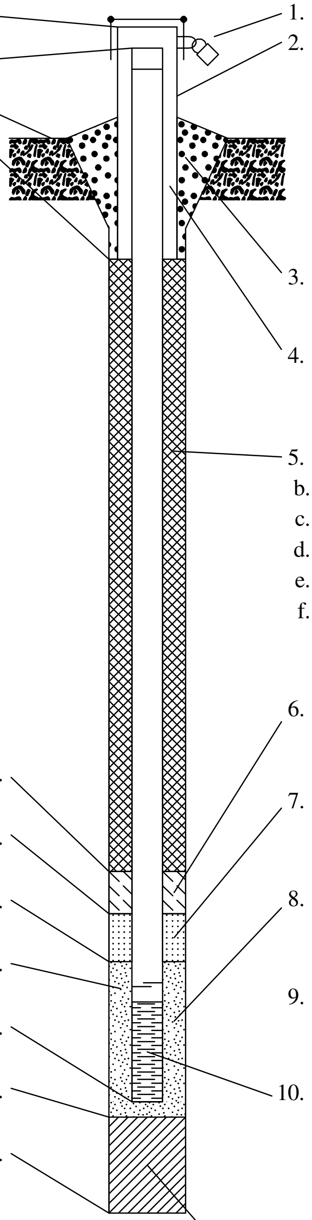
Well Installed By: (Person's Name and Firm)
Bruno Williamson
Ramsey Geotechnical Engineering

Distance from Waste/Source: ____ ft.

State: IL

Location of Well Relative to Waste/Source: u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known

Gov. Lot Number:



A. Protective pipe, top elevation ____ ft. MSL

B. Well casing, top elevation 584.15 ft. MSL

C. Land surface elevation 581.25 ft. MSL

D. Surface seal, bottom 579.3 ft. MSL or 2.0 ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☐ ML ☐ MH ☐ CL ☐ CH ☐
Bedrock ☒

13. Sieve analysis attached? ☐ Yes ☒ No

14. Drilling method used: Rotary ☐
Hollow Stem Auger ☐
HSA / Rotary Other ☒

15. Drilling fluid used: Water ☒ 0 2 Air ☐
Drilling Mud ☐ 0 3 None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe ____

17. Source of water (attach analysis, if required):
City of Champaign

E. Bentonite seal, top 551.3 ft. MSL or 30.0 ft.

F. Fine sand, top ____ ft. MSL or ____ ft.

G. Filter pack, top 548.3 ft. MSL or 33.0 ft.

H. Screen joint, top 546.3 ft. MSL or 35.0 ft.

I. Well bottom 536.3 ft. MSL or 45.0 ft.

J. Filter pack, bottom 535.5 ft. MSL or 45.8 ft.

K. Borehole, bottom 535.5 ft. MSL or 45.8 ft.

L. Borehole, diameter 7.3 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 1.99 in.

1. Cap and lock? ☒ Yes ☐ No

2. Protective cover pipe:
 a. Inside diameter: 6.0 in.
 b. Length: 6.0 ft.
 c. Material: Steel ☒
 Other ☐
 d. Additional protection? ☒ Yes ☐ No
 If yes, describe: 4" diameter protective PVC casing

3. Surface seal: Bentonite ☐
Concrete ☒
Other ☐

4. Material between well casing and protective pipe:
Bentonite ☒
Sand Other ☒

5. Annular space seal: a. Granular/Chipped Bentonite ☐
 b. ____ Lbs/gal mud weight . . . Bentonite-sand slurry ☐
 c. ____ Lbs/gal mud weight . . . Bentonite slurry ☐
 d. 30 % Bentonite . . . Bentonite-cement grout ☒
 e. ____ Ft^3 volume added for any of the above
 f. How installed: Tremie ☒
 Tremie pumped ☐
 Gravity ☐

6. Bentonite seal: a. Bentonite granules ☐
 b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
 c. ____ Other ☐

7. Fine sand material: Manufacturer, product name & mesh size
 a. ____
 b. Volume added ____ ft^3

8. Filter pack material: Manufacturer, product name & mesh size
 a. NSF Quartz Sand #10-20
 b. Volume added ____ ft^3

9. Well casing: Flush threaded PVC schedule 40 ☒
Flush threaded PVC schedule 80 ☐
Other ☐

10. Screen material: Schedule 40 PVC
 a. Screen Type: Factory cut ☒
 Continuous slot ☐
 Other ☐
 b. Manufacturer ____
 c. Slot size: 0.100 in.
 d. Slotted length: 10.0 ft.

11. Backfill material (below filter pack): None ☒
Other ☐

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Date Modified: 4/6/2017

Signature

Firm: Natural Resource Technology
234 W. Florida Street, Floor 5, Milwaukee, WI 53204
Tel: (414) 837-3607
Fax: (414) 837-3608

Geosyntec consultants
engineers | scientists | innovators

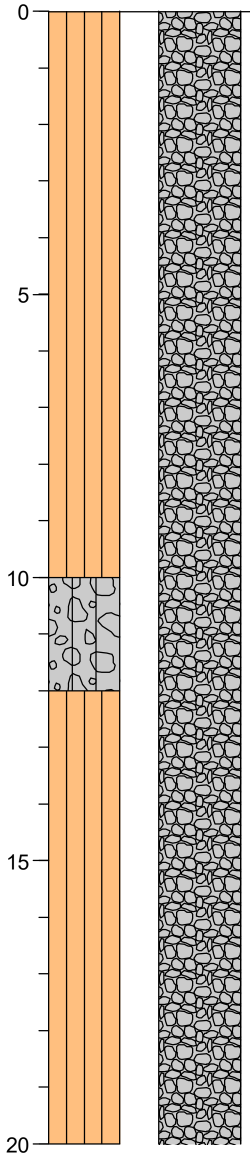
Client: Vistra
Project: Vermilion Power Plant New East Ash Pond
Address: 10188 East 2150 North Road, Oakwood, IL

BORING LOG

Boring No. VER-70
Page: 1 of 4

Drilling Start Date:	**06/23/2023**	Boring Depth (ft):	**80**
Drilling End Date:	**06/23/2023**	Boring Diameter (in):	**6**
Drilling Company:	**Cascade Drilling**	Ground Surface Elev. (ft):	**Not surveyed**
Drilling Method:	**Sonic**		
Drilling Equipment:	**Geoprobe**		
Driller:	**Jeff Jehn**		
Logged By:	**Andrew Kelley**		

Boring was advanced adjacent to well 70D.
Samples collected from 30-40 ft bgs, 41-42 ft bgs and 75-80 ft bgs



DEPTH (ft)	LITHOLOGY	WATER LEVEL	BORING COMPLETION	COLLECT Sample Type	Date & Time	Blow Counts	Recovery (ft)	SOIL/ROCK VISUAL DESCRIPTION
0					10:40	NA	6/10	(0') SILT WITH GRAVEL (ML); light brown, dry, loose, fine to coarse gravel.
								(1') SILT (ML); brown to tan, dry, firm, moderate concretions, little gravel, few clay.
								(3.6') SILT (ML); gray to dark gray with little brown, dry, firm, few fine sand, few fine gravel, coarsens downwards, moderate concretions.
10					10:55		4/10	(10') SILTY GRAVEL (GM); gray to dark gray, moist, loose, some fine to coarse sand.
								(10.5') SILTY GRAVEL (GM); light gray, moist, loose, fines downward.
								(12') SANDY SILT (ML); brown, moist, medium dense, firm, little clay, little fine gravel.

NOTES:

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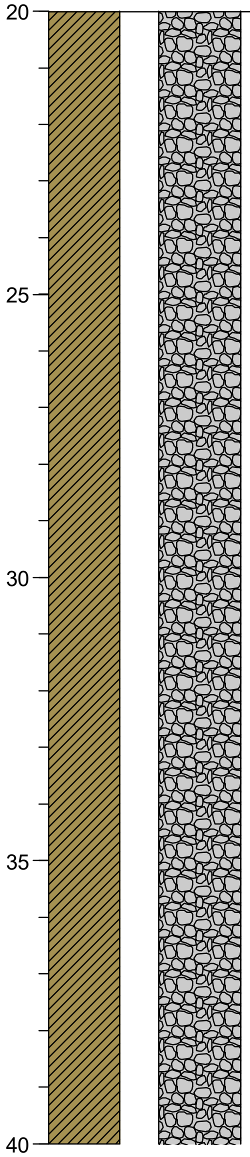
Client:	**Vistra**	**BORING LOG**
Project:	**Vermilion Power Plant New East Ash Pond**	**Boring No. VER-70**
Address:	**10188 East 2150 North Road, Oakwood, IL**	**Page: 2 of 4**

Drilling Start Date:	**06/23/2023**	Boring Depth (ft):	**80**
Drilling End Date:	**06/23/2023**	Boring Diameter (in):	**6**
Drilling Company:	**Cascade Drilling**	Ground Surface Elev. (ft):	**Not surveyed**
Drilling Method:	**Sonic**	Boring was advanced adjacent to well 70D. Samples collected from 30-40 ft bgs, 41-42 ft bgs and 75-80 ft bgs	
Drilling Equipment:	**Geoprobe**		
Driller:	**Jeff Jehn**		
Logged By:	**Andrew Kelley**		



DEPTH (ft)	LITHOLOGY	WATER LEVEL	BORING COMPLETION	COLLECT Sample Type	COLLECT Date & Time	COLLECT Blow Counts	COLLECT Recovery (ft)	SOIL/ROCK VISUAL DESCRIPTION
20					13:00	NA	3/10	(20') CLAY WITH SILT (CL); grayish brown, wet, stiff, little sand, little fine to coarse gravel.
21								(21') SILTY CLAY (CL); grayish brown, wet, soft, little fine gravel, few sand.
21.3								(21.3') SANDY CLAY (CL); grayish brown, wet, very stiff, some gravel.
30							3/10	(30') GRAVELLY CLAY WITH SAND (CL); grayish brown, wet, firm, sand coarsens downward.
31.8								(31.8') CLAY (CL); dark gray to black, wet, firm, little gravel, few roots observed, dark organics.

NOTES:

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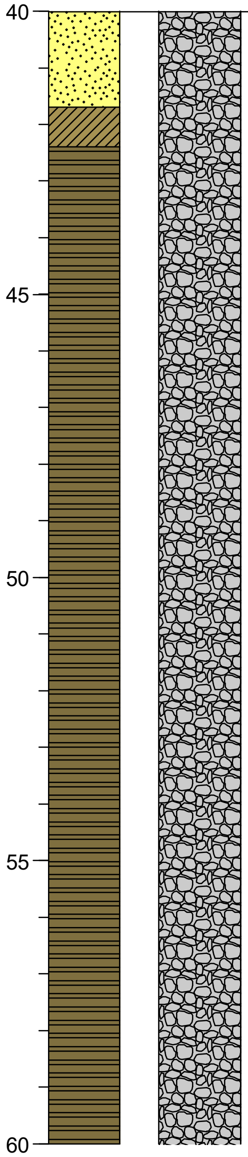
Client: Vistra
Project: Vermilion Power Plant New East Ash Pond
Address: 10188 East 2150 North Road, Oakwood, IL

BORING LOG

Boring No. VER-70
Page: 3 of 4

Drilling Start Date:	**06/23/2023**	Boring Depth (ft):	**80**
Drilling End Date:	**06/23/2023**	Boring Diameter (in):	**6**
Drilling Company:	**Cascade Drilling**	Ground Surface Elev. (ft):	**Not surveyed**
Drilling Method:	**Sonic**		
Drilling Equipment:	**Geoprobe**		
Driller:	**Jeff Jehn**		
Logged By:	**Andrew Kelley**		

Boring was advanced adjacent to well 70D.
Samples collected from 30-40 ft bgs, 41-42 ft bgs and 75-80 ft bgs



DEPTH (ft)	LITHOLOGY	WATER LEVEL	BORING COMPLETION	COLLECT: Sample Type	COLLECT: Date & Time	COLLECT: Blow Counts	COLLECT: Recovery (ft)	SOIL/ROCK VISUAL DESCRIPTION
40					13:50	NA	8/10	(40') POORLY GRADED SAND (SP); brown with hint of gray, wet, medium dense, fine grained.
								(41.7') CLAY (CL); brownish gray, moist, very stiff, few coarse gravel, some sand.
								(42.4') SHALE, gray, moist, laminated, highly decomposed, moderately disintegrated.
45								
50					14:30		5/10	(50') As above.
55								
60								

NOTES:

Geosyntec consultants engineers | scientists | innovators	**Client:** **Vistra** **Project:** **Vermilion Power Plant New East Ash Pond** **Address:** **10188 East 2150 North Road, Oakwood, IL**	**BORING LOG** **Boring No.** **VER-70** **Page:** **4 of 4**

Drilling Start Date:	**06/23/2023**	Boring Depth (ft):	**80**
Drilling End Date:	**06/23/2023**	Boring Diameter (in):	**6**
Drilling Company:	**Cascade Drilling**	Ground Surface Elev. (ft):	**Not surveyed**
Drilling Method:	**Sonic**	Boring was advanced adjacent to well 70D. Samples collected from 30-40 ft bgs, 41-42 ft bgs and 75-80 ft bgs	
Drilling Equipment:	**Geoprobe**		
Driller:	**Jeff Jehn**		
Logged By:	**Andrew Kelley**		

DEPTH (ft)	LITHOLOGY	WATER LEVEL	BORING COMPLETION	COLLECT				SOIL/ROCK VISUAL DESCRIPTION
				Sample Type	Date & Time	Blow Counts	Recovery (ft)	
60	▤		▨		15:15	NA	1/10	(60') SHALE, gray to dark gray, wet (driller water), foliated, highly decomposed, slightly disintegrated, weaker and more highly disintegrated shale likely washed out by driller fluids.
65	▤		▨					
70	▤		▨		17:00		10/10	(70') SHALE, gray to dark gray, wet, highly decomposed, moderately disintegrated, coated in wet clay (likely slough).
75	▤		▨					(75') SHALE, gray to dark gray, moist, highly decomposed, slightly disintegrated.
80								(80') End of Boring.

NOTES:

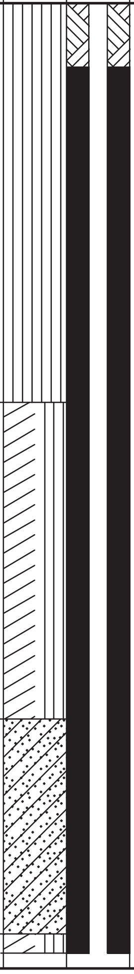
Electronic Filing: Received, Clerk's Office 02/02/2024 **PCB 2024-053**

SOIL BORING LOG INFORMATION

Facility/Project Name Vermilion Power Station		License/Permit/Monitoring Number		Boring Number 70D
Boring Drilled By: Name of crew chief (first, last) and Firm Jason Greer Cascade Drilling		Date Drilling Started 3/4/2021	Date Drilling Completed 3/4/2021	Drilling Method Mini Sonic
Common Well Name 70D		Final Static Water Level Feet (NAVD88)	Surface Elevation 591.90 Feet (NAVD88)	Borehole Diameter 6.0 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☐
State Plane 1,278,929.46 N, 1,150,617.15 E [✓ E]/ W
1/4 of 1/4 of Section , T N, R
Lat ° ' "
Long ° ' "
Local Grid Location
Feet ☐ N ☐ S
Feet ☐ E ☐ W

Facility ID	County	State	Civil Town/City/ or Village
	Vermilion	Illinois	Oakwood



Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Soil Properties: Compressive Strength (tsf)	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
1 CS	60 47		0	0 - 6.3' **SILT:** ML, dark brown (10YR 3/3) to brown (10YR 4/3), clay (15-25%), sand, (0-5%), roots (0-5%), stiff, slow dilatancy, low toughness, low plasticity, moist.	ML				1.5 1.5					CS= Core Sample
2 CS	60 60		5						1.5					
			6.3	6.3 - 11.3' **SILTY CLAY:** CL/ML, brown (10YR 4/3), sand (0-10%), gravel (0-5%), firm, slow dilatancy, low toughness, medium plasticity, moist.	CL/ML				0.75 0.75					
			9.4	9.4' color change to yellowish brown (10YR 5/4).										
3 CS	120 120		10											
			11.3	11.3 - 14.7' **CLAYEY SAND:** SC, yellowish brown (10YR 5/6), rounded fine sand, silt (5-10%), gravel (0-5%), loose, wet.	SC									
			15											

I hereby certify that the information on this form is true and correct to the best of my knowledge.

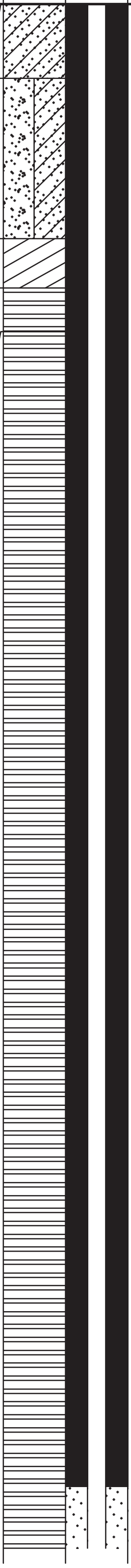
Signature

Firm Ramboll
234 W. Florida Street, Milwaukee,WI 53204
Tel: (414) 837-3607
Fax: (414) 837-3608

SOIL BORING LOG INFORMATION SUPPLEMENT

Boring Number 70D

Page 2 of 3

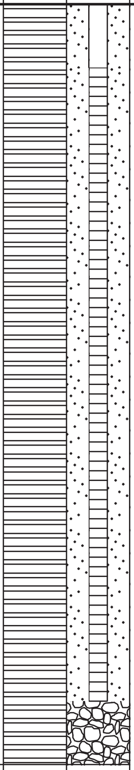


Sample Number and Type	Sample Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Soil Properties Compressive Strength (tsf)	Soil Properties Moisture Content	Soil Properties Liquid Limit	Soil Properties Plasticity Index	Soil Properties P 200	RQD/ Comments
			16	14.7 - 15' **SILTY CLAY:** CL/ML, yellowish brown (10YR 5/6), soft, slow dilatancy, low toughness, medium plasticity.	CL/ML									
			17	15 - 16.2' **CLAYEY SAND:** SC, yellowish brown (10YR 5/6), rounded fine sand, silt (5-10%), gravel (0-5%), loose, wet.	SC									
			18	16.2 - 18.8' **POORLY-GRADED SAND WITH CLAY:** SP-SC, ???, subrounded to rounded, fine to medium sand, loose, wet.	SP-SC									
			19	18.8 - 19.6' **LEAN CLAY:** CL, dark gray (10YR 4/1), gravel, (0-5%), sand (0-5%), stiff, no dilatancy, low toughness, medium plasticity, moist.	CL				2.5					
4 CS	120 97		20	19.6 - 20.3' **Weathered SHALE Bedrock** BDX (SH), gray (10YR 5/1), dry.	BDX (SH)									
			21	20.3 - 52' **SHALE:** BDX (SH), gray (10YR 5/1).										
			22											
			23											
			24											
			25											
			26											
			27											
			28											
			29											
5 CS	132 132		30		BDX (SH)									
			31											
			32											
			33											
			34											
			35											
			36											
			37											
			38											
			39											
			40											

SOIL BORING LOG INFORMATION SUPPLEMENT

Boring Number 70D

Sample									Soil Properties					
Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
6 CS	132 132		41 42 43 44 45 46 47 48 49 50 51 52	20.3 - 52' **SHALE:** BDX (SH), gray (10YR 5/1). *(continued)*	BDX (SH)									
				52' End of Boring.										



RAMBOLL

MONITORING WELL CONSTRUCTION

Facility/Project Name: Vermilion Power Station

Facility License, Permit or Monitoring No.:

Facility ID:

Type of Well: Well Code 12/pz

Distance from Waste/Source: ft.

State: Illinois

Local Grid Location of Well: ____ft. ☐ N. ☐ S. ____ft. ☐ E. ☐ W.

Local Grid Origin ☐ (estimated: ☐) or Well Location ☐

Lat. ____° ____' ____" Long. ____° ____' ____" or

St. Plane 1,278,929 ft. N, 1,150,617 ft. E. [✓ E]/W

Section Location of Waste/Source: ____1/4 of ____ 1/4 of Sec. ____, T. ____ N, R. ____ ☐ E ☐ W

Location of Well Relative to Waste/Source: u ☐ Upgradient s ☐ Sidegradient d ☒ Downgradient n ☐ Not Known

Gov. Lot Number:

Well Name: 70D

Date Well Installed: 03/04/2021

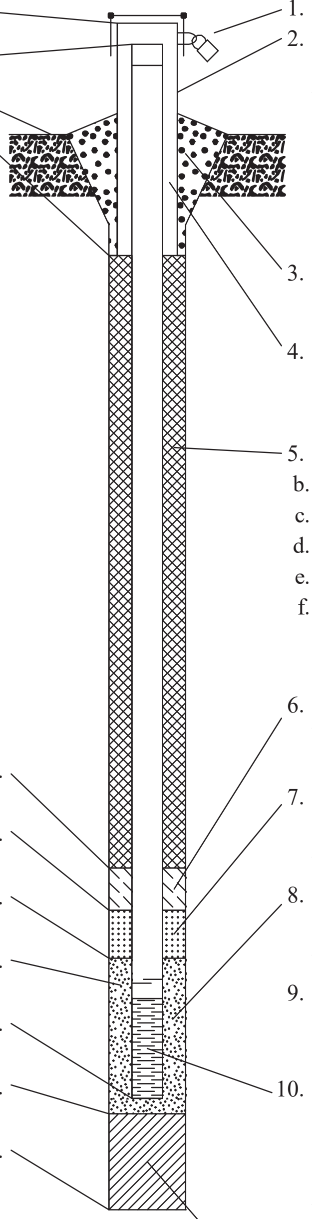
Well Installed By: (Person's Name and Firm): Jason Greer, Cascade Drilling

A. Protective pipe, top elevation 595.10 ft. MSL

B. Well casing, top elevation 594.52 ft. MSL

C. Land surface elevation 591.9 ft. MSL

D. Surface seal, bottom 590.9 ft. MSL or 1.0 ft.



12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☐ ML ☐ MH ☐ CL ☐ CH ☐
Bedrock ☒

13. Sieve analysis attached? ☐ Yes ☒ No

14. Drilling method used: Rotary ☐ Hollow Stem Auger ☐ Other ☒ Sonic

15. Drilling fluid used: Water ☒ 0 2 Air ☐ Drilling Mud ☐ 0 3 None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe

17. Source of water (attach analysis, if required): Potable City Water

E. Bentonite seal, top 557.9 ft. MSL or 34.0 ft.

F. Fine sand, top ____ ft. MSL or ____ ft.

G. Filter pack, top 552.9 ft. MSL or 39.0 ft.

H. Screen joint, top 550.9 ft. MSL or 41.0 ft.

I. Well bottom 540.9 ft. MSL or 51.0 ft.

J. Filter pack, bottom 540.9 ft. MSL or 51.0 ft.

K. Borehole, bottom 539.9 ft. MSL or 52.0 ft.

L. Borehole, diameter 6.0 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.

1. Cap and lock? ☒ Yes ☐ No
2. Protective cover pipe:
   a. Inside diameter: 4.0 in.
   b. Length: 5.0 ft.
   c. Material: Steel ☒ Other ☐
   d. Additional protection? ☒ Yes ☐ No
   If yes, describe: 4 Steel Bollards
3. Surface seal: Bentonite ☐ Concrete ☒ Other ☐
4. Material between well casing and protective pipe: Bentonite ☐ Other ☒ Sand
5. Annular space seal: a. Granular/Chipped Bentonite ☐
   b. ____Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   c. 9.2 Lbs/gal mud weight . . . Bentonite slurry ☒
   d. ____% Bentonite . . . Bentonite-cement grout ☐
   e. ____Ft^3 volume added for any of the above
   f. How installed: Tremie ☐ Tremie pumped ☒ Gravity ☐
6. Bentonite seal: a. Bentonite granules ☐
   b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
   c. ____ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
   a. NA
   b. Volume added 0 ft^3
8. Filter pack material: Manufacturer, product name & mesh size
   a. FILTERSIL 0.85
   b. Volume added ____ ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒ Flush threaded PVC schedule 80 ☐ Other ☐
10. Screen material: Schedule 40 PVC
   a. Screen Type: Factory cut ☒ Continuous slot ☐ Other ☐
   b. Manufacturer Johnson Screens
   c. Slot size: 0.010 in.
   d. Slotted length: 10.0 ft.
11. Backfill material (below filter pack): None ☐ Other ☒ Formation Materials

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Date Modified: 3/31/2021

Signature

Firm: Ramboll
234 W. Florida Street, Milwaukee, WI 53204

Tel: (414) 837-3607
Fax: (414) 837-3608

ATTACHMENT 3

Sequential Extraction Procedure Laboratory Analytical Reports

Electronic Filing: Received, Clerk's Office 02/02/2024 **PCB 2024-053**

Environment Testing

ANALYTICAL REPORT

PREPARED FOR

Attn: Allison Kreinberg
Geosyntec Consultants Inc
941 Chatham Lane
Suite 103
Columbus, Ohio 43221

Generated 8/3/2023 11:56:48 AM

JOB DESCRIPTION

Vermilion SEP

JOB NUMBER

140-32513-1

Eurofins Knoxville
5815 Middlebrook Pike
Knoxville TN 37921

See page two for job notes and contact information.

Eurofins Knoxville

Job Notes

This report may not be reproduced except in full, and with written approval from the laboratory. The results relate only to the samples tested. For questions please contact the Project Manager at the e-mail address or telephone number listed on this page.

The test results in this report relate only to the samples as received by the laboratory and will meet all requirements of the methodology, with any exceptions noted. This report shall not be reproduced except in full, without the express written approval of the laboratory. All questions should be directed to the Eurofins TestAmerica Project Manager.

Authorization

Ryan Henry

Generated
8/3/2023 11:56:48 AM

Authorized for release by
Ryan Henry, Project Manager I
WilliamR.Henry@et.eurofinsus.com
(865)291-3006

Table of Contents

Definitions/Glossary

Qualifiers

Metals

Qualifier	Qualifier Description
B	Compound was found in the blank and sample.
J	Result is less than the RL but greater than or equal to the MDL and the concentration is an approximate value.

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

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Job ID: 140-32513-1

Laboratory: Eurofins Knoxville

Narrative

Job Narrative
140-32513-1

Receipt
The samples were received on 7/3/2023 at 11:15am and arrived in good condition, and where required, properly preserved and on ice. The temperature of the cooler at receipt was 20.3º C.

Receipt Exceptions
The Field Sampler was not listed on the Chain of Custody.

Metals
7 Step Sequential Extraction Procedure

These soil samples were prepared and analyzed using Eurofins TestAmerica Knoxville standard operating procedure KNOX-MT-0008, “7 Step Sequential Extraction Procedure”. SW-846 Method 6010B as incorporated in Eurofins TestAmerica Knoxville standard operating procedure KNOX-MT-0007 was used to perform the final instrument analyses.

An aliquot of each sample was sequentially extracted using the steps listed below:

- Step 1 - Exchangeable Fraction: A 5 gram aliquot of sample was extracted with 25 mL of 1M magnesium sulfate (MgSO4), centrifuged and filtered. 5 mL of the resulting leachate was digested using method 3010A and analyzed by method 6010B. Results are reported in mg/kg on a dry weight basis.
- Step 2 - Carbonate Fraction: The sample residue from step 1 was extracted with 25 mL of 1M sodium acetate/acetic acid (NaOAc/HOAc) at pH 5, centrifuged and filtered. 5 mL of the resulting leachate was digested using method 3010A and analyzed by method 6010B. Results are reported in mg/kg on a dry weight basis.
- Step 3 - Non-crystalline Materials Fraction: The sample residue from step 2 was extracted with 25 mL of 0.2M ammonium oxalate (pH 3), centrifuged and filtered. 5 mL of the resulting leachate was digested using method 3010A and analyzed by method 6010B. Results are reported in mg/kg on a dry weight basis.
- Step 4 - Metal Hydroxide Fraction: The sample residue from step 3 was extracted with 25 mL of 1M hydroxylamine hydrochloride solution in 25% v/v acetic acid, centrifuged and filtered. 5 mL of the resulting leachate was digested using method 3010A and analyzed by method 6010B. Results are reported in mg/kg on a dry weight basis.
- Step 5 - Organic-bound Fraction: The sample residue from step 4 was extracted three times with 25 mL of 5% sodium hypochlorite (NaClO) at pH 9.5, centrifuged and filtered. The resulting leachates were combined and 5 mL were digested using method 3010A and analyzed by method 6010B. Results are reported in mg/kg on a dry weight basis.
- Step 6 - Acid/Sulfide Fraction: The sample residue from step 5 was extracted with 25 mL of a 3:1:2 v/v solution of HCl-HNO3-H2O, centrifuged and filtered. 5 mL of the resulting leachate was diluted to 50 mL with reagent water and analyzed by method 6010B. Results are reported in mg/kg on a dry weight basis.
- Step 7 - Residual Fraction: A 1.0 g aliquot of the sample residue from step 6 was digested using HF, HNO3, HCl and H3BO3. The digestate was analyzed by ICP using method 6010B. Results are reported in mg/kg on a dry weight basis.

In addition, a 1.0 g aliquot of the original sample was digested using HF, HNO3, HCl and H3BO3. The digestate was analyzed by ICP using method 6010B. Total metal results are reported in mg/kg on a dry weight basis.

Results were calculated using the following equation:

$$\text{Result, } \mu\text{g/g or mg/Kg, dry weight} = (C \times V \times V1 \times D) / (W \times S \times V2)$$

Where:
C = Concentration from instrument readout, µg/mL
V = Final volume of digestate, mL
D = Instrument dilution factor
V1 = Total volume of leachate, mL
V2 = Volume of leachate digested, mL
W = Wet weight of sample, g

Job ID: 140-32513-1 (Continued)

Laboratory: Eurofins Knoxville (Continued)

S = Percent solids/100

A method blank, laboratory control sample and laboratory control sample duplicate were prepared and analyzed with each SEP step in order to provide information about both the presence of elements of interest in the extraction solutions, and the recovery of elements of interest from the extraction solutions. Results outside of laboratory QC limits do not reflect out of control performance, but rather the effect of the extraction solution upon the analyte.

A laboratory sample duplicate was prepared and analyzed with each batch of samples in order to provide information regarding the reproducibility of the procedure.

SEP Report Notes:

The final report lists the results for each step, the result for the total digestion of the sample, and a sum of the results of steps 1 through 7 by element.

Magnesium was not reported for step 1 because the extraction solution for this step (magnesium sulfate) contains high levels of magnesium.

Sodium was not reported for steps 2 and 5 since the extraction solution for these steps contain high levels of sodium.

The sum of steps 1 through 7 is much higher than the total result for sodium and magnesium due to the magnesium and sodium introduced by the extraction solutions.

The digestates for steps 1, 2 and 5 were analyzed at a dilution due to instrument problems caused by the high solids content of the digestates. The reporting limits were adjusted accordingly.

The serial diilution is analyzed at an additional 5 fold dilution using the dilution factors applied to the duplicate and the associated original sample. Due to a limitation of the expanded deliverable forms, the dilutions of the duplicate and serial dilution in the expanded deliverable are not expressed on a per analyte basis.

Please refer to the summary section of the report for the duplicate information as it contains the dilution factors at which the sample was analyzed.

Method 6010B: The serial dilution performed for the following samples associated with batch 140-75976 were outside control limits: VER-35 55-60 20230624 (140-32513-1), (140-32513-A-1-C SD ^10) and (140-32513-A-1-C SD ^5)

Method 6010B: The following samples were diluted to bring the concentration of target analyte, Iron, within the calibration range: VER-35 55-60 20230624 (140-32513-1), VER-35 60-63 20230624 (140-32513-2) and VER-70 75-80 20230623 (140-32513-3). Elevated reporting limits (RLs) are provided.

Method 6010B SEP: The serial dilution performed for the following samples associated with batch 140-75894 was outside control limits: VER-35 55-60 20230624 (140-32513-1), (140-32513-A-1-S SD ^5) and (140-32513-A-1-W SD ^5)

No additional analytical or quality issues were noted, other than those described above or in the Definitions/Glossary page.

General Chemistry
% Moisture: The samples were analyzed for percent moisture using SOP number KNOX-WC-0012 (based on Modified MCAWW 160.3 and SM2540B and on the percent moisture determinations described in methods 3540C and 3550B).

No additional analytical or quality issues were noted, other than those described above or in the Definitions/Glossary page.

Sample Summary

Lab Sample ID	Client Sample ID	Matrix	Collected	Received
140-32513-1	VER-35 55-60 20230624	Solid	06/24/23 14:20	07/03/23 11:15
140-32513-2	VER-35 60-63 20230624	Solid	06/24/23 14:50	07/03/23 11:15
140-32513-3	VER-70 75-80 20230623	Solid	06/23/23 17:00	07/03/23 11:15

Client Sample ID: VER-35 55-60 20230624

Date Collected: 06/24/23 14:20
Date Received: 07/03/23 11:15

Lab Sample ID: 140-32513-1

Matrix: Solid
Percent Solids: 95.4

Method: SW846 6010B SEP - SEP Metals (ICP) - Step 1

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	ND		21	12	mg/Kg	☼	07/11/23 08:00	07/27/23 13:01	4
Lithium	ND		10	0.63	mg/Kg	☼	07/11/23 08:00	07/27/23 13:01	4
Manganese	**7.6**		3.1	0.13	mg/Kg	☼	07/11/23 08:00	07/27/23 13:01	4

Method: SW846 6010B SEP - SEP Metals (ICP) - Step 2

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	**560**		16	9.1	mg/Kg	☼	07/12/23 08:00	07/27/23 13:51	3
Lithium	**0.56**	**J**	7.9	0.47	mg/Kg	☼	07/12/23 08:00	07/27/23 13:51	3
Manganese	**29**		2.4	0.88	mg/Kg	☼	07/12/23 08:00	07/27/23 13:51	3

Method: SW846 6010B SEP - SEP Metals (ICP) - Step 3

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	**4300**		5.2	3.0	mg/Kg	☼	07/13/23 08:00	07/27/23 14:40	1
Lithium	**0.52**	**J**	2.6	0.16	mg/Kg	☼	07/13/23 08:00	07/27/23 14:40	1
Manganese	**110**	**B**	0.79	0.028	mg/Kg	☼	07/13/23 08:00	07/27/23 14:40	1

Method: SW846 6010B SEP - SEP Metals (ICP) - Step 4

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	**20000**		5.2	3.0	mg/Kg	☼	07/17/23 08:00	07/28/23 12:49	1
Lithium	**13**		2.6	0.16	mg/Kg	☼	07/17/23 08:00	07/28/23 12:49	1
Manganese	**430**		0.79	0.14	mg/Kg	☼	07/17/23 08:00	07/28/23 12:49	1

Method: SW846 6010B SEP - SEP Metals (ICP) - Step 5

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	ND		79	46	mg/Kg	☼	07/19/23 08:00	07/28/23 13:39	5
Lithium	**4.1**	**J**	39	2.3	mg/Kg	☼	07/19/23 08:00	07/28/23 13:39	5
Manganese	**46**		12	1.9	mg/Kg	☼	07/19/23 08:00	07/28/23 13:39	5

Method: SW846 6010B SEP - SEP Metals (ICP) - Step 6

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	**11000**		5.2	3.0	mg/Kg	☼	07/19/23 08:00	07/28/23 14:29	1
Lithium	**13**		2.6	0.16	mg/Kg	☼	07/19/23 08:00	07/28/23 14:29	1
Manganese	**130**		0.79	0.26	mg/Kg	☼	07/19/23 08:00	07/28/23 14:29	1

Method: SW846 6010B SEP - SEP Metals (ICP) - Step 7

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	**4300**		5.2	4.3	mg/Kg	☼	07/20/23 08:00	07/31/23 12:46	1
Lithium	**15**		2.6	0.16	mg/Kg	☼	07/20/23 08:00	07/31/23 12:46	1
Manganese	**31**		0.79	0.32	mg/Kg	☼	07/20/23 08:00	07/31/23 12:46	1

Method: SW846 6010B SEP - SEP Metals (ICP) - Sum of Steps 1-7

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	**41000**		5.0	4.1	mg/Kg			08/02/23 14:24	1
Lithium	**46**		2.5	0.15	mg/Kg			08/02/23 14:24	1
Manganese	**780**		0.75	0.052	mg/Kg			08/02/23 14:24	1

Method: SW846 6010B - SEP Metals (ICP) - Total

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	**38000**		10	8.6	mg/Kg	☼	07/21/23 08:00	07/31/23 14:12	2
Lithium	**42**		2.6	0.16	mg/Kg	☼	07/21/23 08:00	07/31/23 13:22	1
Manganese	**610**		0.79	0.32	mg/Kg	☼	07/21/23 08:00	07/31/23 13:22	1

Client Sample Results

Client Sample ID: VER-35 60-63 20230624

Date Collected: 06/24/23 14:50
Date Received: 07/03/23 11:15

Lab Sample ID: 140-32513-2

Matrix: Solid
Percent Solids: 95.4

Method: SW846 6010B SEP - SEP Metals (ICP) - Step 1

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	ND		21	12	mg/Kg	☼	07/11/23 08:00	07/27/23 13:11	4
Lithium	ND		10	0.63	mg/Kg	☼	07/11/23 08:00	07/27/23 13:11	4
Manganese	**7.9**		3.1	0.13	mg/Kg	☼	07/11/23 08:00	07/27/23 13:11	4

Method: SW846 6010B SEP - SEP Metals (ICP) - Step 2

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	**570**		16	9.1	mg/Kg	☼	07/12/23 08:00	07/27/23 14:01	3
Lithium	**0.62**	**J**	7.9	0.47	mg/Kg	☼	07/12/23 08:00	07/27/23 14:01	3
Manganese	**29**		2.4	0.88	mg/Kg	☼	07/12/23 08:00	07/27/23 14:01	3

Method: SW846 6010B SEP - SEP Metals (ICP) - Step 3

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	**4200**		5.2	3.0	mg/Kg	☼	07/13/23 08:00	07/27/23 14:50	1
Lithium	**0.74**	**J**	2.6	0.16	mg/Kg	☼	07/13/23 08:00	07/27/23 14:50	1
Manganese	**110**	**B**	0.79	0.028	mg/Kg	☼	07/13/23 08:00	07/27/23 14:50	1

Method: SW846 6010B SEP - SEP Metals (ICP) - Step 4

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	**18000**		5.2	3.0	mg/Kg	☼	07/17/23 08:00	07/28/23 12:59	1
Lithium	**12**		2.6	0.16	mg/Kg	☼	07/17/23 08:00	07/28/23 12:59	1
Manganese	**380**		0.79	0.14	mg/Kg	☼	07/17/23 08:00	07/28/23 12:59	1

Method: SW846 6010B SEP - SEP Metals (ICP) - Step 5

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	ND		79	46	mg/Kg	☼	07/19/23 08:00	07/28/23 13:49	5
Lithium	**3.9**	**J**	39	2.3	mg/Kg	☼	07/19/23 08:00	07/28/23 13:49	5
Manganese	**35**		12	1.9	mg/Kg	☼	07/19/23 08:00	07/28/23 13:49	5

Method: SW846 6010B SEP - SEP Metals (ICP) - Step 6

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	**11000**		5.2	3.0	mg/Kg	☼	07/19/23 08:00	07/28/23 14:39	1
Lithium	**14**		2.6	0.16	mg/Kg	☼	07/19/23 08:00	07/28/23 14:39	1
Manganese	**140**		0.79	0.26	mg/Kg	☼	07/19/23 08:00	07/28/23 14:39	1

Method: SW846 6010B SEP - SEP Metals (ICP) - Step 7

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	**4200**		5.2	4.3	mg/Kg	☼	07/20/23 08:00	07/31/23 12:57	1
Lithium	**14**		2.6	0.16	mg/Kg	☼	07/20/23 08:00	07/31/23 12:57	1
Manganese	**30**		0.79	0.33	mg/Kg	☼	07/20/23 08:00	07/31/23 12:57	1

Method: SW846 6010B SEP - SEP Metals (ICP) - Sum of Steps 1-7

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	**38000**		5.0	4.1	mg/Kg			08/02/23 14:24	1
Lithium	**45**		2.5	0.15	mg/Kg			08/02/23 14:24	1
Manganese	**730**		0.75	0.052	mg/Kg			08/02/23 14:24	1

Method: SW846 6010B - SEP Metals (ICP) - Total

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	**37000**		10	8.6	mg/Kg	☼	07/21/23 08:00	07/31/23 14:22	2
Lithium	**39**		2.6	0.16	mg/Kg	☼	07/21/23 08:00	07/31/23 13:33	1
Manganese	**520**		0.79	0.33	mg/Kg	☼	07/21/23 08:00	07/31/23 13:33	1

Client Sample Results

Client Sample ID: VER-70 75-80 20230623

Lab Sample ID: 140-32513-3

Date Collected: 06/23/23 17:00
Date Received: 07/03/23 11:15
Matrix: Solid
Percent Solids: 90.0

Method: SW846 6010B SEP - SEP Metals (ICP) - Step 1

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	ND		22	13	mg/Kg	☼	07/11/23 08:00	07/27/23 13:16	4
Lithium	ND		11	0.67	mg/Kg	☼	07/11/23 08:00	07/27/23 13:16	4
Manganese	**7.6**		3.3	0.14	mg/Kg	☼	07/11/23 08:00	07/27/23 13:16	4

Method: SW846 6010B SEP - SEP Metals (ICP) - Step 2

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	**730**		17	9.7	mg/Kg	☼	07/12/23 08:00	07/27/23 14:06	3
Lithium	ND		8.3	0.50	mg/Kg	☼	07/12/23 08:00	07/27/23 14:06	3
Manganese	**36**		2.5	0.93	mg/Kg	☼	07/12/23 08:00	07/27/23 14:06	3

Method: SW846 6010B SEP - SEP Metals (ICP) - Step 3

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	**5500**		5.6	3.2	mg/Kg	☼	07/13/23 08:00	07/27/23 14:55	1
Lithium	**0.41**	**J**	2.8	0.17	mg/Kg	☼	07/13/23 08:00	07/27/23 14:55	1
Manganese	**130**	**B**	0.83	0.030	mg/Kg	☼	07/13/23 08:00	07/27/23 14:55	1

Method: SW846 6010B SEP - SEP Metals (ICP) - Step 4

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	**31000**		11	6.4	mg/Kg	☼	07/17/23 08:00	07/28/23 14:55	2
Lithium	**12**		2.8	0.17	mg/Kg	☼	07/17/23 08:00	07/28/23 13:04	1
Manganese	**510**		0.83	0.14	mg/Kg	☼	07/17/23 08:00	07/28/23 13:04	1

Method: SW846 6010B SEP - SEP Metals (ICP) - Step 5

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	**61**	**J**	83	49	mg/Kg	☼	07/19/23 08:00	07/28/23 13:54	5
Lithium	**4.4**	**J**	42	2.4	mg/Kg	☼	07/19/23 08:00	07/28/23 13:54	5
Manganese	**54**		12	2.1	mg/Kg	☼	07/19/23 08:00	07/28/23 13:54	5

Method: SW846 6010B SEP - SEP Metals (ICP) - Step 6

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	**14000**		5.6	3.2	mg/Kg	☼	07/19/23 08:00	07/28/23 14:44	1
Lithium	**15**		2.8	0.17	mg/Kg	☼	07/19/23 08:00	07/28/23 14:44	1
Manganese	**160**		0.83	0.28	mg/Kg	☼	07/19/23 08:00	07/28/23 14:44	1

Method: SW846 6010B SEP - SEP Metals (ICP) - Step 7

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	**5500**		5.6	4.6	mg/Kg	☼	07/20/23 08:00	07/31/23 13:17	1
Lithium	**19**		2.8	0.17	mg/Kg	☼	07/20/23 08:00	07/31/23 13:17	1
Manganese	**39**		0.83	0.34	mg/Kg	☼	07/20/23 08:00	07/31/23 13:17	1

Method: SW846 6010B SEP - SEP Metals (ICP) - Sum of Steps 1-7

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	**57000**		5.0	4.1	mg/Kg			08/02/23 14:24	1
Lithium	**51**		2.5	0.15	mg/Kg			08/02/23 14:24	1
Manganese	**940**		0.75	0.052	mg/Kg			08/02/23 14:24	1

Method: SW846 6010B - SEP Metals (ICP) - Total

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	**66000**		28	23	mg/Kg	☼	07/21/23 08:00	07/31/23 15:08	5
Lithium	**42**		2.8	0.17	mg/Kg	☼	07/21/23 08:00	07/31/23 13:39	1
Manganese	**720**		0.83	0.34	mg/Kg	☼	07/21/23 08:00	07/31/23 13:39	1

Default Detection Limits

Method: 6010B SEP - SEP Metals (ICP) - Step 1

Prep: 3010A

SEP: Exchangeable

Analyte	RL	MDL	Units
Iron	5.0	2.9	mg/Kg
Lithium	2.5	0.15	mg/Kg
Manganese	0.75	0.031	mg/Kg

Method: 6010B SEP - SEP Metals (ICP) - Step 2

Prep: 3010A

SEP: Carbonate

Analyte	RL	MDL	Units
Iron	5.0	2.9	mg/Kg
Lithium	2.5	0.15	mg/Kg
Manganese	0.75	0.28	mg/Kg

Method: 6010B SEP - SEP Metals (ICP) - Step 3

Prep: 3010A

SEP: Non-Crystalline

Analyte	RL	MDL	Units
Iron	5.0	2.9	mg/Kg
Lithium	2.5	0.15	mg/Kg
Manganese	0.75	0.027	mg/Kg

Method: 6010B SEP - SEP Metals (ICP) - Step 4

Prep: 3010A

SEP: Metal Hydroxide

Analyte	RL	MDL	Units
Iron	5.0	2.9	mg/Kg
Lithium	2.5	0.15	mg/Kg
Manganese	0.75	0.13	mg/Kg

Method: 6010B SEP - SEP Metals (ICP) - Step 5

Prep: 3010A

SEP: Organic-Bound

Analyte	RL	MDL	Units
Iron	15	8.8	mg/Kg
Lithium	7.5	0.44	mg/Kg
Manganese	2.3	0.37	mg/Kg

Method: 6010B SEP - SEP Metals (ICP) - Step 6

SEP: Acid/Sulfide

Analyte	RL	MDL	Units
Iron	5.0	2.9	mg/Kg
Lithium	2.5	0.15	mg/Kg
Manganese	0.75	0.25	mg/Kg

Method: 6010B SEP - SEP Metals (ICP) - Step 7

Prep: Residual

Analyte	RL	MDL	Units
Iron	5.0	4.1	mg/Kg
Lithium	2.5	0.15	mg/Kg
Manganese	0.75	0.31	mg/Kg

Default Detection Limits

Method: 6010B SEP - SEP Metals (ICP) - Sum of Steps 1-7

Analyte	RL	MDL	Units
Iron	5.0	4.1	mg/Kg
Lithium	2.5	0.15	mg/Kg
Manganese	0.75	0.052	mg/Kg

Method: 6010B - SEP Metals (ICP) - Total

Prep: Total

Analyte	RL	MDL	Units
Iron	5.0	4.1	mg/Kg
Lithium	2.5	0.15	mg/Kg
Manganese	0.75	0.31	mg/Kg

Method: 6010B - SEP Metals (ICP) - Total

Lab Sample ID: MB 140-75187/5-A
Matrix: Solid
Analysis Batch: 75976
Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 75187

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	ND		5.0	4.1	mg/Kg		07/21/23 08:00	07/31/23 12:31	1
Lithium	ND		2.5	0.15	mg/Kg		07/21/23 08:00	07/31/23 12:31	1
Manganese	ND		0.75	0.31	mg/Kg		07/21/23 08:00	07/31/23 12:31	1

Lab Sample ID: LCS 140-75187/6-A
Matrix: Solid
Analysis Batch: 75976
Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 75187

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec Limits
Iron	50.0	53.2		mg/Kg		106	80 - 120
Lithium	5.00	5.23		mg/Kg		105	80 - 120
Manganese	5.00	5.21		mg/Kg		104	80 - 120

Lab Sample ID: LCSD 140-75187/7-A
Matrix: Solid
Analysis Batch: 75976
Client Sample ID: Lab Control Sample Dup
Prep Type: Total/NA
Prep Batch: 75187

Analyte	Spike Added	LCSD Result	LCSD Qualifier	Unit	D	%Rec	%Rec Limits	RPD	RPD Limit
Iron	50.0	54.5		mg/Kg		109	80 - 120	2	30
Lithium	5.00	5.14		mg/Kg		103	80 - 120	2	30
Manganese	5.00	5.27		mg/Kg		105	80 - 120	1	30

Lab Sample ID: 140-32513-1 DU
Matrix: Solid
Analysis Batch: 75976
Client Sample ID: VER-35 55-60 20230624
Prep Type: Total/NA
Prep Batch: 75187

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
Lithium	42		42.1		mg/Kg	☼	0	30
Manganese	610		613		mg/Kg	☼	0.8	30

Lab Sample ID: 140-32513-1 DU
Matrix: Solid
Analysis Batch: 75976
Client Sample ID: VER-35 55-60 20230624
Prep Type: Total/NA
Prep Batch: 75187

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
Iron	38000		39200		mg/Kg	☼	2	30

Method: 6010B SEP - SEP Metals (ICP)

Lab Sample ID: MB 140-75184/5-B ^4
Matrix: Solid
Analysis Batch: 75871
Client Sample ID: Method Blank
Prep Type: Step 1
Prep Batch: 75207

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	ND		20	12	mg/Kg		07/11/23 08:00	07/27/23 12:47	4
Lithium	ND		10	0.60	mg/Kg		07/11/23 08:00	07/27/23 12:47	4
Manganese	ND		3.0	0.12	mg/Kg		07/11/23 08:00	07/27/23 12:47	4

QC Sample Results

Method: 6010B SEP - SEP Metals (ICP) (Continued)

Lab Sample ID: LCS 140-75184/6-B ^5
Matrix: Solid
Analysis Batch: 75871

Client Sample ID: Lab Control Sample
Prep Type: Step 1
Prep Batch: 75207

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec Limits
Iron	50.0	54.4		mg/Kg		109	80 - 120
Lithium	5.00	5.66	J	mg/Kg		113	80 - 120
Manganese	5.00	5.54		mg/Kg		111	80 - 120

Lab Sample ID: LCSD 140-75184/7-B ^5
Matrix: Solid
Analysis Batch: 75871

Client Sample ID: Lab Control Sample Dup
Prep Type: Step 1
Prep Batch: 75207

Analyte	Spike Added	LCSD Result	LCSD Qualifier	Unit	D	%Rec	%Rec Limits	RPD	RPD Limit
Iron	50.0	54.2		mg/Kg		108	80 - 120	0	30
Lithium	5.00	5.44	J	mg/Kg		109	80 - 120	4	30
Manganese	5.00	5.51		mg/Kg		110	80 - 120	1	30

Lab Sample ID: 140-32513-1 DU
Matrix: Solid
Analysis Batch: 75871

Client Sample ID: VER-35 55-60 20230624
Prep Type: Step 1
Prep Batch: 75207

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
Iron	ND		ND		mg/Kg	☼	NC	30
Lithium	ND		ND		mg/Kg	☼	NC	30
Manganese	7.6		7.29		mg/Kg	☼	4	30

Lab Sample ID: MB 140-75227/5-B ^3
Matrix: Solid
Analysis Batch: 75871

Client Sample ID: Method Blank
Prep Type: Step 2
Prep Batch: 75260

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	ND		15	8.7	mg/Kg		07/12/23 08:00	07/27/23 13:36	3
Lithium	ND		7.5	0.45	mg/Kg		07/12/23 08:00	07/27/23 13:36	3
Manganese	ND		2.3	0.84	mg/Kg		07/12/23 08:00	07/27/23 13:36	3

Lab Sample ID: LCS 140-75227/6-B ^5
Matrix: Solid
Analysis Batch: 75871

Client Sample ID: Lab Control Sample
Prep Type: Step 2
Prep Batch: 75260

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec Limits
Iron	50.0	ND		mg/Kg		3	
Lithium	5.00	5.13	J	mg/Kg		103	80 - 120
Manganese	5.00	5.01		mg/Kg		100	80 - 120

Lab Sample ID: LCSD 140-75227/7-B ^5
Matrix: Solid
Analysis Batch: 75871

Client Sample ID: Lab Control Sample Dup
Prep Type: Step 2
Prep Batch: 75260

Analyte	Spike Added	LCSD Result	LCSD Qualifier	Unit	D	%Rec	%Rec Limits	RPD	RPD Limit
Iron	50.0	ND		mg/Kg		3		28	
Lithium	5.00	4.95	J	mg/Kg		99	80 - 120	4	30
Manganese	5.00	4.96		mg/Kg		99	80 - 120	1	30

Method: 6010B SEP - SEP Metals (ICP) (Continued)

Lab Sample ID: 140-32513-1 DU
Matrix: Solid
Analysis Batch: 75871
Client Sample ID: VER-35 55-60 20230624
Prep Type: Step 2
Prep Batch: 75260

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
Iron	560		531		mg/Kg	☼	5	
Lithium	0.56	J	ND		mg/Kg	☼	NC	30
Manganese	29		27.9		mg/Kg	☼	4	30

Lab Sample ID: MB 140-75274/5-B
Matrix: Solid
Analysis Batch: 75871
Client Sample ID: Method Blank
Prep Type: Step 3
Prep Batch: 75294

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	ND		5.0	2.9	mg/Kg		07/13/23 08:00	07/27/23 14:26	1
Lithium	ND		2.5	0.15	mg/Kg		07/13/23 08:00	07/27/23 14:26	1
Manganese	0.0935	J	0.75	0.027	mg/Kg		07/13/23 08:00	07/27/23 14:26	1

Lab Sample ID: LCS 140-75274/6-B
Matrix: Solid
Analysis Batch: 75871
Client Sample ID: Lab Control Sample
Prep Type: Step 3
Prep Batch: 75294

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec Limits
Iron	50.0	51.9		mg/Kg		104	80 - 120
Lithium	5.00	4.98		mg/Kg		100	80 - 120
Manganese	5.00	5.04		mg/Kg		101	80 - 120

Lab Sample ID: LCSD 140-75274/7-B
Matrix: Solid
Analysis Batch: 75871
Client Sample ID: Lab Control Sample Dup
Prep Type: Step 3
Prep Batch: 75294

Analyte	Spike Added	LCSD Result	LCSD Qualifier	Unit	D	%Rec	%Rec Limits	RPD	RPD Limit
Iron	50.0	49.5		mg/Kg		99	80 - 120	5	30
Lithium	5.00	4.82		mg/Kg		96	80 - 120	3	30
Manganese	5.00	4.89		mg/Kg		98	80 - 120	3	30

Lab Sample ID: 140-32513-1 DU
Matrix: Solid
Analysis Batch: 75871
Client Sample ID: VER-35 55-60 20230624
Prep Type: Step 3
Prep Batch: 75294

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
Iron	4300		4280		mg/Kg	☼	1	30
Lithium	0.52	J	0.516	J	mg/Kg	☼	1	30
Manganese	110	B	114		mg/Kg	☼	2	30

Lab Sample ID: MB 140-75320/5-B
Matrix: Solid
Analysis Batch: 75894
Client Sample ID: Method Blank
Prep Type: Step 4
Prep Batch: 75407

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	ND		5.0	2.9	mg/Kg		07/17/23 08:00	07/28/23 12:35	1
Lithium	ND		2.5	0.15	mg/Kg		07/17/23 08:00	07/28/23 12:35	1
Manganese	ND		0.75	0.13	mg/Kg		07/17/23 08:00	07/28/23 12:35	1

QC Sample Results

Method: 6010B SEP - SEP Metals (ICP) (Continued)

Lab Sample ID: LCS 140-75320/6-B
Matrix: Solid
Analysis Batch: 75894

Client Sample ID: Lab Control Sample
Prep Type: Step 4
Prep Batch: 75407

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec Limits
Iron	50.0	55.0		mg/Kg		110	80 - 120
Lithium	5.00	5.38		mg/Kg		108	80 - 120
Manganese	5.00	5.49		mg/Kg		110	80 - 120

Lab Sample ID: LCSD 140-75320/7-B
Matrix: Solid
Analysis Batch: 75894

Client Sample ID: Lab Control Sample Dup
Prep Type: Step 4
Prep Batch: 75407

Analyte	Spike Added	LCSD Result	LCSD Qualifier	Unit	D	%Rec	%Rec Limits	RPD	RPD Limit
Iron	50.0	54.6		mg/Kg		109	80 - 120	1	30
Lithium	5.00	5.41		mg/Kg		108	80 - 120	0	30
Manganese	5.00	5.45		mg/Kg		109	80 - 120	1	30

Lab Sample ID: 140-32513-1 DU
Matrix: Solid
Analysis Batch: 75894

Client Sample ID: VER-35 55-60 20230624
Prep Type: Step 4
Prep Batch: 75407

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
Iron	20000		19600		mg/Kg	☼	4	30
Lithium	13		12.6		mg/Kg	☼	3	30
Manganese	430		406		mg/Kg	☼	5	30

Lab Sample ID: MB 140-75406/5-B ^5
Matrix: Solid
Analysis Batch: 75894

Client Sample ID: Method Blank
Prep Type: Step 5
Prep Batch: 75487

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	ND		75	44	mg/Kg		07/19/23 08:00	07/28/23 13:24	5
Lithium	ND		38	2.2	mg/Kg		07/19/23 08:00	07/28/23 13:24	5
Manganese	ND		11	1.9	mg/Kg		07/19/23 08:00	07/28/23 13:24	5

Lab Sample ID: LCS 140-75406/6-B ^5
Matrix: Solid
Analysis Batch: 75894

Client Sample ID: Lab Control Sample
Prep Type: Step 5
Prep Batch: 75487

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec Limits
Iron	150	ND		mg/Kg		-0.07	
Lithium	15.0	16.9	J	mg/Kg		112	80 - 150
Manganese	15.0	3.96	J	mg/Kg		26	1 - 60

Lab Sample ID: LCSD 140-75406/7-B ^5
Matrix: Solid
Analysis Batch: 75894

Client Sample ID: Lab Control Sample Dup
Prep Type: Step 5
Prep Batch: 75487

Analyte	Spike Added	LCSD Result	LCSD Qualifier	Unit	D	%Rec	%Rec Limits	RPD	RPD Limit
Iron	150	ND		mg/Kg		-0.5		156	
Lithium	15.0	16.7	J	mg/Kg		111	80 - 150	1	30
Manganese	15.0	4.01	J	mg/Kg		27	1 - 60	1	30

QC Sample Results

Method: 6010B SEP - SEP Metals (ICP) (Continued)

Lab Sample ID: 140-32513-1 DU
Matrix: Solid
Analysis Batch: 75894

Client Sample ID: VER-35 55-60 20230624
Prep Type: Step 5
Prep Batch: 75487

Analyte	Sample Result	Sample Qualifier		DU Result	DU Qualifier	Unit	D			RPD	RPD Limit
Iron	ND			ND		mg/Kg	☼			NC	
Lithium	4.1	J		4.21	J	mg/Kg	☼			2	30
Manganese	46			40.0		mg/Kg	☼			14	30

Lab Sample ID: MB 140-75511/5-A
Matrix: Solid
Analysis Batch: 75894

Client Sample ID: Method Blank
Prep Type: Step 6
Prep Batch: 75511

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	ND		5.0	2.9	mg/Kg		07/19/23 08:00	07/28/23 14:14	1
Lithium	ND		2.5	0.15	mg/Kg		07/19/23 08:00	07/28/23 14:14	1
Manganese	ND		0.75	0.25	mg/Kg		07/19/23 08:00	07/28/23 14:14	1

Lab Sample ID: LCS 140-75511/6-A
Matrix: Solid
Analysis Batch: 75894

Client Sample ID: Lab Control Sample
Prep Type: Step 6
Prep Batch: 75511

Analyte			Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec Limits		
Iron			50.0	54.8		mg/Kg		110	80 - 120		
Lithium			5.00	5.27		mg/Kg		105	80 - 120		
Manganese			5.00	5.47		mg/Kg		109	80 - 120		

Lab Sample ID: LCSD 140-75511/7-A
Matrix: Solid
Analysis Batch: 75894

Client Sample ID: Lab Control Sample Dup
Prep Type: Step 6
Prep Batch: 75511

Analyte			Spike Added	LCSD Result	LCSD Qualifier	Unit	D	%Rec	%Rec Limits	RPD	RPD Limit
Iron			50.0	50.7		mg/Kg		101	80 - 120	8	30
Lithium			5.00	4.89		mg/Kg		98	80 - 120	7	30
Manganese			5.00	5.06		mg/Kg		101	80 - 120	8	30

Lab Sample ID: 140-32513-1 DU
Matrix: Solid
Analysis Batch: 75894

Client Sample ID: VER-35 55-60 20230624
Prep Type: Step 6
Prep Batch: 75511

Analyte	Sample Result	Sample Qualifier		DU Result	DU Qualifier	Unit	D			RPD	RPD Limit
Iron	11000			10600		mg/Kg	☼			4	30
Lithium	13			12.7		mg/Kg	☼			4	30
Manganese	130			127		mg/Kg	☼			2	30

Lab Sample ID: MB 140-75565/5-A
Matrix: Solid
Analysis Batch: 75976

Client Sample ID: Method Blank
Prep Type: Step 7
Prep Batch: 75565

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	ND		5.0	4.1	mg/Kg		07/20/23 08:00	07/31/23 12:16	1
Lithium	ND		2.5	0.15	mg/Kg		07/20/23 08:00	07/31/23 12:16	1
Manganese	ND		0.75	0.31	mg/Kg		07/20/23 08:00	07/31/23 12:16	1

Method: 6010B SEP - SEP Metals (ICP) (Continued)

Lab Sample ID: LCS 140-75565/6-A
Matrix: Solid
Analysis Batch: 75976

Client Sample ID: Lab Control Sample
Prep Type: Step 7
Prep Batch: 75565

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec Limits
Iron	50.0	54.2		mg/Kg		108	80 - 120
Lithium	5.00	5.37		mg/Kg		107	80 - 120
Manganese	5.00	5.35		mg/Kg		107	80 - 120

Lab Sample ID: LCSD 140-75565/7-A
Matrix: Solid
Analysis Batch: 75976

Client Sample ID: Lab Control Sample Dup
Prep Type: Step 7
Prep Batch: 75565

Analyte	Spike Added	LCSD Result	LCSD Qualifier	Unit	D	%Rec	%Rec Limits	RPD	RPD Limit
Iron	50.0	54.0		mg/Kg		108	80 - 120	0	30
Lithium	5.00	5.29		mg/Kg		106	80 - 120	2	30
Manganese	5.00	5.30		mg/Kg		106	80 - 120	1	30

Lab Sample ID: 140-32513-1 DU
Matrix: Solid
Analysis Batch: 75976

Client Sample ID: VER-35 55-60 20230624
Prep Type: Step 7
Prep Batch: 75565

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
Iron	4300		4610		mg/Kg	☼	6	30
Lithium	15		16.0		mg/Kg	☼	9	30
Manganese	31		32.3		mg/Kg	☼	3	30

QC Association Summary

Client: Geosyntec Consultants Inc
Project/Site: Vermilion SEP

Job ID: 140-32513-1

Metals

SEP Batch: 75184

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
140-32513-1	VER-35 55-60 20230624	Step 1	Solid	Exchangeable	
140-32513-2	VER-35 60-63 20230624	Step 1	Solid	Exchangeable	
140-32513-3	VER-70 75-80 20230623	Step 1	Solid	Exchangeable	
MB 140-75184/5-B ^4	Method Blank	Step 1	Solid	Exchangeable	
LCS 140-75184/6-B ^5	Lab Control Sample	Step 1	Solid	Exchangeable	
LCSD 140-75184/7-B ^5	Lab Control Sample Dup	Step 1	Solid	Exchangeable	
140-32513-1 DU	VER-35 55-60 20230624	Step 1	Solid	Exchangeable	

Prep Batch: 75187

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
140-32513-1	VER-35 55-60 20230624	Total/NA	Solid	Total	
140-32513-2	VER-35 60-63 20230624	Total/NA	Solid	Total	
140-32513-3	VER-70 75-80 20230623	Total/NA	Solid	Total	
MB 140-75187/5-A	Method Blank	Total/NA	Solid	Total	
LCS 140-75187/6-A	Lab Control Sample	Total/NA	Solid	Total	
LCSD 140-75187/7-A	Lab Control Sample Dup	Total/NA	Solid	Total	
140-32513-1 DU	VER-35 55-60 20230624	Total/NA	Solid	Total	

Prep Batch: 75207

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
140-32513-1	VER-35 55-60 20230624	Step 1	Solid	3010A	75184
140-32513-2	VER-35 60-63 20230624	Step 1	Solid	3010A	75184
140-32513-3	VER-70 75-80 20230623	Step 1	Solid	3010A	75184
MB 140-75184/5-B ^4	Method Blank	Step 1	Solid	3010A	75184
LCS 140-75184/6-B ^5	Lab Control Sample	Step 1	Solid	3010A	75184
LCSD 140-75184/7-B ^5	Lab Control Sample Dup	Step 1	Solid	3010A	75184
140-32513-1 DU	VER-35 55-60 20230624	Step 1	Solid	3010A	75184

SEP Batch: 75227

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
140-32513-1	VER-35 55-60 20230624	Step 2	Solid	Carbonate	
140-32513-2	VER-35 60-63 20230624	Step 2	Solid	Carbonate	
140-32513-3	VER-70 75-80 20230623	Step 2	Solid	Carbonate	
MB 140-75227/5-B ^3	Method Blank	Step 2	Solid	Carbonate	
LCS 140-75227/6-B ^5	Lab Control Sample	Step 2	Solid	Carbonate	
LCSD 140-75227/7-B ^5	Lab Control Sample Dup	Step 2	Solid	Carbonate	
140-32513-1 DU	VER-35 55-60 20230624	Step 2	Solid	Carbonate	

Prep Batch: 75260

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
140-32513-1	VER-35 55-60 20230624	Step 2	Solid	3010A	75227
140-32513-2	VER-35 60-63 20230624	Step 2	Solid	3010A	75227
140-32513-3	VER-70 75-80 20230623	Step 2	Solid	3010A	75227
MB 140-75227/5-B ^3	Method Blank	Step 2	Solid	3010A	75227
LCS 140-75227/6-B ^5	Lab Control Sample	Step 2	Solid	3010A	75227
LCSD 140-75227/7-B ^5	Lab Control Sample Dup	Step 2	Solid	3010A	75227
140-32513-1 DU	VER-35 55-60 20230624	Step 2	Solid	3010A	75227

SEP Batch: 75274

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
140-32513-1	VER-35 55-60 20230624	Step 3	Solid	Non-Crystalline	

QC Association Summary

Metals (Continued)

SEP Batch: 75274 (Continued)

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
140-32513-2	VER-35 60-63 20230624	Step 3	Solid	Non-Crystalline	
140-32513-3	VER-70 75-80 20230623	Step 3	Solid	Non-Crystalline	
MB 140-75274/5-B	Method Blank	Step 3	Solid	Non-Crystalline	
LCS 140-75274/6-B	Lab Control Sample	Step 3	Solid	Non-Crystalline	
LCSD 140-75274/7-B	Lab Control Sample Dup	Step 3	Solid	Non-Crystalline	
140-32513-1 DU	VER-35 55-60 20230624	Step 3	Solid	Non-Crystalline	

Prep Batch: 75294

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
140-32513-1	VER-35 55-60 20230624	Step 3	Solid	3010A	75274
140-32513-2	VER-35 60-63 20230624	Step 3	Solid	3010A	75274
140-32513-3	VER-70 75-80 20230623	Step 3	Solid	3010A	75274
MB 140-75274/5-B	Method Blank	Step 3	Solid	3010A	75274
LCS 140-75274/6-B	Lab Control Sample	Step 3	Solid	3010A	75274
LCSD 140-75274/7-B	Lab Control Sample Dup	Step 3	Solid	3010A	75274
140-32513-1 DU	VER-35 55-60 20230624	Step 3	Solid	3010A	75274

SEP Batch: 75320

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
140-32513-1	VER-35 55-60 20230624	Step 4	Solid	Metal Hydroxide	
140-32513-2	VER-35 60-63 20230624	Step 4	Solid	Metal Hydroxide	
140-32513-3	VER-70 75-80 20230623	Step 4	Solid	Metal Hydroxide	
MB 140-75320/5-B	Method Blank	Step 4	Solid	Metal Hydroxide	
LCS 140-75320/6-B	Lab Control Sample	Step 4	Solid	Metal Hydroxide	
LCSD 140-75320/7-B	Lab Control Sample Dup	Step 4	Solid	Metal Hydroxide	
140-32513-1 DU	VER-35 55-60 20230624	Step 4	Solid	Metal Hydroxide	

SEP Batch: 75406

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
140-32513-1	VER-35 55-60 20230624	Step 5	Solid	Organic-Bound	
140-32513-2	VER-35 60-63 20230624	Step 5	Solid	Organic-Bound	
140-32513-3	VER-70 75-80 20230623	Step 5	Solid	Organic-Bound	
MB 140-75406/5-B ^5	Method Blank	Step 5	Solid	Organic-Bound	
LCS 140-75406/6-B ^5	Lab Control Sample	Step 5	Solid	Organic-Bound	
LCSD 140-75406/7-B ^5	Lab Control Sample Dup	Step 5	Solid	Organic-Bound	
140-32513-1 DU	VER-35 55-60 20230624	Step 5	Solid	Organic-Bound	

Prep Batch: 75407

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
140-32513-1	VER-35 55-60 20230624	Step 4	Solid	3010A	75320
140-32513-2	VER-35 60-63 20230624	Step 4	Solid	3010A	75320
140-32513-3	VER-70 75-80 20230623	Step 4	Solid	3010A	75320
MB 140-75320/5-B	Method Blank	Step 4	Solid	3010A	75320
LCS 140-75320/6-B	Lab Control Sample	Step 4	Solid	3010A	75320
LCSD 140-75320/7-B	Lab Control Sample Dup	Step 4	Solid	3010A	75320
140-32513-1 DU	VER-35 55-60 20230624	Step 4	Solid	3010A	75320

Prep Batch: 75487

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
140-32513-1	VER-35 55-60 20230624	Step 5	Solid	3010A	75406
140-32513-2	VER-35 60-63 20230624	Step 5	Solid	3010A	75406

QC Association Summary

Metals (Continued)

Prep Batch: 75487 (Continued)

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
140-32513-3	VER-70 75-80 20230623	Step 5	Solid	3010A	75406
MB 140-75406/5-B ^5	Method Blank	Step 5	Solid	3010A	75406
LCS 140-75406/6-B ^5	Lab Control Sample	Step 5	Solid	3010A	75406
LCSD 140-75406/7-B ^5	Lab Control Sample Dup	Step 5	Solid	3010A	75406
140-32513-1 DU	VER-35 55-60 20230624	Step 5	Solid	3010A	75406

SEP Batch: 75511

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
140-32513-1	VER-35 55-60 20230624	Step 6	Solid	Acid/Sulfide	
140-32513-2	VER-35 60-63 20230624	Step 6	Solid	Acid/Sulfide	
140-32513-3	VER-70 75-80 20230623	Step 6	Solid	Acid/Sulfide	
MB 140-75511/5-A	Method Blank	Step 6	Solid	Acid/Sulfide	
LCS 140-75511/6-A	Lab Control Sample	Step 6	Solid	Acid/Sulfide	
LCSD 140-75511/7-A	Lab Control Sample Dup	Step 6	Solid	Acid/Sulfide	
140-32513-1 DU	VER-35 55-60 20230624	Step 6	Solid	Acid/Sulfide	

Prep Batch: 75565

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
140-32513-1	VER-35 55-60 20230624	Step 7	Solid	Residual	
140-32513-2	VER-35 60-63 20230624	Step 7	Solid	Residual	
140-32513-3	VER-70 75-80 20230623	Step 7	Solid	Residual	
MB 140-75565/5-A	Method Blank	Step 7	Solid	Residual	
LCS 140-75565/6-A	Lab Control Sample	Step 7	Solid	Residual	
LCSD 140-75565/7-A	Lab Control Sample Dup	Step 7	Solid	Residual	
140-32513-1 DU	VER-35 55-60 20230624	Step 7	Solid	Residual	

Analysis Batch: 75871

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
140-32513-1	VER-35 55-60 20230624	Step 1	Solid	6010B SEP	75207
140-32513-1	VER-35 55-60 20230624	Step 2	Solid	6010B SEP	75260
140-32513-1	VER-35 55-60 20230624	Step 3	Solid	6010B SEP	75294
140-32513-2	VER-35 60-63 20230624	Step 1	Solid	6010B SEP	75207
140-32513-2	VER-35 60-63 20230624	Step 2	Solid	6010B SEP	75260
140-32513-2	VER-35 60-63 20230624	Step 3	Solid	6010B SEP	75294
140-32513-3	VER-70 75-80 20230623	Step 1	Solid	6010B SEP	75207
140-32513-3	VER-70 75-80 20230623	Step 2	Solid	6010B SEP	75260
140-32513-3	VER-70 75-80 20230623	Step 3	Solid	6010B SEP	75294
MB 140-75184/5-B ^4	Method Blank	Step 1	Solid	6010B SEP	75207
MB 140-75227/5-B ^3	Method Blank	Step 2	Solid	6010B SEP	75260
MB 140-75274/5-B	Method Blank	Step 3	Solid	6010B SEP	75294
LCS 140-75184/6-B ^5	Lab Control Sample	Step 1	Solid	6010B SEP	75207
LCS 140-75227/6-B ^5	Lab Control Sample	Step 2	Solid	6010B SEP	75260
LCS 140-75274/6-B	Lab Control Sample	Step 3	Solid	6010B SEP	75294
LCSD 140-75184/7-B ^5	Lab Control Sample Dup	Step 1	Solid	6010B SEP	75207
LCSD 140-75227/7-B ^5	Lab Control Sample Dup	Step 2	Solid	6010B SEP	75260
LCSD 140-75274/7-B	Lab Control Sample Dup	Step 3	Solid	6010B SEP	75294
140-32513-1 DU	VER-35 55-60 20230624	Step 1	Solid	6010B SEP	75207
140-32513-1 DU	VER-35 55-60 20230624	Step 2	Solid	6010B SEP	75260
140-32513-1 DU	VER-35 55-60 20230624	Step 3	Solid	6010B SEP	75294

QC Association Summary

Metals

Analysis Batch: 75894

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
140-32513-1	VER-35 55-60 20230624	Step 4	Solid	6010B SEP	75407
140-32513-1	VER-35 55-60 20230624	Step 5	Solid	6010B SEP	75487
140-32513-1	VER-35 55-60 20230624	Step 6	Solid	6010B SEP	75511
140-32513-2	VER-35 60-63 20230624	Step 4	Solid	6010B SEP	75407
140-32513-2	VER-35 60-63 20230624	Step 5	Solid	6010B SEP	75487
140-32513-2	VER-35 60-63 20230624	Step 6	Solid	6010B SEP	75511
140-32513-3	VER-70 75-80 20230623	Step 4	Solid	6010B SEP	75407
140-32513-3	VER-70 75-80 20230623	Step 4	Solid	6010B SEP	75407
140-32513-3	VER-70 75-80 20230623	Step 5	Solid	6010B SEP	75487
140-32513-3	VER-70 75-80 20230623	Step 6	Solid	6010B SEP	75511
MB 140-75320/5-B	Method Blank	Step 4	Solid	6010B SEP	75407
MB 140-75406/5-B ^5	Method Blank	Step 5	Solid	6010B SEP	75487
MB 140-75511/5-A	Method Blank	Step 6	Solid	6010B SEP	75511
LCS 140-75320/6-B	Lab Control Sample	Step 4	Solid	6010B SEP	75407
LCS 140-75406/6-B ^5	Lab Control Sample	Step 5	Solid	6010B SEP	75487
LCS 140-75511/6-A	Lab Control Sample	Step 6	Solid	6010B SEP	75511
LCSD 140-75320/7-B	Lab Control Sample Dup	Step 4	Solid	6010B SEP	75407
LCSD 140-75406/7-B ^5	Lab Control Sample Dup	Step 5	Solid	6010B SEP	75487
LCSD 140-75511/7-A	Lab Control Sample Dup	Step 6	Solid	6010B SEP	75511
140-32513-1 DU	VER-35 55-60 20230624	Step 4	Solid	6010B SEP	75407
140-32513-1 DU	VER-35 55-60 20230624	Step 5	Solid	6010B SEP	75487
140-32513-1 DU	VER-35 55-60 20230624	Step 6	Solid	6010B SEP	75511

Analysis Batch: 75976

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
140-32513-1	VER-35 55-60 20230624	Step 7	Solid	6010B SEP	75565
140-32513-1	VER-35 55-60 20230624	Total/NA	Solid	6010B	75187
140-32513-1	VER-35 55-60 20230624	Total/NA	Solid	6010B	75187
140-32513-2	VER-35 60-63 20230624	Step 7	Solid	6010B SEP	75565
140-32513-2	VER-35 60-63 20230624	Total/NA	Solid	6010B	75187
140-32513-2	VER-35 60-63 20230624	Total/NA	Solid	6010B	75187
140-32513-3	VER-70 75-80 20230623	Step 7	Solid	6010B SEP	75565
140-32513-3	VER-70 75-80 20230623	Total/NA	Solid	6010B	75187
140-32513-3	VER-70 75-80 20230623	Total/NA	Solid	6010B	75187
MB 140-75187/5-A	Method Blank	Total/NA	Solid	6010B	75187
MB 140-75565/5-A	Method Blank	Step 7	Solid	6010B SEP	75565
LCS 140-75187/6-A	Lab Control Sample	Total/NA	Solid	6010B	75187
LCS 140-75565/6-A	Lab Control Sample	Step 7	Solid	6010B SEP	75565
LCSD 140-75187/7-A	Lab Control Sample Dup	Total/NA	Solid	6010B	75187
LCSD 140-75565/7-A	Lab Control Sample Dup	Step 7	Solid	6010B SEP	75565
140-32513-1 DU	VER-35 55-60 20230624	Step 7	Solid	6010B SEP	75565
140-32513-1 DU	VER-35 55-60 20230624	Total/NA	Solid	6010B	75187
140-32513-1 DU	VER-35 55-60 20230624	Total/NA	Solid	6010B	75187

Analysis Batch: 76083

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
140-32513-1	VER-35 55-60 20230624	Sum of Steps 1-7	Solid	6010B SEP	
140-32513-2	VER-35 60-63 20230624	Sum of Steps 1-7	Solid	6010B SEP	
140-32513-3	VER-70 75-80 20230623	Sum of Steps 1-7	Solid	6010B SEP	

QC Association Summary

General Chemistry

Analysis Batch: 75814

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
140-32513-1	VER-35 55-60 20230624	Total/NA	Solid	Moisture	
140-32513-2	VER-35 60-63 20230624	Total/NA	Solid	Moisture	
140-32513-3	VER-70 75-80 20230623	Total/NA	Solid	Moisture	
140-32513-1 DU	VER-35 55-60 20230624	Total/NA	Solid	Moisture	

Lab Chronicle

1 2 3 4 5 6 7 8 9 10 11 12 13

Client Sample ID: VER-35 55-60 20230624
Date Collected: 06/24/23 14:20
Date Received: 07/03/23 11:15

Lab Sample ID: 140-32513-1
Matrix: Solid

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Sum of Steps 1-7	Analysis	6010B SEP		1			76083	08/02/23 14:24	KNC	EET KNX
	Instrument ID:	NOEQUIP								
Total/NA	Analysis	Moisture		1			75814	07/26/23 15:29	ACW	EET KNX
	Instrument ID:	NOEQUIP								

Client Sample ID: VER-35 55-60 20230624
Date Collected: 06/24/23 14:20
Date Received: 07/03/23 11:15

Lab Sample ID: 140-32513-1
Matrix: Solid
Percent Solids: 95.4

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	Total			1.00 g	50 mL	75187	07/21/23 08:00	LAH	EET KNX
Total/NA	Analysis	6010B		1			75976	07/31/23 13:22	KNC	EET KNX
	Instrument ID:	DUO								
Total/NA	Prep	Total			1.00 g	50 mL	75187	07/21/23 08:00	LAH	EET KNX
Total/NA	Analysis	6010B		2			75976	07/31/23 14:12	KNC	EET KNX
	Instrument ID:	DUO								
Step 1	SEP	Exchangeable			5.00 g	25 mL	75184	07/10/23 12:30	LAH	EET KNX
Step 1	Prep	3010A			5 mL	50 mL	75207	07/11/23 08:00	LAH	EET KNX
Step 1	Analysis	6010B SEP		4			75871	07/27/23 13:01	KNC	EET KNX
	Instrument ID:	DUO								
Step 2	SEP	Carbonate			5.00 g	25 mL	75227	07/11/23 08:00	LAH	EET KNX
Step 2	Prep	3010A			5 mL	50 mL	75260	07/12/23 08:00	LAH	EET KNX
Step 2	Analysis	6010B SEP		3			75871	07/27/23 13:51	KNC	EET KNX
	Instrument ID:	DUO								
Step 3	SEP	Non-Crystalline			5.00 g	25 mL	75274	07/12/23 08:00	LAH	EET KNX
Step 3	Prep	3010A			5 mL	50 mL	75294	07/13/23 08:00	LAH	EET KNX
Step 3	Analysis	6010B SEP		1			75871	07/27/23 14:40	KNC	EET KNX
	Instrument ID:	DUO								
Step 4	SEP	Metal Hydroxide			5.00 g	25 mL	75320	07/13/23 08:00	LAH	EET KNX
Step 4	Prep	3010A			5 mL	50 mL	75407	07/17/23 08:00	LAH	EET KNX
Step 4	Analysis	6010B SEP		1			75894	07/28/23 12:49	KNC	EET KNX
	Instrument ID:	DUO								
Step 5	SEP	Organic-Bound			5.00 g	75 mL	75406	07/17/23 08:00	LAH	EET KNX
Step 5	Prep	3010A			5 mL	50 mL	75487	07/19/23 08:00	LAH	EET KNX
Step 5	Analysis	6010B SEP		5			75894	07/28/23 13:39	KNC	EET KNX
	Instrument ID:	DUO								
Step 6	SEP	Acid/Sulfide			5.00 g	250 mL	75511	07/19/23 08:00	LAH	EET KNX
Step 6	Analysis	6010B SEP		1			75894	07/28/23 14:29	KNC	EET KNX
	Instrument ID:	DUO								
Step 7	Prep	Residual			1.00 g	50 mL	75565	07/20/23 08:00	LAH	EET KNX
Step 7	Analysis	6010B SEP		1			75976	07/31/23 12:46	KNC	EET KNX
	Instrument ID:	DUO								

Lab Chronicle

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Client Sample ID: VER-35 60-63 20230624

Lab Sample ID: 140-32513-2

Date Collected: 06/24/23 14:50

Matrix: Solid

Date Received: 07/03/23 11:15

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Sum of Steps 1-7	Analysis	6010B SEP		1			76083	08/02/23 14:24	KNC	EET KNX
	Instrument ID: NOEQUIP									
Total/NA	Analysis	Moisture		1			75814	07/26/23 15:29	ACW	EET KNX
	Instrument ID: NOEQUIP									

Client Sample ID: VER-35 60-63 20230624

Lab Sample ID: 140-32513-2

Date Collected: 06/24/23 14:50

Matrix: Solid

Date Received: 07/03/23 11:15

Percent Solids: 95.4

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	Total			1.00 g	50 mL	75187	07/21/23 08:00	LAH	EET KNX
Total/NA	Analysis	6010B		1			75976	07/31/23 13:33	KNC	EET KNX
	Instrument ID: DUO									
Total/NA	Prep	Total			1.00 g	50 mL	75187	07/21/23 08:00	LAH	EET KNX
Total/NA	Analysis	6010B		2			75976	07/31/23 14:22	KNC	EET KNX
	Instrument ID: DUO									
Step 1	SEP	Exchangeable			5.00 g	25 mL	75184	07/10/23 12:30	LAH	EET KNX
Step 1	Prep	3010A			5 mL	50 mL	75207	07/11/23 08:00	LAH	EET KNX
Step 1	Analysis	6010B SEP		4			75871	07/27/23 13:11	KNC	EET KNX
	Instrument ID: DUO									
Step 2	SEP	Carbonate			5.00 g	25 mL	75227	07/11/23 08:00	LAH	EET KNX
Step 2	Prep	3010A			5 mL	50 mL	75260	07/12/23 08:00	LAH	EET KNX
Step 2	Analysis	6010B SEP		3			75871	07/27/23 14:01	KNC	EET KNX
	Instrument ID: DUO									
Step 3	SEP	Non-Crystalline			5.00 g	25 mL	75274	07/12/23 08:00	LAH	EET KNX
Step 3	Prep	3010A			5 mL	50 mL	75294	07/13/23 08:00	LAH	EET KNX
Step 3	Analysis	6010B SEP		1			75871	07/27/23 14:50	KNC	EET KNX
	Instrument ID: DUO									
Step 4	SEP	Metal Hydroxide			5.00 g	25 mL	75320	07/13/23 08:00	LAH	EET KNX
Step 4	Prep	3010A			5 mL	50 mL	75407	07/17/23 08:00	LAH	EET KNX
Step 4	Analysis	6010B SEP		1			75894	07/28/23 12:59	KNC	EET KNX
	Instrument ID: DUO									
Step 5	SEP	Organic-Bound			5.00 g	75 mL	75406	07/17/23 08:00	LAH	EET KNX
Step 5	Prep	3010A			5 mL	50 mL	75487	07/19/23 08:00	LAH	EET KNX
Step 5	Analysis	6010B SEP		5			75894	07/28/23 13:49	KNC	EET KNX
	Instrument ID: DUO									
Step 6	SEP	Acid/Sulfide			5.00 g	250 mL	75511	07/19/23 08:00	LAH	EET KNX
Step 6	Analysis	6010B SEP		1			75894	07/28/23 14:39	KNC	EET KNX
	Instrument ID: DUO									
Step 7	Prep	Residual			1.00 g	50 mL	75565	07/20/23 08:00	LAH	EET KNX
Step 7	Analysis	6010B SEP		1			75976	07/31/23 12:57	KNC	EET KNX
	Instrument ID: DUO									

Lab Chronicle

1 2 3 4 5 6 7 8 9 10 11 12 13

Client Sample ID: VER-70 75-80 20230623
Lab Sample ID: 140-32513-3
Date Collected: 06/23/23 17:00
Matrix: Solid
Date Received: 07/03/23 11:15

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Sum of Steps 1-7	Analysis	6010B SEP		1			76083	08/02/23 14:24	KNC	EET KNX
	Instrument ID:	NOEQUIP								
Total/NA	Analysis	Moisture		1			75814	07/26/23 15:29	ACW	EET KNX
	Instrument ID:	NOEQUIP								

Client Sample ID: VER-70 75-80 20230623
Lab Sample ID: 140-32513-3
Date Collected: 06/23/23 17:00
Matrix: Solid
Date Received: 07/03/23 11:15
Percent Solids: 90.0

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	Total			1.00 g	50 mL	75187	07/21/23 08:00	LAH	EET KNX
Total/NA	Analysis	6010B		1			75976	07/31/23 13:39	KNC	EET KNX
	Instrument ID:	DUO								
Total/NA	Prep	Total			1.00 g	50 mL	75187	07/21/23 08:00	LAH	EET KNX
Total/NA	Analysis	6010B		5			75976	07/31/23 15:08	KNC	EET KNX
	Instrument ID:	DUO								
Step 1	SEP	Exchangeable			5.00 g	25 mL	75184	07/10/23 12:30	LAH	EET KNX
Step 1	Prep	3010A			5 mL	50 mL	75207	07/11/23 08:00	LAH	EET KNX
Step 1	Analysis	6010B SEP		4			75871	07/27/23 13:16	KNC	EET KNX
	Instrument ID:	DUO								
Step 2	SEP	Carbonate			5.00 g	25 mL	75227	07/11/23 08:00	LAH	EET KNX
Step 2	Prep	3010A			5 mL	50 mL	75260	07/12/23 08:00	LAH	EET KNX
Step 2	Analysis	6010B SEP		3			75871	07/27/23 14:06	KNC	EET KNX
	Instrument ID:	DUO								
Step 3	SEP	Non-Crystalline			5.00 g	25 mL	75274	07/12/23 08:00	LAH	EET KNX
Step 3	Prep	3010A			5 mL	50 mL	75294	07/13/23 08:00	LAH	EET KNX
Step 3	Analysis	6010B SEP		1			75871	07/27/23 14:55	KNC	EET KNX
	Instrument ID:	DUO								
Step 4	SEP	Metal Hydroxide			5.00 g	25 mL	75320	07/13/23 08:00	LAH	EET KNX
Step 4	Prep	3010A			5 mL	50 mL	75407	07/17/23 08:00	LAH	EET KNX
Step 4	Analysis	6010B SEP		1			75894	07/28/23 13:04	KNC	EET KNX
	Instrument ID:	DUO								
Step 4	SEP	Metal Hydroxide			5.00 g	25 mL	75320	07/13/23 08:00	LAH	EET KNX
Step 4	Prep	3010A			5 mL	50 mL	75407	07/17/23 08:00	LAH	EET KNX
Step 4	Analysis	6010B SEP		2			75894	07/28/23 14:55	KNC	EET KNX
	Instrument ID:	DUO								
Step 5	SEP	Organic-Bound			5.00 g	75 mL	75406	07/17/23 08:00	LAH	EET KNX
Step 5	Prep	3010A			5 mL	50 mL	75487	07/19/23 08:00	LAH	EET KNX
Step 5	Analysis	6010B SEP		5			75894	07/28/23 13:54	KNC	EET KNX
	Instrument ID:	DUO								
Step 6	SEP	Acid/Sulfide			5.00 g	250 mL	75511	07/19/23 08:00	LAH	EET KNX
Step 6	Analysis	6010B SEP		1			75894	07/28/23 14:44	KNC	EET KNX
	Instrument ID:	DUO								
Step 7	Prep	Residual			1.00 g	50 mL	75565	07/20/23 08:00	LAH	EET KNX
Step 7	Analysis	6010B SEP		1			75976	07/31/23 13:17	KNC	EET KNX
	Instrument ID:	DUO								

