DOE/LX/07-2499&D1
Primary Document

Compilation of Meeting Summaries and White Papers
(Fiscal Year 2023)

A Product of the Paducah Gaseous Diffusion Plant
Site Groundwater Modeling Working Group

CLEARED FOR PUBLIC RELEASE

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A Product of the Paducah Gaseous Diffusion Plant Site Groundwater Modeling Working Group

Date Issued—January 2024

U.S. DEPARTMENT OF ENERGY
Office of Environmental Management

Prepared by
FOUR RIVERS NUCLEAR PARTNERSHIP, LLC,
managing the
Deactivation and Remediation Project at the
Paducah Gaseous Diffusion Plant
under Contract DE-EM0004895

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ACRONYMS

FY	fiscal year
KRCEE	Kentucky Research Consortium for Energy and the Environment
KY	Commonwealth of Kentucky
MWG	Modeling Working Group
PGDP	Paducah Gaseous Diffusion Plant
RGA	Regional Gravel Aquifer
TVA	Tennessee Valley Authority
UCRS	Upper Continental Recharge System

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INTRODUCTION

The purpose of this document is to present the meeting summaries from the Paducah Site Groundwater Modeling Working Group (MWG) that were completed during fiscal year (FY) 2023. Activities for the MWG from September 2017 through July 2022 are documented in DOE/LX/07-2437&D1, DOE/LX/07-2451&D1, DOE/LX/07-2475&D1, and DOE/LX/07-2485&D1. Notes from MWG meetings held in 2016 and in January and March 2017 are presented in Appendix A of *2016 Update of the Paducah Gaseous Diffusion Plant Sitewide Groundwater Flow Model*, DOE/LX/07-2415&D2/A1. The meeting summaries are provided for historical information to promote program consistency over time and facilitate succession planning. The meeting summaries include slides from the presentations provided during the FY 2023 meetings. The following meeting summaries are included in the appendices.

- October 5, 2022, Meeting Summary (Appendix A)
  - Attachment 1: Groundwater Strategy Potentiometric Map, May 2022
  - Attachment 2: Groundwater Elevation Data for Tennessee Valley Authority (TVA) Wells, August 2022
  - Attachment 3: Presentation: 2023 Groundwater Model Update
  - Attachment 4: Precipitation and Ohio River Stage Data
  - Attachment 5: Water Line Leak Location Map
- January 18, 2023, Meeting Summary (Appendix B)
  - Attachment 1: Groundwater Strategy Potentiometric Maps, August 2022
  - Attachment 2: Groundwater Elevation Data for TVA Wells, November 2022
  - Attachment 3: Water Line Leak Location Map and KDEP Walkdown Photographs
  - Attachment 4: Precipitation and Ohio River Stage Data
  - Attachment 5: Kentucky Research Consortium for Energy and Environment (KRCEE) Report on Stream Gauging along Bayou Creek, Little Bayou Creek, and Tributaries, August 16–17, 2022
- April 5, 2023, Meeting Summary (Appendix C)
  - Attachment 1: Groundwater Strategy Potentiometric Map, November 2022
  - Attachment 2: Precipitation and Ohio River Stage Data
- July 19, 2023, Meeting Summary (Appendix D)
  - Attachment 1: Groundwater Strategy Potentiometric Map, May 2023, and Groundwater Elevation Data for TVA Wells, March 2023
  - Attachment 2: Environmental Indicator Information
  - Attachment 3: Precipitation and Ohio River Stage Data

Organizations that participate in the MWG are the U.S. Department of Energy, the U.S. Environmental Protection Agency Region 4, the Commonwealth of Kentucky (KY) Energy and Environment Cabinet, the KY Radiation Health Branch, KRCEE, and TVA.

Throughout FY 2023, quarterly synoptic water level measurement events were conducted and potentiometric maps for the site were generated and discussed as part of the quarterly Paducah Site Groundwater MWG meetings. The following potentiometric maps are included in Appendix E.

- November 2022
- March 2023
- May 2023
- August 2023

During FY 2023, the Paducah Site Groundwater MWG participated in the development of three white papers by reviewing and providing input to those papers. The white papers include the following:

- *Detailed Correlations between Lithologic Units in the McNairy Formation across the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* FRNP-RPT-0249. This paper was prepared to be consistent with and to satisfy a requirement in the Memorandum of Agreement for resolution of informal dispute concerning the 2018 Five-Year Review.

  This paper provides a review of the available lithologic information for the Paducah Gaseous Diffusion Plant (PGDP) and assesses the presence and displacement of faulting within the McNairy Formation. Based on the review of the lithologic information, no evidence of faulting is apparent from the correlation of soil borings; however, this paper concludes that the deep PGDP soil borings with available lithologic logs are spaced too far apart to identify the occurrence of faults with offsets of approximately 25 ft or less within the McNairy Formation. The closely-spaced soil borings of the C-400 Complex operable unit remedial investigation did not identify faulting within the upper McNairy Formation.

  The MWG was provided the draft paper on June 30, 2022. The group provided comments on July 28, 2022, and August 1, 2022. The MWG comments are reflected in the final paper, which was formally issued on January 13, 2023, and is included in Appendix F.

- *Comparison of Regional Groundwater Flow Pre- and Post-Construction and Operation of Olmsted Locks and Dam*, FRNP-RPT-0260. This paper provides a comparison of synoptic groundwater level measurements (i.e., synoptic events), precipitation records, and Ohio River elevations collected from September 2013 through February 2022, and is reflective of the pre- and post-construction and operation periods of the Olmsted Locks and Dam. The evaluation presented in the paper is intended to be used for consideration when the Paducah Site groundwater model is updated.