Lab Chronicle

Client Sample ID: Method Blank

Lab Sample ID: MB 140-75184/5-B ^4

Date Collected: N/A

Matrix: Solid

Date Received: N/A

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Step 1	SEP	Exchangeable			5.00 g	25 mL	75184	07/10/23 12:30	LAH	EET KNX
Step 1	Prep	3010A			5 mL	50 mL	75207	07/11/23 08:00	LAH	EET KNX
Step 1	Analysis	6010B SEP		4			75871	07/27/23 12:47	KNC	EET KNX
	Instrument ID: DUO									

Client Sample ID: Method Blank

Lab Sample ID: MB 140-75187/5-A

Date Collected: N/A

Matrix: Solid

Date Received: N/A

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	Total			1.00 g	50 mL	75187	07/21/23 08:00	LAH	EET KNX
Total/NA	Analysis	6010B		1			75976	07/31/23 12:31	KNC	EET KNX
	Instrument ID: DUO									

Client Sample ID: Method Blank

Lab Sample ID: MB 140-75227/5-B ^3

Date Collected: N/A

Matrix: Solid

Date Received: N/A

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Step 2	SEP	Carbonate			5.00 g	25 mL	75227	07/11/23 08:00	LAH	EET KNX
Step 2	Prep	3010A			5 mL	50 mL	75260	07/12/23 08:00	LAH	EET KNX
Step 2	Analysis	6010B SEP		3			75871	07/27/23 13:36	KNC	EET KNX
	Instrument ID: DUO									

Client Sample ID: Method Blank

Lab Sample ID: MB 140-75274/5-B

Date Collected: N/A

Matrix: Solid

Date Received: N/A

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Step 3	SEP	Non-Crystalline			5.00 g	25 mL	75274	07/12/23 08:00	LAH	EET KNX
Step 3	Prep	3010A			5 mL	50 mL	75294	07/13/23 08:00	LAH	EET KNX
Step 3	Analysis	6010B SEP		1			75871	07/27/23 14:26	KNC	EET KNX
	Instrument ID: DUO									

Client Sample ID: Method Blank

Lab Sample ID: MB 140-75320/5-B

Date Collected: N/A

Matrix: Solid

Date Received: N/A

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Step 4	SEP	Metal Hydroxide			5.00 g	25 mL	75320	07/13/23 08:00	LAH	EET KNX
Step 4	Prep	3010A			5 mL	50 mL	75407	07/17/23 08:00	LAH	EET KNX
Step 4	Analysis	6010B SEP		1			75894	07/28/23 12:35	KNC	EET KNX
	Instrument ID: DUO									

Lab Chronicle

Client Sample ID: Method Blank

Lab Sample ID: MB 140-75406/5-B ^5

Date Collected: N/A
Date Received: N/A
Matrix: Solid

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Step 5	SEP	Organic-Bound			5.00 g	75 mL	75406	07/17/23 08:00	LAH	EET KNX
Step 5	Prep	3010A			5 mL	50 mL	75487	07/19/23 08:00	LAH	EET KNX
Step 5	Analysis	6010B SEP		5			75894	07/28/23 13:24	KNC	EET KNX

Instrument ID: DUO

Client Sample ID: Method Blank

Lab Sample ID: MB 140-75511/5-A

Date Collected: N/A
Date Received: N/A
Matrix: Solid

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Step 6	SEP	Acid/Sulfide			5.00 g	250 mL	75511	07/19/23 08:00	LAH	EET KNX
Step 6	Analysis	6010B SEP		1			75894	07/28/23 14:14	KNC	EET KNX

Instrument ID: DUO

Client Sample ID: Method Blank

Lab Sample ID: MB 140-75565/5-A

Date Collected: N/A
Date Received: N/A
Matrix: Solid

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Step 7	Prep	Residual			1.00 g	50 mL	75565	07/20/23 08:00	LAH	EET KNX
Step 7	Analysis	6010B SEP		1			75976	07/31/23 12:16	KNC	EET KNX

Instrument ID: DUO

Client Sample ID: Lab Control Sample

Lab Sample ID: LCS 140-75184/6-B ^5

Date Collected: N/A
Date Received: N/A
Matrix: Solid

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Step 1	SEP	Exchangeable			5.00 g	25 mL	75184	07/10/23 12:30	LAH	EET KNX
Step 1	Prep	3010A			5 mL	50 mL	75207	07/11/23 08:00	LAH	EET KNX
Step 1	Analysis	6010B SEP		5			75871	07/27/23 12:52	KNC	EET KNX

Instrument ID: DUO

Client Sample ID: Lab Control Sample

Lab Sample ID: LCS 140-75187/6-A

Date Collected: N/A
Date Received: N/A
Matrix: Solid

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	Total			1.00 g	50 mL	75187	07/21/23 08:00	LAH	EET KNX
Total/NA	Analysis	6010B		1			75976	07/31/23 12:36	KNC	EET KNX

Instrument ID: DUO

Lab Chronicle

Client: Geosyntec Consultants Inc
Project/Site: Vermilion SEP

Job ID: 140-32513-1

Client Sample ID: Lab Control Sample

Lab Sample ID: LCS 140-75227/6-B ^5
Date Collected: N/A
Matrix: Solid
Date Received: N/A

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Step 2	SEP	Carbonate			5.00 g	25 mL	75227	07/11/23 08:00	LAH	EET KNX
Step 2	Prep	3010A			5 mL	50 mL	75260	07/12/23 08:00	LAH	EET KNX
Step 2	Analysis	6010B SEP		5			75871	07/27/23 13:41	KNC	EET KNX
	Instrument ID: DUO									

Client Sample ID: Lab Control Sample

Lab Sample ID: LCS 140-75274/6-B
Date Collected: N/A
Matrix: Solid
Date Received: N/A

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Step 3	SEP	Non-Crystalline			5.00 g	25 mL	75274	07/12/23 08:00	LAH	EET KNX
Step 3	Prep	3010A			5 mL	50 mL	75294	07/13/23 08:00	LAH	EET KNX
Step 3	Analysis	6010B SEP		1			75871	07/27/23 14:31	KNC	EET KNX
	Instrument ID: DUO									

Client Sample ID: Lab Control Sample

Lab Sample ID: LCS 140-75320/6-B
Date Collected: N/A
Matrix: Solid
Date Received: N/A

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Step 4	SEP	Metal Hydroxide			5.00 g	25 mL	75320	07/13/23 08:00	LAH	EET KNX
Step 4	Prep	3010A			5 mL	50 mL	75407	07/17/23 08:00	LAH	EET KNX
Step 4	Analysis	6010B SEP		1			75894	07/28/23 12:40	KNC	EET KNX
	Instrument ID: DUO									

Client Sample ID: Lab Control Sample

Lab Sample ID: LCS 140-75406/6-B ^5
Date Collected: N/A
Matrix: Solid
Date Received: N/A

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Step 5	SEP	Organic-Bound			5.00 g	75 mL	75406	07/17/23 08:00	LAH	EET KNX
Step 5	Prep	3010A			5 mL	50 mL	75487	07/19/23 08:00	LAH	EET KNX
Step 5	Analysis	6010B SEP		5			75894	07/28/23 13:29	KNC	EET KNX
	Instrument ID: DUO									

Client Sample ID: Lab Control Sample

Lab Sample ID: LCS 140-75511/6-A
Date Collected: N/A
Matrix: Solid
Date Received: N/A

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Step 6	SEP	Acid/Sulfide			5.00 g	250 mL	75511	07/19/23 08:00	LAH	EET KNX
Step 6	Analysis	6010B SEP		1			75894	07/28/23 14:19	KNC	EET KNX
	Instrument ID: DUO									

Lab Chronicle

Client Sample ID: Lab Control Sample

Lab Sample ID: LCS 140-75565/6-A

Date Collected: N/A
Matrix: Solid
Date Received: N/A

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Step 7	Prep	Residual			1.00 g	50 mL	75565	07/20/23 08:00	LAH	EET KNX
Step 7	Analysis	6010B SEP		1			75976	07/31/23 12:21	KNC	EET KNX
	Instrument ID:	DUO								

Client Sample ID: Lab Control Sample Dup

Lab Sample ID: LCSD 140-75184/7-B ^5

Date Collected: N/A
Matrix: Solid
Date Received: N/A

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Step 1	SEP	Exchangeable			5.00 g	25 mL	75184	07/10/23 12:30	LAH	EET KNX
Step 1	Prep	3010A			5 mL	50 mL	75207	07/11/23 08:00	LAH	EET KNX
Step 1	Analysis	6010B SEP		5			75871	07/27/23 12:57	KNC	EET KNX
	Instrument ID:	DUO								

Client Sample ID: Lab Control Sample Dup

Lab Sample ID: LCSD 140-75187/7-A

Date Collected: N/A
Matrix: Solid
Date Received: N/A

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	Total			1.00 g	50 mL	75187	07/21/23 08:00	LAH	EET KNX
Total/NA	Analysis	6010B		1			75976	07/31/23 12:41	KNC	EET KNX
	Instrument ID:	DUO								

Client Sample ID: Lab Control Sample Dup

Lab Sample ID: LCSD 140-75227/7-B ^5

Date Collected: N/A
Matrix: Solid
Date Received: N/A

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Step 2	SEP	Carbonate			5.00 g	25 mL	75227	07/11/23 08:00	LAH	EET KNX
Step 2	Prep	3010A			5 mL	50 mL	75260	07/12/23 08:00	LAH	EET KNX
Step 2	Analysis	6010B SEP		5			75871	07/27/23 13:46	KNC	EET KNX
	Instrument ID:	DUO								

Client Sample ID: Lab Control Sample Dup

Lab Sample ID: LCSD 140-75274/7-B

Date Collected: N/A
Matrix: Solid
Date Received: N/A

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Step 3	SEP	Non-Crystalline			5.00 g	25 mL	75274	07/12/23 08:00	LAH	EET KNX
Step 3	Prep	3010A			5 mL	50 mL	75294	07/13/23 08:00	LAH	EET KNX
Step 3	Analysis	6010B SEP		1			75871	07/27/23 14:36	KNC	EET KNX
	Instrument ID:	DUO								

Client Sample ID: Lab Control Sample Dup

Lab Sample ID: LCSD 140-75320/7-B

Date Collected: N/A
Date Received: N/A

Matrix: Solid

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Step 4	SEP	Metal Hydroxide			5.00 g	25 mL	75320	07/13/23 08:00	LAH	EET KNX
Step 4	Prep	3010A			5 mL	50 mL	75407	07/17/23 08:00	LAH	EET KNX
Step 4	Analysis	6010B SEP		1			75894	07/28/23 12:44	KNC	EET KNX

Instrument ID: DUO

Client Sample ID: Lab Control Sample Dup

Lab Sample ID: LCSD 140-75406/7-B ^5

Date Collected: N/A
Date Received: N/A

Matrix: Solid

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Step 5	SEP	Organic-Bound			5.00 g	75 mL	75406	07/17/23 08:00	LAH	EET KNX
Step 5	Prep	3010A			5 mL	50 mL	75487	07/19/23 08:00	LAH	EET KNX
Step 5	Analysis	6010B SEP		5			75894	07/28/23 13:34	KNC	EET KNX

Instrument ID: DUO

Client Sample ID: Lab Control Sample Dup

Lab Sample ID: LCSD 140-75511/7-A

Date Collected: N/A
Date Received: N/A

Matrix: Solid

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Step 6	SEP	Acid/Sulfide			5.00 g	250 mL	75511	07/19/23 08:00	LAH	EET KNX
Step 6	Analysis	6010B SEP		1			75894	07/28/23 14:24	KNC	EET KNX

Instrument ID: DUO

Client Sample ID: Lab Control Sample Dup

Lab Sample ID: LCSD 140-75565/7-A

Date Collected: N/A
Date Received: N/A

Matrix: Solid

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Step 7	Prep	Residual			1.00 g	50 mL	75565	07/20/23 08:00	LAH	EET KNX
Step 7	Analysis	6010B SEP		1			75976	07/31/23 12:26	KNC	EET KNX

Instrument ID: DUO

Client Sample ID: VER-35 55-60 20230624

Lab Sample ID: 140-32513-1 DU

Date Collected: 06/24/23 14:20
Date Received: 07/03/23 11:15

Matrix: Solid

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	Moisture		1			75814	07/26/23 15:29	ACW	EET KNX

Instrument ID: NOEQUIP

Lab Chronicle

1 2 3 4 5 6 7 8 9 10 11 12 13

Client Sample ID: VER-35 55-60 20230624
Date Collected: 06/24/23 14:20
Date Received: 07/03/23 11:15

Lab Sample ID: 140-32513-1 DU
Matrix: Solid
Percent Solids: 95.4

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	Total			1.00 g	50 mL	75187	07/21/23 08:00	LAH	EET KNX
Total/NA	Analysis	6010B		1			75976	07/31/23 13:28	KNC	EET KNX
	Instrument ID:	DUO								
Total/NA	Prep	Total			1.00 g	50 mL	75187	07/21/23 08:00	LAH	EET KNX
Total/NA	Analysis	6010B		2			75976	07/31/23 14:17	KNC	EET KNX
	Instrument ID:	DUO								
Step 1	SEP	Exchangeable			5.00 g	25 mL	75184	07/10/23 12:30	LAH	EET KNX
Step 1	Prep	3010A			5 mL	50 mL	75207	07/11/23 08:00	LAH	EET KNX
Step 1	Analysis	6010B SEP		4			75871	07/27/23 13:06	KNC	EET KNX
	Instrument ID:	DUO								
Step 2	SEP	Carbonate			5.00 g	25 mL	75227	07/11/23 08:00	LAH	EET KNX
Step 2	Prep	3010A			5 mL	50 mL	75260	07/12/23 08:00	LAH	EET KNX
Step 2	Analysis	6010B SEP		3			75871	07/27/23 13:56	KNC	EET KNX
	Instrument ID:	DUO								
Step 3	SEP	Non-Crystalline			5.00 g	25 mL	75274	07/12/23 08:00	LAH	EET KNX
Step 3	Prep	3010A			5 mL	50 mL	75294	07/13/23 08:00	LAH	EET KNX
Step 3	Analysis	6010B SEP		1			75871	07/27/23 14:45	KNC	EET KNX
	Instrument ID:	DUO								
Step 4	SEP	Metal Hydroxide			5.00 g	25 mL	75320	07/13/23 08:00	LAH	EET KNX
Step 4	Prep	3010A			5 mL	50 mL	75407	07/17/23 08:00	LAH	EET KNX
Step 4	Analysis	6010B SEP		1			75894	07/28/23 12:54	KNC	EET KNX
	Instrument ID:	DUO								
Step 5	SEP	Organic-Bound			5.00 g	75 mL	75406	07/17/23 08:00	LAH	EET KNX
Step 5	Prep	3010A			5 mL	50 mL	75487	07/19/23 08:00	LAH	EET KNX
Step 5	Analysis	6010B SEP		5			75894	07/28/23 13:44	KNC	EET KNX
	Instrument ID:	DUO								
Step 6	SEP	Acid/Sulfide			5.00 g	250 mL	75511	07/19/23 08:00	LAH	EET KNX
Step 6	Analysis	6010B SEP		1			75894	07/28/23 14:34	KNC	EET KNX
	Instrument ID:	DUO								
Step 7	Prep	Residual			1.00 g	50 mL	75565	07/20/23 08:00	LAH	EET KNX
Step 7	Analysis	6010B SEP		1			75976	07/31/23 12:51	KNC	EET KNX
	Instrument ID:	DUO								

Laboratory References:

EET KNX = Eurofins Knoxville, 5815 Middlebrook Pike, Knoxville, TN 37921, TEL (865)291-3000

Accreditation/Certification Summary

Laboratory: Eurofins Knoxville

All accreditations/certifications held by this laboratory are listed. Not all accreditations/certifications are applicable to this report.

Authority	Program	Identification Number	Expiration Date
	AFCEE	N/A	
ANAB	Dept. of Defense ELAP	L2311	02-13-25
ANAB	Dept. of Energy	L2311.01	02-13-25
ANAB	ISO/IEC 17025	L2311	02-13-25
Arkansas DEQ	State	88-0688	06-16-24
Colorado	State	TN00009	02-29-24
Connecticut	State	PH-0223	09-30-23
Florida	NELAP	E87177	06-30-24
Georgia (DW)	State	906	07-27-25
Hawaii	State	NA	07-27-23 *
Kansas	NELAP	E-10349	10-31-23
Kentucky (DW)	State	90101	12-31-23
Louisiana (All)	NELAP	83979	06-30-24
Louisiana (DW)	State	LA019	12-31-23
Maryland	State	277	03-31-24
Michigan	State	9933	07-27-25
Nevada	State	TN00009	07-31-23 *
New Hampshire	NELAP	2999	01-17-24
New Jersey	NELAP	TN001	07-01-24
New York	NELAP	10781	03-31-24
North Carolina (DW)	State	21705	07-31-24
North Carolina (WW/SW)	State	64	12-31-23
Oklahoma	State	9415	08-31-23
Oregon	NELAP	TNI0189	01-01-24
Pennsylvania	NELAP	68-00576	12-01-23
Tennessee	State	02014	07-27-25
Texas	NELAP	T104704380-22-17	08-31-23
US Fish & Wildlife	US Federal Programs	058448	07-31-24
USDA	US Federal Programs	525-22-279-18762	10-06-25
Utah	NELAP	TN00009	07-31-24
Virginia	NELAP	460176	09-14-23
Washington	State	C593	01-19-24
West Virginia (DW)	State	9955C	12-31-23
West Virginia DEP	State	345	04-30-24
Wisconsin	State	998044300	08-31-23

* Accreditation/Certification renewal pending - accreditation/certification considered valid.

Method Summary

Method	Method Description	Protocol	Laboratory
6010B	SEP Metals (ICP) - Total	SW846	EET KNX
6010B SEP	SEP Metals (ICP)	SW846	EET KNX
Moisture	Percent Moisture	EPA	EET KNX
3010A	Preparation, Total Metals	SW846	EET KNX
Acid/Sulfide	Sequential Extraction Procedure, Acid/Sulfide Fraction	TAL-KNOX	EET KNX
Carbonate	Sequential Extraction Procedure, Carbonate Fraction	TAL-KNOX	EET KNX
Exchangeable	Sequential Extraction Procedure, Exchangeable Fraction	TAL-KNOX	EET KNX
Metal Hydroxide	Sequential Extraction Procedure, Metal Hydroxide Fraction	TAL-KNOX	EET KNX
Non-Crystalline	Sequential Extraction Procedure, Non-crystalline Materials	TAL-KNOX	EET KNX
Organic-Bound	Sequential Extraction Procedure, Organic Bound Fraction	TAL-KNOX	EET KNX
Residual	Sequential Extraction Procedure, Residual Fraction	TAL-KNOX	EET KNX
Total	Preparation, Total Material	TAL-KNOX	EET KNX

Protocol References:

EPA = US Environmental Protection Agency
SW846 = "Test Methods For Evaluating Solid Waste, Physical/Chemical Methods", Third Edition, November 1986 And Its Updates.
TAL-KNOX = TestAmerica Laboratories, Knoxville, Facility Standard Operating Procedure.

Laboratory References:

EET KNX = Eurofins Knoxville, 5815 Middlebrook Pike, Knoxville, TN 37921, TEL (865)291-3000

Eurofins TestAmerica, Knoxville
5815 Middlebrook Pike

Knoxville, TN 37921-5947
phone 865.291.3000 fax 865.584.4315

Chain of Custody Record

eurofins
Environment Testing
TestAmerica

Regulatory Program: ☐ DW ☐ NPDES ☐ RCRA ☑ Other:

TestAmerica Laboratories, Inc. d/b/a Eurofins TestAmerica

Client Contact	**Project Manager: Allison Kreinberg**	**Site Contact: NA**	**Date:**	COC No:
Geosyntec Consultants, Inc.	**Tel/Fax:**	**Lab Contact: Ryan Henry**	**Carrier:**	1 of 1 COCs
941 Chatham Lane, Suite 103	**Analysis Turnaround Time**			Sampler:
Columbus, OH 43221	☐ CALENDAR DAYS ☐ WORKING DAYS			**For Lab Use Only:**
(614) 468-0421 Phone	TAT if different from Below ______			Walk-in Client:
	☒ 2 weeks			Lab Sampling:
Project Name: Vistra	☐ 1 week			
Site: Vermilion	☐ 2 days			Job / SDG No.:
P O #	☐ 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)	6010B SEP (Li, Fe, Mn)	Sample Specific Notes:
VER-35 55-60 20230624	6/24/2023	1420	G	Solid	1	N	N	X	
VER-35 60-63 20230624	6/24/2023	1450	G	Solid	1	N	N	X	
VER-70 75-80 20230623	6/23/2023	1700	G	Solid	1	N	N	X	

No Custody Seal
Received Ambient AT: 20.0/CT: 20.3°C
DH 7/3/23
1 Box FedEx 7804 7929 1869 G

140-32513 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:

Custody Seals Intact: ☐ Yes ☐ No	Custody Seal No.:		Cooler Temp. (°C): Obs'd: ______ Corr'd: ______ Therm ID No.: ______		
Relinquished by: Andrew Kelley	Company: GEOSYNTEC	Date/Time: 6/28/23 1600	Received by: Dean Hick	Company: ETA KNX	Date/Time: 7/3/23 11:15 ~~9:00~~ DH 7/3/23
Relinquished by:	Company:	Date/Time:	Received by:	Company:	Date/Time:
Relinquished by:	Company:	Date/Time:	Received in Laboratory by:	Company:	Date/Time:

Form No. CA-C-WI-002, Rev. 4.21, dated 4/4/2019

Loc: 140
32513

EUROFINS/TESTAMERICA KNOXVILLE SAMPLE RECEIPT/CONDITION UPON RECEIPT ANOMALY CHECKLIST

Log In Number:

Review Items	**Yes**	**No**	**NA**	**If No, what was the problem?**
1. Are the shipping containers intact?	✓			☐ **Containers, Broken**
2. Were ambient air containers received intact?			✓	☐ Checked in lab
3. The coolers/containers custody seal if present, is it intact?			✓	☐ Yes ☐ NA
4. Is the cooler temperature within limits? (> freezing temp. of water to 6 °C, VOST: 10°C) Thermometer ID : SC73 Correction factor: +0.3°C			✓	☐ **Cooler Out of Temp, Client Contacted, Proceed/Cancel** ☐ **Cooler Out of Temp, Same Day Receipt**
5. Were all of the sample containers received intact?	✓			☐ **Containers, Broken**
6. Were samples received in appropriate containers?			✓	☐ **Containers, Improper; Client Contacted; Proceed/Cancel**
7. Do sample container labels match COC? (IDs, Dates, Times)	✓			☐ **COC & Samples Do Not Match** ☐ **COC Incorrect/Incomplete** ☐ **COC Not Received**
8. Were all of the samples listed on the COC received?	✓			☐ **Sample Received, Not on COC** ☐ **Sample on COC, Not Received**
9. Is the date/time of sample collection noted?	✓			☐ **COC; No Date/Time; Client Contacted**
10. Was the sampler identified on the COC?		✓		☐ **Sampler Not Listed on COC**
11. Is the client and project name/# identified?	✓			☐ **COC Incorrect/Incomplete**
12. Are tests/parameters listed for each sample?	✓			☐ **COC No tests on COC**
13. Is the matrix of the samples noted?	✓			☐ **COC Incorrect/Incomplete**
14. Was COC relinquished? (Signed/Dated/Timed)	✓			☐ **COC Incorrect/Incomplete**
15. Were samples received within holding time?	✓			☐ **Holding Time - Receipt**
16. Were samples received with correct chemical preservative (excluding Encore)?			✓	☐ **pH Adjusted, pH Included (See box 16A)** ☐ **Incorrect Preservative**
17. Were VOA samples received without headspace?			✓	☐ **Headspace (VOA only)**
18. Did you check for residual chlorine, if necessary? (e.g. 1613B, 1668) Chlorine test strip lot number:			✓	☐ **Residual Chlorine**
19. For 1613B water samples is pH<9?			✓	☐ If no, notify lab to adjust
20. For rad samples was sample activity info. Provided?			✓	☐ Project missing info

Comments/Actions Taken

10,

Labeling Verified by: **Date:**

pH test strip lot number:

	Box 16A: pH Preservation	Box 18A: Residual Chlorine
Preservative:		
Lot Number:		
Exp Date:		
Analyst:		
Date:		
Time:		

Project #: 14006199 PM Instructions:

Sample Receiving Associate: Date: 7/3/23

QA026R32.doc, 062719

Page 36 of 36

8/3/2023

ATTACHMENT 4

X-Ray Diffraction
Laboratory Analytical Report

Quantitative X-Ray Diffraction by Rietveld Refinement

Report Prepared for: *Environmental Services*

Project Number/ LIMS No. *Custom XRD/MI4526-AUG23*

Sample Receipt: *August 10, 2023*

Sample Analysis: *August 31, 2023*

Reporting Date: *September 13, 2023*

Instrument: BRUKER AXS D8 Advance Diffractometer

Test Conditions: Co radiation, 35 kV, 40 mA; Detector: LYNXEYE
Regular Scanning: Step: 0.02°, Step time: 0.75s, 2θ range: 6-80°
Clay Section Scanning: Step: 0.01°, Step time:0.2s, 2θ range: 3-40°

Interpretations : PDF2/PDF4 powder diffraction databases issued by the International Center for Diffraction Data (ICDD). DiffracPlus Eva and Topas software.

Detection Limit : 0.5-2%. Strongly dependent on crystallinity.

Contents:

1) Method Summary
2) Quantitative XRD Results
3) XRD Pattern(s)

Kim Gibbs

Zhihai (Adrian) Zhang, Ph.D
Mineralogist

Kim Gibbs, H.B.Sc., P.Geo.
Senior Mineralogist

ACCREDITATION: SGS Natural Resources Lakefield is accredited to the requirements of ISO/IEC 17025 for specific tests as listed on our scope of accreditation, including geochemical, mineralogical and trade mineral tests. To view a list of the accredited methods, please visit the following website and search SGS Canada Inc. - Minerals: https://www.scc.ca/en/search/palcan.

SGS Natural Resources
a division of SGS Canada Inc.

P.O. Box 4300, 185 Concession Street, Lakefield, Ontario, Canada K0L 2H0
Tel: (705) 652-2000 Fax: (705) 652-6365 www.sgs.com www.sgs.com/met
Member of the SGS Group (SGS SA)

Method Summary

The Rietveld Method of Mineral Identification by XRD (ME-LR-MIN-MET-MN-D05) method used by SGS Natural Resources is accredited to the requirements of ISO/IEC 17025.

Mineral Identification and Interpretation:

Mineral identification and interpretation involves matching the diffraction pattern of an unknown material to patterns of single-phase reference materials. The reference patterns are compiled by the Joint Committee on Powder Diffraction Standards - International Center for Diffraction Data (JCPDS-ICDD) database and released on software as Powder Diffraction Files (PDF).

Interpretations do not reflect the presence of non-crystalline and/or amorphous compounds, except when internal standards have been added by request. Mineral proportions may be strongly influenced by crystallinity, crystal structure and preferred orientations. Mineral or compound identification and quantitative analysis results should be accompanied by supporting chemical assay data or other additional tests.

Clay Mineral Separation and Identification:

Clay minerals are typically fine-grained (<2 µm) phyllosilicates in sedimentary rock. Due to the poor crystallinity and fine size of clay minerals, separation of the clay fraction from bulk samples by centrifuge is required. A slide of the oriented clay fraction is prepared and scanned followed by a series of procedures (the addition of ethylene glycol and high temperature heating). Clay minerals are identified by their individual diffraction patterns and changes in their diffraction pattern after different treatments. Clay speciation and mineral identification of the bulk sample are performed using DIFFRACplus EVA (Bruker AXS).

Quantitative Rietveld Analysis:

Quantitative Rietveld Analysis is performed by using Topas 4.2 (Bruker AXS), a graphics based profile analysis program built around a non-linear least squares fitting system, to determine the amount of different phases present in a multicomponent sample. Whole pattern analyses are predicated by the fact that the X-ray diffraction pattern is a total sum of both instrumental and specimen factors. Unlike other peak intensity-based methods, the Rietveld method uses a least squares approach to refine a theoretical line profile until it matches the obtained experimental patterns.

Rietveld refinement is completed with a set of minerals specifically identified for the sample. Zero values indicate that the mineral was included in the refinement calculations, but the calculated concentration was less than 0.05wt%. Minerals not identified by the analyst are not included in refinement calculations for specific samples and are indicated with a dash.

Environmental Services
Custom XRD/MI4526-AUG23
13-Sep-23

Summary of Rietveld Quantitative Analysis X-Ray Diffraction Results

Mineral/Compound	**VER-35 55-60 20230624 AUG4526-01** (wt %)	**VER-35 60-63 20230624 AUG4526-02** (wt %)	**VER-70 30-40 20230623 AUG4526-03** (wt %)	**VER-70 41-42 20230623 AUG4526-04** (wt %)	**VER-70 75-80 20230623 AUG4526-05** (wt %)
Quartz	38.5	38.1	48.6	48.2	35.0
Chlorite	6.9	6.8	1.2	3.6	7.7
Muscovite	23.4	23.0	13.5	15.2	27.0
Albite	12.6	12.6	10.6	10.8	11.5
Microcline	1.0	1.1	1.3	1.1	0.7
Siderite	4.9	5.0	0.9	0.1	5.4
Actinolite	-	-	0.8	-	-
Dolomite	-	-	11.7	11.7	-
Clays					
Illite	7.1	8.0	7.4	5.6	5.2
Kaolinite	5.6	5.4	3.2	3.7	7.5
Montmorillonite	-	-	0.8	-	-
TOTAL	100	100	100	100	100

Zero values indicate that the mineral was included in the refinement, but the calculated concentration is below a measurable value.

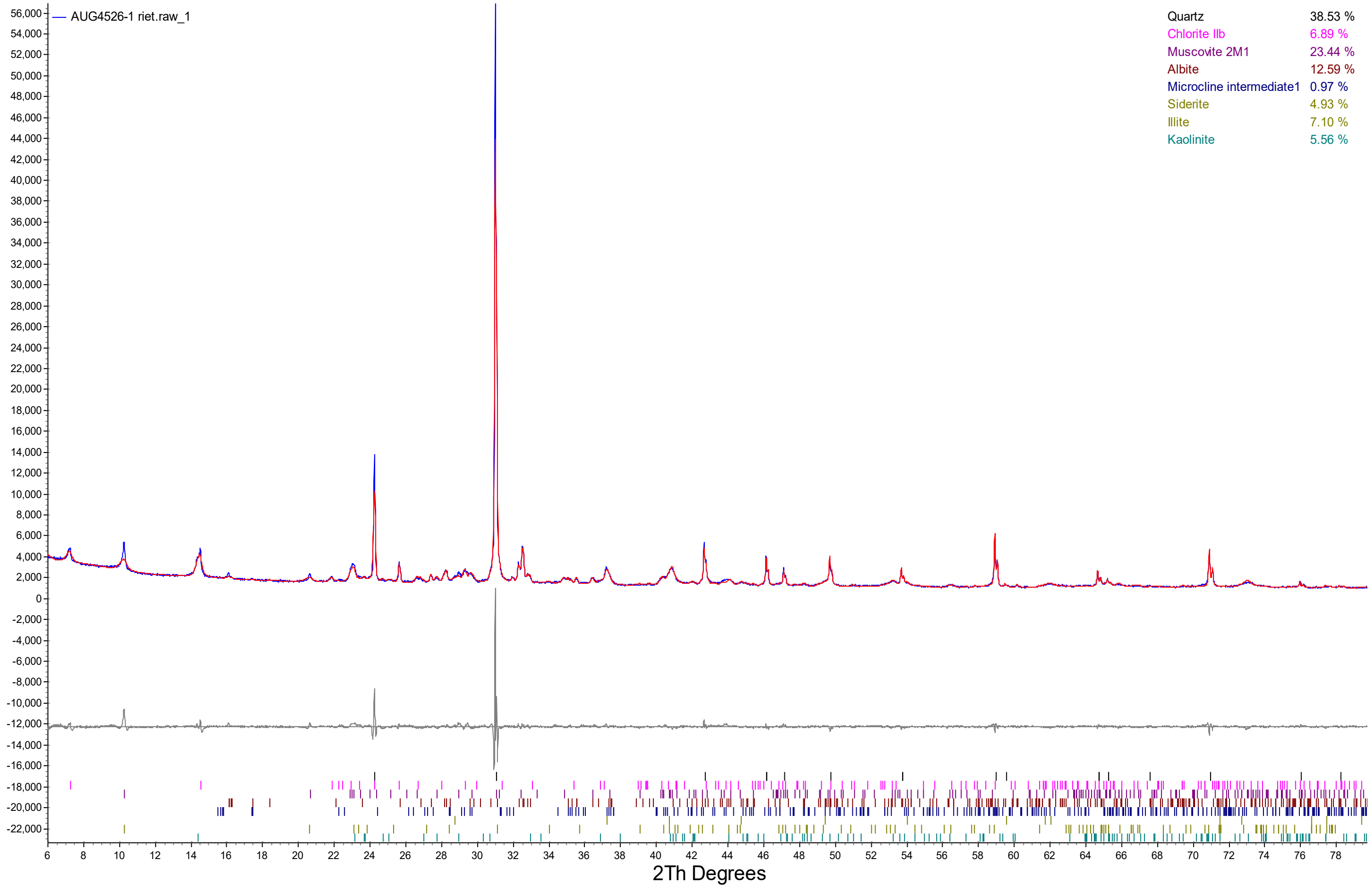
Dashes indicate that the mineral was not identified by the analyst and not included in the refinement calculation for the sample.

The weight percent quantities indicated have been normalized to a sum of 100%. The quantity of amorphous material has not been determined.

Mineral/Compound	**Formula**
Quartz	SiO_2
Chlorite	$(Fe,(Mg,Mn)_5,Al)(Si_3Al)O_{10}(OH)_8$
Muscovite	$KAl_2(AlSi_3O_{10})(OH)_2$
Albite	$NaAlSi_3O_8$
Microcline	$KAlSi_3O_8$
Siderite	$FeCO_3$
Illite	$(K,H_3O)(Al,Mg,Fe)_2(Si,Al)_4O_{10}[(OH)_2,(H_2O)]$
Kaolinite	$Al_2Si_2O_5(OH)_4$
Actinolite	$Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2$
Dolomite	$CaMg(CO_3)_2$
Montmorillonite	$(Na,Ca)_{0.3}(Al,Mg)_2Si_4O_{10}(OH)_2\cdot 10H_2O$

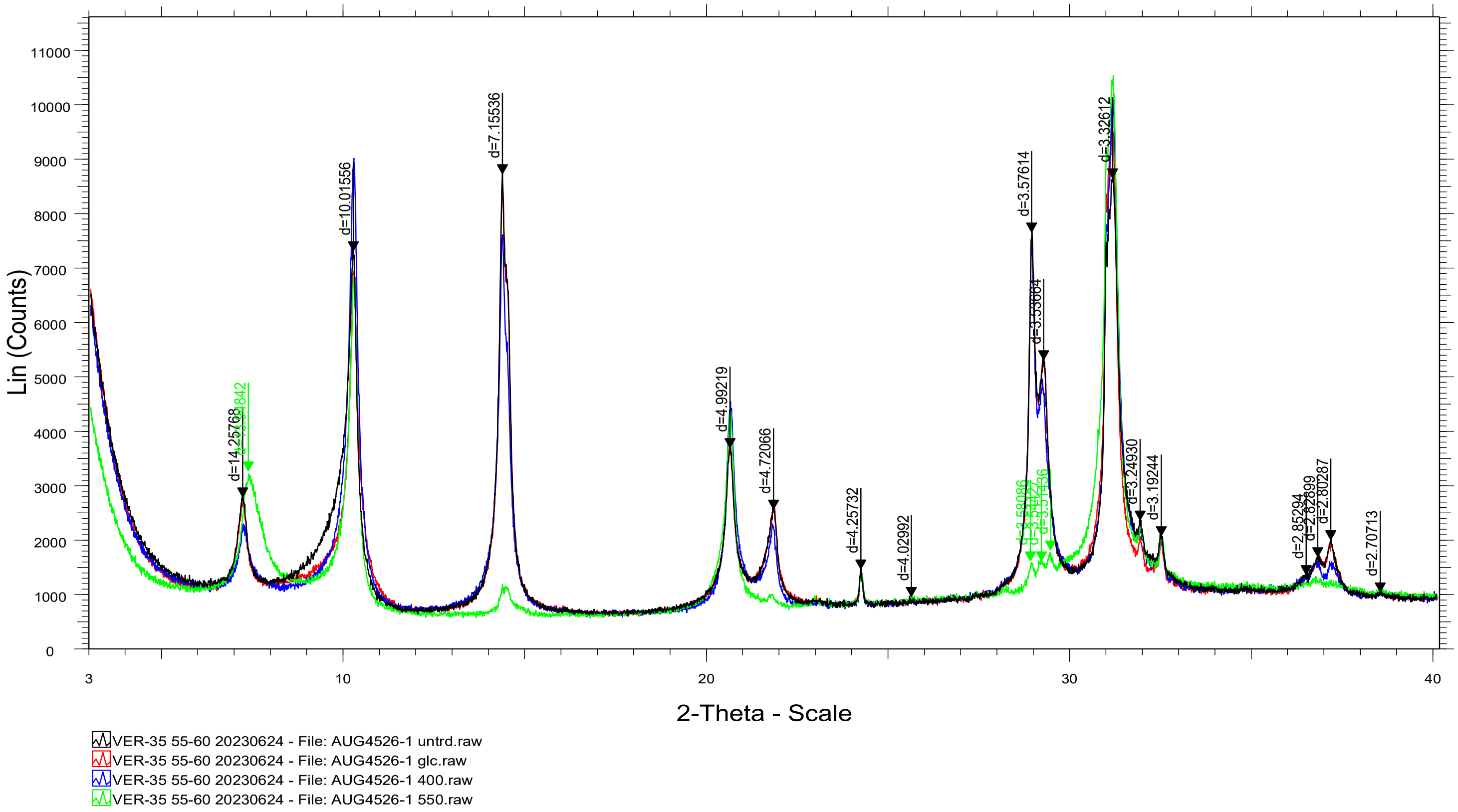
Environmental Services
Custom XRD/MI4526-AUG23
13-Sep-23

VER-35 55-60 20230624



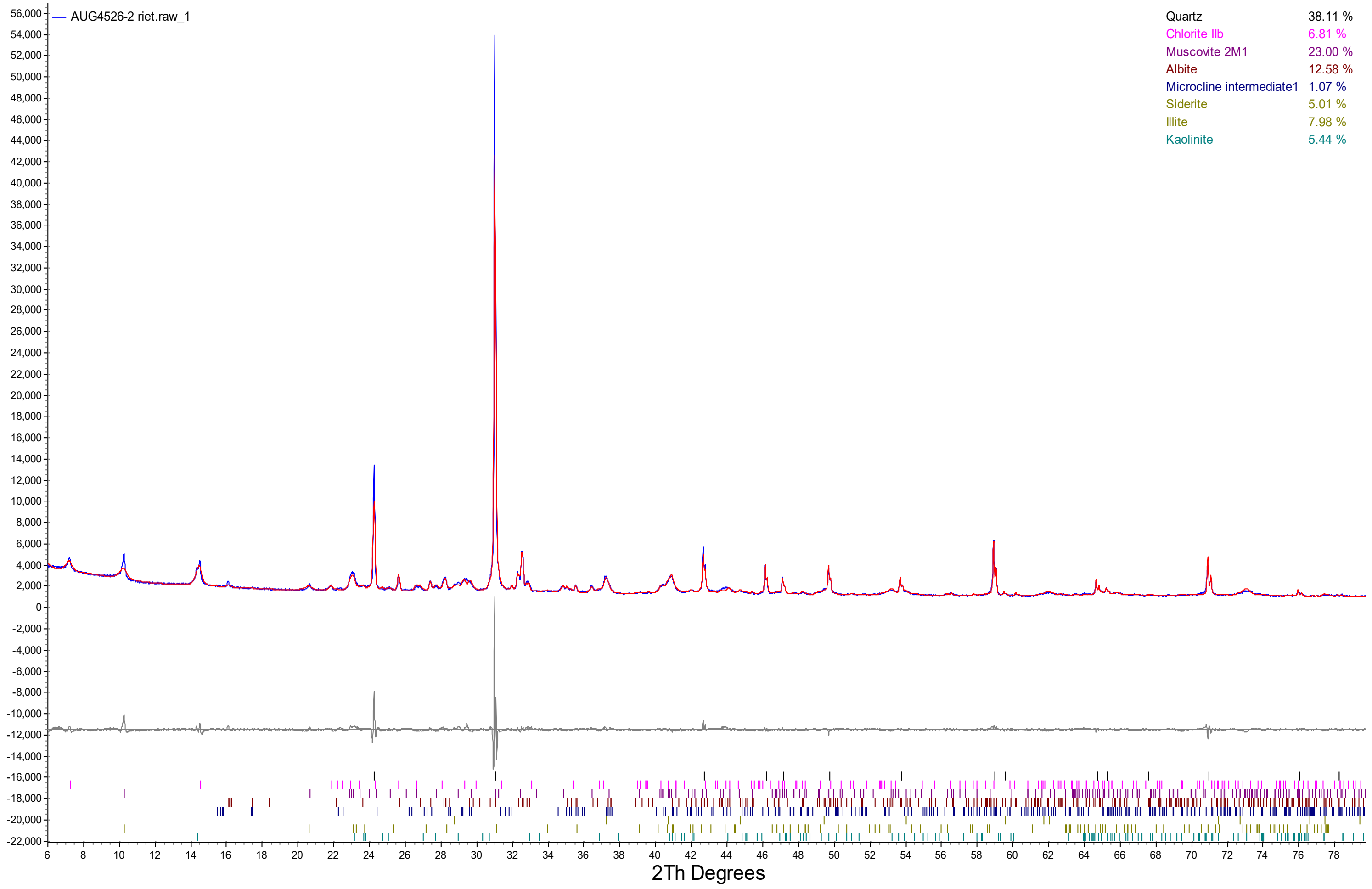
Environmental Services
Custom XRD/MI4526-AUG23
13-Sep-23

VER-35 55-60 20230624



Environmental Services
Custom XRD/MI4526-AUG23
13-Sep-23

VER-35 60-63 20230624



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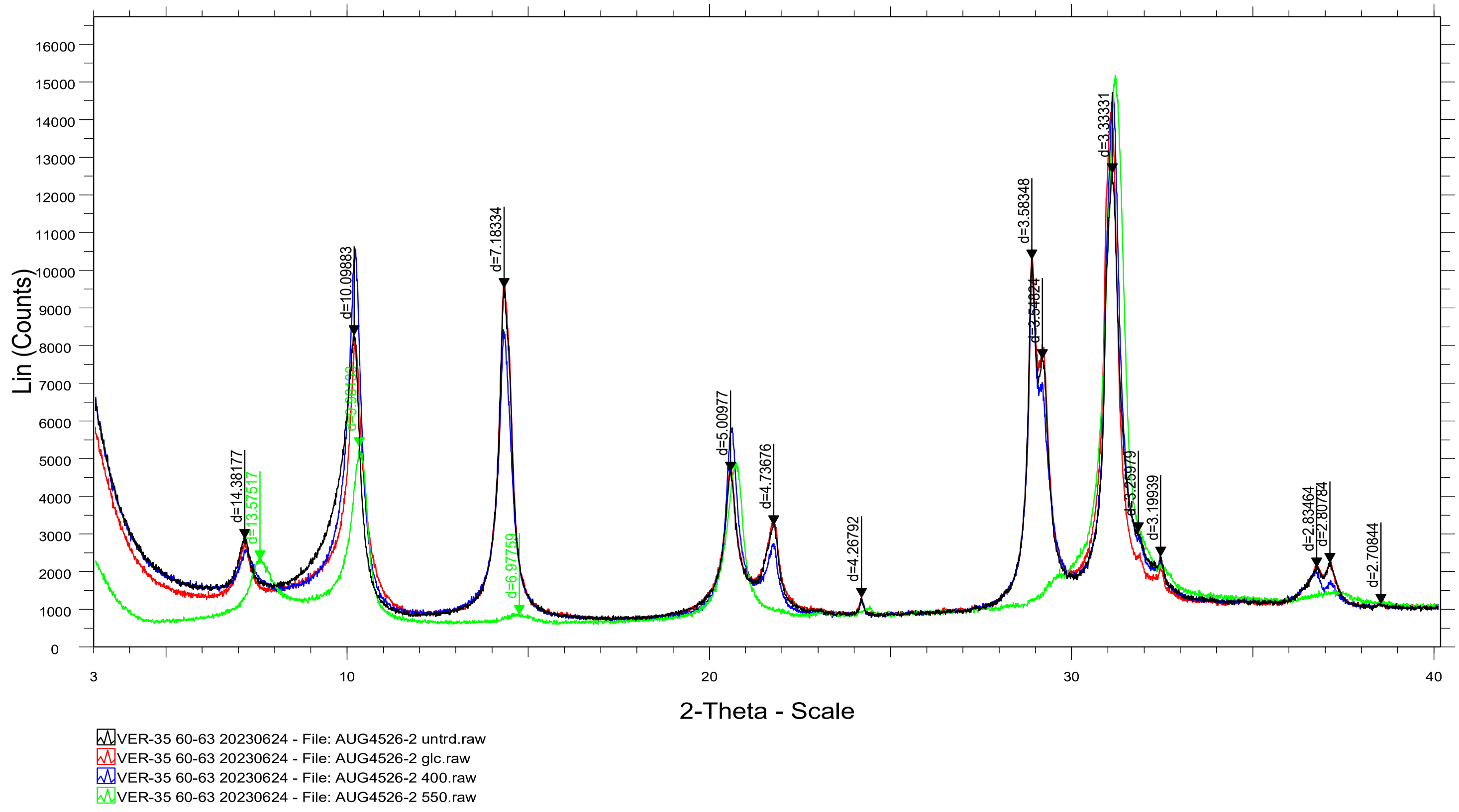
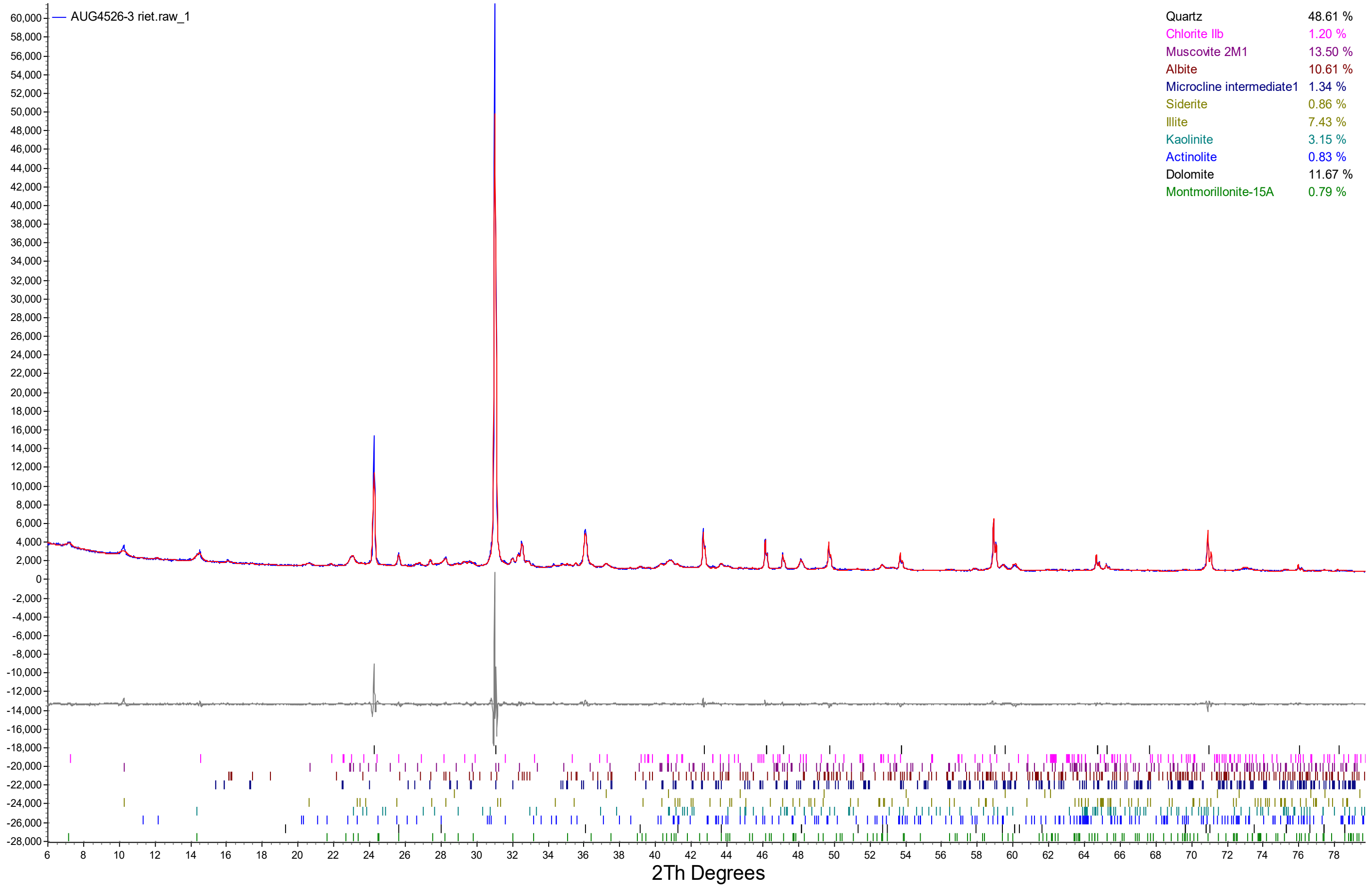


Environmental Services
Custom XRD/MI4526-AUG23
13-Sep-23

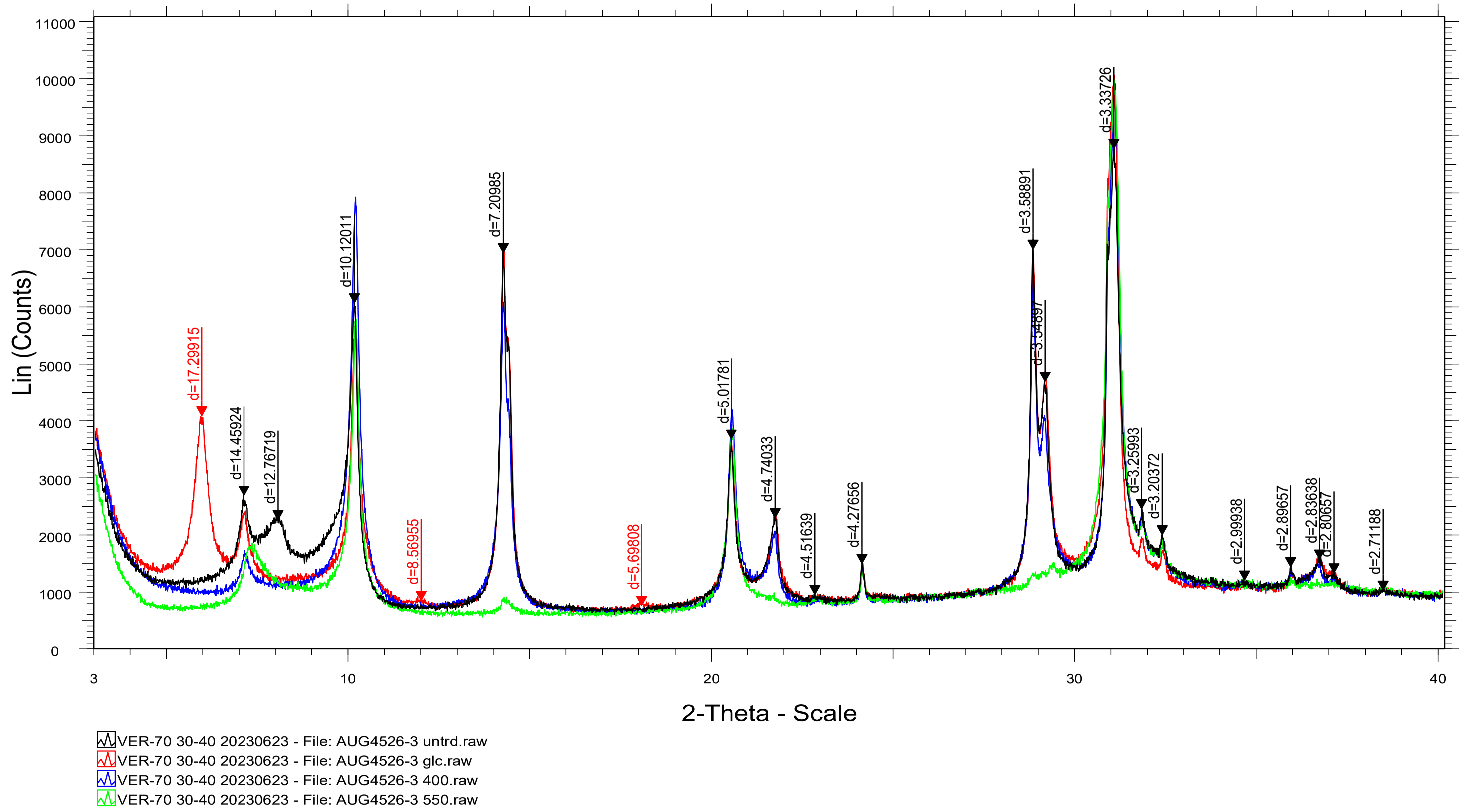
VER-70 30-40 20230623

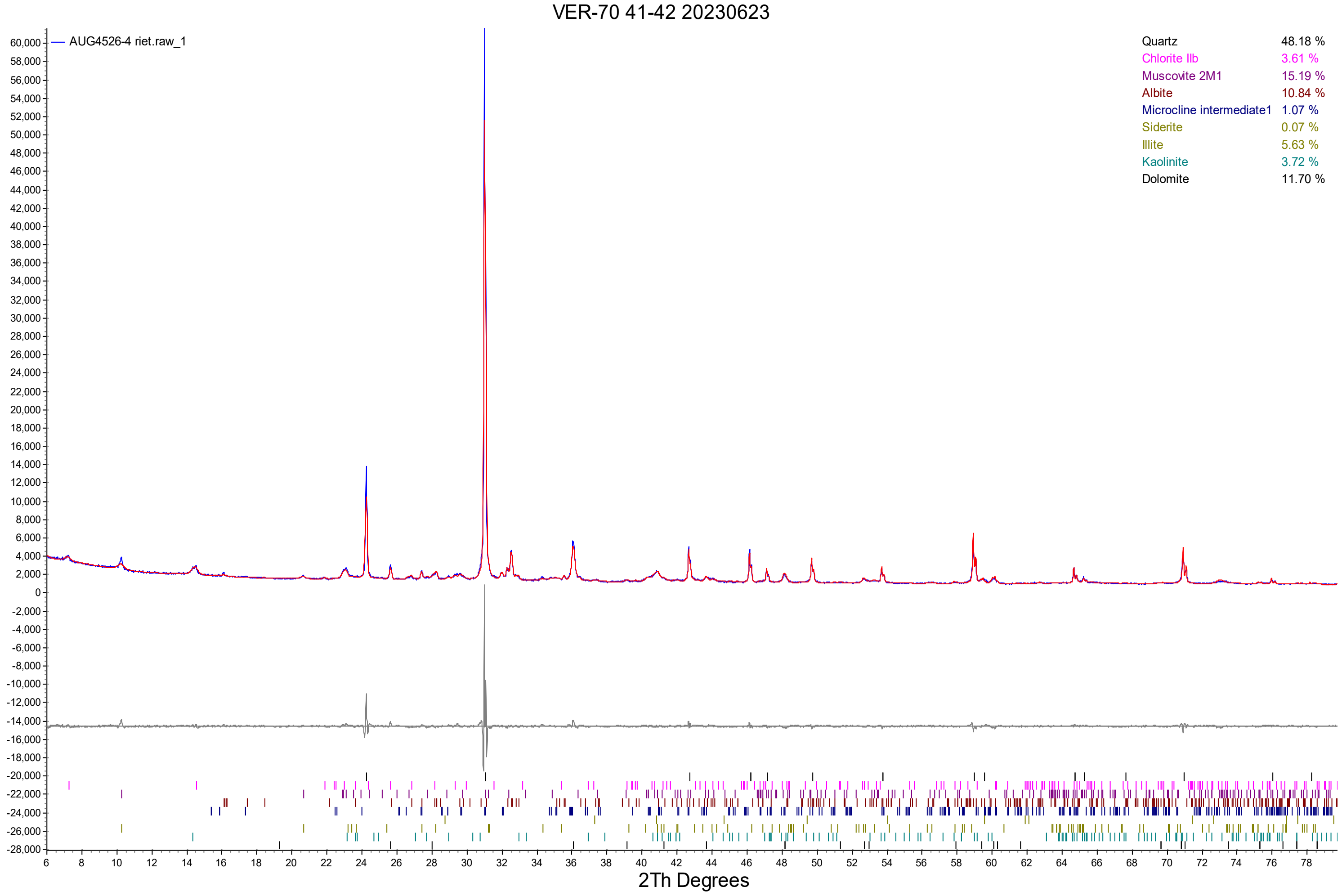


Quartz	48.61 %
Chlorite IIb	1.20 %
Muscovite 2M1	13.50 %
Albite	10.61 %
Microcline intermediate1	1.34 %
Siderite	0.86 %
Illite	7.43 %
Kaolinite	3.15 %
Actinolite	0.83 %
Dolomite	11.67 %
Montmorillonite-15A	0.79 %

Environmental Services
Custom XRD/MI4526-AUG23
13-Sep-23

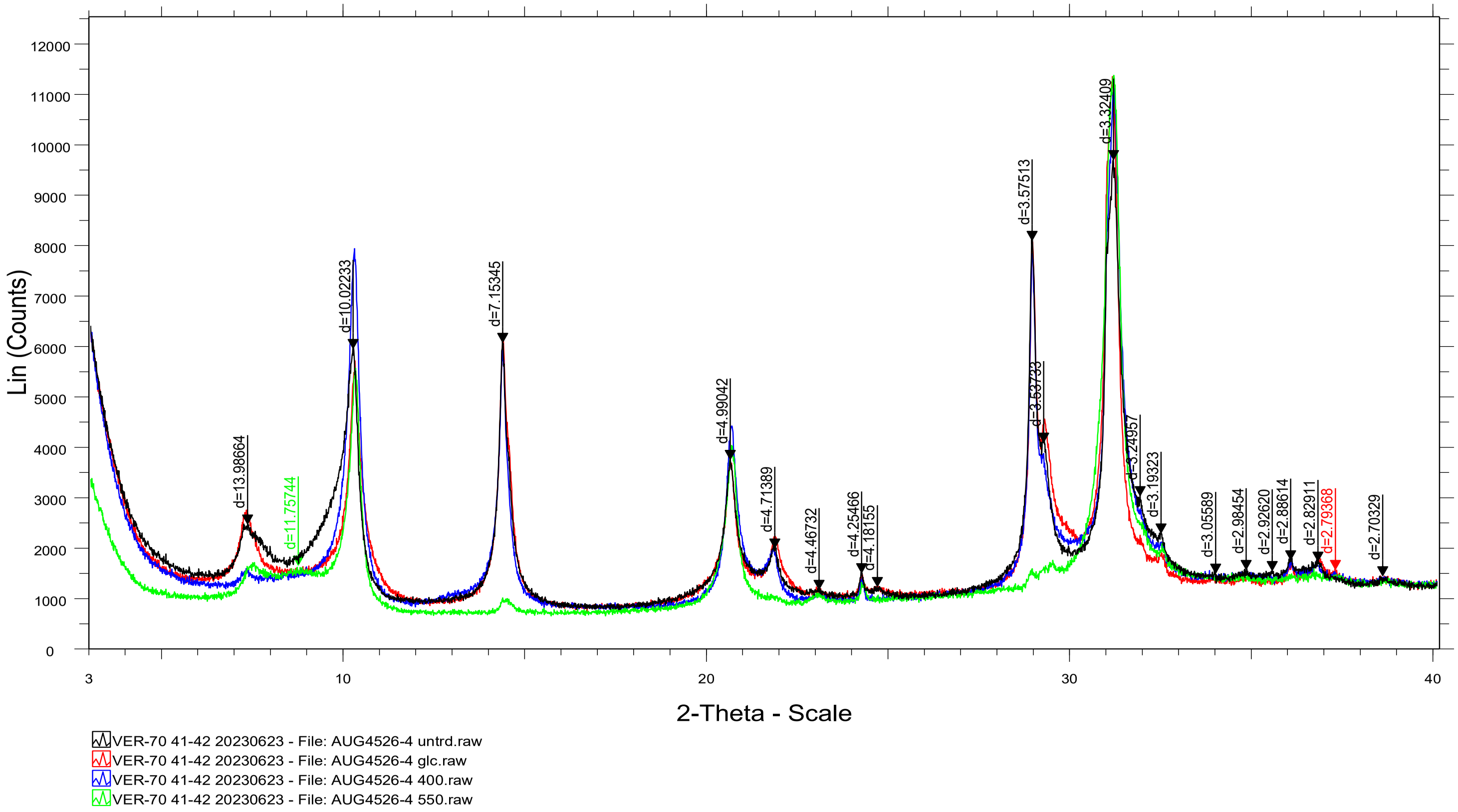
VER-70 30-40 20230623





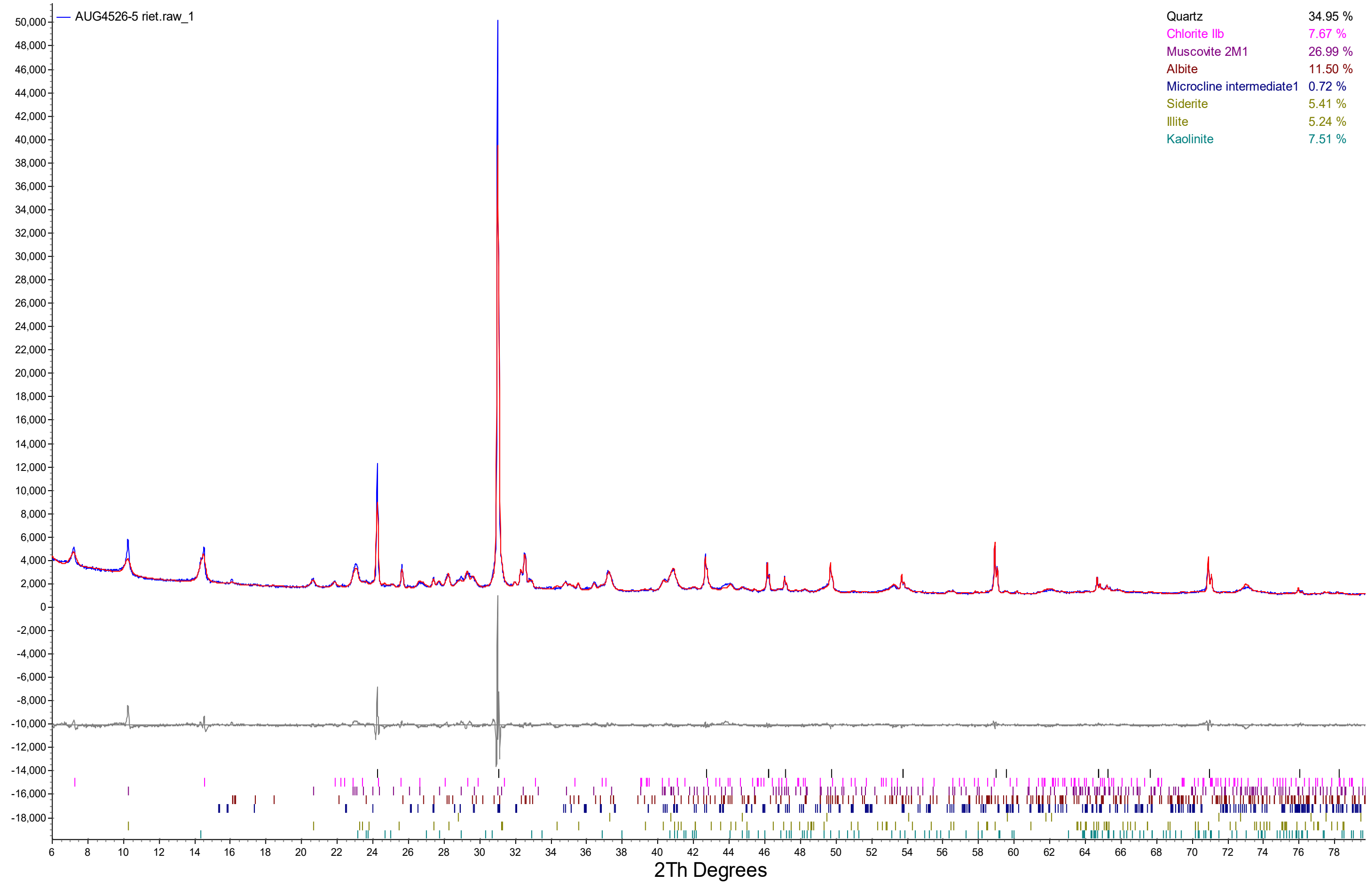
VER-70 41-42 20230623

VER-70 41-42 20230623



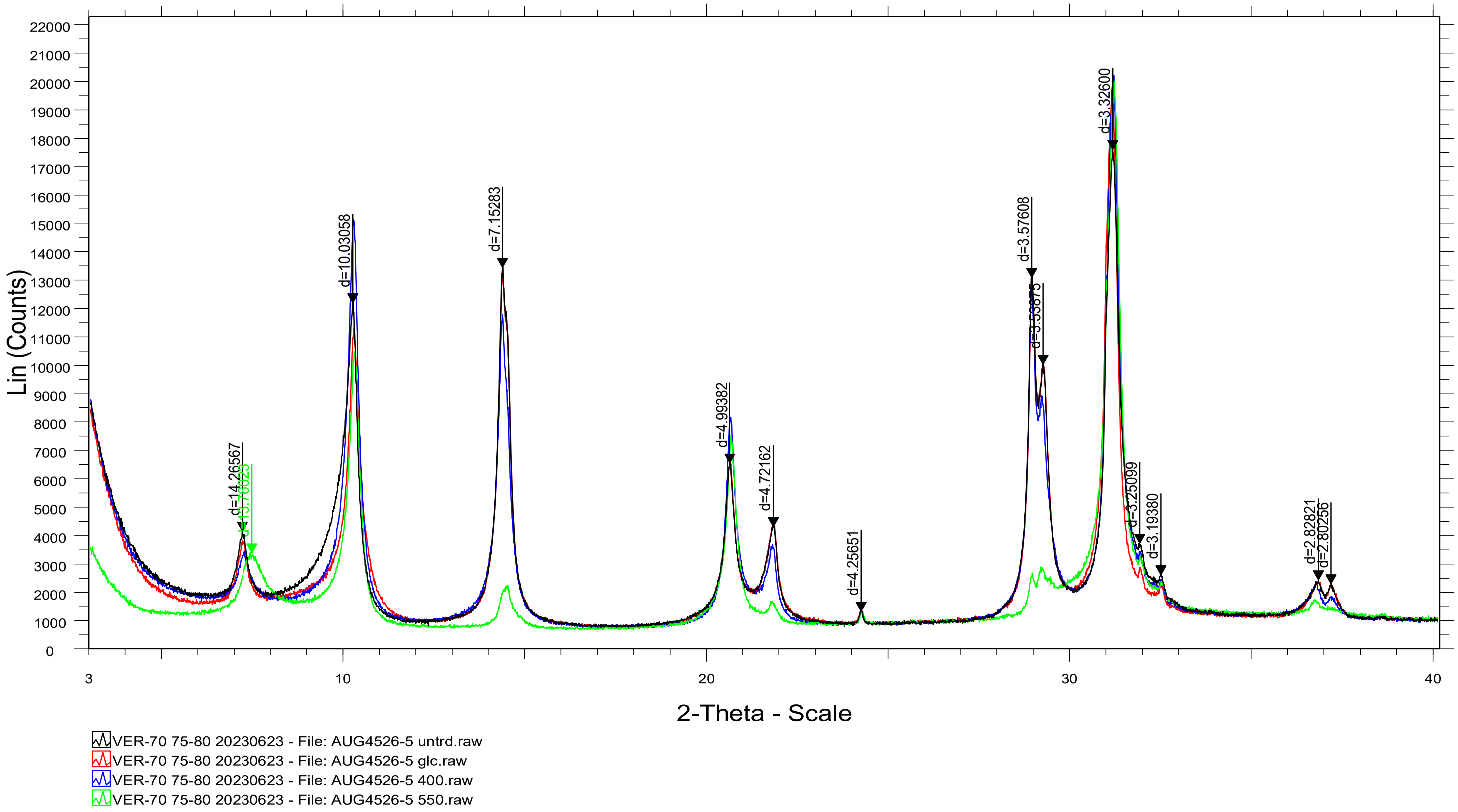
Environmental Services
Custom XRD/MI4526-AUG23
13-Sep-23

VER-70 75-80 20230623



Environmental Services
Custom XRD/MI4526-AUG23
13-Sep-23

VER-70 75-80 20230623



ATTACHMENT 5

Principal Component Analysis Input Data

ELECTRONIC PCA DATA FOR ATTACHMENT 5
35 I.A.C. § 845: ALTERNATIVE SOURCE DEMONSTRATION
VERMILION POWER PLANT
NEW EAST ASH POND
OAKWOOD, IL

Well	HSU	Date	Well Type	pH (SU)	Alkalinity, bicarbonate (mg/L)	Alkalinity, carbonate (mg/L)	Barium (mg/L)	Boron (mg/L)	Calcium (mg/L)	Chloride (mg/L)	Fluoride (mg/L)
16A	BCU	4/1/2021	Downgradient	7.50	390	1.5	0.261	0.675	40.8	131	0.77
16A	BCU	4/21/2021	Downgradient	7.20	407	1.5	0.335	0.613	71.10	106	0.64
16A	BCU	5/11/2021	Downgradient	7.40	361	1.5	0.245	0.807	36.6	139	0.78
16A	BCU	6/3/2021	Downgradient	7.26	405	1.5	0.272	0.716	51.60	128	0.68
16A	BCU	6/17/2021	Downgradient	7.40	406	1.5	0.251	0.746	42.20	144	0.78
16A	BCU	7/8/2021	Downgradient	7.31	404	1.5	0.249	0.768	38.00	151	0.77
16A	BCU	7/27/2021	Downgradient	7.45	390	1.5	0.248	0.794	35.30	163	0.84
16A	BCU	8/17/2021	Downgradient	7.50	393	1.5	0.261	0.755	33.30	176	0.84
35D	BCU	4/1/2021	Downgradient	8.20	707	1.5	0.111	2.01	112.0	529	0.76
35D	BCU	4/21/2021	Downgradient	7.76	533	1.5	0.0294	1.8	93.60	281	0.65
35D	BCU	6/3/2021	Downgradient	7.25	637	1.5	0.0546	2.5	98.10	461	0.75
35D	BCU	6/17/2021	Downgradient	7.25	603	1.5	0.14	1.8	99.40	393	0.75
35D	BCU	7/8/2021	Downgradient	7.22	582	1.5	0.0297	1.9	86.00	372	0.74
35D	BCU	7/27/2021	Downgradient	7.37	507	1.5	0.0263	1.5	70.40	234	0.79
35D	BCU	8/17/2021	Downgradient	7.30	491	1.5	0.0269	1.4	65.7	199	0.76
70D	BCU	4/1/2021	Downgradient	7.60	262	1.5	0.3360	0.712	39.6	317	0.76
70D	BCU	4/21/2021	Downgradient	7.28	334	1.5	0.521	1.01	48.1	517	0.57
70D	BCU	6/3/2021	Downgradient	7.03	416	1.5	0.687	1.56	68.6	665	0.47
70D	BCU	6/17/2021	Downgradient	7.14	443	1.5	0.7260	1.33	73.1	680	0.5
70D	BCU	7/8/2021	Downgradient	6.85	527	1.5	0.954	1.58	82.5	735	0.41
70D	BCU	7/27/2021	Downgradient	6.96	540	1.5	0.734	1.54	78.1	745	0.44
70D	BCU	8/17/2021	Downgradient	6.84	610	1.5	0.761	1.54	91.5	716	0.36
71D	BCU	4/1/2021	Downgradient	7.60	258	1.5	0.299	0.58	37.7	172	0.92
71D	BCU	6/17/2021	Downgradient	7.15	475	1.5	0.4	1.1	28.7	563	0.73
71D	BCU	8/17/2021	Downgradient	6.95	628	1.5	0.677	1.3	34.9	674	0.56
22	BCU	4/1/2021	Upgradient	7.40	390	1.5	0.0723	0.41	41.5	23	0.43
22	BCU	4/20/2021	Upgradient	7.58	407	1.5	0.0798	0.4	37.5	11	0.4000
22	BCU	5/10/2021	Upgradient	7.29	395	1.5	0.0795	0.433	45.7	11	0.4200
22	BCU	6/3/2021	Upgradient	7.26	390	1.5	0.0787	0.361	48.3	7	0.3800
22	BCU	6/17/2021	Upgradient	7.23	406	1.5	0.0791	0.377	50.3	7	0.3900
22	BCU	7/8/2021	Upgradient	7.20	412	1.5	0.082	0.348	47.7	7	0.37
22	BCU	7/27/2021	Upgradient	7.34	401	1.5	0.0795	0.311	48.2	7	0.39
22	BCU	8/17/2021	Upgradient	7.26	402	1.5	0.0785	0.34	47.1	7	0.38
NED1	CCR	4/1/2021	CCR	9.20	1.5	81	0.032	18.6	497.0	44	0.3200
NED1	CCR	4/21/2021	CCR	8.86	4	62	0.029	19.3	472.0	32	0.3800
NED1	CCR	5/11/2021	CCR	7.88	132	1.5	0.0289	14	674.0	18	0.2
NED1	CCR	6/4/2021	CCR	7.55	117	1.5	0.0319	13.5	532.0	18	0.24
NED1	CCR	8/17/2021	CCR	8.73	18	41	0.0314	18.3	531.0	25	0.29
10	UCU	4/1/2021	Upgradient	6.80	550	1.5	0.079	0.0587	182.0	6	0.13
10	UCU	4/21/2021	Upgradient	6.80	546	1.5	0.047	0.0587	193.0	6	0.14
10	UCU	5/10/2021	Upgradient	6.76	476	1.5	0.068	0.053	160.0	4	0.14
10	UCU	6/3/2021	Upgradient	6.74	579	1.5	0.0795	0.0835	186.0	5	0.14
10	UCU	6/17/2021	Upgradient	6.76	550	1.5	0.0625	0.111	186.0	6	0.14
10	UCU	7/8/2021	Upgradient	6.69	561	1.5	0.068	0.0499	166.0	5	0.13
10	UCU	7/27/2021	Upgradient	6.80	550	1.5	0.0712	0.237	182.0	4	0.14
10	UCU	8/17/2021	Upgradient	6.69	582	1.5	0.0772	0.0695	192.0	5	0.13
70S	UU	4/1/2021	Downgradient	7.00	310	1.5	0.018	0.457	253.0	19	0.14
70S	UU	4/21/2021	Downgradient	6.94	270	1.5	0.0205	0.403	281.0	17	0.14
70S	UU	5/10/2021	Downgradient	6.99	262	1.5	0.0185	0.382	270.0	16	0.14
70S	UU	6/3/2021	Downgradient	6.91	272	1.5	0.0165	0.424	245.0	15	0.14
70S	UU	6/17/2021	Downgradient	6.85	278	1.5	0.0187	0.363	250.0	15	0.15
70S	UU	7/8/2021	Downgradient	6.80	305	1.5	0.0172	0.253	220.0	14	0.16
70S	UU	7/27/2021	Downgradient	7.01	287	1.5	0.01	0.556	229.0	11	0.17
70S	UU	8/17/2021	Downgradient	6.87	272	1.5	0.02	0.538	232.0	15	0.16
71S	UU	4/1/2021	Downgradient	6.90	422	1.5	0.0476	0.179	115.0	2	0.18
71S	UU	4/21/2021	Downgradient	6.73	419	1.5	0.0534	0.215	116.0	3	0.17
71S	UU	5/12/2021	Downgradient	6.84	403	1.5	0.0487	0.227	124.0	3	0.18
71S	UU	6/3/2021	Downgradient	6.71	419	1.5	0.0446	0.229	116.0	2	0.18
71S	UU	6/17/2021	Downgradient	6.76	422	1.5	0.0421	0.219	117.0	2	0.19
71S	UU	7/8/2021	Downgradient	6.60	462	1.5	0.0493	0.173	128.0	2	0.19
71S	UU	7/27/2021	Downgradient	6.83	421	1.5	0.0462	0.251	132.0	2	0.2
71S	UU	8/17/2021	Downgradient	6.73	442	1.5	0.0672	0.272	122.0	3	0.19

Notes:
mg/L = milligrams per liter
SU= standard units
HSU = hydrostratigraphic unit
CCR = coal combustion residual
BCU = Bedrock Confining Unit
UCU = Upper Confining Unit
UU = Upper Unit
Non-detect values were replaced with half of detection limit.

Exhibit C

DECLARATION OF MELINDA W. HAHN, PhD

In support of Dynegy Midwest Generation, LLC's (DMG's) Petition for Review of IEPA's Non-concurrence with the Vermilion Alternative Source Demonstration and Request for Stay

I, Dr. Melinda W. Hahn, declare and state as follows:

Introduction

1) I am an Environmental Engineer and Senior Managing Consultant with Ramboll Americas Engineering Solutions, Inc. Attachment A is a true and accurate copy of my Curriculum Vitae.

2) I hold a PhD in Environmental Engineering from Johns Hopkins University. The focus of my research for my PhD dissertation was contaminant transport in porous media (e.g., groundwater).

3) My practice over my 25-year career includes site investigation and remediation in multiple state and federal programs, such as voluntary remediation, Resource Conservation and Recovery Act (RCRA) corrective action, and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) response action. My work in these programs includes contaminant fate

and transport modelling, site investigation and remediation, and statistics and forensic analysis of environmental contamination data. I have evaluated sites from many different industrial sectors with many different contaminants of concern, including volatile organic compounds (VOCs), which includes chlorinated volatile organic compounds (CVOCs), semivolatile organic compounds (SVOCs), metals, polychlorinated biphenyls (PCBs), and dioxins/furans.

4) To prepare this Declaration, I reviewed the DMG December 1, 2023 Alternative Source Demonstration (ASD) Report for lithium, chloride, sulfate and total dissolved solids (TDS) observed in groundwater from bedrock wells 35D and 70D at the Vermilion Power Plant (VPP) New East Ash Pond (NEAP), the December 28, 2023 IEPA denial of the ASD, and supporting information for the ASD. I reviewed the documents submitted by DMG independently and was not personally involved in their preparation.

5) The ASD report addresses exceedances of lithium, chloride, sulfate and TDS above their respective Groundwater Protection Standards (GPS) observed in groundwater in bedrock wells 35D (lithium, chloride, sulfate and TDS) and 70D (lithium, chloride and TDS) at the VPP NEAP in the 2nd quarter of 2023.[1] The ASD report relies on a multiple lines of evidence (MLE) approach that is standard practice

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[1] Ramboll, Groundwater Monitoring Data and Exceedances Report, 2nd Quarter 2023, New East Ash Pond, Vermilion Power Plant, October 2, 2023, Table 2.

in causal determinations in environmental forensic analysis, risk assessment, and site investigation.[2,3,4,5,6] The MLE approach involves analysis of multiple independent sets of data to test whether an identified source can explain observed data. Information to consider can be site-specific, regional, or from the literature.[7,8] These independent lines of evidence are developed until sufficient confidence is achieved to either confirm or rule out a source.[9] The lines of evidence (LOE) presented in the Vermilion ASD that demonstrate that a source other than the NEAP is causing the exceedances and the NEAP is not the source of or contributing to the observed exceedances are the following:[10]

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[2] Miller, J. Methods and Advances in the Forensic Analysis of Contaminated Rivers, E3S Web of Conferences Vol. 125, 2019, p. 3.

[3] U.S. EPA, U.S. Navy SPAWAR Systems Center, GeoChem Metrix Inc., and Battelle Memorial Institute, A Handbook for Determining the Sources of PCB Contamination in Sediments, Technical Report, TR-NAVFAC EXWC-EV-1302, October 2012, p. 13.

[4] U.S. EPA, Office of the Science Advisor, Risk Assessment Forum, Weight of Evidence in Ecological Assessment, EPA/100/R-16/001, December 2016.

[5] U.S. EPA, Office of Solid Waste and Emergency Response, OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor in Indoor Air, June 2015, pp. xv-xvii, 17-18, 38-40, 60-61, 117-123.

[6] EPRI, Guidelines for Development of Alternative Source Demonstrations at Coal Combustion Residual Sites, 2017 Technical Report, p. viii.

[7] U.S. EPA, Office of the Science Advisor, Risk Assessment Forum, Weight of Evidence in Ecological Assessment, EPA/100/R-16/001, December 2016, p. 20 et seq.

[8] U.S. EPA, U.S. Navy SPAWAR Systems Center, GeoChem Metrix Inc., and Battelle Memorial Institute, A Handbook for Determining the Sources of PCB Contamination in Sediments, Technical Report, TR-NAVFAC EXWC-EV-1302, October 2012, p. 30.

[9] Miller, J. Methods and Advances in the Forensic Analysis of Contaminated Rivers, E3S Web of Conferences Vol. 125, 2019, p. 3.

[10] Ramboll, Alternative Source Demonstration Report, New East Ash Pond, Vermilion, December 1, 2023, p. 8.

LOE 1 – The ionic composition of bedrock groundwater is different than the ionic composition of porewater and consistent with published observations for Pennsylvanian Bedrock.

LOE 2 – Concentrations of chloride in the NEAP porewater are lower than those observed in the groundwater.

LOE 3 – A bedrock solids and geochemical evaluation identified naturally occurring shales as the source of lithium and chloride exceedances at 35D and 70D.

LOE 4 – A bedrock solids and geochemical evaluation identified naturally occurring coal seams as the source of the sulfate exceedance at 35D due to regional upward vertical hydraulic gradients in the shale bedrock.

LOE 5 – Isotopic analysis of groundwater from the bedrock and overlying Quaternary deposits indicate that bedrock groundwater is between 13,000 and 35,000 years older than groundwater in the Quaternary deposits; and bedrock groundwater is isolated from the groundwater in the Quaternary deposits.

Background

6) The Vermilion Power Plant (VPP) property and nearby properties were historically used for coal mining. The coal seam, where present typically between approximately 80 and 100 feet below grade, is contained within the bedrock unit and can influence bedrock geochemistry above the seams due to the local and regional

upward hydraulic gradient within the bedrock unit. Coal mining leaves behind voids that can collapse and disturb the overlying rock and soil, causing fracturing (that changes the hydraulic properties of the bedrock by creating preferential flow pathways) and soil subsidence. A test boring on-site at the VPP during the Kelron investigation in 2002 hit one such location that caused an above-ground geyser of sulfur-rich water from the coal seam.[11] This example indicates the presence of a strong upward hydraulic gradient within the bedrock aquifer.

7) The regional and local geology, hydrogeology and groundwater geochemistry at the VPP, and near the Old East Ash Pond (OEAP) area in particular, were extensively studied by Kelron Environmental in collaboration with the Illinois State Geological Survey (ISGS) in 2003 (the report for this investigation in provided as Attachment B to this Declaration). This investigation included a review of historical mining activity and seismic investigation of on-site historic mine sites, review of regional groundwater quality in the alluvial deposits and the bedrock, installation of 40 soil borings and 11 new monitoring wells (for a total of 16), collection of groundwater data in the bedrock and alluvial sediments monthly for six consecutive months (including background and monitoring data for inorganic parameters for the Old East Ash Pond), collection and analysis of soil and coal

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[11] Ramboll, Alternative Source Demonstration Report for New East Ash Pond, Vermilion Power Plant, December 1, 2023. P. 7, Appendix A pp. 2, 8.; Kelron Environmental, Regional and Local Hydrogeology and Geochemistry, Vermilion Power Plant, Vol. 1. p. 26 (The report for this investigation was referenced and relied upon in the preparation of the Vermilion ASD and is included as Attachment B to this Declaration).

samples, permeability testing, downhole geophysical logging by ISGS, laboratory analysis of rock samples by ISGS, isotopic analysis for tritium and carbon-14 of groundwater samples, and significant data analysis including extensive mapping of data, cross section preparation, summary statistics, geochemical analysis of groundwater data in Piper, Stiff, Box Whiskers, and Cation plots, and multivariate components and cluster analysis. The analysis is presented in a 2003 report, and the primary conclusions of the report are:[12]

a) The top of the Danville Coal or the void remaining where the coal was removed through mining is located at depths between 80 and 102.5 feet in the floodplain east of the Old East Ash Pond within the Pennsylvanian bedrock.

b) The Middle Fork of the Vermilion River is a zone of discharge for the bedrock aquifer due to the upward vertical hydraulic gradients measured within the shale.

c) The former coal mines in the vicinity of the East Ash Pond System have significant collapse features, resulting in fracturing of the overlying bedrock and in some cases, surface subsidence.

d) The isotopic, geochemical, and hydraulic data support the conclusion that groundwater within the bedrock has upward hydraulic gradients,

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[12] Kelron Environmental, Regional and Local Hydrogeology and Geochemistry, Vermilion Power Plant, pp. viii – x.

high dissolved mineral content, and is thousands of years older than recent groundwater in the overlying unlithified deposits.

e) Multiple bedrock background and monitoring wells at the Old East Ash Pond regularly exceeded contemporaneous groundwater standards for chloride, sulfate and TDS (note that lithium in these wells also exceeded the current groundwater protection standard). The occurrence of these parameters within the bedrock at concentrations higher than groundwater standards can be attributed to three sources: natural geochemistry, natural geochemistry associated with coal deposits, and impacts from the former coal mining activities.

8) For the Vermilion ASD, the independent lines of evidence supporting its conclusions include hydrogeological data to establish the direction of groundwater flow (groundwater flows horizontally generally from northwest to southeast toward the Vermilion River at the VPP, but the bedrock aquifer has a significant upward vertical component), chemical porewater data from a well set in the NEAP to characterize source concentrations, chemical groundwater data from upgradient and compliance wells, empirical observations of geologic layers from boring logs, and geochemical and multivariate analysis of chemical data. The lines of evidence also rely on the principles of geochemistry and the fundamental concept of contaminant migration: that contaminant concentrations decrease in the downgradient direction due to the successive dilution of dispersion and diffusion

(i.e., downgradient concentrations cannot be higher than steady source concentrations). In a coal combustion residual (CCR) surface impoundment release scenario, leachate is subject to physical processes that dilute solute concentrations including mixing, dispersion and dilution.[13]

9) The porewater well source concentrations in the NEAP have been characterized through the collection of porewater samples. The source porewater data for the NEAP are consistent with literature values for CCR leachate,[14,15,16] and define the maximum concentrations for CCR groundwater impact outside of the NEAP. NEAP source porewater is characterized by elevated levels of boron, calcium, and molybdenum relative to background bedrock groundwater concentrations as described in the Kelron/ISGS investigation report.[17]

10) Background bedrock well 22 at the NEAP is more shallow than all of the other bedrock background and compliance wells for the OEAP and the NEAP.[18,19] This single well is not representative of all bedrock background

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[13] U.S. EPA Office of Solid Waste and Emergency Response, Solid Waste Disposal Criteria, Technical Manual, EPA530-R-93-017, p. 126.

[14] U.S. EPA, Industrial Environmental Research Laboratory, Chemical and Biological Characterization of Leachates from Coal Solid Wastes, EPA-600/7-80-039, March 1980.

[15] U.S. EPA and TVA, Effects of Coal-ash Leachate on Ground Water Quality, EPA-600/7-80-066, March 1980.

[16] U.S. EPA, Office of Research and Development, Characterization of Coal Combustion Residues from Electric Utilities – Leaching and Characterization Data, EPA-600/R-09/151, December 2009.

[17] Kelron, Regional and Local Hydrogeology and Geochemistry Report, Vermilion Power Plant, November 30, 2003, Table 11.

[18] Kelron, Regional and Local Hydrogeology and Geochemistry Report, Vermilion Power Plant, November 30, 2003, Table 2

[19] Ramboll, Hydrogeologic Characterization Report, New East Ash Pond, Vermilion Power Plant, October 25, 2021, Table 3-1.

groundwater quality throughout the VPP because there is dramatic variability in natural bedrock groundwater chemistry onsite due to the presence of coal, the changes in chemistry with depth, and the upward vertical gradient in the bedrock aquifer. Samples from the multiple background wells identified in the Kelron/ISGS investigation with varying screen depths and proximities to a coal seam provide a more fulsome picture.

11) The Kelron/ISGS investigation identified significant variability among the background bedrock well chemistry, particularly for sulfate. The background bedrock sulfate concentrations ranged over almost two orders of magnitude among the tested wells,[20] likely due to the natural variability and random nature of the location of coal seams and mine voids, and preferential vertical pathways that move groundwater upward.

Chloride, Lithium, Sulfate and TDS Exceedances

12) A key LOE that the NEAP did not cause the GPS exceedances at 35D and 70D is that samples from these wells contain more chloride than the NEAP source porewater, and are consistent with established background concentrations in the upgradient bedrock aquifer and regional literature values. The measured chloride

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[20] Kelron, Regional and Local Hydrogeology and Geochemistry Report, Vermilion Power Plant, November 30, 2003, Table 11.

concentrations at 35D and 70D in 2nd Quarter 2023 were 493 and 573 mg/L,[21] respectively. The mean chloride concentration in the porewater is more than one order of magnitude lower at 27 mg/L, and the maximum reported value is 44 mg/L.[22] Due to advection and dilution, groundwater concentrations decrease moving away from the source, so downgradient areas necessarily have lower concentrations than constant strength source areas. For comparison to upgradient site background, the range of mean chloride concentrations in OEAP bedrock background wells is 60 to 1,233 mg/L.[23] The highest mean chloride concentration reported in the Kelron/ISGS study was observed at the deepest bedrock well (MW30). The mean reported concentration by the ISGS for the regional bedrock aquifer is 1,689 mg/L.[24] This evidence supports the conclusion that the NEAP is not the source of GPS exceedances at 35D and 70D.