  The two main findings of this evaluation are: (1) seasonal variation of groundwater flow occurs in the Regional Gravel Aquifer (RGA) with relatively lower gradients when the river elevation rises; and (2) although no changes in groundwater flow direction are observed due to operations of the Olmsted Dam, an increase in river water elevation after operation of the Olmsted Dam showed a decline in hydraulic gradient between the river and monitoring wells located north of PGDP. These observations are consistent with prior studies that indicated a decline in hydraulic gradients and short-term flow of river water into the northernmost part of the RGA. A decline in hydraulic gradient associated with increased river elevation contributes to lower groundwater flow velocity. Based on the findings of this evaluation, the use of the pre- and post-operation Olmsted Dam datasets are available (and appropriate) for groundwater model calibration; however, predictive modeling should be limited to Olmsted Dam post-operation conditions.

  The MWG was provided the draft paper on October 20, 2022. The group provided comments on February 1 and 2, 2023. As agreed with the MWG, a revised final version of the document was not submitted separately and the MWG comments are reflected in the final paper attached in Appendix G.

- *Degradation of Trichloroethene at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* FRNP-RPT-0282. This paper summarizes documented information on the degradation of dissolved phase trichloroethene (TCE) at PGDP within the RGA and Upper Continental Recharge System (UCRS) that comprise the Northeast, Northwest, and Southwest Plumes. The information presented in this paper is evaluated to ensure it is consistent with current information before it is used for decision making.

This white paper considers historical RGA groundwater sampling analytical data from upgradient TCE source areas at the C-400 Cleaning Building and the C-720 Maintenance and Storage Building as well as downgradient areas in the dissolved phase portion of the plume(s) and historical soils data from the UCRS. Evaluation of this data shows that estimated TCE degradation rates for PGDP are consistent with published literature for aerobic cometabolism in large aerobic plumes and are on the order of 9 to 25 years half-life. The evaluation further demonstrated the presence of appropriate genetic material to produce the enzymes capable of TCE cometabolism, including the presence of active enzymes being produced by microbes in both the Northwest Plume core and in control well groundwater samples; and that the number of microbes in the Northwest Plume sample populations that express the enzymes are capable of TCE cometabolism.

The MWG was provided with the draft paper on March 1, 2023. The group provided comments on April 5 and 11, 2023. The Paducah Site Groundwater MWG comments are reflected in the final paper, which was provided to the MWG on May 2, 2023, and is included in Appendix H.

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APPENDIX A

GROUNDWATER MODELING WORKING GROUP MEETING SUMMARY—OCTOBER 5, 2022

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Paducah Site Groundwater Modeling Working Group
Meeting Summary—October 5, 2022

MWG Attendees:

DOE
Rich Bonczek ✓
Dave Dollins ✓
Brian Looney (SRNL) ✓

ETAS
Martin Clauberg ✓
Bruce Stearns ✓
Tracy Taylor ✓

KRCEE
Steve Hampson ✓

TVA
Tabitha Ester ✓
Anna Fisher
Dominic Norman
Jeffrey Frazier ✓

EPA and Contractors
Noman Ahsanuzzaman ✓
Ben Bentkowski
Eva Davis ✓
Mac McRae ✓
Victor Weeks ✓

Kentucky
Brian Begley ✓
Stephanie Brock
Nathan Garner ✓
Brian Lainhart
Bart Schaffer ✓
Chris Travis ✓

FRNP
Bryan Clayton
Lisa Crabtree
Ken Davis ✓
Rob Flynn
Bruce Ford
Stefanie Fountain ✓
LeAnne Garner
Todd Powers ✓
Joe Tarantino ✓
Denise Tripp ✓
Dawit Yifru
Bruce Meadows
Evan Clark ✓
Jason Orr ✓

✓ Indicates the Attendee was present

Original meeting agenda items are provided followed by meeting notes; the meeting notes are provided in italics with action items noted in green. Additions or revisions to the agenda items are noted in [].

1. Call for Issues from Groundwater Modeling Working Group (MWG) Members

No comments were received to the July 13, 2022 Meeting Summary (sent to participants on 8/17/2022). This summary will be considered final.

No comments were received to the July 13, 2022 Meeting Summary. The meeting summary is now final.

2. FY 2022 Work Plan/Schedule

Activity	Date
~~Quarterly Meeting (October/FY22Q1)~~	~~10/6/2021~~
~~MWG Concurs with FY 2022 Work Plan/Schedule~~	~~11/12/2021~~
~~Submit Draft Meeting Summaries and White Papers Compilation (FY21)~~	~~11/15/2021~~
~~MWG Provide Comments on Draft Compilation of Meeting Summaries and White Papers (FY21)~~	~~11/30/2021~~
~~Submit Final Meeting Summaries and White Papers Compilation (FY21)~~	~~12/21/2021 Planned~~ ~~12/13/2021 Actual~~
~~Quarterly Meeting (January/FY22Q2)~~	~~1/12/2022~~
~~Submit Draft Large Building PZ White Paper to MWG~~	~~2/17/2022~~

Activity	Date
~~Submit Draft Survey White Paper 2 to MWG~~	~~3/18/2022~~ ~~Actual: 2/28/2022~~
~~MWG Review Draft Large Building PZ White Paper~~	~~3/25/2022~~
~~Quarterly Meeting (April/FY22Q3)~~	~~4/6/2022~~
~~Submit Draft McNairy Lithologic Technical Paper to MWG~~	~~7/1/2022~~ ~~(was 8/11/2022)~~
~~Quarterly Meeting (July/FY22Q4)~~	~~7/13/2022~~
~~MWG Meeting to Discuss Draft McNairy Lithologic Technical Paper~~	~~7/13/2022~~ ~~(was 7/20/2022)~~
~~Submit Final Large Building PZ White Paper to EPA and KY~~	~~7/19/2022~~
~~MWG Provide Comments on Draft McNairy Lithologic Technical Paper~~	~~7/28/2022~~ ~~8/1/2022~~

Color code for schedules:

Due date	Quarterly meeting
Submittal date	Concurrence/acknowledgement date

The group did not have any comments on the now completed FY 2022 schedule.