13) Another key LOE is that upward hydraulic gradients exist within the bedrock. This fact demonstrates that the bedrock aquifer is not downgradient from the NEAP. As described above, groundwater contaminant fate and transport must be considered in three dimensions at the VPP. Water coming from the sampled

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[21] Ramboll, Groundwater Monitoring Data and Exceedances Report, 2nd Quarter 2023, New East Ash Pond, Vermilion Power Plant, October 2, 2023, Table 1.

[22] Ramboll, Hydrogeologic Characterization Report, New East Ash Pond, Vermilion Power Plant, October 25, 2021, Table 2-2.

[23] Kelron, Regional and Local Hydrogeology and Geochemistry Report, Vermilion Power Plant, November 30, 2003, Table 11.

[24] Kelron, Regional and Local Hydrogeology and Geochemistry Report, Vermilion Power Plant, November 30, 2003, Table 11.

bedrock intervals is coming from deeper within the bedrock. This concept is supported by the chemical isotope data (carbon-14) that indicates that VPP bedrock groundwater is tens of thousands of years old, whereas groundwater in the overburden (the alluvial sediments above the bedrock) has detectable tritium isotopes indicating a "young" groundwater that has recently been in contact with the atmosphere.[25] These results indicate that there is no or very little mixing of groundwater between the bedrock and the overburden. If a small amount of mixing is occurring, it is most likely migration from the bedrock to the overburden due to the observed upward hydraulic gradients within the bedrock.

14) Concentrations of lithium and TDS in 35D and 70D are also consistent with those observed in bedrock background wells identified in the Kelron/ISGS hydrogeologic investigation. Second quarter 2023 lithium concentrations in 35D and 70D were 0.144 and 0.085 mg/L respectively[26], versus a measured site-specific range of means of 0.04 to 0.11 mg/L and a maximum of 0.4 mg/L in background bedrock wells.[27] Second quarter TDS concentrations in 35D and 70D were 3,370 and 1,590 mg/L respectively,[28] versus a reported site-specific range of means of 863

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[25] Kelron, Regional and Local Hydrogeology and Geochemistry Report, Vermilion Power Plant, November 30, 2003, p. ix.

[26] Ramboll, Groundwater Monitoring Data and Exceedances Report, 2nd Quarter 2023, New East Ash Pond, Vermilion Power Plant, October 2, 2023, Table 1.

[27] Kelron, Regional and Local Hydrogeology and Geochemistry Report, Vermilion Power Plant, November 30, 2003, Table 11.

[28] Ramboll, Groundwater Monitoring Data and Exceedances Report, 2nd Quarter 2023, New East Ash Pond, Vermilion Power Plant, October 2, 2023, Table 1.

to 2,433 mg/L, and a reported regional mean of 3,540 mg/L in background bedrock wells.[29]

15) The ASD presented the results of multiple geochemical data analyses (Piper diagram), multivariate analysis including Principal Components Analysis (PCA) and Hierarchical Clustering Analysis (HCA) of NEAP background wells in bedrock and overburden, compliance wells in bedrock and overburden, and porewater.[30] The results indicated that the porewater chemical signature is dominated by boron and carbonate alkalinity, whereas the bedrock groundwater chemical signature is dominated, in part, by chloride. Compliance groundwater samples have a different ionic composition compared to porewater, and a composition relative to background that is consistent with expected changes due to screen depth. The clustering results show that the chemical composition of groundwater samples is primarily influenced by their lithography (aquifer solids) rather than their relative location with respect to the CCR unit. These results provide an independent LOE to support the conclusion that the lithium and chloride exceedances in 35D and 70D are not driven by the CCR unit, but rather by the native lithology.

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[29] Kelron, Regional and Local Hydrogeology and Geochemistry Report, Vermilion Power Plant, November 30, 2003, Table 11

[30] Ramboll, Alternative Source Demonstration Report, New East Ash Pond, Vermilion, December 1, 2023, Appendix A, pp. 6-7.

16) Geochemical analysis of site-specific bedrock and coal solids samples was completed in 2002 and 2023,[31] and the results confirm that native lithology drives the detection of lithium and sulfate in NEAP bedrock groundwater. Sequential extraction procedure (SEP) and X-ray diffraction conducted on bedrock solid samples in 2023 demonstrated the presence of micas and clay minerals that contain lithium. Geochemical conditions in the groundwater support the desorption or dissolution of the sulfide and iron oxide mineral phases that host lithium. Similarly, chemical analysis of coal seam solids collected and analyzed by Kelron/ISGS indicates that the coal contains up to 10% iron sulfide that readily undergoes oxidation to iron and sulfate. These analyses provide another LOE and demonstrate that aquifer solids within the bedrock contain and release lithium and sulfate. The underlying coal seam is the likely alternative source of the sulfate exceedance at 35D. The well construction log for this well indicates significant fracturing in the bedrock. The fractures are likely present due to underlying mining voids and also likely serve as preferential pathways for coal-impacted water from below to reach the sampled interval.

17) The major contributors to TDS are chloride and sulfate in groundwater observed at 35D and 70D.[32] All LOEs that apply to chloride and sulfate, therefore

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[31] Ramboll, Alternative Source Demonstration Report, New East Ash Pond, Vermilion, December 1, 2023, Appendix A, pp. 3, 8.

[32] Ramboll, Alternative Source Demonstration Report, New East Ash Pond, Vermilion, December 1, 2023, Figure A.

also apply to TDS. The presented lines of evidence demonstrate that the NEAP is not the source of and does not contribute to the observed GPS exceedances of lithium, chloride, sulfate and TDS in 35D and 70D.

IEPA Denial

18) In its December 28, 2023 letter, the IEPA denied the Vermilion ASD due to perceived "data gaps" that included the following:

a) Characterization that the draw water from the bedrock is completely isolated from local groundwater system.

b) No assessment of the interaction between bedrock groundwater and the old east ash pond. Based on Fig. 1 shows to be upgradient of the New East Ash Pond.

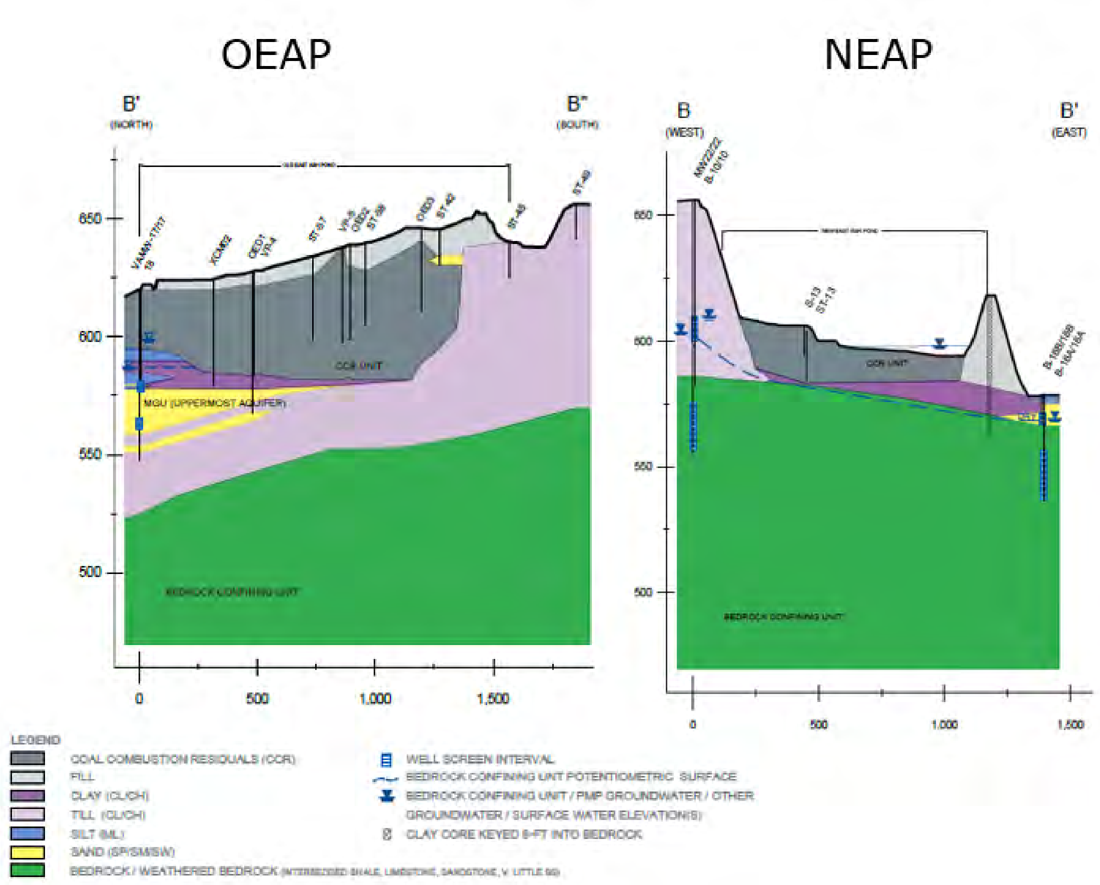
c) Lack of analysis of the leachable metals from the CCR to the New East Ash Pond.

19) The first identified data gap is confusing as the bedrock is necessarily part of the "local groundwater system". However, if the IEPA is referring to the isolation of the bedrock from the CCR unit or the overlying alluvial sediments, the ASD presented several facts that support the conclusion that there is no or very little mixing between the bedrock aquifer and the overburden. The chemical isotopic analysis that shows that the bedrock groundwater and the alluvial groundwater have very different ages (tens of thousands of years for the bedrock versus very recent for

the alluvial sediments) and are therefore not subject to mixing. Further, the strong upward vertical hydraulic gradients observed within the bedrock indicate that the origin of the sampled bedrock groundwater is deeper within the bedrock, and that if a small amount of mixing does occur, it is most likely bedrock groundwater moving into the overburden. Thus, based on available evidence any further evaluation of the isolation of the bedrock from the NEAP or overlying alluvial sediments is unnecessary and would not change the conclusions of the ASD.

20) In its second stated data gap, the IEPA points out the OEAP is located hydraulically upgradient of the NEAP and the ASD does not assess the interaction between the OEAP and the bedrock aquifer. The groundwater flow at the VPP must be understood in three dimensions. Figure 1 of the ASD may suggest that the OEAP is upgradient of shallow groundwater at the NEAP, but it does not suggest that contaminants from the OEAP could potentially migrate to the bedrock aquifer. This Declaration has demonstrated, through the discussion above, the lack of a migration pathway for NEAP contaminants to the bedrock. The OEAP is even further removed than the NEAP from the bedrock due to its higher elevation and additional till layer between the CCR unit and the bedrock. The following cross sections show the vertical relationship between the respective ash ponds and the bedrock aquifer. The cross sections from the respective Hydrogeologic Characterization reports for the

CCR units run from northwest to southeast through the OEAP, then the NEAP with very little gap in between.[33]



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[33] Ramboll, Hydrogeologic Characterization Report, Vermilion Power Plant, North Ash Pond and Old East Ash Pond, October 25, 2021, Fig. 2-10. Ramboll, Hydrogeologic Characterization Report, Vermilion Power Plant, New East Ash Pond, October 25, 2021, Fig. 2-10.

The juxtaposed cross sections show that the OEAP is separated from the bedrock with an additional layer of till. The bedrock was not considered to be a potential migration pathway for evaluation of the OEAP. Also, the background wells 10 and 22 for the NEAP, located on the left hand (west) side of the NEAP cross section, do not exhibit exceedances of the GPS as one might expect if a plume was migrating from the OEAP. This evidence demonstrates that the OEAP is not a source of exceedances observed in NEAP bedrock wells 35D and 70D and thus any further evaluation of the interaction between the OEAP and the bedrock aquifer is unnecessary and would not result in any change to the ASD's conclusions.

21) In its third stated data gap, the IEPA suggests that there is insufficient analysis of leachable metals from the CCR in the NEAP. The IEPA does not specify what type of analysis is requested. If the IEPA is requesting laboratory leach testing of solid CCR samples either by Toxicity Characteristic leaching procedure (TCLP), Synthetic Precipitation Leaching Procedure (SPLP), or Leaching Environmental Assessment Framework (LEAF), that information would not be more appropriate for a source impact analysis than the actual porewater data collected from the CCR presented in the Vermilion ASD. All of the synthetic laboratory leach tests on a solid sample aim to simulate a landfill environment in order to predict leachate quality from a solid sample. Synthetic leach test results are compared to actual field leachate data for fly ash and slag in order to evaluate the representativeness of their results,

i.e., field verification.[34] U.S. EPA advises that these "batch" 1-day laboratory tests on a relatively small sample do not account for the long-term climatic and meteorological influences on a full-scale landfill operation.[35] These tests often yield high initial concentrations that are not typical of a full-scale operation.[36] Other researchers evaluating the utility of the synthetic precipitation leaching procedure (SPLP) to assess the risk of groundwater contamination posed by the land application of granular solid waste report that the use of a total pollutant concentration (mg/kg) in conjunction with SPLP concentrations (milligrams per liter [mg/L]) to estimate pore water concentration was unreliable as this method underestimates the measured porewater concentrations.[37]

22) Clearly, directly measuring CCR analyte concentrations in actual porewater samples from the actual disposal environment is a more accurate basis for an impact analysis than using laboratory predictions of those values. The Vermilion NEAP CCR and adjacent groundwater quality have been adequately characterized for performing an alternative source demonstration. Data from the NEAP porewater

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[34] Tiwari, M.K., et al, Suitability of Leaching Test Methods for Fly Ash and Slag: A Review, Journal of Radiation Research and Applied Sciences, Vol.8, 2015. pp. 523-537.

[35] U.S. EPA Office of Solid Waste and Emergency Response, Solid Waste Disposal Criteria, Technical Manual, EPA530-R-93-017, p. 125.

[36] *Ibid.*

[37] Townsend, T, et al, Interpretation of Synthetic Precipitation Leaching Procedure (SPLP) Results for Assessing Risk to Groundwater from Land-Applied Granular Waste, Environmental Engineering Science, Vol. 23, No. 1, 2005.

samples relied upon in the ASD Report[38] are sufficient to define the strength and variability of source water for this assessment. Collection of additional CCR source characterization data suggested in IEPA's December 28, 2023 letter is not required for the ASD by Part 845 or Part 257 and would not change the conclusion of the ASD that the CCR in the NEAP did not cause or contribute to the noted exceedances.

I declare under penalty of perjury that the foregoing is true and correct.

Dated: February 2, 2024

Melinda W Hahn

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Melinda W. Hahn, PhD

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[38] Ramboll, Alternative Source Demonstration Report, New East Ash Pond, Vermilion Power Plant, December 1, 2023. Appendix A, Attachment 5.

ATTACHMENT A

Curriculum Vitae of Melinda Hahn, PhD

ENVIRONMENT
& HEALTH

MELINDA W. HAHN, PH.D.

Senior Managing Consultant

Dr. Hahn's practice areas include site investigation and remediation, contaminant fate and transport modelling, statistics of environmental data, forensic analysis, and litigation support, including primarily environmental liability and cost allocation. Regulatory areas include RCRA, CERCLA, TSCA, and Voluntary Cleanup/Risk-Based Corrective Action. Dr. Hahn has experience in the following industry categories: energy (electric utilities, petroleum dispensing, pipeline operations, former manufactured gas plant sites), industrial equipment manufacturing, metal working and metal recycling, automobile manufacturing, ink and chemical manufacturing, wood treating, mining, cement manufacturing, milling and smelting operations, secondary aluminum production, and dry cleaning.

EDUCATION

1995
PhD, Environmental Engineering
The Johns Hopkins University

1990
BS, Physics
The University of Texas at Austin

1990
BS, Mathematics
The University of Texas at Austin

ACADEMIC HONORS

1992-1995
Graduate Fellow, National Science Foundation

1995
Most Distinguished Environmental Engineering Dissertation, Association of Environmental Engineering Professors

CAREER

1998-Present
Senior Managing Consultant, ENVIRON/Ramboll

1997-1998
Consultant, Roy Ball, PC

1995-1997
Senior Project Engineer, Environmental Resources Management-North Central, Inc.

CONTACT INFORMATION

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PROJECTS

- Provided technical litigation support for over 50 matters regarding extent, severity, timing, and source of soil and ground water contamination and vapor intrusion, necessity for and costs of remediation, human health risk assessment, toxic tort liability, Superfund cost allocation (including consistency with the NCP), insurance cost recovery, and the siting and monitoring of a hazardous waste landfill. The regulatory frameworks included Illinois Voluntary Cleanup Program, Illinois Leaking Underground Storage Tank Program, RCRA, CERCLA, TSCA, NCP, and California Proposition 65. Completed projects in more than twenty states, with a focus in the Midwest.
- Provided expert testimony in matters involving Superfund cost allocation, statistics of environmental data, and contaminant fate and transport.
- Retained as an expert witness and provided litigation/mediation support for a number of cost allocation cases involving remediation of contaminated soil, groundwater, and sediment.
- Provided litigation support for environmental liability/cost allocation mediation and litigation at several large sediment sites. Evaluated historical information on industrial processes and discharges, and conducted forensic/statistical analysis to estimate the relative contribution of contaminants to sediments.
- Provided litigation support for a number of insurance cost recovery projects, including a former wood treating facility, a jewelry manufacturer, metal plating facility, machine shop and dry cleaner. Tasks included the identification of likely sources and timing of contamination.
- Evaluated claims of residents living near a scrap metal facility of transport and deposition of lead-containing particles in their homes using statistical analysis of plaintiffs' chemical data. Provided expert testimony based on this analysis.
- Evaluated the hydrogeological setting of a proposed petroleum pipeline pumping station and estimated the likelihood of a release and groundwater contamination. Provided expert testimony based on this analysis.
- Provided expert testimony on proposed coal ash impoundment closure regulations and proposed new state groundwater standards in Illinois.
- Conducted environmental forensic evaluations to determine sources of observed environmental contamination in soil, groundwater, sediment and sub-slab/indoor air for sites in litigation and pre-litigation phases.
- Performed multivariate statistical analyses of data for forensic analysis, for contaminant ecological impact analysis, to determine appropriate remedial objectives, and as part of human health and ecological risk assessments.
- Lead RCRA Corrective Action at a former manufacturing facility.
- Directed and assisted in the closure of a number of sites in the Illinois Voluntary Cleanup Program and the Illinois Leaking Underground Storage Tank Program.
- Evaluated the potential contribution of urban industrial sources of heavy metals to urban soil and sediments using both simple data comparisons and multivariate statistical techniques.
- Performed ground water and contaminant fate and transport modeling using MODFLOW and MT3D for use as a Superfund cost allocation tool in support of expert testimony. Relative mass of TCE entering the Superfund Site from sources on two PRP's properties was used as a basis for cost allocation. A Monte Carlo analysis was also performed to evaluate the sensitivity of the proposed allocation to changes in key variables.

- Performed Monte Carlo analysis of risk to ground water posed by a proposed petroleum pipeline in support of expert testimony. The analysis examined the likelihood of the exceedance of the Illinois Class I ground water standard for benzene per mile of proposed pipeline.
- Performed Monte Carlo cost allocation among four PRPs for a Superfund Site in support of expert testimony. Total volume, volume of hazardous substances, and volume of drummed materials were considered.
- Utilized 3-D geostatistical interpolation techniques to visualize environmental data, to estimate excavation volumes for remediation, and to identify and distinguish source areas and potential preferential pathways of migration for a number of contaminated sites.
- Performed research and analysis of remedial activities and associated costs to determine compliance with the NCP for cost recovery matters for a number of sites.

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Making the Case for Causation in Toxic Tort Cases: Superfund Rules Don't Apply
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ATTACHMENT B

Kelron/ISGS Investigation Report: Regional and Local Hydrogeology and Geochemistry, Vermilion Power Plant, Illinois, 2003

REGIONAL AND LOCAL HYDROGEOLOGY AND GEOCHEMISTRY VERMILION POWER PLANT, ILLINOIS

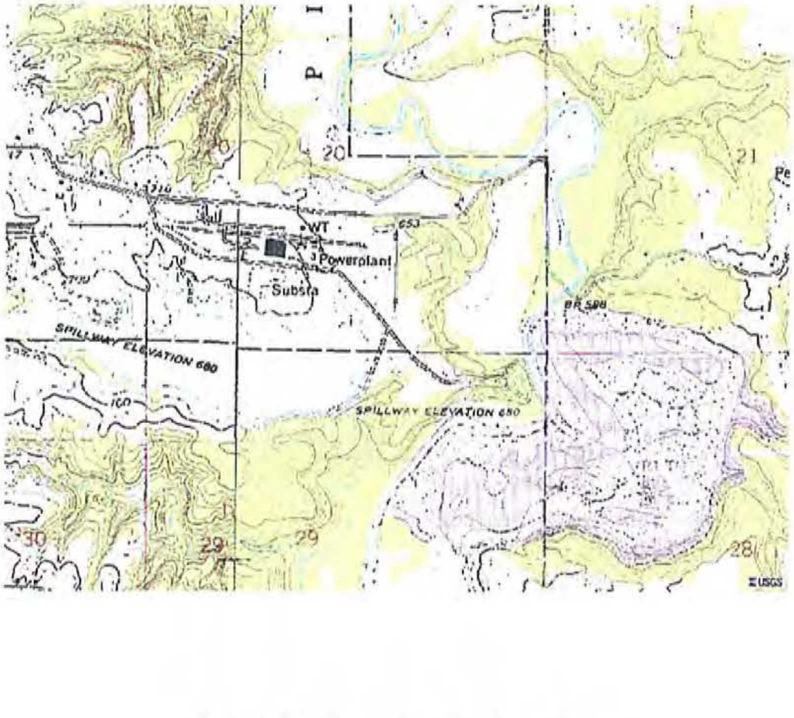
VOLUME 1 OF 2

November 30, 2003

Prepared for:

Dynegy Midwest Generation, Inc.

Decatur, Illinois



KELRON ENVIRONMENTAL
CHAMPAIGN, ILLINOIS

REGIONAL AND LOCAL HYDROGEOLOGY AND GEOCHEMISTRY VERMILION POWER PLANT, ILLINOIS

VOLUME 1 OF 2

November 30, 2003

Prepared for:

Dynegy Midwest Generation, Inc.
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EXECUTIVE SUMMARY

Background and Objectives

The East Ash Pond System (East Ash Pond) of the Vermilion Power Plant is owned and operated by Dynegy Midwest Generation, Inc. (DMG). The Vermilion Power Plant is located in Vermilion County, Illinois. Following a hydrogeologic investigation by Mathes Geotechnical Services, Inc. in 1987, the primary and secondary cells of the East Ash Pond were constructed in 1989. A planned expansion of the primary cell of the East Ash Pond beginning in 2002 prompted DMG to authorize in October 2001 a comprehensive regional and local hydrogeologic and geochemical investigation. Secondary objectives of the study were:

- To determine if the East Ash Pond was causing any changes to groundwater quality in the alluvial deposits or underlying bedrock;
- To assess the impacts of nearby coal mines on the hydrology and groundwater quality; and,
- To determine the appropriate groundwater classification for the East Ash Pond.

Due to the large scope of work involved and the need to establish the background geochemistry both in the vicinity of the study site (see Figures 1, 2, 3) and within the larger region, the Illinois State Geological Survey (ISGS) was contracted by Kelron Environmental (Kelron) to provide technical assistance in determining the background geochemistry of the bedrock deposits in the vicinity of the study site. The results of the ISGS investigation have been incorporated into this report.

Investigation Methods

In order to characterize both the geology and groundwater quality in the vicinity of the study site, a total of 40 borings and 16 monitoring wells were utilized. Groundwater and surface-water quality data were collected monthly over a six-month period for 19 inorganic parameters and four field parameters. In addition, as part of their separate study the ISGS collected groundwater samples from both DMG wells and private wells for inorganic and isotopic (tritium and Carbon-14) chemical analysis.

Other data collection activities employed during the study included:

- field permeability testing and analysis of the geologic materials by Kelron;
- seismic investigation of bedrock and coal mines near the East Ash Pond by URS Corp.;
- downhole geophysical logging of borings by the ISGS; and,
- laboratory analysis of rock-core samples by the ISGS.

The field and laboratory data collected during 2001 and 2002 were used to create a variety of products, including topographic maps, geologic maps, potentiometric surface maps, geologic cross-sections, hydrographs, and geochemical tables and figures.

Results

Geology

The deposits covering the bedrock in the study site are derived from recent river deposition (alluvial sediments) in the river valleys and glacial drift deposits occurring below the alluvial sediments and in the upland areas. Thickness of these deposits in the region range from zero thickness along portions of the Middle Fork of the Vermilion River (Middle Fork) where bedrock is exposed, to over 200 feet in the upland areas. The unlithified alluvial and glacial deposits in the vicinity of the East Ash Pond and within the floodplain generally range in thickness from 10 to 25 feet.

Rocks of Pennsylvanian age form the bedrock surface in the region surrounding the site. The Danville area is located on the northeast flank of the Illinois basin. Regionally, the Pennsylvanian bedrock consists of mainly shale with thin limestone, sandstone, and coal beds. The upper 75 feet of bedrock at the study site typically consists of the Shelburn Formation, which is composed of non-marine and marine, silty and micaceous shales. The Shelburn Formation contains a major coal seam mined in the region, the Danville Coal, also called the No. 7 Coal.

The top of the Danville Coal, or the void remaining where the coal was removed through mining, was intercepted at depths of 80 to 102.5 feet on the floodplain adjacent to the East Ash Pond. The thickness of the coal seam ranged from four to seven feet with an average thickness of 5.4 feet.

Hydrogeology

Groundwater within the alluvial and, where present, the glacial (till) deposits within the floodplain generally conforms to the ground surface topography. Groundwater elevations in the glacial and alluvial deposits demonstrate that groundwater elevations in the unlithified materials are higher than those in the adjacent Middle Fork through much of the year. The groundwater surface in the alluvial deposits fluctuates in response to changes in river stage and variations in precipitation. The groundwater surface is not affected by water levels in the East Ash Pond, which has been hydraulically isolated from both the shale and alluvial deposits by soil/bentonite slurry walls and a compacted clay core. Changes in pond elevation do not result in any corresponding changes in the shallow groundwater levels.

Groundwater elevations in the bedrock shale are highest in the topographically highest areas to the west and east of the Middle Fork of the Vermilion River. The lowest groundwater elevations occur at wells located adjacent to the Middle Fork. **Flow lines derived from the potentiometric surface maps indicate that the Middle Fork of the Vermilion in this area is a zone of discharge for the shale. The occurrence of the Middle Fork in this area as a regional discharge zone for the shallow bedrock is supported by the upward vertical hydraulic gradients measured within the shale. The shale outcrops along the banks of the Middle Fork and groundwater moving**

upward through the shale discharges into both the alluvium and directly into the Middle Fork.

The coal mines in the vicinity of the East Ash Pond System have been shown to have significant collapse features where the overlying shale has collapsed or partially collapsed downward into the void or mined coal seam. The collapse of the shale into the void translates upward through the shale, resulting in fracturing and in some cases surface subsidence.

Groundwater Chemistry

Based on the groundwater and surface water quality data collected in 2002, the affects of the East Ash Pond on groundwater quality are either negligible or not present. Groundwater quality data for most major ions and trace constituents is similar to background groundwater quality. In cases where elevated concentrations of a parameter were found to occur in groundwater near the East Ash Pond there were also elevated concentrations in background wells screened within coal deposits or in the proximity of abandoned coal mines.

Trace metal concentrations in groundwater were compared to East Ash Pond water samples and there was no commonality between the two water types. The deficiency of trace metals such as molybdenum, selenium, and vanadium in groundwater within both the alluvial deposits and the Pennsylvanian age bedrock at both background and East Ash Pond wells, as compared to their ubiquitous presence within waters of the East Ash Pond, suggests that **based on trace water quality data there is no impact to unlithified or bedrock groundwater quality by the East Ash Pond**.

The results of the isotopic analyses of groundwater samples from the background bedrock wells by the ISGS resulted in Carbon-14 ages ranging from 13,000 to 35,000 RYBP (radiocarbon years before present). In support of the Carbon-14 results, tritium concentrations for the same set of bedrock groundwater samples were all below detection limits ranging from 0.43 to 0.52 TU (tritium units). Water with non-detectable tritium concentrations is considered to be greater than 50 years old (Mehnert and Dreher, 2002).

The isotopic and other geochemical data from background monitoring wells supports the hydrogeologic conceptualization that **the Middle Fork of the Vermilion River is a regional discharge area for the bedrock.** Groundwater within the bedrock is at the end of its flow path and has upward hydraulic gradients, high dissolved mineral content, and is thousands of years older than recent groundwater in the overlying unlithified deposits.

Groundwater Classification

No groundwater parameters measured in the unlithified (i.e., alluvium and till) deposits of the study site exceeded Class I or II groundwater standards during March through August 2002. However, background well MW28 (see Figures 7, 8) exceeded the sulfate and TDS standards of 400 and 1,200 mg/L, respectively, during January and February 2002. Three bedrock monitoring wells at the East Ash Pond and four background wells regularly exceeded standards for at least one of the parameters of chloride, sulfate, and TDS.

The occurrence of parameters within the bedrock at sufficiently high concentrations to exceed groundwater standards can be attributed to three sources: natural geochemistry; natural geochemistry associated with coal deposits; and, anthropogenic (man-made) affects on geochemistry associated with former coal mines and mine spoil. Similarly, high concentrations of inorganic parameters within the unlithified deposits can be attributed to natural geochemistry and the impacts of former coal mines and mine spoil.

Based on the hydrogeology and geochemistry established for the vicinity of the East Ash Pond and surrounding region, and given the influence of former coal mines documented at the study site on the geochemistry of groundwater, it appears that the groundwater designation is Class IV – Other Groundwater, in accordance with Section 620.201 of Part 620 (IAC Title 35, Subtitle F, Chapter I). Class IV groundwater is defined as groundwater within a previously mined area that cannot meet the standards of Class I or II groundwater.

1.0 INTRODUCTION

1.1 PURPOSE

The East Ash Pond System (East Ash Pond) of the Vermilion Power Plant, which is owned and operated by Dynegy Midwest Generation, Inc. (DMG), is located in Vermilion County, Illinois (Figures 1, 2, 3). Following a hydrogeologic investigation by Mathes Geotechnical Services, Inc. (Mathes) in 1987, the primary and secondary cells of the East Ash Pond were constructed in 1989. A planned expansion of the primary cell of the East Ash Pond beginning in 2002 prompted DMG to authorize in October 2001 a comprehensive regional and local hydrogeologic and geochemical investigation by Kelron Environmental (Kelron). The secondary purpose of the investigation was to determine if the East Ash Pond was impacting groundwater quality in the surficial and underlying bedrock deposits.

1.2 APPROACH

In order to characterize both the regional and local groundwater quality, the existing groundwater data collected from five monitoring wells from the earlier Mathes investigation had to be supplemented with new data from an expanded network of downgradient and background wells. Eleven new monitoring wells were installed to expand the existing network from 5 to 16 wells (Figures 7, 8). The larger network of wells and new boring data were used to re-define and expand upon the earlier hydrogeologic conceptualization by Mathes. In addition, the new groundwater quality data were combined with surface-water quality data collected from the East Ash Pond and the Middle Fork of the Vermilion River to determine potential interactions between natural and man-made surface water bodies with the shallow and deeper groundwater systems.

Due to the large scope of work involved and the need to establish the background geochemistry both in the vicinity of the study site and within the larger region, the Illinois State Geological Survey (ISGS) was contracted by Kelron to conduct an independent research investigation. The ISGS research and approach is discussed in the following section.

1.2.1 Illinois State Geological Survey Research

Kelron Environmental contracted with the ISGS to provide technical assistance in determining the background geochemistry of the bedrock deposits in the vicinity of the study site. As part of their independent study of background geochemistry, the ISGS performed the following tasks.

- Literature search, including unpublished data sources, for information pertaining to groundwater geochemistry of shale and coal. The search focused on the groundwater quality of Pennsylvanian-age shale and coal in Illinois and the Midwest. Unpublished data sources included the ISGS and Illinois State Water Survey (ISWS) databases.

- Reviewed geologic data from bedrock cores obtained during drilling of monitoring wells by Kelron and also reviewed geophysical logs recorded by the ISGS scientists.
- Reviewed and incorporated groundwater chemistry data for samples collected from background monitoring wells by Kelron and Dynegy.
- Provided advice on the list of analytes for groundwater sampling of monitoring wells by Kelron.
- Analyzed rock samples from bedrock cores for mineralogy.
- Collected groundwater samples from four private wells, two in the vicinity of the study site, and analyzed samples for anions, cations, pH, and alkalinity.
- Collected groundwater samples from two private wells and analyzed for the isotopes tritium [^{3}H] and Carbon-14 [^{14}C].
- Collected groundwater samples from six background monitoring wells installed by Kelron and analyzed for anions, cations, pH, alkalinity, and selected isotopes (^{3}H and ^{14}C).
- Prepared a final report that included pertinent literature and data on the geochemistry of shale and coal, discussion of the geochemistry of shallow bedrock groundwater in background wells based on the data collected as part of the study, and conclusions on the geochemistry of shallow bedrock groundwater in background wells in the region surrounding Dynegy's Vermilion Power Plant.

The results of the ISGS study have been incorporated into this report. The full ISGS study report is included as Appendix A.

1.3 SITE DESCRIPTION

The East Ash Pond is located in Vermilion County, primarily in the east half of the northeast quarter of the southeast quarter of Section 20, Township 20 North, Range 12 West (Figure 1). The entire study site, encompassing both the East Ash Pond and background wells, is located in the east half of Section 20 and the west half of Section 21. The Middle Fork of the Vermilion River (Middle Fork) borders the East Ash Pond along its north and east edges. The East Ash Pond lies in the flood plain of the Middle Fork and is bordered by bluffs to the west.

A topographic map (Figure 2) and aerial photograph (Figure 3) show the topographic and natural features in the vicinity of the East Ash Pond. The V-shaped lake in the lower right hand corner of the aerial photograph is a remnant of strip mining activity southeast of the East Ash Pond on the east side of the Middle Fork.

1.4 SITE HISTORY

1.4.1 Previous Investigations

A hydrogeological investigation was performed by Mathes in 1987 in the vicinity of the current East Ash Pond. The purpose of the 1987 study was to obtain sufficient information concerning subsurface conditions at the site to make recommendations concerning location and construction of a new ash pond system for the Vermilion Power Plant.

Information from the 1987 Mathes investigation was incorporated into the current study. In addition, several monitoring wells from the Mathes study, which were not destroyed during construction of the East Ash Pond in 1989, were incorporated into the current investigation.

1.4.2 East Ash Pond Construction and Expansion

The East Ash Pond consists of two cells: an 11-acre primary (main) pond and a 0.8-acre secondary (polishing) pond. Ash in the main pond settles out of the sluice water, is decanted to the secondary pond, and then discharged to the Middle Fork in accordance with the effluent limits and monitoring requirements of an NPDES permit.

The original primary and secondary cells of the East Ash Pond System were constructed in 1989. The entire East Ash Pond was built directly overtop a thick shale formation which is greater than 80 feet thick in the vicinity of the ash ponds. The alluvial deposits overlying the shale formation were excavated so that the shale surface was exposed. The earthen berms on the north, east, and south sides of the primary cell are "keyed" into the underlying shale formation with two four-foot thick soil/bentonite slurry walls. Bentonite is an absorbent aluminum silicate clay formed from volcanic ash. These walls extend approximately 8 feet down into the shale and approximately 12 feet above the shale surface into the clay-core center of the earthen berms (see Figure 4). A natural earthen bluff composed of low permeability native clays forms the west side of the primary cell. The maximum permeability of the soil/bentonite slurry wall was specified not to exceed $1x10^{-8}$ cm/s.

The earthen berms built on top of the soil/bentonite slurry walls are approximately 18 feet tall, 80 to 120 feet wide at the base, and 15 feet wide at the top. The outside portion of the berms is constructed of locally excavated sand and clay. The center of these berms is constructed with a compacted clay core ranging in thickness from 15 feet at the top to 30 feet near the base. The permeability of the clay core is approximately 10^{-7} cm/s.

The new berms constructed to expand the capacity of the primary cell of the East Ash Pond System in 2002 raised the height of the original berms by approximately 20 feet. The new berms are constructed with 8-foot clay liners keyed into the underlying clay core. The 8-foot clay liners are on the wetted-side of the berm surrounding the expanded ash pond. The clay liners are placed within berms constructed of local clay and silty clay materials. The permeabilities of these materials are within the same specification range as for the original ash pond. A natural earthen bluff wall forms the west side of the enlarged primary cell.

The secondary pond is not being expanded or modified as part of the East Ash Pond System expansion.

1.4.3 Coal Mines

The vicinity of the Vermilion Power Plant has seen extensive coal-mining activity from 1893 to 1970. Two coal mines, called the Crawford Mine (ISGS Mine Index No. 3889) and Fletcher's Middlefork Mine (ISGS Mine Index No. 3888), are located beneath the East Ash Pond and vicinity (Figure 5). Based on data and maps obtained from the ISGS, the former entrances to the two coal mines beneath the site are located just north of the secondary cell of the East Ash Pond (Mine 3889) and 600 hundred feet southwest of the primary cell (Mine 3888) (ISGS, 1996). Information pertaining to both these mines and other mines in the vicinity of the Site are provided in Appendix B.

The entrance to the Crawford Mine was field located. It is a slope shaft mine with the main coal seam (the Danville, or No. 7 Coal) located between the depths of 80 and 92 feet below land surface (BLS). The average thickness of the main coal seam is approximately 5 ½ feet. Several borings were advanced in order to locate both this mine and the Middlefork Mine. The procedures and data gathered during the coal-mine investigation, in addition to the subsequent geophysical investigation, are discussed later in the report. The Middlefork Mine operated between 1939 and 1949 using the room-and-pillar method, whereby the coal is removed in 'rooms' with 'pillars' of coal left in place to support the roof. During the course of the investigation of this mine both mined and un-mined areas were intercepted during exploratory borings. Mined areas were identified based on the drill bit dropping through voids where the coal had been removed. In addition to locating the mined interval, the slope shaft descending to the coal seam was intercepted near the mine entrance at a depth of 28 to 37 feet BLS.

The exact entrance to Middlefork Mine was not located, although based on mine tailings, topography, and historic records it is somewhere between the north end of the secondary cell and the Middle Fork of the Vermilion River. This mine is a vertical shaft mine with the main seam of the Danville Coal located between the depths of 102 and 115 feet BLS. The average thickness of the seam in this area is estimated at five to six feet. This mine operated between 1905 and 1919 using the room-and-pillar method. Three borings were advanced to locate this mine and two of them intercepted mined-out coal seams, one of which had collapsed. The coal mine collapse and subsidence at the Middlefork Mine caused some fracturing of the overlying shale and also changed the groundwater hydraulics in the vicinity of the mine. The potential effect of the coal mine on the groundwater hydrology is discussed in Section 5.

Other mines, both shaft and strip, are located south and southeast of the Crawford and Middlefork mines discussed above (Appendix B). Some of these mines are located within or adjoining the property of the Vermilion Power Plant. The Danville Coal has been extensively mined using both subsurface and strip methods in the vicinity of the Site. To varying degrees, these mining activities have altered the natural topography, hydrology, surface water chemistry, and groundwater chemistry that existed in the area before mining began.

A geophysical study was conducted by URS Corp. in early 2002 to further investigate and locate the coal mines in the vicinity of the East Ash Pond. The results of this investigation are presented in Section 4.2.1.2.

2.0 STUDY METHODS AND PROCEDURES

The objective of the investigation was to conduct a full hydrogeologic and groundwater geochemical characterization in the vicinity of the East Ash Pond of the Vermilion Power Plant and compare the investigation results to the regional background hydrogeology and geochemistry. Secondary objectives of the study were:

- To determine if the East Ash Pond was causing any changes to groundwater quality in the alluvial deposits or underlying bedrock;
- To assess the impacts of nearby coal mines on the hydrology and groundwater quality; and,
- To determine the appropriate groundwater classification for the site.

Data collected from the previous investigation at the site (Mathes, 1987) and quarterly groundwater quality data collected since 1994 were incorporated into the study. The methods used to conduct the study and procedures used for obtaining the necessary geologic, hydrologic, and chemical data are presented in this section.

2.1 METHODS

2.1.1 Previous Data

As mentioned earlier, the prior investigation by Mathes (1987) was incorporated into the study, both as background data for developing an initial conceptual understanding of the hydrogeology and for inclusion of pertinent hydrogeologic data directly into the current investigation. Five wells installed by Mathes in 1987 that were not destroyed by the subsequent construction of the East Ash Pond were incorporated into the study. These five wells include the alluvial wells MW13B and MW16B, which were nested with the shale bedrock wells MW13A and MW16A, respectively, and the till well MW10 (Figures 6, 7, 8). In addition to the existing wells, the Mathes study provided borehole geologic data and hydraulic conductivity data.

Supplementing the geologic data available for the site, inorganic groundwater quality data and water-level data were available for the five monitoring wells for the period of 1994 to the present. Quarterly groundwater monitoring for selected inorganic parameters was instituted beginning in 1994.

Site topographic maps, as-built diagrams of the East Ash Pond, and aerial photographs were used to develop base maps, locate wells, and develop geologic cross-sections.

2.1.2 Geologic Data

The geology presented in this report is primarily based on the geotechnical and monitoring well borings listed in Table 1 and summarized below.

- Nine borings drilled by Mathes (1987) as part of a hydrogeologic investigation for construction of the East Ash Pond.

- Eleven borings drilled in 2001 as part of the current investigation. Four borings were drilled at locations near the East Ash Pond and seven were placed at locations to the south, east, and north.
- Twelve borings drilled in 2001 for geotechnical characterization for expansion of the East Ash Pond; and,
- Eight exploratory borings drilled in 2002 for locating and characterizing the coal mines in the vicinity of the East Ash Pond.

Detailed geologic logs are provided for all of the borings in Appendix C.

Other information incorporated into the study for characterizing the geology was provided by the ISGS. The ISGS performed downhole geophysical logging of three of the deepest borings, logged three bedrock cores, and provided geologic logs and well construction data for a one-mile radius around the study site. The ISGS also provided information for coal mines and coal seams in the vicinity of the site.

In addition to the above geologic information, the results of the geophysical investigation into coal mine locations at the East Ash Pond, conducted in early 2002 by URS Corp., have also been incorporated into this report.

The assembled geologic data were used to develop the following:

- thickness maps of the unlithified deposits;
- bedrock elevation map;
- coal seam elevation map; and,
- coal mine location maps.

2.1.3 Hydrologic Data

The hydrology of the unlithified deposits and underlying bedrock presented in this report was based on the data obtained from a network of 16 monitoring wells installed at the site: five from the 1987 Mathes study and 11 installed in 2001 (Table 2 and Figure 6). Six monitoring wells are installed in the unlithified deposits, with four located near the East Ash Pond and two background wells located north of the Middle Fork (Figure 7). Ten monitoring wells are installed in the bedrock, with five installed near the East Ash Pond, four background wells located to the north and east of the Middle Fork, and one background well located south near the river pump station. Water-level measurements were made monthly for the eight months from January through August 2002 (Table 3 and Figure 8).

In addition to the hydrologic data collected from the monitoring wells, surface water measurements were obtained from the Middle Fork upriver from the East Ash Pond near nested wells MW26/MW27, downriver at MW25, and from the primary and secondary cells of the East Ash Pond. Surface water measurements of the East Ash Pond were not conducted after May 22 because the primary and secondary ponds were drained during construction activities. The last discharge from the East Ash Pond outfall to the Middle

Fork during 2002 was on May 26. Discharging from the East Ash Pond System resumed in January 2003 after construction of the enlarged primary cell was completed.

The groundwater and surface water measurements were used to develop the following:

- potentiometric surface maps;
- groundwater and surface water hydrographs showing temporal variations in water levels;
- horizontal groundwater flow directions and velocities;
- vertical hydraulic gradients between the alluvial deposits and underlying bedrock;
- hydraulic connection between groundwater in the alluvium and bedrock with surface water in the Middle Fork; and,
- impact assessment of the East Ash Pond on alluvium and bedrock groundwater levels.

2.1.4 Groundwater and Surface Water Chemical Data

The groundwater chemistry data presented in this report is based on six months (March through August 2002) of field and laboratory data collected from 16 monitoring wells. Three of the wells (MW13B, MW16B, and MW22) were typically dry or had insufficient water for groundwater sampling. In addition to the above samples, inorganic and isotopic chemistry data analyzed by the ISGS for the five background bedrock wells (MW25, MW27, MW29, MW30 and MW31) sampled in June 2002 were also incorporated into this report. The surface water chemistry data are based on five months of data collected from the East Ash Pond primary cell (January through May 2002) and six months (March through August 2002) of data collected upriver on the Middle Fork at the Higginsville Bridge. No East Ash Pond samples were collected after May 2002 because the pond was drained and no further effluents were being discharged into the impoundment during construction activities.

The chemical data presented in this report for the monitoring wells includes the field parameters temperature, pH, and conductivity and the following laboratory analytical parameters:

Alkalinity
Chloride
Molybdenum
Strontium
Aluminum
Iron
Phosphorus
Sulfate
Barium
Lithium
Potassium
TDS
Boron
Magnesium
Selenium
Vanadium
Calcium
Manganese
Sodium

The above parameters, with the exception of the field parameters, were also analyzed in the surface water samples. However, all of the inorganic parameters in groundwater were analyzed as dissolved while those in surface water were analyzed as totals.

In addition to the samples collected and analyzed monthly from March through August 2002, the background monitoring wells MW25 through MW31 and the East Ash Pond primary cell were sampled in February 2002 for the same inorganic constituents listed above plus cadmium, chromium, and zinc. Based on this first round of sampling in February, the analytes cadmium, chromium, and zinc were dropped from the study because they were below their respective method detection limits (1, 1, and 5 micrograms per liter [ug/L], respectively) in almost all of the samples analyzed.

2.2 TECHNICAL PROCEDURES

2.2.1 Borehole Drilling

Eleven boreholes drilled for the installation of monitoring wells were numbered sequentially from MW22 to MW32. Borehole logs are provided in Appendix C for both the current and prior studies at the Site. The eight boreholes drilled for the coal mine investigation were numbered sequentially from B201 through B208. Boreholes were drilled using a Diedrich D-120 rig equipped with hollow-stem augers and rock coring equipment. Drilling through the unlithified deposits was performed utilizing hollow-stem augers. Samples were obtained using a 24-inch long by two-inch outside diameter (O.D.) split-spoon sampler. The sampler was mechanically driven using a 140-pound hammer with a 30-inch drop. Soil samples were collected continuously in unlithified deposits less than 25 feet thick and at intervals of five to ten feet in deposits greater than 100 feet thick.

All soil samples were logged in the field for sample interval and soil recovery, stratum thickness and depth, visual soil classification by the Unified Soil Classification System [(USCS); ASTM D 2487 and 2488], moisture content and presence of water, soil stiffness, and horizontal compressive strength using a pocket penetrometer.

For those boreholes cored into the underlying bedrock, 4.5-inch O.D. steel surface casing was installed to the top of the bedrock. The outer casing was left permanently in place for all of the bedrock holes with the exception of MW25, MW30, MW31, and the coal mine boreholes. Following installation of the outer casing, continuous sampling of the bedrock was performed using an HQ-core (2.25-inch I.D.) for the monitoring well locations and NQ-core (1.88-inch I.D.) for coal mine borings. Wireline coring, which is a type of rotary drilling, was used to obtain continuous samples of consolidated (i.e., bedrock) formations. A hollow coring bit was used to cut the rock and the samples of rock were removed at designated intervals, in the case of this study every 10 feet. Clean water was used as the drilling fluid.

All core samples were logged in the field for sample interval and soil recovery, stratum thickness and depth, and visual soil classification by the USCS System. In addition, the cores obtained from boreholes MW25, MW30, and MW31 were delivered to the ISGS for more detailed classification and analysis (Appendix A).

2.2.2 Monitoring Well Installation and Development

Groundwater monitoring wells were constructed of two-inch diameter, flush-threaded (Schedule 40) polyvinyl chloride (PVC) screens and risers. Well screens were 0.010-inch slot size machine cut. Screen lengths (Table 2) were 20 feet for all of the bedrock wells except MW32, which had a 10-foot screen. Screen lengths for new wells installed in the unlithified deposits were five feet for MW26 and MW28 and 10 feet for MW23.

Following placement of the screen and riser, the annular space between the well screen and borehole wall was backfilled with well-sorted quartz sand. The sand filter was placed from the bottom of the borehole to approximately 2-feet above the top of the well screen. A minimum two-foot thick bentonite seal (bentonite chips, pellets, or grout) was placed above the sand pack. The remainder of the borehole annulus was filled to the surface with bentonite grout using a 1.25-inch ID PVC tremie pipe which was placed down the inside of the augers as they were removed from the ground. Monitoring wells were completed with steel well protectors extending approximately 2 ½ to 3 feet above ground surface and set in a cement pad. Monitoring well construction forms and diagrams are provided in Appendix C. In addition, the Well Completion Reports and Well Construction Reports required by the Illinois Environmental Protection Agency and the Illinois Department of Public Health, respectively, are provided in Appendix D.

At least 48-hours following well completion, all monitoring wells were developed to attempt to restore the natural hydraulic conductivity of the monitored formation and remove all drilling-induced sediment to provide turbidity-free groundwater samples. Development was performed using air-lift displacement and submersible pumps. The wells were developed until a minimum three to five well volumes were removed from each well. However, some of the wells installed into the shale did not produce sufficient groundwater before being pumped dry (i.e., MW25, MW31 and MW32); in those cases the wells were developed on more than one occasion in order to remove at least two to three well volumes. Water samples collected during well development were monitored for the field parameters pH, temperature, and conductivity. Development was considered complete when the field parameters had stabilized. Well development data sheets are provided in Appendix E.

2.2.3 Site Surveying

Monitoring well locations were surveyed by an Illinois Professional Land Surveyor to an accuracy of 0.1-foot horizontal and 0.01-foot vertical relative to the state planar horizontal datum NAD83 and vertical datum NAVD88 Geoid 96, respectively. Borehole locations were surveyed to a minimum accuracy of 1-foot horizontal and 0.1-foot vertical. Boring and monitoring well locations are shown in Figure 7 and elevations are provided in Table 1.

2.2.4 Water-Level Measurement Collection

Prior to collecting groundwater samples, static water depth was measured to an accuracy of 0.01 foot in each monitoring well using a Solinst-101 electronic water-level indicator. The groundwater depths were measured relative to the top of the PVC riser and subsequently subtracted from the measuring point elevation to determine the groundwater elevation within the well. In addition to groundwater elevation at all of the monitoring wells, surface water elevation measurements were obtained from the following locations:

- Middle Fork of Vermilion River adjacent to wells MW26/MW27;
- Middle Fork of Vermilion River adjacent to well MW25 at the downriver pump station;

- Primary cell of the East Ash Pond; and,
- Secondary cell (i.e., Polishing Pond) of the East Ash Pond.

Groundwater and surface water level measurements were conducted on a monthly basis from January through August 2002. The measurements were used to develop hydrographs, potentiometric surface maps, vertical gradients between formations, and evaluate hydrologic interactions between the unlithified deposits, bedrock, Middle Fork, and East Ash Pond. Water levels and elevations for the period of investigation are provided in Table 3.

2.2.5 Groundwater and Surface Water Sampling and Chemical Analyses

Water samples were collected from the background wells MW25 through MW31 and the primary cell of the East Ash Pond on a monthly basis by the DMG Environmental Laboratory beginning in January 2002. The remaining monitoring wells in the vicinity of the East Ash Pond, and upriver samples from the Middle Fork at the Higginsville Bridge, were sampled monthly beginning in March 2002. Samples from all wells and surface-water collection points were obtained within a period of one to two days each month with the exception of the March sampling event, when poor weather and equipment problems extended the sampling period to three days.

Groundwater samples were collected using a low-flow sampling technique with Well Wizard® bladder pumps and MicroPurge® equipment. The bladder pumps prevent contact between the pump drive air and the sample, and the downhole equipment is permanently dedicated to each well, preventing cross-contamination caused by transporting pumps between wells. The specification sheets for each of the bladder pumps placed in monitoring wells at the Site are provided in Appendix F. The bladder pumps were placed within the screened interval of each well so that groundwater being pumped would come from the formation pore water and minimize pumping of the overlying static water within the well casing. The only wells that did not have bladder pumps installed were MW10, MW13B, and MW16B. These three wells are typically dry or have insufficient groundwater for sampling. In those cases where there was sufficient groundwater to be sampled from these wells it was removed using dedicated bailers or a peristaltic pump.

The low-flow ground water sampling procedures followed for this study are based on the sampling protocol provided by the United States Environmental Protection Agency (USEPA) in a document authored by Puls and Barcelona (1995). This document has been incorporated into the report as Appendix G. Due to the extremely low permeability of the shale formation from which many of the groundwater samples were obtained, passive sample collection techniques were utilized. Passive sample collection was conducted at the bedrock wells by setting the pump rate at less than 0.2 Liters per minute (L/m), pumping sufficient water to clear the tubing and bladder pump of stagnant water, and collection of samples for laboratory analysis. Three sets of measurements for the field parameters of temperature, pH, and conductivity were collected and documented as follows: at the start of pumping, prior to sample collection, and at the conclusion of sample collection. Sampling of the higher permeability wells installed within the unlithified deposits was conducted at higher flow rates of 0.2 to 0.5 L/m.

Analysis of field parameters (pH, specific conductivity, and temperature) were conducted using either a Hydrolab® Minisonde Model 4a or a Hydrolab Surveyor Model 4a water quality analyzer connected directly to the discharge tubing from the bladder pump. Samples for laboratory chemical analysis were collected using in-line filtration (0.45 micron filter size) that prevented contract with air prior to collection. Water samples were collected in new or acid-washed polypropylene bottles and subsequently stored at 4° C for transport back to the laboratory.

Surface water samples were collected from the East Ash Pond primary cell and the Middle Fork upriver by submerging the sample bottles directly into the water and, where possible, capping under water to minimize air contact. Surface water samples were collected for analysis of total inorganic parameters and were not field filtered. No field parameters were analyzed for the surface water samples.

Chemical analyses were performed by the DMG laboratory. Inorganic analyses were performed in accordance with U.S. EPA SW-846 and Standard Methods for the Examination of Water and Wastewater, 19th Edition. The following parameters and analytical methods were analyzed by DMG for the groundwater and surface water samples:

- Total Alkalinity: EPA Method 310.1 (Titremetric Method);
- Total Dissolved Solids (TDS): EPA Method 160.1 (Gravimetric Method);
- Chloride: Standard Methods, Method 4500-Cl (Potentiomeric Method);
- Sulfate: EPA Method 375.4 (Turbidimetric Method);
- Phosphorus: EPA SW-846 Method 365.2 (ascorbic-acid Colorometric Method); and,
- Boron, Manganese, Magnesium, Calcium, Potassium, Iron, Aluminum, Lithium, Molybdenum, Selenium, Strontium, Vanadium, Barium: EPA Method 200.7 (ICP).

2.2.6 Illinois State Geological Survey Sampling and Chemical Analyses

The ISGS accompanied DMG laboratory personnel on June 18, 2002 in order to obtain split samples for analysis. The ISGS returned to the study site on June 25 and 26 along with Kelron to obtain groundwater for isotope analyses. The methods by which samples were collected and analyzed by the ISGS for their background water quality study are presented in detail in the ISGS report (Appendix A).

2.2.7 Field Permeability Tests

In-situ hydraulic conductivity tests were performed on seven of the newly installed shale monitoring wells (MW24, MW25, MW27, MW29, MW30, MW 31, and MW32) and two of the newly installed alluvial monitoring wells (MW26 and MW28) during September 2002. The monitoring wells were tested by the variable head ("slug") test method.

Most of the slug tests were conducted using three and four foot long by 1-1/4 inch diameter PVC slugs with rope and recorded using In-Situ® Troll 8000 datalogger with 15 pounds per square inch (psi) transducer. The Troll 8000 is a combination downhole transducer and datalogger. Due to the slow recharge of some of the shale monitoring wells, a few tests were conducted without the Troll 8000 by measuring water levels using the Solinst 101 electronic water-level meter and recording the measurements by hand. In some cases only rising head tests were performed and in others both rising and falling head tests were performed.

A laptop computer was used to download the data from the datalogger and analyze the data with the use of AQTESOLV™ for Windows (Version 2.5), an aquifer test analysis software package by HYDROSOLVE. All of the analytical solutions used the Bouwer-Rice method (1980). The AQTESOLV™ for Windows output is included in Appendix H.

2.2.8 Data Management

Field data were recorded on pre-printed forms including:

- Daily field reports;
- Boring logs;
- Monitoring well completion reports;
- Well development reports; and,
- Water sampling forms.

Groundwater and surface water sample data, including water levels, field parameter analyses, and laboratory chemical analyses, were entered and stored on a proprietary groundwater data management software package (MANAGES™ Version 2.7, Electric Power Research Institute). Data collected from wells MW10, MW13A/13B, and MW16A/16B beginning in 1994 were already incorporated into the database prior to the beginning of the current study.

3.0 REGIONAL GEOLOGY AND HYDROLOGY

3.1 TOPOGRAPHY

The uplands are fairly uniform in elevation. They generally occur between the elevations of 650 and 700 feet National Geodetic Vertical Datum (NGVD) in the vicinity of the study site. The lowland areas (floodplains) along the Middle Fork lie between elevations of 550 and 600 feet NGVD. The natural surface topography within the floodplain is relatively flat with drainage toward the river.

3.2 BEDROCK GEOLOGY

The Danville area is located on the northeast flank of the Illinois basin. The bedrock strata are of Pennsylvanian age and in general dip gently southwestward toward the center of the basin.

The study site lies approximately 3 miles west of the central axis of the Danville Bedrock Valley, which is oriented northwest to southeast and midway between the Middle Fork and North Fork of the Vermilion River (Selkregg and Kempton, 1958).

Regionally, the Pennsylvanian bedrock consists of mainly shale with thin limestone, sandstone, and coal beds (Selkregg and Kempton, 1958). The bedrock surface elevation in the vicinity of the study site is between 500 and 600 feet NGVD (Willman et al., 1967). The rocks were originally deposited as unlithified sediments in coastal marshes or in shallow seas that repeatedly formed in the area. The shale was originally deposited as clay, while coal was formed from plants buried in the coastal swamps. Sandstone was deposited as sand and the limestone was formed by precipitation of carbonates and by accumulation of seashells on the sea floor (Selkregg and Kempton, 1958).

After the Pennsylvanian sediments were deposited, the seas retreated and the upper part of the bedrock was deeply eroded. During the Pleistocene epoch, continental glaciers advanced from the north and overrode the eroded bedrock surface (Selkregg and Kempton, 1958), leaving the glacial deposits that mantle the area today.

The principal formations within the Pennsylvanian bedrock in the region are, from upper to lower, the Bond, Shelburn, and Carbondale Formations. In the vicinity of the Site the principal formation is the Shelburn, which contains a major coal seam mined in the region, the Danville (No. 7). The Danville coal has been mined extensively in the region both as surface (strip) mines and underground mines. The northernmost mines identified by the ISGS (ISGS, 1996) are located in the immediate vicinity of the Site (Figure 5) within Township 20 North and Range 12 West. Additional information pertaining to coal seams and mines in the vicinity of the Site is provided in Section 4.2.1.1.

Several geologic logs obtained from the ISGS files (ISGS, 2001) were for exploratory borings for coal seams in 1910 and 1911 (Appendix I). In the vicinity of the site (Sections 20 and 21), the deepest borings were to depths of 166 and 131 feet BLS with bedrock intercepted at depths of 105 and 26 feet BLS, respectively. The formations intercepted by the two borings consisted of shale containing the following two coal seams:

- Danville (No. 7) coal at depths of 113 to 120 feet BLS and 79 to 83 feet BLS; and,
- Herrin (No. 6) coal at depths of 144 to 148 feet BLS and 110 to 114 feet BLS.

No limestone or sand layers were identified on these borings. However, further to the south in Section 28, a 1910 boring for the Big Four Railroad was progressed to 312 feet BLS. The Danville and Herrin coal seams were intercepted at depths of 72 and 96 feet BLS, respectively. Several other layers of coal, less than two feet in thickness, were intercepted. Five limestone layers ranging in thickness from one to eight feet were intercepted between 99 and 257 feet BLS. One sandstone layer was intercepted at 211 to 213 feet BLS. The entire bedrock interval cored was 247 feet, of which 220 feet was shale, 11 feet coal, 14 feet limestone, and 2 feet sandstone.

3.3 UNLITHIFIED DEPOSITS GEOLOGY

The deposits covering the bedrock in the region surrounding the study site are derived from recent river deposition (alluvial sediments) in the river valleys and glacial drift deposits occurring below the alluvial sediments and in the upland areas. The glacial and interglacial geologic events that shaped the topography seen today occurred during the Pleistocene Epoch, about two million to 12,000 years ago (ISWPTF, 1997). Thickness of these deposits in the region range from zero thickness along portions of the Middle Fork where bedrock is exposed to over 200 feet in the upland areas (Piskin and Bergstrom, 1975).

Although there were several major glaciations – pre-Illinoisan, Illinoisan, and Wisconsin – glaciers of only the last three are known to have entered the east-central Illinois region (Selkregg and Kempton, 1958). Each glaciation was followed by an interglacial period in which the climate warmed and the ice front moved back. The surficial features seen in the upland areas are part of the Gifford Moraine, which was formed during the Woodfordian Substage of the Wisconsinan Stage of glaciation (Willman and Frye, 1970).

Based on stack-unit maps of geologic materials to a depth of 15 meters (49.3 feet) prepared by Berg and Kempton (1988), the lowlands (floodplains) adjacent to the Middle Fork are characterized by the following downward sequence of unlithified deposits:

- Less than six meters (19.7 feet) of Cahokia Alluvium (i.e., alluvial sediments deposited by streams and rivers);
- Less than six meters of Henry Formation deposits of Wisconsinan age, which consist of glacial outwash dominated by sand and gravel; and,
- Less than six meters of Glasford Formation deposits of Illinoian age, which consist of silty and clayey diamictons.

Diamicton is unsorted, nonstratified sediment with a wide range of particle sizes (i.e., clay, silt, sand, gravel, cobbles, and boulders). When diamicton is due to glacial deposition it is known as till. The diamictons in the vicinity of the study site are till deposits characterized by a clay matrix containing variable percentages of silt, sand, gravel, cobbles, and boulders.

The unlithified deposits of the upland areas bordering the Middle Fork are characterized by the following downward sequence:

- Greater than six meters (19.7 feet) of Wedron Formation deposits of Wisconsinan age, which consist of silty and clayey diamictons; and
- Less than six meters of Glasford Formation silty and clayey diamictons (Berg and Kempton, 1988).

Unlithified deposits below 15 meters (49.3 feet) are not identified in the stack-unit maps, but based on published literature the Glasford Formation deposits either extend to the top of bedrock or are underlain by the Banner Formation of pre-Illinoisan age (i.e., greater than 500,000 years of age). The Banner Formation, which consists of till and intercalcated outwash where present, is draped over the bedrock surface and is generally deepest where the bedrock is deepest.

3.4 BEDROCK HYDROLOGY

The Pennsylvanian rocks generally have low porosities and permeabilities. The porosity of shale typically ranges from 1 to 20 percent (Walton, 1988). Representative horizontal field hydraulic conductivity (permeability) for shale typically ranges from 5×10^{-6} to 5×10^{-10} centimeters per second (cm/s). Representative aquitard field permeability ranges for shale, which is defined as the rate of vertical flow of water through a unit horizontal cross-sectional area of the aquitard, are 5×10^{-8} to 5×10^{-12} cm/s. In contrast to the low permeability of shale, coal deposits have horizontal permeability ranging from 5×10^{-2} to 5×10^{-5} cm/s (Walton, 1988).

The Pennsylvanian rocks in the region yield small amounts of water to wells from interconnected pores, cracks, fractures, crevices, joints, and bedding planes. Water-bearing openings are variable from place to place and are best developed near the surface in thin limestones and sandstones, when present, within the predominantly shale formation. Shallow sandstone and creviced limestone may yield small supplies in some areas, but water quality becomes poorer with increasing depth. The Pennsylvanian bedrock is not a reliable source of groundwater and the quality varies considerably. Small domestic supplies have been obtained from creviced limestone, permeable sandstone, or cracked shale and coal in the upper part of the bedrock (Selkregg and Kempton, 1958).

Water in the Pennsylvanian rocks becomes highly mineralized with increasing depth. Recharge to the Pennsylvanian rocks is derived locally from vertical leakage through the glacial drift and other unlithified materials that are in turn recharged from precipitation.

Water occurs in these rocks mainly under artesian and leaky-artesian conditions (Csallany, 1966).

3.5 UNLITHIFIED DEPOSITS HYDROLOGY

Alluvial deposits along the Middle Fork valley contain a wide variety of sediments ranging from clay to sand, gravel, and cobbles. The effective porosities for the types of sediments found in the vicinity of the study site range from 20 to 35 percent for poorly sorted sand and gravel alluvial deposits to 10 to 20 percent for the diamictons found in the upland areas (Fetter, 1980). Effective porosity, which is a measure of the pore space thorough which saturated flow can occur, typically ranges from 10 to 30 percent for poorly sorted sand and gravel deposits to 5 to 20 percent for diamictons (Walton, 1988).

Horizontal hydraulic conductivity for the alluvial deposits as measured by field tests can vary greatly depending on the percentage of fine-grained materials within those deposits. Deposits with materials ranging from sand to gravel typically have horizontal permeability ranging from 10^{-1} to 10^{-4} cm/s. Silt, clay, and mixtures of sand, silt, and clay typically have horizontal permeability ranging from 10^{-4} to 10^{-7} cm/s (USDI, 1981; Fetter, 1980).

Groundwater in the alluvial deposits discharges into the Middle Fork during most of the year with the exception of flood events, when localized flow-reversals may occur. No published information is available concerning the hydrology of the shallow deposits in the vicinity of the study site.

Permeable deposits capable of supplying sufficient groundwater for domestic use are scattered and discontinuous, with aquifers varying in permeability (Selkregg and Kempton, 1958). Water-well logs and a well location map were obtained from the ISGS during October 2001 (Appendix I; ISGS, 2001) for a four square mile area surrounding the study site. Ten water wells installed between 1967 and 1999 in upland areas were screened across permeable formations ranging in depth from 40 to 160 feet BLS. Eight of the ten wells were screened at depths greater than 100 feet BLS and had an average depth of 132 feet BLS. Groundwater was obtained primarily from sand and gravel deposits within the drift. The sand and gravel layers ranged from 3 to 13 feet in thickness. However, one well obtained groundwater from gravelly clay at 135 to 160 feet BLS and another well, drilled in 1999, was a dry hole.

4.0 STUDY SITE GEOLOGY AND HYDROLOGY

Characterization of the geology and hydrogeology at the study site is based on previous investigations conducted prior to construction of the East Ash Pond in 1989 and on new boring and monitoring well data from the current 2001-2002 investigation. Mathes Geotechnical Services, Inc. conducted a hydrogeologic investigation in a portion of the current study site (Mathes, 1987) prior to construction of the original East Ash Pond. The information used to describe the study site geology and hydrogeology is based on the borings and monitoring wells summarized in Table 1 and provided in Appendix C in addition to all of the field data collected during the course of the study in 2001 and 2002.

The two types of materials present at the study site consist of unlithified deposits (alluvium and glacial deposits) and bedrock. Each of these materials will be discussed in detail in order to establish a framework with which to understand the hydrogeology, and in later sections the geochemistry, of the site. Figure 7 shows the locations of all of the borings used in describing the geology of the site. Figure 9 shows the locations of the east-west (Figure 10) and north-south (Figure 11) geologic cross-sections through the study site.

4.1 UNLITHIFIED DEPOSITS

4.1.1 Alluvial and Glacial Geology

The cross-sections across the Site (Figures 9, 10, and 11) best demonstrate the correlation between topography and stratigraphy of the unlithified deposits. The other variable that affects the thickness and composition of the unlithified deposits is the bedrock surface topography. Glacial deposits are thickest (greater than 100 feet) where the shale bedrock decreases in elevation. The glacial materials consist primarily of low plasticity silty to sandy clays with occasional layers of silt, sand, and gravel.

The unlithified alluvial and glacial deposits in the vicinity of the East Ash Pond and within the floodplain generally range in thickness from 10 to 25 feet (Figure 12). Thickness of the alluvial deposits immediately adjacent to the Middle Fork is generally 10 to 15 feet. The unlithified deposits increase in thickness towards the uplands as the alluvial deposits pinch out and are supplanted by glacial deposits at higher topographic elevations.

Along the western portion of the study site, to the west of the East Ash Pond, the thickest glacial deposits range from 71 feet at Well MW22 to the north to 103 feet at Boring B208 to the south. North and east of the Middle Fork the thickness of the glacial deposits are 116 feet at Well MW30 and 155 feet at Well MW31, respectively.

The uppermost unlithified deposits in the floodplain consist of alluvium composed primarily of sand with occasional layers of silty clay. The sand is generally a fine to medium sand that contains silts, clays, and gravels in varying amounts. The sand in some areas may be overlain by silty to sandy clay. In places where the unlithified deposits in the floodplain become thicker, the alluvium may be underlain by glacial deposits consisting of outwash sand and gravel or diamictons. The shallow geology at Boring MW23, located within 25 feet of the south bank of the Middle Fork, has approximately 14 feet of alluvial deposits ranging from silt to gravel overlying eight feet of glacial deposits consisting of sandy clay with gravel.

4.1.2 Alluvial and Glacial Hydrology

Groundwater elevation within the alluvial and, where present, the glacial deposits within the floodplain generally conform to the ground surface topography. Prior to construction of the East Ash Pond, groundwater elevations documented by Mathes (1987) in the alluvial deposits generally ranged from five to six feet below ground surface in most of the alluvial wells where the East Ash Pond was constructed.

The only alluvial wells remaining from the 1987 study are MW13B and MW16B, located between the East Ash Pond and the Middle Fork. Hydrographs of groundwater levels in these two wells for 2002 are provided in Figures 13 and 14. Groundwater elevations measured in Well MW13B in 2002 have ranged from dry (no groundwater) in January and July to 573.44 feet NGVD in May, which is approximately 1.9 feet above the bottom of the screen and two feet above the bedrock surface. Groundwater elevations in Well MW16B were dry (no groundwater) in January, February, May, July, and August and were approximately 570 feet NGVD in March, April and June. The bottom of the well screen and the bedrock surface are at elevations of 566.5 and 566 feet NGVD, respectively.

Figure 15 shows the relationship of groundwater-levels in the alluvial wells MW26 and MW28 versus the Middle Fork of the Vermilion River elevations during 2002. During the period of measurement in 2002 groundwater levels in both these wells were above river elevation, demonstrating the potential for shallow groundwater discharge to the Middle Fork.

Groundwater elevations in the till and alluvial deposits in January 2002 (Figure 16) and hydrographs (Figure 15) demonstrate that groundwater elevations in the unlithified materials are higher than those in the adjacent Middle Fork through much of the year. The groundwater surface in the alluvial deposits fluctuates in response to changes in river stage and variations in precipitation. Based on the groundwater levels measured in wells MW13B and MW16B during 2002 and earlier years, groundwater elevations within the alluvial deposits in the vicinity of the East Ash Pond have not been elevated since the East Ash Pond was constructed. Groundwater levels are frequently measured at or near the base of the well screens of MW13B and MW16B, suggesting that the East Ash Pond has been hydraulically isolated from both the shale and alluvial deposits by soil/bentonite slurry walls and a compacted clay core.

Groundwater-level contour maps of the unlithified deposits could not be prepared due to the limited number and distribution of shallow wells. All of the shallow wells with the exception of Well MW10, which is installed in till, are adjacent to the Middle Fork. The presence of the East Ash Pond prevented the installation of upgradient wells within the alluvial deposits.

Groundwater gradients in the alluvial deposits prior to pond construction were determined by Mathes (1987). During the period of April to July 1987, horizontal gradients between downgradient wells MW13B and MW16B and upgradient alluvial wells ranged from 0.014 to 0.028 ft/ft and flow direction was towards the Middle Fork.

The hydraulic conductivity of the alluvium was estimated by Mathes (1987) by conducting field permeability (slug) tests. The horizontal hydraulic conductivity ranged from $1x10^{-3}$ to $7x10^{-3}$ cm/s. Field hydraulic conductivities determined during September 2002 for the alluvial deposits at monitoring wells MW26 and MW28, located on the north side of the Middle Fork across from the East Ash Pond, resulted in a computed geometric mean hydraulic conductivity of $1.5x10^{-2}$ cm/s (Table 4). The higher permeabilities calculated at wells MW26 and MW28 during 2002 relative to the lower values calculated by Mathes (1987) could be either from actual permeability differences of the alluvial deposits (i.e., coarser-grained or better sorted alluvium at MW26 and MW28 relative to the Mathes well locations) or systematic differences due to differences in analysis methods.

4.2 BEDROCK

The bedrock at the study site has been investigated using the following sources of data:

- Six borings from the 1987 Mathes hydrogeologic investigation;
- Two monitoring wells (MW13A and MW16A) remaining from the 1987 Mathes investigation;
- Eight borings and monitoring wells installed in 2001 as part of the current hydrogeologic investigation;
- Eight borings from the 2001 geotechnical investigation for expansion of the East Ash Pond;
- Eight borings from the 2002 coal mine investigation at the East Ash Pond;
- Geophysical logging of three boreholes by the Illinois State Geological Survey in 2001 (Appendix A);
- Geophysical investigation for location of coal mines by URS Corp in 2002;
- Bedrock core logs prepared by the ISGS (Appendix A); and,
- Mineralogical analyses of 19 rock samples (from three bedrock cores) by the ISGS in addition to geochemical modeling (Appendix A).

Based on the above sources of information a comprehensive evaluation of the bedrock geology and hydrology is presented below.

4.2.1 Bedrock Geology

The upper 75 feet of bedrock was cored at the study site and consists of non-marine and marine, silty and micaceous shales of the Pennsylvanian Age Shelburn Formation. The Shelburn Formation contains a major coal seam mined in the region, the Danville Coal, also called the No. 7 Coal. Geologic logs of selected cores (from borings for Wells MW25, MW30, and MW31) were prepared by the ISGS (Appendix A). Based on these logs, the shale has been described as medium to dark gray, massive, and with blocky fracture. Some intervals have thin interbeds of light gray shale.

The shale cores at Well MW25, located to the south of the East Ash Pond, are non-marine and contain abundant carbonized plant material. The shale cores at Well MW30, a background well located at the north end of the study area, have been identified as non-marine from 116 to 135 feet BLS and marine from 135 to 144 feet BLS, with abundant fossils, including brachiopods, gastropods, and bivalves. The Danville Coal was intercepted at 145 feet BLS before the coring was discontinued at 148 feet BLS. The coal contained abundant pyrite along cleats. The shale cores at Well MW31, located at the east end of the study site, also consist of a non-marine shale overlying a fossiliferous marine shale.

The upper zone of the shale is often weathered so that it appears as a greenish-gray to bluish-gray silty clay. Determination of the interval at which weathered shale turns into an unlithified silty clay is often based on the presence of fissility.

Based on the mineralogical analyses of 19 samples from three cores (from the borings for MW29, MW30, and MW31) conducted by the ISGS (Appendix A), the shale is composed principally of clay minerals and quartz with minor amounts of potassium feldspar, plagioclase feldspar, siderite, and marcasite or pyrite. The most abundant clay minerals in the cores were illite, kaolinite, and chlorite, with minor amounts of illite/smectite mixed-layer clay.

The depth to the top of the bedrock (i.e., shale), bedrock surface elevation, and depth/elevation of the Danville Coal are provided in Table 5. Figure 12, which shows the thickness of the unlithified deposits, also provides the depth to bedrock. Generally, the top of the shale occurs within 10 to 25 feet of ground surface in the vicinity of the East Ash Pond and rapidly increases in depth toward the western upland bordering the Site. The depth to bedrock is greatest towards the east, where it exceeds 150 feet.

Another way to view the shale bedrock is by looking at a bedrock elevation map, which can also be called a bedrock topography map. Figure 17 shows that the bedrock high within the study area occurs directly west of the East Ash Pond and the higher elevations trend toward the northeast. The lowest bedrock elevations occur to the north (530 feet NGVD at Well MW30) and the east (544 feet NGVD at Well MW31). The slope of the bedrock surface between the bedrock high and the eastern low at MW31 is approximately 0.018 foot per foot (95 feet per mile), which is a relatively mild slope when compared to the greater relief of the glacially-carved Middle Fork valley.

4.2.1.1 Danville (No. 7) Coal

The Danville (No. 7) Coal is found within the Shelburn Formation (ISGS, 1996) and was intercepted at eight locations (Table 5) in the vicinity of the East Ash Pond (Borings B201 to B208) and one location to the north of the Middle Fork (Boring MW30). Most of the borings advanced during both this and prior studies did not penetrate deep enough into the bedrock to intercept the coal seam. The top of the Danville Coal was intercepted at depths of 80 to 102.5 feet BLS on the floodplain adjacent to the East Ash Pond. Greater boring depths were required to intercept the coal seam in the upland areas. Borings B203, B208, and MW30 intercepted the coal seam at depths of 127, 152, and 144 feet BLS, respectively.

The top of the Danville Coal, or the void remaining where the coal was removed through mining, was intercepted at elevations between 496 and 509 feet NGVD. The thickness of the coal seam ranged from four to seven feet with an average thickness of 5.4 feet. Thin layers of coal interlayered with shale occurred above or below the main coal seam; these were not included in calculating the main seam thickness. The elevation of the top of the Danville Coal has been mapped on Figure 18. The Danville Coal generally decreases in elevation northward under the East Ash Pond at a gradient of 0.004 ft/ft (22 feet per mile). The coal increases in elevation from north of the East Ash Pond (493 to 496.6 feet NGVD at B201 and B202) to 501.5 feet NGVD at Well MW30 at a gradient of 0.0024 ft/ft (12.8 feet per mile).

Further information about the occurrence and mining of the Danville Coal in the vicinity of the East Ash Pond and other portions of the Vermilion Power Plant is provided in Section 1.4.3. Coal mine maps prepared by the ISGS, and other historical information pertaining to coal mining at the site is discussed. The potential effects of coal mines on subsurface geology, groundwater hydraulics, and water quality are discussed in greater detail in Sections 4.2.1.2, 4.2.2.5, and 5.2, respectively.

4.2.1.2 Geophysical Investigation of East Ash Pond

A geophysical investigation was conducted by URS Corp. in April 2002 (URS, 2002) to determine if mining occurred below the East Ash Pond, and if so to determine its lateral extent. The investigation was conducted by running five separate high-resolution seismic lines (Figure 19): three along the south, east, and north dikes (Lines A, B, and C, respectively), one calibration line (Line D) over an area of known mine voids based on test borings, and a final Line E over an area of suspected mine collapse features north of the secondary pond.

Based on the data obtained from the geophysics investigation, the findings are summarized below.

- The survey confirmed that mining occurred in the vicinity of the East Ash Pond; however, the mining appeared to be sporadic and of limited extent along the lines of seismic investigation.
- The surface depressions north of the secondary (polishing) pond (along Line E of Figure 19) are most likely mine collapse features. The largest of these features is about 100 feet across and shows 4 to 5 feet of vertical displacement. These features are pit-type collapses consistent with mining depths less than about 150 feet below grade.

- The survey detected 12 anomalies judged to be mine-related voids, collapse features, or partial collapse features along the five lines A through E. The mine-related voids are locations where the coal has been mined, leaving a void in the bedrock. The voids may eventually work to the surface resulting in settlement (surface depressions) similar to the collapse features north of the secondary pond.

4.2.2 Bedrock Hydrology

Hydrologic data have been incorporated from data collected from both the current investigation and from the previous hydrogeologic study completed in 1987 (Mathes, 1987). Both observed and predicted effects of coal mines on the hydrology of the bedrock are discussed at the conclusion of this section.

4.2.2.1 Hydraulic Conductivity

The upper zone of the shale is moderately weathered at the surface at most of the boring locations. Generally, the shale is massive with very few horizontal joints or partings. Some near vertical joints were observed near the surface, but these were typically irregular and closed.

The horizontal hydraulic conductivity of the shale was determined by Mathes (1987) from field permeability tests. Seven wells screened in the shale were tested and the computed hydraulic conductivity ranged from 4×10^{-10} to 1×10^{-8} cm/s. The geometric mean hydraulic conductivity of the shale based on the seven wells tested was 4.3×10^{-9} cm/s. The vertical hydraulic conductivity calculated from tests performed in the laboratory on one shale core ranged from 1×10^{-8} to 5×10^{-8} cm/s. The field and laboratory values for hydraulic conductivity of the shale all fall within the range of 5×10^{-6} to 5×10^{-10} cm/s reported by Walton (1988).

Field hydraulic conductivity tests conducted by Kelron in 2002 (Table 4) on seven monitoring wells screened within the Pennsylvanian Shale at the Site resulted in a higher estimate of permeability than Mathes (1987). The geometric mean hydraulic conductivity for all seven shale wells was 3×10^{-6} cm/s and the range was 1.04×10^{-4} to 1.45×10^{-7} cm/s.

The higher permeabilities calculated by Kelron during 2002 relative to the lower values calculated by Mathes (1987) could be either from actual permeability differences of the bedrock deposits or systematic differences due to differences in analysis methods.

4.2.2.2 Potentiometric Surface Maps

Potentiometric surface maps of the upper shale were prepared using groundwater-elevation data from January and May 2002 for the nine shale monitoring wells located at the study site (Figures 20 and 21). Groundwater elevations in the shale are highest in the topographically highest areas to the west and east of the Middle Fork. The lowest groundwater elevations occur at wells located adjacent to the Middle Fork. Flow lines derived from the potentiometric surface maps indicate that the Middle Fork of the Vermilion River in this area is a zone of discharge for the shale.

Horizontal hydraulic gradients in the shallow shale range from 0.026 to 0.038 ft/ft and are towards the Middle Fork. However, the upland wells are screened at shallower (MW22) or deeper (MW30 and MW31) elevations then most of the shale wells along the Middle Fork, possibly resulting in lower or higher gradient calculations then actually exist.

The occurrence of the Middle Fork in this area as a regional discharge zone for the shallow bedrock is supported by the upward vertical hydraulic gradients measured within the shale and the upward vertical hydraulic gradients observed during various periods and at multiple locations between the shale and the alluvium. The shale outcrops along the banks of the Middle Fork in this area and groundwater moving upward through the shale discharges into both the alluvium and directly into the Middle Fork.

The east-west and north-south cross sections shown on Figures 22 and 23, respectively, show the groundwater elevations at the monitoring wells relative to the geology

4.2.2.3 Vertical Hydraulic Gradients

Vertical hydraulic gradients are a measure of the change in total head with a change in vertical distance. The vertical hydraulic gradient measures the potential for groundwater to move upward or downward. Vertical gradients were calculated using the monthly groundwater data for the five paired (nested) well sets within the shale and alluvium and at one nested set within the shale. Gradients were computed by dividing the difference in the potentiometric head in the nested wells (i.e., dh) by the difference in the midpoint of the screened elevations (i.e., dl). A positive vertical gradient indicates a downward potential for groundwater movement and a negative gradient indicates an upward potential for groundwater movement.

All of the nested wells within the floodplain of the Middle Fork, with the exception of MW23/MW24, had an upward gradient from the shale to the overlying unlithified deposits during part of the eight months of monitoring (Table 6). Two sets of nested wells, MW13A/MW13B/MW32 and MW28/MW29, had large upward gradients during the entire study period with only one exception during May.

Nested wells MW13A/MW13B/MW32, located between the East Ash Pond and the Middle Fork, had an average upward gradient of 0.043 ft/ft between the shale well MW13B and alluvial well MW13A. The average upward gradient within the shale, between wells MW32 and MW13A, was even greater at 0.585 ft/ft. The only time that the gradient was measured as downward instead of upward between the alluvium and shale (MW13A and MW13B) was during May, when a slight downward gradient of 0.003 ft/ft was measured. However, during this same time the gradient within the shale was upward at 0.588 ft/ft. Figure 24 shows the relationship between water levels in the shale and alluvial wells relative to the land surface. The upward gradient within the shale is so great that groundwater at the deepest shale well (MW32) was under flowing artesian conditions during the study.

Nested wells MW16B and MW16A, also located between the East Ash Pond and Middle Fork, had an upward gradient during one of the three months during which the alluvial well (MW16B) was not dry (Figure 25). The vertical gradient at this location was downward during the March and April measurements and upward in June.

Nested wells MW28 and MW29, located northeast of the East Ash Pond on the north side of the Middle Fork, had an average upward gradient of 0.228 ft/ft between the shale and alluvium (Figure 26). The upward gradient over the eight months study period was very consistent, ranging from 0.204 to 0.251. Similarly, nested wells MW26 and MW27, located west of MW28/MW29, had an upward gradient of 0.01 to 0.053 ft/ft during five of the eight months (Figure 26). During March, April, and May the gradient at this location was downward from the alluvium to the shale at 0.001 to 0.032 ft/ft.

The only location within the floodplain where the gradient between the unlithified deposits and the shale was downward throughout the study was at nested wells MW23 and MW24, located north of the East Ash Pond. The unlithified deposits are thicker at this location and consist of finer grained alluvial deposits overlying glacial sediments. The 8-month average downward gradient at this location was 0.018 ft/ft. This is most likely a very localized flow cell where groundwater moves downward from the unlithified deposits to the shale. However, groundwater elevations in the shale during the study were still higher then river elevations, meaning that groundwater was discharging from the shale into the river.

Unlike the lowlands along the Middle Fork where groundwater within the shale is typically discharging upward into the unlithified deposits and the river, vertical groundwater movement in the uplands to the east, west, and north is downward. Figure 27 shows groundwater levels within the diamicton and shale wells MW10 and MW22, respectively. Groundwater levels in the glacial deposits are consistently higher than those in the underlying shale.

4.2.2.4 Groundwater-Flow Direction and Velocity

In upland areas bordering the Middle Fork valley the groundwater within the glacial deposits flows downward into the shale bedrock and along the top of the shale. Groundwater within the shale moves from upland areas and discharges into the regional discharge area of the Middle Fork (Figure 28). Groundwater generally moves upward from the shale deposits into the overlying alluvial (and glacial) sediments within the Middle Fork valley. Groundwater from the shale also discharges into the Middle Fork either through the overlying alluvium or, where bedrock is exposed, directly into the river. The groundwater elevations measured in the shale monitoring wells and shown on Figure 28 support this conceptualization of groundwater movement within the Pennsylvanian bedrock.

Groundwater flow velocity within the shale bedrock, computed based on a horizontal gradient of 0.027 ft/ft, hydraulic conductivity of $3x10^{-6}$ cm/s, and an effective porosity of 0.10, was 0.26 meters per year (0.85 feet per year), or 10.2 inches per year. The calculated velocity is based on the geometric mean hydraulic conductivity determined by Kelron in 2002.

4.2.2.5 Coal Mine Effects on Hydrology

The presence of a coal mine beneath portions of the East Ash Pond and study area has been documented based on exploratory borings, geophysics, and historic data acquired from the ISGS. The coal mine has been shown to have significant collapse features where the overlying bedrock (shale) has collapsed or partially collapsed downward into the void or mined coal seam. The collapse of the shale into the void translates upward through the shale, resulting in fracturing and in some cases surface subsidence. Both surface depressions from subsidence and fractured shale within bedrock cores were observed during coal mine investigation activities.

A hydrologic feature noted during the exploratory boring phase of the coal mine investigation was the presence of substantial hydraulic head within the coal and overlying fractured shale in proximity to mined areas. Borings B201 and B202 (Figure 18 and Appendix C), located northwest of the East Ash Pond and secondary pond, both intercepted groundwater under high hydraulic head that resulted in temporary suspension of drilling. Upon intercepting fractured shale above the coal mines during coring, the groundwater, which had accumulated within the fractured shale and underlying coal seam and voids, rose to over 30 feet above ground surface at an estimated flow volume of greater than 100 gallons per minute. The flow rate slowly subsided, but groundwater continued to flow above the ground surface for several hours following penetration of the fractured (collapsed) shale.

The high hydraulic head that developed in the coal mine and overlying shale would be expected based on the strong upward gradient measured within the shale in monitoring wells located along the Middle Fork of the Vermilion River (see Section 4.2.2.3). Since groundwater within the shallow Pennsylvanian bedrock at the study site discharges upward into the Middle Fork, the buildup of groundwater with high hydraulic head within a more permeable confined unit of coal and fractured shale would be expected.

In addition to the high hydraulic head associated with the mined area at borings B201 and B202, hydrogen sulfide gas (developed within the reducing environment of the sulfur-rich coal beds) vented at a high rate and continued to vent until the borings were sealed over 12 hours later.

A major concern at the study site is the affects of abandoned mines on the water quality of the overlying shale, alluvial deposits and the Middle Fork. Groundwater quality issues related to coal mines are discussed further in Sections 5.2.1.3 and 6.4.

5.0 WATER QUALITY

Water quality of the groundwater and surface water at the East Ash Pond and in the surrounding region has been extensively assessed during 2002. Kelron has assessed groundwater quality at background and site wells for 22 parameters. The ISGS has evaluated background groundwater quality for 40 parameters, including the carbon and hydrogen (tritium) isotopes. In addition, the ISGS evaluated the background bedrock groundwater quality for 31 samples acquired from databases from the ISGS, ISWS, IEPA, and Indiana Geological Survey.

DMG collected groundwater samples from all of the site and background wells, both in the unlithified and bedrock deposits, monthly from March through August of 2002. Various wells were also sampled during January and February 2002, but that data was not used in statistical analyses because it was only a subset of all wells used in the study, the wells were still being developed and uniform sampling equipment had not been put into all the wells.

During June 2002 the ISGS split samples with DMG at background wells MW25 through MW 30 (ISGS designation KELRON 25 to KELRON 30) for separate analysis by the ISGS laboratory. In addition to groundwater samples, surface water samples were collected by DMG from the East Ash Pond monthly from January through May of 2002 and from upriver on the Middle Fork from March through August 2002. No East Ash Pond water samples were collected after May 2002 because of construction activities associated with expansion of the East Ash Pond. All effluent discharges to the East Ash Pond were halted and the remaining water was pumped to the secondary pond for discharge to the Middle Fork, resulting in almost no standing water within the East Ash Pond. The last discharge from the East Ash Pond outfall into the Middle Fork of the Vermilion River during the study period was May 26, 2002. Discharging from the East Ash Pond System did not resume until January 2003.

Water quality analytical results for both groundwater and surface water are provided in Appendix J for analyses conducted by DMG. All analytical results for ISGS samples are included with their report in Appendix A.

5.1 GROUNDWATER QUALITY OF THE UNLITHIFIED DEPOSITS

Water quality in the unlithified deposits at the East Ash Pond was evaluated by looking at groundwater in background wells MW26 and MW28 and comparing to East Ash Pond well MW23, located north of the secondary (polishing) pond. Groundwater quality was also compared to surface water quality upgradient on the Middle Fork and in the East Ash Pond. In addition, isotopic data collected and evaluated by the ISGS are included for the background wells MW26 and MW28 (ISGS designation's KELRON 26 and KELRON 28). No water quality data were available for East Ash Pond wells MW10, MW13B, and MW16B due to the lack of water in the wells. Wells MW13B and MW16B are typically dry or have insufficient water-column depth to obtain groundwater samples.

5.1.1 Summary of Groundwater and Surface Water Quality

5.1.1.1 Major Anions and Cations

Groundwater compositions can be grouped into identifiable categories to assist in interpreting the distribution of principal types of groundwater. A hydrochemical facies diagram, also called a Piper diagram, displays the position of water samples with respect to their major cation and anions so that composition categories can be defined (Walton, 1998). Figure 29 shows the position of groundwater samples obtained in June 2002 from East Ash Pond well MW23 and background wells MW26 and MW28. Also shown on the diagram are the surface water samples from the East Ash Pond and from the Middle Fork (labeled as "Upstream River" on the diagram).

The principal anion in background wells MW26 and MW28 and in the Middle Fork sample is bicarbonate. Well MW23 has no dominant type of anion, but is dominated by both bicarbonate and sulfate. In contrast is the East Ash Pond water sample, which has sulfate as the dominant anion. The cation portion of the diagram is much more definitive in grouping the data. All three of the wells and the Middle Fork sample cluster together between calcium and magnesium while the East Ash Pond sample is clearly dominated by calcium. Based on the observed cations and anions, and looking at the upper portion of the diagram, the hydrochemical facies of the water samples can be defined as follows: wells MW26, and MW28 and the Middle Fork of the Vermilion River are calcium-magnesium and bicarbonate type waters; the East Ash Pond is a calcium-sulfate dominated water; and, MW23 falls in-between.

The above categorizations of water types based on principal anions and cations are further demonstrated by the Stiff diagrams shown on Figure 30. The Stiff diagram for the June 2002 water samples shows the similarity between all three of the wells. The higher sulfate in well MW23 relative to bicarbonate is again demonstrated, but all other cations and anions in MW23 are similar to the background wells. The East Ash Pond water is clearly dominated by the cation calcium and the anion sulfate.

The correlation between parameters in groundwater within the unlithified materials is displayed on Table 7. The cations calcium and magnesium have a high correlation of 0.84, which indicates that these parameters vary proportionately within groundwater adjacent to the Middle Fork. The bicarbonate anion has a very high correlation of 0.94 with magnesium and the sulfate anion has a very high correlation of 0.92 with calcium. TDS concentrations in the shallow groundwater are principally controlled by the cations calcium and magnesium (correlation coefficients with TDS of 0.97 and 0.89, respectively) and the anions bicarbonate and sulfate (correlation coefficients with TDS of 0.72 and 0.89, respectively).

5.1.1.2 Statistical Analyses

In order to summarize all of the water quality data generated during 2002 so that some clear observations can be made about both the major and minor ions, including trace elements, several types of tables and figures were prepared. Each of the forms of analysis is discussed below with a summary of all the inorganic data and statistical analyses provided in Section 5.1.1.3.

Detailed Statistical Tables

A summary of groundwater quality data for the unlithified wells, East Ash Pond, and Middle Fork of the Vermilion River (Table 8) lists the mean, median, minimum, and maximum concentration for each chemical parameter. The comments under each parameter include the results of a non-parametric test called the Wilcoxon Rank-Sum Test for Comparison of Means. This statistical test, which has no distributional assumptions, was used to compare the data collected for each parameter at East Ash Pond well MW23 versus the pooled background data from wells MW26 and MW28 to determine if there was any significant difference between their means at a 95 percent confidence level. The detailed test results (Appendix K) were used to make one of three statements for each individual parameter: (1) groundwater from the East Ash Pond well MW23 comes from the same population as the background wells; (2) groundwater from the East Ash Pond well has a statistically significant lower concentration than the background wells; or, (3) groundwater from the East Ash Pond well has a statistically significant higher concentration than the background wells.

Box-and-Whisker Plots

The box-and-whisker plots in Figure 31 provide a visual representation of some of the statistical data presented on Table 8. The rectangular part of the plot extends from the lower quartile to the upper quartile, covering the center half of each sample. The center lines within each box show the sample medians and the plus signs the sample means. The whiskers extend from the box to the minimum and maximum values in each sample, except for any outside or far outside points, which are plotted separately. Outside points are points that lie more than 1.5 times the interquartile range above or below the box and are shown as small squares. Far outside points, more than 3 times the interquartile range above or below the box, are shown as small squares with plus signs through them. Far outside points may indicate outliers or a highly skewed distribution.

Cluster Analysis

Cluster analysis is a descriptive statistical method used to identify groupings (i.e., clusters) of samples or variables. Cluster analysis is used to reveal the latent structure within a data set and is an exploratory tool only. The data from the East Ash Pond study were analyzed using cluster analysis to demonstrate the following:

- grouping of samples from wells and the Middle Fork into clusters based on water quality as defined by absolute concentrations of the major cations and anions (alkalinity, calcium, chloride, potassium, magnesium, sodium, and sulfate);
- grouping of samples from wells and the Middle Fork into clusters based on water quality as defined by absolute concentrations of minor and trace metals (aluminum, boron, barium, iron, lithium, manganese, selenium, and strontium);
- grouping of major cations and anions into clusters with common characteristics; and,
- grouping of minor and trace metals into clusters with common characteristics.

The cluster analysis results can be presented in several ways. In order to visually interpret how the data have been categorized, a graphical depiction of the clusters is shown with a dendrogram. The dendrogram is a linkage tree which first links those samples or parameters that have the greatest similarity (i.e., highest correlation). Each subsequent linkage (or cluster) is less similar than earlier linkages. The greater the distance on the y-axis between linkages, the lower the significance between the linked samples or variables.

The dendrograms of major and minor/trace ions (Figure 32) both show that the first sets of clusters are within each sample location (i.e., samples from each monitoring point cluster together first since they are most similar). The next set of clusters occurs between some of the samples from background well MW26 and samples from the Middle Fork. Although the major ions do not result in any significant linkages after well MW26 and the Middle Fork are grouped together, the minor/trace metals in the water samples result in clustering of East Ash Pond well MW23 with MW26 and the Middle Fork. The final cluster, based on minor/trace metals, is the samples from background well MW28. Based on these dendrograms, the samples from well MW28 are the least similar to samples from the other locations.

The dendrograms formed by looking only at the parameters irrespective of the specific sample locations (Figure 33) used the same data as for Figure 32. The most similar major ions (i.e., the first linkages) were calcium and sulfate followed by: magnesium, alkalinity, sodium, chloride, and finally potassium. The relationship between the parameters clustered together in the dendrograms is partially quantified by the correlation coefficients listed in Table 7. The correlation coefficient between calcium and sulfate was very high at 0.92. The correlation between calcium and magnesium was 0.84 and between sulfate and magnesium was 0.97. Alkalinity had a correlation with magnesium of 0.94. The least similar parameter to the other major ions was potassium, which had a negative (i.e., inverse) correlation with magnesium of –0.69.

The dendrogram for the minor/trace metal parameters (Figure 33) has the first clusters between iron and manganese (correlation coefficient {R} = 0.82 [Table 7]) and lithium and strontium (R = 0.89). These two clusters are then clustered with selenium. Later linkages with boron, barium, and aluminum are much less significant as the similarities between parameters in all of the groundwater and Middle Fork river samples markedly decrease.

5.1.1.2 Summary of Data

All of the statistical analyses and observations listed on Table 8 and graphically presented in Figures 29 to 33 are summarized and consolidated onto Table 9 so that all of the parameters can be assessed together. Based on the Wilcoxon Rank-Sum tests presented in Table 8, the only parameters that have statistically significant greater concentrations in East Ash Pond well MW23 relative to background groundwater concentrations are boron, chloride, potassium, sodium, and sulfate. Each of these parameters will be discussed in detail below along with other trace parameters.

Boron

The box-and-whisker diagram for boron on Figure 31 shows the relative concentrations of boron in the East Ash Pond versus the background wells, well MW23, and the Middle Fork of the Vermilion River. The median boron concentration of 0.27 milligrams per liter (mg/L) in MW23 is 0.15 mg/L above background concentrations, but is 38 times lower than the 10 mg/L median concentration in the East Ash Pond samples. Figure 34a shows the trend in boron concentrations in shallow groundwater versus the river during 2002. Boron concentrations in groundwater at MW23 trend independently from wells MW26 and MW28 and the river. Boron in wells MW26 and MW28 has a parallel trend. Boron concentrations in the river generally lay between those observed in MW26 and MW28.

Boron concentrations in MW23 are due to either natural variation as a result of geologic and hydrologic differences at MW23 relative to the background wells or may be partly affected by the presence of the former coal mine, mine spoil, or the presence of the East Ash Pond. Any impact by the East Ash Pond on shallow groundwater quality is uncertain due to the similarity between groundwater quality impacts from coal ash disposal, coal mine spoil, and coal mine drainage.

Chloride

Chloride concentrations on the box-and-whisker diagram (Figure 31) are similar between the East Ash Pond well MW23 and the Middle Fork of the Vermilion River. Well MW23 has a median chloride concentration of 38.5 mg/L, which is only 9 mg/L above the median Middle Fork concentration. Chloride in MW23 is 5.2 times lower than the median East Ash Pond concentration of 200 mg/L. Chloride has a high correlation of 0.89 (Table 7) with boron based on data from both background wells and MW23. The natural correlation between boron and chloride makes it difficult to distinguish the co-variance of these parameters in groundwater versus potential impacts from the East Ash Pond water, which also has a high correlation between boron and chloride.

The trend in chloride concentrations (Figure 34b) are very different between groundwater sampled from well MW23 versus wells 26, 28, and the river. Wells 26 and 28 have similar chloride trends but are markedly different from chloride concentration changes in the Middle Fork.

The chloride concentrations observed in MW23 are most likely due to either natural variation as a result of geologic and hydrologic differences at MW23 relative to the background wells or may be partly affected by the presence of the former coal mine and mine spoil. Impact by the East Ash Pond on shallow groundwater quality is uncertain due to the similarity between groundwater quality impacts from coal ash disposal, coal mine spoil, and coal mine drainage.

Potassium

Potassium concentrations are similar between East Ash Pond wells MW23, background wells, and the Middle Fork. Median concentrations of 3.25 mg/L in MW23 are 0.9 mg/L above background. Potassium in MW23 is 7.7 times lower than the median East Ash

Pond concentration of 25 mg/L. The trend in potassium concentrations (Figure 34c) demonstrate the similarity between background wells MW26 and MW28, although concentrations in MW23 and the river also have similar trends to the background wells.

The potassium concentrations observed in MW23 are most likely due to either natural variation as a result of geologic and hydrologic differences at MW23 relative to the background wells or may be partly affected by the presence of the former coal mine or associated mine spoils. Impact by the East Ash Pond on potassium concentrations is uncertain due to the similarity between groundwater quality impacts from coal ash disposal, coal mine spoil, and coal mine drainage. However, the similarity between potassium concentration trends in well MW23 and background wells suggests that the East Ash Pond has negligible impact on shallow groundwater concentrations of potassium.

Sodium

Median sodium concentration of 19.5 mg/L in well MW23 is 2.5 mg/l above the median in the background well MW28 and 10.3 mg/L above the median concentration in the Middle Fork of the Vermilion River. Sodium in MW23 is 7.2 times lower than the median East Ash Pond concentration of 140 mg/L. Maximum observed sodium concentrations in 2002 at MW23 and the East Ash Pond were 26 and 240 mg/L, respectively. Similar to chloride trends, the trend in sodium concentrations (Figure 34d) are very different between groundwater sampled from well MW23 versus wells 26, 28, and the river.

The sodium concentrations observed in MW23 are most likely due to either natural variation as a result of geologic and hydrologic differences at MW23 relative to the background wells or may be partly affected by the presence of the former coal mine and mine spoil. Impact by the East Ash Pond on shallow groundwater quality is uncertain due to the similarity between groundwater quality impacts from coal ash disposal, coal mine spoil, and coal mine drainage.

Sulfate

Sulfate concentrations in East Ash Pond well MW23 in 2002 ranged from 280 to 380 mg/L with a median concentration of 320 mg/L. Concentrations in surface water at the East Ash Pond ranged from 440 to 1,500 mg/L with a median concentration of 780 mg/L, or approximately 2.4 times higher than observed in groundwater at MW23. Sulfate concentrations in the shallow unlithified deposits at MW23 and MW28 have a high variability, as seen by the box-and-whisker diagram for sulfate (Figure 31). Sulfate also has a very high correlation of 0.92 with calcium (Table 7) and these two parameters are within the first (most similar) cluster in the dendrogram discussed earlier (Figure 33).

Trends in sulfate concentration (Figure 34e) at well MW23 and background well MW28 are very similar. Sulfate concentrations at wells MW23 and MW28 are above those observed in background well MW26 and the river, which also trend closely together.

The concentrations observed for sulfate in well MW23 can partly be attributed to natural groundwater variations in conjunction with changes observed for calcium. Calcium in groundwater at MW23 is statistically from the same population as background groundwater concentrations and the high correlation between calcium and sulfate in groundwater suggests that the sulfate concentrations at MW23 are also partly natural. Impacts by the East Ash Pond, coal mine, or mine spoils on sulfate concentrations are uncertain.

Aluminum, Barium, Lithium, Molybdenum, Selenium, Strontium, and Vanadium
Concentrations of the trace metals aluminum, barium, lithium, molybdenum, selenium, strontium, and vanadium in the East Ash Pond during 2002 were all significantly higher than those in groundwater within the unlithified deposits (background and on-site). Lithium, molybdenum, selenium, and vanadium concentrations in all shallow groundwater samples were typically below or near their detection limits compared to significantly higher concentrations in the East Ash Pond surface water samples.

Statistically, the trace metal groundwater parameters sampled at well MW23 near the East Ash Pond are from the same population as the background groundwater (exception is barium, which has lower concentrations than background). The deficiency of all the trace metals in shallow groundwater near the East Ash Pond, as compared to their ubiquity in the surface water of the pond itself, suggests there is no impact on shallow groundwater by the East Ash Pond.

5.1.2 Exceedances of Groundwater Quality Standards

During March through August 2002 no groundwater samples collected from the unlithified deposits at the East Ash Pond or from the background monitoring wells exceeded any of the Class I or II groundwater standards (Illinois Administrative Code [IAC] Title 35, Part 620, Section 620.410 and 620.420) for inorganic parameters. However, background well MW28 did exceed the sulfate and TDS standards of 400 and 1,200 mg/L, respectively, during January and February 2002.

5.2 GROUNDWATER QUALITY OF THE BEDROCK DEPOSITS

Water quality in the bedrock was evaluated by comparing background wells to the East Ash Pond wells. Both the ISGS and Kelron investigated background groundwater quality through independent investigations. The ISGS investigated background groundwater quality of the Pennsylvanian age bedrock in two ways: literature and database search, including unpublished data sources, for information pertaining to groundwater geochemistry of shale and coal in Illinois and the Midwest; and, groundwater sampling and analysis during June 2002 using four private wells in Vermilion County and four of the site background wells (MW25, MW27, MW29, and MW30). Kelron investigated the background groundwater quality of the bedrock by utilizing the same four Site wells as the ISGS in addition to well MW31 and had the wells sampled by DMG for 6 consecutive months from March through August 2002.

Utilizing the data collected and analyzed by both the ISGS and DMG, the groundwater quality data from the background wells was grouped according to the source of the data and compared to the East Ash Pond bedrock wells (MW13A, MW16A, MW22, MW24, and MW32) using a variety of statistical and graphical methods.

5.2.1 Summary of Groundwater Quality

5.2.1.1 Major Anions and Cations

The major anions and cations of background and East Ash Pond wells are graphically displayed on the hydrochemical facies (Piper) diagram of Figure 35 and the Stiff diagrams of Figure 36. The principal cations in groundwater from the background wells are typically sodium and potassium, although a few wells have groundwater with higher concentrations of calcium and magnesium. The median value derived from the ISGS literature and database search, which is weighted heavily by groundwater samples from coal-bearing deposits, is dominated by calcium. A ternary plot of the cation data for background bedrock wells (Figure 37; modified from ISGS Figure 13, Appendix A) displays the linear nature of the data points. The ISGS (Mehnert and Dreher, 2002) hypothesized that "groundwater with greater concentrations of sodium plus potassium (Na+K, e.g., KELRON 27 or KELRON 29) migrated over a longer distance from the recharge area to the respective well than samples with lower concentrations of Na+K (e.g., well 23343). During migration, the groundwater dissolved increasingly greater amounts of sodium from the aquifer rocks and increasing amounts of calcium and magnesium were removed from the water, probably by adsorption of clay minerals in the aquifer rocks."

Cation data for groundwater sampled from the East Ash Pond wells plots along the same line as the background wells. Most of the East Ash Pond wells are dominated by sodium and potassium relative to calcium and magnesium. Conversely, surface water sampled from the East Ash Pond is dominated by calcium.

The principal anion in groundwater from background wells and East Ash Pond wells in the vicinity of the Site is chloride. The median value from the ISGS database is dominated by bicarbonate. Surface water from the East Ash Pond is also dominated by sulfate.

The correlation between parameters in groundwater sampled from background and East Ash Pond bedrock wells at the Site is displayed on Table 10. The cations calcium and magnesium have a very high correlation of 0.98, which reflects the data shown on the Piper and Stiff diagrams that calcium and magnesium have been removed from the groundwater by clay minerals in the shale during migration. Sodium and chloride, the principal cations and anions in bedrock groundwater at the Site, are also highly correlated with a coefficient of 0.94. These two parameters, as will be discussed later, account for much of the variability observed in groundwater from the bedrock. In addition, sodium and chloride have correlation coefficients of 0.88 and 0.93, respectively, with TDS. A large amount of the TDS observed in groundwater from the bedrock wells, both background and at the East Ash Pond, is directly correlated to changes in sodium and chloride concentrations.

As observed by the ISGS (Mehnert and Dreher, 2002) for samples from bedrock wells, "sodium and chloride concentrations apparently increase at the expense of calcium, magnesium, and other high valence cations due to adsorption as groundwater moves away from recharge areas."

5.2.1.2 Statistical Analyses

Several types of tables and figures were prepared to summarize the groundwater quality data for the bedrock. Each of the forms of analysis is discussed in the following sections. A summary of all the anlyses for each of the major ions and minor ions, including trace metals, is provided in Section 5.2.1.3

Detailed Statistical Tables

A summary of groundwater quality data is presented in Table 11 for the following groupings of data:

- Background bedrock wells at the Site using all results from the 6 monthly samplings from March through August 2002: wells MW25, MW27, MW29, MW30, and MW30;
- ISGS background data for 27 wells derived from the scientific literature and state databases (see Appendix A);
- ISGS background data for 4 wells sampled and analyzed by the ISGS in Vermilion County: wells 1349, 21903, 23343, and 25531;
- East Ash Pond bedrock wells using all results from the 6 monthly samplings in 2002: MW13A, MW16A, MW22, MW24, and MW32; and,
- East Ash Pond surface water samples from the 5 monthly samplings from January to May 2002.

The statistical summary lists the mean, median, minimum, and maximum concentration for each parameter. The comments under each parameter include the results of a non-parametric test called the Wilcoxon Rank-Sum Test for Comparison of Means. This statistical test, which has no distributional assumptions, was used to compare the data collected for each parameter at each individual East Ash Pond bedrock well (MW13A, MW16A, MW22, MW24, and MW32) versus the pooled background data from the Site background wells (MW25, MW27, MW29, MW30, and MW31) to determine if there was any significant difference between their means at a 95 percent confidence level. The detailed test results (Appendix K) were used to make one of three statements for each individual parameter: (1) groundwater from the East Ash Pond well(s) comes from the same population as the background wells; (2) groundwater from the East Ash Pond well(s) has a statistically significant lower concentration than the background wells; or, (3) groundwater from the East Ash Pond well(s) has a statistically significant higher concentration than the background wells.

Box-and-Whisker Plots

The box-and-whisker plots in Figure 38 provide a visual representation of some of the statistical data presented in Table 11. The rectangular part of the plot extends from the lower quartile to the upper quartile, covering the center half of each sample. The center-lines within each box show the sample medians and the plus signs the sample means. The whiskers extend from the box to the minimum and maximum values in each sample, except for any outside or far outside points, which are plotted separately. Outside points are points that lie more than 1.5 times the interquartile range above or below the box and are shown as small squares. Far outside points, more than 3 times the interquartile range above or below the box, are shown as small squares with plus signs through them. Far outside points may indicate outliers or a highly skewed distribution.

Cluster Analysis

Cluster analysis is a descriptive statistical method used to identify groupings (i.e., clusters) of samples or variables. Cluster analysis is used to reveal the latent structure within a data set and is an exploratory tool only. The data from the East Ash Pond study was analyzed using cluster analysis to demonstrate the following:

- grouping of samples from background wells and East Ash Pond wells at the Site into clusters based on water quality as defined by the major cations and anions (alkalinity, calcium, chloride, potassium, magnesium, sodium, and sulfate);
- grouping of samples from background wells and East Ash Pond wells at the Site into clusters based on water quality as defined by minor and trace metals (aluminum, boron, barium, iron, lithium, manganese, and strontium);
- grouping of major cations and anions into clusters with common characteristics; and,
- grouping of minor and trace metals into clusters with common characteristics.

The cluster analysis results can be presented in several ways. In order to visually interpret how the data have been categorized, a graphical depiction of the clusters is shown with a dendrogram. The dendrogram is a linkage tree which first links those samples or parameters that have the greatest similarity. Each subsequent linkage (or cluster) is less similar than earlier linkages. The greater the distance on the y-axis between linkages, the lower the significance between the linked samples or variables.

The dendrogram of major ions (Figure 39 top) shows that the first sets of clusters are typically within each sample location (i.e., groundwater sample data from each monitoring point cluster together first since they are most similar). The next set of clusters occur between East Ash Pond well MW32 and background well MW30, followed by a cluster with East Ash Pond well MW13A. Wells MW13A and MW32, located immediately east of the East Ash Pond, are nested within the bedrock; well MW32 is the screened at a lower elevation than well MW13A. Another separate clustering occurs between East Ash Pond wells MW22 and MW24 with background wells MW27 and MW29, located on the other side of the Middle Fork of the Vermilion River. The clusterings of background wells with East Ash Pond wells based on major ion composition is indicative of strong similarities between the overall groundwater composition at these locations and depths within the Pennsylvanian bedrock.

The dendrogram of minor ions and trace metals (Figure 39 bottom) has a slightly different set of clusters than that of the major ions above. The first sets of clusters following those within each sample location are between wells MW13A - MW32, MW27 - MW29, and MW22 - MW24. Wells MW13A and MW32 are the nested wells that clustered together for the major ions, but well MW30 no long clusters with these wells due to the differences in the trace element composition of the groundwater. This may be due to the presence of coal within the screened interval of well MW30. The next level of clusters occurs between all of the wells listed above: MW13A, MW32, MW27, MW29, MW22, and MW24; four of these wells are at the East Ash Pond and two (MW27 and MW29) are background wells. The next set of clusters in order of distance along the dendrogram incorporates background wells MW25 and MW31 followed by East Ash Pond well MW16A. The trace metal data from MW30 is very dissimilar from all other wells and is clustered last.

The dendrograms formed by looking only at the parameters irrespective of the specific sample locations (Figure 40 used the same data as for Figure 39. The most similar major ions (i.e., the first linkages) were calcium-magnesium and sodium-chloride followed by: calcium-magnesium and sulfate, sodium-chloride and alkalinity, and sodium-chloride-alkalinity and potassium. The relationship between the parameters clustered together in the dendrograms is partially quantified by the correlation coefficients listed in Table 10. The correlation coefficients between calcium-magnesium and sodium-chloride were very high at 0.98 and 0.94, respectively. The correlations between calcium and magnesium with sulfate were both 0.86. The correlations between sodium and chloride with alkalinity were 0.70 and 0.46, respectively.

The dendrogram for the minor/trace metal parameters (Figure 40, bottom) has the first clusters between barium and iron (correlation coefficient {R} = 0.87 [Table 10]) and aluminum and lithium (R = 0.63). Next, barium-iron is clustered with strontium (R = 0.54 and 0.56, respectively) and aluminum-lithium is clustered with boron (R= -0.02 and 0.47, respectively). Manganese concentrations in groundwater at the study site are very poorly correlated with all the other minor/trace metals and there is no cluster formed with any other parameters.

5.2.1.3 Summary of Data

All of the statistical analyses and observations listed on Table 11 and graphically presented in figures 35 to 40 are summarized on Table 12 so that all of the parameters can be assessed together. Based on the Wilcoxon Rank-Sum tests presented in Table 11, the only parameters that have statistically significant greater concentrations in any of the East Ash Pond wells relative to background groundwater quality in the bedrock are the following:

- Boron at wells MW13A and MW32;
- Calcium at well MW16A;

- Lithium at wells MW13A and MW16A;
- Magnesium at well MW16A;
- Manganese at wells MW13A and MW16A;
- Phosphorus at well MW24;
- Sodium at wells MW13A and MW32;
- Sulfate at wells MW16A, MW22, and MW24; and,
- TDS at wells MW13A and MW32.

Each of these parameters and wells listed above will be discussed in detail below. Other parameters measured in groundwater samples from the bedrock and East Ash Pond will also be discussed.

Boron

The box-and-whisker diagram for boron on Figure 38 shows the relative concentrations of boron in the East Ash Pond wells relative to background wells and the East Ash Pond. The range of boron concentrations in the Site background wells during 2002 was between 0.20 and 1.30 mg/L versus a range for the East Ash Pond wells of 0.30 to 1.60 mg/L. Median boron concentrations at East Ash Pond wells MW13A and MW32 were 1.40 and 1.50 mg/L, respectively. These median boron concentrations are approximately 7 times lower than those observed in the East Ash Pond sluice water.

Wells MW13A and MW32 are both at a location where groundwater has a large upward vertical gradient as it discharges into the alluvial deposits and the Middle Fork of the Vermilion River. The similarity of boron concentrations at this nested well location, along with the upward gradient, indicates that the occurrence of boron is either naturally occurring or may be influenced by the occurrence of past coal mining activities as discussed earlier in Section 4.2.2.5.

Calcium

Calcium concentrations in all of the East Ash Pond wells with the exception of MW16A are either equal to or below background concentrations based on the Wilcoxon Rank-Sum Test. Well MW16A has a median calcium concentration of 135 mg/L, which is above the range of values observed at the Site background wells (median values of 29.5 to 85.5 mg/L). However, the concentrations measured for calcium at well MW16A in 2002 are well above the historical median of 33 mg/L for the period of 1993 through 2001. Calcium concentrations at well MW16A have historically been similar to those at well MW13A and the Site background wells. East Ash Pond surface water samples had calcium concentrations ranging from 150 to 450 mg/L and a median concentration of 350 mg/L.

It is uncertain what factors may have resulted in higher calcium concentrations at well MW16A during 2002. However, well MW16A also had historically high concentrations of magnesium, sulfate, and TDS during 2002. Calcium and magnesium are very highly correlated (R = 0.98, Table 10) in groundwater at the Site and the higher observed concentrations of both these parameters at only one location may be due to the affects of the former coal mine on groundwater geochemistry.

Chloride

Chloride concentrations at the East Ash Pond wells are generally below those observed at Site background wells (Figure 38). The highest chloride concentrations at the East Ash Pond are found in groundwater at nested wells MW13A and MW32, with median concentrations of 570 and 845 mg/L, respectively. These concentrations are below the median chloride concentrations of 840 and 1,200 mg/L measured in groundwater at Site background wells MW25 and MW30, respectively. It is of interest that the highest chloride concentrations occur at well MW30, which is partially screened across coal deposits, and at wells MW25, MW13A, and MW32, all of which occur near (and may be impacted by) former coal mines.

The median chloride concentration in surface water at the East Ash Pond ranged from 100 to 240 mg/L with a median value of 200 mg/L during the study period, or approximately 3 to 4 times lower than the median chloride concentrations observed at wells MW13A and MW32. Chloride in groundwater at the Site is naturally occurring at most bedrock well locations, including the elevated concentrations observed at well MW30 due to coal deposits. However, elevated concentrations observed in some bedrock wells may occur due to former coal mines located nearby.

Lithium

Although lithium concentrations in groundwater at East Ash Pond wells MW13A and MW32 were identified by the Wilcoxon Rank-Sum Test as being above site background, a closer look at the data on the box-and-whisker diagrams (Figure 38) and on Table11 show that the relative concentrations of lithium in wells MW13A and MW32 are within the range of data at Site background wells MW25 and MW30. Lithium concentrations in all of the East Ash Pond wells range from non-detect at 0.005 mg/L to 0.19 mg/L versus a range of non-detect to 0.40 mg/L in the Site background wells.

Similar to observed chloride concentrations, the lithium concentrations in groundwater at wells MW13A and MW32 are higher than other East Ash Pond wells but within the range of values observed in background wells MW25 and MW30. As discussed for chloride, the higher lithium concentration at well MW30 may be caused by the presence of coal in the screened interval. Similarly, higher lithium concentrations in wells MW13A, MW32, and MW25 may be related to the presence of former coal mines.

Lithium concentrations in the East Ash Pond ranged from non-detect to 0.30 mg/L with a median concentration of 0.27 mg/L, or approximately 3 to 14 times greater than the median concentrations observed in the East Ash Pond wells.

Magnesium

Magnesium concentrations in all of the East Ash Pond wells with the exception of MW16A are either equal to or below background concentrations based on the Wilcoxon Rank-Sum Test. Well MW16A has a median manganese concentration of 72.5 mg/L, which is above the range of values observed at the Site background wells. However, the concentrations measured for magnesium at well MW16A in 2002 are well above the historical median of 20 mg/L for the period of 1993 through 2001. Magnesium concentrations at well MW16A have historically been similar to those at well MW13A and the Site background wells. East Ash Pond surface water samples had magnesium concentrations ranging from 8.4 to 42 mg/L and a median concentration of 30 mg/L.

It is uncertain what factors may have resulted in higher magnesium concentrations at well MW16A during 2002. However, well MW16A also had historically high concentrations of calcium, sulfate, and TDS during 2002. Magnesium and calcium are very highly correlated (R = 0.98, Table 10) in groundwater at the Site and the higher observed concentrations of both these parameters at only one location may be attributed to impacts from the former coal mine.

Manganese

As with magnesium, manganese concentrations in well MW16A are statistically above Site background concentrations. The highest manganese concentrations observed in any of the East Ash Pond or background wells occurs in groundwater at well MW16A. The median manganese concentration at well MW16A during the study was 14 times greater than the median in surface water from the East Ash Pond. Since manganese is highly correlated with magnesium concentrations in groundwater at the Site (R = 0.86, Table 10), the higher manganese concentrations observed at well MW16A would be expected based on the high magnesium concentrations also observed in groundwater at this location.

Manganese concentrations at Well MW13A were also above Site background, but were similar to the concentrations observed at background well MW31. The concentrations at MW13A were also within the range documented by the ISGS from the scientific literature and state databases (Table 11).

The degree to which manganese concentrations at MW13A and MW16A might be impacted by the presence of former coal mines is unknown, although any decrease in pH values or presence of reducing conditions associated with former mines would result in increased manganese concentrations in groundwater.

Phosphorus

Phosphorus concentrations in all of the East Ash Pond wells with the exception of MW24 are either equal to or below background concentrations based on the Wilcoxon Rank-Sum Test. Well MW24 has a median phosphorus concentration of 0.047 mg/L, which is within the range observed in groundwater at wells MW16A and MW31. Phosphorus concentrations at well MW24 are most likely naturally occurring based on concentrations observed in the East Ash Pond, other East Ash Pond wells, and Site background wells.

Sodium

Sodium concentrations at the East Ash Pond wells are generally within the same range as those observed at Site background wells (Figure 38). The highest sodium concentrations mg/L). The highest TDS concentrations observed in groundwater in 2002, ranging from 2,400 to 2,500 mg/L, occurred at background well MW30. Well MW30 is partially screened across a coal seam. The median TDS concentration of 1,400 mg/L in groundwater at well MW16A is statistically from the same population as the background bedrock wells using the Wilcoxon Rank-Sum Test and 1,000 mg/L below the median TDS concentration in groundwater at background well MW30.

The high TDS concentrations observed at wells MW13A and MW32 can be attributed to the high sodium and chloride concentrations in groundwater at this nested well location. TDS is most highly correlated with sodium (R = 0.93) and chloride (R = 0.88). As discussed earlier, high sodium and chloride concentrations in groundwater at the Site are a function of naturally occurring conditions at most bedrock wells. Naturally elevated concentrations of these major ions are reflected by similarly high TDS concentrations. However, the highest elevated concentrations of TDS (as with sodium and chloride) may occur in some bedrock wells due to coal deposits (i.e., at well MW30) or former coal mines located nearby (MW25, MW13A, and MW16A).

The median TDS concentration of 1,400 mg/L in groundwater at well MW16A in 2002 is significantly higher than the historical median of 760 mg/L for the period 1993 through 2001. The high TDS concentrations observed at well MW16A in 2002 are attributed primarily to calcium, magnesium, and sulfate, all of which were elevated in groundwater at well MW16A relative to other bedrock wells.

Factors contributing to the higher concentrations of these parameters at well MW16A are difficult to determine since this is the only well with elevated calcium, magnesium, and sulfate concentrations relative to background. However, based on an upward hydraulic gradient within the bedrock and the presence of former coal mines in the vicinity of the well, it is surmised that the occurrence of high TDS in groundwater in this area may be impacted by the former coal mines.

Barium

Barium concentrations in the East Ash Pond wells are at statistically significant lower concentrations than observed in the background bedrock wells based on the Wilcoxon Rank-Sum Test. The lowest mean and median concentrations of barium are found in surface water of the East Ash Pond. The highest barium concentrations are found in the background bedrock wells and the nested East Ash Pond bedrock wells MW13A and MW32.

The nested bedrock wells MW13A and MW32 may have higher barium concentrations than other East Ash Pond wells due to either naturally higher concentrations or may be affected by the former coal mines. The influence of former coal mines on groundwater quality of the bedrock at MW13A and MW32 is hypothesized based on the higher barium concentrations observed in background bedrock wells MW25 and MW30. Wells MW25 and MW30 have elevated barium concentrations relative to the other background wells. Well MW25 is located near a former coal mine and well MW30 is partially screened across a coal seam.

Strontium

Strontium concentrations in the East Ash Pond bedrock wells are at statistically significant lower concentrations or from the same population as the background bedrock wells based on the Wilcoxon Rank-Sum Test. Concentrations of strontium in the East Ash Pond water samples are within the range of both background wells and East Ash Pond wells. Based on the data collected, strontium is not a useful parameter for distinguishing groundwater types or the potential influence of anthropogenic sources.

Aluminum, Molybdenum, Selenium, and Vanadium

Concentrations of the trace metals aluminum, molybdenum, selenium, and vanadium in the East Ash Pond during 2002 were all significantly higher than observed in groundwater within the bedrock deposits (background and on-site). Concentrations of aluminum, molybdenum, selenium, and vanadium in groundwater samples from all bedrock wells were typically below or near their detection limits compared to significantly higher concentrations in the East Ash Pond surface water samples. All of the East Ash Pond bedrock well samples for these four trace metals are statistically from the same population as the background samples using the Wilcoxon Rank-Sum Test for comparison of means.

The deficiency of these four trace metals in groundwater within the Pennsylvanian age bedrock at both background and East Ash Pond wells, as compared to their presence within waters of the East Ash Pond, suggests there is no impact to bedrock groundwater quality by the East Ash Pond.

5.2.2 Exceedances of Groundwater Quality Standards

Groundwater samples collected from bedrock wells at the East Ash Pond and background locations in 2002 (Appendix J) exceeded several Class II groundwater standards (IAC Title 35, Part 620.420) for inorganic parameters. The parameters exceeded by one or more groundwater samples from the bedrock wells at the Site include chloride, sulfate, and TDS. As discussed in Section 5.2.1.3 and displayed on Table 11, many parameters detected at elevated concentrations in groundwater were elevated in both background wells and the East Ash Pond wells.

As seen on the following table, the chloride standard was exceeded at four background wells and two East Ash Pond wells, the sulfate standard at one East Ash Pond well, and the TDS standard at two background wells and three East Ash Pond wells.

Parameter	Class II Groundwater Standard (mg/L)	Background Bedrock Wells Exceeding Class II Standard in 2002	East Ash Pond Bedrock Wells Exceeding Class II Standard in 2002
Chloride	200	MW25, MW27, MW29, MW30	MW13A, MW32
Sulfate	400	none	MW16A
TDS	1,200	MW25, MW30	MW13A, MW16A, MW32

The occurrence of parameters in groundwater at sufficiently high concentrations to exceed groundwater standards can be attributed to three sources: natural geochemistry of the shale bedrock; natural geochemistry associated with coal deposits, particularly at MW30; and, anthropogenic affects on geochemistry associated with former coal mines in the vicinity of background well MW25 and the East Ash Pond wells, particularly wells MW13A, MW16A, and MW32.

5.3 ISOTOPE RESEARCH RESULTS

The carbon and hydrogen (tritium) isotopic data analyzed by the ISGS for groundwater "reveal that some wells produce recent water, while others yield much older water" (Mehnert and Dreher, 2002; Appendix A). Groundwater sampled from the alluvial deposits at wells MW26 and MW28 is indicative of recent water. Tritium values in Illinois precipitation as reported by the ISGS (Appendix A, Table 11) typically range from 3 to 10 tritium units (TU). In the subsurface, tritium has a half-life of 12.3 years and water with tritium concentrations greater than 5 TU is considered recent water. Tritium concentrations in groundwater from the unlithified deposits at wells MW26 and MW28 were 5.3 and 5.8 TU, respectively. Conversely, tritium concentrations in groundwater from the bedrock deposits at wells MW25, MW27, MW29, and MW30 were all below detection limits ranging from 0.43 to 0.52 TU. Water with non-detectable tritium concentrations is considered to be greater than 50 years old.

The Carbon-14 (^{14}C) data for groundwater from the alluvial deposits was consistent with the tritium data. ^{14}C, which has a much longer half-life than tritium, is presented by the ISGS (Appendix A, Table 11) as radiocarbon years before present (RYBP) and as percent (%) modern carbon, both of which provide relative ages. Groundwater from the shallow alluvial wells (MW26 and MW28) had % modern carbon values of 97 and 102 and RYBP values of 210 and "modern", respectively. Based on the tritium and ^{14}C data for groundwater from MW26 and MW28, it is apparent that wells completed in Quaternary geologic materials (i.e., alluvial deposits) "appear to draw water from the local groundwater flow system" (Mehnert and Dreher, 2002).

In contrast to water sampled from the alluvial wells, ^{14}C data from the bedrock wells indicates that the groundwater is significantly older. The ^{14}C data for the background wells installed in the Pennsylvanian bedrock is listed below.

Well Number	Radiocarbon Years Before Present (RYBP)	% Modern Carbon
MW25 (Kelron 25)	13,920	18
MW27 (Kelron 27)	19,400	8.9
MW29 (Kelron 29)	34,610	1.4
MW30 (Kelron 30)	20,850	7.5

The conclusions of the ISGS concerning the four bedrock wells sampled for ^{14}C analysis were that they "apparently draw water from the bedrock and are either only slightly connected to or completely isolated from the local groundwater flow system".

The results of the isotopic analyses of groundwater samples from the background bedrock wells support the hydrogeologic data and conceptualization established earlier. Namely, the Middle Fork of the Vermilion River is a regional discharge area for the bedrock and groundwater within the bedrock is at the end of its flow path, with upward hydraulic gradients, high dissolved mineral content, and significantly older by 13,000 to 35,000 RYBP than groundwater in the overlying unlithified deposits.

6.0 CONCLUSIONS

A comprehensive hydrogeologic and geochemical study of the East Ash Pond System and surrounding region at DMG's Vermilion Power Plant was conducted during 2001-2002. Background geochemical data on the bedrock and groundwater was collected and evaluated by the ISGS for comparison to site-specific data. The collected body of data has been summarized below for the geology, hydrogeology and groundwater chemistry. Utilizing all the available data from the study site and surrounding region, a final section provides the proposed groundwater classification for groundwater at the Vermilion Power Plant and East Ash Pond System.

6.1 GEOLOGY

The deposits covering the bedrock in the region surrounding the study site are derived from recent river deposition (alluvial sediments) in the river valleys and glacial drift deposits occurring below the alluvial sediments and in the upland areas. The glacial and interglacial geologic events that shaped the topography seen today occurred during the Pleistocene Epoch, about 2 million to 12,000 years ago. Thickness of these deposits in the region range from zero thickness along portions of the Middle Fork where bedrock is exposed to over 200 feet in the upland areas.

The unlithified alluvial and glacial deposits in the vicinity of the East Ash Pond and within the floodplain generally range in thickness from 10 to 25 feet. The unlithified deposits increase in thickness as the alluvial deposits pinch out and are supplanted by glacial deposits at higher topographic elevations. Along the western portion of the study site, to the west of the East Ash Pond, the thickest glacial deposits range from 71 feet to the north to 103 feet in the south.

Rocks of Pennsylvanian age form the bedrock surface in the region surrounding the study site. The Danville area is located on the northeast flank of the Illinois basin. Regionally, the Pennsylvanian bedrock consists of mainly shale with thin limestone, sandstone, and coal beds. The upper 75 feet of bedrock at the Site consists of non-marine and marine, silty and micaceous shales of the Pennsylvanian Age Shelburn Formation. The Shelburn Formation contains a major coal seam mined in the region, the Danville Coal, also called the No. 7 Coal.

The top of the Danville Coal, or the void remaining where the coal was removed through mining, was intercepted at depths of 80 to 102.5 feet BLS on the floodplain adjacent to the East Ash Pond. The thickness of the coal seam ranged from 4 to 7 feet with an average thickness of 5.4 feet. A geophysical survey by URS Corp. along 5 lines in 2002 detected 12 anomalies judged to be mine-related voids, collapse features, or partial collapse features in the vicinity of the East Ash Pond System.

The region surrounding the Vermilion Power Plant, including portions of the plant property, has seen extensive coal-mining activity from 1893 to 1970. Two coal mines are located within the vicinity of the East Ash Pond System. Based on data and maps obtained from the ISGS, the former entrances to the two coal mines beneath the site are located just north of the secondary cell of the East Ash Pond and 600 feet southwest of the primary cell.

6.2 HYDROGEOLOGY

Groundwater within the alluvial and, where present, the glacial (till) deposits within the floodplain generally conforms to the ground surface topography. Groundwater elevations in the till and alluvial deposits demonstrate that groundwater elevations in the unlithified materials are higher than those in the adjacent Middle Fork through much of the year. The groundwater surface in the alluvial deposits fluctuates in response to changes in river stage and variations in precipitation. The groundwater surface is not affected by water levels in the East Ash Pond, which has been hydraulically isolated from both the shale and alluvial deposits by soil/bentonite slurry walls and a compacted clay core. Changes in pond elevation do not result in any corresponding changes in the shallow groundwater levels.

Groundwater elevations in the shale are highest in the topographically highest areas to the west and east of the Middle Fork of the Vermilion River. The lowest groundwater elevations occur at wells located adjacent to the Middle Fork. Flow lines derived from the potentiometric surface maps indicate that the Middle Fork in this area is a zone of discharge for the shale. The occurrence of the Middle Fork in this area as a regional discharge zone for the shallow bedrock is supported by the upward vertical hydraulic gradients measured within the shale and the upward vertical hydraulic gradients observed during various periods and at multiple locations between the shale and the alluvium. The shale outcrops along the banks of the Middle Fork and groundwater moving upward through the shale discharges into both the alluvium and directly into the Middle Fork.

The coal mines in the vicinity of the East Ash Pond System have been shown to have significant collapse features where the overlying shale has collapsed or partially collapsed downward into the void or mined coal seam. The collapse of the shale into the void translates upward through the shale, resulting in fracturing and in some cases surface subsidence. A hydrologic feature noted during the exploratory boring phase of the coal mine investigation was the presence of substantial hydraulic head within the coal and overlying fractured shale in proximity to mined areas. Borings located northwest of the East Ash Pond intercepted groundwater under flowing artesian conditions that resulted in temporary suspension of drilling.

6.3 GROUNDWATER CHEMISTRY

Based on all of the groundwater and surface water quality data collected in 2002, the affects of the East Ash Pond on groundwater quality are either negligible or not present. Groundwater quality data for most major ions and trace constituents is similar to background groundwater quality. In cases where elevated concentrations of a parameter were found to occur in groundwater near the East Ash Pond there were also elevated concentrations in background wells screened within coal deposits or in the proximity of abandoned coal mines.

Trace metal concentrations in groundwater were compared to East Ash Pond water samples and there was no commonality between the two water types. The deficiency of trace metals such as molybdenum, selenium, and vanadium in groundwater within both the alluvial deposits and the Pennsylvanian age bedrock at both background and East Ash Pond wells, as compared to their ubiquitous presence within waters of the East Ash Pond, suggests that based on trace water quality data there is no impact to unlithified or bedrock groundwater quality by the East Ash Pond.

Finally, the results of the isotopic analyses of groundwater samples from the background bedrock wells by the ISGS resulted in Carbon-14 ages ranging from 13,000 to 35,000 RYBP (radiocarbon years before present). In support of the Carbon-14 results, tritium concentrations for the same set of bedrock groundwater samples were all below detection limits ranging from 0.43 to 0.52 TU (tritium units). Water with non-detectable tritium concentrations is considered to be greater than 50 years old (Mehnert and Dreher, 2002).

The isotopic and other geochemical data supports the hydrogeologic conceptualization established earlier. Namely, the Middle Fork of the Vermilion River is a regional discharge area for the bedrock and groundwater within the bedrock is at the end of its flow path, with upward hydraulic gradients, high dissolved mineral content, and significantly older by 13,000 to 35,000 RYBP than recent groundwater in the overlying unlithified deposits.

6.4 GROUNDWATER CLASSIFICATION

During March through August 2002, no groundwater parameters measured in shallow monitoring wells in the unlithified deposits exceeded Class I or II groundwater standards. However, background well MW28 exceeded the sulfate and TDS standards of 400 and 1,200 mg/L, respectively, during January and February 2002.

Three bedrock monitoring wells at the East Ash Pond and four background wells regularly exceeded standards for at least one of the parameters of chloride, sulfate, and TDS. The occurrence of parameters within the bedrock at sufficiently high concentrations to exceed groundwater standards can be attributed to three sources: natural geochemistry of the shale bedrock; natural geochemistry associated with coal deposits; and, anthropogenic (man-made) affects on geochemistry associated with former coal mines.

Based on the hydrogeology and geochemistry established for the vicinity of the East Ash Pond and surrounding region, and given the influence of former coal mines documented at the Site on the geochemistry of groundwater within the unlithified and bedrock deposits, it is proposed that the groundwater designation in accordance with Section 620.201 of Part 620 (IAC Title 35, Subtitle F, Chapter I) be Class IV – Other Groundwater, as documented by the following excerpt from Section 620.240:

> "g) Groundwater within a previously mined area, unless monitoring demonstrates that the groundwater is capable of consistently meeting the standards of Sections 620.410 or 620.420. If such capability is determined, groundwater within the previously mined area shall not be Class IV."

The groundwater quality established at the East Ash Pond is within a previously mined area and has been documented to be influenced by both natural geochemistry and the influences of abandoned coal mines and mine spoils. Groundwater quality at the Vermilion Power Plant and in background wells have consistently not met the Class I and II standards for chloride, sulfate, and TDS as documented in Sections 620.410 and 620.420, respectively, of the IAC. Therefore, groundwater in the unlithified deposits and bedrock at the East Ash Pond and surrounding area of the DMG property at the Vermilion Power Plant should be designated Class IV.

7.0 REFERENCES

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Tables

Table 1. Boring and Monitoring Well Summary

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant, Illinois

Boring or Monitoring Well	Drilling / Installation Date	Status / Purpose as of November 2002	Land Surface Elevation (feet) 2001 Survey	State Planar X-Coord (feet)	State Planar Y-Coord (feet)
MW10	1987	Quarterly Monitoring Well	656.3	1,150,091	1,279,665
MW13A	1987	Quarterly Monitoring Well	581.9	1,151,313	1,279,859
MW13B	1987	Quarterly Monitoring Well	582.0	1,151,313	1,279,865
MW16A	1987	Quarterly Monitoring Well	578.3	1,151,425	1,279,349
MW16B	1987	Quarterly Monitoring Well	578.5	1,151,418	1,279,347
MW-11A	1987	destroyed - E.Ash Pond construction	594.7	1,150,764	1,279,956
MW-12A	1987	destroyed - E.Ash Pond construction	590.0	1,151,082	1,280,323
MW-14A	1987	destroyed - E.Ash Pond construction	586.1	1,150,877	1,279,520
MW-15A	1987	destroyed - E.Ash Pond construction	589.0	1,150,650	1,279,242
MW22	2001	2001-2002 Hydrogeologic Investigation / In Use	655.6	1,150,083	1,279,669
MW23	2001	2001-2002 Hydrogeologic Investigation / In Use	599.1	1,150,788	1,280,399
MW24	2001	2001-2002 Hydrogeologic Investigation / In Use	598.8	1,150,783	1,280,404
MW25	2001	2001-2002 Hydrogeologic Investigation / In Use	578.8	1,150,916	1,278,027
MW26	2001	2001-2002 Hydrogeologic Investigation / In Use	580.5	1,150,782	1,280,741
MW27	2001	2001-2002 Hydrogeologic Investigation / In Use	580.4	1,150,787	1,280,744
MW28	2001	2001-2002 Hydrogeologic Investigation / In Use	581.0	1,151,565	1,281,552
MW29	2001	2001-2002 Hydrogeologic Investigation / In Use	580.9	1,151,564	1,281,557
MW30	2001	2001-2002 Hydrogeologic Investigation / In Use	645.7	1,150,347	1,282,360
MW31	2001	2001-2002 Hydrogeologic Investigation / In Use	698.2	1,152,932	1,279,256
MW32	2001	2001-2002 Hydrogeologic Investigation / In Use	581.9	1,151,312	1,279,850
B101	2001	Geotechnical Boring - E.Ash Pond Expansion	604.0	1,150,224	1,279,157
B102	2001	Geotechnical Boring - E.Ash Pond Expansion	642.0	1,150,264	1,279,708
B103	2001	Geotechnical Boring - E.Ash Pond Expansion	653.9	1,150,323	1,279,872
B104	2001	Geotechnical Boring - E.Ash Pond Expansion	652.4	1,150,287	1,279,540
B105	2001	Geotechnical Boring - E.Ash Pond Expansion	652.4	1,150,360	1,279,510
B106	2001	Geotechnical Boring - E.Ash Pond Expansion	659.2	1,150,353	1,279,348
B107	2001	Geotechnical Boring - E.Ash Pond Expansion	658.6	1,150,188	1,279,346
B108	2001	Geotechnical Boring - E.Ash Pond Expansion	658.0	1,150,259	1,279,463
B109	2001	Geotechnical Boring - E.Ash Pond Expansion	655.8	1,150,194	1,279,559
B110	2001	Geotechnical Boring - E.Ash Pond Expansion	654.6	1,149,682	1,279,283
B111	2001	Geotechnical Boring - E.Ash Pond Expansion	653.7	1,149,852	1,279,443
B112	2001	Geotechnical Boring - E.Ash Pond Expansion	652.7	1,149,843	1,279,285
B201	2002	Exploratory Boring - Coal Mine Investigation	599.1	1,150,614	1,280,277
B202	2002	Exploratory Boring - Coal Mine Investigation	606.0	1,150,547	1,280,287
B203	2002	Exploratory Boring - Coal Mine Investigation	627.1	1,150,427	1,280,159
B204	2002	Exploratory Boring - Coal Mine Investigation	588.0	1,150,065	1,278,812
B205	2002	Exploratory Boring - Coal Mine Investigation	589.6	1,150,223	1,278,791
B206	2002	Exploratory Boring - Coal Mine Investigation	589.0	1,150,345	1,278,682
B207	2002	Exploratory Boring - Coal Mine Investigation	595.6	1,150,358	1,278,992
B208	2002	Exploratory Boring - Coal Mine Investigation	657.6	1,149,885	1,278,897

Table 2. Monitoring Well Depths and Screened Elevations

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant, Illinois

Monitoring Well	TOC/MP Elevation (feet)	Land Surface Elevation (feet)	Well Stickup (feet)	Screen Top from LS (feet)	Screen Bot from LS (feet)	Screen Length (feet)	Screen Elevation		Total Well Depth from LS (feet)	Total Well Depth from TOC/MP (feet)
							Top (feet)	Bottom (feet)		
MW10	659.10	656.3	2.8	46.60	56.60	10.00	609.70	599.70	56.6	59.4
MW13A	583.47	581.9	1.6	21.00	41.00	20.00	560.90	540.90	41.0	42.6
MW13B	583.84	582.0	1.8	5.50	10.50	5.00	576.50	571.50	10.5	12.3
MW16A	580.17	578.3	1.9	21.80	41.80	20.00	556.50	536.50	41.8	43.7
MW16B	580.56	578.5	2.1	7.00	12.00	5.00	571.50	566.50	12.0	14.1
MW22	658.60	655.6	3.0	80.00	100.00	20.00	575.60	555.60	100.0	103.0
MW23	601.89	599.2	2.7	11.80	21.80	10.00	587.40	577.40	22.0	24.7
MW24	601.81	598.8	3.0	34.80	54.80	20.00	564.00	544.00	54.8	57.8
MW25	581.65	578.8	2.9	19.10	39.10	20.00	559.70	539.70	39.1	42.0
MW26	583.52	580.5	3.0	7.75	12.75	5.00	572.75	567.75	13.0	16.0
MW27	583.39	580.4	3.0	23.00	43.00	20.00	557.40	537.40	43.0	46.0
MW28	583.79	581.0	2.8	8.00	13.00	5.00	573.00	568.00	13.0	15.8
MW29	583.90	580.9	3.0	23.00	43.00	20.00	557.90	537.90	43.0	46.0
MW30	648.71	645.7	3.0	127.00	147.04	20.04	518.70	498.66	147.0	150.1
MW31	701.21	698.2	3.0	162.00	182.00	20.00	536.20	516.20	182.0	185.0
MW32	585.00	581.9	3.1	45.80	55.80	10.00	536.10	526.10	55.8	58.9

Notes:

Shale
Till or Alluvial

All elevations measured during December 2001 except MW13A,B; and, MW16A,B from 1999 survey.

Table 3. Groundwater and Surface-Water Levels and Elevations: 2002

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant, Illinois

Monitoring Well or Surface Water Point	Measuring Point Elevation[1] (feet NGVD)	Groundwater Depth (feet below MP)								Groundwater Elevation (feet NGVD)							
		1 1/22-23/02	2 2/18/2002	3 3/19-21/02	4 4/16-17/02	5 5/22/2002	6 6/18/2002	7 7/16/2002	8 8/27/2002	1 1/22-23/02	2 2/18/2002	3 3/19-21/02	4 4/16-17/02	5 5/22/2002	6 6/18/2002	7 7/16/2002	8 8/27/2002
MW10	659.10	52.99	52.41	51.89	51.62	52.63	51.62	51.81	52.26	606.11	606.69	607.21	607.48	606.47	607.48	607.29	606.84
MW13A	583.47	10.73	10.56	10.32	10.59	10.11	10.73	10.82	8.82	572.74	572.91	573.15	572.88	573.36	572.74	572.65	574.65
MW13B	583.84	dry	12.03	11.79	11.90	10.40	12.12	12.61	10.67	dry	571.81	572.05	571.94	573.44	571.72	571.23	573.17
MW16A	580.17	10.34	10.60	10.36	10.74	9.65	9.86	9.99	6.6	569.83	569.57	569.81	569.43	570.52	570.31	570.18	573.57
MW16B	580.56	dry	dry	10.05	10.22	dry	10.51	dry	9.63	dry	dry	570.51	570.34	dry	570.05	dry	dry
MW22	658.60	56.61	56.52	56.60	58.54	57.42	58.78	59.10	60.35	601.99	602.08	602.00	600.06	601.18	599.82	599.50	598.25
MW23	601.89	13.79	12.98	12.00	12.39	12.06	13.80	14.49	13.46	588.10	588.91	589.89	589.50	589.83	588.09	587.40	588.43
MW24	601.81	22.71	23.86	21.90	22.39	21.80	22.06	22.48	21.20	579.10	577.95	579.91	579.42	580.01	579.75	579.33	580.61
MW25	581.65	16.02	15.89	15.39	15.46	14.82	15.25	15.84	13.97	565.63	565.76	566.26	566.19	566.83	566.40	565.81	567.68
MW26	583.52	10.03	9.11	7.91	7.83	6.40	8.13	9.83	8.86	573.49	574.41	575.61	575.69	577.12	575.39	573.69	574.66
MW27	583.39	8.70	8.52	7.80	7.88	7.00	7.77	8.60	7.54	574.69	574.87	575.59	575.51	576.39	575.62	574.79	575.85
MW28	583.79	9.36	8.53	7.95	7.77	7.42	8.70	10.09	8.44	574.43	575.26	575.84	576.02	576.37	575.09	573.70	575.35
MW29	583.90	4.04	3.42	3.04	2.83	2.71	3.38	4.52	3.95	579.86	580.48	580.86	581.07	581.19	580.52	579.38	579.95
MW30	648.71	63.94	63.18	62.57	62.57	62.34	62.26	62.83	62.70	584.77	585.53	586.14	586.14	586.37	586.45	585.88	586.01
MW31	701.21	88.12	87.94	87.55	87.30	87.00	87.41	87.89	86.06	613.09	613.27	613.66	613.91	614.21	613.80	613.32	615.15
MW32	585.00	0.09	0.12	0.00	0.00	0.00	0.00	1.98	0.00	584.91	584.88	585.00	585.00	585.00	585.00	583.02	585.00
River at MW26/MW27[2]	580.81	na	na	na	na	na	na	na	na	572.01	572.14	573.47	572.86	573.26	573.31	nm	573.83
River at MW25[3]	573.00	12.71	12.33	11.93	11.91	11.60	11.78	nm	11.20	560.29	560.67	561.07	561.09	561.40	561.22	nm	561.80
Secondary Ash Pond[4]	599.43	na	nm	7.20	7.56	7.21	nm	nm	nm	593.17	nm	592.23	591.87	592.22	nm	nm	nm
Primary Ash Pond[5]	599.77	na	nm	6.11	12.8	nm	nm	nm	nm	592.66	nm	593.66	586.97	586.65	nm	nm	nm

Notes:

[1] As measured at top of riser pipe for wells and surveyed or measured for surface water points.

[2] Control Monument 0109 adjacent to Wells MW26 and MW27.

[3] Control Point is scribe mark on lower deck of Pump House.

[4] Control Point is scribe mark on concrete base of east catwalk.

[5] Control Point is scribe mark on concrete base of north catwalk.

MP	Measuring point.
MW	Monitoring well.
NGVD	National Geodetic Vertical Datum.
MW27	Shale Monitoring Wells
MW26	Till or Alluvial Monitoring Wells
na	not applicable
nm	not measured

Table 4. Field Hydraulic Conductivity Results

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant, Illinois

Monitoring Well	Formation	Analytical Solution	Number of Field Tests	Average Hydraulic Conductivity (cm/sec)
MW24	Pennsylvanian Shale	Bouwer-Rice (confined)	1	3.85×10^{-5}
MW25	Pennsylvanian Shale	Bouwer-Rice (confined)	1	2.47×10^{-6}
MW27	Pennsylvanian Shale	Bouwer-Rice (confined)	2	1.04×10^{-4}
MW29	Pennsylvanian Shale	Bouwer-Rice (confined)	1	5.76×10^{-7}
MW30	Pennsylvanian Shale and Coal	Bouwer-Rice (confined)	1	1.80×10^{-6}
MW31	Pennsylvanian Shale	Bouwer-Rice (confined)	1	1.45×10^{-7}
MW32	Pennsylvanian Shale	Bouwer-Rice (confined)	1	1.49×10^{-6}
Geometric Mean Hydraulic Conductivity (all shale wells)				**3.0×10^{-6}**
MW26	Recent Alluvium (sand and gravel)	Bouwer-Rice (unconfined)	2	2.16×10^{-2}
MW28	Recent Alluvium (silt, some sand)	Bouwer-Rice (unconfined)	2	1.02×10^{-2}
Geometric Mean Hydraulic Conductivity (alluvial wells only)				**1.5×10^{-2}**

Table 5. Depths and Elevations of Pennsylvanian Shale Bedrock and Danville Coal

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant, Illinois

Boring or Monitoring Well	Land Surface Elevation	Pennsylvanian Shale		Danville (No. 6) Coal			
		Depth (feet)	Elevation (feet)	Top of Coal Seam		Bottom of Coal Seam	
				Depth (feet)	Elevation (feet)	Depth (feet)	Elevation (feet)
MW13A	581.9	11	571	- -	- -	- -	- -
MW16A	578.3	12	566	- -	- -	- -	- -
MW22	655.6	71	585	- -	- -	- -	- -
MW24	598.8	22	577	- -	- -	- -	- -
MW25	578.8	10	569	- -	- -	- -	- -
MW27	580.4	13	567	- -	- -	- -	- -
MW29	580.9	18	566	- -	- -	- -	- -
MW30	645.7	116	530	144.2	501.5	Borehole terminated above base of unit.	
MW31	698.2	155	545	- -	- -	- -	- -
MW32	581.9	11	571	- -	- -	- -	- -
B-11A	594.7	10	585	- -	- -	- -	- -
B-12A	590.0	12	578	- -	- -	- -	- -
B-14A	586.1	10	576	- -	- -	- -	- -
B-15A	589.0	12	578	- -	- -	- -	- -
B101	604.0	29	575	- -	- -	- -	- -
B102	642.0	49	594	- -	- -	- -	- -
B103	653.9	69	585	- -	- -	- -	- -
B104	652.4	64	588	- -	- -	- -	- -
B105	652.4	64	588	- -	- -	- -	- -
B106	659.2	69	590	- -	- -	- -	- -
B107	658.6	70	589	- -	- -	- -	- -
B108	658.0	67	591	- -	- -	- -	- -
B109	655.8	>71	na	- -	- -	- -	- -
B110	654.6	>86	na	- -	- -	- -	- -
B111	653.7	>76	na	- -	- -	- -	- -
B112	652.7	>76	na	- -	- -	- -	- -
B201	599.1	41	559	102.5	496.6	107.5	491.6
				Mined Out Coal Seam. Mine Void Intercepted - Coal Seam Removed.			
B202	606.0	48	558	*Mined Out Coal Seam. Collapsed Mine.*		114.7	491.3
B203	627.1	66	561	127.0	500.1	132.3	494.8
B204	588.0	15	574	83.0	505.0	88.9	499.1
				Sloped Mineshaft (Void) Intercepted from 28 to 37 feet below ground surface.			
B205	589.6	22	568	86.3	503.3	91.8	497.8
B206	589.0	16	573	80.4	508.6	84.4	504.6
				Mined Out Coal Seam. Mine Void Intercepted - Coal Seam Removed.			
B207	595.6	22	574	90.0	505.6	95.5	500.1
B208	657.6	103	554	152.0	505.6	159.0	498.6

Notes:

- - Borehole terminated at a depth shallower than the Danville (No. 6) Coal.

Table 6. Vertical Groundwater Gradients in Shale and Between Shale and Alluvium

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant, Illinois

Monitoring Wells for Gradient Calculations with Screened Formations		Groundwater Level Measurement Date During 2002								8-month Average
		22-23 Jan	18-Feb	19-21 March	16-17 April	22-May	18-Jun	16-Jul	27-Aug	
MW13B alluvial	MW13A shale	alluvial dry	**-0.048**	**-0.048**	**-0.041**	0.003	**-0.044**	**-0.061**	**-0.064**	**-0.043**
MW13A shale	MW32 shale	**-0.615**	**-0.605**	**-0.598**	**-0.612**	**-0.588**	**-0.619**	**-0.524**	**-0.523**	**-0.585**
MW16B alluvial	MW16A shale	alluvial dry	alluvial dry	0.031	0.040	alluvial dry	**-0.012**	alluvial dry	alluvial dry	0.020
MW23 alluvial	MW24 shale	0.317	0.386	0.351	0.355	0.346	0.294	0.284	0.275	0.326
MW26 alluvial	MW27 shale	**-0.053**	**-0.020**	0.001	0.008	0.032	**-0.010**	**-0.048**	**-0.052**	**-0.018**
MW28 alluvial	MW29 shale	**-0.240**	**-0.231**	**-0.222**	**-0.223**	**-0.213**	**-0.240**	**-0.251**	**-0.204**	**-0.228**

Notes:	**-0.615**	Vertical gradient is upwards between the screened well intervals and formations indicated.
	0.386	Vertical gradient is downwards between the screened well intervals and formations indicated.
	alluvial dry	Shallow alluvial monitoring well did not have a measurable water level on the date indicated.

Table 7. Correlation Between Groundwater Quality Parameters in Unlithified Deposits

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant, Illinois

	Aluminum	Alkalinity	Boron	Barium	Calcium	Chloride	Iron	Potassium	Lithium	Magnesium	Manganese	Sodium	Selenium	Sulfate	Strontium	TDS
Aluminum		-0.38	-0.53	0.10	-0.80	-0.28	-0.03	0.07	-0.47	-0.59	-0.20	-0.50	-0.35	-0.80	-0.55	-0.73
Alkalinity			-0.16	0.66	0.63	-0.30	0.49	-0.83	**0.92**	**0.94**	**0.82**	0.42	0.36	0.38	**0.96**	0.72
Boron				-0.51	0.61	**0.89**	-0.11	0.58	-0.15	0.12	-0.18	0.72	-0.01	0.79	0.06	0.53
Barium					0.05	-0.47	0.45	-0.59	0.49	0.47	0.53	-0.06	0.22	-0.09	0.59	0.20
Calcium						0.36	0.18	-0.24	0.66	**0.84**	0.38	0.79	0.36	**0.92**	0.77	**0.97**
Chloride							-0.21	0.66	-0.27	-0.08	-0.32	0.68	-0.08	0.55	-0.11	0.29
Iron								-0.41	0.33	0.37	**0.82**	0.13	-0.13	0.09	0.51	0.28
Potassium									**-0.81**	-0.69	-0.67	0.03	-0.39	0.09	-0.69	-0.33
Lithium										**0.91**	0.59	0.36	0.54	0.40	**0.89**	0.71
Magnesium											0.69	0.59	0.47	0.63	**0.97**	**0.89**
Manganese												0.29	-0.01	0.21	**0.81**	0.49
Sodium													0.07	0.78	0.56	0.78
Selenium														0.26	0.33	0.39
Sulfate															0.57	**0.89**
Strontium																**0.83**
TDS																

Notes:

between the variables. The number of pairs of data values used to compute each coefficient was 18 (6 observations of each chemical parameter in groundwater per well for wells MW23, MW26, and MW28). Generally, correlations greater than 0.50 or less than -0.50 indicate statistically significant non-zero correlations at the 95% confidence level.

Data for determination of correlations are the 6 monthly samples collected from March to August 2002 at unconsolidated wells MW23 at the East Ash Pond and background wells MW26 and MW28.

0.89 Bold-face numbers highlighted in boxes indicate a high level of correlation between two parameters. Positive numbers indicate that the parameters are directly proportional and negative numbers indicate the parameters are inversely proportional.

Table 8. Summary of Groundwater Quality Data in Unlithified Deposits, East Ash Pond, and Middle Fork River

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant, Illinois

Parameter: Aluminum, diss (mg/L)	**Samples per Location**	**Mean***	**Median***	**Minimum****	**Maximum**
Background Alluvial Wells (2002 Kelron Study)					
MW26	6	0.013	0.013	0.010	0.017
MW28	6	0.007	0.008	<0.005	0.010
East Ash Pond Alluvial Wells (2002 Kelron Study)					
MW23	6	0.007	0.008	<0.005	0.010
Upstream Middle Fork at Higginsville Bridge (2002 Kelron Study)	6	0.015	0.013	<0.005	0.030
East Ash Pond Surface Water Samples (2002 Kelron Study) (monthly samples from Jan-May 2002)	5	**0.124**	**0.140**	0.011	0.25

Comments:

1. East Ash Pond alluvial well MW23 comes from same population as Background alluvial wells MW26 and MW28 based on the Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level.
2. Median Aluminum concentrations in East Ash Pond Surface Water Samples are 10 to 18 times greater than in Background and East Ash Pond alluvial wells.
3. Median Aluminum concentrations upstream on the Middle Fork are equivalent to or slightly greater than the Background Alluvial Wells.

Parameter: Barium, diss (mg/L)	**Samples per Location**	**Mean***	**Median**	**Minimum****	**Maximum**
Background Alluvial Wells (2002 Kelron Study)					
MW26	6	0.030	0.029	0.028	0.031
MW28	6	0.033	0.033	0.028	0.041
East Ash Pond Alluvial Wells (2002 Kelron Study)					
MW23	6	0.025	0.025	0.023	0.027
Upstream Middle Fork at Higginsville Bridge (2002 Kelron Study)	6	0.041	0.039	0.036	0.054
East Ash Pond Surface Water Samples (2002 Kelron Study) (monthly samples from Jan-May 2002) not applicable	5	**0.14**	**0.13**	0.03	0.28

Comments:

1. East Ash Pond alluvial well MW23 has a statistically significant lower concentration than Background alluvial wells MW26 and MW28 based on the Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level.
2. Median Barium concentrations in East Ash Pond Surface Water Samples are 4 to 5 times greater than in Background and East Ash Pond alluvial wells.
3. Median Barium concentrations upstream on the Middle Fork are slightly greater than (within 35 percent) the Background Alluvial Wells.

Parameter: Boron, diss (mg/L)	**Samples per Location**	**Mean***	**Median**	**Minimum****	**Maximum**
Background Alluvial Wells (2002 Kelron Study)					
MW26	6	0.038	0.025	<0.05	0.076
MW28	6	0.122	0.120	0.110	0.140
East Ash Pond Alluvial Wells (2002 Kelron Study)					
MW23	6	**0.265**	**0.265**	0.20	0.32
Upstream Middle Fork at Higginsville Bridge (2002 Kelron Study)	6	0.057	0.065	<0.05	0.091
East Ash Pond Surface Water Samples (2002 Kelron Study) (monthly samples from Jan-May 2002) not applicable	5	**10.88**	**10.00**	5.1	18.0

Comments:

1. East Ash Pond alluvial well MW23 has a statistically significant higher concentration than Background alluvial wells MW26 and MW28 based on the Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level.
2. Median Boron concentrations in East Ash Pond Surface Water Samples are 38 times greater than those in East Ash Pond alluvial well MW23.
3. Median Boron concentrations upstream on the Middle Fork are within the range of the Background Alluvial Wells.

Notes:

* Less than points were replaced by one-half the detection limit.
** Some parameters had multiple detection limits. Lowest detection limit is reported.
Highest mean and median concentrations of parameter are shown in boldface.

Table 8. Summary of Groundwater Quality Data in Unlithified Deposits, East Ash Pond, and Middle Fork River

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant, Illinois

Parameter: Calcium, diss (mg/L)	**Samples per Location**	**Mean***	**Median**	**Minimum****	**Maximum**
Background Alluvial Wells (2002 Kelron Study)					
MW26	6	89	92	75	100
MW28	6	203	195	180	250
East Ash Pond Alluvial Wells (2002 Kelron Study)					
MW23	6	185	185	180	190
Upstream Middle Fork at Higginsville Bridge (2002 Kelron Study)	6	77	82	60	93
East Ash Pond Surface Water Samples (2002 Kelron Study) (monthly samples from Jan-May 2002) not applicable	5	**322**	**350**	150	450

Comments:
1. East Ash Pond alluvial well MW23 comes from same population as Background alluvial wells MW26 and MW28 based on the Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level.
2. Median Calcium concentrations in East Ash Pond Surface Water Samples are 1.9 times greater than those in East Ash Pond alluvial well MW23.
3. Median Calcium concentrations upstream on the Middle Fork are slighly lower than the Background Alluvial Wells.

Parameter: Chloride, total (mg/L)	**Samples per Location**	**Mean***	**Median**	**Minimum****	**Maximum**
Background Alluvial Wells (2002 Kelron Study)					
MW26	6	11.1	12.0	7.3	13
MW28	6	13	12.5	11	18
East Ash Pond Alluvial Wells (2002 Kelron Study)					
MW23	6	35.2	38.5	10	54
Upstream Middle Fork at Higginsville Bridge (2002 Kelron Study)	6	28.8	29.5	18	41
East Ash Pond Surface Water Samples (2002 Kelron Study) (monthly samples from Jan-May 2002)	5	**172**	**200**	100	240

Comments:
1. East Ash Pond alluvial well MW23 has a statistically significant higher concentration than Background alluvial wells MW26 and MW28 based on the Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level.
2. Median Chloride concentrations in East Ash Pond Surface Water Samples are 5.2 times greater than those in East Ash Pond alluvial well MW23.
3. Median Chloride concentrations upstream on the Middle Fork are about 2.5 times higher than the Background Alluvial Wells.

Parameter: Iron, diss (mg/L)	**Samples per Location**	**Mean***	**Median***	**Minimum****	**Maximum**
Background Alluvial Wells (2002 Kelron Study)					
MW26	6	**0.015**	**0.013**	<0.025	0.025
MW28	6	**0.040**	**0.029**	<0.025	0.11
East Ash Pond Alluvial Wells (2002 Kelron Study)					
MW23	6	nd	nd	<0.025	<0.025
Upstream Middle Fork at Higginsville Bridge (2002 Kelron Study)	6	nd	nd	<0.025	<0.025
East Ash Pond Surface Water Samples (2002 Kelron Study) (monthly samples from Jan-May 2002)	5	nd	nd	<0.025	<0.025

Comments:
1. East Ash Pond alluvial well MW23 comes from same population as Background alluvial wells MW26 and MW28 based on the Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level.
2. The only detected iron concentrations were in the Background Alluvial Wells; all other locations were below the method detection limit of 0.025 mg/L.

Notes:
* Less than points were replaced by one-half the detection limit.
** Some parameters had multiple detection limits. Lowest detection limit is reported.
nd No samples were above method detection limit.
Highest mean and median concentrations of parameter are shown in boldface.

Table 8. Summary of Groundwater Quality Data in Unlithified Deposits, East Ash Pond, and Middle Fork River

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant, Illinois

Parameter: Lithium, diss (mg/L)	**Samples per Location**	**Mean***	**Median***	**Minimum****	**Maximum**
Background Alluvial Wells (2002 Kelron Study)					
MW26	6	0.004	0.003	<0.005	0.007
MW28	6	nd	nd	<0.005	<0.005
East Ash Pond Alluvial Wells (2002 Kelron Study)					
MW23	6	0.004	0.003	<0.005	0.007
Upstream Middle Fork at Higginsville Bridge (2002 Kelron Study)	6	0.004	0.003	<0.005	0.007
East Ash Pond Surface Water Samples (2002 Kelron Study) (monthly samples from Jan-May 2002)	5	**0.19**	**0.27**	<0.005	0.30

Comments:
1. East Ash Pond alluvial well MW23 comes from same population as Background alluvial wells MW26 and MW28 based on the Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level.
2. Median Lithium concentrations in East Ash Pond Surface Water Samples are over 90 times greater than in Background and East Ash Pond alluvial wells.
3. Median Lithium concentrations upstream on the Middle Fork are equivalent to the Background Alluvial Wells.

Parameter: Magnesium, diss (mg/L)	**Samples per Location**	**Mean***	**Median**	**Minimum****	**Maximum**
Background Alluvial Wells (2002 Kelron Study)					
MW26	6	34	35	28	42
MW28	6	**98**	**100**	90	110
East Ash Pond Alluvial Wells (2002 Kelron Study)					
MW23	6	56	55	53	62
Upstream Middle Fork at Higginsville Bridge (2002 Kelron Study)	6	35.3	36	24	41
East Ash Pond Surface Water Samples (2002 Kelron Study) (monthly samples from Jan-May 2002)	5	26.5	30	8.4	42

Comments:
1. East Ash Pond alluvial well MW23 comes from same population as Background alluvial wells MW26 and MW28 based on the Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level.
2. Median Magnesium concentrations in East Ash Pond Surface Water Samples are lower than those observed in East Ash Pond alluvial well MW23 and the Middle Fork.
3. Median Magnesium concentrations upstream on the Middle Fork are within the range of the Background Alluvial Wells.

Parameter: Manganese, diss (mg/L)	**Samples per Location**	**Mean***	**Median**	**Minimum****	**Maximum**
Background Alluvial Wells (2002 Kelron Study)					
MW26	6	nd	nd	<0.005	<0.005
MW28	6	**0.062**	**0.065**	0.019	0.11
East Ash Pond Alluvial Wells (2002 Kelron Study)					
MW23	6	nd	nd	<0.005	<0.005
Upstream Middle Fork at Higginsville Bridge (2002 Kelron Study)	6	0.011	0.010	0.005	0.019
East Ash Pond Surface Water Samples (2002 Kelron Study) (monthly samples from Jan-May 2002)	5	0.025	0.024	0.003	0.057

Comments:
1. Background alluvial wells MW26 and MW28 have a statistically significant higher concentration than East Ash Pond alluvial well MW23 based on the Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level.
2. Median Manganese concentrations upstream on the Middle Fork are within the range of the Background Alluvial Wells.

Notes:
* Less than points were replaced by one-half the detection limit.
** Some parameters had multiple detection limits. Lowest detection limit is reported.
*** Sample data contained censored values, did not compute means.
nd No samples were above method detection limit.
Highest mean and median concentrations of parameter are shown in boldface.

Table 8. Summary of Groundwater Quality Data in Unlithified Deposits, East Ash Pond, and Middle Fork River

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant, Illinois

Parameter: Molybdenum, diss (mg/L)	**Samples per Location**	**Mean***	**Median***	**Minimum****	**Maximum**
Background Bedrock Wells (2002 Kelron Study)					
MW26	6	nd	nd	<0.010	<0.010
MW28	6	nd	nd	<0.010	<0.010
East Ash Pond Bedrock Wells (2002 Kelron Study)					
MW23	6	nd	nd	<0.010	<0.010
East Ash Pond Surface Water Samples (2002 Kelron Study)					
(monthly samples from Jan-May 2002)	5	**0.22**	**0.24**	0.130	0.298

Comments:
1. All Bedrock Wells (Background and East Ash Pond wells) had no detectable concentrations of Molybdenum.
2. East Ash Pond Surface Water Samples had Molybdenum in all samples, ranging from 0.13 to 0.298 mg/L.

Parameter: Phosphorus, diss (mg/L)	**Samples per Location**	**Mean***	**Median***	**Minimum****	**Maximum**
Background Alluvial Wells (2002 Kelron Study)					
MW26	6	0.060	0.057	0.018	0.095
MW28	6	0.019	0.022	<0.010	0.029
East Ash Pond Alluvial Wells (2002 Kelron Study)					
MW23	6	0.011	0.010	<0.010	0.017
Upstream Middle Fork at Higginsville Bridge (2002 Kelron Study)	6	**0.104**	**0.063**	0.014	0.310
East Ash Pond Surface Water Samples (2002 Kelron Study)					
(monthly samples from Jan-May 2002)	5	0.071	0.031	0.010	0.23

Comments:
1. Background alluvial wells MW26 and MW28 have a statistically significant higher concentration than East Ash Pond alluvial well MW23 based on the Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level.
2. Median Phosphorus concentrations upstream on the Middle Fork are two times greater than those observed in the East Ash Pond Surface Water Samples.
3. East Ash Pond alluvial well MW23 has the lowest phosphorus concentrations compared to all other locations.

Parameter: Potassium, diss (mg/L)	**Samples per Location**	**Mean***	**Median**	**Minimum****	**Maximum**
Background Alluvial Wells (2002 Kelron Study)					
MW26	6	2.35	2.35	2.2	2.5
MW28	6	0.97	0.82	0.7	1.8
East Ash Pond Alluvial Wells (2002 Kelron Study)					
MW23	6	3.32	3.25	2.8	4.0
Upstream Middle Fork at Higginsville Bridge (2002 Kelron Study)	6	1.60	1.20	1.1	3.0
East Ash Pond Surface Water Samples (2002 Kelron Study)					
(monthly samples from Jan-May 2002)	5	**24.0**	**25.0**	17	31

Comments:
1. East Ash Pond alluvial well MW23 has a statistically significant higher concentration than Background alluvial wells MW26 and MW28 based on the Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level.
2. Median Potassium concentrations in East Ash Pond Surface Water Samples are 7.7 times greater than those in East Ash Pond alluvial well MW23.
3. Median Potassium concentrations upstream on the Middle Fork are within the range of the Background Alluvial Wells.

Notes:
* Less than points were replaced by one-half the detection limit.
** Some parameters had multiple detection limits. Lowest detection limit is reported.
*** Sample data contained censored values, did not compute means.
nd No samples were above method detection limit.
Highest mean and median concentrations of parameter are shown in boldface.

Table 8. Summary of Groundwater Quality Data in Unlithified Deposits, East Ash Pond, and Middle Fork River

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant, Illinois

Parameter: Selenium, diss (mg/L)	**Samples per Location**	**Mean***	**Median**	**Minimum****	**Maximum**
Background Bedrock Wells (2002 Kelron Study)					
MW26	6	nd	nd	<0.005	<0.005
MW28	6	0.004	0.003	<0.005	0.005
East Ash Pond Bedrock Wells (2002 Kelron Study)					
MW23	6	***	0.003	<0.005	0.006
Upstream Middle Fork at Higginsville Bridge (2002 Kelron Study)	6	***	0.003	<0.005	0.005
East Ash Pond Surface Water Samples (2002 Kelron Study) (monthly samples from Jan-May 2002)	5	***	**0.022**	<0.005	0.043

Comments:
1. All Alluvial Wells (Background and East Ash Pond wells) had Selenium concentrations equal to or less than 0.006 milligrams per Liter.
2. East Ash Pond Surface Water Samples had median Selenium concentrations at least 7 times greater than in Background Wells or East Ash Pond alluvial well MW23.

Parameter: Sodium (mg/L)	**Samples per Location**	**Mean***	**Median**	**Minimum****	**Maximum**
Background Alluvial Wells (2002 Kelron Study)					
MW26	6	4.2	4.2	3.1	5.1
MW28	6	17.0	17.0	15.0	19.0
East Ash Pond Alluvial Wells (2002 Kelron Study)					
MW23	6	17.7	19.5	8.4	26
Upstream Middle Fork at Higginsville Bridge (2002 Kelron Study)	6	9.4	9.2	7	14
East Ash Pond Surface Water Samples (2002 Kelron Study) (monthly samples from Jan-May 2002)	5	**160**	**140**	100	240

Comments:
1. East Ash Pond alluvial well MW23 has a statistically significant higher concentration than Background alluvial wells MW26 and MW28 based on the Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level.
2. Median Sodium concentrations in East Ash Pond Surface Water Samples are 7.2 times greater than those in East Ash Pond alluvial well MW23.
3. Median Sodium concentrations upstream on the Middle Fork are within the range of the Background Alluvial Wells.

Parameter: Strontium, diss (mg/L)	**Samples per Location**	**Mean***	**Median**	**Minimum****	**Maximum**
Background Alluvial Wells (2002 Kelron Study)					
MW26	6	0.07	0.07	0.067	0.076
MW28	6	0.33	0.32	0.300	0.390
East Ash Pond Alluvial Wells (2002 Kelron Study)					
MW23	6	0.14	0.14	0.128	0.160
Upstream Middle Fork at Higginsville Bridge (2002 Kelron Study)	6	0.12	0.12	0.094	0.160
East Ash Pond Surface Water Samples (2002 Kelron Study) (monthly samples from Jan-May 2002) not applicable	5	**0.51**	**0.57**	0.27	0.65

Comments:
1. East Ash Pond alluvial well MW23 comes from same population as Background alluvial wells MW26 and MW28 based on the Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level.
2. Median Strontium concentrations in East Ash Pond Surface Water Samples are 4 times greater than those in East Ash Pond alluvial well MW23.
3. Median Strontium concentrations upstream on the Middle Fork are within the range of the Background Alluvial Wells.

Notes:
* Less than points were replaced by one-half the detection limit.
** Some parameters had multiple detection limits. Lowest detection limit is reported.
*** Sample data contained censored values, did not compute means.
nd No samples were above method detection limit.
Highest mean and median concentrations of parameter are shown in boldface.

Table 8. Summary of Groundwater Quality Data in Unlithified Deposits, East Ash Pond, and Middle Fork River

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant, Illinois

Parameter: Sulfate (mg/L)	**Samples per Location**	**Mean***	**Median***	**Minimum****	**Maximum**
Background Alluvial Wells (2002 Kelron Study)					
MW26	6	23.8	23.5	18	30
MW28	6	273	270	170	360
East Ash Pond Alluvial Wells (2002 Kelron Study)					
MW23	6	327	320	280	380
Upstream Middle Fork at Higginsville Bridge (2002 Kelron Study)	6	40	41.5	26	52
East Ash Pond Surface Water Samples (2002 Kelron Study) (monthly samples from Jan-May 2002)	5	**808**	**780**	440	1,500

Comments:

1. East Ash Pond alluvial well MW23 has a statistically significant higher concentration than Background alluvial wells MW26 and MW28 based on the Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level.
2. Median Sulfate concentrations in East Ash Pond Surface Water Samples are 2.4 times greater than those in East Ash Pond alluvial well MW23.
3. Median Sulfate concentrations upstream on the Middle Fork are within the range of the Background Alluvial Wells.

Parameter: TDS (mg/L)	**Samples per Location**	**Mean***	**Median**	**Minimum****	**Maximum**
Background Alluvial Wells (2002 Kelron Study)					
MW26	6	403	395	290	520
MW28	6	1,038	1,040	900	1,200
East Ash Pond Alluvial Wells (2002 Kelron Study)					
MW23	6	868	860	810	970
Upstream Middle Fork at Higginsville Bridge (2002 Kelron Study)	6	382	385	290	430
East Ash Pond Surface Water Samples (2002 Kelron Study) (monthly samples from Jan-May 2002)	5	**1,650**	**1,800**	950	2,100

Comments:

1. East Ash Pond alluvial well MW23 comes from same population as Background alluvial wells MW26 and MW28 based on the Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level.
2. Median TDS concentrations in East Ash Pond Surface Water Samples are 2 times greater than those in East Ash Pond alluvial well MW23.
3. Median TDS concentrations upstream on the Middle Fork are slighly lower than the Background Alluvial Wells.

Parameter: Vanadium (mg/L)	**Samples per Location**	**Mean***	**Median***	**Minimum****	**Maximum**
Background Bedrock Wells (2002 Kelron Study)					
MW26	6	nd	nd	<0.010	<0.010
MW28	6	nd	nd	<0.010	<0.010
East Ash Pond Bedrock Wells (2002 Kelron Study)					
MW23	6	nd	nd	<0.010	<0.010
East Ash Pond Surface Water Samples (2002 Kelron Study) (monthly samples from Jan-May 2002)	5	**0.04**	**0.03**	<0.010	0.078

Comments:

1. All Alluvial Wells (Background and East Ash Pond wells) had Vanadium concentrations below 0.01 milligrams per Liter.
2. East Ash Pond Surface Water Samples had median Vanadium concentrations at least 3 times greater than in Background Wells or East Ash Pond Alluvial Wells.

Notes:

*	Less than points were replaced by one-half the detection limit.
**	Some parameters had multiple detection limits. Lowest detection limit is reported.
***	Sample data contained censored values, did not compute means.
na	Not analyzed.
nd	No samples were above method detection limit.

Highest mean and median concentrations of parameter are shown in boldface.

Table 9. Summary of Impacts on Groundwater Quality in Unlithified Deposits

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant, Illinois

Parameter	COLUMN 2 Mean Groundwater Concentrations in Alluvial Wells[1] at East Ash Pond Compared to Background Alluvial Wells[2]	COLUMN 3 Groundwater Quality in East Ash Pond Alluvial Wells[1] Compared to East Ash Pond Surface Water	Impact by East Ash Pond on Groundwater Quality in Alluvial Deposits	Other Conclusions
Aluminum	**0**	LT	No impact	
Barium	**LT**	LT	No impact	
Boron	GT	LT	**Uncertain**	Median B in MW23 is above background by 0.15 mg/L, but at 0.27 mg/L the source of impact, if any, is uncertain. Slightly higher B may be from natural variation, presence of former coal mine, or East Ash Pond.
Calcium	**0**	LT	No impact	
Chloride	GT	LT	**Uncertain**	Median Cl in MW23 is above background by 26 mg/L and only 9 mg/L above Middle Fork. Slighly higher Cl may be due to natural variation, presence of former coal mine, or East Ash Pond.
Iron	**0**	**All non-detect**	No impact	
Lithium	**0**	LT	No impact	
Magnesium	**0**	GT	No impact	
Manganese	**LT**	LT	No impact	
Molybdenum	**All wells non-detect**	LT	No impact	
Phosphorus	**LT**	LT	No impact	
Potassium	GT	LT	**Uncertain**	Median K in MW23 is above background by 0.9 mg/L, but at 3.25 mg/L may be due to either natural variation or impacts from former coal mine. Concentrations are similar to bedrock.
Selenium	**0**	LT	No impact	
Sodium	GT	LT	**Uncertain**	Median Na in MW23 is above background by 2.5 mg/L, but at 19.5 mg/L the source of impact, if any, is uncertain. Slightly higher Na may be from natural variation, presence of former coal mine, or East Ash Pond.
Strontium	**0**	LT	No impact	
Sulfate	GT	LT	**Uncertain**	Median sulfate in MW23 is above background by 50 mg/L. Higher concentrations are most likely from natural variation. Impacts by East Ash Pond or nearby coal mine are relatively minor or negligible.
TDS	**0**	LT	No impact	
Vanadium	**0**	LT	No impact	

Key to Symbols

COLUMN 2

0	Groundwater quality for given parameter in East Ash Pond wells is statistically from the same population as Background Wells (26 and 28) based on the Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level.
LT	Groundwater quality for given parameter in East Ash Pond wells has a statistically significant lower mean concentration compared to Background Wells (26 and 28) based on the Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level.
GT	Groundwater quality for given paramter in East Ash Pond wells has a statistically significant higher mean concentration compared to Background Wells (26 and 28) based on the Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level.