3. Draft FY 2023 Work Plan/Schedule

Activity	Date
Provide Draft Agenda Including FY 2023 Work Plan/Schedule (October/FY23Q1) to MWG	9/28/2022
Quarterly Meeting (October/FY23Q1)	10/5/2022
~~Submit Final Lithologic Technical Paper to EPA and KY~~	~~10/7/2022~~
MWG Concurs with FY 2023 Work Plan	10/21/2022
Submit Draft MWG Compilation (FY 2022) to MWG	11/3/2022
MWG Provide Comments on Draft MWG Compilation (FY 2022)	12/2/2022
Submit Final MWG Compilation (FY 2022)	12/20/2022
Quarterly Meeting (January/FY23Q2)	1/11/2023
Submit Final Lithologic Technical Paper to EPA and KY (See discussion below)	1/18/2023
Quarterly Meeting (April/FY23Q3)	4/5/2023
Quarterly Meeting (July/FY23Q4)	7/12/2023

During the meeting the parties discussed the submittal schedule for the now final Lithologic Technical Paper. The MOA stipulates that this paper is to be submitted 30 days following the submittal of the D1 C-400 RI/FS Report. The schedule for the D1 C-400 RI/FS Report has been revised to December 19, 2022 by the FFA parties. This would result in a submittal date for the Lithologic Technical Paper of January 18, 2023; DOE is evaluating submittal of the paper prior to this date or coincidental with the D1 C-400 RI/FS Report.

4. Draft FY 2023+ Work Plan/Schedule

Activity	Date
Quarterly Meeting (October/FY24Q1)	10/4/2023 (Planning date)

The group did not have any comments on the planning date for the FY 2024 October MWG meeting.

5. Update on Water Levels

Synoptic water level events are being collected quarterly. The potentiometric map for the synoptic water level event in May 2022 is included in Attachment 1. A synoptic water level event was performed August 22-25, 2022 and will be included in the next meeting agenda. As part of each quarterly synoptic water level event, the TVA well water levels will be reviewed for inclusion on future potentiometric maps. The potentiometric maps from 2022 [will be included] in a separate section of the next MWG compendium document. FRNP continues to coordinate with KY on the AIP monitoring wells sampling schedule.

[August 2022] groundwater elevation data for TVA wells collected by KY included as Attachment 2. During the January 12, 2022 and April 6, 2022 meetings, the group discussed that TVA has abandoned monitoring wells AR76, AR75B, and B10 along Little Bayou Creek and one new well screened in the RGA has been installed by TVA. Tabitha Ester (TVA) continues to coordinate with Brian Lainhart (KY) on collection of water level measurements and monitoring well abandonment plans. Possible localized impacts on water levels due to the TVA sheet pile wall installation are an ongoing topic of discussion (see Agenda Item 11, Projects on the “Watch Topics” List, TVA Changes).

An addendum to the *2016 Update of the Paducah Gaseous Diffusion Plant Sitewide Groundwater Flow Model*, DOE/LX/07-2415&D2/A1, which incorporated the final *Evaluation of the 2016 Groundwater Model with Updated Reference Point Elevations for the Groundwater Monitoring Network at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* FRNP-RPT-0234, was issued on [June] 27, 2022. EPA and KDEP acknowledged receipt of the revised report on July 8, 2022.

During the July 13, 2022 Meeting, KY requested the new monitoring well survey data be provided in a table. FRNP plans to provide the information once processed consistent the data [being] available through PEGASIS.

The group discussed that it takes some time to code data properly for inclusion in OREIS/PEGASIS and that once that coding is complete and the data are uploaded, a download table will be generated and provided to KY.

6. Update on Paducah Site Groundwater Strategy

The overall objectives for the Groundwater Strategy Project (GWSP) is to develop a groundwater strategy that closes out various issues for the site:

- Change status of two Environmental Indicator Performance Measures to “Yes”
    - Human exposure under control
    - Groundwater migration under control

- Resolution of data needs
- Groundwater Modeling Working Group (MWG) recommended [model] maintenance and updates

The GWSP is a multi-year plan with near-term (0-3 years) activities and longer-term (beyond 3 years) activities planned. The specific timing and scope of each activity are developed by DOE based on data collected in the prior year(s). The GWSP and the C-400 OU Remedial Investigation projects are separate, but where activities overlap they are coordinated and the relevant information obtained from the remedial investigation will be incorporated into the GWSP. The Groundwater Strategy FY 2023 activities are in development and will be discussed during the October MWG meeting. The draft Olmsted Dam White Paper is planned to be submitted to the MWG in FY 2023.

The group discussed that there is a leak in the main raw water line from the Ohio River to the site. Ken Davis (FRNP) has walked upstream and identified the location of the water line leak along Water Line Road (Attachment 5). The leak is about a mile from the creek crossing. Ken and KY noted that this area stays wet year round.

Seeps. There have been no seep results above the maximum concentration limit (MCL) for trichloroethene (TCE) for many years. During the October 6, 2021 meeting, the group discussed that LBCSP5 routinely has flow and is able to be sampled, whereas many of the other previously identified seeps do not have flow consistently. KY reported that they have revised their stream walkdowns to go further up and downgradient of LBCSP5. KY also suggested the use of thermal imaging for seep identification in the winter months.

KRCEE has a task to look at seeps using a drone equipped with FLIR (Forward Looking InfraRed). The project will look at other project sites then apply what is learned to the Paducah site. The project intends to provide a proof-of-concept and an understanding of whether the seeps have or have not shifted. The drones will be tied to GPS, potentially also with LiDAR. In coordination with the KRCEE project, FRNP/DOE provided KRCEE with a map with potential stream gauge locations and times for data collection for coordination of this effort in support of the Groundwater Strategy Project on June 27, 2022.

Steve Hampson (KRCEE) noted that the FLIR work is planned to be performed if funding is available.

"No Go" Areas for Monitoring Well Installations. Corridors where overhead transmission lines have been removed have been considered for monitoring well placement, especially with respect to the west side of the NE Plume. No additional changes to the power line configurations are planned at this time. Other medium and low voltage lines around the plant would need to be accounted for in any project, including monitoring well installation. Generally these lines would have 50 ft buffer. A figure of the current high-voltage overhead power lines has been included in prior meeting summaries. Any future changes to facility overhead lines that may impact environmental scopes or data collection will be shared with the MWG.

The group did not have any comments on this topic.

Sitewide Groundwater Model Update. The update to the model is being accelerated at DOE PPPO manager direction and a contract change is being finalized. Savannah River National Laboratory

(SRNL) is participating in the update and will review the 2008 and 2016 model updates and provide input to the 2023 update. Modeling will be performed and discussions will be held following submittal of the draft model report. The overarching goal of the model update is to obtain EPA and KDEP approval to use the model to support remedial decision making.

A presentation including a summary of the 2023 Sitewide Groundwater Model Update team, schedule, and crosswalk of recommendations from the 2016 model update is included as Attachment 3.

In reviewing the schedule, the group discussed that EPA thought that no regulatory approval would be requested for the model. DOE clarified that the document will be sent per the schedule and that the group can discuss approval versus acknowledgment during a future meeting. Until then, the schedule will be revised to put approval in quotation marks.

KY asked if status updates on the modeling would be provided prior to the submittal of the report. DOE plans to provide updates during the Routine Paducah Groundwater Update meetings on Thursdays and the quarterly MWG meetings and will provide meeting materials in advance if seeking input or agreement on an item.

FRNP provided the presentation on the summary of the 2023 sitewide groundwater model update (Attachment 3):

- *Steve Hampson confirmed that the new lithology database is planned to be available at the end of September. He noted that everything done from top of gravel down is completed and the remaining item involves changes to HU3 that have an impact on HU4 and the vertical extents of the RGA.*
- *Rich Bonczek (DOE) noted that the Olmsted Dam White Paper is now final and will be sent to the MWG.*
- *The group had a question on water balance and whether there is a flow meter or water level gauge on the Ohio River at the raw water intake or any other gauge to measure the water elevation drop between the Paducah water intake and the Olmsted Dam. FRNP will look into this.*
- *The group discussed that the Large Building PZ White Paper noted that the thickness of gravel under the process buildings is less than previously thought and that the C-400 remedial investigation showed that the gravel layer under C400 was dry. The vapor intrusion ports installed in the process buildings during the sitewide vapor intrusion project also did not have any evidence of water under the foundations.*
- *The modeling team plans to revise recharge to be lower in some areas (such as the process buildings), but noted that this may translate to higher recharge rates elsewhere. The group discussed that the 2016 model is water starved.*
- *KY requested that DOE and FRNP look at opportunities to think outside the box on performing some of the GWSP activities.*
- *The group discussed the need for recalibration of the northeast plume area in the model. Past models did not predict well compared to what is observed in the field [i.e., the model is not able to replicate the migration of the eastern half of the Northeast Plume)], but several members noted that this was identified in both 2008 and 2016 model updates and that concerns were distal to the plant. The technical team noted that there may be flow field considerations in addition to source term uncertainties and better information from the C-400 investigation*

may now be available. The technical team also noted that the source terms for the Northeast Plume had more uncertainty than those of the Northwest Plume and they will be looking at the source terms. The flow model may need to be adjusted after the fate and transport model is run.

7. Anthropogenic Recharge

This sub-topic will capture discussion on site changes, such as the recent changes to the high pressure fire water system.

The draft paper *Evaluation of Anthropogenic Recharge Associated with the Process Buildings in Support of the Sitewide Groundwater Model* (Large Building PZ White Paper) was provided to the MWG for review on 2/15/2022. Comments were provided by EPA and KY on 3/22/2022 and 3/23/2022, respectively, and were discussed during the July 13, 2022 MWG meeting. The paper was subsequently revised and the final paper was provided to the MWG on July 19, 2022. EPA and KDEP acknowledged receipt of the revised white paper on July 22, 2022. The paper will be included in the FY 2022 Meeting Summaries and White Papers Compilation. During prior meetings, the group agreed to discuss whether the approaches included in the paper are needed for near-term projects and if field implementation should be pursued.

The group discussed that there is currently no funding for this investigation and likely this work would need to be performed as part of the GWSP. The group acknowledged that understanding of the recharge associated with the process buildings was identified as a data need during the 2016 groundwater model update.

8. Plant-Wide Seismic Update

DOE and FRNP periodically review whether there are any ways to further reduce (temporarily) sources of noise to facilitate new testing without disrupting site activities. Seismic investigation is not currently a project (either DOE or KRCEE). The group discussed that this topic may be informed by the McNairy Lithologic Technical Paper and that seismic information will be needed for the selection of the on-site waste disposal facility and potentially for the Groundwater Operable Unit Dissolved Phase Plume project.