COLUMN 3

LT	Groundwater concentrations in East Ash Pond Alluvial Wells are less than East Ash Pond surface water for given parameter.
GT	Groundwater concentrations in East Ash Pond Alluvial Wells are greater than East Ash Pond surface water for given parameter.

[1] Alluvial wells at East Ash Pond include MW13B, MW16B, and MW23. Only MW23 had sufficient water for sampling in 2002.

[2] Background alluvial wells used for statistical comparison to East Ash Pond wells using Wilcoxon Rank-Sum Test include the following: MW26 and MW28.

Table 10. Correlation Between Groundwater Quality Parameters in Bedrock

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant, Illinois

	Aluminum	Alkalinity	Boron	Barium	Calcium	Chloride	Iron	Potassium	Lithium	Magnesium	Manganese	Sodium	Selenium	Sulfate	Strontium	TDS
Aluminum		-0.17	-0.02	-0.01	0.16	-0.09	0.06	0.68	0.63	0.10	0.05	-0.05	0.65	0.09	0.27	-0.03
Alkalinity			0.39	0.39	-0.14	0.46	0.46	0.56	0.42	-0.07	0.05	0.70	0.21	0.01	0.46	0.67
Boron				0.13	-0.20	0.65	-0.02	0.25	0.47	-0.10	-0.04	0.63	-0.02	-0.19	0.17	0.61
Barium					-0.11	0.77	**0.87**	0.38	0.28	-0.04	-0.16	0.73	-0.06	-0.23	0.54	0.72
Calcium						-0.30	0.06	0.18	0.01	**0.98**	**0.81**	-0.34	0.51	**0.86**	0.57	0.00
Chloride							0.55	0.32	0.48	-0.17	-0.23	**0.94**	-0.17	-0.37	0.33	**0.88**
Iron								0.40	0.31	0.11	0.10	0.58	0.22	0.06	0.56	0.62
Potassium									0.67	0.15	0.07	0.37	0.50	0.06	0.73	0.42
Lithium										0.05	0.08	0.45	0.48	-0.08	0.38	0.47
Magnesium											**0.86**	-0.21	0.46	**0.86**	0.58	0.14
Manganese												-0.18	0.52	**0.91**	0.38	0.15
Sodium													-0.08	-0.29	0.33	**0.93**
Selenium														0.63	0.36	0.06
Sulfate															0.36	0.01
Strontium																0.54
TDS																

Notes:

between the variables. The number of pairs of data values used to compute each coefficient was 60 (6 observations of each chemical parameter in groundwater per well for wells MW13A, MW16A, MW22, MW24, MW25, MW27, MW29, MW30, MW31, and MW32.
Generally, correlations greater than 0.50 or less than -0.50 indicate statistically significant non-zero correlations at the 95% confidence level.

Data for determination of correlations are the 6 monthly samples collected from March to August 2002 at bedrock wells MW13A, MW16A, MW22, MW24, MW25, MW27, MW29, MW30, MW31, and MW32.

0.89 Bold-face numbers highlighted in boxes indicate a high level of correlation between two parameters. Positive numbers indicate that the parameters are directly proportional and negative numbers indicate the parameters are inversely proportional.

Table 11. Summary of Groundwater Quality Data in Bedrock and East Ash Pond
Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant, Illinois

Parameter: Aluminum, diss (mg/L)	**Number of Wells**	**Samples per Location**	**Mean***	**Median***	**Minimum****	**Maximum**
Background Bedrock Wells (2002 Kelron Study)						
MW25	1	6	0.006	0.007	<0.005	0.009
MW27	1	6	0.011	0.011	0.010	0.013
MW29	1	6	0.006	0.007	<0.005	0.009
MW30	1	6	0.016	0.010	0.009	0.044
MW31	1	5	0.006	0.009	<0.005	0.009
ISGS Background Wells (Scientific Literature and State Databases) see Appendix A						
	27	1	***	**0.20**	<0.02	8.47
ISGS Background Wells (2002 ISGS Study) see Appendix A						
(wells 1349,21903,23343,25531)	4	1	<0.1	<0.1	<0.1	<0.1
East Ash Pond Bedrock Wells (2002 Kelron Study)						
MW13A	1	6	0.008	0.007	<0.005	0.017
MW16A	1	6	0.008	0.008	0.005	0.013
MW22	1	6	0.008	0.007	0.005	0.013
MW24	1	6	0.016	0.010	0.007	0.040
MW32	1	6	0.036	0.042	<0.005	0.047
East Ash Pond Surface Water Samples (2002 Kelron Study)						
(monthly samples from Jan-May 2002)	not applicable	5	**0.124**	**0.140**	0.011	0.25

Comments:
1. All East Ash Pond Bedrock Wells except MW32 come from same population as Background Bedrock Wells (2002 Kelron Study) based on Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level.
2. East Ash Pond Bedrock Well MW32 has a higher mean and median concentration than the Background Bedrock Wells (2002 Kelron Study) and other shallower East Ash Pond Bedrock Wells.
3. Highest mean and median concentrations of Aluminum are found in East Ash Pond water samples and in ISGS Background Wells (Scientific Literature and State Databases).
4. Median Aluminum concentrations in East Ash Pond Surface Water Samples are 12 to 20 times greater than in Background Bedrock Wells (2002 Kelron Study) and 3 to 20 times greater than in East Ash Pond Bedrock Wells (2002 Kelron Study).

Parameter: Barium, diss (mg/L)	**Number of Wells**	**Samples per Location**	**Mean***	**Median**	**Minimum****	**Maximum**
Background Bedrock Wells (2002 Kelron Study)						
MW25	1	6	**1.66**	**1.60**	1.6	1.7
MW27	1	6	**0.66**	**0.67**	0.63	0.69
MW29	1	6	**0.47**	**0.47**	0.45	0.49
MW30	1	6	**4.57**	**4.30**	4.2	5.3
MW31	1	6	**0.57**	**0.67**	0.052	0.71
ISGS Background Wells (Scientific Literature and State Databases) see Appendix A						
	27	1	***	0.28	0.02	2.44
ISGS Background Wells (2002 ISGS Study) see Appendix A						
(wells 1349,21903,23343,25531)	4	1	**0.46**	**0.37**	0.14	0.98
East Ash Pond Bedrock Wells (2002 Kelron Study)						
MW13A	1	6	**0.41**	**0.41**	0.39	0.43
MW16A	1	6	0.07	0.04	0.04	0.18
MW22	1	6	0.06	0.06	0.06	0.071
MW24	1	6	0.16	0.14	0.13	0.25
MW32	1	6	**0.48**	**0.49**	0.45	0.50
East Ash Pond Surface Water Samples (2002 Kelron Study)						
(monthly samples from Jan-May 2002)	not applicable	5	0.14	0.13	0.03	0.28

Comments:
1. Each of the East Ash Pond Bedrock Wells have a statistically significant lower mean concentration than the Background Bedrock Wells (2002 Kelron Study) based on the Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level.
2. Lowest mean and median concentrations of Barium are found in East Ash Pond water samples. Highest Barium concentrations are found in the Background Bedrock Wells (2002 Kelron Study) and in the East Ash Pond Bedrock Wells MW13A and MW32.

Notes:
* Less than points were replaced by one-half the detection limit.
** Some parameters had multiple detection limits. Lowest detection limit is reported.
*** Sample data contained censored values, did not compute means.
Highest mean and median concentrations of parameter are shown in boldface.

Table 11. Summary of Groundwater Quality Data in Bedrock and East Ash Pond
Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant, Illinois

Parameter: Boron, diss (mg/L)	**Number of Wells**	**Samples per Location**	**Mean***	**Median**	**Minimum****	**Maximum**
Background Bedrock Wells (2002 Kelron Study)						
MW25	1	6	1.17	1.15	1.10	1.30
MW27	1	6	0.83	0.83	0.79	0.87
MW29	1	6	1.12	1.10	1.10	1.20
MW30	1	6	0.90	0.99	0.85	0.96
MW31	1	6	0.68	0.77	0.20	0.82
ISGS Background Wells (Scientific Literature and State Databases) see Appendix A						
	30	1	***	0.28	ND	2.08
ISGS Background Wells (2002 ISGS Study) see Appendix A						
(wells 1349,21903,23343,25531)	4	1	0.85	0.85	0.29	1.4
East Ash Pond Bedrock Wells (2002 Kelron Study)						
MW13A	1	6	**1.40**	**1.40**	1.30	1.60
MW16A	1	6	0.79	0.77	0.70	0.92
MW22	1	6	0.33	0.32	0.30	0.38
MW24	1	6	0.55	0.47	0.43	0.86
MW32	1	6	**1.45**	**1.50**	1.30	1.50
East Ash Pond Surface Water Samples (2002 Kelron Study)						
(monthly samples from Jan-May 2002)	not applicable	5	**10.88**	**10.00**	5.1	18.0

Comments:

1. East Ash Pond Bedrock Wells MW16A, MW22, and MW24 have statistically significant lower concentrations than Background Wells (2002 Kelron Study) based on Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level.
   Bedrock Wells MW13A and MW32 have statistically significant higher concentrations than Background Wells (2002 Kelron Study).
2. Median Boron concentrations in East Ash Pond Surface Water Samples are 9 to 13 times greater than in Background Bedrock Wells (2002 Kelron Study) and 7 to 31 times greater than in East Ash Pond Bedrock Wells.

Parameter: Calcium, diss (mg/L)	**Number of Wells**	**Samples per Location**	**Mean***	**Median**	**Minimum****	**Maximum**
Background Bedrock Wells (2002 Kelron Study)						
MW25	1	6	84.7	85.0	80	89
MW27	1	6	31.8	32.0	30	33
MW29	1	6	28.7	29.5	26	30
MW30	1	6	34.5	34.0	31	38
MW31	1	6	79.3	85.5	13	110
ISGS Background Wells (Scientific Literature and State Databases) see Appendix A						
	31	1	***	83	<1	951
ISGS Background Wells (2002 ISGS Study) see Appendix A						
(wells 1349,21903,23343,25531)	4	1	69.9	55.8	36.8	131
East Ash Pond Bedrock Wells (2002 Kelron Study)						
MW13A	1	6	19.8	20.0	18	21
MW16A	1	6	**149.3**	**135.0**	96	210
MW22	1	6	48.7	49.0	45	51
MW24	1	6	34.0	35.5	25	38
MW32	1	6	15.2	16.0	13	17
East Ash Pond Surface Water Samples (2002 Kelron Study)						
(monthly samples from Jan-May 2002)	not applicable	5	**322**	**350**	150	450

Comments:

1. East Ash Pond Bedrock Wells MW13A and MW32 have a statistically significant lower mean concentration than the Background Bedrock Wells (2002 Kelron Study) based on the Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level.
   East Ash Pond Bedrock Wells MW22 and MW24 are statistically from the same population as the Background Bedrock Wells.
   East Ash Pond Bedrock Well MW16A is has a statistically significant higher mean concentration than the Background Bedrock Wells.
2. Highest mean and median concentrations of Calcium are found in East Ash Pond water samples.
3. Median Calcium concentrations in East Ash Pond Surface Water Samples are 4 to 11 times greater than in Background Bedrock Wells (2002 Kelron Study) and 2.6 to 22 times greater than in East Ash Pond Bedrock Wells.

Notes:

* Less than points were replaced by one-half the detection limit.

** Some parameters had multiple detection limits. Lowest detection limit is reported.

*** Sample data contained censored values, did not compute means.

Highest mean and median concentrations of parameter are shown in boldface.

Table 11. Summary of Groundwater Quality Data in Bedrock and East Ash Pond
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Vermilion Power Plant, Illinois

Parameter: Chloride, total (mg/L)	**Number of Wells**	**Samples per Location**	**Mean***	**Median**	**Minimum****	**Maximum**
Background Bedrock Wells (2002 Kelron Study)						
MW25	1	6	**820**	**840**	720	910
MW27	1	6	353	370	290	390
MW29	1	6	333	285	270	570
MW30	1	6	**1,233**	**1,200**	1,100	1,400
MW31	1	6	60	69	19	79
ISGS Background Wells (Scientific Literature and State Databases) see Appendix A						
	31	1	1,689	13	2.1	30,269
ISGS Background Wells (2002 ISGS Study) see Appendix A						
(wells 1349,21903,23343,25531)	4	1	244	165	5	640
East Ash Pond Bedrock Wells (2002 Kelron Study)						
MW13A	1	6	**630**	**570**	500	1000
MW16A	1	6	90	71	45	170
MW22	1	6	11	11	9.9	13
MW24	1	6	65	40	31	190
MW32	1	6	**860**	**845**	830	930
East Ash Pond Surface Water Samples (2002 Kelron Study)						
(monthly samples from Jan-May 2002)	not applicable	5	172	200	100	240

Comments:

1. East Ash Pond Bedrock Wells MW16A, MW22, and MW24 have statistically significant lower concentrations than Background Wells (2002 Kelron Study) based on Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level. Wells MW13A and MW32 are statistically from the same population as the Background Wells (2002 Kelron Study).
2. Median Chloride concentrations in East Ash Pond Surface Water Samples are 3 to 18 times greater than in East Ash Pond Bedrock Wells MW16A, MW22, and MW24 (2002 Kelron Study). East Ash Pond Bedrock Wells MW13A and MW32 are 3 to 4 times greater than the East Ash Pond Surface Water Samples.

Parameter: Iron, diss (mg/L)	**Number of Wells**	**Samples per Location**	**Mean***	**Median***	**Minimum****	**Maximum**
Background Bedrock Wells (2002 Kelron Study)						
MW25	1	6	0.13	0.05	<0.025	0.27
MW27	1	6	0.19	0.18	0.10	0.22
MW29	1	6	0.22	0.23	<0.025	0.40
MW30	1	6	**1.66**	**1.70**	0.83	2.20
MW31	1	6	0.37	0.33	0.26	0.55
ISGS Background Wells (Scientific Literature and State Databases) see Appendix A						
	31	1	***	**0.69**	<0.006	26.8
ISGS Background Wells (2002 ISGS Study) see Appendix A						
(wells 1349,21903,23343,25531)	4	1	**1.95**	**2.00**	<0.01	3.8
East Ash Pond Bedrock Wells (2002 Kelron Study)						
MW13A	1	6	0.15	0.16	0.067	0.25
MW16A	1	6	0.34	0.33	0.063	0.79
MW22	1	6	0.12	0.13	0.096	0.15
MW24	1	6	0.036	0.013	<0.025	0.11
MW32	1	6	0.037	0.024	<0.025	0.11
East Ash Pond Surface Water Samples (2002 Kelron Study)						
(monthly samples from Jan-May 2002)	not applicable	5	0.013	0.013	0.013	0.013

Comments:

1. All East Ash Pond Bedrock Wells have a statistically significant lower mean concentration than the Background Bedrock Wells (2002 Kelron Study) or are statistically from the same population based on the Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level.
2. Highest mean and median concentrations of Iron are found in ISGS Background Wells (2002 ISGS Study and Scientific Literature and State Databases), and in Background Bedrock Well MW30 (Kelron Study).

Notes:

* Less than points were replaced by one-half the detection limit.
** Some parameters had multiple detection limits. Lowest detection limit is reported.
*** Sample data contained censored values, did not compute means.
Highest mean and median concentrations of parameter are shown in boldface.

Table 11. Summary of Groundwater Quality Data in Bedrock and East Ash Pond
Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant, Illinois

Parameter: Lithium, diss (mg/L)	Number of Wells	Samples per Location	Mean*	Median*	Minimum**	Maximum
Background Bedrock Wells (2002 Kelron Study)						
MW25	1	6	**0.11**	**0.08**	0.071	0.18
MW27	1	6	0.04	0.04	<0.005	0.086
MW29	1	6	0.04	0.04	<0.005	0.089
MW30	1	6	**0.11**	**0.10**	0.010	0.26
MW31	1	6	0.09	0.05	<0.005	0.40
ISGS Background Wells (Scientific Literature and State Databases) see Appendix A						
	31	1	na	na	na	na
ISGS Background Wells (2002 ISGS Study) see Appendix A						
(wells 1349,21903,23343,25531)	4	1	0.025	0.015	0.01	0.07
East Ash Pond Bedrock Wells (2002 Kelron Study)						
MW13A	1	6	**0.11**	**0.08**	0.070	0.19
MW16A	1	6	0.04	0.04	0.022	0.069
MW22	1	6	0.04	0.03	<0.005	0.089
MW24	1	6	0.02	0.02	<0.005	0.070
MW32	1	6	**0.12**	**0.09**	<0.087	0.23
East Ash Pond Surface Water Samples (2002 Kelron Study)						
(monthly samples from Jan-May 2002)	not applicable	5	**0.19**	**0.27**	<0.005	0.30

Comments:

1. East Ash Pond Bedrock Wells MW16A, MW22, and MW24 have statistically significant lower concentrations than Background Wells (2002 Kelron Study) or are statistically from the same population based on the Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level. Wells MW13A and MW32 have a statistically significant higher mean concentration than the Background Bedrock Wells.
2. Median Lithium concentrations in East Ash Pond Surface Water Samples are 3 to 14 times greater than in East Ash Pond Bedrock Wells (2002 Kelron Study) and IGSG Background Wells (2002 ISGS Study).

Parameter: Magnesium, diss (mg/L)	Number of Wells	Samples per Location	Mean*	Median	Minimum**	Maximum
Background Bedrock Wells (2002 Kelron Study)						
MW25	1	6	44.7	44.5	44	46
MW27	1	6	19.5	19.5	19	20
MW29	1	6	15.0	15.0	14	16
MW30	1	6	25.2	25.0	24	27
MW31	1	6	33.7	37.0	4.1	46
ISGS Background Wells (Scientific Literature and State Databases) see Appendix A						
	31	1	***	31.1	<0.5	454
ISGS Background Wells (2002 ISGS Study) see Appendix A						
(wells 1349,21903,23343,25531)	4	1	39.3	37.0	27	56
East Ash Pond Bedrock Wells (2002 Kelron Study)						
MW13A	1	6	18.2	18.0	18	19
MW16A	1	6	**77.0**	**72.5**	53	100
MW22	1	6	26.3	26.0	26	27
MW24	1	6	16.2	16.5	14	17
MW32	1	6	15.5	16.0	14	16
East Ash Pond Surface Water Samples (2002 Kelron Study)						
(monthly samples from Jan-May 2002)	not applicable	5	26.5	30.0	8.4	42

Comments:

1. East Ash Pond Bedrock Wells MW13A , MW24, and MW32 have a statistically significant lower mean concentration than the Background Bedrock Wells (2002 Kelron Study) based on the Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level.
   East Ash Pond Bedrock Well MW22 is statistically from the same population as the Background Bedrock Wells.
   East Ash Pond Bedrock Well MW16A is has a statistically significant higher mean concentration than the Background Bedrock Wells.
2. Highest median concentrations of Magnesium are found in ISGS Background Wells (Scientific Literature and State Databases) and in East Ash Pond Bedrock Well MW16A.

Notes:

* Less than points were replaced by one-half the detection limit.
** Some parameters had multiple detection limits. Lowest detection limit is reported.
*** Sample data contained censored values, did not compute means.
na Not analyzed.
Highest mean and median concentrations of parameter are shown in boldface.

Table 11. Summary of Groundwater Quality Data in Bedrock and East Ash Pond
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Parameter: Manganese, diss (mg/L)	**Number of Wells**	**Samples per Location**	**Mean***	**Median**	**Minimum****	**Maximum**
Background Bedrock Wells (2002 Kelron Study)						
MW25	1	6	**0.041**	**0.041**	0.028	0.053
MW27	1	6	0.023	0.022	0.018	0.029
MW29	1	6	0.015	0.016	0.010	0.020
MW30	1	6	**0.043**	**0.041**	0.034	0.059
MW31	1	6	**0.085**	**0.081**	0.072	0.110
ISGS Background Wells (Scientific Literature and State Databases) see Appendix A						
	31	1	***	**0.100**	0.015	1.47
ISGS Background Wells (2002 ISGS Study) see Appendix A						
(wells 1349,21903,23343,25531)	4	1	**0.057**	**0.041**	0.035	0.11
East Ash Pond Bedrock Wells (2002 Kelron Study)						
MW13A	1	6	**0.082**	**0.087**	0.018	0.120
MW16A	1	6	**0.330**	**0.345**	0.200	0.390
MW22	1	6	0.017	0.017	0.014	0.019
MW24	1	6	0.012	0.012	0.010	0.012
MW32	1	6	0.014	0.013	0.011	0.022
East Ash Pond Surface Water Samples (2002 Kelron Study)						
(monthly samples from Jan-May 2002)	not applicable	5	0.025	0.024	0.003	0.057

Comments:

1. East Ash Pond Bedrock Wells MW22, MW24, and MW32 have statistically significant lower concentrations than Background Wells (2002 Kelron Study) based on the Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level. Wells MW13A and MW16A have a statistically significant higher mean concentration than the Background Bedrock Wells.
2. Median Manganese concentrations in Background Bedrock Wells MW25, MW30, and MW31 (2002 Kelron Study), ISGS Background Wells (ScientificLiterature and State Databases), and ISGS Background Wells (2002 ISGS Study) are significantly greater than in East Ash Pond Surface Water Samples and East Ash Pond Bedrock Wells MW22, MW24, and MW32 (2002 Kelron Study).
3. Median Manganese concentrations in East Ash Pond Bedrock Well MW16A is 14 times greater than median concentrations for the East Ash Pond Surface Water Samples.

Parameter: Molybdenum, diss (mg/L)	**Number of Wells**	**Samples per Location**	**Mean***	**Median***	**Minimum****	**Maximum**
Background Bedrock Wells (2002 Kelron Study)						
MW25	1	6	nd	nd	<0.010	<0.010
MW27	1	6	nd	nd	<0.010	<0.010
MW29	1	6	nd	nd	<0.005	<0.010
MW30	1	6	nd	nd	<0.010	<0.010
MW31	1	6	nd	nd	<0.010	<0.010
ISGS Background Wells (Scientific Literature and State Databases) see Appendix A						
	31	1	na	na	na	na
ISGS Background Wells (2002 ISGS Study) see Appendix A						
(wells 1349,21903,23343,25531)	4	1	nd	nd	<0.01	<0.01
East Ash Pond Bedrock Wells (2002 Kelron Study)						
MW13A	1	6	nd	nd	<0.010	<0.010
MW16A	1	6	nd	nd	<0.010	<0.010
MW22	1	6	nd	nd	<0.010	<0.010
MW24	1	6	nd	nd	<0.010	<0.010
MW32	1	6	nd	nd	<0.010	<0.010
East Ash Pond Surface Water Samples (2002 Kelron Study)						
(monthly samples from Jan-May 2002)	not applicable	5	**0.22**	**0.24**	0.130	0.298

Comments:

1. All Bedrock Wells (Background and East Ash Pond wells) had no detectable concentrations of Molybdenum.
2. East Ash Pond Surface Water Samples had Molybdenum in all samples, ranging from 0.13 to 0.298 mg/L.

Notes:

* Less than points were replaced by one-half the detection limit.
** Some parameters had multiple detection limits. Lowest detection limit is reported.
*** Sample data contained censored values, did not compute means.
na Not analyzed.
nd No samples were above method detection limit.
Highest mean and median concentrations of parameter are shown in boldface.

Table 11. Summary of Groundwater Quality Data in Bedrock and East Ash Pond
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Parameter: Phosphorus, diss (mg/L)	**Number of Wells**	**Samples per Location**	**Mean***	**Median***	**Minimum****	**Maximum**
Background Bedrock Wells (2002 Kelron Study)						
MW25	1	6	0.012	0.008	<0.010	0.031
MW27	1	6	0.028	0.027	0.019	0.038
MW29	1	6	0.023	0.024	<0.010	0.036
MW30	1	6	0.037	0.036	0.027	0.053
MW31	1	6	0.067	0.041	0.032	0.19
ISGS Background Wells (Scientific Literature and State Databases) see Appendix A						
	31	1	na	na	na	na
ISGS Background Wells (2002 ISGS Study) see Appendix A						
(wells 1349,21903,23343,25531)	4	1	na	na	na	na
East Ash Pond Bedrock Wells (2002 Kelron Study)						
MW13A	1	6	0.038	0.033	0.022	0.070
MW16A	1	6	0.069	0.093	<0.010	0.110
MW22	1	6	0.015	0.017	<0.010	0.022
MW24	1	6	0.048	0.047	0.023	0.081
MW32	1	6	0.027	0.023	0.016	0.045
East Ash Pond Surface Water Samples (2002 Kelron Study)						
(monthly samples from Jan-May 2002)	not applicable	5	0.071	0.031	0.010	0.23

Comments:

1. East Ash Pond Bedrock Wells MW13A, MW16A, MW22, and MW32 are statistically from the same population or have statistically significant lower concentrations than Background Wells (2002 Kelron Study) based on the Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level. Well MW24 has a statistically significant higher mean concentration than Background Wells (2002 Kelron Study).

Parameter: Potassium, diss (mg/L)	**Number of Wells**	**Samples per Location**	**Mean***	**Median**	**Minimum****	**Maximum**
Background Bedrock Wells (2002 Kelron Study)						
MW25	1	6	5.2	5.2	4.9	5.4
MW27	1	6	3.3	3.4	3.1	3.6
MW29	1	6	3.2	3.2	3.1	3.4
MW30	1	6	6.6	6.6	6.2	7.4
MW31	1	6	9.4	8.2	6.6	17
ISGS Background Wells (Scientific Literature and State Databases) see Appendix A						
	30	1	7.4	2.1	0.67	63
ISGS Background Wells (2002 ISGS Study) see Appendix A						
(wells 1349,21903,23343,25531)	4	1	4.5	4.25	3.0	5.0
East Ash Pond Bedrock Wells (2002 Kelron Study)						
MW13A	1	6	4.8	4.9	4.5	5.2
MW16A	1	6	3.5	3.6	2.5	4.6
MW22	1	6	2.6	2.6	2.5	2.7
MW24	1	6	2.0	1.8	1.8	2.5
MW32	1	6	5.4	5.4	5.1	6.0
East Ash Pond Surface Water Samples (2002 Kelron Study)						
(monthly samples from Jan-May 2002)	not applicable	5	**24.0**	**25.0**	17	31

Comments:

1. East Ash Pond Bedrock Wells MW16A, MW22, and MW24 have a statistically significant lower mean concentration than the Background Bedrock Wells (2002 Kelron Study) based on the Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level. East Ash Pond Bedrock Well MW13A and MW32 are statistically from the same population as the Background Bedrock Wells.
2. Median Potassium concentrations in the East Ash Pond Surface Water Samples are 3 to 12 times greater than median concentrations in Background Bedrock Wells (2002 Kelron Study), ISGS Background Wells (Scientific Literature and State Databases), or ISGS Background Wells (2002 ISGS Study).

Notes:

*	Less than points were replaced by one-half the detection limit.
**	Some parameters had multiple detection limits. Lowest detection limit is reported.
***	Sample data contained censored values, did not compute means.
na	Not analyzed.
nd	No samples were above method detection limit.

Highest mean and median concentrations of parameter are shown in boldface.

Table 11. Summary of Groundwater Quality Data in Bedrock and East Ash Pond
Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant, Illinois

Parameter: Selenium, diss (mg/L)	**Number of Wells**	**Samples per Location**	**Mean***	**Median**	**Minimum****	**Maximum**
Background Bedrock Wells (2002 Kelron Study)						
MW25	1	6	nd	nd	<0.005	<0.005
MW27	1	6	***	***	0.005	<0.005
MW29	1	6	nd	nd	<0.005	<0.005
MW30	1	6	***	***	0.005	<0.005
MW31	1	6	***	***	0.005	<0.005
ISGS Background Wells (Scientific Literature and State Databases) see Appendix A						
	30	1	***	0.001	<0.001	0.002
ISGS Background Wells (2002 ISGS Study) see Appendix A						
(wells 1349,21903,23343,25531)	4	1	nd	nd	<0.1	<0.1
East Ash Pond Bedrock Wells (2002 Kelron Study)						
MW13A	1	6	nd	nd	<0.005	<0.005
MW16A	1	6	nd	nd	<0.005	<0.005
MW22	1	6	nd	nd	<0.005	<0.005
MW24	1	6	nd	nd	<0.005	<0.005
MW32	1	6	nd	nd	<0.005	<0.005
East Ash Pond Surface Water Samples (2002 Kelron Study)						
(monthly samples from Jan-May 2002)	not applicable	5	***	**0.022**	<0.005	0.043

Comments:

1. All Bedrock Wells (Background and East Ash Pond wells) had Selenium concentrations equal to or less than 0.005 milligrams per Liter.
2. East Ash Pond Surface Water Samples had median Selenium concentrations 22 times greater than in Background Wells or East Ash Pond Bedrock Wells.

Parameter: Sodium (mg/L)	**Number of Wells**	**Samples per Location**	**Mean***	**Median**	**Minimum****	**Maximum**
Background Bedrock Wells (2002 Kelron Study)						
MW25	1	6	385	390	360	400
MW27	1	6	267	270	250	280
MW29	1	6	257	250	250	280
MW30	1	6	**887**	**890**	850	910
MW31	1	6	176	195	88	210
ISGS Background Wells (Scientific Literature and State Databases) see Appendix A						
	31	1	1,083	28.7	6	18,078
ISGS Background Wells (2002 ISGS Study) see Appendix A						
(wells 1349,21903,23343,25531)	4	1	241	154	67	590
East Ash Pond Bedrock Wells (2002 Kelron Study)						
MW13A	1	6	**507**	**505**	490	520
MW16A	1	6	180	185	120	240
MW22	1	6	102	100	100	110
MW24	1	6	130	110	100	210
MW32	1	6	**730**	**735**	680	760
East Ash Pond Surface Water Samples (2002 Kelron Study)						
(monthly samples from Jan-May 2002)	not applicable	5	160	140	100	240

Comments:

1. East Ash Pond Bedrock Wells MW16A, MW22, and MW24 have a statistically significant lower mean concentration than the Background Bedrock Wells (2002 Kelron Study) based on the Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level. East Ash Pond Bedrock Well MW13A and MW32 have a statistically significant higher mean concentration than the Background Bedrock Wells.
2. Median Sodium concentrations in Background Bedrock Wells (2002 Kelron Study) are 1.4 to 6.4 times greater than the median East Ash Pond Surface Water Samples.
3. Median Sodium concentrations in East Ash Pond Bedrock Wells MW13A and MW32 are a 3.6 and 5.3 times greater, respectively, than the median concentration in the East Ash Pond Surface Water Samples and 6.4 times greater than East Ash Pond samples.

Notes:

*	Less than points were replaced by one-half the detection limit.
**	Some parameters had multiple detection limits. Lowest detection limit is reported.
***	Sample data contained censored values, did not compute means or medians.
na	Not analyzed.
nd	No samples were above method detection limit.

Highest mean and median concentrations of parameter are shown in boldface.

Table 11. Summary of Groundwater Quality Data in Bedrock and East Ash Pond
Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant, Illinois

Parameter: Strontium, diss (mg/L)	**Number of Wells**	**Samples per Location**	**Mean***	**Median**	**Minimum****	**Maximum**
Background Bedrock Wells (2002 Kelron Study)						
MW25	1	6	0.57	0.56	0.54	0.60
MW27	1	6	0.36	0.36	0.34	0.38
MW29	1	6	0.33	0.33	0.31	0.35
MW30	1	6	0.65	0.64	0.61	0.70
MW31	1	6	0.67	0.78	0.14	0.79
ISGS Background Wells (Scientific Literature and State Databases) see Appendix A						
	30	1	na	na	na	na
ISGS Background Wells (2002 ISGS Study) see Appendix A						
(wells 1349,21903,23343,25531)	4	1	0.71	0.55	0.23	1.5
East Ash Pond Bedrock Wells (2002 Kelron Study)						
MW13A	1	6	0.35	0.38	<0.366	0.39
MW16A	1	6	0.55	0.54	0.44	0.67
MW22	1	6	0.32	0.31	0.30	0.34
MW24	1	6	0.22	0.22	0.21	0.23
MW32	1	6	0.38	0.38	0.36	0.40
East Ash Pond Surface Water Samples (2002 Kelron Study)						
(monthly samples from Jan-May 2002)	not applicable	5	0.51	0.57	0.27	0.65

Comments:

1. East Ash Pond Bedrock Wells MW22 and MW24 have a statistically significant lower mean concentration than the Background Bedrock Wells (2002 Kelron Study) based on the Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level. East Ash Pond Bedrock Wells MW13A, MW16A, and MW32 are statistically from the same population as the Background Bedrock Wells.

Parameter: Sulfate (mg/L)	**Number of Wells**	**Samples per Location**	**Mean***	**Median***	**Minimum****	**Maximum**
Background Bedrock Wells (2002 Kelron Study)						
MW25	1	6	***	2.5	<5.0	7
MW27	1	6	nd	nd	<5.0	<5.0
MW29	1	6	nd	nd	<5.0	<5.0
MW30	1	6	4.5	4.3	<5.0	7
MW31	1	6	**123**	**125**	58	160
ISGS Background Wells (Scientific Literature and State Databases) see Appendix A						
	31	1	***	31	<1	847
ISGS Background Wells (2002 ISGS Study) see Appendix A						
(wells 1349,21903,23343,25531)	4	1	38	5.8	<0.1	140
East Ash Pond Bedrock Wells (2002 Kelron Study)						
MW13A	1	6	nd	nd	<5.0	<5.0
MW16A	1	6	**415**	**510**	120	620
MW22	1	6	30	31	27	32
MW24	1	6	35	34	30	41
MW32	1	6	nd	nd	<5.0	<5.0
East Ash Pond Surface Water Samples (2002 Kelron Study)						
(monthly samples from Jan-May 2002)	not applicable	5	**808**	**780**	440	1,500

Comments:

1. East Ash Pond Bedrock Wells MW16A, MW22, and MW24 have a statistically significant higher mean concentration than the Background Bedrock Wells (2002 Kelron Study) based on the Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level. East Ash Pond Bedrock Wells MW13A and MW32 are statistically from the same population as the Background Bedrock Wells.
2. Mean and median Sulfate concentrations in East Ash Pon Bedrock Wells MW13A, MW22, MW24, and MW32 are within range of Background Bedrock Wells (2002 Kelron Study), ISGS Background Wells (Scientific Literature and State Databases), and ISGS Background Wells (2002 ISGS Study).
3. Median Sulfate concentration in East Ash Pond Bedrock Well MW16A is 4 times greater than highest concentration in Background Bedrock Wells (i.e., Well MW31).
4. Median Sulfate concentration in East Ash Pond Surface Water Samples is 1.5 times greater than in East Ash Pond Bedrock Well MW16A.

Notes:

* Less than points were replaced by one-half the detection limit.

** Some parameters had multiple detection limits. Lowest detection limit is reported.

*** Sample data contained censored values, did not compute means.

na Not analyzed. nd No samples were above method detection limit.

Highest mean and median concentrations of parameter are shown in boldface.

Table 11. Summary of Groundwater Quality Data in Bedrock and East Ash Pond
Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant, Illinois

Parameter: TDS (mg/L)	Number of Wells	Samples per Location	Mean*	Median	Minimum**	Maximum
Background Bedrock Wells (2002 Kelron Study)						
MW25	1	6	**1,450**	**1,400**	1,400	1,600
MW27	1	6	910	905	850	980
MW29	1	6	838	825	800	900
MW30	1	6	**2,433**	**2,400**	2,400	2,500
MW31	1	6	863	940	410	1,000
ISGS Background Wells (Scientific Literature and State Databases) see Appendix A						
	28	1	3,540	426	280	52,100
ISGS Background Wells (2002 ISGS Study) see Appendix A						
(wells 1349,21903,23343,25531)	4	1	633	510	210	1,300
East Ash Pond Bedrock Wells (2002 Kelron Study)						
MW13A	1	6	**1,467**	**1,450**	1,400	1,600
MW16A	1	6	**1,383**	**1,400**	1,200	1,600
MW22	1	6	532	525	470	620
MW24	1	6	532	495	410	750
MW32	1	6	**1,933**	**1,900**	1,900	2,000
East Ash Pond Surface Water Samples (2002 Kelron Study)						
(monthly samples from Jan-May 2002)	not applicable	5	**1,650**	**1,800**	950	2,100

Comments:

1. East Ash Pond Bedrock Wells MW13A and MW32 have a statistically significant higher mean concentration than the Background Bedrock Wells (2002 Kelron Study) based on the Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level. East Ash Pond Bedrock Well MW16A is statistically from the same population as the Background Bedrock Wells. Wells MW22 and MW24 have a statistically significant lower mean concentration than the Background Wells (2002 Kelron Study).
2. Median TDS concentrations in the East Ash Pond Surface Water Samples are within the same range of values as Background Bedrock Wells (2002 Kelron Study) MW25 and MW30 and East Ash Pond Bedrock Wells MW13A, MW16A, and MW32.

Parameter: Vanadium (mg/L)	Number of Wells	Samples per Location	Mean*	Median*	Minimum**	Maximum
Background Bedrock Wells (2002 Kelron Study)						
MW25	1	6	nd	nd	<0.010	<0.010
MW27	1	6	nd	nd	<0.010	<0.010
MW29	1	6	nd	nd	<0.010	<0.010
MW30	1	6	nd	nd	<0.010	<0.010
MW31	1	6	nd	nd	<0.010	<0.010
ISGS Background Wells (Scientific Literature and State Databases) see Appendix A						
	31	1	na	na	na	na
ISGS Background Wells (2002 ISGS Study) see Appendix A						
(wells 1349,21903,23343,25531)	4	1	nd	nd	<0.01	<0.01
East Ash Pond Bedrock Wells (2002 Kelron Study)						
MW13A	1	6	nd	nd	<0.010	<0.010
MW16A	1	6	nd	nd	<0.010	<0.010
MW22	1	6	nd	nd	<0.010	<0.010
MW24	1	6	nd	nd	<0.010	<0.010
MW32	1	6	nd	nd	<0.010	<0.010
East Ash Pond Surface Water Samples (2002 Kelron Study)						
(monthly samples from Jan-May 2002)	not applicable	5	**0.04**	**0.03**	<0.010	0.078

Comments:

1. All Bedrock Wells (Background and East Ash Pond wells) had Vanadium concentrations below 0.01 milligrams per Liter.
2. East Ash Pond Surface Water Samples had median Vanadium concentrations at least 3 times greater than in Background Wells or East Ash Pond Bedrock Wells.

Notes:

* Less than points were replaced by one-half the detection limit.
** Some parameters had multiple detection limits. Lowest detection limit is reported.
*** Sample data contained censored values, did not compute means.
na Not analyzed.
nd No samples were above method detection limit.
Highest mean and median concentrations of parameter are shown in boldface.

Table 12. Summary of Impacts on Groundwater Quality in Bedrock
Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant, Illinois

Parameter	COLUMN 2 Mean Groundwater Concentrations in Bedrock Wells[1] at East Ash Pond Compared to Background Bedrock Wells[2]	COLUMN 3 Groundwater Quality in East Ash Pond Bedrock Wells[1] Compared to East Ash Pond Surface Water	Impact by East Ash Pond on Groundwater Quality in Bedrock	Other Conclusions
Aluminum	0 all wells	LT	No impact	
Barium	LT all wells	GT	No impact	Wells 13A and 32 may be affected by past coal mining activities.
Boron	LT 16A,22,24 GT 13A,32	LT	No impact	Wells 13A and 32 may be affected by past coal mining activities.
Calcium	0 22,24 LT 13A,32 GT 16A	LT	No impact	Well 16A has higher Ca concentrations than background wells. Ca is higly correlated with Mg at 0.98. Ca is either naturally occurring or influenced by former coal mines.
Chloride	0 13A,32 LT 16A,22,24	LT (16A,22,24) GT (13A,32)	No impact	Wells 13A and 32 may be affected by past coal mining activities. Background well 25 may also be affected by coal mining. Background well 30 is in coal and shale and has highest Cl concentrations at study site.
Iron	0 16A LT 13A,22,24,32	GT	No impact	Well 30, background well installed in coal and shale, has the highest Fe concentration at the study site.
Lithium	0 16A LT 22,24 GT 13A,32	LT	No impact	Wells 13A and 32 may be affected by past coal mining activities. Background well 25 may also be affected by coal mining. Background well 30 is in coal and shale and has similar Li concentrations to 13A, 32, and 25.
Magnesium	0 22 LT 13A,24,32 GT 16A	LT (13A,22,24,32) GT (16A)	No impact	Well 16A has higher Mg concentrations than background wells and East Ash Pond and is not impacted by surface water from East Ash Pond. All other East Ash Pond wells are either equal to or below background concentrations.
Manganese	LT 22,24,32 GT 13A,16A	LT (22,24,32) GT (13A,16A)	No impact	Wells 13A and 16A may be affected by past coal mining activities. These wells have higher concentrations than most background wells and East Ash Pond water.
Molybdenum	0 all wells	LT	No impact	All background wells and East Ash Pond wells have no detectable concentrations of Mo. Only East Ash Pond water samples have detected concentrations of Mo.
Phosphorus	0 13A,16A,32 LT 22 GT 24	Variable (no determination)	No impact	
Potassium	0 13A,32 LT 16A,22,24	LT	No impact	
Selenium	0 all wells	LT	No impact	Almost all samples from background wells and East Ash Pond wells have no detectable concentrations of Se. Only East Ash Pond water samples have detectable Se levels.
Sodium	LT 16A,22,24 GT 13A,32	Variable (no determination)	No impact	Wells 13A and 32 may be affected by past coal mining activities. Background well 30 is in coal and shale and has similar high Na concentrations as wells 13A and 32.
Strontium	0 13A,16A,32 LT 22,24	LT	No impact	
Sulfate	0 13A,32 GT 16A,22,24	LT	No impact	Well 16A is the only bedrock well in the vicinity of East Ash Pond with elevated sulfate relative to background. Water quality is most likely affected by past coal mining.
Total Dissolved Solids	0 16A LT 22,24 GT 13A,32	Variable (no determination)	No impact	Wells 13A, 16A and 32 may be affected by past coal mining activities. Background well 25 may also be affected by coal mining. Background well 30 is in coal and shale and has the highest mean and median TDS concentrations.
Vanadium	0 all wells	LT	No impact	All samples from background wells and East Ash Pond wells were below detection limits for Vanadium. Only East Ash Pond water samples have detectable Vanadium.

Key to Symbols

COLUMN 2

0	Groundwater quality for given parameter in East Ash Pond wells is statistically from the same population as Background Wells (25,27,29,30, and 31) based on the Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level.
LT	Groundwater quality for given parameter in East Ash Pond wells has a statistically significant lower mean concentration compared to Background Wells (25,27,29,30, and 31) based on the Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level.
GT	Groundwater quality for given parameter in East Ash Pond wells has a statistically significant higher mean concentration compared to Background Wells (25,27,29,30, and 31) based on the Wilcoxon Rank-Sum Test for Comparison of Means, 95 % confidence level.

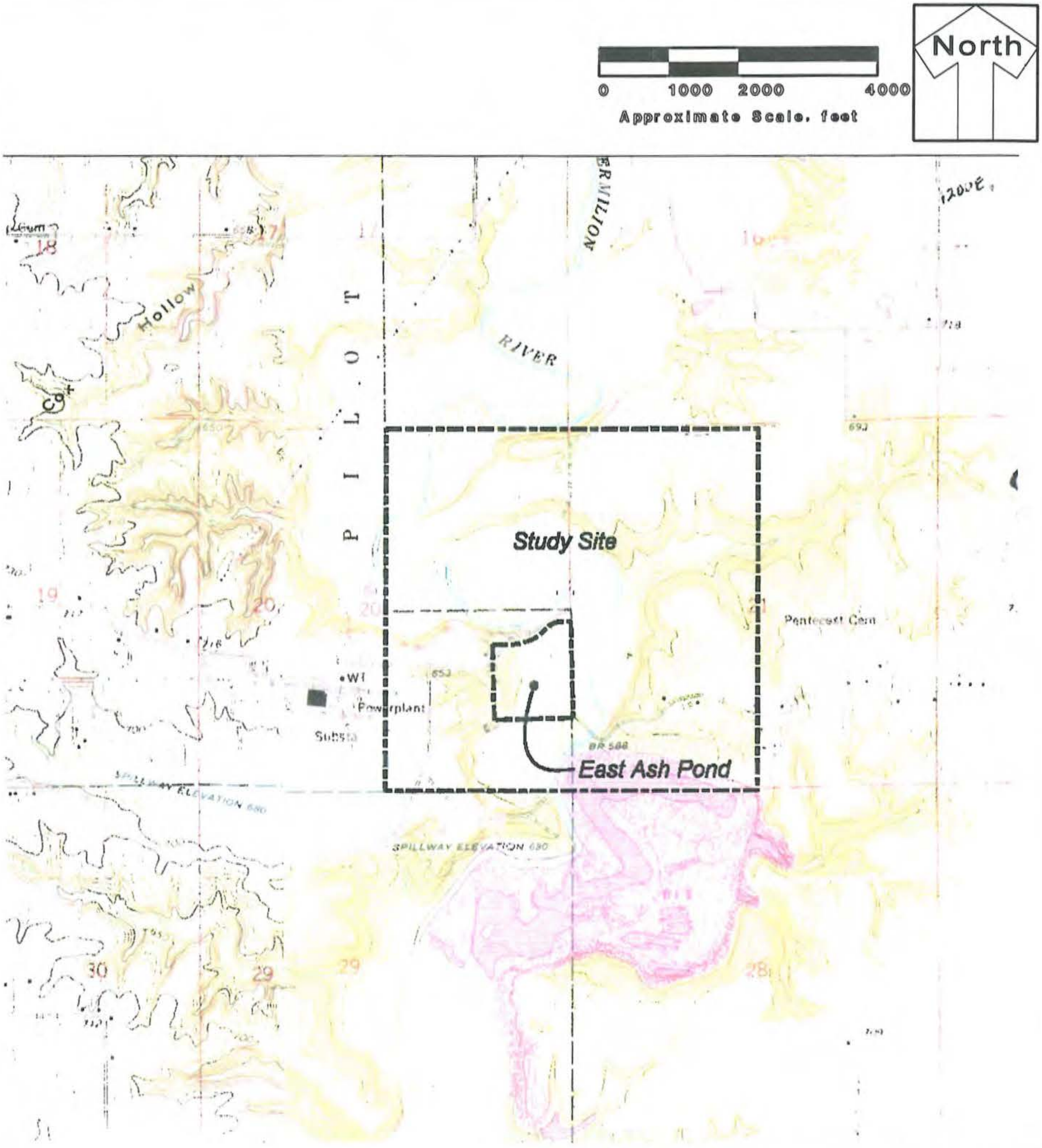
COLUMN 3

LT	Groundwater concentrations in East Ash Pond Bedrock Wells are less than East Ash Pond surface water for given parameter.
GT	Groundwater concentrations in East Ash Pond Bedrock Wells are greater than East Ash Pond surface water for given parameter.

[1] Bedrock wells at East Ash Pond include MW13A (13A), MW16A (16A), MW22 (22), MW24 (24), and MW32 (32).

[2] Background bedrock wells used for statistical comparison to East Ash Pond wells using Wilcoxon Rank-Sum Test include the following: MW25 (25), MW27 (27), MW29 (29), MW30 (30), and MW31 (31).

Figures



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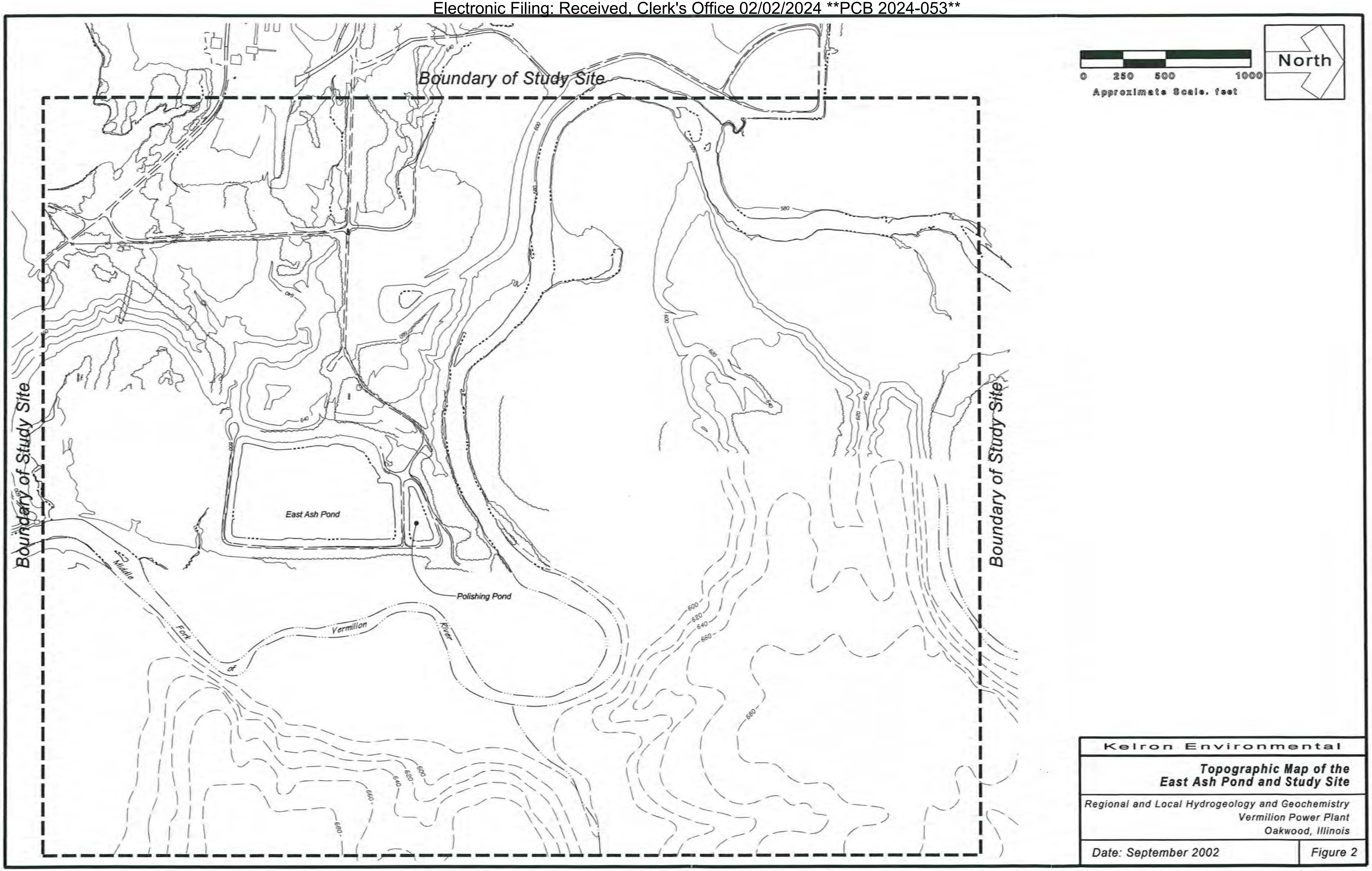
Site Location Map of the Vermilion Power Station and East Ash Pond

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002

Figure 1



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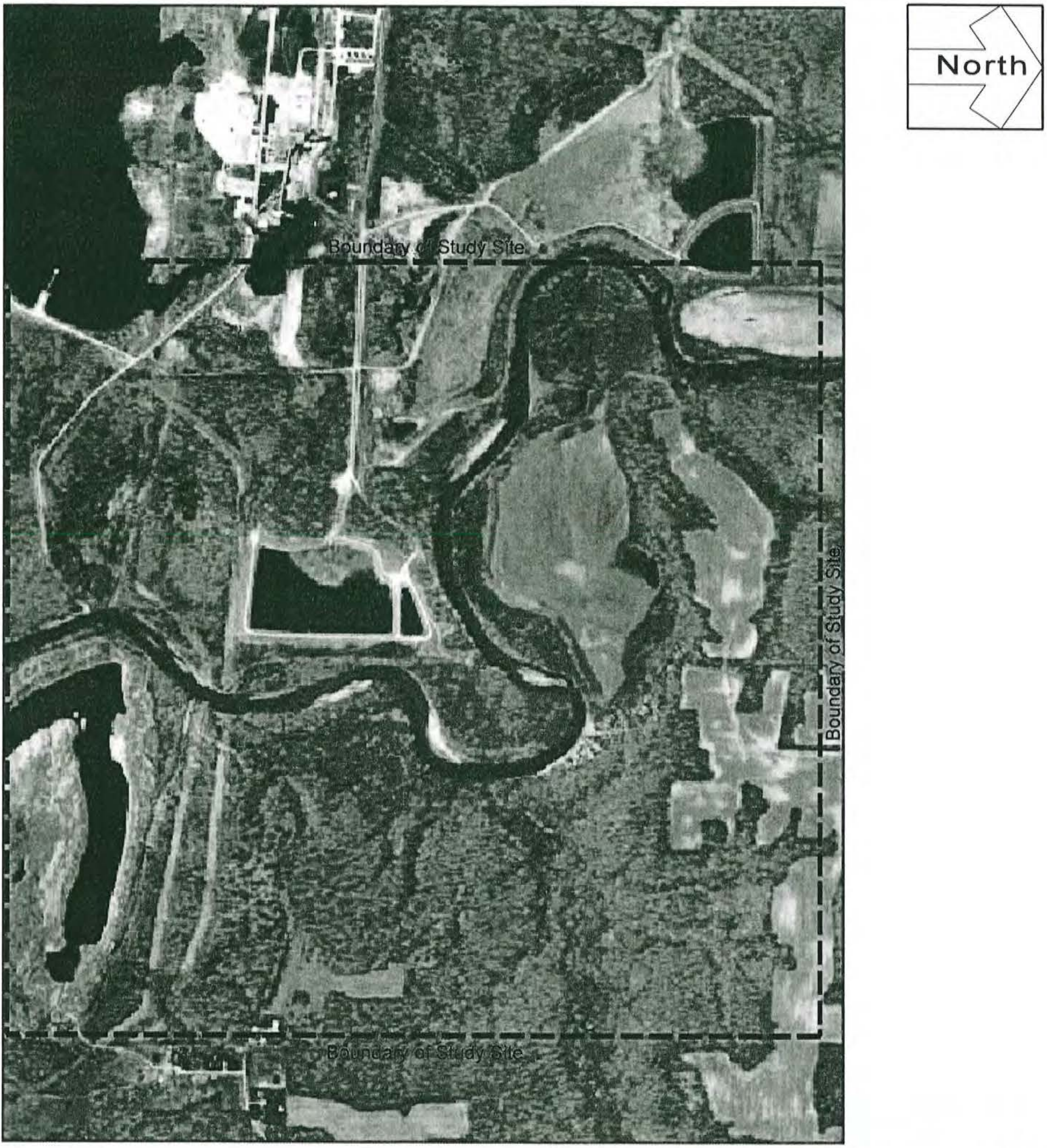
Topographic Map of the East Ash Pond and Study Site

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002

Figure 2



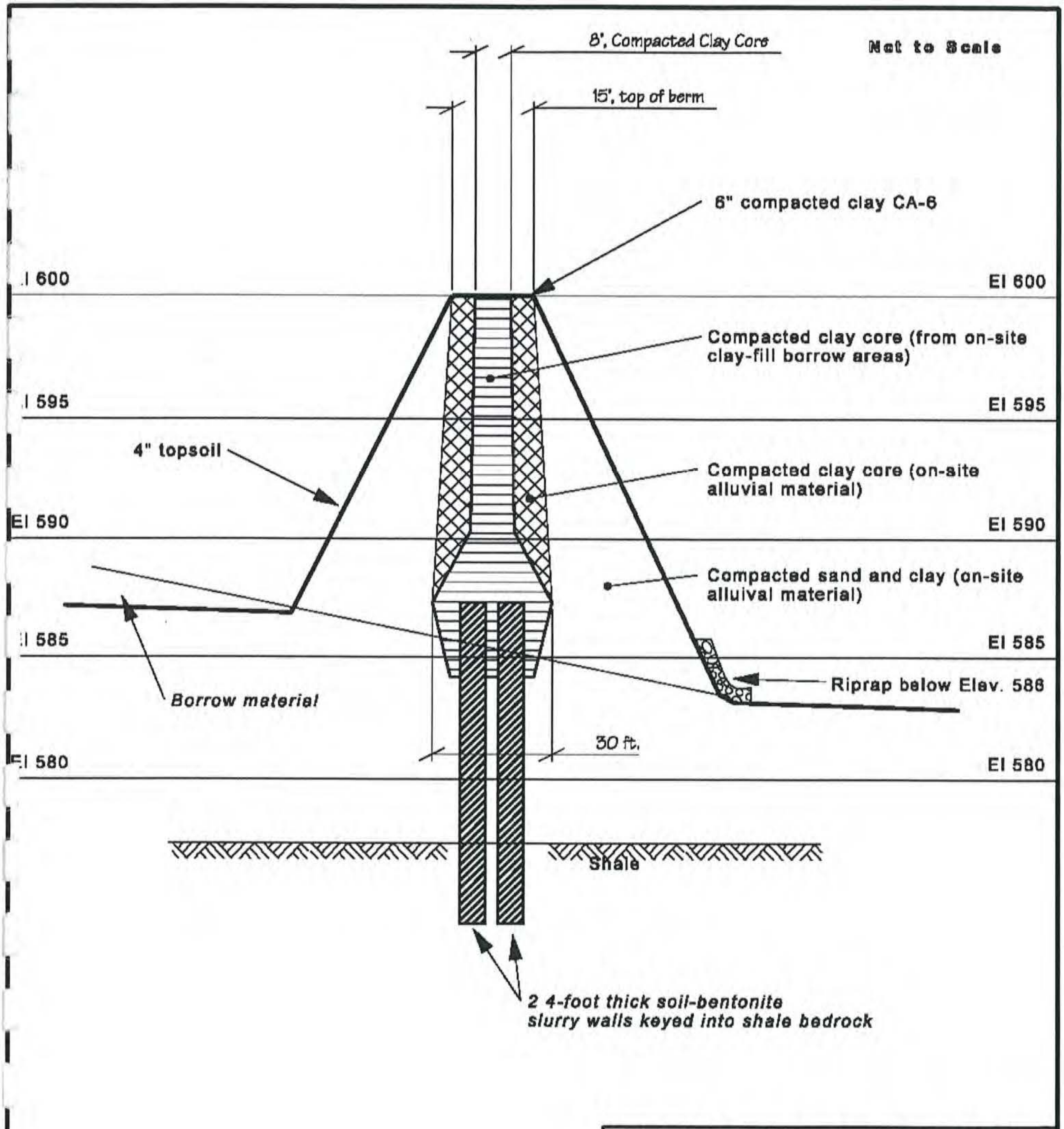
Kelron Environmental

Aerial Photograph of the East Ash Pond and Study Site

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002

Figure 3



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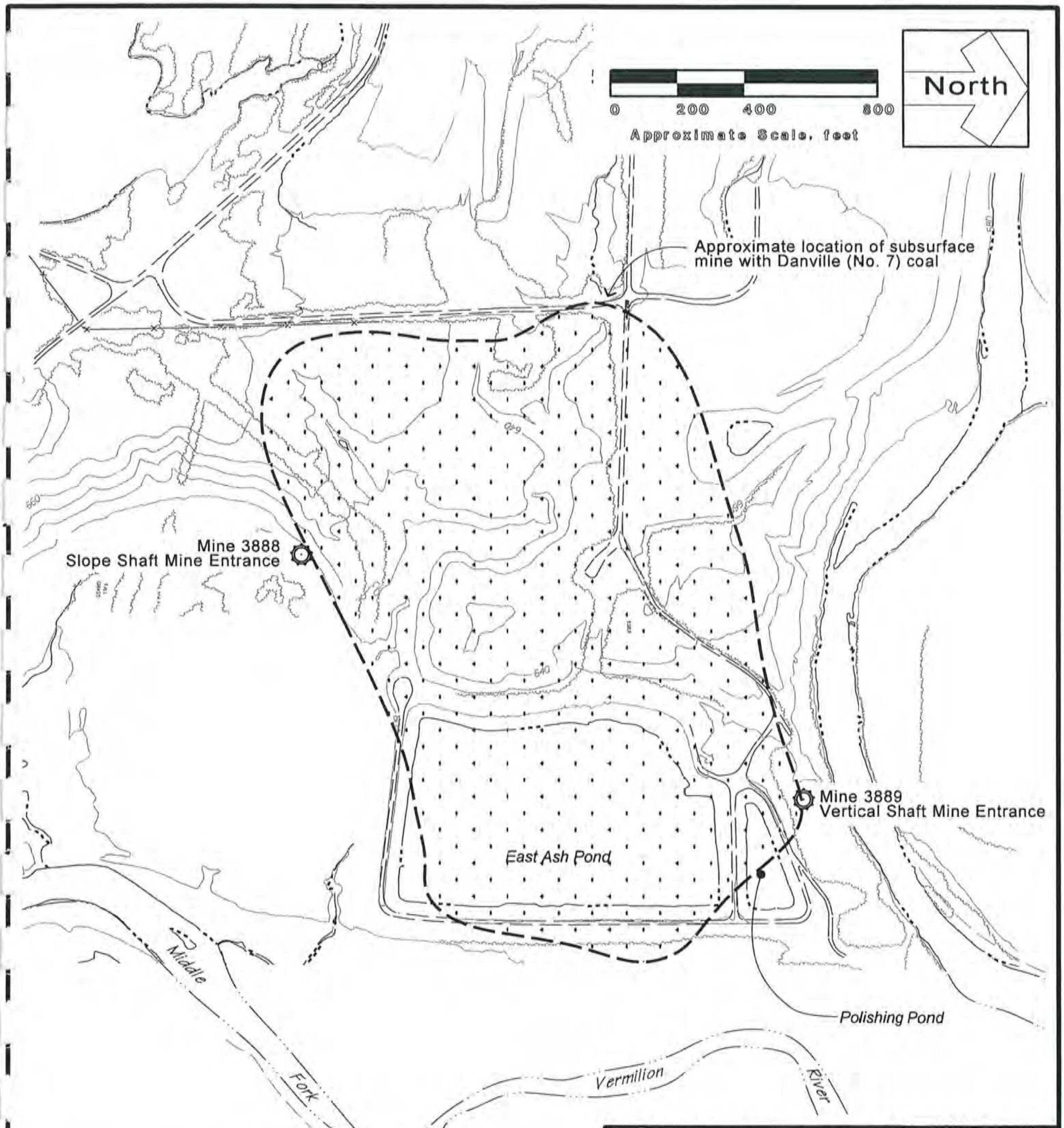
Typical Cross-Section of Original East Ash Pond Berm

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002

Figure 4



Legend

⊙ Location of Mine Entrance

Note: Modified after " Directory of Coal Mines in Illinois - Vermilion County "; ISGS 1996.

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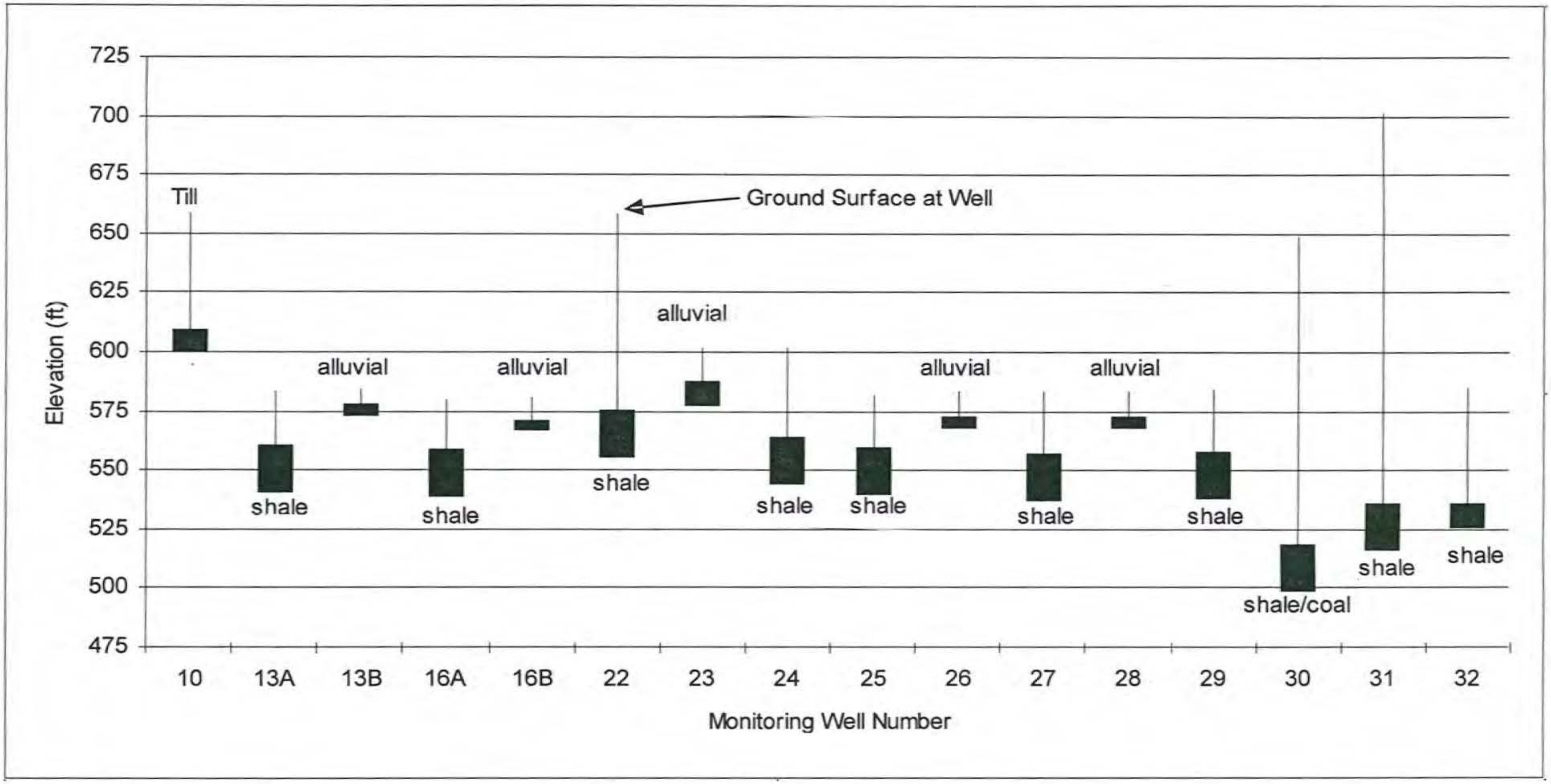
Map of Coal Mines in the Vicinity of the East Ash Pond - Illinois State Geological Survey

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002 | *Figure 5*

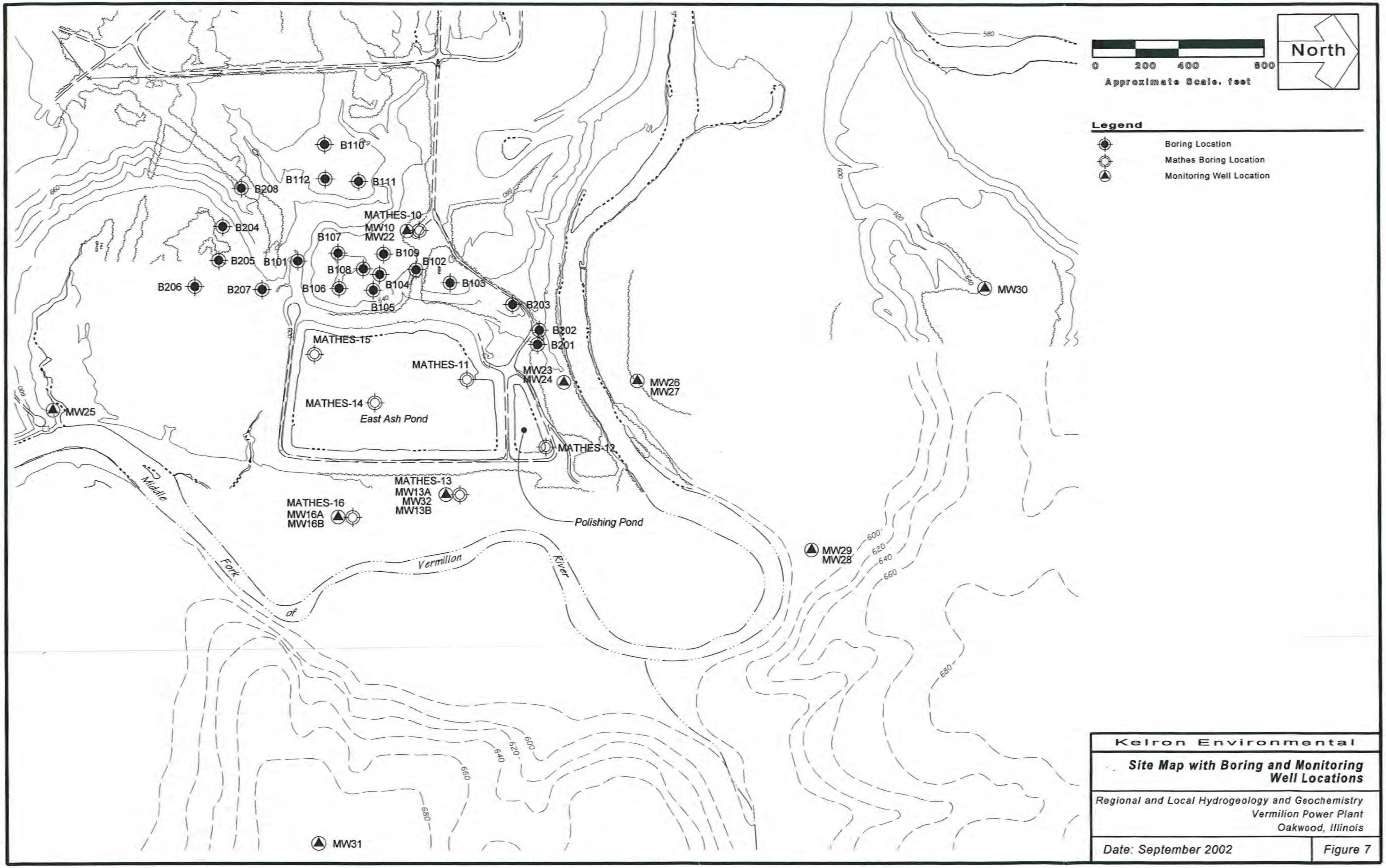


K e l r o n   E n v i r o n m e n t a l

Monitoring Well Screen Intervals

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002 | *Figure 6*



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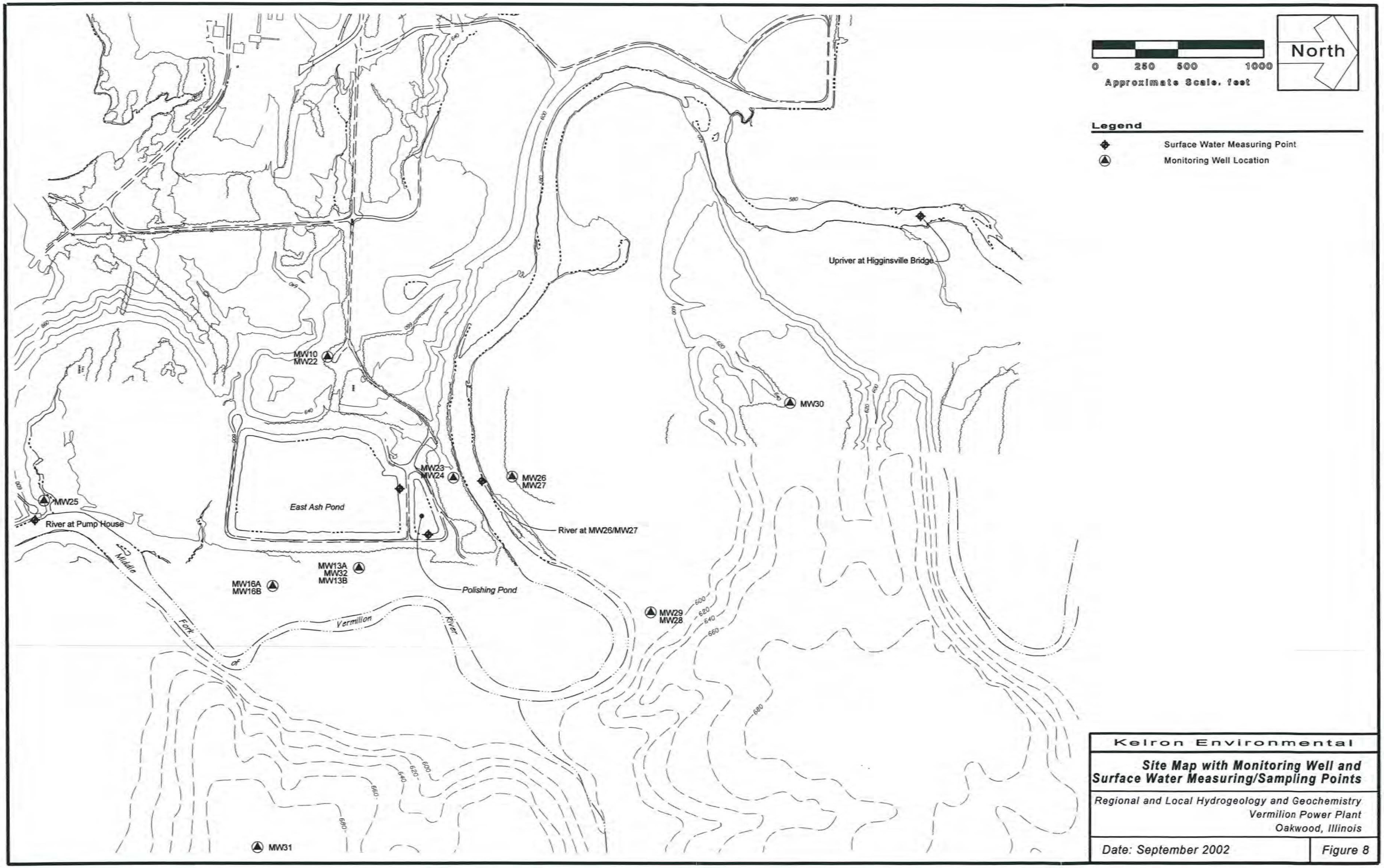
Site Map with Boring and Monitoring Well Locations

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002

Figure 7



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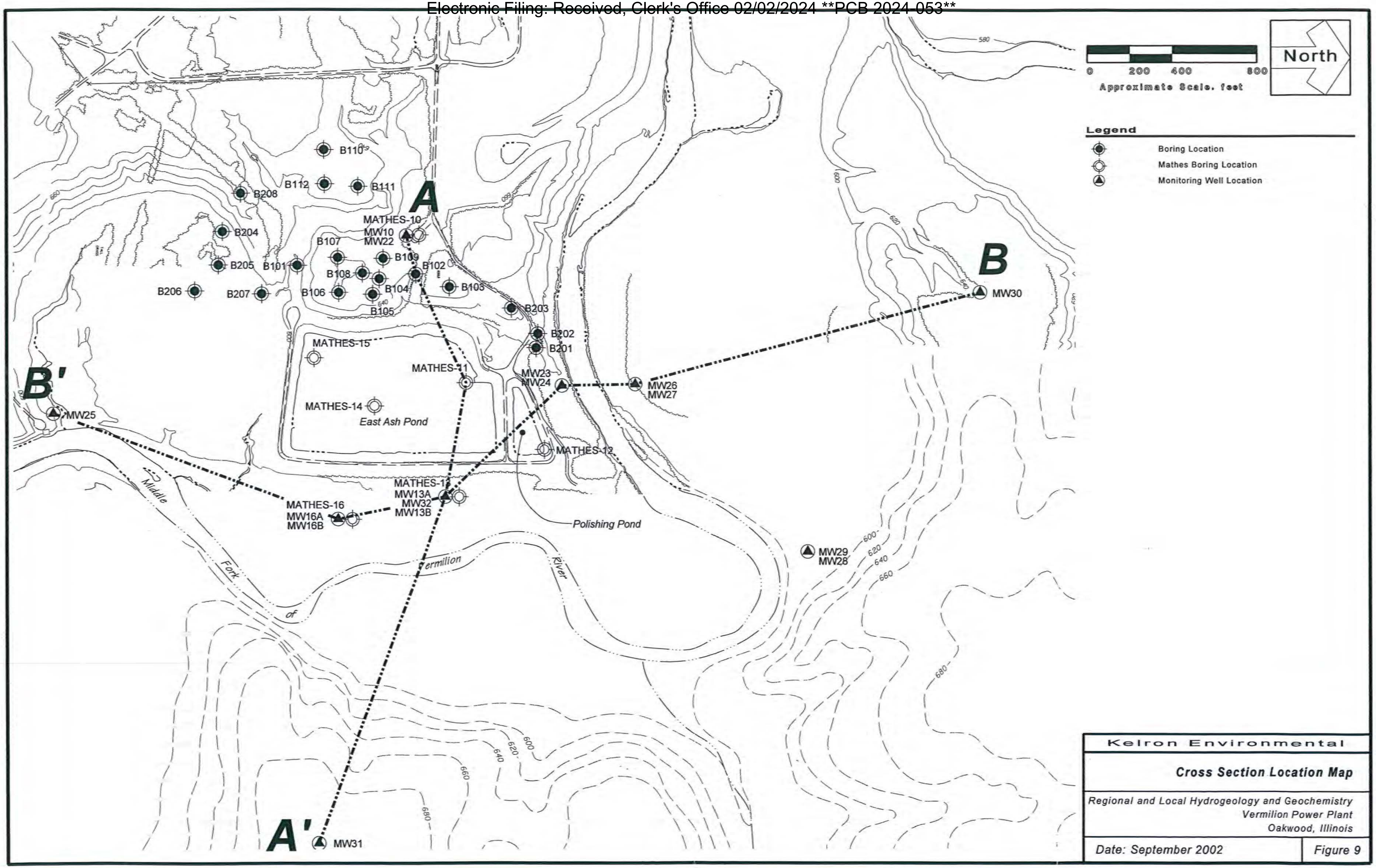
Site Map with Monitoring Well and Surface Water Measuring/Sampling Points

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002 | *Figure 8*



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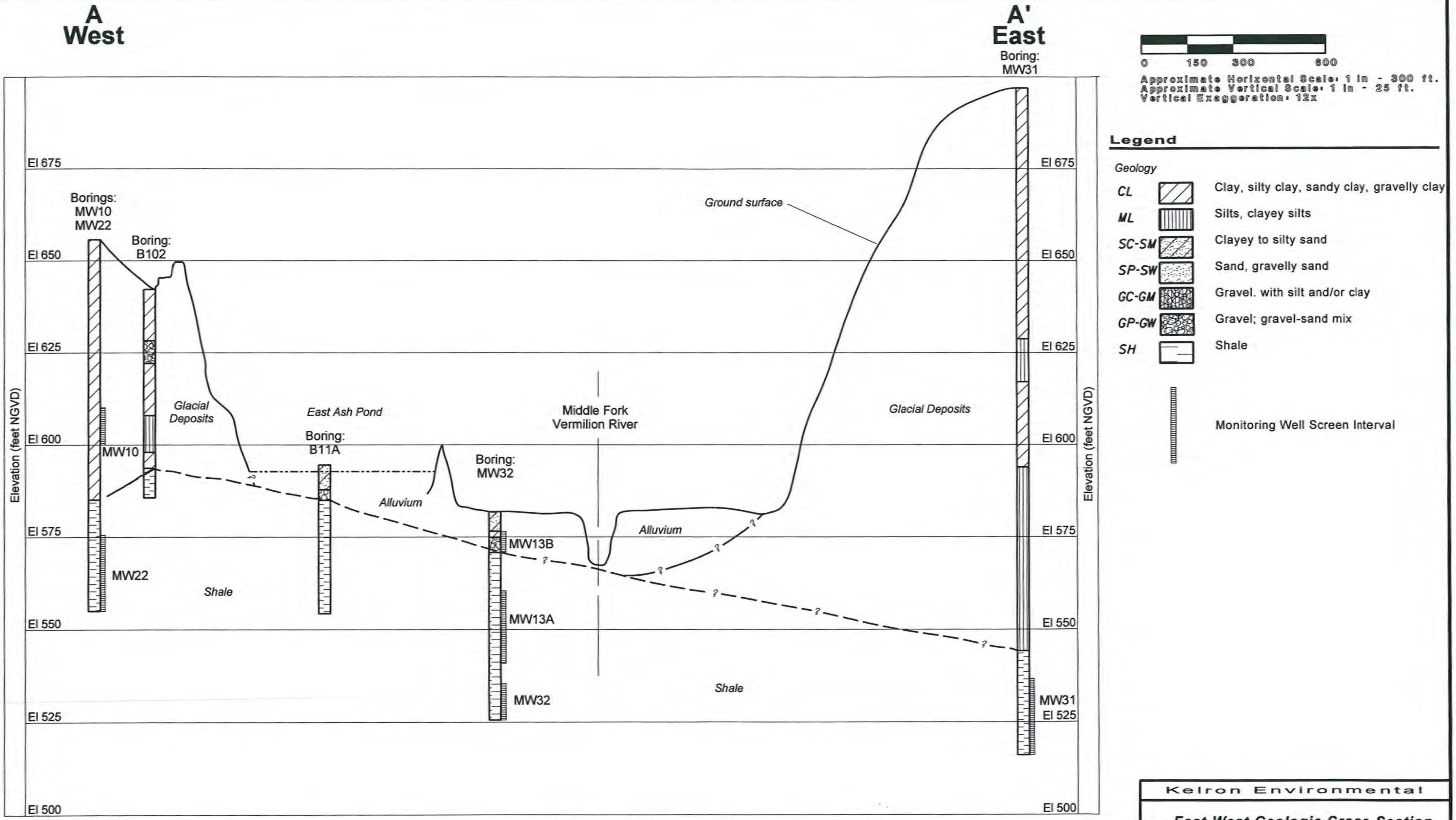
Cross Section Location Map

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002

Figure 9



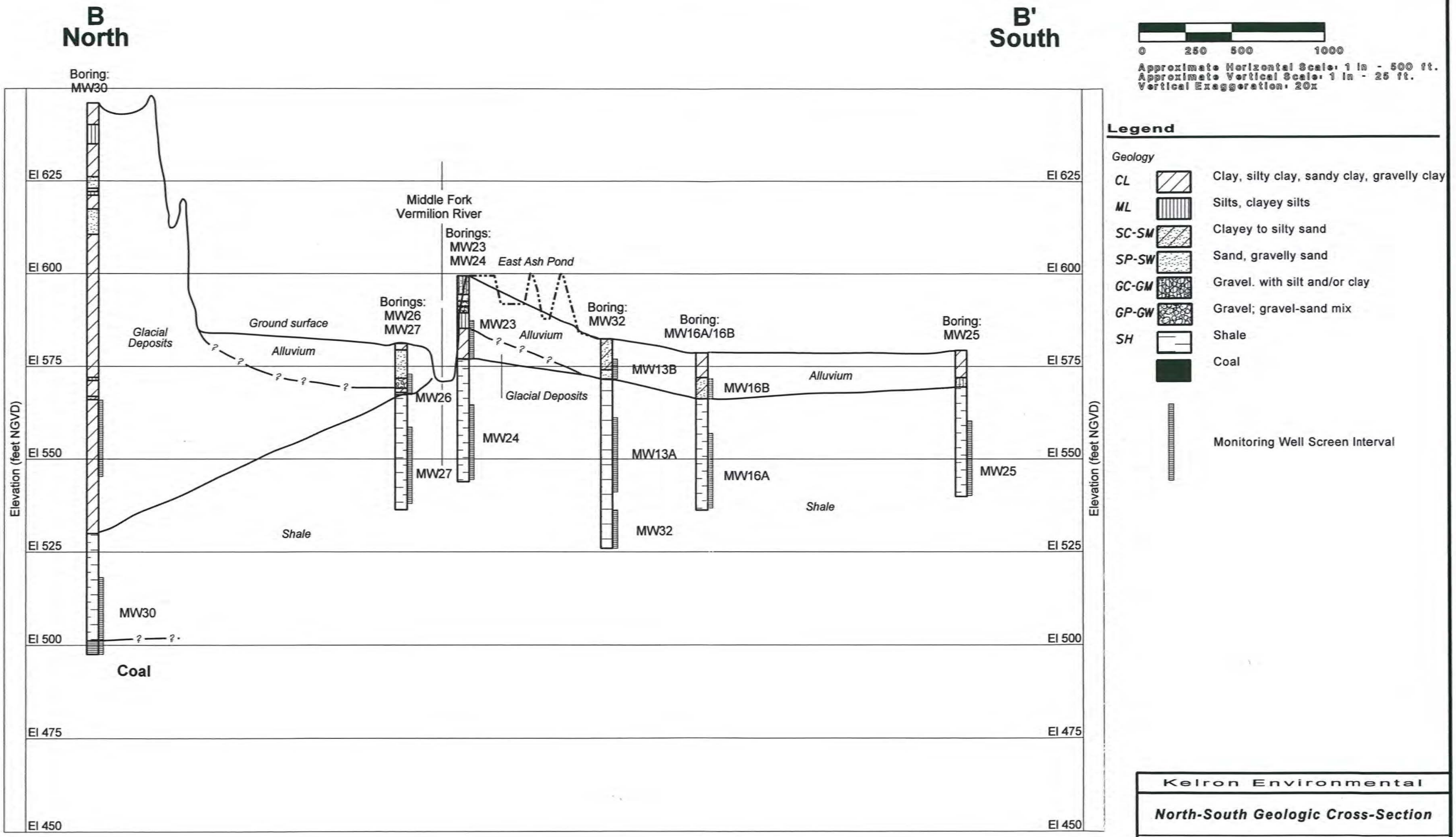
Kelron Environmental

East-West Geologic Cross-Section

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002

Figure 10

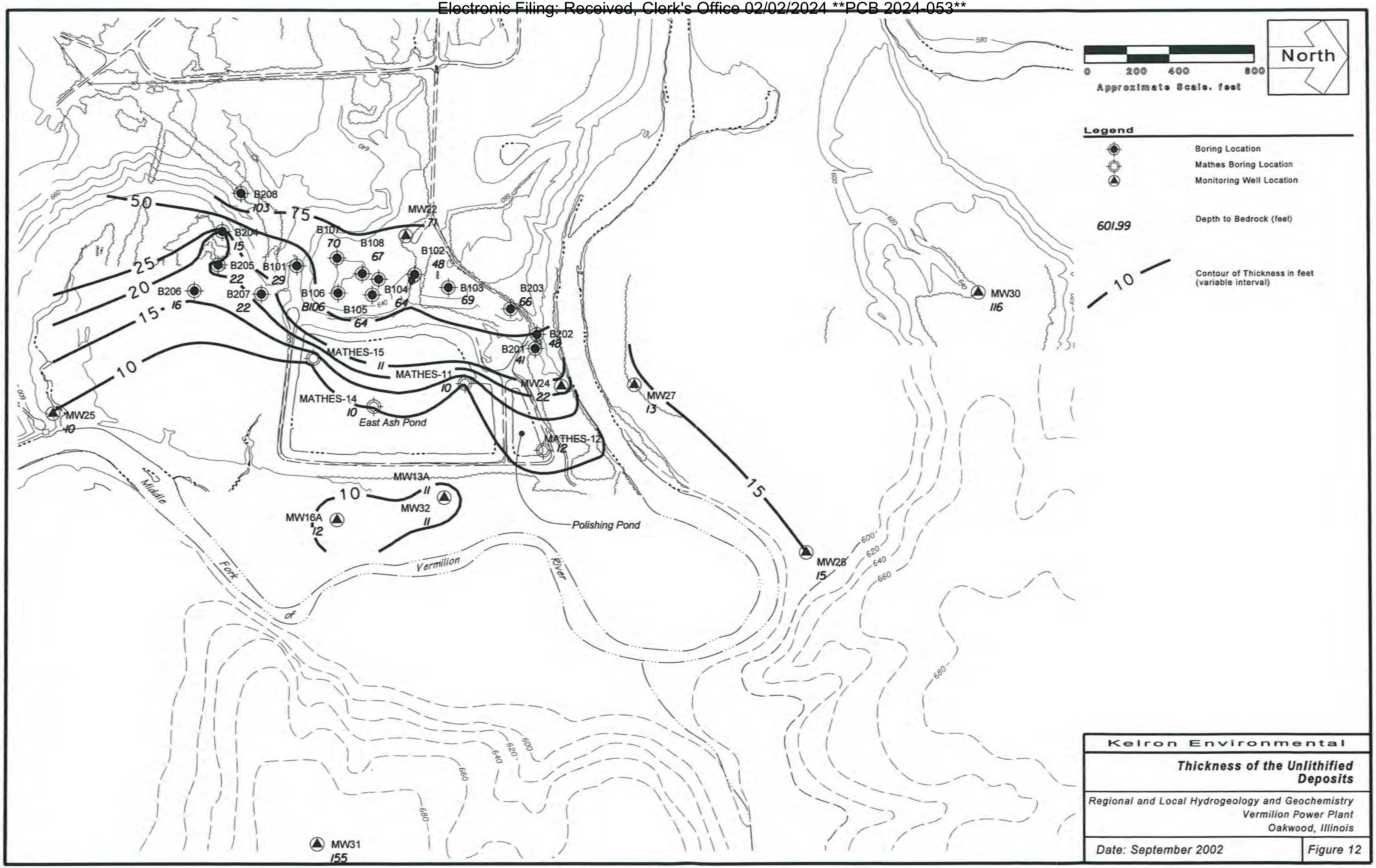


Kelron Environmental

North-South Geologic Cross-Section

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002 | *Figure 11*



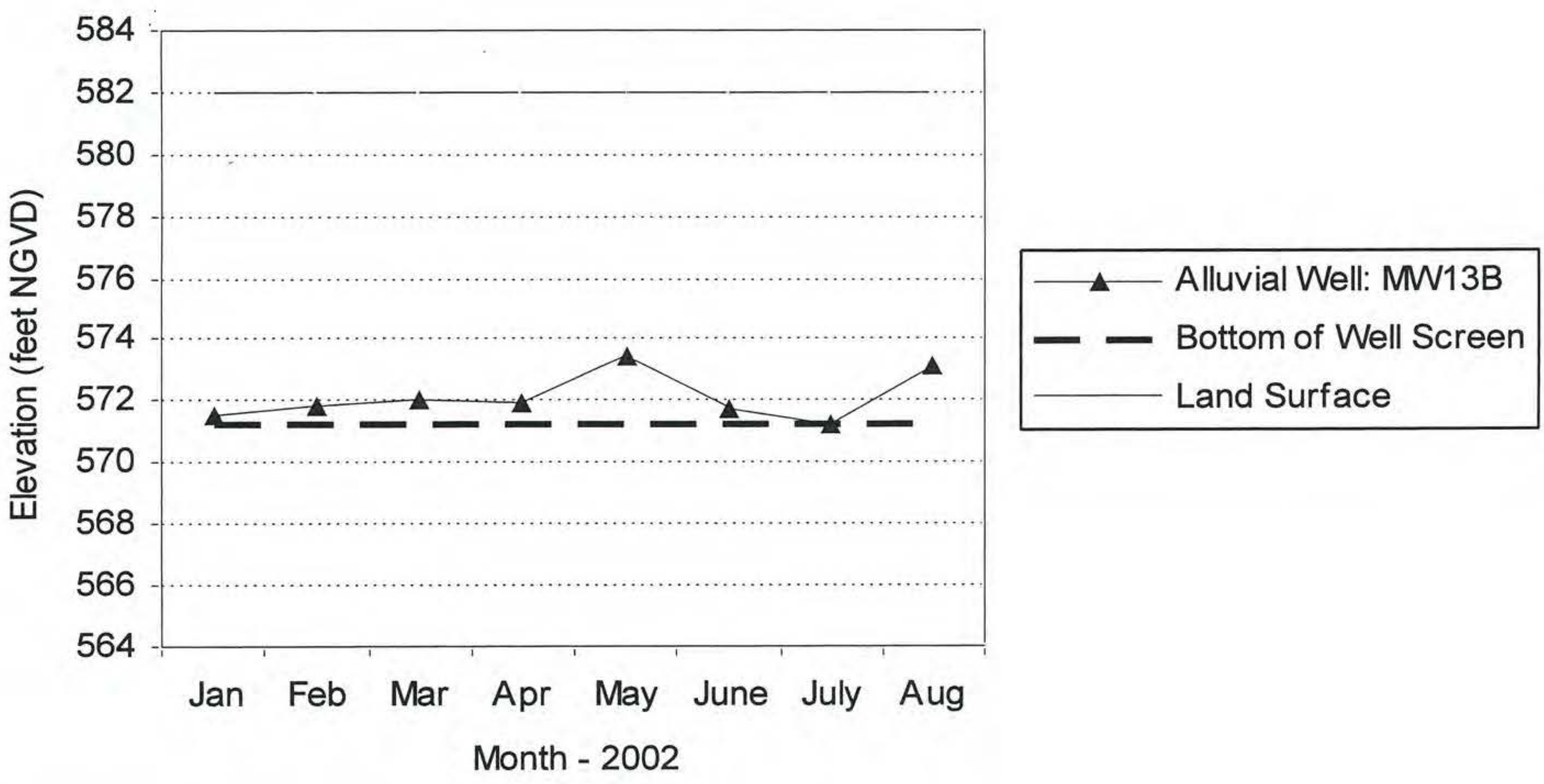
Kelron Environmental

Thickness of the Unlithified Deposits

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002

Figure 12



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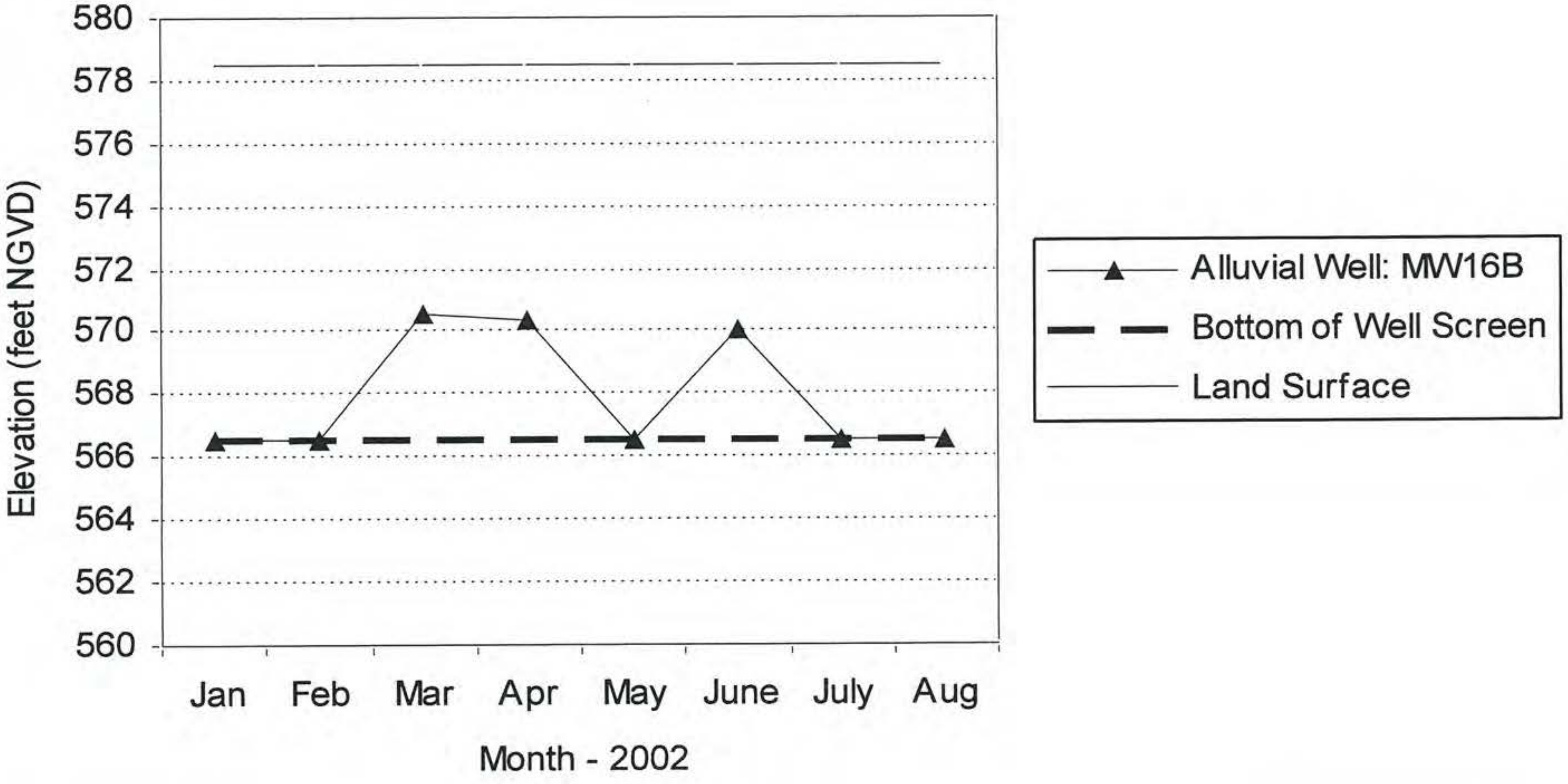
Groundwater Hydrograph of Alluvial Well MW13B