During the April 6, 2022 meeting, the group discussed that there was no evidence of faulting encountered during the C-400 remedial investigation. The group also discussed whether this topic should follow the lithology paper discussions or if this topic could be advanced independently. KY's understanding is that the current level of plant operations with updated technology may provide a possibility for seismic studies in the plant area. S. Hampson (KRCEE) is willing to discuss with Dr. Woolery if that is the appropriate next step. There is no funding currently for this type of work, but could be discussed for FY 2023.

Steve Hampson noted that KGS is working on regional compilation of seismic data focused on extents of the New Madrid centroid and on the northwest leg along the Mississippi River and that KGS plans to generate a report this year to summarize information compiled to date. The group discussed that there is no new on-site information and Steve reported that KRCEE/KGS is updating some testing equipment. The current plan for seismic information is to look at this topic on a project-specific basis *going forward and that seismic information will be most relevant for the Waste Disposal Alternatives project or the Groundwater Operable Unit dissolved phase plume projects.*

9. CSM for the McNairy in the C-400 Complex Area

FRNP has set up a website to house a library of McNairy information. Access the website at the following link: https://fourriversnuclearpartnership.com/McNCSM. The site requires a password that has been sent separately. Contact Stefanie if you need the password to the website.

The KRCEE spreadsheet database of soil boring logs (R10 HydroLitho Dbase posted 121620.xlsx) is available at https://fourriversnuclearpartnership.com/McNCSM.

A lithology white paper has been prepared as part of the resolution of dispute on the CERCLA Five Year Review. DOE will issue the final technical paper within one month of submittal of the D1 C-400 Complex OU RI/FS Report to support the review and comment of the C-400 specific data interpretation as part of the C-400 Complex OU RI/FS Report review process and the performance of the FY 2023 Five-Year Review revised protectiveness determinations for the Northeast, Northwest, and Water Policy response actions. The regulatory milestone date for the D1 C-400 Complex OU RI/FS Report is being revised by the FFA parties.

The draft paper was issued to the MWG for review on June 30, 2022. During the July 13, 2022 meeting, EPA discussed that for C-400, they believe the paper has enough data and agreed that faulting was not observed and although other parts of the site do not have as high a resolution of data as the C-400 area, that the risk of faulting is low. They acknowledge that some projects may use the McNairy Formation as a vertical [flow or transport] boundary. This paper should be factored into the CERCLA Five Year Review (FYR) with a strong conclusion that faulting was not observed in the primary area of concern at the site and that this issue from the 2018 FYR should be closed out. EPA discussed use of a FYR addenda to the 2023 FYR for this process and noted that there is good risk control due to good evidence of no faulting at C-400. KDEP recommended that the FYR addenda not go beyond the conclusions presented in the paper. DOE noted that a FYR kickoff call is planned for the fall for scoping and that the open issues from the 2018 FYR should be on that meeting agenda.

A plant tour and senior managers meeting are planned for the week of November 8, 2022. EPA expressed interest in scheduling a meeting with the parties' legal teams on the C-400 project prior to that date to discuss the rad effluent discharge topic. DOE plans to brief their management on October 17, 2022 and then to update to EPA/KY on October 20, 2022, including a technical presentation and the concentrations DOE will propose to include in the C-400 project record of decision.

10. Precipitation and Ohio River Stage

Attachment 4 includes precipitation and Ohio River stage charts through September 26, 2022.

The group discussed that the site is currently in a drought (0.02" of rain in the last month). The August 2022 potentiometric map will be useful for understanding dry conditions at the plant. The Ohio River levels have been low and steady for a long period.

11. Synoptic Water Level Events and Ohio River Levels

In August 2022, KRCEE performed a stream gauging event for portions of Bayou Creek and Little Bayou Creek. The findings of the gauging will be discussed at a subsequent MWG meeting once the report is available.

The group did not have any comments on this topic.

12. Projects on the "Watch Topics" List

- **TVA Changes.** TVA has completed construction of a 3,800 ft sheet pile wall in close proximity to Little Bayou Creek and several seeps in December 2021. The wall is intended to stabilize the creek's bank, as opposed to control groundwater. KY/TVA provided as-built drawings showing the installation depth of the wall. Based on the information available in the TVA drawings, the sheet pile wall extends a significant depth into the RGA. The wall joints are not sealed, and the sheet piles themselves are solid (not perforated).

  Figures showing the alignment of the wall and a cross section of the sheet pile wall, the creek, and the interpolated upper and lower limits of the RGA were included in the July 13, 2022 meeting summary.

  During the July 13, 2022 meeting, the group discussed that some portions of the sheet pile wall extend into the McNairy Formation and that restriction of flow in the RGA may result in new seeps in Little Bayou Creek (LBC). KY noted that there have been decreases in TCE concentrations in the LBC seeps over time, and that they are interested in understanding the impacts of the wall on groundwater flow and whether the wall will result in a shift in the plume(s). The group noted that there is not pressure data on both sides [of] the wall and the impact of the wall on the groundwater flow model is not currently known.

  KDEP continues to do creek walkdowns to look for seeps. The most recent KDEP walkdown was in August 2022. A beaver dam and elevated water levels behind the dam were noted on Little Bayou Creek off of DOE property.

  KY performs a walkdown of the beaver dam area every 2-3 weeks and has attempted water level measurements behind the beaver dam and at the waterline crossing at the entry to Little Bayou Creek. KY will continue to share their findings with the group. The group discussed that a portion of flow in the area of the beaver dam is from a leaky water supply line. Brian Looney (SRNL) discussed that SRS has experienced multiple beaver dams over history of the site and that the beaver dams serve as locations for sediment accumulation.

  FRNP asked if the 2018 Terracon TVA report is available to share with the group. Tabitha Ester (TVA) will look into this and let the group know.

  The group discussed the TVA Discharge and Intake channels. The discharge channel is a KPDES outfall. Tabitha Ester will check to see if the channels are lined. The group also discussed the discharge canal that runs parallel to the Ohio River. Tabitha Ester will check to see to see if there *is more information available on the connection of the canal to the river. FRNP will send an email with specific questions.*

Tabitha Ester shared with the group that TVA is updating their groundwater model and that they are looking at the data collected during construction of the sheet pile wall. There were areas of refusal and areas where the targeted depth of the wall was not achieved. TVA will be reviewing the logs and will look to provide a summary of those findings.

- **PFAS.** PFAS is discussed as part of the Risk Assessment Working Group and has ties to this working group as well.

  The Paducah Site continues to participate in the DOE HQ PFAS Working Group Meetings (last meeting held September 22, 2022).

  Rich Bonczek is a member of the DOE PFAS Coordinating Committee (last meeting held September 14, 2022).

  The Paducah Site has provided input to the DOE PFAS Roadmap. On Thursday, August 18, the new DOE PFAS website https://www.energy.gov/pfas/pfas-and-polyfluoroalkyl-substances went live! Also on Thursday, August 18, DOE released the PFAS Strategic Roadmap: DOE's Commitments to Action 2022-2025, which outlines goals, objectives and specific actions DOE is taking to address risk from PFAS (https://www.energy.gov/sites/default/files/2022-08/DOE%20PFAS%20Roadmap%20August%202022.pdf).

  DOE issued a memorandum from EM-3/EM-4 on September 21, 2022: *Per- and Polyfluoroalkyl Substances Strategic Roadmap: Department of Energy Commitments to Action 2022-2025, and the Office of Environmental Management's Response*. Actions Paducah will take in response to the memo are being determined.

  Site-wide PFAS screening assessment planned for FY 2023:
  - QAPP worksheets have been developed and are incorporated into the documented in the FY 2023 EMP as Appendix E.
    - Regular sampling equipment and methods will be used.
    - Planned sampling:
      - Groundwater from selected UCRS and RGA monitoring wells,
      - Groundwater from Fire Training Area locations MW315 and MW3301,
      - Groundwater from K Landfill area monitoring wells (Terrace Gravel) (MW300, MW302, and MW344),
      - RGA groundwater from two Northeast Plume Containment System (NEPCS) influent locations (SP234 and SP235),
      - Treated groundwater from two NEPCS effluent locations (765ASP3 and 765SP3),
      - RGA groundwater from one Northwest Plume Groundwater System (NWPGS) influent location (HV-082),
      - Treated groundwater from one NWPGS effluent location (HV-171),
      - Influent and drinking water effluent from the site water treatment plant (C-611),
      - Drinking water from four tap locations,(DW-036 and DW-037 at C-611, DW-038 at C-755, and DW-040 at C-615-G),

    - Surface water upstream and near Outfalls 001, 002, 004, 006, 008, 009, 010, 011, 012, 013, 015, 016, 017, 019, and 020,
    - Treated wastewater at the effluent of the Wastewater Treatment Plant (C-615), and
    - Leachate from landfill sumps at the C-404 Landfill, C-746-S Landfill, and the C-746-U Landfill.
- Meetings with EPA and KY were held June 23, 2022, July 21, 2202, and September 29, 2022 to discuss the project schedule, analytical methods, and sampling procedures. No changes were made in the FY 2023 EMP in FY 2023 that impact the scope of this project.

Rich Bonczek discussed that the draft DOE historical assessment plan is out for DOE review and comment, as is the draft DOE disposal plan. There is currently no regulatory driver for PFAS for the Paducah Site; the only drivers for the Paducah Site currently are included in the DOE memoranda dated September 16, 2021, and September 21, 2022.

A DOE EM memorandum providing an overview of what is required in the DOE PFAS roadmap, including the requirement for an implementation plan, was issued on September 21, 2022. DOE discussed that the Paducah Site has multiple actions in progress associated with this memorandum.

- *Paducah has begun preparing the implementation plan; a table is being generated to submit to DOE by the end of December.*
- *Paducah Site drinking water samples will be collected and reported to DOE HQ this year.*
- *Paducah Site PFAS results will be reported in the Annual Site Environmental Report (ASER) and the DOE preliminary assessment report.*

EPA asked if drinking water sampling was still on schedule for October. Field sampling is currently planned to start in October; FRNP will confirm laboratory contracting and provide an updated schedule. EPA has created a new category of remedial work tracking and will use the FY 2023 EMP approval date as the start date for this activity. KY requested a copy of the FY 2023 EMP as soon as it is available so that they may perform their calendar year planning.

DOE has established a new PFAS committee that Rich is a member of. There will be a DOECAP meeting in December and PFAS is on the agenda for that meeting.

The group discussed that as documented in the DOE preliminary assessment document, PORTS sampling of raw water going into the site water treatment plant contained PFAS, but PFAS was not detected in the finished water. At PORTS, the supply groundwater well field is connected to the Scioto River, but not plant groundwater. The Paducah municipal water supply did sample Ohio River and had detections in excess of the current EPA health advisory values. The Paducah Site will be sampling raw water and finished water as part of the sitewide PFAS screening assessment. Based on the results of the sampling of the municipal water supply, concentrations of PFAS are anticipated in the Paducah Site raw water supply (Ohio River water). The group also discussed that the DOE Idaho site has had detections of PFAS in site drinking water.