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002	*Figure 13*



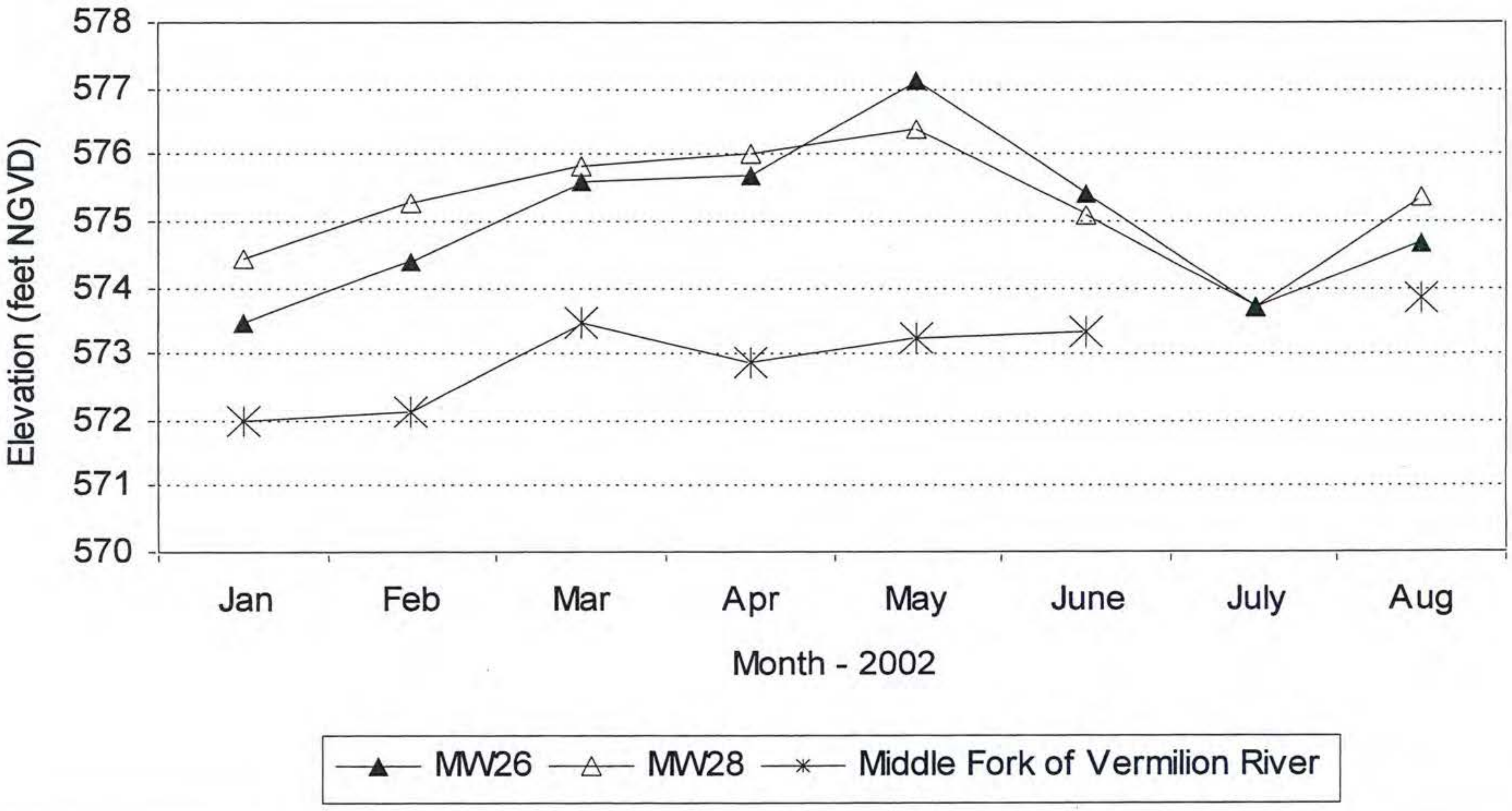
Kelron Environmental

Groundwater Hydrograph of Alluvial Well MW16B

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002

Figure 14



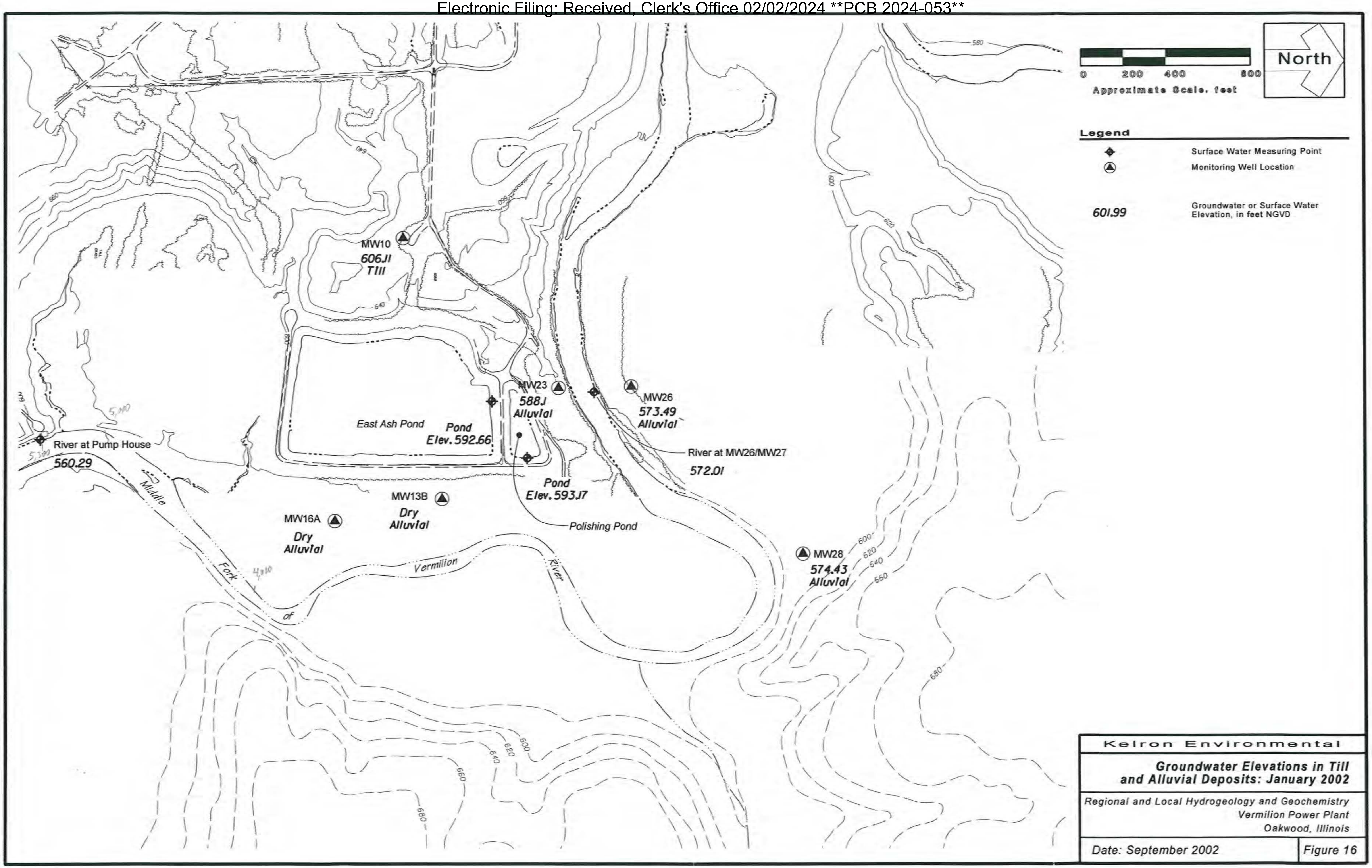
Kelron Environmental

Hydrographs of Alluvial Wells MW26, MW28, and Middle Fork of Vermilion River

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002

Figure 15



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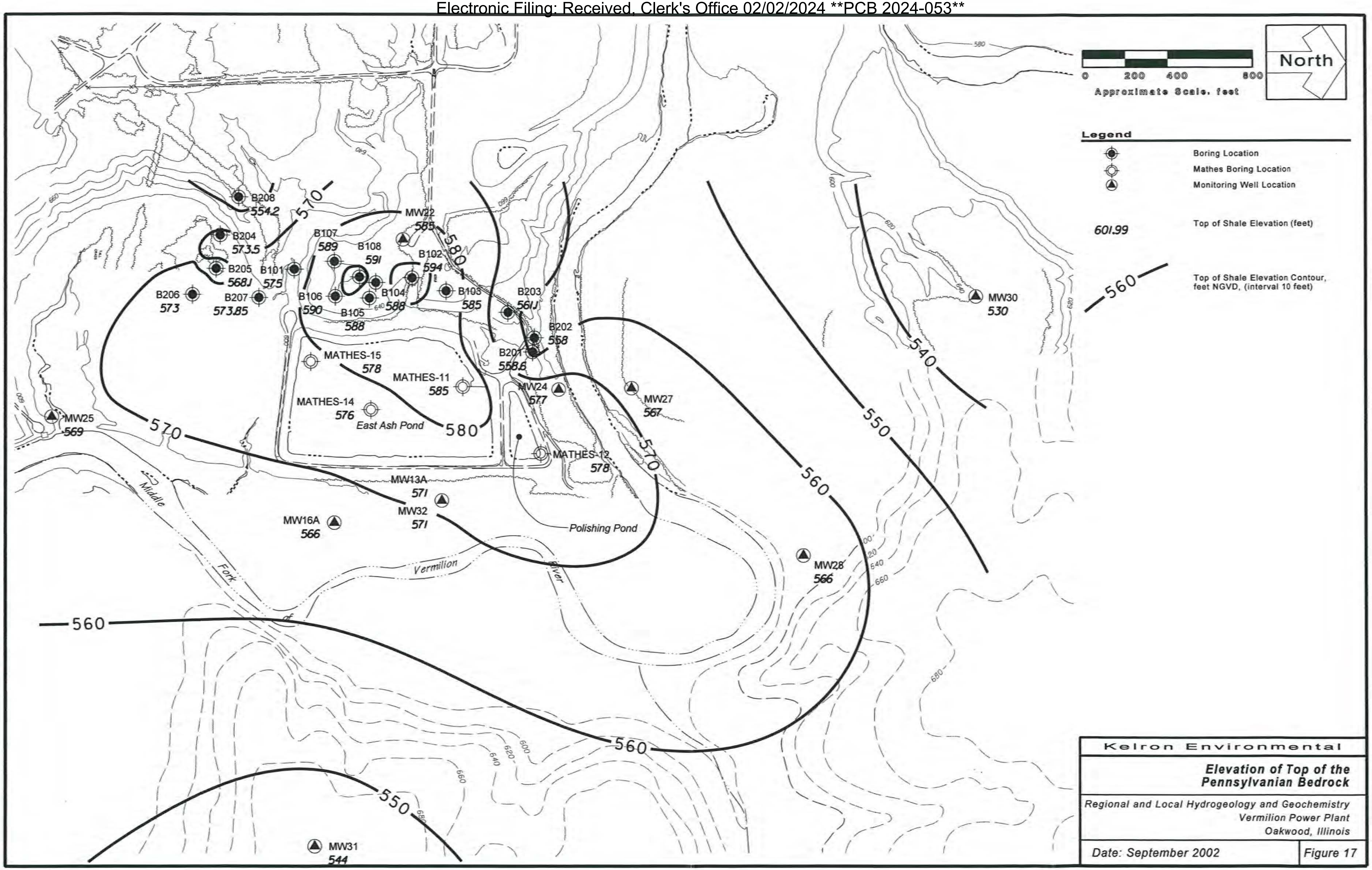
Groundwater Elevations in Till and Alluvial Deposits: January 2002

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002

Figure 16



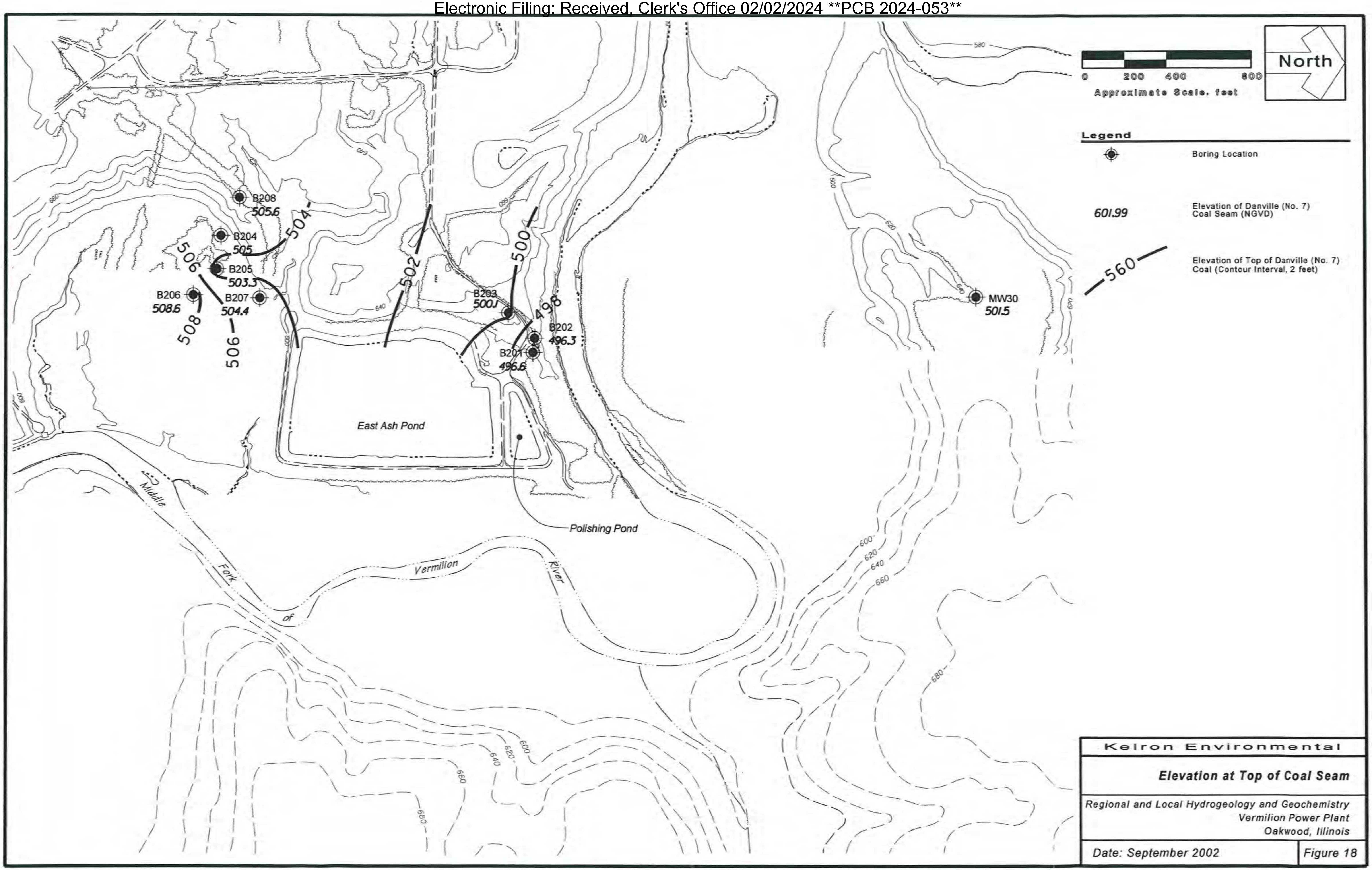
Kelron Environmental

Elevation of Top of the Pennsylvanian Bedrock

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002

Figure 17



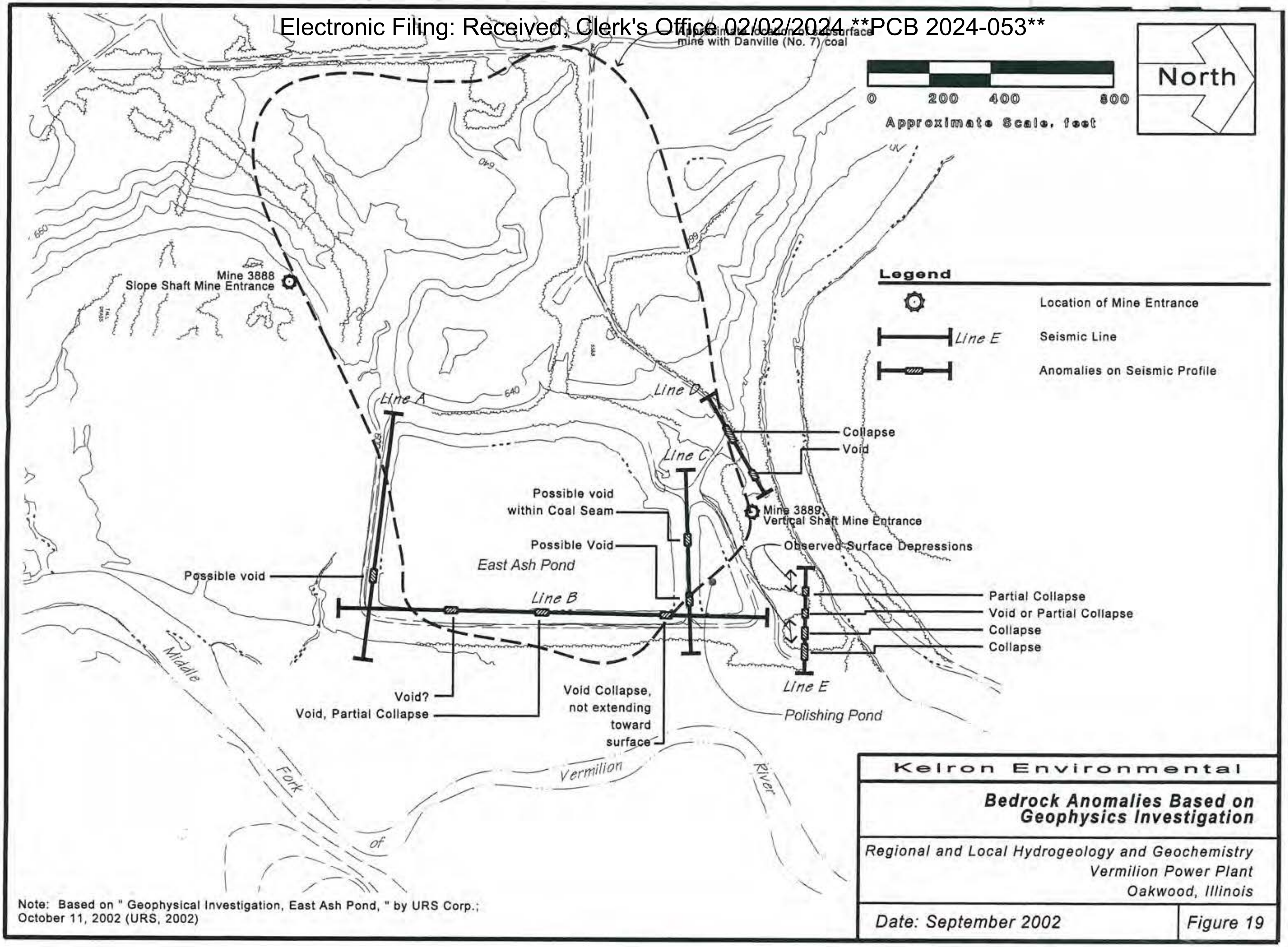
Kelron Environmental

Elevation at Top of Coal Seam

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002

Figure 18



Kelron Environmental

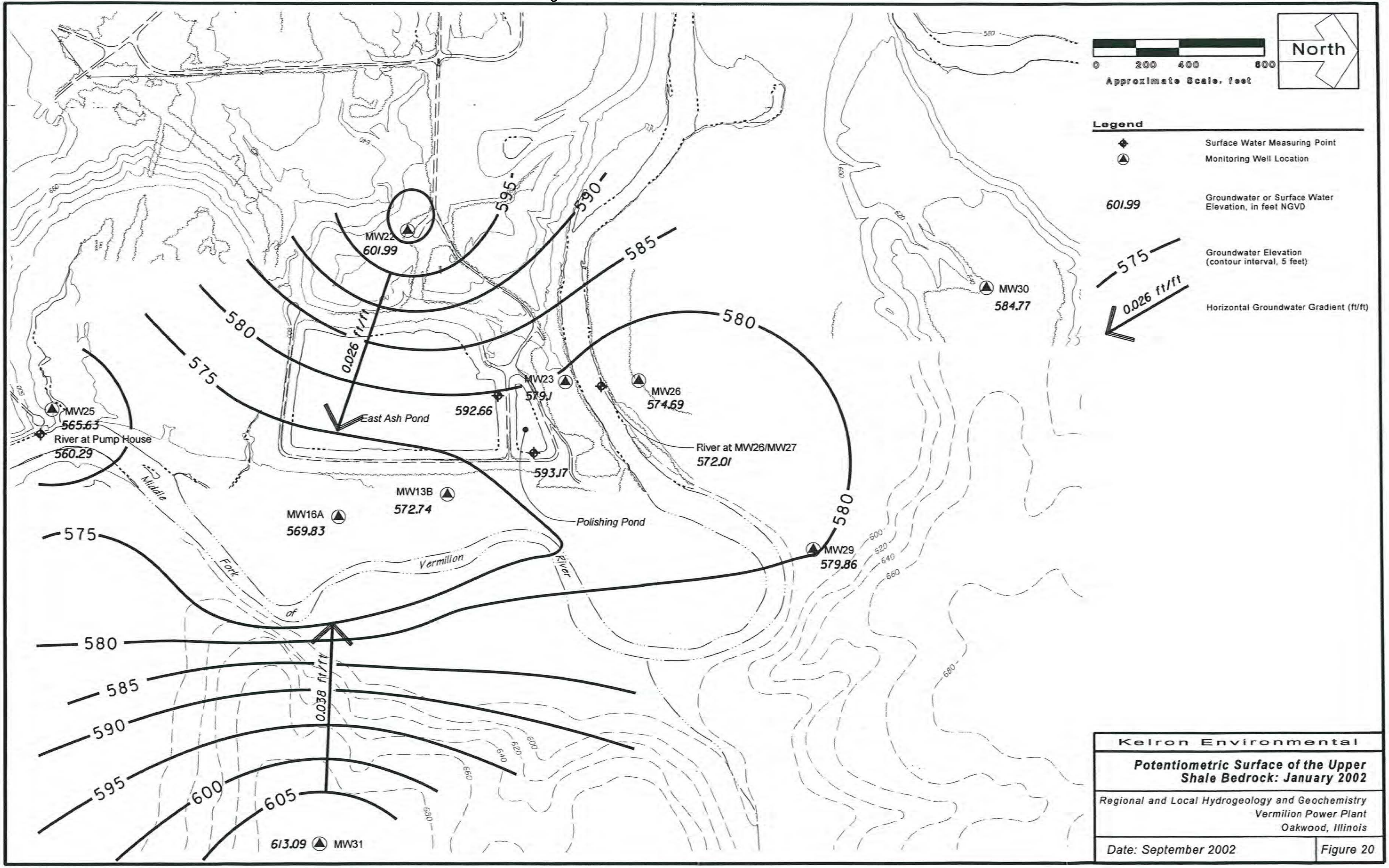
Bedrock Anomalies Based on Geophysics Investigation

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002

Figure 19

Note: Based on " Geophysical Investigation, East Ash Pond, " by URS Corp.; October 11, 2002 (URS, 2002)



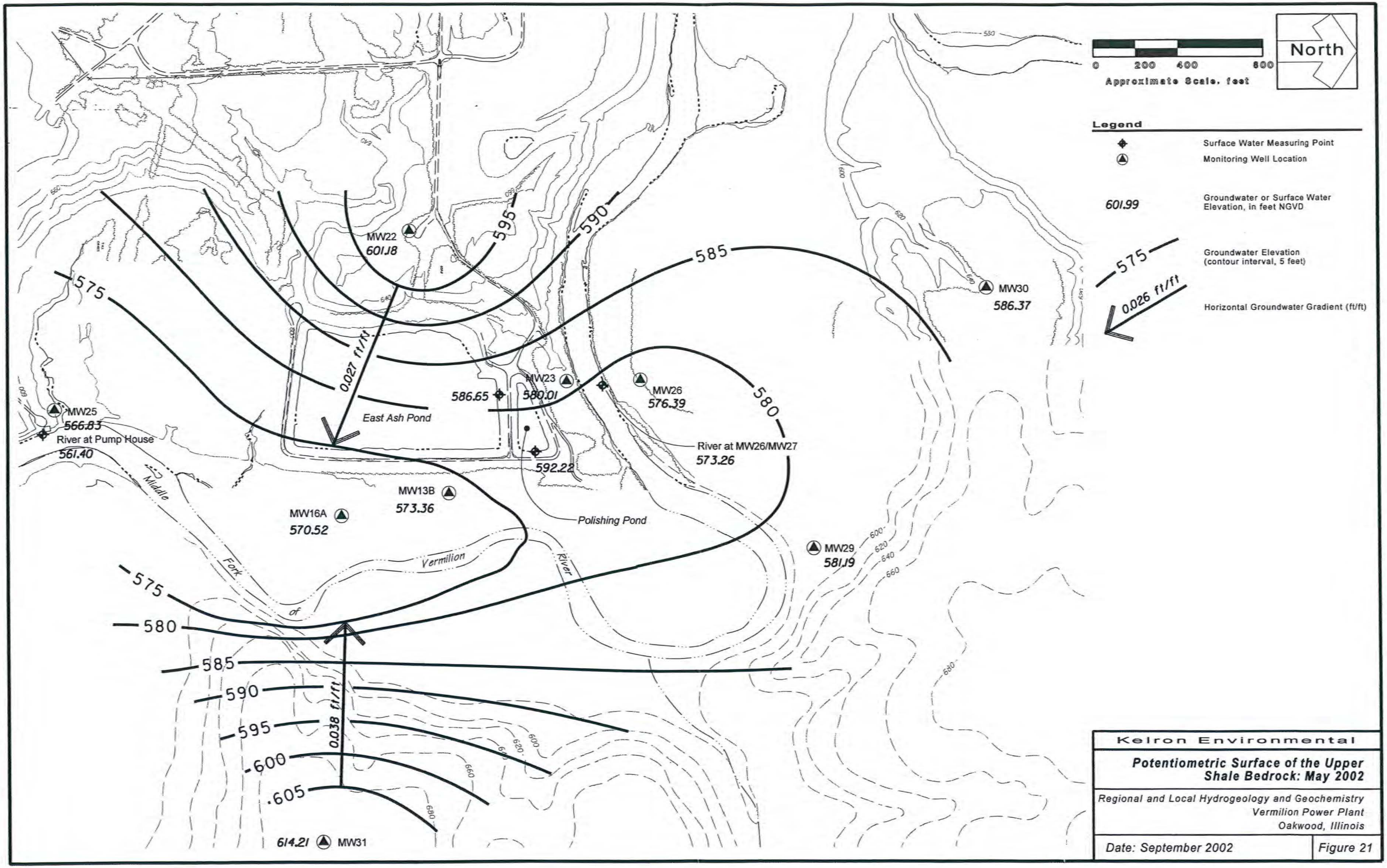
Kelron Environmental

Potentiometric Surface of the Upper Shale Bedrock: January 2002

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002

Figure 20



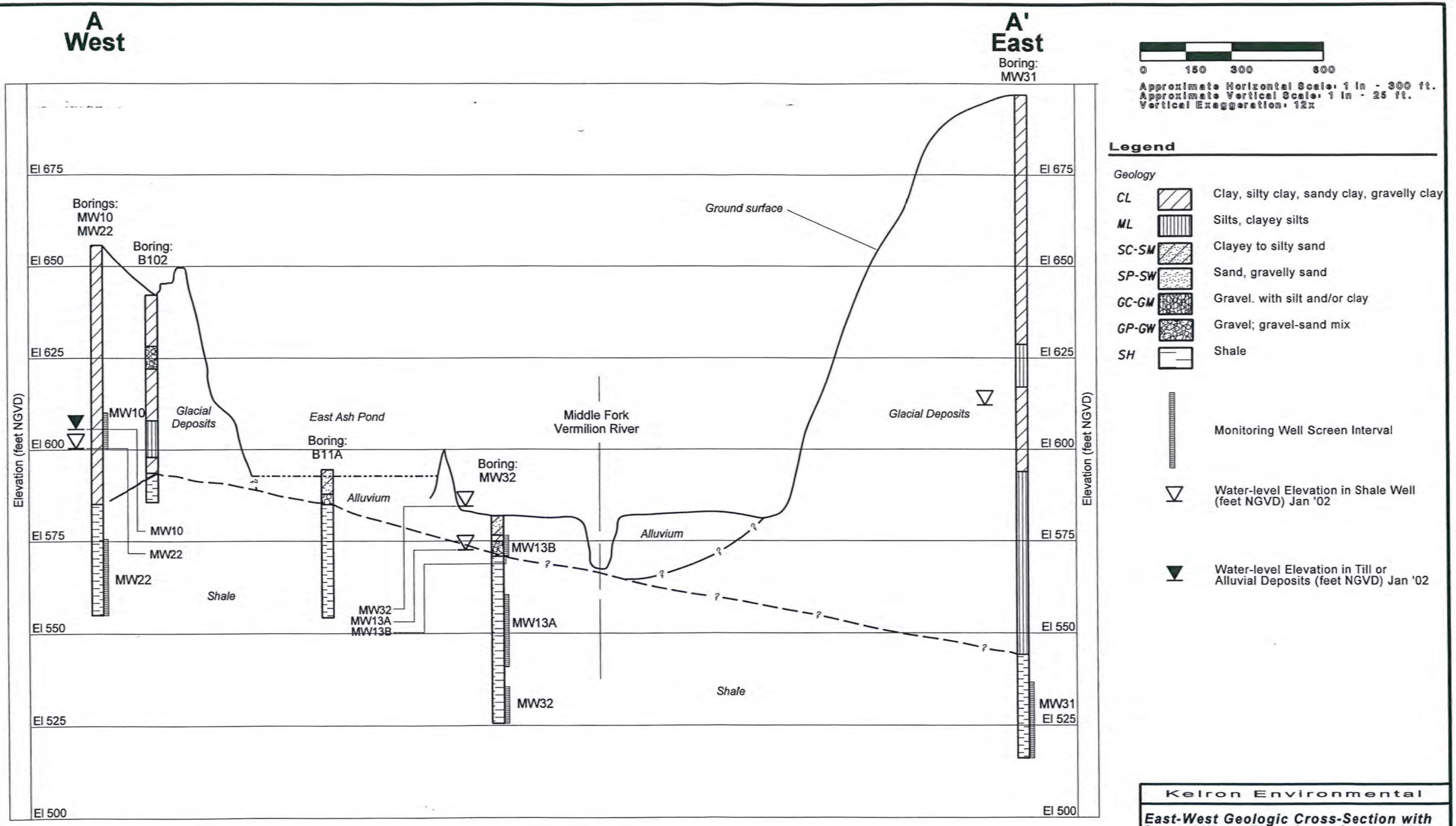
Kelron Environmental

Potentiometric Surface of the Upper Shale Bedrock: May 2002

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002

Figure 21

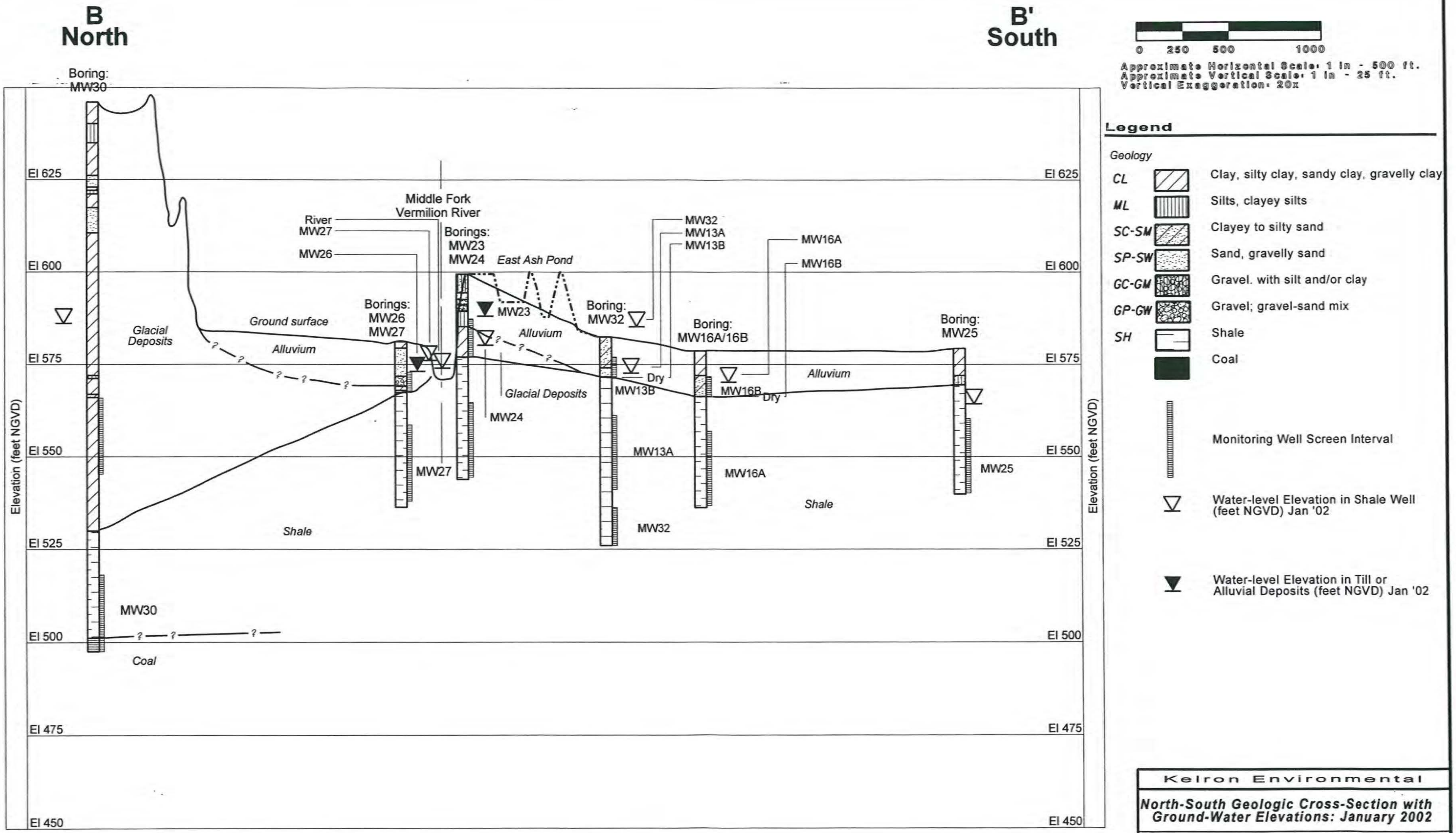


Kelron Environmental

East-West Geologic Cross-Section with Ground-Water Elevations: January 2002

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002 | *Figure 22*



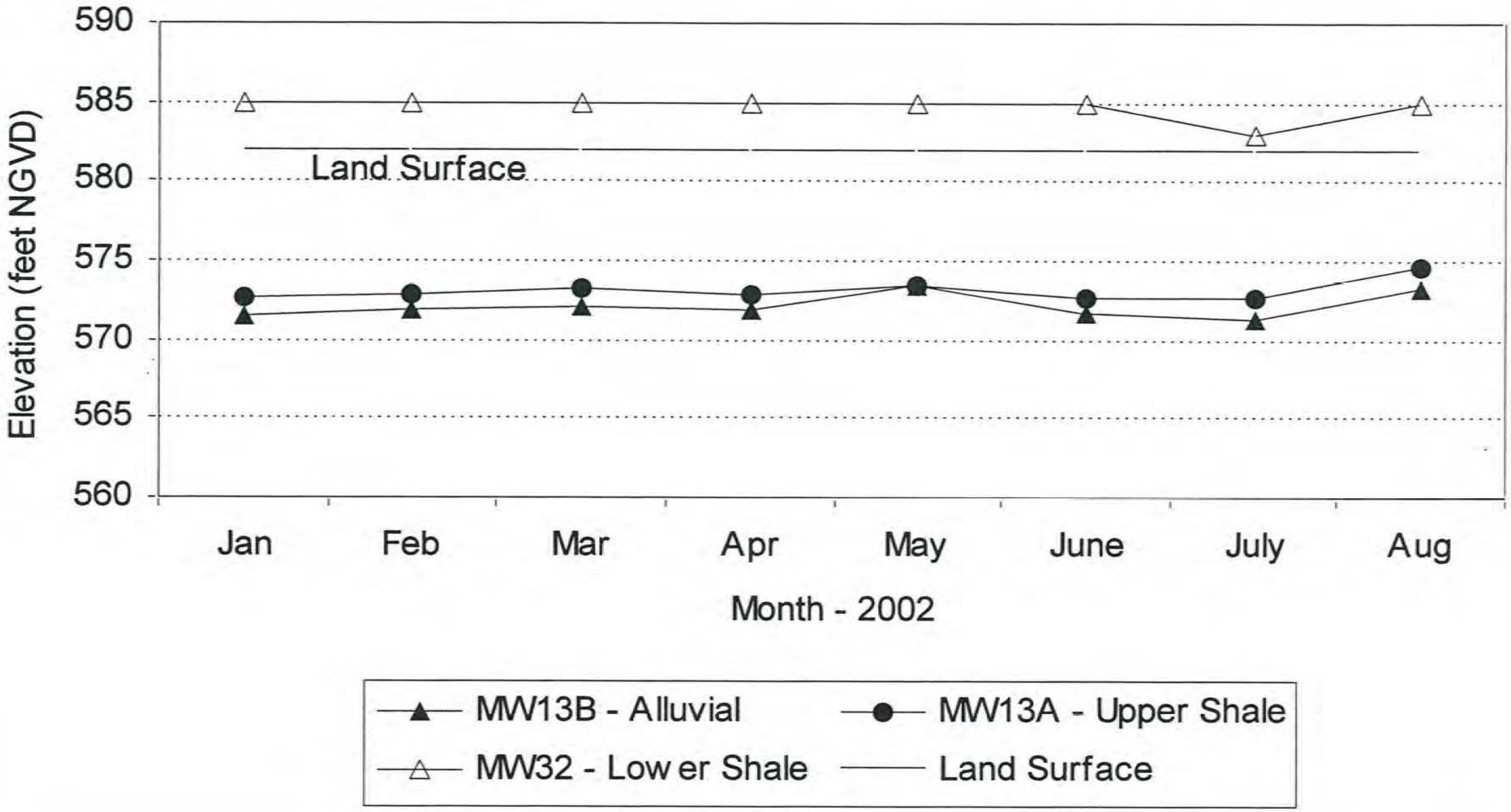
Kelron Environmental

North-South Geologic Cross-Section with Ground-Water Elevations: January 2002

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002

Figure 23

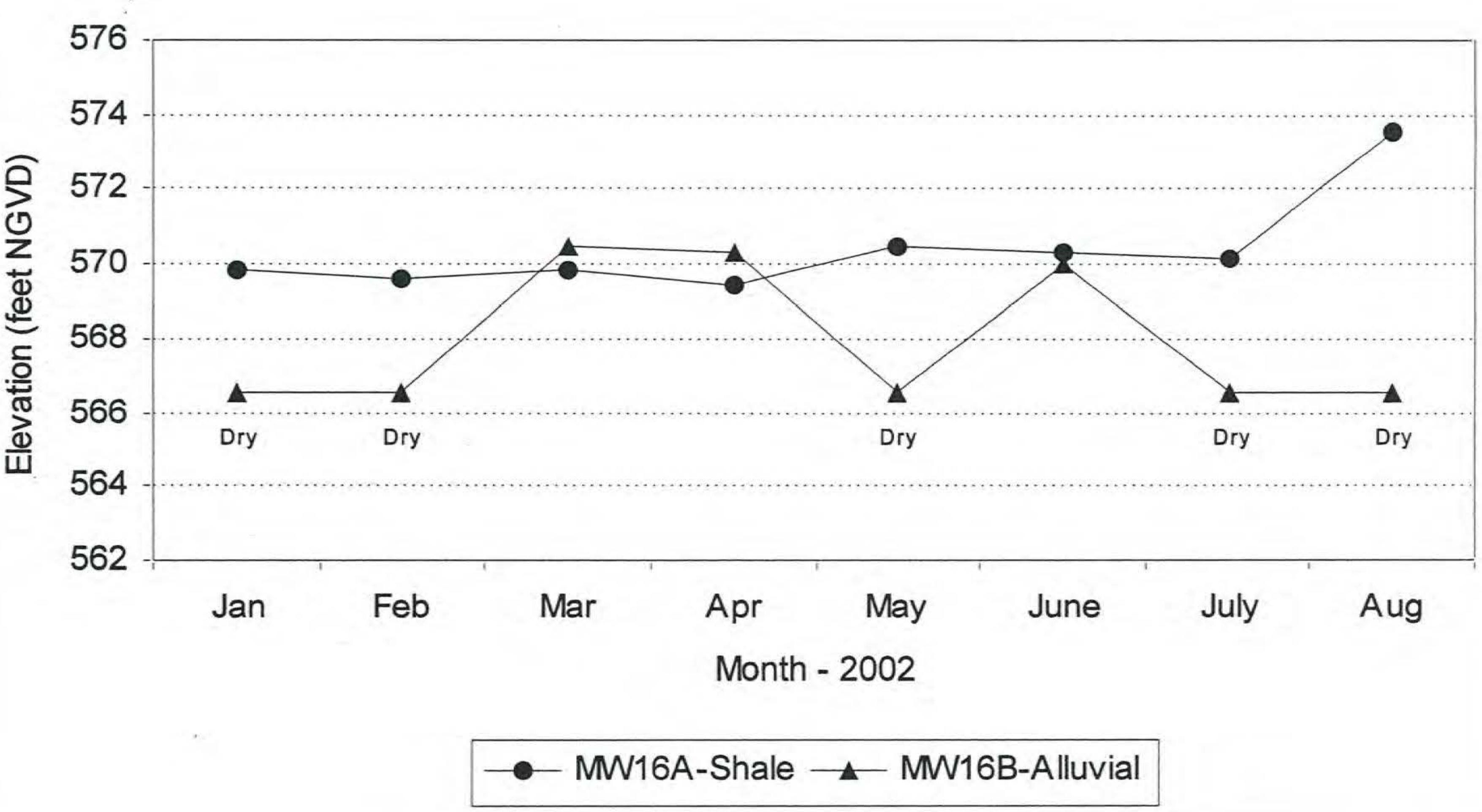


Kelron Environmental

Groundwater Hydrographs of Nested Wells MW13A, MW13B and MW32

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002	*Figure 24*



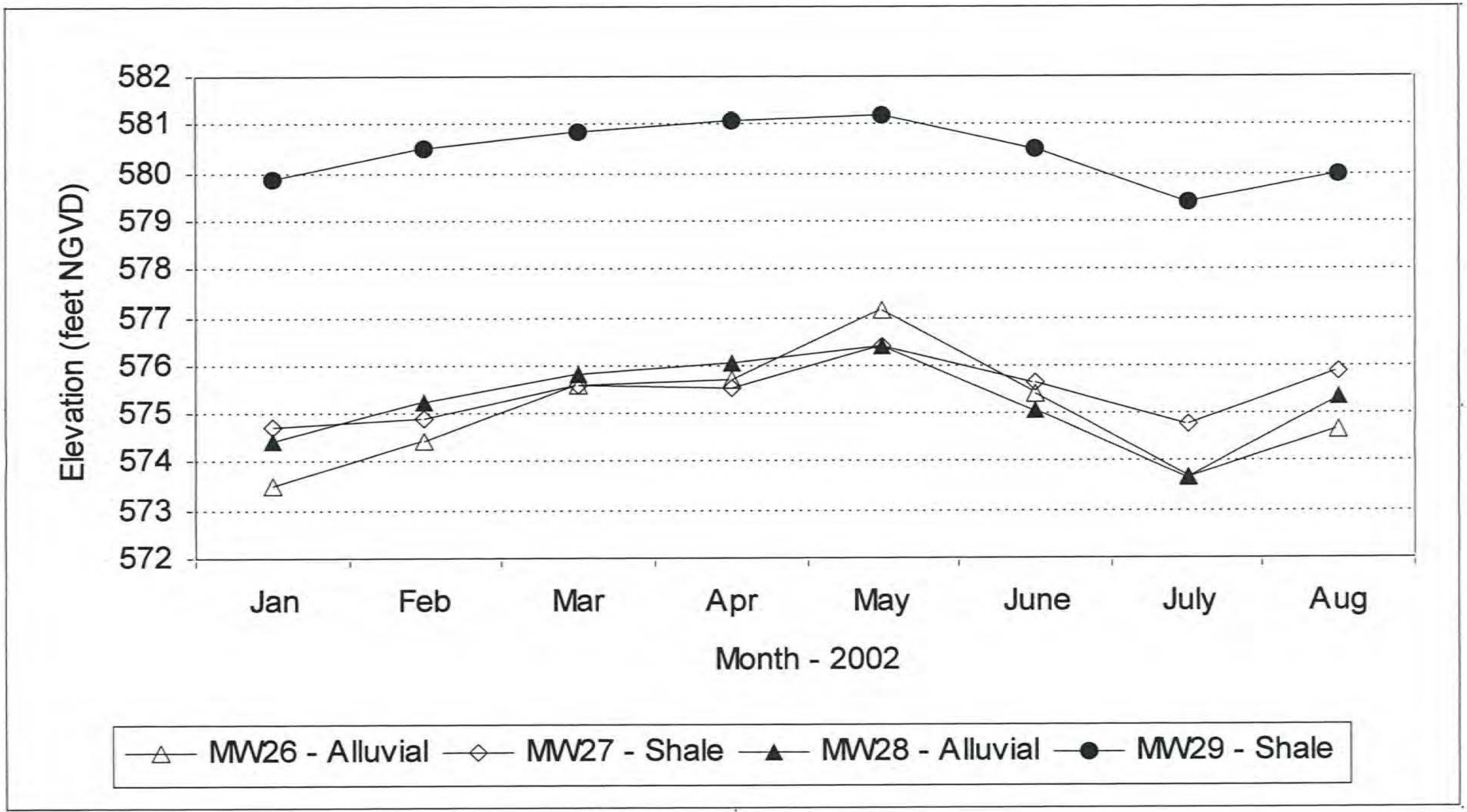
Kelron Environmental

Groundwater Hydrographs of Nested Wells MW16A and MW16B

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002

Figure 25



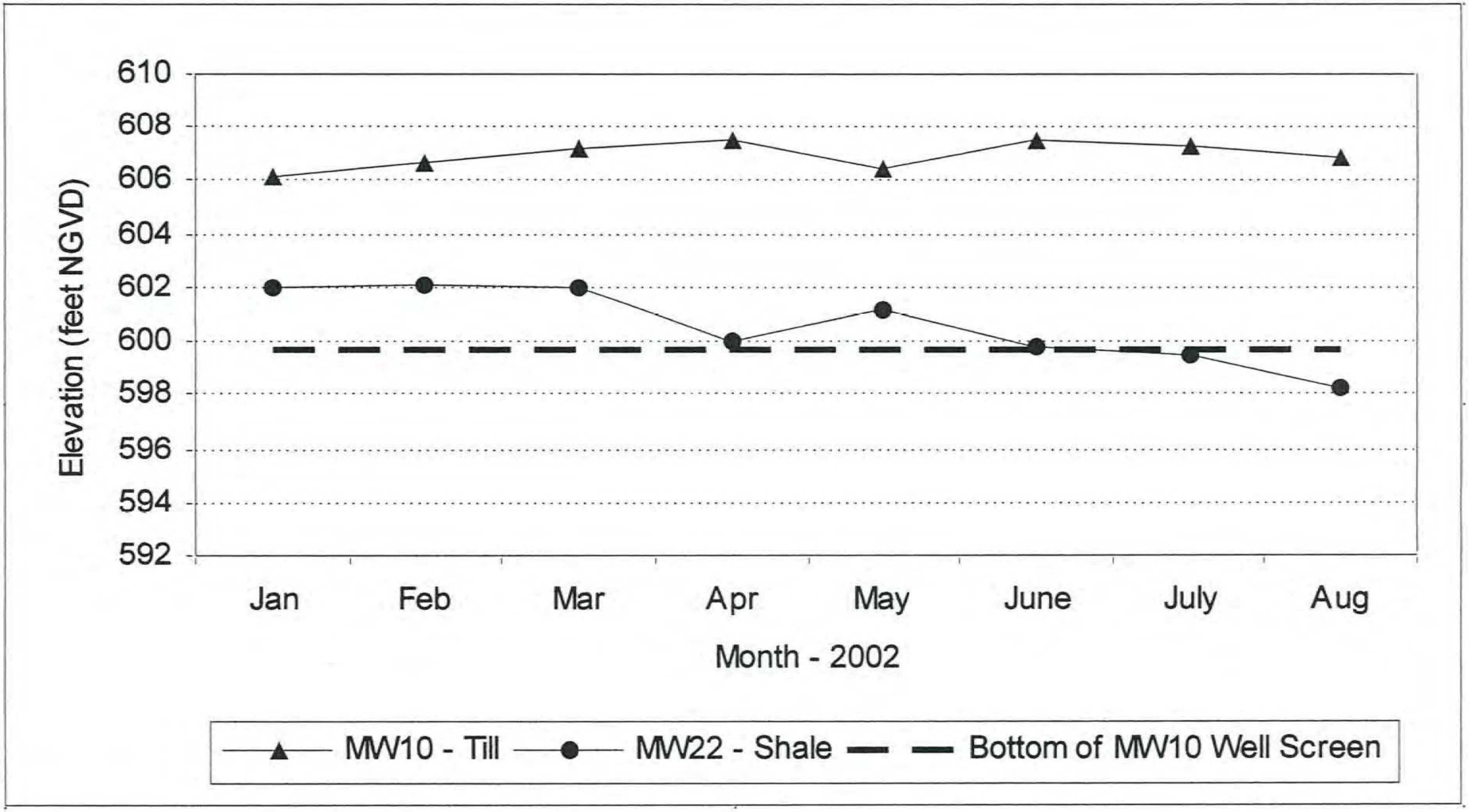
Kelron Environmental

Groundwater Hydrographs of Nested Wells
MW26 / MW27 and MW28 / MW29

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002

Figure 26



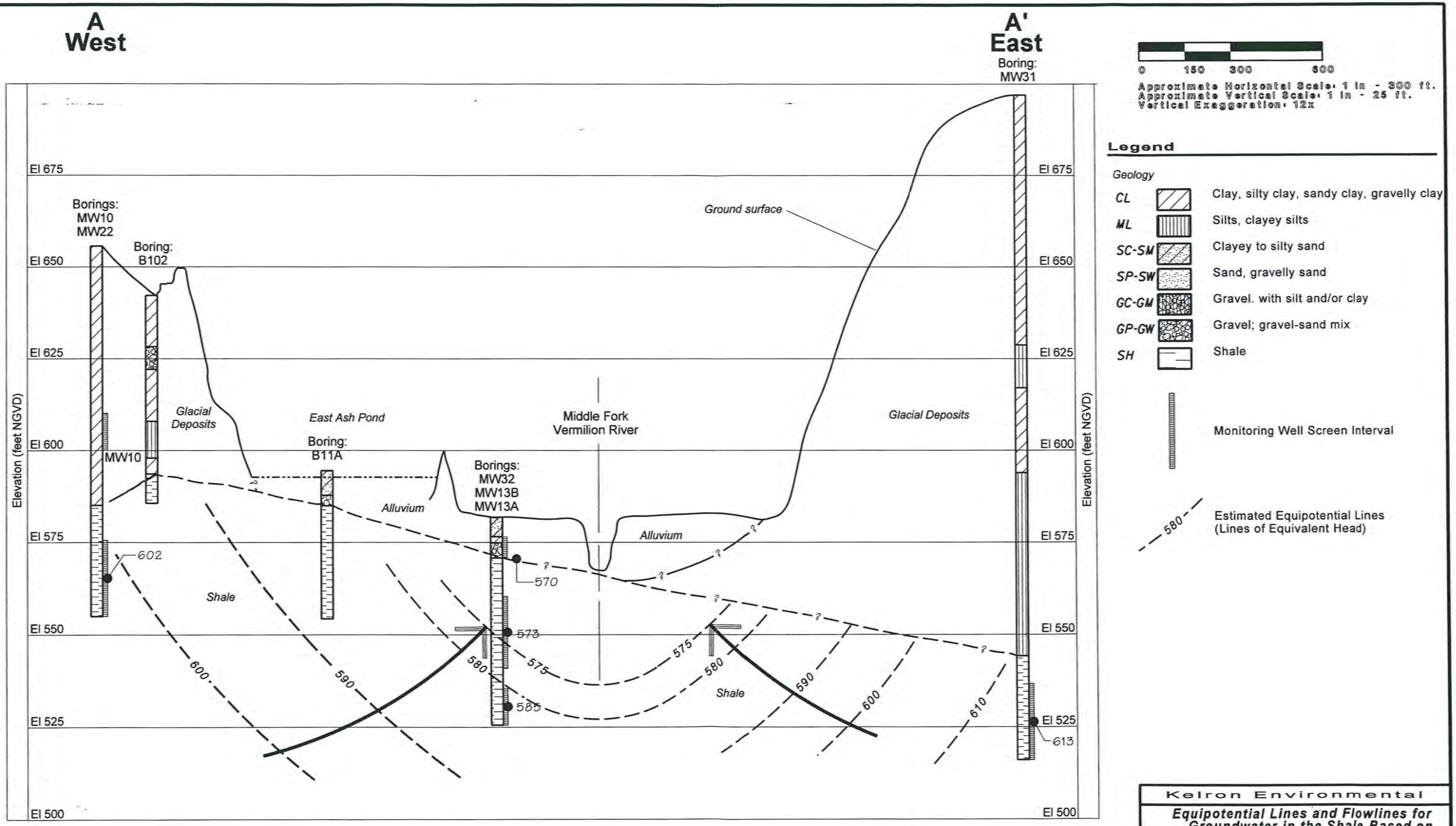
Kelron Environmental

Groundwater Hydrographs of Nested Wells MW10 and MW22

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002

Figure 27

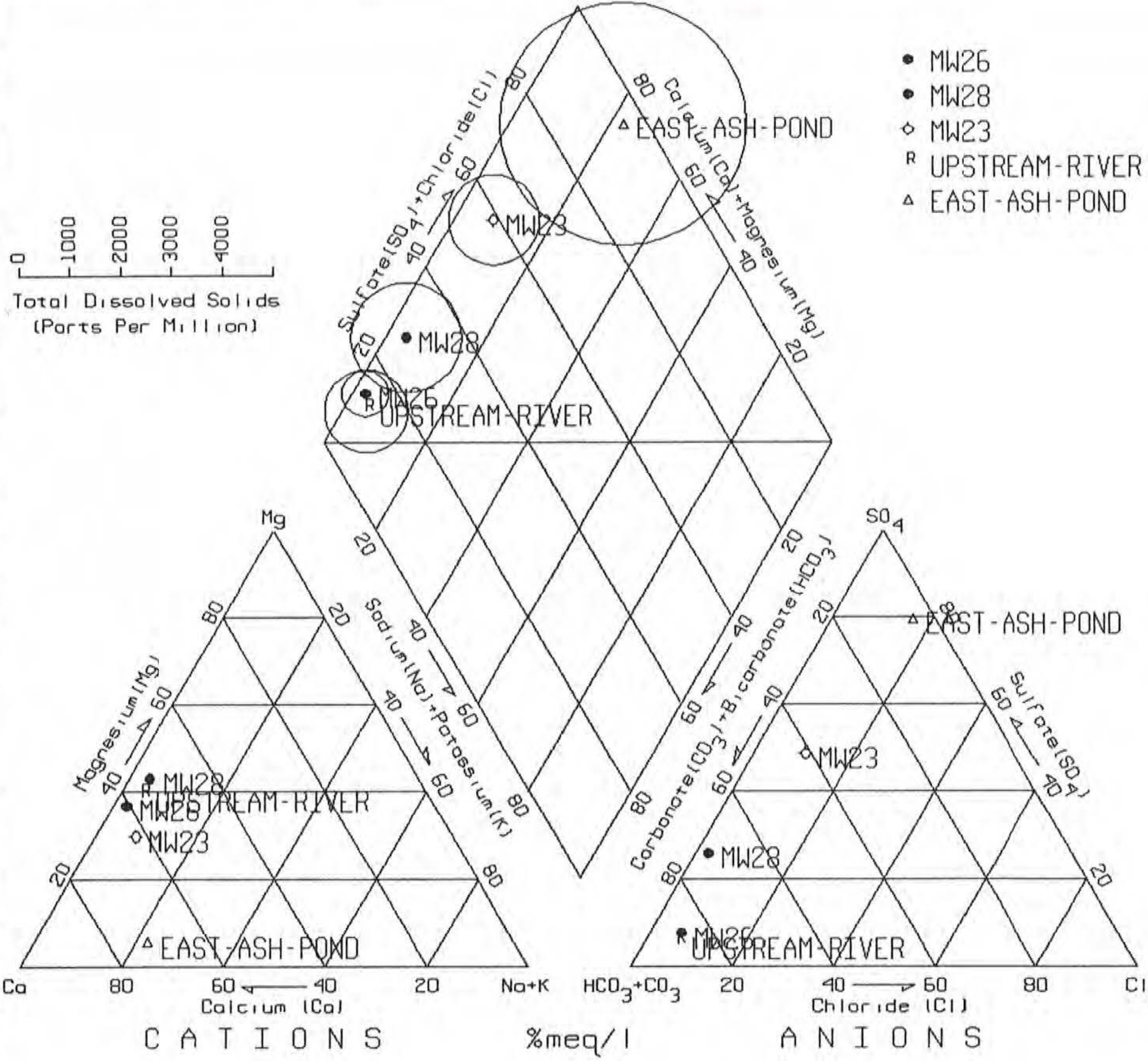


Kelron Environmental

Equipotential Lines and Flowlines for Groundwater in the Shale Based on Observed Hydraulic Head in January 2002

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002 | *Figure 28*



Note: Groundwater samples and Middle Fork River Sample are from June 2002; East Ash Pond sample is from March 2002

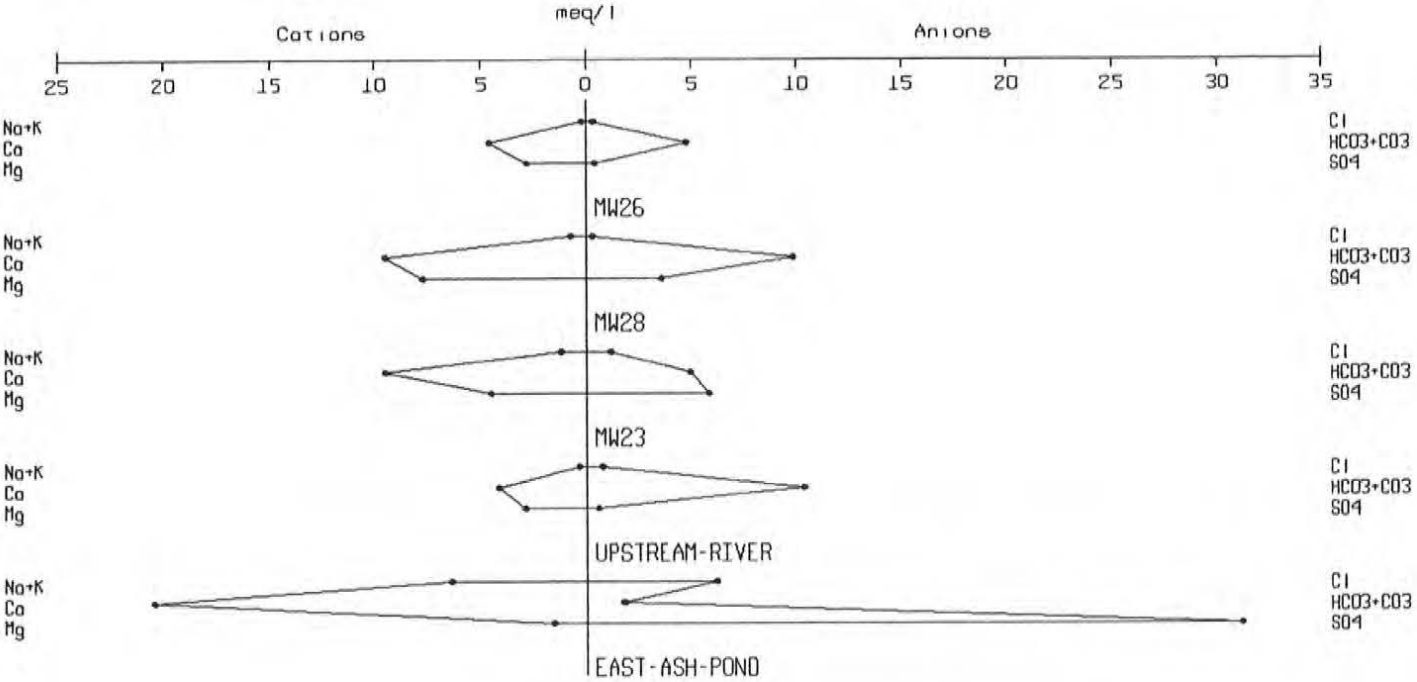
Kelron Environmental

Piper Diagram of Water Samples from Unlithified Deposits, Middle Fork River, and East Ash Pond

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002

Figure 29



Note: Groundwater samples and Middle Fork River Sample are from June 2002; East Ash Pond sample is from March 2002

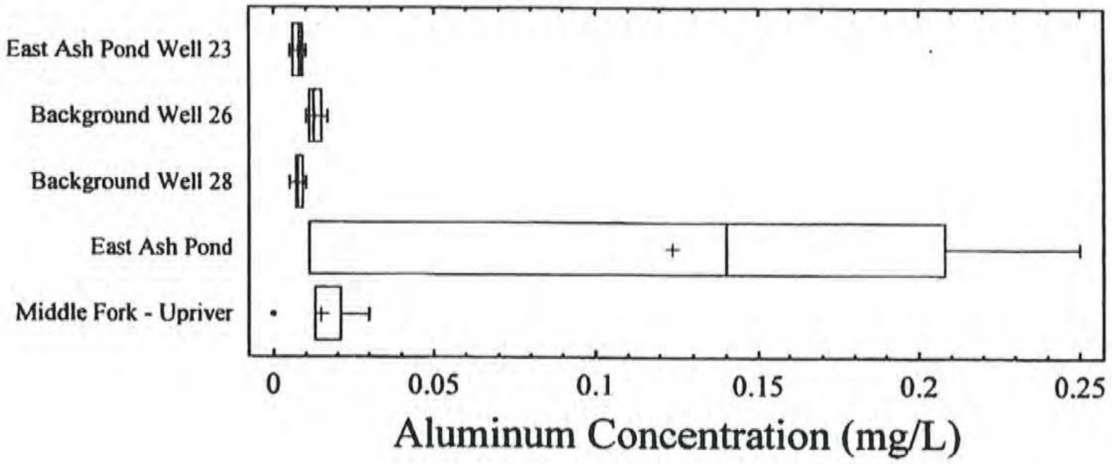
Kelron Environmental

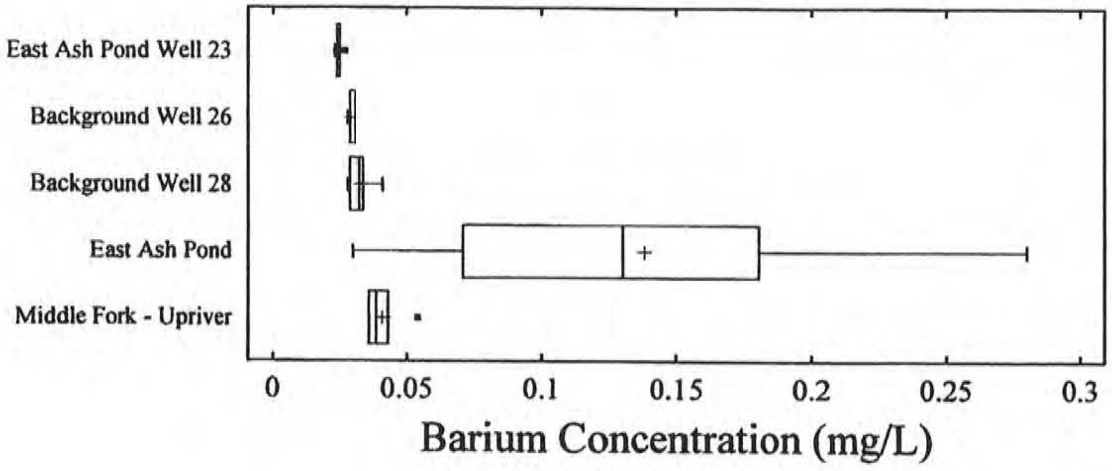
Stiff Diagrams of Water Samples from Unlithified Deposits, Middle Fork River, and East Ash Pond

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002

Figure 30





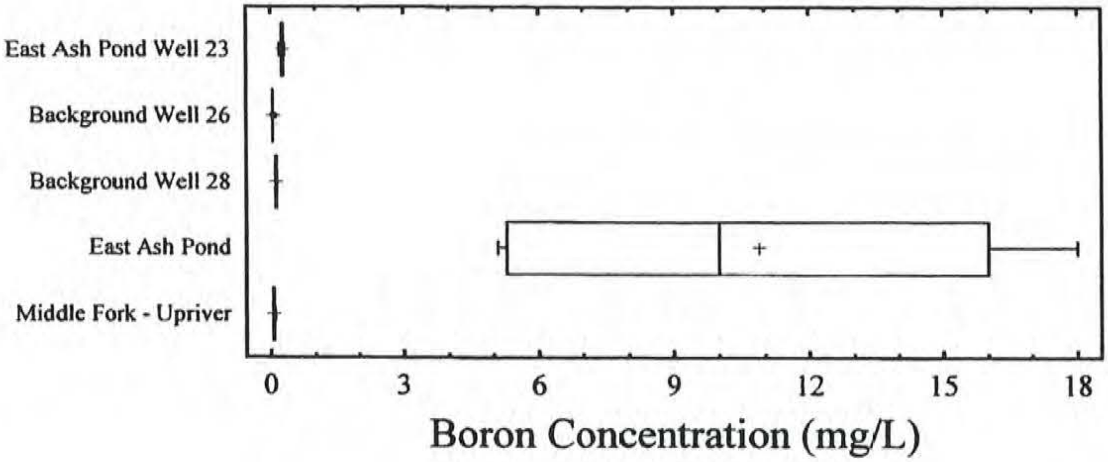
Kelron Environmental

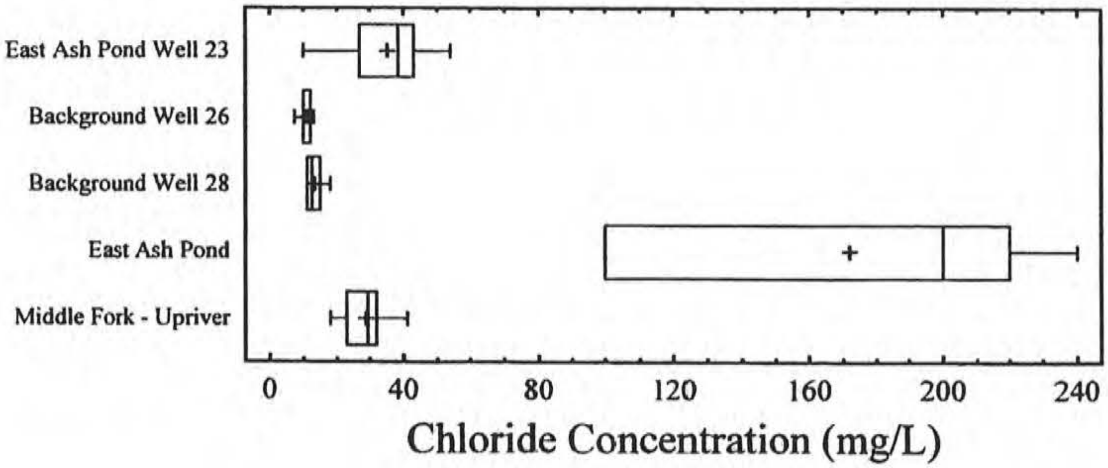
Box-and-Whisker Diagrams for Water Samples from Unlithified Deposits, Middle Fork River, and East Ash Pond in 2002

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002

Figure 31a



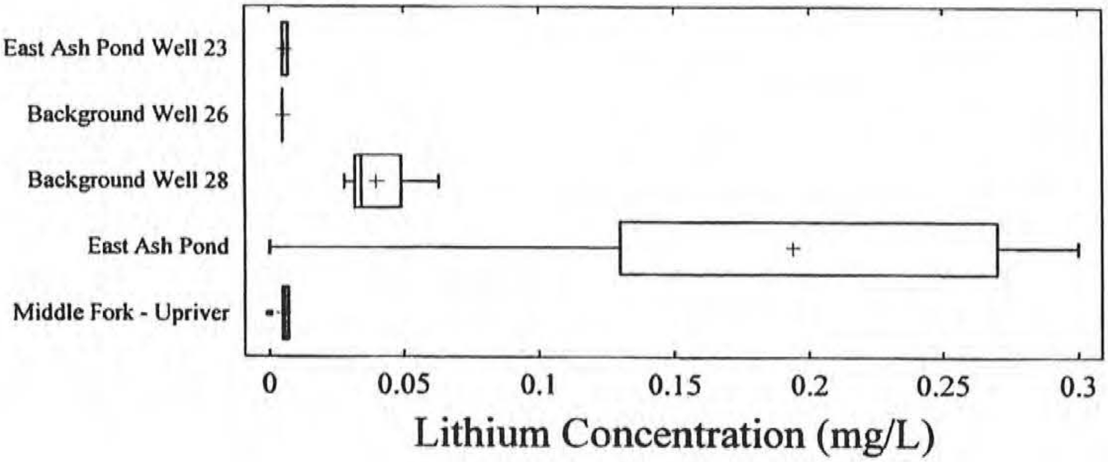


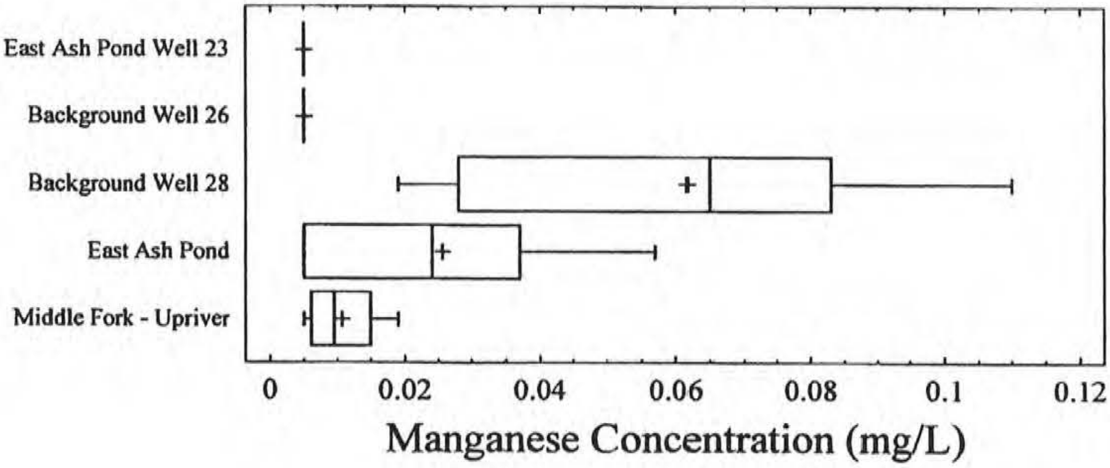
Kelron Environmental

Box-and-Whisker Diagrams for Water Samples from Unlithified Deposits, Middle Fork River, and East Ash Pond in 2002

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002 | *Figure 31b*





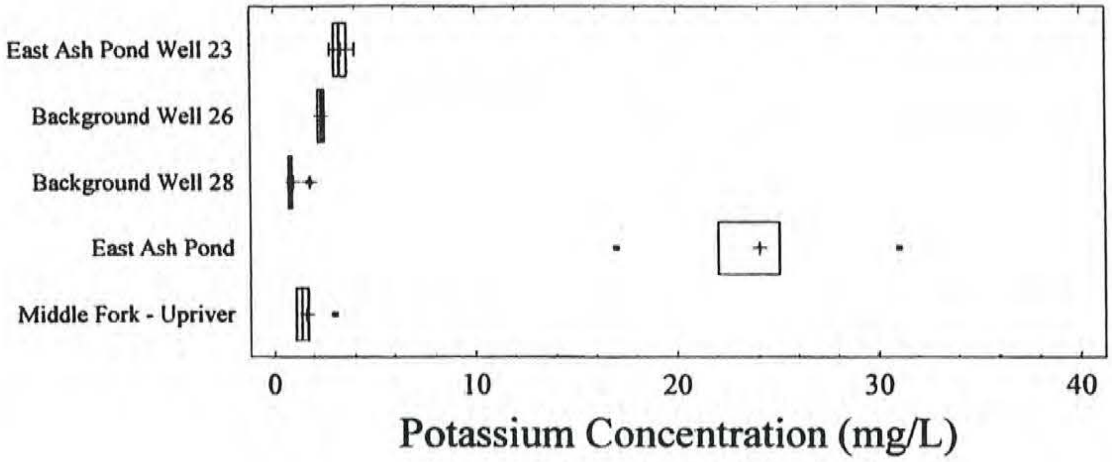
Kelron Environmental

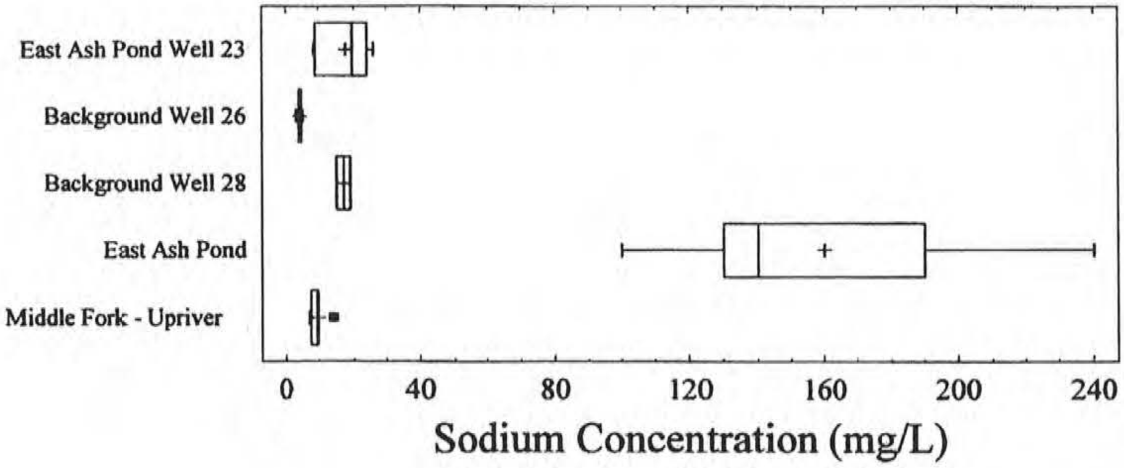
Box-and-Whisker Diagrams for Water Samples from Unlithified Deposits, Middle Fork River, and East Ash Pond in 2002

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002

Figure 31c



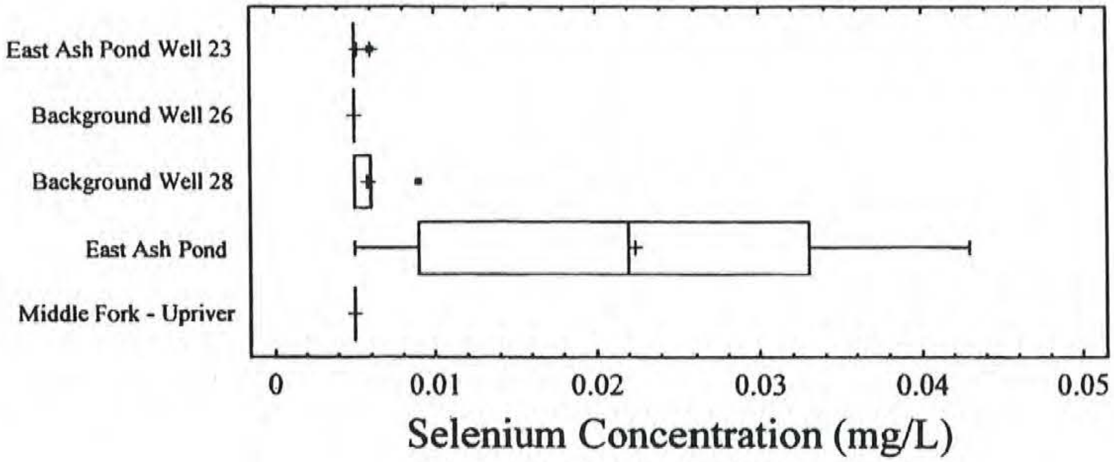


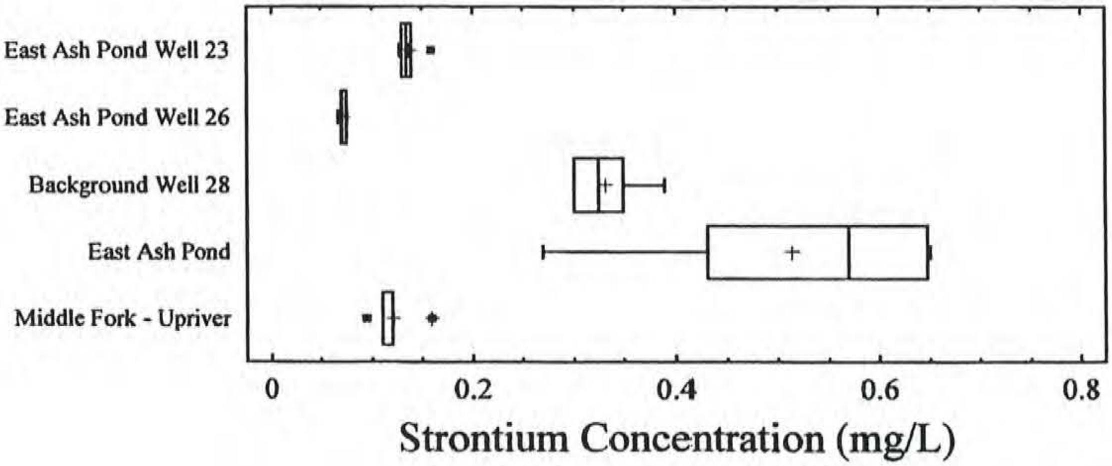
Kelron Environmental

Box-and-Whisker Diagrams for Water Samples from Unlithified Deposits, Middle Fork River, and East Ash Pond in 2002

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002 | *Figure 31d*



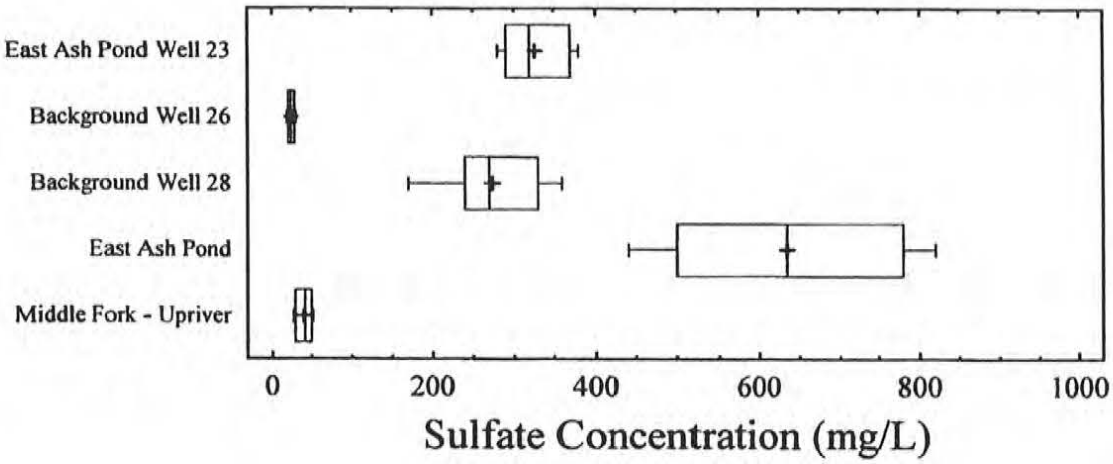


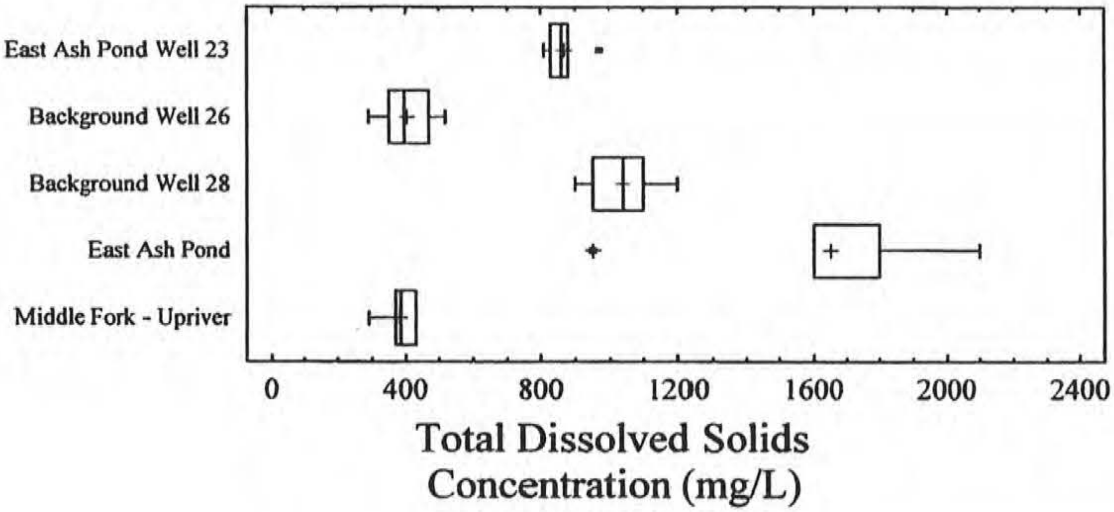
Kelron Environmental

Box-and-Whisker Diagrams for Water Samples from Unlithified Deposits, Middle Fork River, and East Ash Pond in 2002

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002 | *Figure 31e*





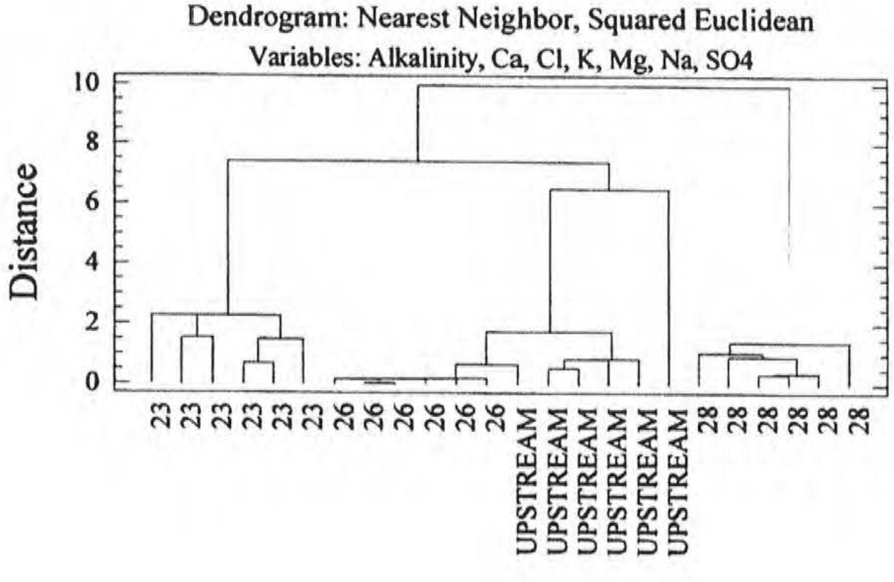
Kelron Environmental

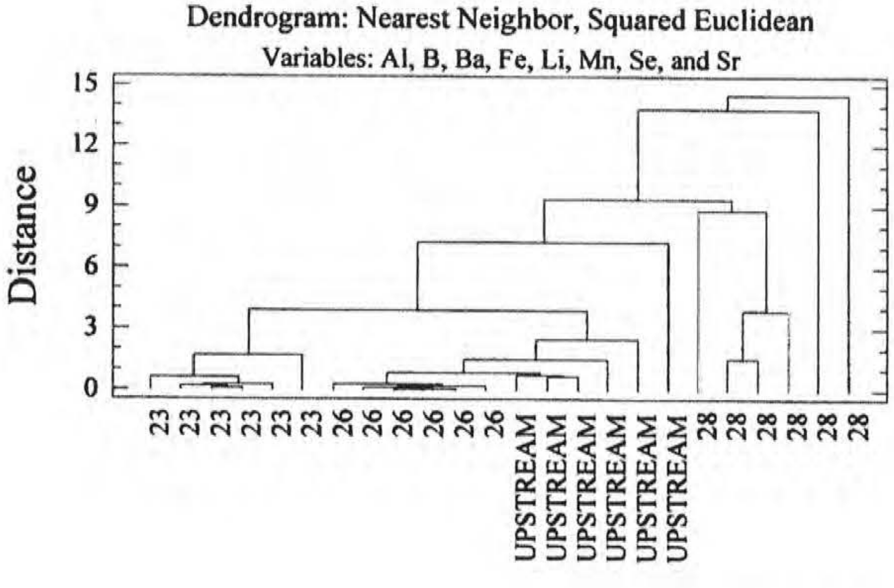
Box-and-Whisker Diagrams for Water Samples from Unlithified Deposits, Middle Fork River, and East Ash Pond in 2002

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002

Figure 31f





Note: Wells used in dendograms are: background wells MW26 and MW28; and, East Ash Pond well MW23. Upstream surface water quality is from Middle Fork of Vermilion River)

Kelron Environmental

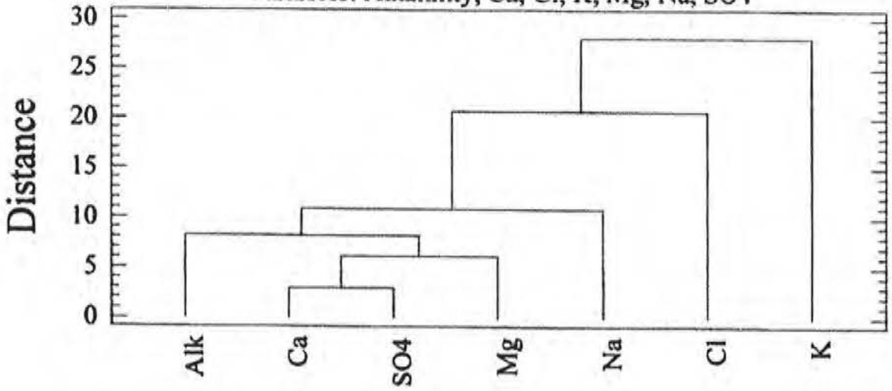
Dendrograms of Monthly Water Chemistry Data in Unlithified Deposits and Middle Fork River Based on Major Ions and Trace Metals

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

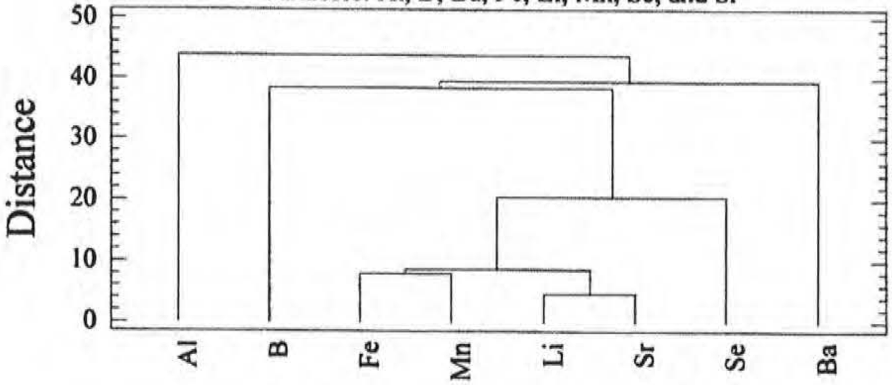
Date: September 2002

Figure 32

Dendrogram: Nearest Neighbor, Squared Euclidean
Variables: Alkalinity, Ca, Cl, K, Mg, Na, SO4



Dendrogram: Nearest Neighbor, Squared Euclidean
Variables: Al, B, Ba, Fe, Li, Mn, Se, and Sr



Kelron Environmental

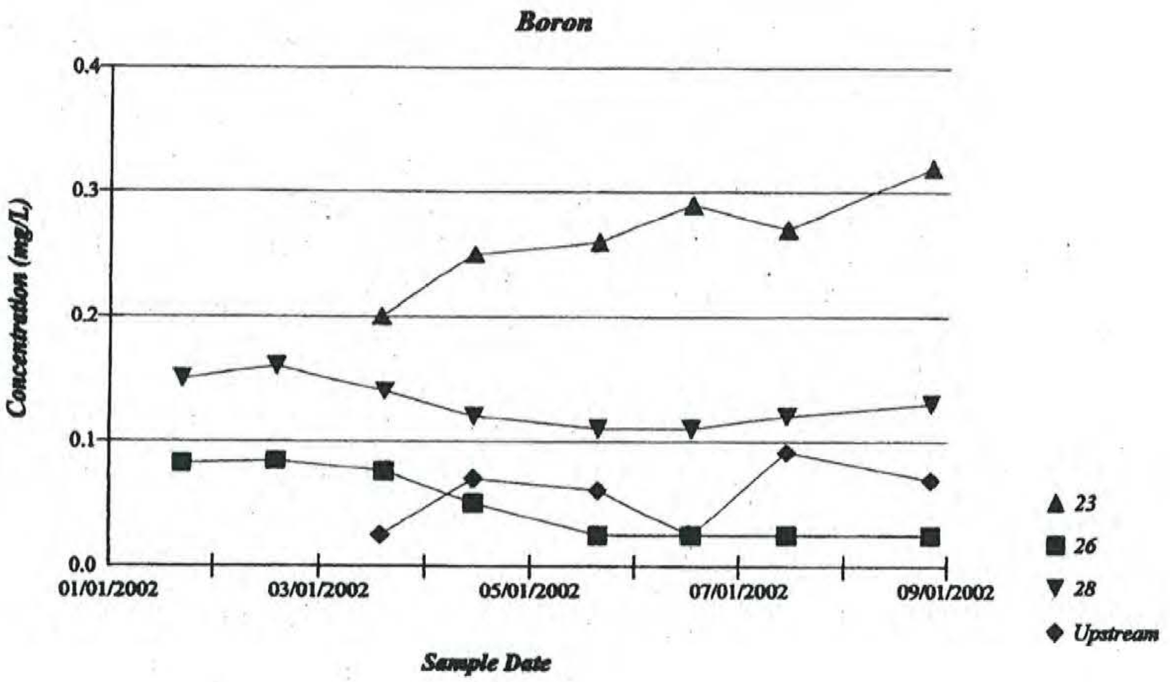
Dendrograms of Major Ions and Trace Metals in Water from Unconsolidated Deposits and Middle Fork River

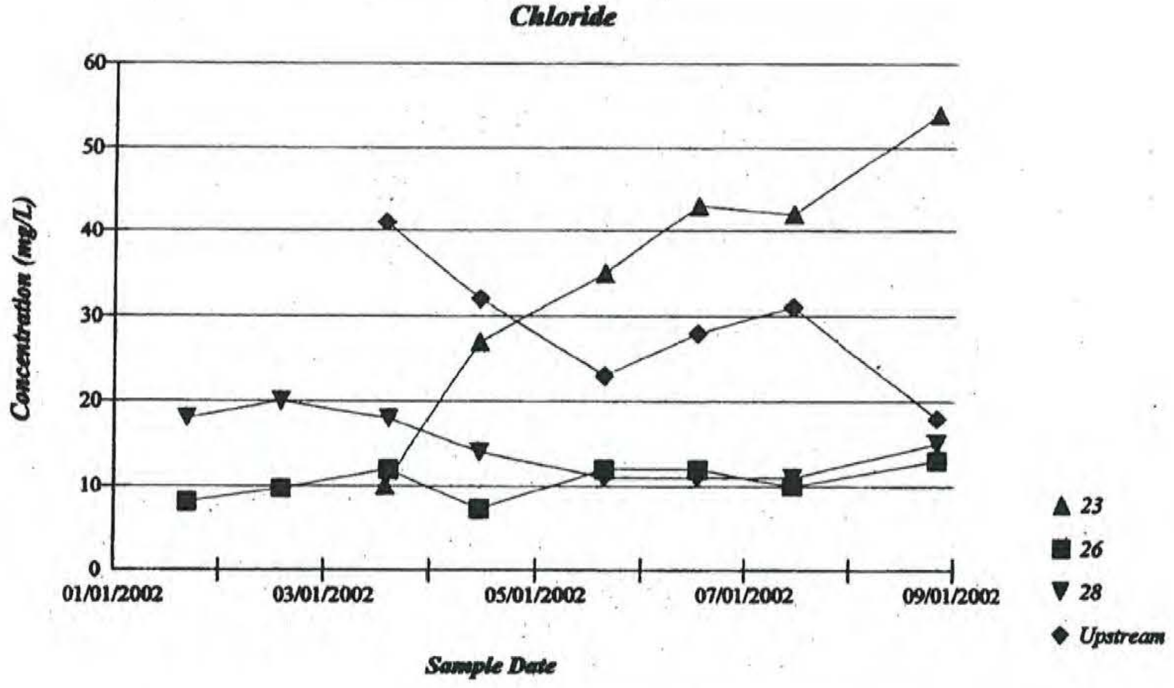
Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002

Figure 33

Note: Data used in dendograms are for background wells MW26 and MW28, East Ash Pond well MW23, and upstream surface water from the Middle Fork of Vermilion River)



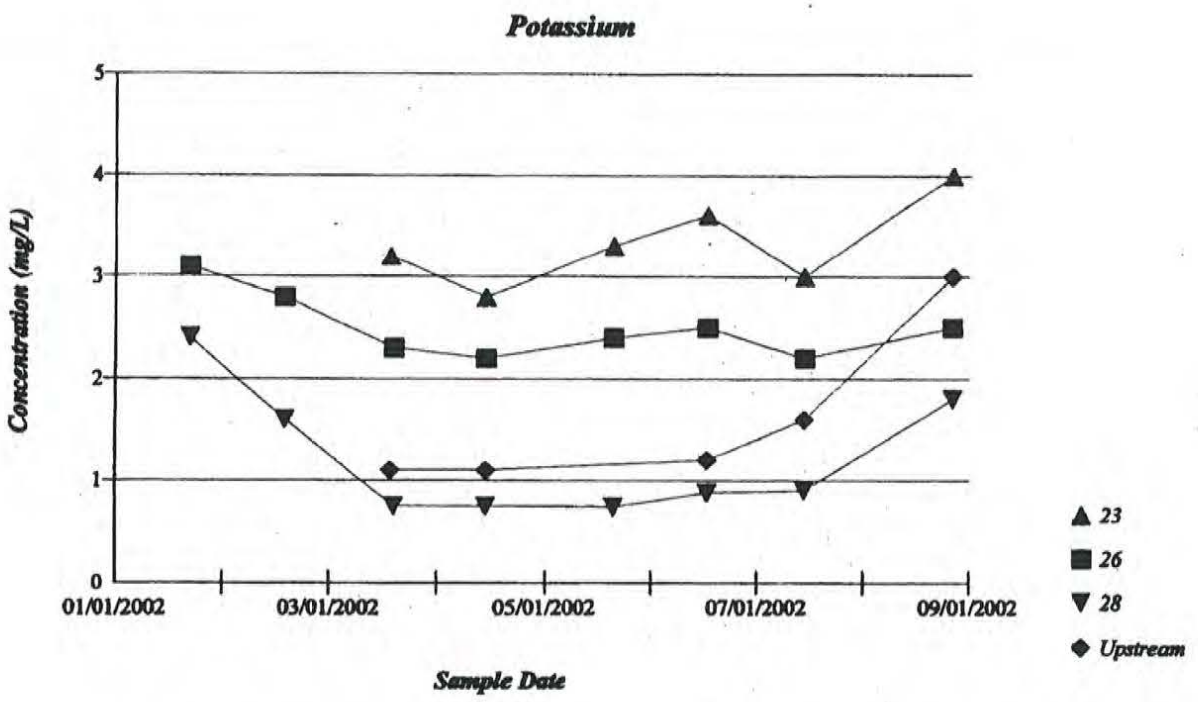


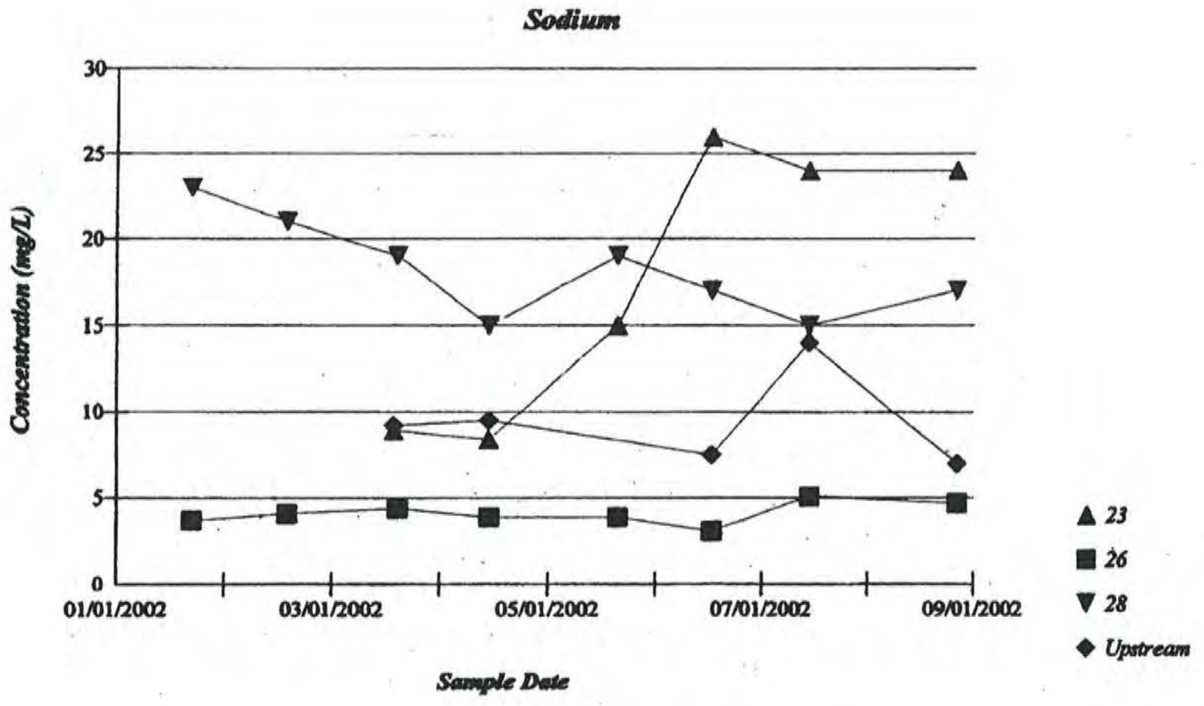
Kelron Environmental

Chloride Trends in Unlithified Deposits and Upstream on Middle Fork River

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002 | *Figure 34A*


Potassium

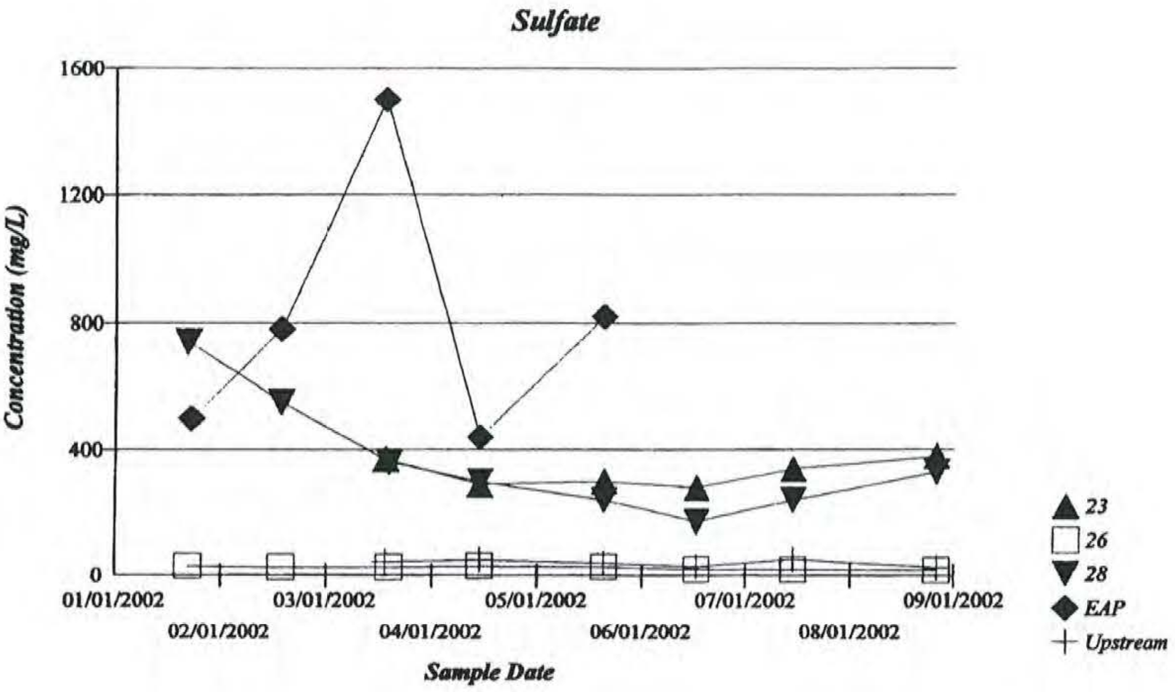

Sodium

Kelron Environmental

Potassium and Sodium Trends in Unlithified Deposits and Upstream on Middle Fork River

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002	Figure 34B

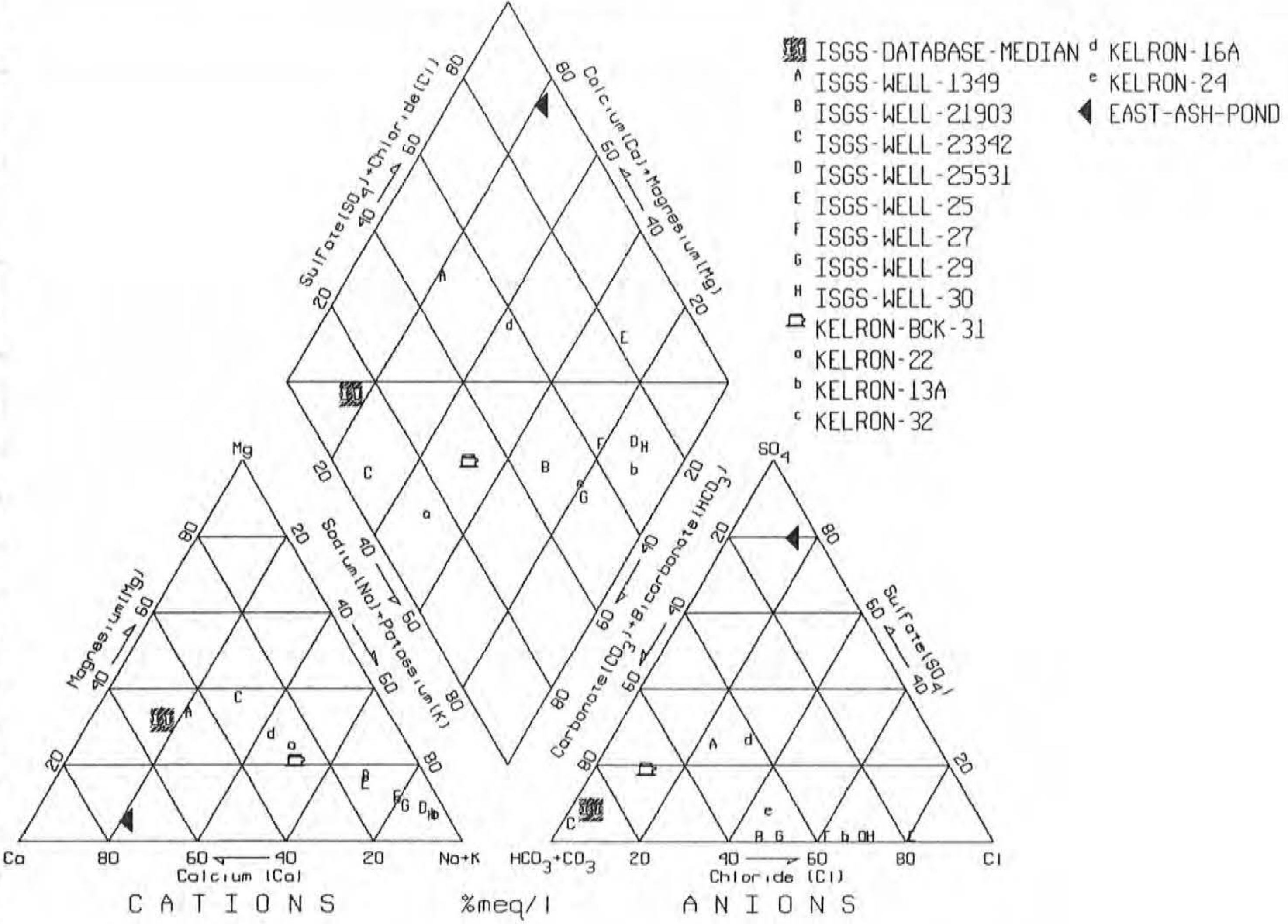


Kelron Environmental

Sulfate Trends in Unlithified Deposits, Upstream on Middle Fork River, and East Ash Pond

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002	Figure 34C



Note: Groundwater samples are from June 2002; East Ash Pond sample is from March 2002)

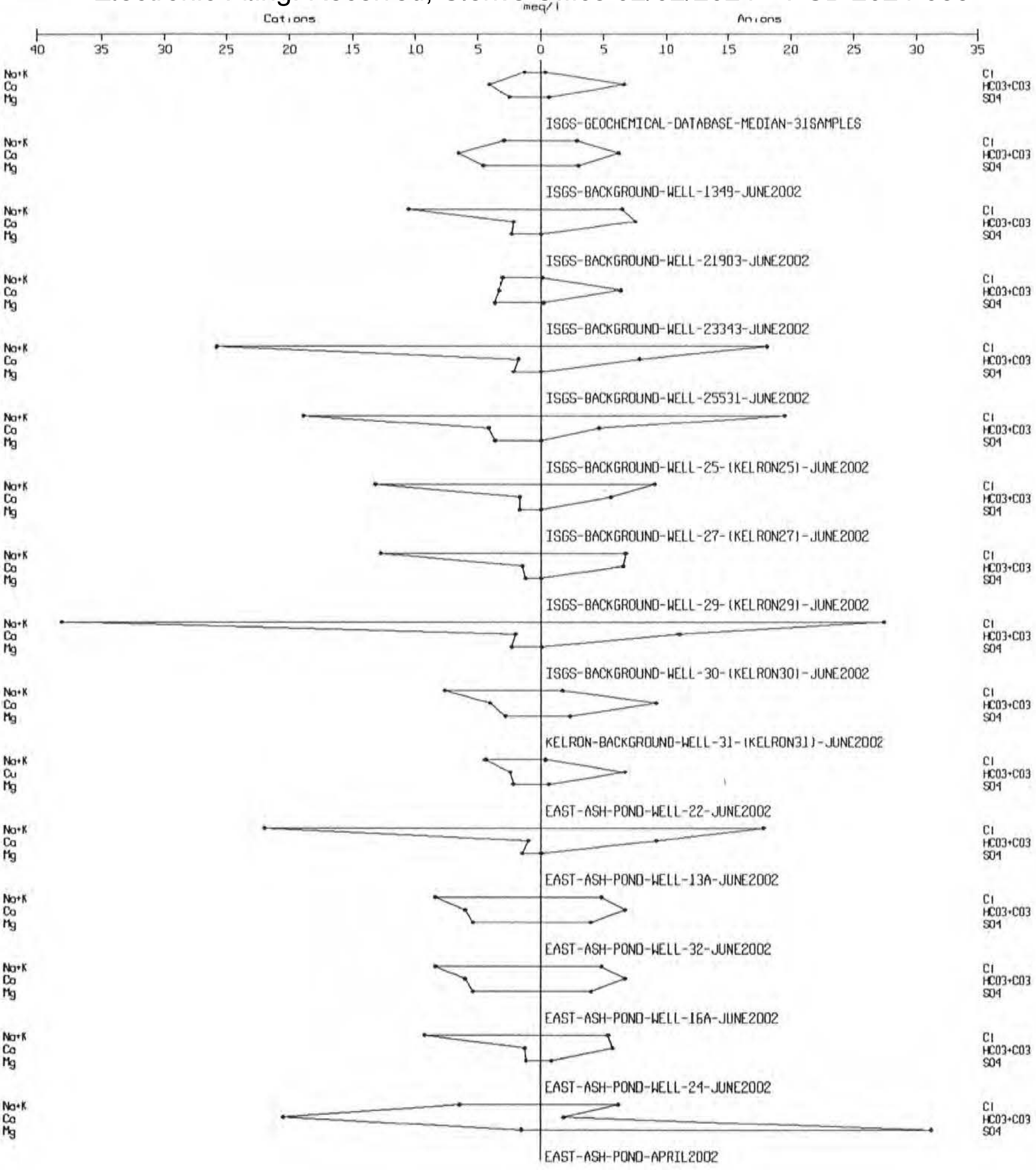
Kelron Environmental

Piper Diagram of Groundwater Samples from Bedrock and Surface Water Samples from East Ash Pond

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002

Figure 35



Note: Groundwater samples are from June 2002; East Ash Pond sample is from March 2002)

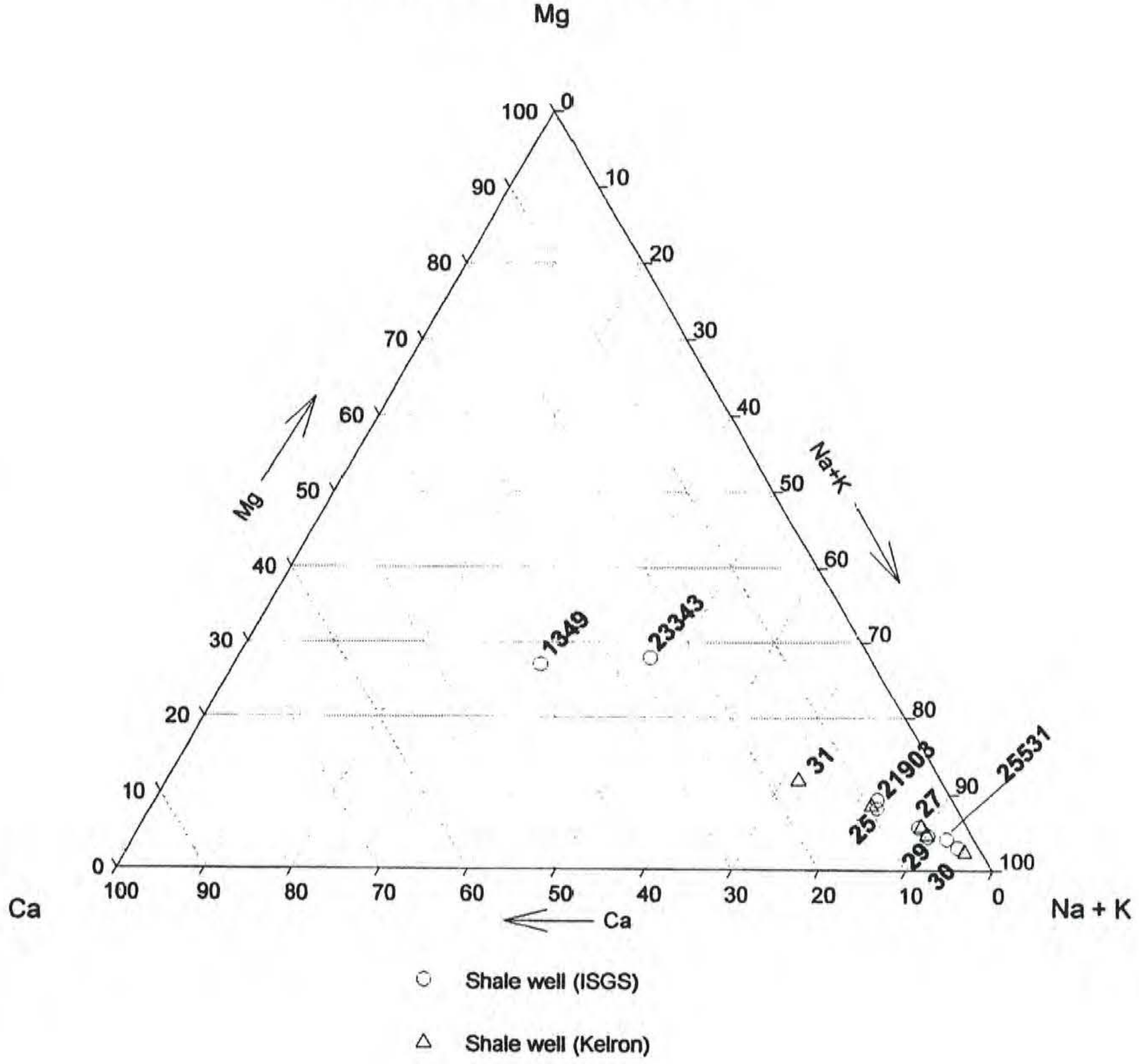
Kelron Environmental

Stiff Diagrams of Groundwater Samples from Bedrock and Surface Water Samples from East Ash Pond

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002	*Figure 36*

Cation Plot of Piper Diagram



Kelron Environmental

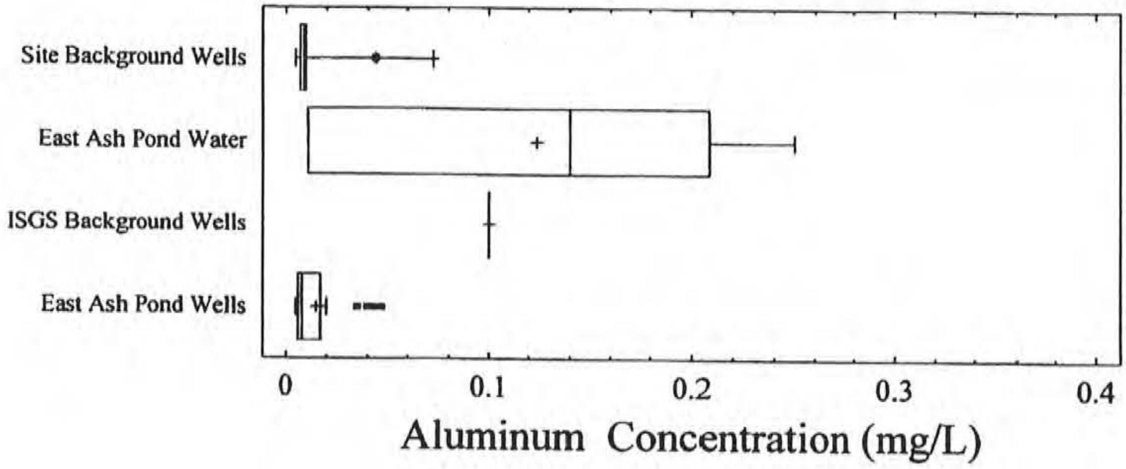
Cation Plot of Piper Diagram for June 2002 Groundwater Samples Collected by the ISGS and Kelron

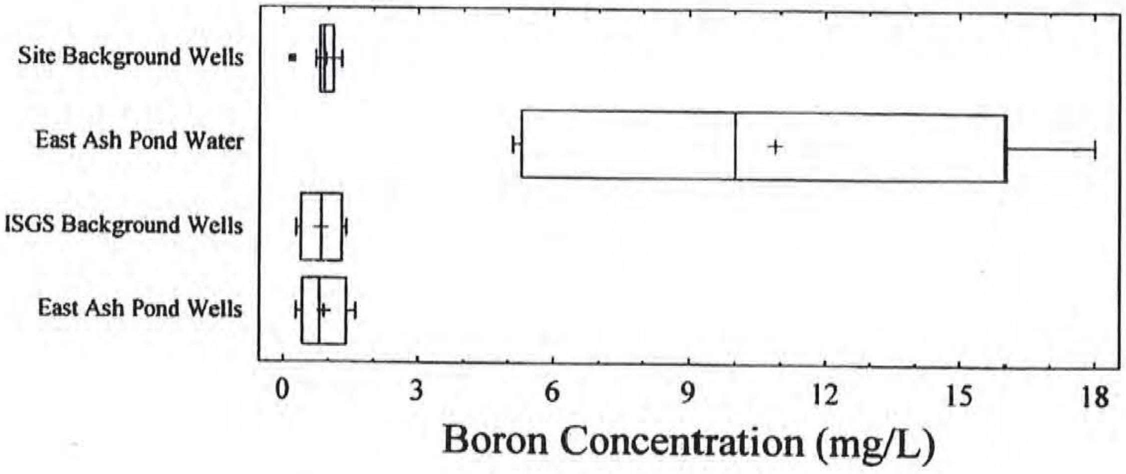
Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002

Figure 37

Note: modified after Figure 13, Appendix A (Mehnert and Dreher, 2002)



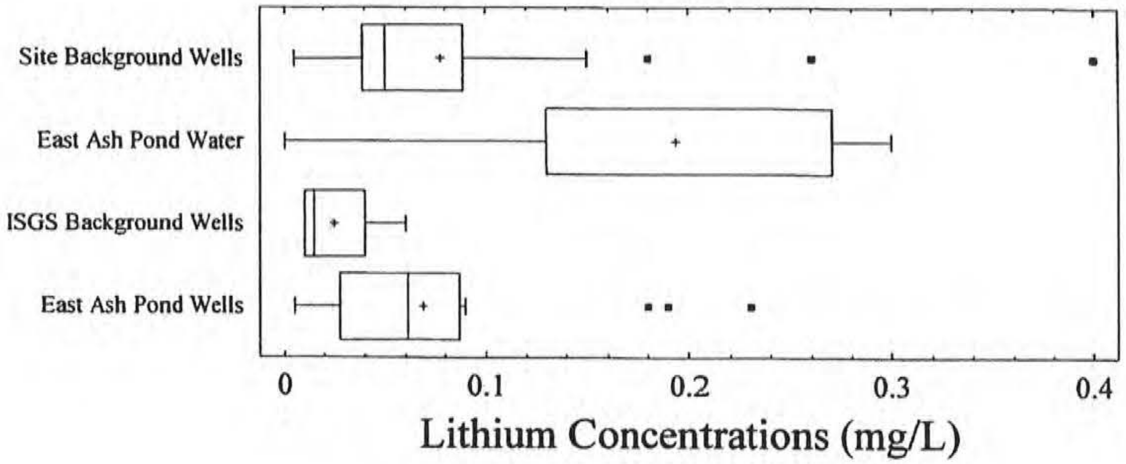


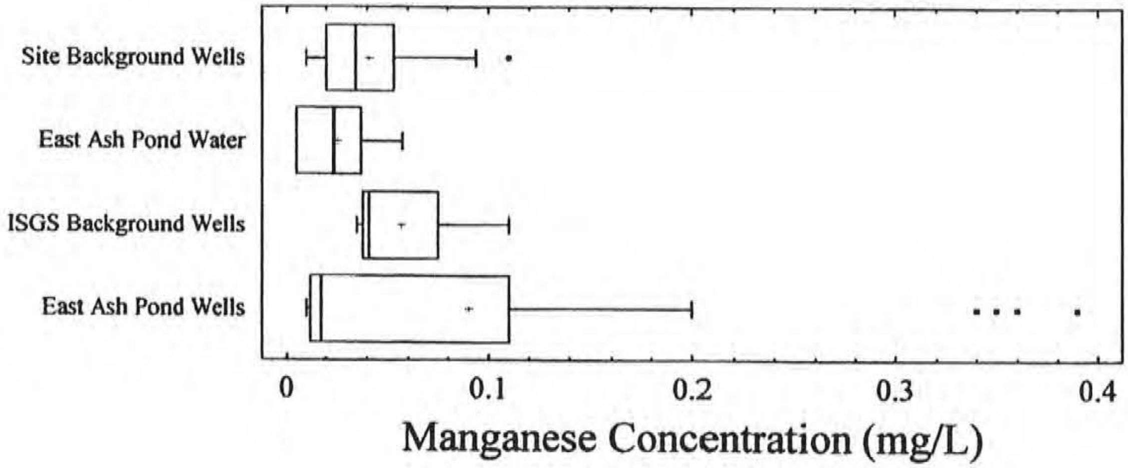
Kelron Environmental

Box-and-Whisker Diagrams for Groundwater Samples from Bedrock and Surface Water Samples from East Ash Pond in 2002

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002 | *Figure 38A*





Kelron Environmental

Box-and-Whisker Diagrams for Groundwater Samples from Bedrock and Surface Water Samples from East Ash Pond in 2002

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
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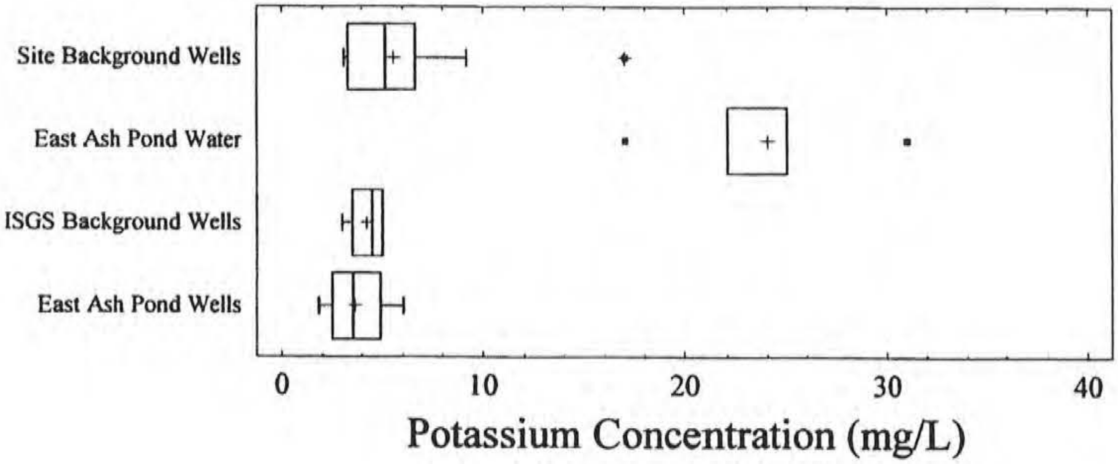
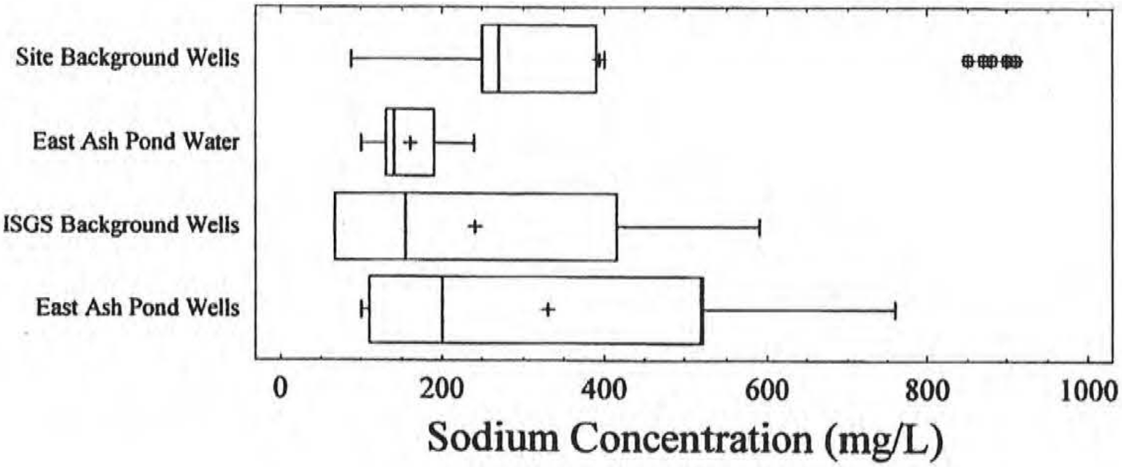
Figure 38C



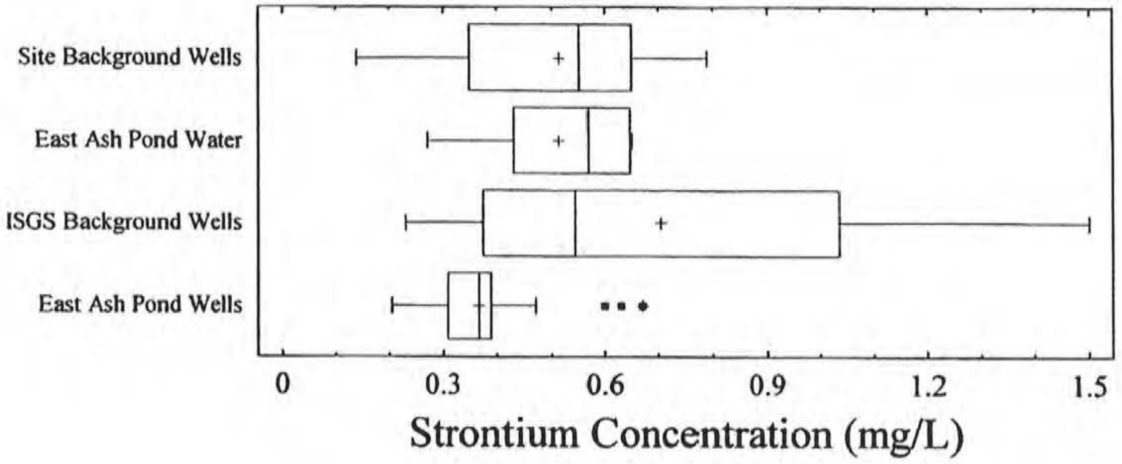


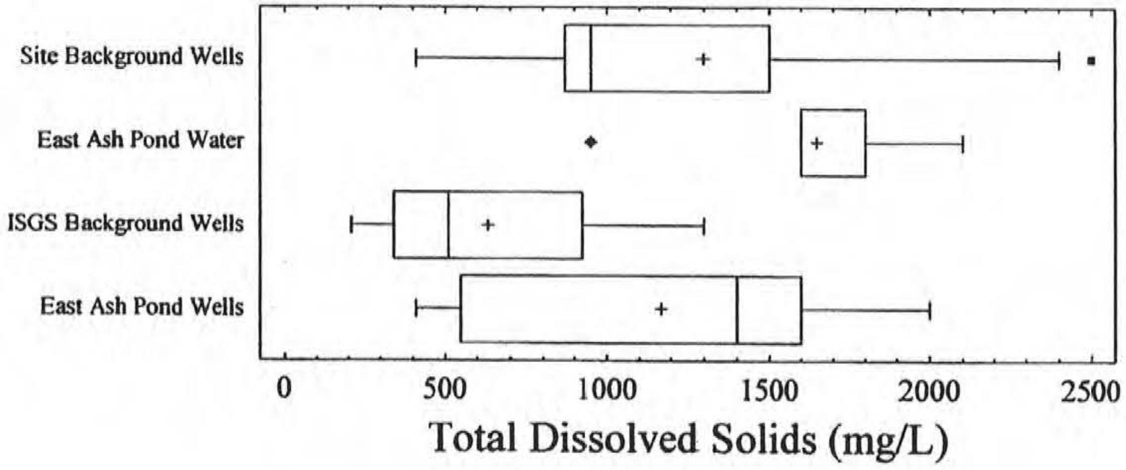
Kelron Environmental

Box-and-Whisker Diagrams for Groundwater Samples from Bedrock and Surface Water Samples from East Ash Pond in 2002

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002 | *Figure 38D*





Kelron Environmental

Box-and-Whisker Diagrams for Groundwater Samples from Bedrock and Surface Water Samples from East Ash Pond in 2002

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

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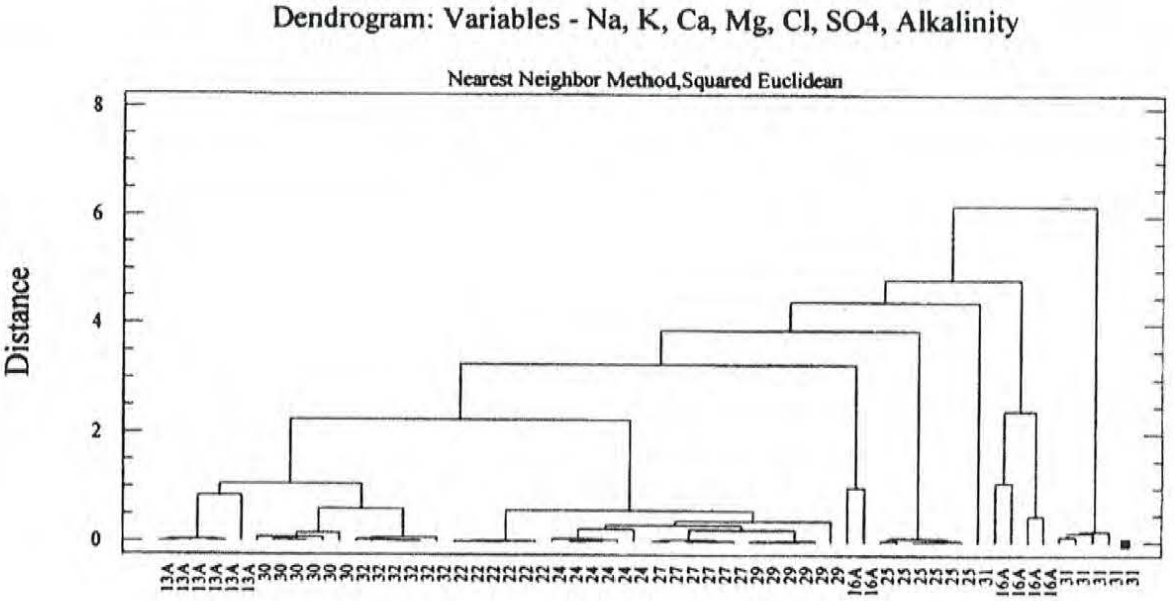
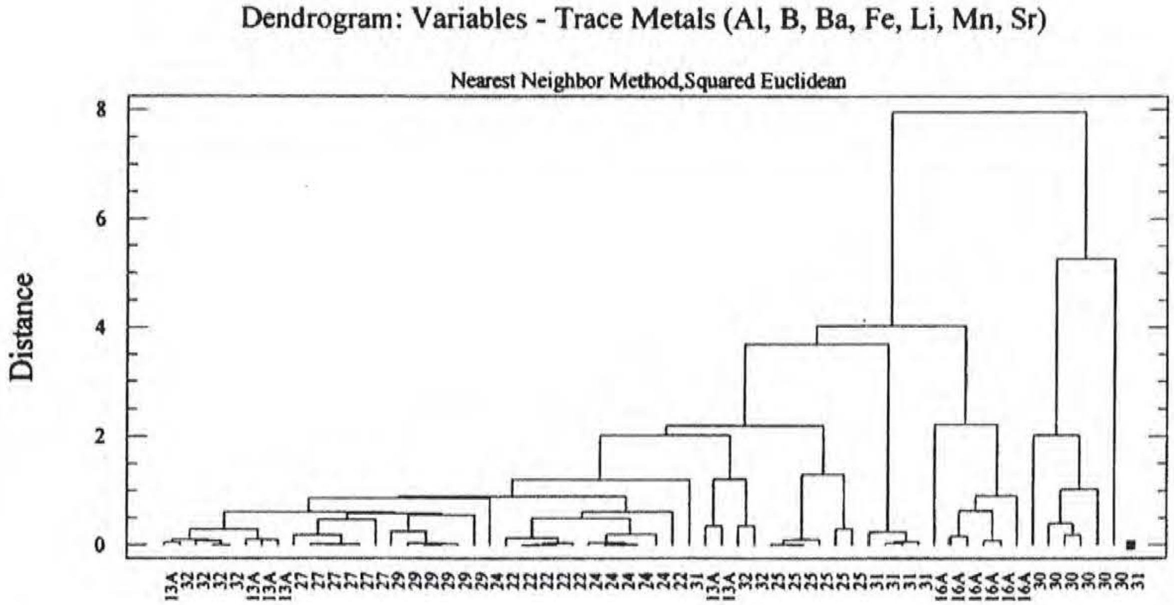
Figure 38E





Kelron Environmental

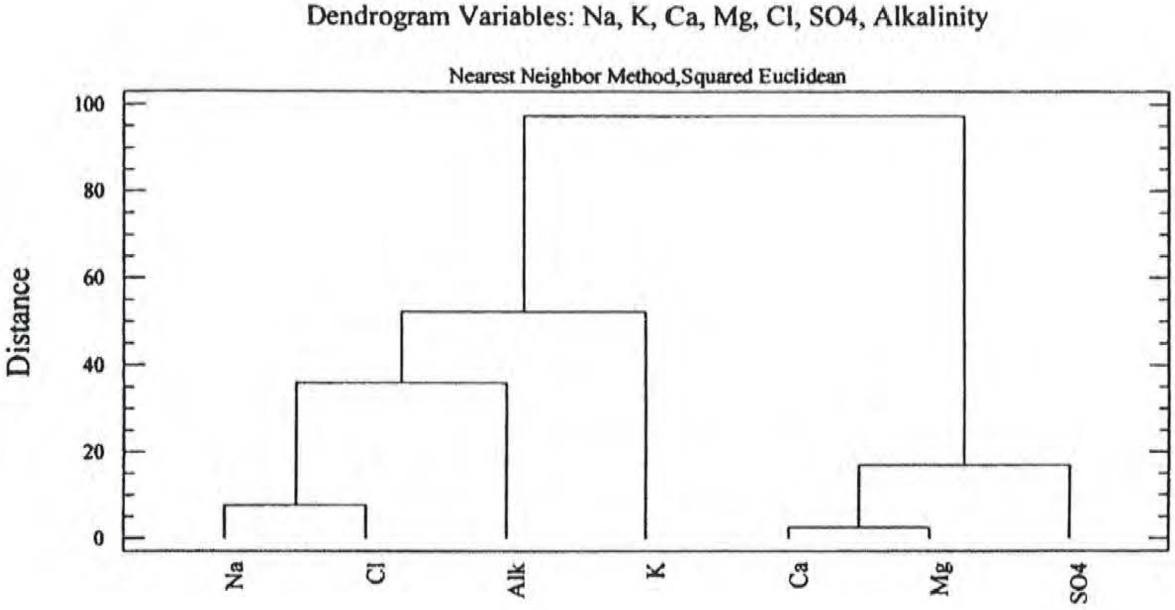
Dendrograms of Monthly Groundwater Chemistry Data in Bedrock Deposits Based on Major Ions and Trace Metals

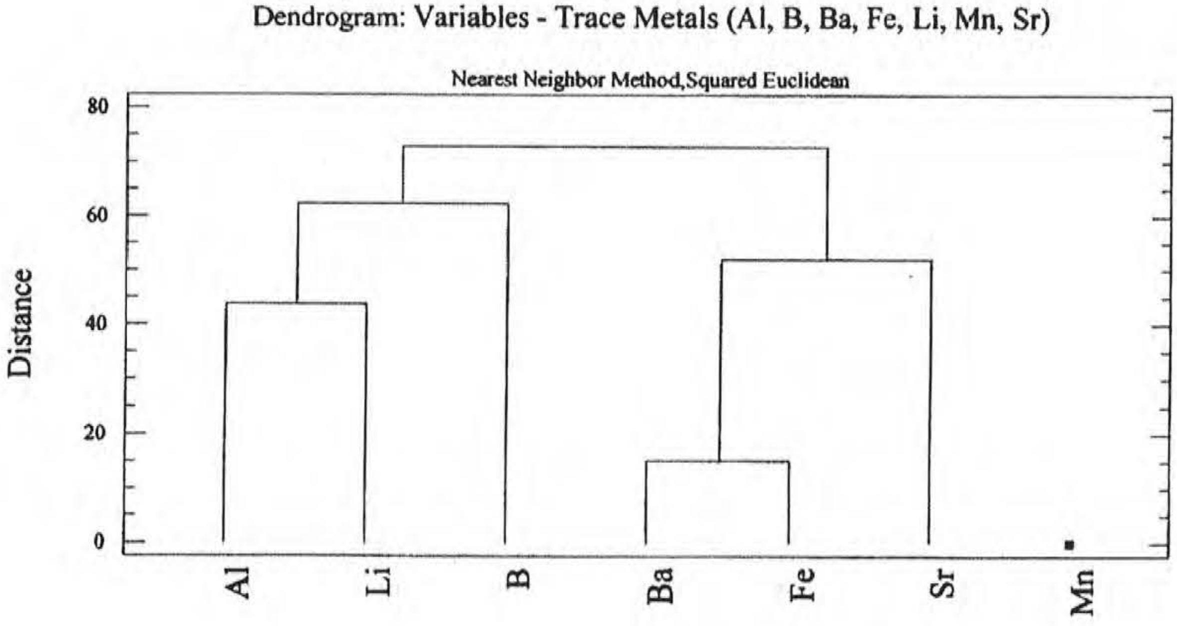
Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002

Figure 39

Note: Wells used in dendogram are background and East Ash Pond wells: MW13A, MW16A, MW22, MW24, MW25, MW27, MW29, MW30, and MW31)





Note: Data used in dendogram are for background and East Ash Pond wells: MW13A, MW16A, MW22, MW24, MW25, MW27, MW29, MW30, and MW31)

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Dendrograms of Major Ions and Trace Metals in Groundwater of Bedrock Deposits

Regional and Local Hydrogeology and Geochemistry
Vermilion Power Plant
Oakwood, Illinois

Date: September 2002

Figure 40

Appendix A

Volume 1

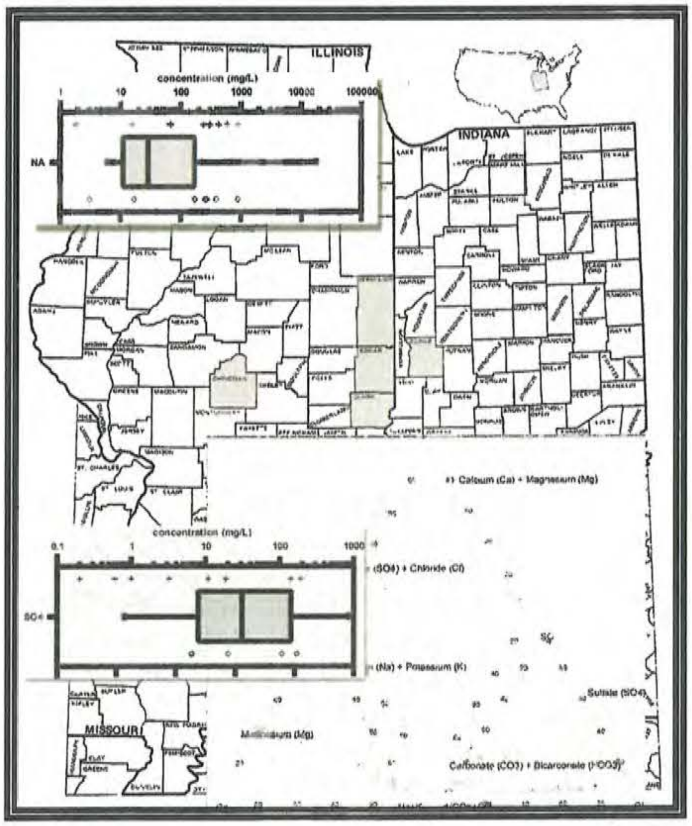
Geochemistry of Groundwater from the Shallow Bedrock in Central Vermilion County, Illinois.

Edward Mehnert and Gary B. Dreher, Illinois State Geological Survey. Illinois State Geological Survey Open-File Series Report 2002-4.

The Geochemistry of Groundwater from the Shallow Bedrock in Central Vermilion County, Illinois

Edward Mehnert and Gary B. Dreher
Illinois State Geological Survey

Illinois State Geological Survey
Open-File Series Report 2002-4



Illinois State Geological Survey
ILLINOIS DEPARTMENT OF NATURAL RESOURCES

The Geochemistry of Groundwater from the Shallow Bedrock in Central Vermilion County, Illinois

ABSTRACT

The background groundwater conditions in the shallow bedrock of central Vermilion County, Illinois, were assessed by reviewing available geochemical data and by analyzing a limited number of water and rock samples. Water samples were collected from monitoring wells and water-supply wells and were analyzed for anions, cations, and carbon and hydrogen isotopes. Rock samples were obtained from cores collected by KELRON and were analyzed using a portable infrared mineral analyzer and x-ray diffraction.

Great variability was observed in the geochemical data for the Pennsylvanian bedrock, Pennsylvanian groundwater, and other data collected for this project. Some of this variability is due to the different lithologies which included sandstone, shale, coal, limestone, and sand and gravel. Some of this variability is also due to the depth of the sample. For example, groundwater samples from KELRON 26 and 28 are significantly different from other samples because they were from shallow wells and are completely connected to the local groundwater system, whereas water samples from deeper wells were largely isolated from the local groundwater flow system. Overall, the geochemical data collected for this project are similar to the available data from Vermilion and surrounding counties.

1. INTRODUCTION

Using available data and limited sampling, we sought to define the background groundwater conditions in the shallow bedrock of central Vermilion County. Most of the wells sampled for this study were concentrated around the Middle Fork of the Vermilion River, as shown in figures 1 and 2. We had access to and sampled monitoring wells on land owned by Dynegy, Inc. as well as private and public water supply wells (figure 2) . Because of the limited number of Vermilion County wells completed in the bedrock, we sought and used available data from surrounding counties in Illinois and Indiana.

2. GEOLOGY

The surficial bedrock geology in Vermilion County is variable. The youngest formation, the Pennsylvanian-aged Bond Formation, is found beneath southwestern Vermilion County (figure 3). Pennsylvanian-aged bedrock underlies most of Vermilion County, except in the northern portion of the county where Mississippian and Devonian rocks are present. Older units can be found at the bedrock surface to the west and north, which reflects the erosional surface of the Mahomet Bedrock Valley and the structure of the Illinois Basin. In Vermilion County, the thickness of the Pennsylvanian bedrock varies from 0 feet in the

Figure 1. Map showing sampling locations in Illinois and Indiana

Figure 2. Map showing sampling locations in Vermilion County, Illinois

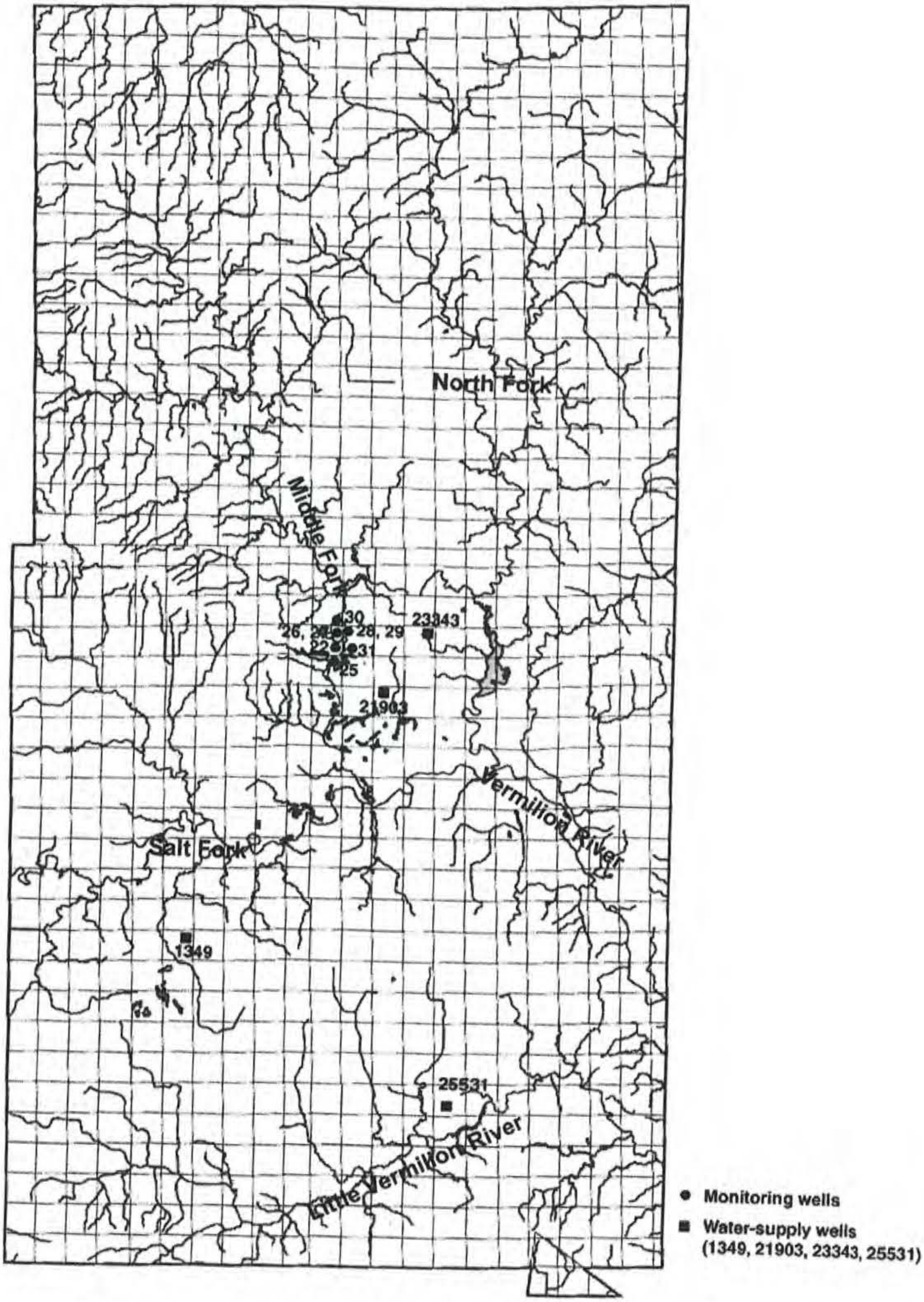
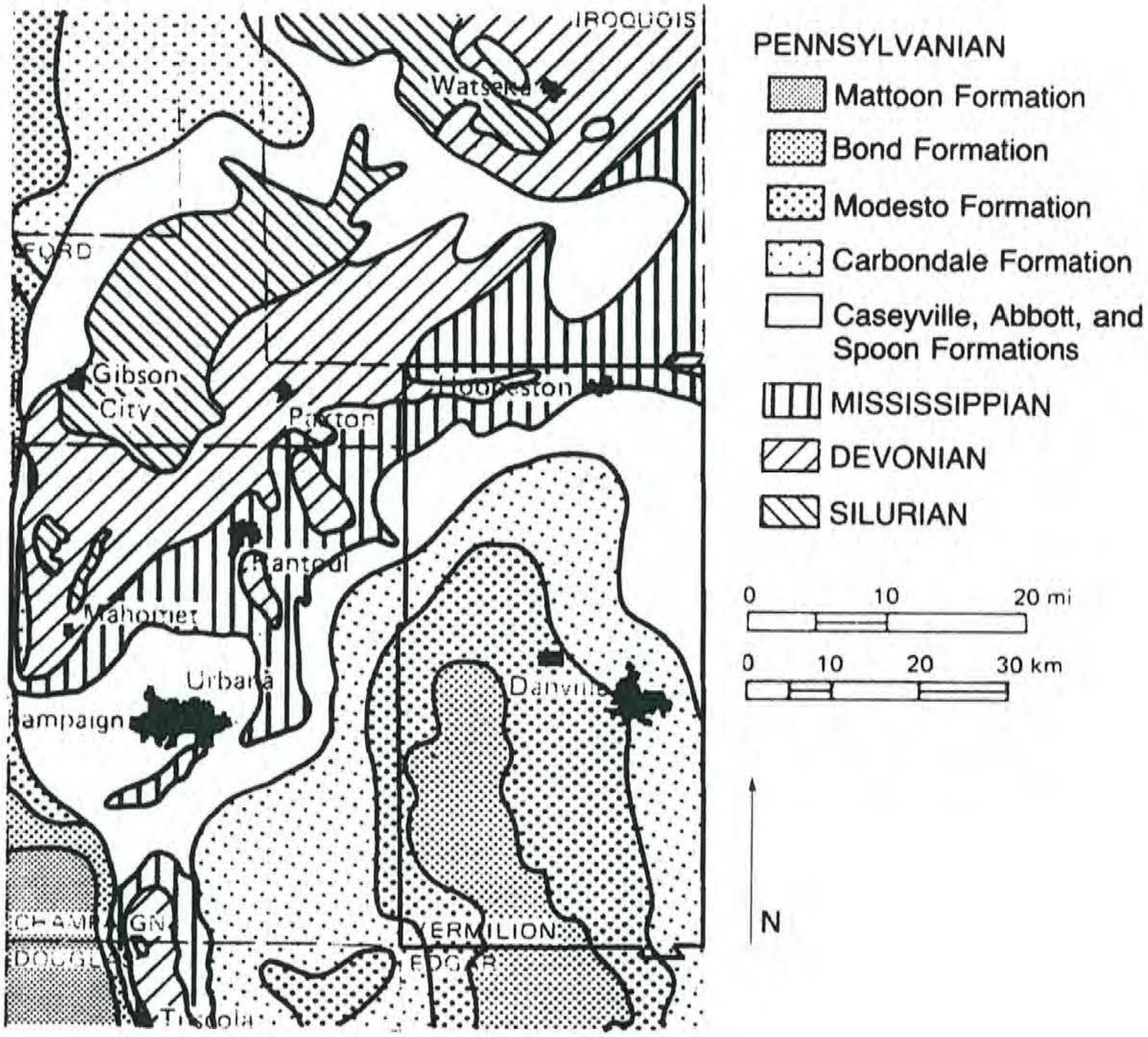


Figure 3. Surficial Bedrock Geology in Vermilion County (adapted from Kempton et al., 1982)



north to greater than 400 feet in the southeast (Willman et al., 1975).

The location of the Mahomet Bedrock Valley can be seen in the drift thickness map (figure 4). The thalweg of the valley, defined by the 400-foot thickness contour, runs east-west through the northern tier of townships in Vermilion County. In addition, a northwest-southeast trending tributary underlies parts of T23N R13W, T22N R13W, T22N R12W, and T21N R12W. The drift thickness also exceeds 200 feet in the southwest portion of the county. However, in the central portion of the county, the drift is generally less than 100 feet thick and bedrock outcrops are common in the river valleys (Piskin and Bergstrom, 1975).

KELRON collected core at 3 locations in T20N R12W (KELRON 25, KELRON 30, and KELRON 31). Descriptions of these cores appear in Appendices A and B. At this location, the uppermost bedrock was mapped as the Pennsylvanian-aged, Modesto Formation by Willman et al. (1975). The core from KELRON 30 penetrated 3 feet into the Danville (No. 7) Coal Member, which was considered the uppermost member of the Carbondale Formation. The stratigraphic nomenclature of the Pennsylvanian system was recently revised by the Tri-State Committee (2001). Using this new nomenclature, the bedrock from the three cores collected by KELRON (KELRON 25, KELRON 30, and KELRON 31) was assigned to the Shelburn Formation (Appendix A). Natural gamma logs for these wells, collected by the ISGS, appear in Appendix B.

In west-central Indiana, the surficial bedrock is Pennsylvanian-age along the IL-IN state line and Mississippian-age to the east (figure 5).

3. GEOCHEMISTRY

We reviewed the available geochemical data for both groundwater and bedrock from Vermilion County and surrounding counties in Illinois and Indiana. In addition, during June 2002, we collected groundwater samples from several monitoring wells and water wells. We also analyzed samples from core collected from three KELRON monitoring wells. To determine the geochemistry of the groundwater in chemical equilibrium with the host rock, equilibrium geochemical modeling was conducted.

3.1 Review of Available Data

To obtain data on the geochemistry of groundwater from Pennsylvanian bedrock and the Pennsylvanian

bedrock itself, we searched the scientific literature and databases at the Illinois State Geological Survey, Illinois State Water Survey, Illinois Environmental Protection Agency, and the Indiana Geological Survey. These data are summarized in tables 1 through 5. The locations for available groundwater samples are summarized by county in table 1. The geochemical data for these 31 samples are presented in table 2. The lithologies of the Pennsylvanian bedrock samples are summarized in table 3. We obtained data for 56 bedrock samples– 35 coal and 21 non-coal samples. The geochemistry of the non-coal samples (table 4) and the coal samples (table 5) has been summarized. Table 5 includes 1 sample from the Springfield (No.

Figure 4. Drift Thickness in Vermilion County (adapted from Piskin and Bergstrom, 1975)

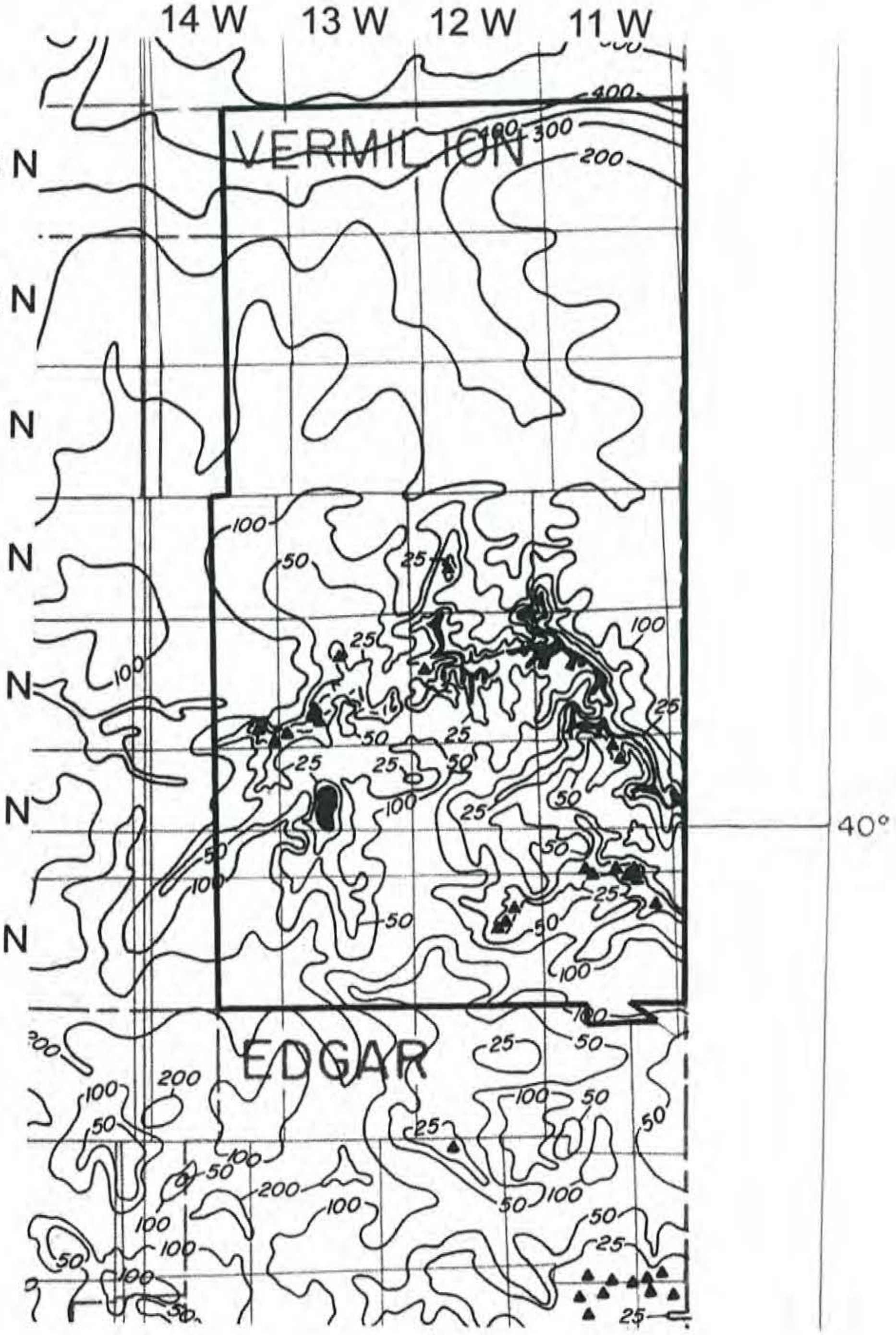


Figure 5. Surficial Bedrock Geology of west-central Indiana including Parke County (from Indiana Geological Survey, 1970) The dashed line shows the limit of the Wisconsin Episode glacial sediments.

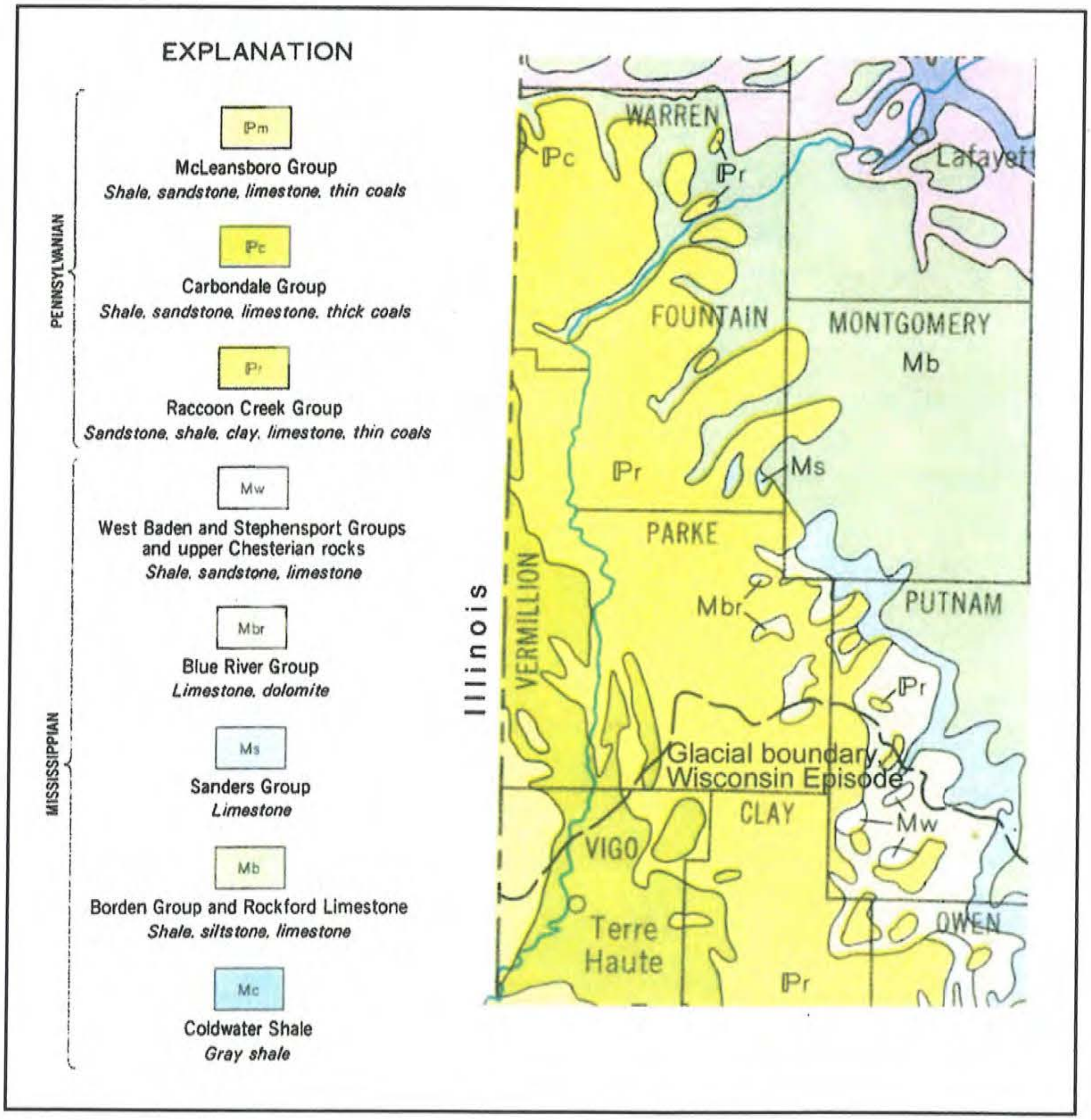


Table 1: Summary of available well data

County	# of Wells	Sampling Dates	Well Depths (ft)
Vermilion	6	10/9/74 - 11/9/93	72 - 220
Clark	1	6/3/99	155
Edgar	1	8/7/48	422
Christian	4	1/22/97 - 2/20/97	276 - 344
Parke (IN)	19	7/10/95 - 7/20/95	100 - 307
TOTAL	31	10/9/74 - 2/20/97	72 - 422

Table 2: Geochemical summary for available water samples
(Sources: Chugh et al., 1997; ISGS Geochemical Database, Meents et al., 1952)

	Units	# of Records	Minimum*	Maximum	Mean	Median
TDS	ppm	28	280	52100	3540	426
Alkalinity	mg/L as $CaCO_3$	30	56	485	321	335
pH	--	27	6.5	10.0	7.5	7.3
Temperature	°C	23	11.0	22.8	15.5	14.8
Bicarbonate	mg/L	31	63	591	389	407
Chloride	mg/L	31	2.1	30269	1689	13
Fluoride	mg/L	26	0.09	1.06	0.49	0.47
Nitrate	mg/L	31	<0.01	29.0	***	2.95
Sulfate	mg/L	31	<1	847	***	31
Aluminum	mg/L	27	<0.02	8.47	***	0.20
Arsenic	mg/L	30	<0.001	0.023	***	0.0050
Barium	mg/L	30	0.02	2.44	***	0.28
Boron	mg/L	30	ND**	2.08	***	0.0047
Cadmium	mg/L	30	<0.0002	0.0044	***	0.00020
Calcium	mg/L	31	<1	951	***	83
Chromium	mg/L	30	<0.001	0.005	***	0.0015
Iron	mg/L	31	<0.006	26.8	***	0.69
Lead	mg/L	29	<0.001	0.018	***	0.003
Magnesium	mg/L	31	<0.5	454	***	31.1
Manganese	mg/L	31	0.015	1.47	***	0.10
Mercury	mg/L	30	<0.00005	1.0	***	0.000025
Potassium	mg/L	30	0.67	63	7.4	2.1
Selenium	mg/L	30	<0.001	0.002	***	0.001
Silicon	mg/L	31	0.69	10.0	6.51	7.12
Sodium	mg/L	31	6	18078	1083	28.7
Zinc	mg/L	30	<0.01	1.43	***	0.21

* Some parameters had multiple detection levels. The lowest detection level is reported.

** Not detected, detection limit was not reported.

*** Sample data contain censored values, did not compute mean.

Table 3: Lithology of the available Pennsylvanian bedrock samples

Lithology	Number of Samples
Sandstone	2
Limestone	2
Shale	4
Carbonaceous Shale	13
Coal	35
TOTAL	56

Table 4: Geochemical summary for available non-coal solid samples
(Sources: Bradbury et al., 1962; Chugh et al., 1997; Schultz and Coveney, 1992)

Analyte	Units	# of Records	Minimum	Maximum	Mean	Median
Al_2O_3	wt. %	21	0.42	20.8	11.7	11.1
CaO	wt. %	21	0.15	54.1	7.57	1.27
Fe_2O_3	wt. %	21	0.63	21.4	8.65	7.02
K_2O	wt. %	21	0.09	4.20	2.51	2.61
MgO	wt. %	21	0.36	2.17	1.44	1.63
MnO	wt. %	18	0.017	1.83	0.20	0.045
Na_2O	wt. %	21	0.030	1.68	0.59	0.58
P_2O_5	wt. %	17	0.030	18.4	2.31	0.53
SiO_2	wt. %	21	2.09	85.7	37.0	33.8
TiO_2	wt. %	21	<0.1	0.92	***	0.51
As	mg/kg	18	19.8	119	57.7	53.8
B	mg/kg	18	31	385	123	112
Ba	mg/kg	18	122	543	***	333
Be	mg/kg	16	<1	4.8	***	2.0
Ce	mg/kg	18	52	233	134	125
Co	mg/kg	18	15.9	68.5	28.3	24.6
Cr	mg/kg	18	68.5	643	289	281
Cs	mg/kg	18	<2	13.4	***	7.0
Cu	mg/kg	16	9.0	192.3	94.3	84.3
Ga	mg/kg	18	6.5	29.3	18.7	17.9

Analyte	Units	# of Records	Minimum	Maximum	Mean	Median
Hg	mg/kg	6	<0.5	5.4	***	2.8
La	mg/kg	18	16.4	99.2	50.8	44
Li	mg/kg	16	11	130.	51.2	37.0
Ni	mg/kg	18	50.	530.	288	280
Pb	mg/kg	16	32	812	167	79
Rb	mg/kg	18	<3.	201	***	127
Sb	mg/kg	18	1.9	56.0	27.2	29.7
Sc	mg/kg	18	9.3	23.6	15.5	14.9
Se	mg/kg	18	4.0	260	104	97
Sr	mg/kg	18	<80	699	210	147
V	mg/kg	18	80.	5600	1770	790
Zn	mg/kg	18	30.3	3350	1000	522
Zr	mg/kg	16	20.8	103	***	49.3
Cl	mg/kg	7	240	698	532	563
Total Carbon	wt. %	17	0.91	>33	***	6.0
Inorganic Carbon	wt. %	17	0.02	11.7	1.7	0.49
Organic Carbon	wt. %	16	0.48	>33	***	3.7

*** Sample data contain censored values, did not compute mean.

Table 5: Geochemical summary for available coal samples
(Sources: Bradbury et al., 1962; Chugh et al., 1997; Schultz and Coveney, 1992; Yates, 1984)

	Sample Data						Illinois Basin Coals*		
	Units	# of Records	Min.	Max.	Mean	Median	Min.	Max.	Mean
Al	mg/kg	34	2300	16800	10400	10400	4300	30000	12000
As	mg/kg	35	0.4	52	***	5.1	1	120	14
B	mg/kg	32	37	149	97.3	99.0	12	230	110
Ba	mg/kg	33	8.9	231	64.6	38.8	5	750	100
Be	mg/kg	35	<0.12	2.5	***	1.5	0.5	4	1.7
Ca	mg/kg	34	1500	21300	8740	8100	100	27000	6700
Ce	mg/kg	33	2.0	30	10.0	8.0	4.4	46	14
Co	mg/kg	35	0.9	23.9	5.1	4.0	2	34	7.3
Cr	mg/kg	35	4.0	32	14.7	13.0	4	60	18
Cs	mg/kg	33	<0.3	3.2	***	0.9	0.5	3.6	1.4
Cu	mg/kg	35	2.0	39	10.6	9.0	5	44	14
Fe	mg/kg	35	4300	57900	19500	18600	4500	41000	20000
Ga	mg/kg	35	1.7	5.55	3.4	3.3	0.8	10	3.2
Hg	mg/kg	34	0.07	0.52	0.14	0.11	0.03	1.6	0.2
K	mg/kg	35	300	3800	1610	1500	400	5600	1700
La	mg/kg	33	1.2	12.7	***	4.2	2.7	20	6.8
Li	mg/kg	30	2.0	39.7	13.7	12.5	Not determined		
Mg	mg/kg	34	<100	2200	***	600	100	1700	500
Na	mg/kg	35	400	2300	989	1000	40	2000	500
Ni	mg/kg	35	2.0	93	15.7	9.0	7.6	68	21
Pb	mg/kg	35	2.0	191	***	8.0	0.8	220	32
Rb	mg/kg	33	1.6	44	13.1	11.5	2	46	19
Sb	mg/kg	35	0.06	3.3	1.0	0.8	0.1	8.9	1.3
Sc	mg/kg	33	0.8	5.2	2.7	2.6	1.2	7.7	2.7
Se	mg/kg	35	0.7	12.3	2.2	1.8	0.4	7.7	2.2
Si	mg/kg	34	3300	37800	21200	20700	5800	47000	24000
Sr	mg/kg	33	9	127	***	20.6	10	130	35
Ti	mg/kg	34	100	1000	550	500	200	1500	600
V	mg/kg	35	3.3	59	14.2	11	11	90	32
Zn	mg/kg	35	7.0	318	***	51.5	10	5300	250

	Sample Data						Illinois Basin Coals*		
	Units	# of Records	Min.	Max.	Mean	Median	Min.	Max.	Mean
Zr	mg/kg	33	3.1	42	20.3	18.0	12	130	47
Cl	mg/kg	22	400	4600	1700	1600	100	5400	1400
Org. S	wt. %	33	0.6	2.04	1.6	1.7	0.37	3.2	1.6
Pyr. S	wt. %	33	0.36	4.18	1.8	1.8	0.29	4.6	2
Su. S	wt. %	33	0.01	0.42	0.1	0.1	0.01	1.1	0.1
Tot. S	wt. %	33	1.68	6.01	3.5	3.5	0.56	6.4	3.6
Ash	wt. %	34	3.71	19.7	12.1	11.5	4.6	20	11

* Gluskoter et al.,1977

*** Sample data contain censored values, did not compute mean.

5) coal, 23 samples from the Herrin (No. 6) coal, 10 samples from the Danville (No. 7) coal, and one other sample whose stratigraphic source is unknown.

For the liquid samples, the available data have been plotted on box plots and a Piper diagram. A box plot shows the distribution of concentrations. The left side of the box shows the 25th percentile. The center of the box shows the 50th percentile or the median. The right side of the box shows the 75th percentile. The difference between the 75th percentile and 25th percentile is the Hspread, which is used to define outliers. The whiskers on the box show approximately the 5th percentile (left) and the 95th percentile (right). Additional data outside these ranges are shown with asterisks (points between 1.5*Hspread and 3*Hspread) and circles (points >3*Hspread). Box plots were constructed for major cations (figure 6) and anions (figure 7) using SYSTAT version 9. A Piper diagram (figure 8) was constructed for the water samples using RockWorks (Rockware Inc.).

Of the major cation concentrations, sodium (Na) had the greatest variability and calcium (Ca) and magnesium (Mg) had the least variability. Of the major anion concentrations, chloride (Cl) had the greatest variability and bicarbonate (HCO_3) had the least variability. The Piper diagram will be discussed later in this report.

3.2 Summary of New Chemical and Mineralogical Data

New chemical and mineralogical data were obtained from samples of cores previously collected by KELRON (KELRON 25, KELRON 30, and KELRON 31). In addition, we collected groundwater samples from 6 KELRON wells and 4 water-supply wells in central Vermilion County. KELRON provided geochemical data for 7 wells.