13. Meeting Presentations

FY 2022 Presentations:

- October 2021: FRNP presented on the *2016 Update of the Paducah Gaseous Diffusion Plant Sitewide Groundwater Flow Model* (DOE/LX/07-2415&D2).

- January 12, 2022: KRCEE presented on their reviews of the Paducah site groundwater models.
- April 6, 2022: FRNP presented a summary of the EPA and KY comments to the *Summary of the 2016 Groundwater Flow Model Update.*
- July 13, 2022: The draft Lithology Paper was discussed in place of a presentation.

FY 2023 Presentations:

- October 2022: Summary of the 2023 Sitewide Groundwater Model Update team, schedule, and crosswalk of recommendations from the 2016 model update.

MWG members should provide any presentation requests to Stefanie. Potential topics for future meetings:

- C-400 Complex remedial investigation
- Lithology
- TCE degradation rates
- Site water balance items (e.g., leaks from piping, above and below ground piping, building foundation gravel layers, etc.)
- EarthCon (following contracting and completion of evaluation)
- Groundwater model updates
- Topics from the Site Management Plan

DOE discussed that they may have the contract in place for EarthCon update during this quarter and potentially have a presentation by EarthCon during January 2023 meeting. The EarthCon report shows more detail on plume remediation than what plume map update document shows.

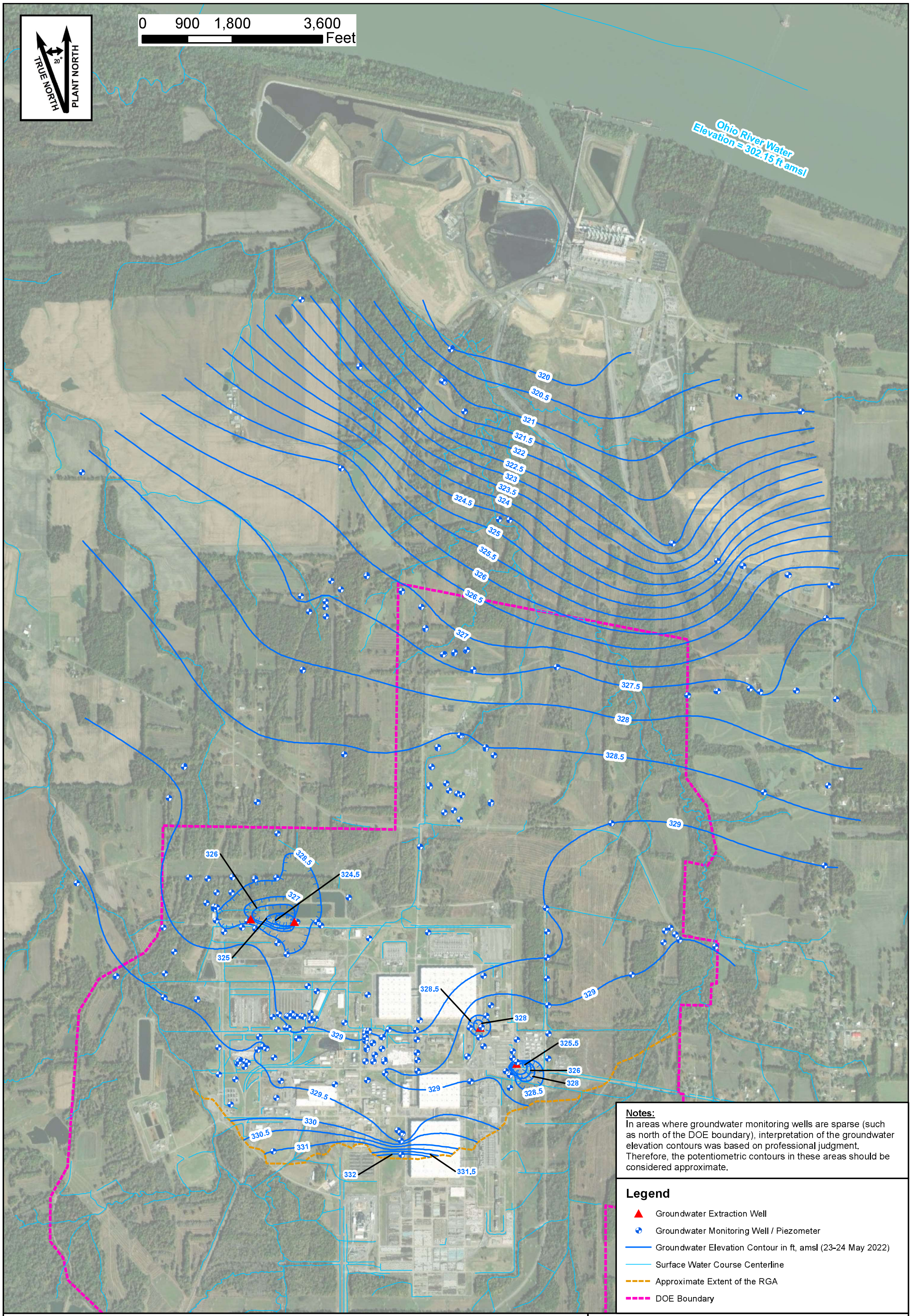
14. Poll MWG Members/Open Discussion

Rich discussed the DOE Groundwater Booklet (ceased production in 2017-2018) and the new Pacific Northwest National Laboratory (PNNL) TRAC (Tracking Restoration And Closure) initiative. The Paducah Site will be meeting with PNNL to support TRAC updates for Paducah. https://www.pnnl.gov/projects/trac and https://trac.pnnl.gov

The group discussed that a new plume map update document will be developed and issued next year, with a kickoff planned for December 2022.