Figure 6. Box plot of major cations for the available groundwater samples

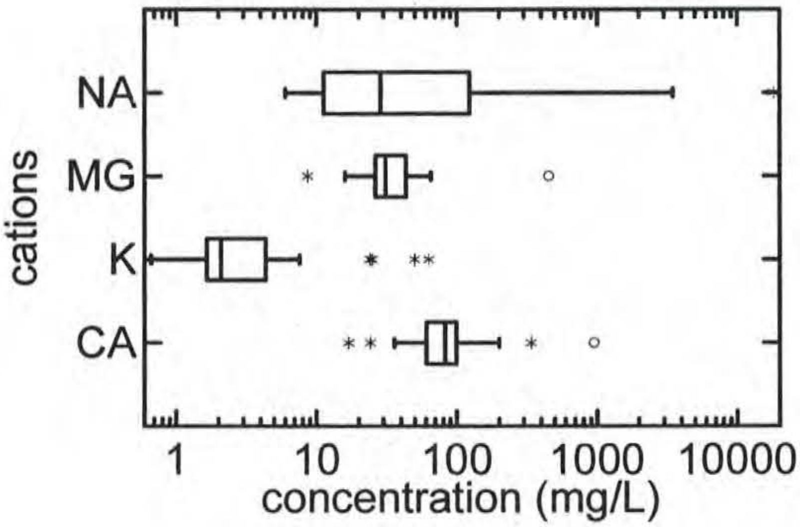


Figure 7. Box plot of major anions for the available groundwater samples

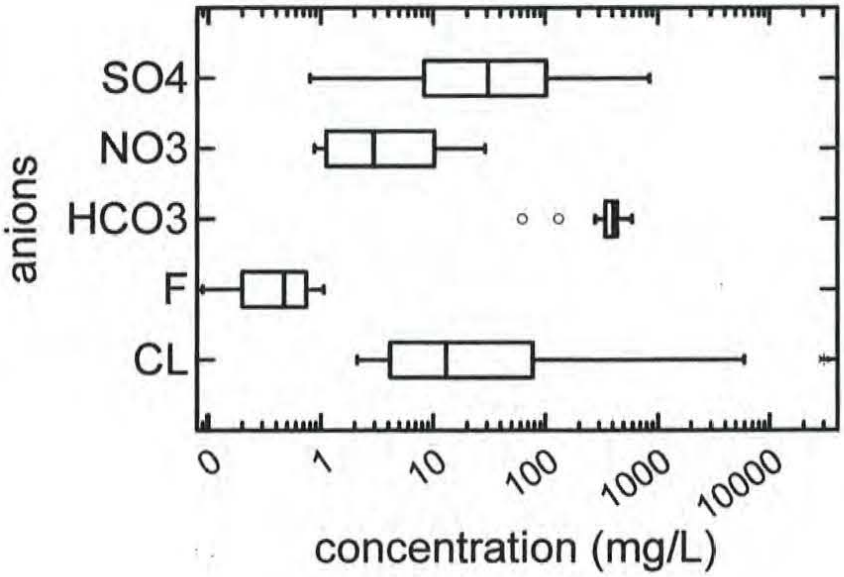
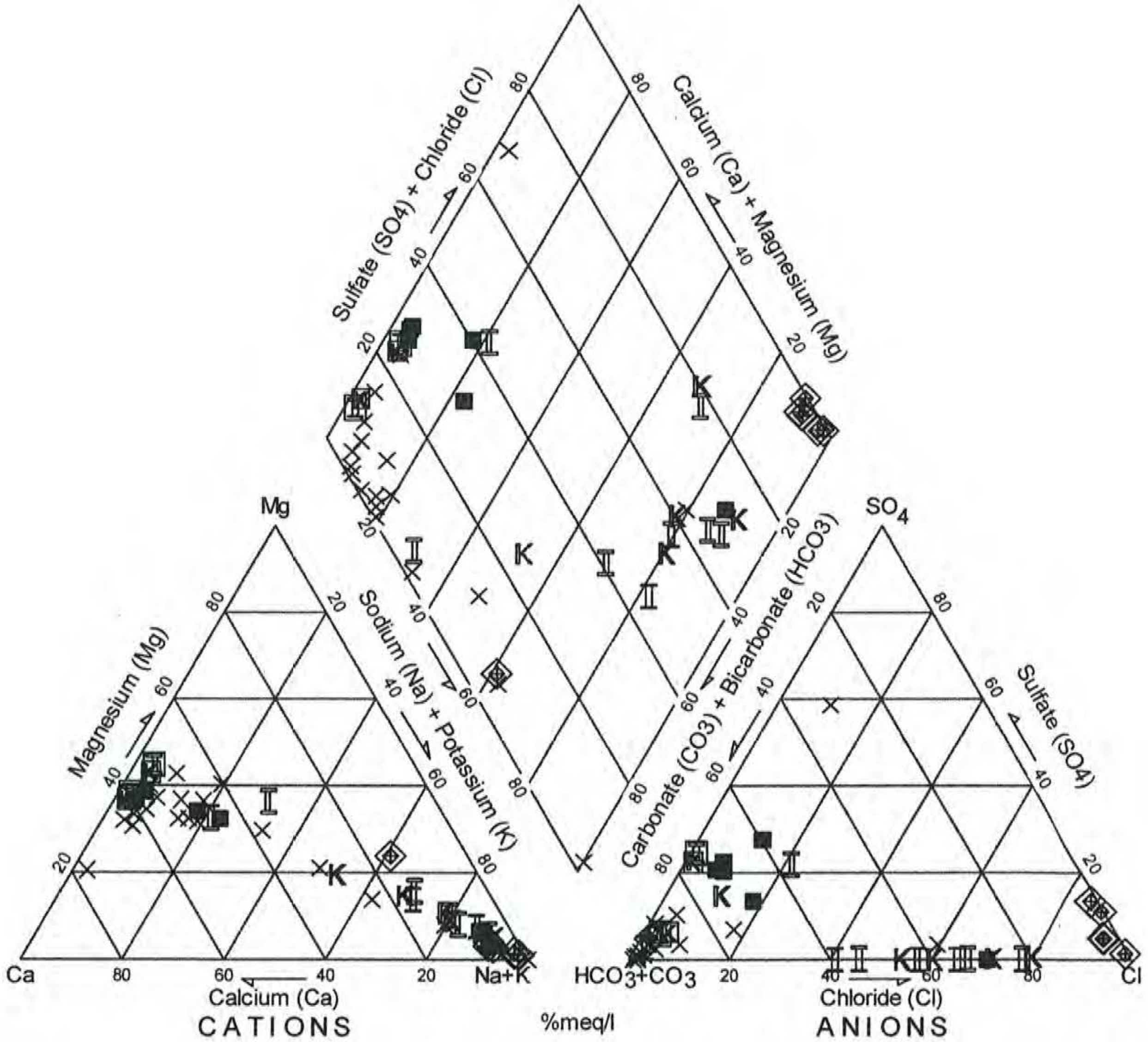


Figure 8. A Piper diagram of the groundwater samples (Vermilion Co., IL= squares, other IL counties= diamond, Parke Co., IN= x, ISGS samples= I and KELRON samples= K, non-bedrock samples from ISGS & KELRON are boxed.)



Analytical Methods

PIMA and X-ray diffraction (XRD) analyses. Core samples were analyzed using a portable infrared mineral analyzer (PIMA), manufactured by Integrated Spectronics Pty. Ltd. (Baulkham Hills, New South Wales, Australia). The PIMA-SP™ reflectance spectrometer (figure 9) provided analyses as quickly as one per minute, portability, and good data from irregular, round or flat core- or hand-specimen samples. The instrument's 1.25 cm-diameter window allowed close-interval core logging and determinations on small features in samples. In the analysis mode, the PIMA's 1300 to 2500 nm spectra were matched with reference spectra to determine percentages for up to six minerals. Quartz and feldspar produce no PIMA spectra, thus PIMA sees through these grains to give better-than-expected spectra for minerals that are usually of primary concern, e.g., clay minerals, iron hydroxides, and carbonates. Custom reference spectra can be created for the specific minerals of concern, and the spectral processing programs provide several methods for analyzing spectra, including instantaneous display of calculated features in each spectrum in a "special stack" from outcrop or borehole samples (figure 10).

For six geochemical-PIMA-XRD samples, the core was sawed and about a 15-cm-thick composite of half of the core was crushed and split. The other 13 samples of the three cores were removed, either by drilling perpendicular to bedding with a ¼ inch carbide drill bit, or, for core segments that broke into thin bedding layers, by breaking a 5 to10 g fragment of the layer. For PIMA and XRD analyses, all 19 samples were hand ground with a mortar and pestle, and packed into end-loading XRD sample holders. The samples were x-rayed using standard operating procedures (SOPs) on file at the ISGS. The same sample surface was later inverted into a calibrated petri dish for PIMA analyses. Hughes and Warren (1989) Hughes et al. (1994) and Hughes et al. (2002) summarize the methods used. Demir et al. (2001), Hughes et al. (1987), Hughes et al. (1989), Hughes et al. (1992), Hughes (1993), Hughes et al. (1994), and Hughes et al. (2002) summarize the range of composition normally found for these types of sediments.

Smear samples. Smears of the particles with diameters <8μm were prepared by placing 1 to 3 g of sample in a 150 mL beaker, adding 100 mL of deionized H_2O, dispersing the slurry with an ultrasonic probe for 60 seconds, and allowing the samples to soak overnight. For samples that flocculated and had clear supernates, the clear water was decanted and the beakers refilled with deionized water. Five drops of dispersant solution were added to each of the beakers, each beaker was stirred for 30 seconds, and the samples were allowed to settle 3 minutes per cm of slurry depth. After settling, the fine fractions were poured into 400 mL glass beakers and flocculated with $CaCl_2 \bullet nH_2O$. The glass beakers were refilled, two drops of dispersant were added, the mixtures were stirred, allowed to settle, and the fine fractions were added to the glass beakers containing the first settlings. A third settling was completed, and the >8 μm fractions were allowed to dry, after which, the sample and beaker were weighed, to estimate the weights of the coarse and fine fractions. The <8 μm fractions were flocculated and allowed to settle overnight, the clear supernate was decanted, the fines were transferred to 40 mL centrifuge tubes, and after centrifuging 20 minutes @ 2000 RPM, the clear supernates were decanted, the sediment plugs were thoroughly mixed with a microspatula, and the paste was smeared on a round, glass XRD slide. After the smear dried in air, the slides were x-rayed using ISGS SOPs.

Figure 9. A typical laboratory setup for PIMA showing the power supply at left, a limestone sample on the PIMA's analysis window on the tabletop, and a laptop computer with a spectrum for pure calcite from a limestone sample.

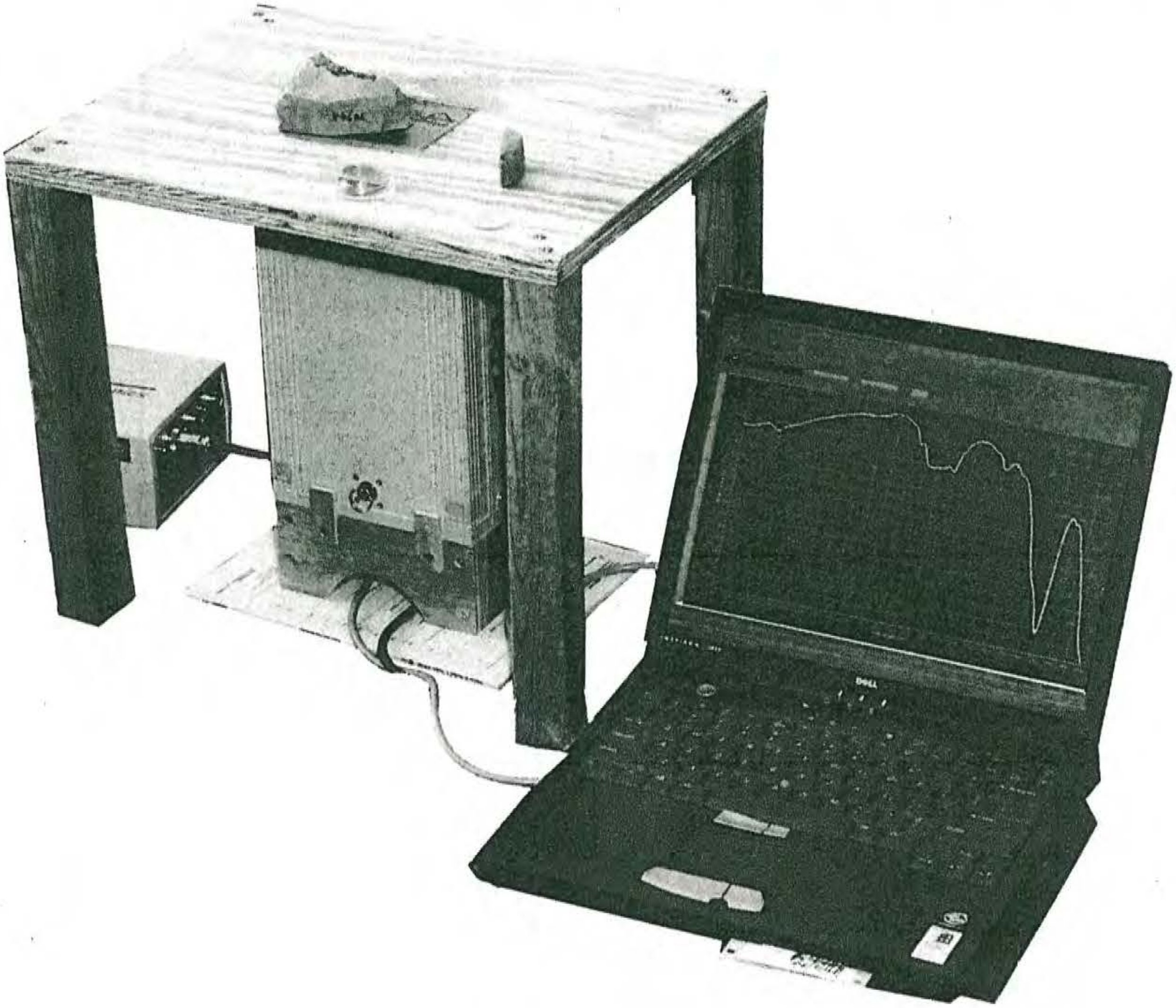
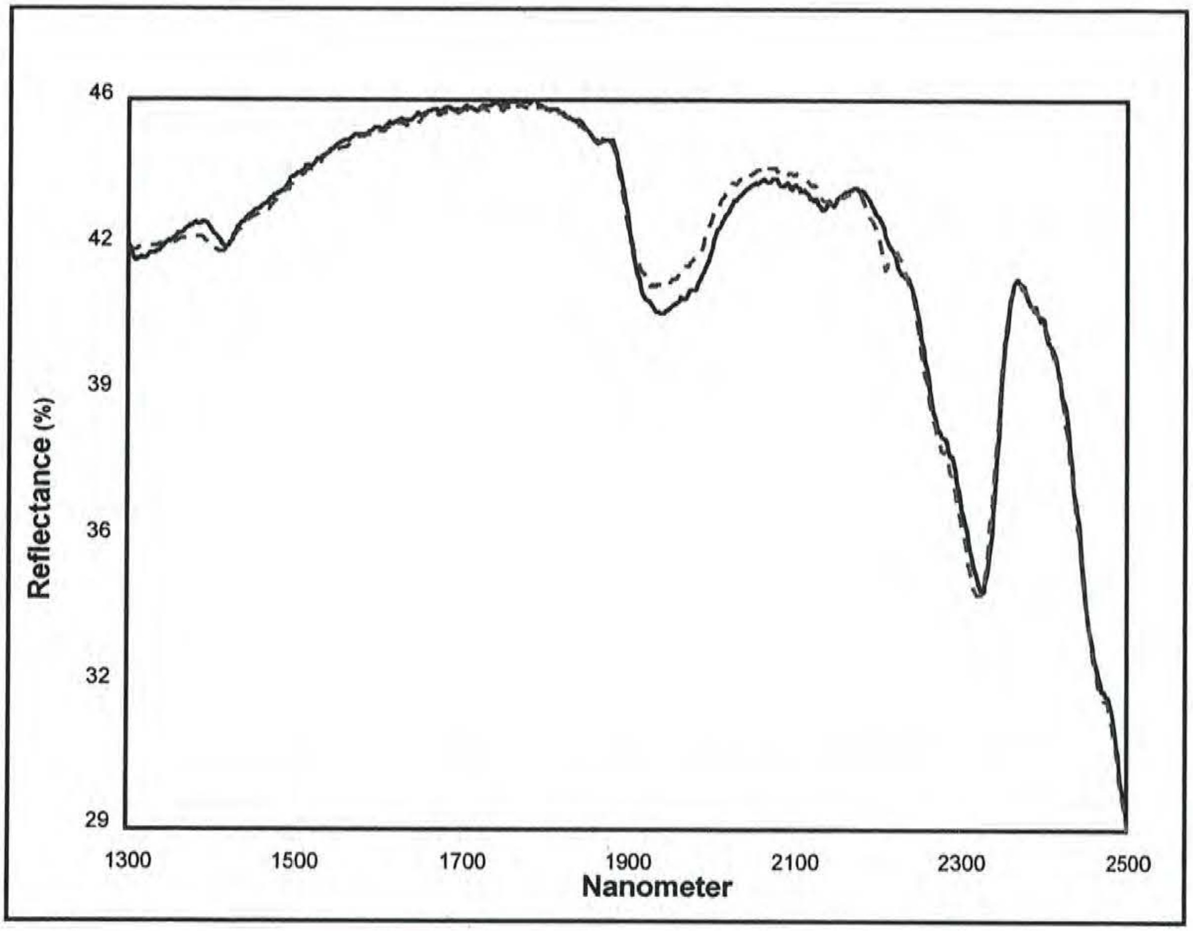


Figure 10. Overlay of the spectrum for western Illinois dolomite (dark trace) and a calculated spectrum (light, dashed trace) for 100% dolomite (PIMA's MinIDB reference standards library).



Water samples. Water samples were collected from monitoring and water-supply wells. Groundwater samples from the KELRON monitoring wells were collected using Dynegy-owned equipment including dedicated, low-flow sampling pumps. The June 18, 2002 samples were collected as split samples during Dynegy's regular sampling. Groundwater samples from water-supply wells were collected using the installed pumps, from taps prior to any water treatment such as water softeners. Prior to sample collection, field parameters (temperature, dissolved oxygen, pH, Eh, and specific conductance) were monitored and were allowed to stabilize, unless the well appeared to be running out of water. Water samples were transported on ice and stored at 4 °C until analyzed.

Water samples collected by the ISGS were analyzed for anions and cations by the ISGS Geochemistry Laboratory. Anions were determined using a Dionex DX-120 Ion Chromatograph with Ionpac AG14 Guard Column, Ionpac AS14 Analytical Column, and ASRS-ULTRA (4mm) suppressor module. Analytes were measured with a CDM-3 conductivity detector cell with a DS4 detection stabilizer. The eluent was 3.5mM sodium carbonate and 1.0 mM sodium bicarbonate. The following were approximate retention times in minutes: fluoride, 2.9; chloride, 4.0; bromide, 5.6; nitrate, 6.4; phosphate, 8.0; and sulfate, 9.5. Instrument operation and data collection were controlled using PeakNet 5.01 software. A calibration check standard and blank were run with each analysis set.

Cations were determined with a Thermo Jarrell-Ash Model ICAP 61e inductively coupled plasma spectrometer. The list of elements and their wavelengths in nanometers are: Al(308.2), As(193.6), B(249.6), Ba(493.4), Be(313.0), Ca(393.3, 317.9), Cd(228.8), Co(228.6), Cr(267.7), Cu(324.7), Fe(259.9, 271.4), K(766.4), Li(670.7), Mg(279.5, 383.2), Mn(257.6), Mo(202.0), Na(588.9, 330.2), Ni(231.6), P(214.9), Pb(220.3), S(182.0), Sb(206.8), Sc(361.3), Se(196.0), Si(288.1), Sr(421.5), Te(214.2), Ti(334.9), Tl(190.8), V(292.4), and Zn(213.8). Instrument operation, inter-element interference correction, background correction, and data collection were controlled using ThermoSPEC/AE 6.20 software. Blanks, calibration check standards, and reference standards were run with each analysis set.

For tritium analyses, water samples were collected in 1L HDPE bottles. Tritium was determined with 200 mL of water using the enrichment technique (Ostlund and Dorsey, 1977). The tritium enriched samples were purified by vacuum distillation, mixed with a scintillation cocktail, and counted in a low-level scintillation counter (Packard 2000 CA/LL). The tritium results are reported in tritium units (TU), which is defined as one tritium atom per 10^{18} hydrogen atoms.

The dissolved inorganic carbon (DIC) in water was analyzed at the ISGS for carbon-14 activity using conventional techniques (Hackley, 2002). The DIC is extracted from water samples by the addition of acid. The carbon dioxide released from water samples is quantitatively collected and cryogenically purified on a vacuum line. The purified carbon dioxide is converted to high-purity benzene following the technique described in Coleman (1976). The carbon-14 activity is measured using the liquid scintillation spectrometry method developed by Noakes et al. (1965, 1967).
Groundwater samples from the KELRON wells also were collected and analyzed by Dynegy. Prior

to sample collection, Dynegy monitored several field parameters (temperature, dissolved oxygen, pH, Eh, and specific conductance) using a calibrated Hydrolab Minisonde. Cations were determined by inductively coupled plasma emission spectroscopy (ICP) (USEPA method 200.7). Alkalinity was determined by a titrimetric method (USEPA method 310.1). Total dissolved solids were determined by a gravimetric method (USEPA method 160.1). Sulfate was determined using a turbidimetric method (USEPA method 375.4). Total phosphorus was determined using an ascorbic acid/colorimetric method (USEPA 365.2). Finally, chloride was determined using a potentiometric method (Standard method 4500-Cl).

Solid Samples

Detailed descriptive logs (see DeMaris logs, Appendix A) were compiled for three new holes drilled by KELRON and used to select 19 samples for PIMA-SP^{TM} and XRD analyses. Table 6 gives the lab number, core number, depth, and material type for the 19 samples. The coal in core KELRON 30 had been sealed, and a sample of the white oxidation product on top of the coal was analyzed by PIMA and XRD. Separately, one or two siderite nodules were analyzed, and 19 PIMA and XRD samples were chosen to contrast the mineralogical composition of silt- and clay-rich zones. Over 90 PIMA analyses were run for this project, 54 on the cores, and 39 on bulk and <8µm smear samples. The results from the PIMA analyses of the cores were quite uniform, suggesting that little mineralogical variation was present. Table 6 gives the XRD analysis results for bulk sample preparations that show: a) 10 to 60% clay minerals, b) 35 to 75% quartz, 0 to 3% K-feldspar, 2 to 13% plagioclase feldspar, and 0 to 10% siderite. Samples 3955S and T also contained 2.3 and 10% pyrite/marcasite, respectively. The iron sulfide in both samples is mostly marcasite, a form of the compound that oxidizes very quickly. The needle-like white precipitate above the coal in core KELRON 30 is undoubtedly the result of this rapid oxidation. In general, silt-rich samples had lower clay mineral contents and higher quartz and feldspar contents than shaly zones.

The XRD analyses of the <8µm smear samples (table 7) showed that the clay mineral suites were composed mostly of illite, kaolinite, chlorite, and small amounts of mixed-layered illite/smectite (I/S). Coarser, more permeable zones normally have higher fluid flow rates and this results in higher kaolinite contents, and so as expected, the silt-rich samples in this set contained relatively more kaolinite, a higher kaolinite:chlorite ratio, and less illite, I/S, and chlorite. Table 8 gives the ranges of the clay mineral contents from the smear slides- 50 to 65% illite, 12 to 32% kaolinite, 9 to 22% chlorite, and 3 to 7% I/S (atypical sample 3955T had 19% I/S).

PIMA analyses of core, hand specimen, bulk powder, and smear samples confirmed the generally uniform composition of these strata, but showed significant differences in the compositions of the silty and shaly samples. These results also are qualitatively consistent with the XRD results. Finally, the PIMA analyses of the core required only a few minutes each, and these results confirmed the value of the PIMA to identify compositional changes and refine the sample selection process.

Table 6. PIMA-XRD sample description and mineral percentages from XRD analysis

Well	Sample No.	Depth (ft)	Material	% Clay minerals	% Quartz	%K-Feldspar	%Plagiclase feldspar	% Siderite
KELRON 25	3955A1	18.17	siltstone	14	72	2.3	10	1.2
	3955A2	18.13	siltstone	14	69	0.9	12	3.6
	3955A3	18.10	shale	25	61	0.8	8.8	4.5
	3955B	28.17	shale	11	74	0.0	12	2.6
	3955C	36.0	shale	26	59	1.1	8.1	5.8
	3955E	12.55-12.75	silty-shale	21	63	1.8	11	3.6
	3955G	32.0-32.25	shale	23	61	0.0	9.0	6.5
KELRON 31	3955I	156.6-156.8	shale	24	60	1.5	10	3.8
	3955J1	154.22	shale	27	56	1.2	11	4.5
	3955J2	162.0	shale	22	55	0.0	13	10
	3955K	165.7-165.95	shale	26	60	1.5	8.4	4.0
	3955L	178.18	shale	36	53	0.0	7.8	2.8
	3955M	174.4-174.62	shale	34	53	0.0	7.4	5.0
KELRON 30	3955N	120.3	shale	24	67	0.0	9.1	0.0
	3955O	127.2-127.45	shale	34	52	1.4	8.8	4.2
	3955P	132.5	shale	36	55	0.0	7.2	2.6
	3955Q	136.25-136.43	shale	40	51	0.0	5.1	3.2
	3955S	141.15-141.4	shale	39	49	0.0	6.2	3.1
	3955T	144.0	C-Py-shale	56	30	2.5	2.0	0.0

Key: C = carbonaceous; Py = pyritic (pyrite or marcasite)

Samples 3955S and T had pyrite/marcasite, which was mostly marcasite; percentages = 2.3 and 6.7%, respectively.

Table 7. Percentages of mixed-layered illite/smectite, illite, kaolinite, and chlorite from X-ray diffraction data based on 8μm smear samples. The ratio of kaolinite:chlorite (K:C), the clay index (CI), and %<8μm also are given.

Sample	%I/S	%I	%K	%C	K:C	CI	%<8μm
3955A1	3.6	48	32	16	0.67	0.73	35
3955A2	3.9	48	30	18	0.63	0.78	49
3955A3	4.0	62	15	19	0.44	0.87	54
3955B	3.3	51	29	16	0.64	0.81	38
3955C	4.5	62	16	17	0.48	0.84	59
3955E	5.0	59	17	18	0.49	0.91	31
3955G	4.5	60	17	19	0.47	0.89	39
3955I	5.8	58	15	21	0.42	0.88	40
3955J1	5.8	60	16	18	0.47	0.90	44
3955J2	4.9	60	17	18	0.49	0.83	57
3955K	4.3	64	13	19	0.40	0.89	47
3955L	5.0	60	13	22	0.36	0.86	79
3955M	5.1	60	14	21	0.39	0.85	72
3955N	4.8	57	18	20	0.48	0.88	47
3955O	5.4	62	13	20	0.41	0.88	75
3955P	6.0	59	14	21	0.39	0.85	75
3955Q	6.4	58	13	22	0.38	0.85	91
3955S	6.6	61	12	20	0.39	0.86	88
3955T	19	60	13	8.6	0.60	0.81	62

Key: I/S = mixed-layered illite/smectite; I = illite; K = kaolinite; C = chlorite; K:C = the ratio of the kaolinite 002 peak to the chlorite 004 peak; CI = the clay index, which equals the corrected sum of the peaks for the clay minerals divided by the sum of the corrected intensities of the clay and nonclay minerals; the higher the ratio, the higher the clay mineral content; the %<8μm was estimated from the initial weight of the sample minus the final weight of the >8μm.

Water Samples

The ISGS sampled the wells described in table 8 in mid- to late June 2002. These wells included 6 monitoring wells and 4 water-supply wells located in Vermilion County. All but two wells were completed in shallow bedrock. Two monitoring wells (KELRON 26 & 28), completed in shallow Quaternary materials, were sampled to provide data on shallow groundwater. The chemical data for the ISGS samples are summarized in table 9. Dynegy sampled numerous monitoring wells from February through August 2002 (table 10). Some of these data are reported here. On June 18th, split samples were collected from 6 KELRON wells and sent to ISGS and Dynegy laboratories. The results for these split samples were within 20%, except for a few samples for chloride, iron, and potassium.

Table 8. Description of wells sampled by the ISGS and/or Dynegy

Well #	Location	Total Depth (ft)	Lithology @ screen
1349	T18N, R13W, Sec 9	72	sandstone & shale
21903	T20N, R12W, Sec 34	147	sandstone & shale
23343	T20N, R12W, Sec 23	175	sandstone & shale
25531	T17N, R12W, Sec 1	140	rock & shale
KELRON 25	T20N, R12W, Sec 29	39	shale
KELRON 26	T20N, R12W, Sec 20	16	sand & shale
KELRON 27	T20N, R12W, Sec 20	44	shale
KELRON 28	T20N, R12W, Sec 21	15	sand & silt
KELRON 29	T20N, R12W, Sec 21	45	shale
KELRON 30	T20N, R12W, Sec 20	148	shale & coal
KELRON 31	T20N, R12W, Sec 21	184	shale

The range of concentrations of major anions (figure 11) and major cations (figure 12) for the samples collected for this study (by the ISGS and Dynegy) are shown by the dots, while the box plots display the available data. These box plots were generated using GRAPHER version 3. The whiskers cover the entire range of data, which differs from the whiskers for the SYSTAT box plots (e.g., figure 6).

The dot and box plots are similar; thus, the data collected from the sampled wells are similar to the available data, which cover a broader geographic area. Only 2 sampled wells (well 23343 and KELRON 26) had TDS values below 250 mg/L. Well 23343 is a 175-foot, domestic well completed in bedrock. KELRON 26 is a 16-foot monitoring well completed in Quaternary geologic materials. Another shallow monitoring well, KELRON 28, had a TDS similar to the bedrock wells.

Some of the concentration data can be explained by the lithology of the aquifer materials (table 8). KELRON 30 was completed in shale and coal, wells 1349, 21903 and 23343 in sandstone and shale, well
25531 in rock and shale, KELRON 26 and 28 in sand, while the remaining wells were completed in shale. For example, a groundwater sample from KELRON 30 (the only well completed in coal) had the highest concentration of Ba, Li, Na, and Cl. Data from tables 4 and 5 show that coal generally has higher concentrations of Cl than other geologic materials.

Table 9. Geochemical data for ISGS sampled wells

	Well Number									
	1349	21903	23343	25531	KELRON 25	KELRON 26	KELRON 27	KELRON 28	KELRON 29	KELRON 30
n*	1	1	1	1	2	2	2	2	2	2
Al	<0.1**	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
As	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
B	0.29	0.50	1.4	1.2	1.14	.055	.086	0.09	1.2	0.93
Ba	0.14	0.98	0.26	0.47	2.0	0.031	0.77	0.034	0.55	5.3
Be	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ca	131	44.2	67.4	36.8	84.4	87.3	34.8	186	30.4	42.0
Cd	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Co	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cr	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cu	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fe	2.4	<0.01	1.6	3.8	0.06	<0.01	0.20	0.04	0.22	1.9
K	3.0	4.0	5.0	5.0	6.5	3.5	4.5	<1	4.0	7.0
Li	0.01	0.02	0.01	0.06	0.07	<0.01	0.04	0.03	0.04	0.10
Mg	56	29	45	27	45	34	21	98	15	29
Mn	0.11	0.041	0.035	0.041	0.057	<0.001	0.020	0.081	0.015	0.047
Mo	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Na	67	240	68	590	430	1.9	300	16	290	870
Ni	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.005	0.005	<0.01
Pb	<0.02	<0.02	<0.02	<0.02	<0.02	0.015	0.015	<0.02	<0.02	<0.02
S	49	0.03	5.4	0.38	0.46	7.9	0.19	72	0.3	1.5
Sb	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Sc	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Se	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Si	8.0	3.4	7.5	3.3	5.4	4.4	6.1	6.2	5.8	4.7
Sr	0.23	0.52	1.5	0.57	0.7	0.1	0.4	0.3	0.4	0.8
Ti	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Tl	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
V	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

	1349	21903	23343	25531	KELRON 25	KELRON 26	KELRON 27	KELRON 28	KELRON 29	KELRON 30
Zn	0.055	<0.001	0.018	0.074	<0.001	<0.001	<0.001	0.004	<0.001	0.003
F	0.2	0.2	0.5	0.5	0.5	0.1	0.7	0.1	0.8	0.7
Cl	100	230	5.0	640	690	7.0	320	7.0	240	970
Br	<0.05	<0.05	<0.05	0.72	1.3	<0.05	0.61	<0.05	0.51	2.5
NO_3-N	<0.02	<0.02	<0.02	<0.02	<0.02	6.7	<0.02	<0.02	<0.02	0.15
PO_4	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SO_4	140	<0.1	11	0.6	1.0	19	0.2	190	0.6	3.2
Total Alk	380	460	390	480	280	280	340	600	400	670
pH	7.7	7.8	8.2	8.0	7.8	7.9	8.0	7.9	8.1	8.2
TDS	470	550	210	1300	1300	150	700	450	590	1900

* n= number of samples. For n>1, average values are reported.

**: All values are reported in units of mg/L except pH.

Table 10. Geochemical data from KELRON well samples

Parameter	Units	Well Number						
		KELRON 25	KELRON 26	KELRON 27	KELRON 28	KELRON 29	KELRON 30	KELRON 31
n*	–	7	1	7	1	7	7	7
pH	--	7.3	7.2	7.6	7.0	7.5	7.4	7.2
Temperature	°C	12.5	11.6	12.0	13.6	13.0	14.5	12.4
TDS	mg/L	1500	350	900	900	830	2400	860
Alkalinity	mg/L	280	290	330	600	390	670	560
B	mg/L	1.2	<0.05	0.83	0.11	1.1	0.9	0.7
Ba	mg/L	1.6	0.03	0.7	0.03	0.47	4.6	0.58
Ca	mg/L	85	92	32	190	29	34	82
Fe	mg/L	0.15	<0.025	0.18	0.05	0.26	1.8	0.40
K	mg/L	5.8	2.2	3.7	0.88	3.7	7.7	9.5
Li	mg/L	0.11	<0.005	0.04	0.03	0.05	0.12	0.10
Mg	mg/L	45	34	20	94	15	25	35
Mn	mg/L	0.05	<0.005	0.02	0.07	0.01	0.04	0.08
Na	mg/L	390	3.1	270	17	260	890	170
Sr	mg/L	0.57	0.07	0.4	0.3	0.3	0.7	0.7
Cl	mg/L	820	12	360	11	320	1200	59
PO_4	mg/L	0.03	0.10	0.02	0.01	0.03	0.04	0.06
SO_4	mg/L	6.6	20	<5	170	<5	6.5	110

* n= number of samples. For n>1, average values are reported.

Figure 11. Major anions: box plot for the available wells along with dot plots of the ISGS (+) and Dynegy (◇) samples

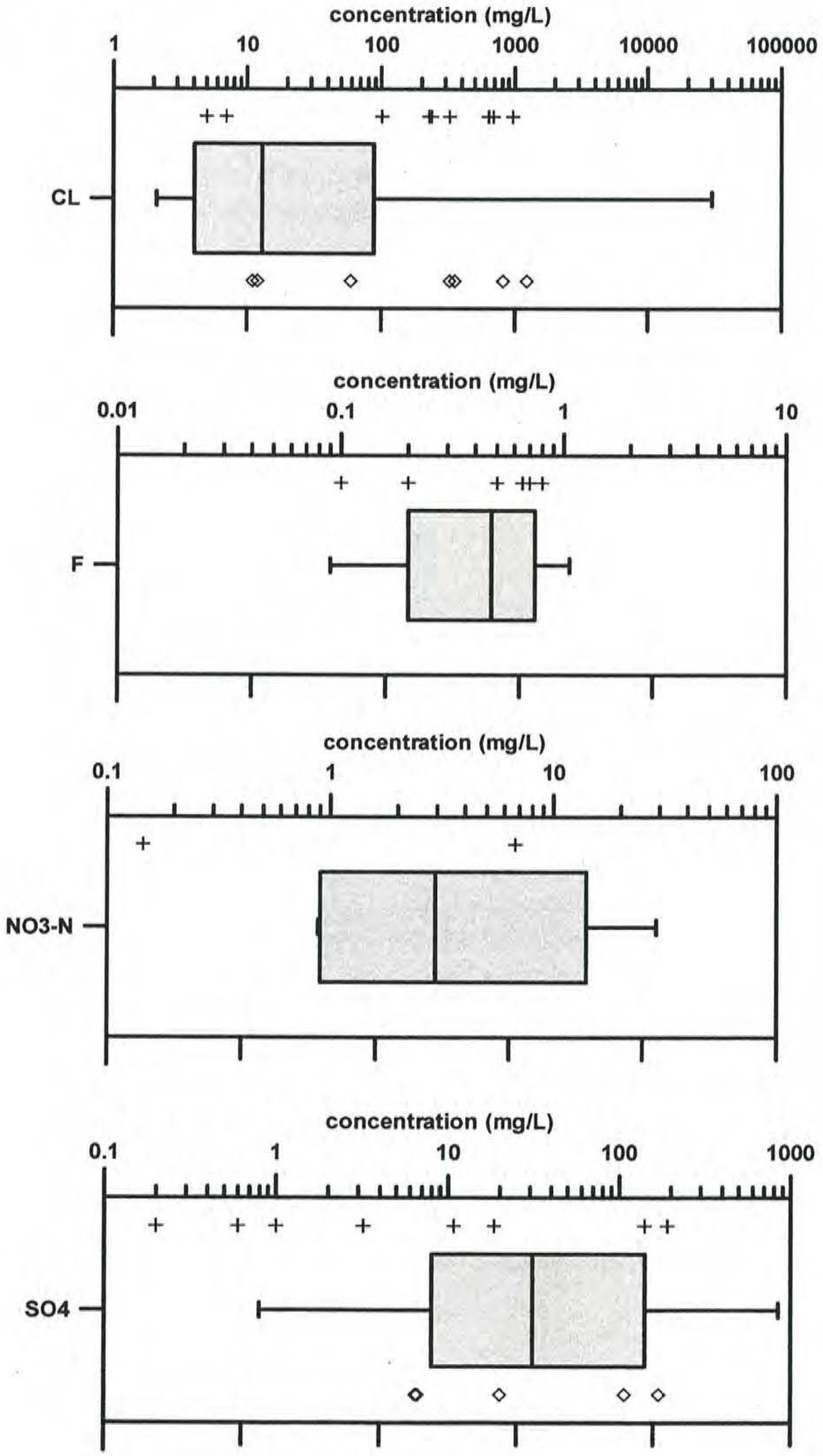
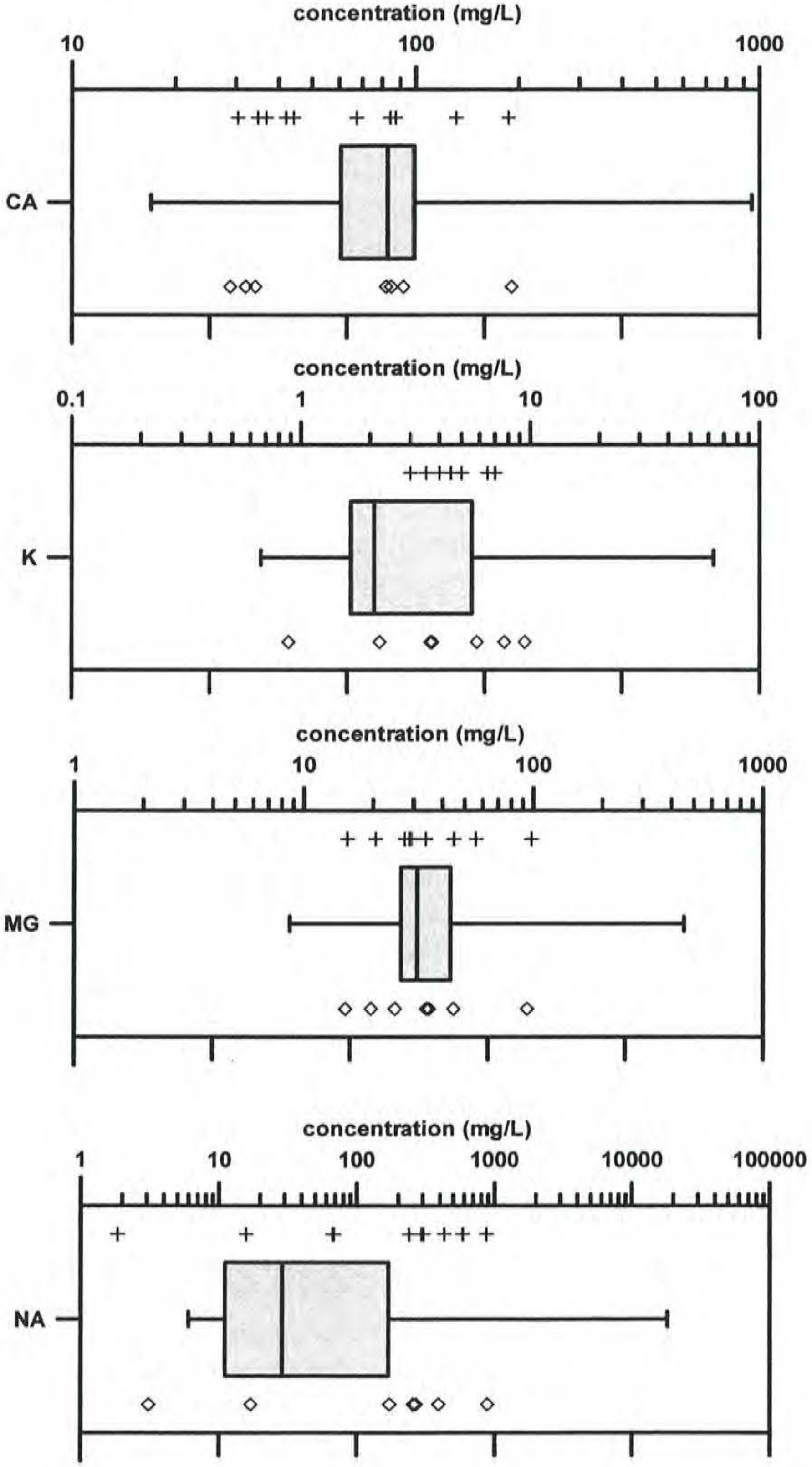


Figure 12. Major cations: box plot for the available wells along with dot plots of the ISGS (+) and Dynegy (◇) samples



The concentration data for the ISGS and Dynegy groundwater samples were also plotted on a Piper diagram (figure 8). The major cation concentrations for these groundwater samples appear in the left-hand ternary plot of the Piper diagram (figures 8 & 13). The linear nature of the data points leads to the hypothesis that groundwater with the greater concentrations of sodium plus potassium (Na+K, e.g., KELRON 27 or KELRON 29) migrated over a longer distance from the recharge area to the respective well than samples with lower concentrations of Na+K (e.g., well 23343). During migration, the groundwater dissolved increasingly greater amounts of sodium from the aquifer rocks and increasing amounts of calcium and magnesium were removed from the water, probably by adsorption by clay minerals in the aquifer rocks. In general, the chemistry of the water samples tends to cluster based on the lithology of the geologic materials in which they are screened. For example, the two wells completed in Quaternary materials plot to the far left in figure 13, and wells 1349 and 23343 (sandstone and shale) in the center of the plot. Well 25531 is the only well that does not fit this pattern.

The diamond-shaped plot in the Piper diagram (figure 8) indicates that for the water samples collected in June 2002, 35% displayed temporary hardness (moderate amounts of Mg, Ca, and HCO_3^-); 41% of these samples are classified as saline (contained relatively large amounts of Na and Cl); the remaining samples were of intermediate classification between temporary hardness and saline.

The position of water quality results plotted on a Piper diagram can be misleading, however, because the Piper diagram is based on the mole percent of four major cations and four major anions. For a given water sample, the number of moles of each of the eight major ions is calculated, then the mole percent is calculated on the basis of the total moles of either cations or anions, respectively. The mole percent of sodium, for example, in a water sample that contains low concentrations of the major cations and anions can be the same as in a water sample that contains high concentrations of major anions and cations. A water that is classified as temporarily hard might not be hard at all, according to the accepted definition of hard water. The hardness of water is defined by the concentration of calcium carbonate in the water. Water containing 0 to 60 mg $CaCO_3$/L is defined as "soft," whereas water that contains 121 to 180 mg $CaCO_3$/L is defined as "hard" (Hem, 1970).

The carbon and hydrogen (tritium) isotopic data (table 11) reveal that some wells produce recent water, while others yield much older water. Tritium values in Illinois precipitation typically range from 3 to 10 tritium units (TU) (Hackley et al., 1996; Hackley, personal communication, 2002). Tritium is generated in the atmosphere. In the subsurface, tritium decays exponentially with a half-life of 12.3 years (Freeze and Cherry, 1979). Thus, water with tritium concentrations greater than 5 TU is considered recent water (wells 1349, KELRON 26, and KELRON 28), while water with nondetectable tritium concentrations is considered to be >50 years old. ^{14}C has a longer half-life than tritium and is expressed as radiocarbon years before present (RYBP) and as % modern carbon. Both units provide relative ages. Due to the complexities of carbon chemistry, a great deal of additional analysis is needed to obtain definitive dates. The ^{14}C data are consistent with the tritium data, showing that three wells (wells 1349, KELRON 26 and KELRON 28) yield recent water and the others yield much older water. Two wells (KELRON 26 and

Figure 13. Cation plot of the Piper diagram for ISGS and Dynegy samples

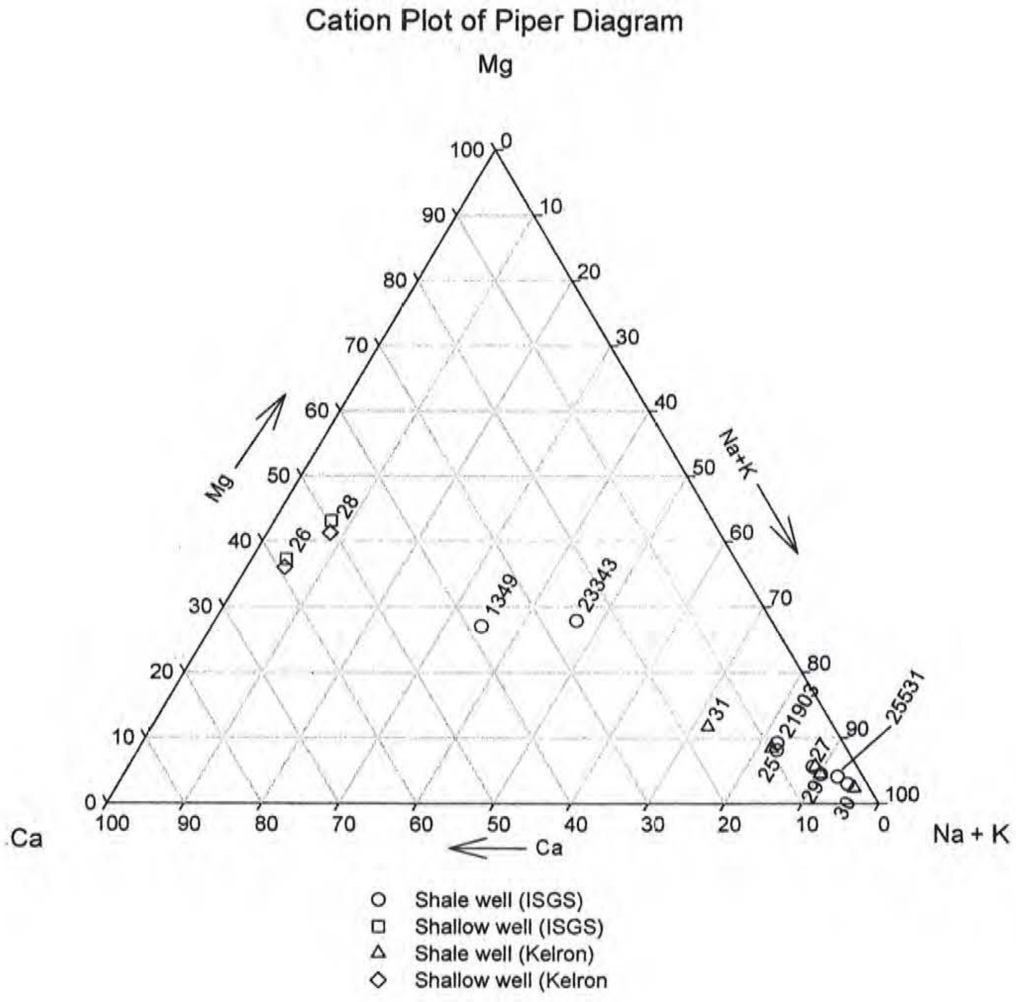


Table 11. Isotopic data for ISGS sampled wells

Parameter	Units	Well Number							
		1349	25531	KELRON 25	KELRON 26	KELRON 27	KELRON 28	KELRON 29	KELRON 30
^{14}C	RYBP	2,180	21,160	13,920	210	19,400	modern	34,610	20,850
	% modern carbon	76	7.2	18	97	8.9	102	1.4	7.5
Tritium	TU	7.8	<0.43	<0.43	5.3	<0.43	5.8	<0.52	<0.43

KELRON 28) were completed in Quaternary geologic materials and appear to draw water from the local groundwater flow system. The third well (well 1349) is completed in the shallow bedrock, but apparently draws some recent water from the overlying Quaternary geologic materials. The remaining wells (KELRON 25, KELRON 27, KELRON 29, KELRON 30, and KELRON 31) apparently draw water from the bedrock and are either only slightly connected to or completely isolated from the local groundwater flow system.

When expressing ^{14}C as % modern carbon, ^{14}C has an inverse linear relationship with TDS, sodium, and chloride and a positive linear relationship with calcium. These relationships were determined using linear regression and had coefficients of determination or R^2 ranging from 0.46 (for TDS) to 0.73 (for Ca).

3.3 Equilibrium Geochemical Modeling

The geochemical model, MINTEQA2 (Allison et al., 1990), is an equilibrium geochemical model used to calculate the theoretical composition of an aqueous solution at equilibrium, with or without contacting solids (minerals). Because they are in dynamic relationships with their environment, most groundwater systems are not at equilibrium. The use of a geochemical equilibrium model, however, provides an approximation of the geochemical reactions that might occur in a groundwater system.

Input data for MINTEQA2 from the two KELRON wells screened in Pennsylvanian shale (KELRON 25 and KELRON 30) included major element water chemistry and selected mineral components of the shale in the screened interval of the wells. The aqueous components input to the model were carbonate (from alkalinity determinations), calcium, iron (as Fe^{2+}), magnesium, potassium, sodium, silicon (as H_4SiO_4), chloride, sulfate, Eh, and pH. Trace elements were not used because of their negligible influence on the water chemistry. The only minerals included in the model were kaolinite, quartz, and siderite. Thermodynamic data for other minerals present in the shale, such as illite, K-feldspar, plagioclase feldspar, and chlorite, were not available in the model's database. Kaolinite, quartz, and siderite were set as infinitely available, i.e., they were assumed to never completely dissolve from the rock.

In operation, MINTEQA2 initially calculates the charge balance of the input solution. The errors for the charge balances between anions and cations were 2% and 6% for KELRON 25 and KELRON 30, respectively, using data derived by the ISGS for the aqueous composition. After the initial calculation of the charge balance, the model determines which minerals in its database could potentially precipitate, due to the components in the aqueous phase. For example, if manganese were not present as an aqueous component, then rhodochrosite ($MnCO_3$) would not be among the potential precipitates. The model then calculates which of the potential solid phases is most supersaturated according to a comparison of the mineral's solubility product (K_{sp}) with the activity product of the relevant components of the aqueous phase. For example, if calcite ($CaCO_3$) is the most supersaturated mineral, MINTEQA2 calculates the activity product of $(Ca^{2+})(CO_3^{2-})$ and compares this product with the K_{sp} for calcite. Sufficient Ca^{2+} and CO_3^{2-} are subtracted from the aqueous phase and added to the solid phase so that the resulting aqueous activity product equals the K_{sp}. At this point, the solid and aqueous phases are in equilibrium with respect to calcite. MINTEQA2 then calculates the next most supersaturated solid phase and repeats the above procedure. Dissolution of minerals is also accomplished in an iterative manner, by addition of solutes from the solid phase to the aqueous phase.

The modeling results for KELRON 25 and KELRON 30 were that calcite ($CaCO_3$) and wustite (FeO) are allowed to precipitate from the water in both wells. In addition, magnesite ($MgCO_3$) is allowed to precipitate from the water in KELRON 30. The mass of minerals that were calculated to precipitate per liter of water were small: 0.1 to 0.2 g calcite, 0.08 to 0.4 g wustite, and approximately 0.09 g magnesite. The calculated equilibrium pH values for the water in KELRON 25 and KELRON 30 were 8.55 and 9.20 while the mean observed pH values at the time of collection were 7.78 and 8.24, respectively.

When the mean observed pH values were imposed as the equilibrium values, then only about 0.09 g of calcite was calculated to precipitate per liter of water in both wells, with neither wustite nor magnesite precipitating. This is the most likely scenario. Given sufficient time, calcite will probably precipitate in the wells screened in the Pennsylvanian shale. If water were removed from the wells and stored (e.g., in a tank), then calcite and siderite ($FeCO_3$) were calculated to precipitate when the observed pH was imposed as the equilibrium pH.

4. SUMMARY & CONCLUSIONS

Great variability was observed in the geochemical data for the Pennsylvanian bedrock, Pennsylvanian groundwater, and other data collected for this project. Some of this variability is due to the different lithologies which includes sandstone, shale, coal, limestone, and sand and gravel. Some of this variability is also due to the depth of the sample. For example, groundwater samples from KELRON 26 and 28 are significantly different from other samples because they were from shallow wells and are completely connected to the local groundwater system, whereas water samples from deeper wells were largely isolated from the local groundwater flow system. Although little data are available regarding the hydraulic connection between the Vermilion River and the shallow bedrock which crops out locally, we suspect that a well's position relative to recharge and discharge areas affects the concentrations of major cations and anions in the groundwater samples.

Some general observations can be made regarding the groundwater compositions, although exceptions can be found for most of these observations.

> The samples collected for this study have a similar range in the concentrations of major anions and cations as those from available groundwater samples collected over a broader geographic area.
>
> The average concentrations of calcium, magnesium, sulfate, and alkalinity were higher in water from two shallow wells (KELRON 26 and 28) than in the wells developed in shale (KELRON 25, 27, 29, 30, and 31). This indicates a possibility that the aquifer rocks of the shallow wells contained greater contents of calcite/dolomite and gypsum or magnesite than the wells completed in shale. Water from the wells completed in shale contained higher concentrations of aluminum, barium, bromide, boron, chloride, fluoride, iron, lithium, potassium, sodium, and strontium. The greater aluminum concentration in the water suggests greater clay contents in the shale aquifer rocks than in the shallow wells.
>
> For samples from bedrock wells, sodium and chloride concentrations apparently increase at the expense of calcium, magnesium, and other higher valence cations due to adsorption as groundwater moves away from recharge areas.
>
> Compared to samples from the deeper bedrock wells, samples from shallow wells generally have higher tritium and % modern carbon, suggesting the addition of recent water.
>
> Equilibrium modeling showed that calcite is expected to precipitate from water derived from the shale wells, given enough time for equilibrium to become established. The calcite might eventually plug well screens. If water is pumped from the shale aquifer and stored in a tank, calcite is expected to precipitate in the tank and accumulate slowly on the tank walls and bottom.

The mineralogy of an aquifer governs the chemical composition of the associated groundwater. Mineralogical analyses were conducted to aid in understanding the chemical composition of the groundwater, and to provide information for geochemical modeling. The mineralogical analyses showed that three cores collected during this project (KELRON 29, KELRON 30, and KELRON 31) consisted principally of shale, composed of clay minerals and quartz with minor amounts of K-feldspar, plagioclase feldspar, siderite, and marcasite or pyrite. Coal was penetrated while drilling KELRON 30, and a small amount was recovered at the bottom of that core. The most abundant clay minerals in the cores were illite, kaolinite, and chlorite, with minor amounts of illite/smectite mixed-layer clay.

ACKNOWLEDGMENTS

This study was partially funded by a grant from KELRON Environmental, Inc. of Champaign, IL. We gratefully acknowledge the well owners who allowed us to sample their wells. In addition, we received technical assistance with sampling from Gina Eversole, Dynegy, Inc., Lindsay Hagemeyer, Dynegy, Inc. and Stuart Cravens, KELRON.

Chris Stohr, ISGS, collected the natural gamma logs from 3 wells.

Randy Hughes, Phil DeMaris, Makiko Otao, and Mary Hynes of the ISGS conducted the PIMA and XRD analyses.

The ISGS Isotope Geochemistry Lab ran the tritium and ^{14}C analyses. Keith Hackley, ISGS, assisted with the interpretation of the isotopic data.

Alec M. Davis, ISGS, compiled much of the geochemical data and prepared some of the figures for this report.

Mike Knapp, ISGS, drafted figures 1 & 2 for this report.

Tracy D. Branam, Indiana Geological Survey, provided data for the Indiana wells included in this report.

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Appendix A. Geologic Logs of Selected Bedrock Core

The core descriptions by Kolata and Jacobson include a stratigraphic interpretation of the core and appear first. The core descriptions by DeMaris emphasize lithologic and structural features of the core.

Kelron Environmental MW 25
Vermilion Power Station
Danville, Vermilion County, IL
(NW, NW, NW, Sec. 29, T. 20 N., R. 12 W.)
Description by Dennis R. Kolata and Russell J. Jacobson, March 14, 2002

Pennsylvanian System
Shelburn Formation
Unnamed Shale above the Danville Coal

9' to at 39' (TD)
Shale, light to medium gray, massive beds, blocky fracture, silty, micaceous, abundant carbonized plant material, bioturbated; interbeds of very light gray shale between 1 mm and 30 mm thick.

Kelron Environmental MW 30
Vermilion Power Station
Danville, Vermilion County, IL
(SW, NE, NE, Sec. 20, T. 20 N., R. 12 W.)
Description by Dennis R. Kolata and Russell J. Jacobson, March 14, 2002

Pennsylvanian System
Shelburn Formation

Farmington Shale
116' to 135'
Shale, medium gray, massive beds, blocky fractures, silty, micaceous; 1-2 " thick brownish-gray siderite nodules beginning a 128', non-marine.

135' to 144'
Shale, medium to dark gray, somewhat less silty than above, brownish-gray siderite nodules mostly 1 cm thick; first appearance of marine fossils 135.5' (strophomenid brachiopods, gastropods, and bivalves increase in abundance downward).

144' to 145'
Shale, dark gray to black, organic-rich, contains white needle-like crystals.

Danville Coal
145' to 148'
Coal, abundant pyrite along cleats

Kelron Environmental MW 31
Vermilion Power Station
Danville, Vermilion County, IL
(SW, NE, NE, Sec. 20, T. 20 N., R. 12 W.)
Description by Dennis R. Kolata and Russell J. Jacobson, March 14, 2002

Pennsylvanian System
Shelburn Formation?

Unnamed Shale above the Danville Coal
154' to 173'
Shale, medium gray, massive beds, blocky fractures, bioturbated, silty, micaceous, not fossiliferous.

173' to 183' (TD)
Shale, medium to dark gray, siderite nodules up to 3 cm thick, bioturbated, silty, micaceous; small bivalves suggest that this is a marine shale.

Boring: **KELRON 25** (HQ or 2.5 inch core)
Location: NW/4 of NW/4 of NW/4, Sec 29, T20N, R12W, Vermilion County, IL

Total Depth= 39 feet, Surface Elevation= 578.8 feet
Description by Philip J. DeMaris, June 2002

Interval (ft)			**Description**
Top	Bottom	Thickness	
9.00	11.25	2.25	Shale– light to medium gray, slightly silty, especially as silt lenses from 10.35 to 11.25', slightly micaeous, horizontal bedding, slightly weathered at top
11.25	30.60	19.35	Shale– medium gray, silty, slightly micaeous and finely carbonaceous, multiple siltstone bands in interval from 18.10 to 30.60', planar bedding
30.60	36.87	6.27	Shale– medium gray, slightly silty, some pyrite, predominantly planar bedding
36.87	38.82	1.95	Shale– medium gray, very slightly silty, some clay lenses, silt lenses and carbonaceous debris rare, faint planar bedding with some bioturbation
			total core= 29.82'

Boring: **KELRON 30** (HQ or 2.5 inch core)
Location: SW/4 of NE/4 of NE/4, Sec 20, T20N, R12W, Vermilion County, IL

Total Depth= 148 feet, Surface Elevation= 645.7 feet
Description by Philip J. DeMaris, June 2002

Interval (ft)			**Description**
Top	Bottom	Thickness	
119.00	126.92	7.92	Shale– light to medium gray, slightly silty, sparsely micaeous above 123', slightly weathered at top, fractured on multiple low-angle planes in top 1.5', generally planar bedding throughout, two medium-angle faults from 121.1 to 121.7'
126.92	131.20	4.28	Shale– medium gray, nonmicaeous, multiple siderite bands/nodules

Interval (ft)			**Description**
Top	Bottom	Thickness	
131.20	138.68	7.48	Shale– medium gray, finely carbonaceous, many siderite bands/ nodules throughout, scattered marine fossils in interval 136-138'
138.68	144.38	5.70	Shale– dark gray, becoming more carbonaceous and pyritic downward, siderite nodules present in top 1.3', sulfide-rich carb. claystone at base, strongly weathered
144.38	148.00	3.62	Coal (Danville Coal)– normally bright banded, well cleated, pyritic, calcite and kaolinite on cleat, some fusain present throughout
			total core= 29.0'

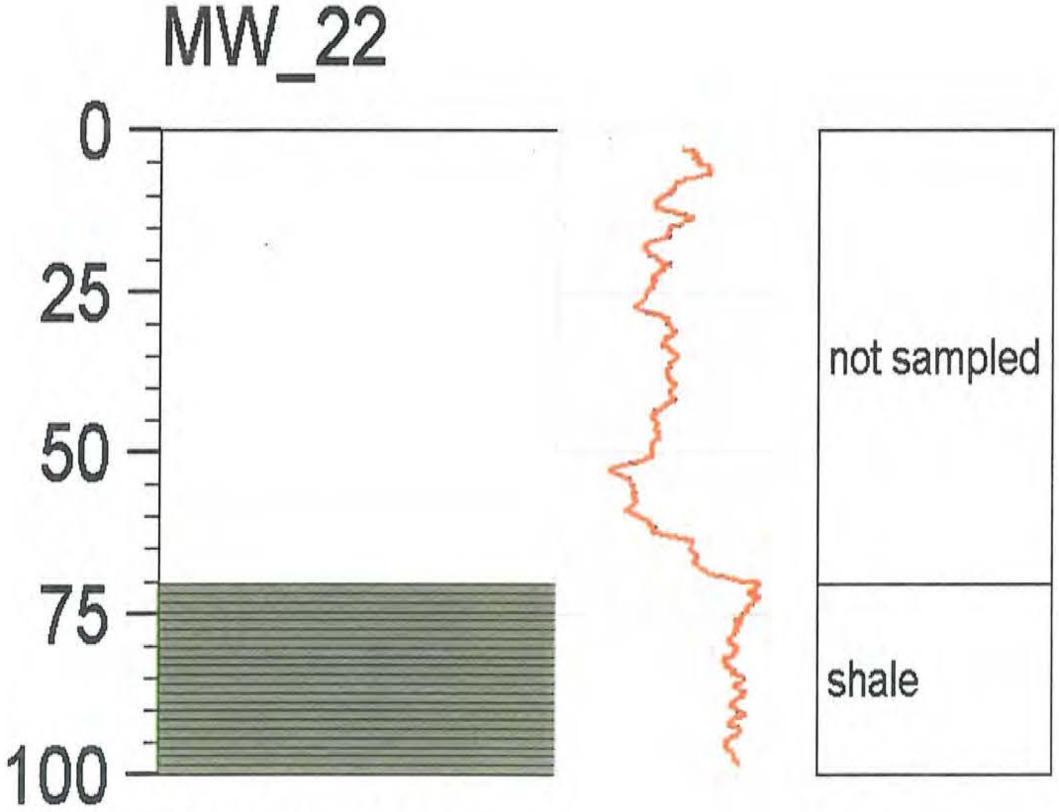
Boring: **KELRON 31** (HQ or 2.5 inch core)
Location: NE/4 of SW/4 of SW/4, Sec 21, T20N, R12W, Vermilion County, IL

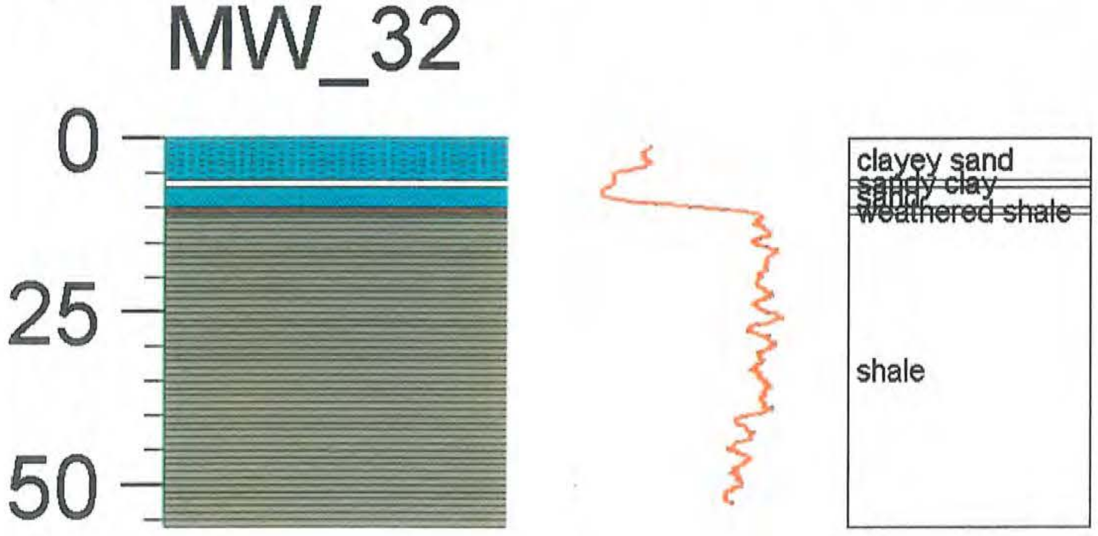
Total Depth= 184 feet, Surface Elevation= 698.2 feet
Description by Philip J. DeMaris, June 2002

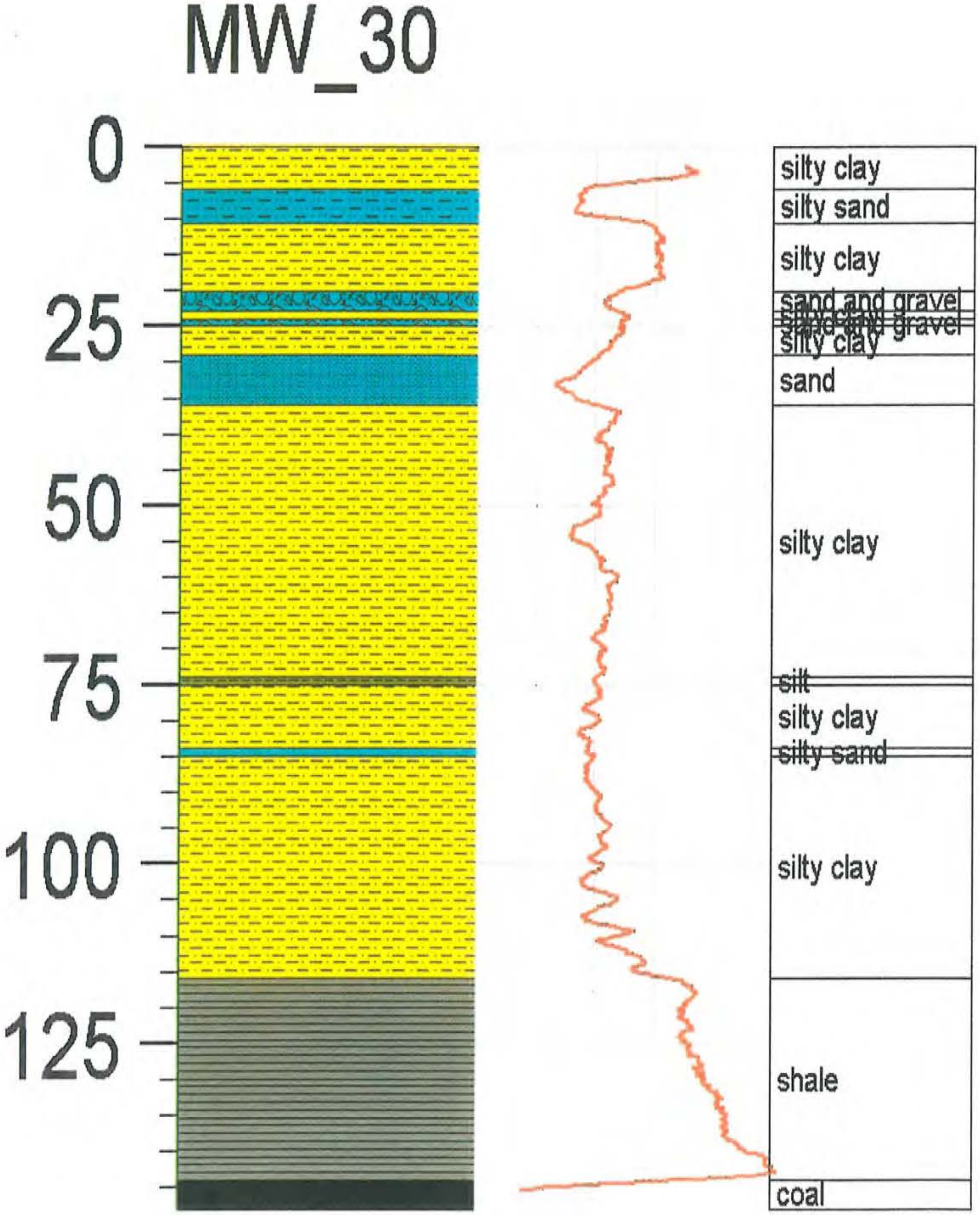
Interval (ft)			**Description**
Top	Bottom	Thickness	
153.00	157.55	4.55	Shale– light to medium gray, slightly silty, well weathered in top 1.2', carbonaceous debris rare, several low angle faults
157.55	170.30	12.75	Shale– light to medium gray, silty, slightly micaeous, unweathered, competent, uniformly faintly laminated, less silty below 164', very faintly horizontally bedded, planar fault (59° dip) centered at 168.8'
170.30	180.80	10.50	Shale– medium gray, slightly silty at top, minor sideritized banding near top of interval, many siderite bands and nodules from 173.7' to base
180.80	182.82	2.02	Shale– dark gray, with multiple siderite bands, very finely carbonaceous
			total core= 29.82'

Appendix B. Natural Gamma Logs of Selected KELRON Wells

Natural gamma logs for three KELRON wells (KELRON 22, KELRON 30, and KELRON 32) were collected by Chris Stohr of the ISGS in May 2002. The natural gamma logs shown in this appendix are scaled from 0 to 100 cps. In general, higher gamma counts reflect geologic materials with higher clay content such as shales and clayey diamictons.






MW_30
0
25
50
75
100
125
silty clay
silty sand
silty clay
sand and gravel
sand and gravel
silty clay
sand
silty clay
silt
silty clay
silty sand
silty clay
shale
coal

Appendix B Volume 2

Coal Mine Maps and Logs from Illinois State Geological Survey

Item 1: Directory of Coal Mines in Vicinity of Vermilion Power Station Sorted by Mine Location (from: Illinois State Geological Survey. 1996. *Directory of Coal Mines in Illinois: Vermilion County*. Champaign, Illinois).

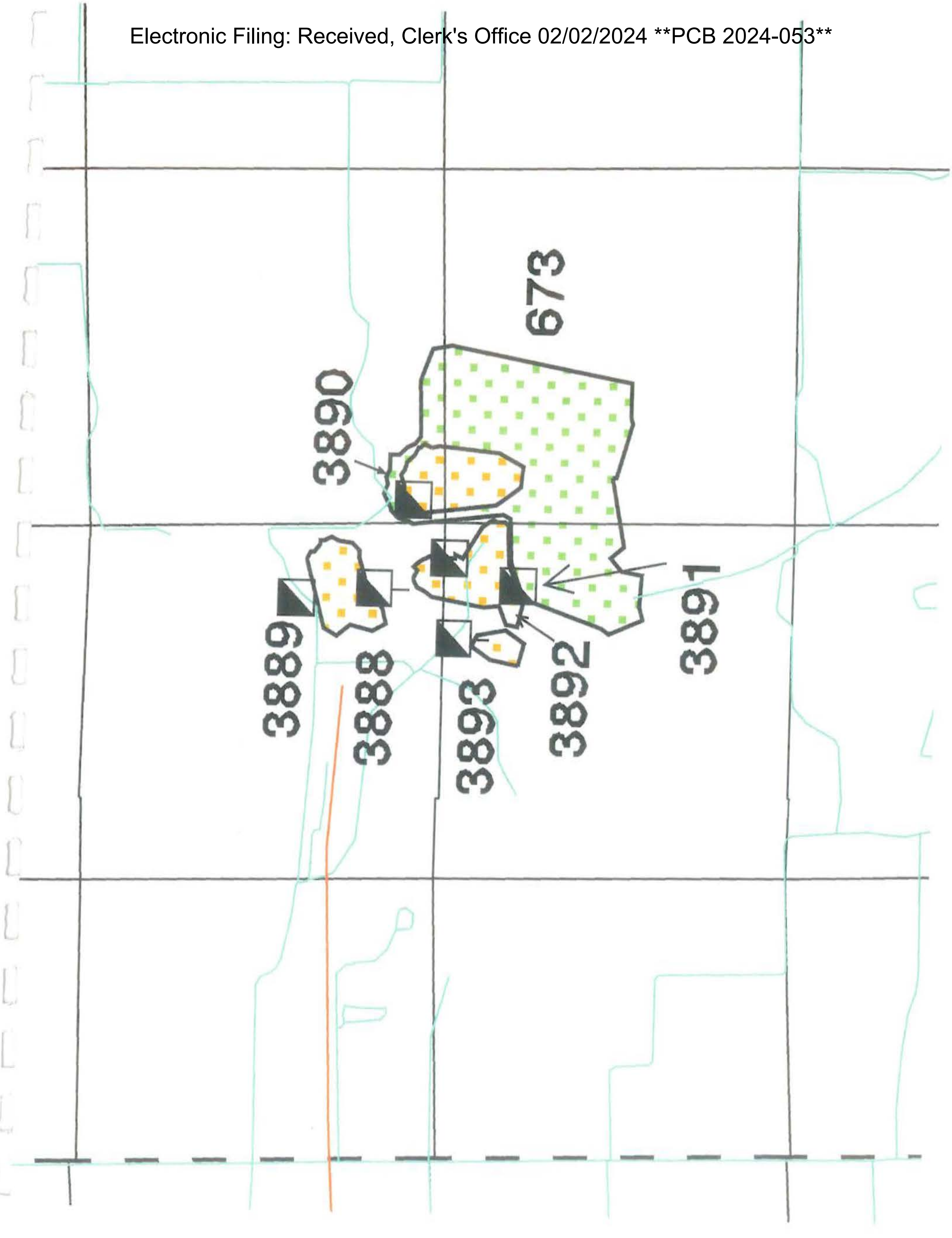
Item 2: Map of Coal Mine Locations (with ISGS Index Numbers) in Vicinity of Vermilion Power Station (cross-reference to Item 1). Printed by Illinois State Geological Survey in 2002 from Coal-Mine Database.

Item 3: Quade Map from 1933. Retrieved and printed from Illinois State Geological Survey reference files in 2002. Map shows locations of coal mines in vicinity of Vermilion Power Station based on 1933 mapping by Quade (reference unknown).

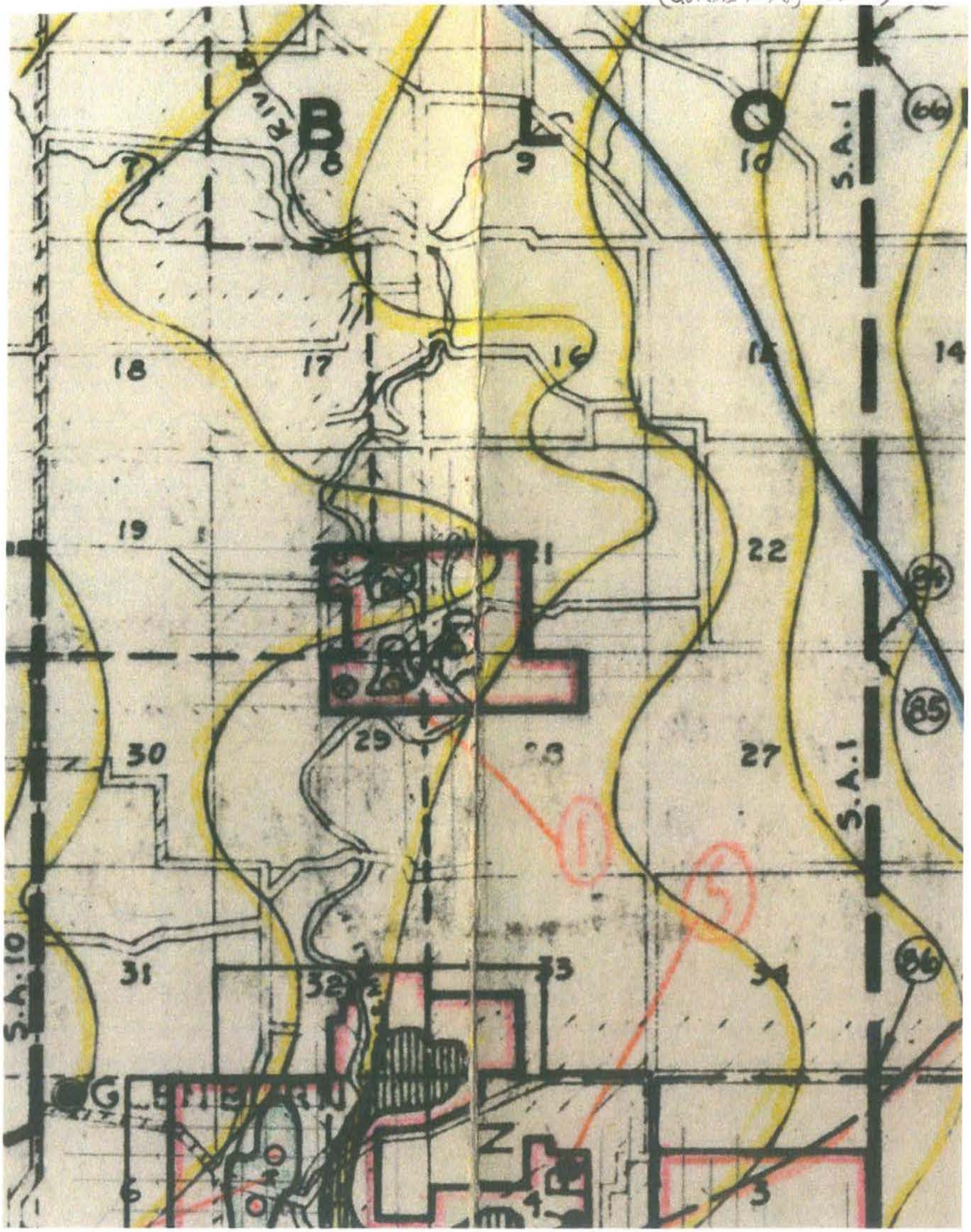
Item 4: Logs of Coal Mines 3888 (Fletcher's Middlefork Mine) and 3889 (Crawford Mine) from Illinois State Geological Survey Reference Files

TABLE 3. DIRECTORY OF COAL MINES SORTED BY MINE LOCATION

ISGS INDEX	COMPANY NAME	MINE NAME	MINE NO.	MINE TYPE	METHOD	YEARS OPERATED	SEAM MINED	COUNTY	LOCATION: TWP	RGE	SEC
3889	CRAWFORD, M. F. & SONS	CRAWFORD		SHAFT	RPB	1905-19	DANVILLE	VERMILION	20N	12W	20
3888	MIDDLEFORK C C	MIDDLEFORK	2	SLOPE		1939-49	DANVILLE	VERMILION	20N	12W	20
3890	DEAMODE	DEAMODE		SHAFT	RP	1873-84	DANVILLE	VERMILION	20N	12W	21
3890	SWISHER, SAM	PILOT		SHAFT		1885-89	DANVILLE	VERMILION	20N	12W	21
673	AYRSHIRE COLLIERIES	HARMATTAN		STRIP		1968-70	DANVILLE	VERMILION	20N	12W	28
3891	BONNETT, A. H.	BONNETT	1	SHAFT	RP	1893-07	DANVILLE	VERMILION	20N	12W	29
3892	SWISHER, SAM	BONNETT		SHAFT		1907-08	DANVILLE	VERMILION	20N	12W	29
3893	CALVERT	CALVERT		SLOPE		1930	DANVILLE	VERMILION	20N	12W	29


673
3890
3891
3892
3893
3888
3889

(QUADE MAP, 1933)



John C. Moore Corporation, Rochester, N. Y. Binder and holes in leaves Patented. FORM 403497

MOORE'S MODERN METHODS

ISGS
3888

Location and Elevation Data

Location: Exact Approximate

(Approximate only if no trace of record of original exists)

Location by G.M. WILSON

Date Oct. 1945 Notebook No. 667 Page 53-2551

Looseleaf ref.

Map files No. 14-92-35

Description of Location

Position in sec., ¼ sec., 40 acres

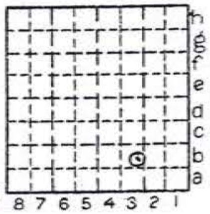
feet from North line Co #850 Airshaft

feet from East line

840 feet from South line ± 390

3800 feet from West line ± 4000

80'-6' #7 Coal (512)



Sec. 20

T 20 N. ~~S.~~

R ~~E.~~ 12 W.

Other description: L-191

Farm

No.

1949 - 300 TONS

Company FLETCHERS'

MIDDLE FORK MINE

No. 2

County No. ~~857~~

ABD 1949

OPENED NOV. 13, 1939

Elevation 588.0 ft. Airshaft 592.5 GMW

By G.M.W.

Method: Level, transit, alidade, hand level

Elevation of

Height of point above ground

Date Notebook P.

Looseleaf ref.

Map files No.

Description of item: (drill hole, mine, etc.) SLOPE MINE (Act 1945)

82' to 6' of #7 Coal (DMM film 1939)

County VERMILION Quadrangle DANVILLE Index No. 1520 B3

(A4242—5M—8-39)

1

John C. Moore Corporation, Rochester, N. Y. Binder and holes in leaves Patented. FORM 401500

Mine originally operated by: (1) Middlefork Coal Co
R#1 Danville, Ill.
Date
1940
(1939?)
Original name or number: #2
Illinois Coal Report p. operator's report 1948

LATER OPERATORS

Date	Operator	Name or No.
2		
3		
4		
5		
6	('48) 300 tons	
7		
8		
9		
10		
11		
12		
13		
14	v (1948) See Vermilion Mine book	

*Also owners #See ownership sheet

87'
(1948)
To coal

Railroad, Wagon, Strip, Idle, Abandoned Slope
1949

IDENTIFICATION

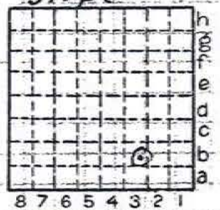
County No.

Coal No. ☐ 7

Coal Report No. L-191

Quad. Danville (1948) 6'0"

County Vermillion



Sec. 20

T. 20 N. S.

R. 12 E. W.

Index No.

1520 B3

COAL MINE OPERATOR

(68020—1500—11-38) 2

John C. Moore Corporation, Rochester, N. Y. Binder and holes in leaves Patented. FORM 408992 A

(Sheets) COAL PRODUCTION (Sheet)

Period Mo.	Day	Year	Mo.	Day	Year	Tons
					1939	30
					1940	958
					1941	2964
					1942	1197
					1943	379
					1944	405
					1945	500
					1946	350
					1947	550
					1948	300
					1949	

SUMMARIES

No. to No.

Railroad, Wagon, Strip, Idle, Abandoned slope
1949

IDENTIFICATION

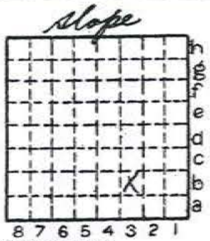
County No. 850

Coal No. ☐ 7

Coal Report No. L-191

Quad. 149

County Vermilion



Sec. 20

T. 20 N. ~~S.~~

R. 12 ~~E.~~ W.

Index No.

1520 B3

COAL MINE—PRODUCTION

ILLINOIS GEOLOGICAL SURVEY, URBANA

(2732—2M—7-41)

2

W. F. Crawford Mine

County No. 852

John C. Moore Corporation, Rochester, N. Y. Binder and holes in leaves, each Patented 1906.
MOORE'S MODERN METHODS

ISGS
3889

Location and Elevation Data

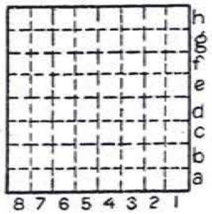
Location: Exact Approximate
(Approximate only if no trace of record of original exists)

Location by GMW
Date Notebook No. 667 Page 53-2548
Looseleaf ref.
Map files No. 14-92-35

Description of Location

Position in sec., ¼ sec., 40 acres

feet from North line
feet from East line
✓ 2375 feet from South line
4540 feet from West line



Sec. 20
T 20 N. ~~S.~~
R ~~E.~~ 12 W.

Other description: 107' to 6'6" #7 coal
First prod 5000 Tons/year in 1908
1919 ABD ABD 1910?

IN TABULATIONS

Farm
No.

Company W. F. Crawford Mine
(Collison)
No.
County No. 852

Elevation 598.3 ft.
By GMW
Method: Level, transit, alidade, hand level

Elevation of
Height of point above ground
Date Notebook P.
Looseleaf ref.

Map files No.
Description of item: (drill hole, mine, etc.) ABD Shaft Mine
Log in files
County Vermilion Quadrangle Danville Index No. 152002
(50167—5M—2-38) 2

2

Mine originally operated by: (1)

Date
1905 R. Crawford & Sns., 1

Original name or number: #1

Illinois Coal Report p.

LATER OPERATORS

	Date	Operator	Name or No.
2	1907	W. F. Crawford & Sn.	
3	1909	M. F. Crawfora & Sns.	
4	1910	W. F. Crawford & Sns.	
5	1917	W.F. Crawford	
6			
7			
8			
9			
10			
11			
12			
13			
14			

*Also owners #See ownership sheet

Railroad, Wagon, Strip, Idle, Abandoned 1919 Shaft mine

Local Mine IDENTIFICATION

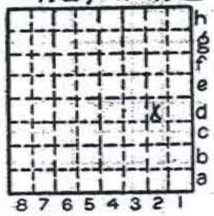
County No. 852

Coal Report No.

Coal No. ☐ 7

Quad. Danville

County Vermilion



Sec. 20

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R. 12 ~~E.~~ W.

Index. No.

1520 D2

COAL MINE OPERATOR

(92753—1M—6-54) 2

John C. Moore Corporation, Rochester, N. Y. Binder and holes in leaves Patented. FORM 408992 A

MOORE'S MODERN METHODS

(Sheets) COAL PRODUCTION (Sheet)

Period Mo. Day Year	Period Mo. Day Year		Tons	Tons	
	1908		5	000	
	1909				MINOR PROD
	1910		5	000	
	1911		5	000	
	1912				MINOR PROD
	1913		6	000	
	1914				MINOR PROD
	1915		5	265	
	1916		5	000	
	1917		4	850	
	1918		10	000	
	1919				ABD

SUMMARIES

No.	to	No.		Tons	Tons
1908		1918		46	115

Railroad, Wagon, Strip, Idle, Abandoned SHAFT MINE

IDENTIFICATION

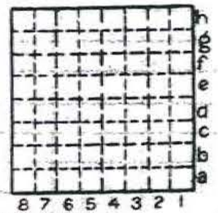
County No.

Coal Report No.

Coal No. ☐

Quad. DANVILLE

County VERMILION



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1520D2

COAL MINE—PRODUCTION

Exhibit D

DECLARATION OF CYNTHIA VODOPIVEC
ON BEHALF OF ELECTRIC ENERGY INC.

I, Cynthia Vodopivec, affirm and declare as follows:

1. I present this Declaration on behalf of Dynegy Midwest Generation, LLC (hereinafter "DMG"). I am Senior Vice President, Environmental Health and Safety at Vistra Corp., the indirect corporate parent of DMG. As part of my duties, I oversee permitting, regulatory development, compliance (air, water, and waste issues), and health and safety at the Company, including DMG's Vermilion Power Plant in Vermilion County, Illinois. I received a Bachelor's Degree in Engineering from Dartmouth College in 1998 and an MBA from Rensselaer in 2009. I state the following in support of DMG's Petition for Review of Illinois Environmental Protection Agency's Non-Concurrence with Alternative Source Demonstration under 35 Ill. Adm. Code Part 845 and Motion for Stay ("Petition").

2. DMG received IEPA's letter dated December 28, 2023, notifying DMG of IEPA's nonconcurrence with the Vermilion Power Plant New East Ash Pond ("NEAP") Alternative Source Demonstration via U.S. Mail on January 2, 2024. This letter is attached as Exhibit A of the Petition.

3. Conducting a characterization of the draw water from the bedrock has technical limitations given current monitoring requirements at the NEAP. The NEAP monitoring wells are sampled on a quarterly basis. These wells have a slow recharge/recovery rate after samples are collected from them. Accordingly, there is no opportunity to characterize the groundwater under conditions that would be required to analyze natural flow conditions using these wells. To the extent characterization of the draw water from the bedrock was conducted, it would likely include installation of two new monitoring wells into the bedrock, with screens vertically separated by at least 20 feet in order to evaluate vertical gradients and collection of groundwater samples from two different depths. Due to the low permeability of the predominantly shale bedrock in the vicinity of the NEAP, this work would entail drilling the two bedrock wells, developing the wells, allowing for water level recovery to static conditions within the wells, followed by groundwater sampling and analyses, data evaluation and reporting. Assuming a driller is readily available, which is not always the case, this process would take approximately 64 weeks and would cost approximately $315,000.

4. Assuming an assessment of the interaction between bedrock groundwater and the old east ash pond would include the installation of three new bedrock wells followed by sampling and analysis activities, this process would take approximately 54 weeks and would likely cost approximately $320,000.

5. Conducting an analysis of leachable metals from CCR in the NEAP using leach tests would involve drilling into the NEAP with up to 4 borings using specialized equipment to collect 8 samples. It would further require laboratory analysis, data evaluation and reporting for those samples. Assuming a driller is readily available, which is not always the case, this process would likely take approximately 20 weeks, and would likely cost approximately $195,000.

6. Completing an assessment of corrective measures for chloride, lithium, sulfate, and total dissolved solids ("TDS") exceedances identified in the ASD (together the "Vermilion Exceedances") in accordance with the requirements and deadlines of 35 Ill. Adm. Code § 845.660 would likely cost approximately $35,000. Completing the requirements of 35 Ill. Adm. Code § 845.670, including determining nature and extent, conducting geochemical evaluation, preparing and submitting the semi-annual reports, a construction permit application and a corrective action plan for the Vermilion Exceedances would likely cost approximately $225,000. Undertaking the steps required in Sections 845.660 and 845.670 is a considerable undertaking that requires the dedication of many resources. For example, the corrective measures assessment may require development of groundwater models specific to chloride, lithium, sulfate and TDS, and could result in the development of potential engineered remedies. The corrective action plan may require a 30 percent design for the selected remedy, a groundwater monitoring plan, a new construction permit application, and attendance at a public meeting. Significant personnel time and resources will be necessary to dedicate specifically to this work.

FURTHER, the Declarant sayeth not.

Dated: February _1_, 2024