Attachment 1

Groundwater Strategy Potentiometric Map
May 2022



Notes:
In areas where groundwater monitoring wells are sparse (such as north of the DOE boundary), interpretation of the groundwater elevation contours was based on professional judgment. Therefore, the potentiometric contours in these areas should be considered approximate.

Legend

- ▲ Groundwater Extraction Well
- ● Groundwater Monitoring Well / Piezometer
- ― Groundwater Elevation Contour in ft, amsl (23-24 May 2022)
- ― Surface Water Course Centerline
- - - Approximate Extent of the RGA
- - - DOE Boundary

MAP SOURCE INFORMATION

Map Generation Date and Location - 7/11/2022 Geosyntec\\fedprojects-01\paducah$\Knoxville\GW Strategy\GIS\MXDs\2021-2022 Potentiometric Surface Maps
Map Layer Location: Geosyntec\\fedprojects-01\paducah$\Knoxville\GW Strategy\GIS\MXDs\2021-2022 Potentiometric Surface Maps\May 2022 2022 Potentiometric Surface Map.mxd
Image Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Shapefile for Surface Water Course Centerline was obtained from Pegasis (https://pegasis.pad.pppo.gov/), downloaded on 6/27/2022.
DOE Property Boundary provided by FRNP 2/4/2021.
Northing and easting of wells obtained from Pegasis, downloaded on 6/14/2022.
Groundwater elevation was based on the May 23-24, 2022 measurements. Ohio River elevation was estimated as the average
of elevations measured by the USGS at Paducah Station USGS 0361100 and Olmsted, IL Station (USGS 03612600) between May 23-24, 2022.
amsl = above mean sea level

U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

FOUR RIVERS
NUCLEAR PARTNERSHIP, LLC

Figure 1. May 2022 RGA Potentiometric Surface Map

Attachment 2

Groundwater Elevation Data for TVA Wells
August 2022

OREIS Name	Well	Description	Aquifer	Top of Casing	Top of Ground	xconv Easting (Ft)	yconv Northing (Ft)	Status	Screen Top Depth (Ft)	Screen Bot Depth (Ft)	tscreenelev (Ft)	bscreenelev (Ft)	GW Elev. (Datum - DTW)	Water Level	Date & Time	Barometric Pressure (inHg)	Measuring Point
TVAGW-6D	TVAGW-6D	4" PVC	Upper RGA	372.77	369.38	760787.88	1946731.54	Active	65.2	75.2	307.57	297.57	319.22	53.55	08/22/2022_1313	29.57	TOC
TVAGW-5D	TVAGW-5D	4" PVC	Upper RGA	372.55	369.14	760131.63	1947315.95	Active	66.9	76.9	305.65	295.65	318.75	53.8	08/22/2022_1316	29.57	TOC
TVAGW-4D	TVAGW-4D	4" PVC	Upper RGA	369.26	365.84	759456.72	1947561.73	Active	63.3	73.3	305.96	295.96	318.76	50.5	08/22/2022_1319	29.57	TOC
TVAGW-3D	TVAGW-3D	4" PVC	Upper RGA	366.9	363.42	758982.49	1947793.86	Active	71.3	81.3	295.6	285.6	318.72	48.18	08/22/2022_1321	29.57	TOC
TVAGW-2D	TVAGW-2D	4" PVC	Upper RGA	372.82	369.24	759966.78	1944870.47	Active	61.2	71.2	311.62	301.62	323.85	48.97	08/22/2022_1309	29.57	TOC
TVAGW-1D	TVAGW-1D	4" PVC	Upper RGA	374.94	371.56	757847.05	1946203.79	Active	63.4	73.4	311.54	301.54	319.48	55.46	08/22/2022_1327	29.57	TOC
TVA-D74B	SHF-D74B	2" PVC	Upper RGA	332.16	329	756125.35	1956489.82	Active	42.3	52.3	289.86	279.86	305.27	26.89	08/22/2022_1050	29.60	TOC
TVA-D30B	SHF-D30B	2" PVC	Upper RGA	324.36	320.6	757594	1955563.41	Active	42.7	52.7	281.66	271.66	298.26	26.1	08/22/2022_1047	29.60	TOC
TVA-D17	SHF-D17	2" PVC	Upper RGA	365.43	362.8	758809.17	1950015.71	Active	14	17	351.43	348.43	315.87	49.56	08/22/2022_1038	29.60	TOC
TVA-D11B	SHF-D11B	2" PVC	Upper RGA	321.79	319.2	753434.76	1958481.44	Active	32	42	289.79	279.79	301.29	20.5	08/22/2022_1103	29.60	TOC
SHF-201C	SHF-201C	4" PVC	Upper RGA	323.75	320	746799.24	1960068.889	Active	44.5	54.5	279.25	269.25	305.38	18.37	08/22/2022_1008	29.60	TOC
SHF-201B	SHF-201B	4" PVC	Upper RGA	323.75	320.2	746641.107	1960082.768	Active	32	37	291.75	286.75	305.47	18.28	08/22/2022_1007	29.60	TOC
SHF201A	SHF201A	4" PVC	Upper RGA	323.75	320	747030.226	1960036.252	Active	14.5	24.5	309.25	299.25	305.36	18.39	08/22/2022_1006	29.60	TOC
SHF-102G	SHF-102G	4" PVC	Upper RGA	362.85	359.1	845764.387	1927473.284	Active	47.1	57.4	315.75	305.45	319.85	43	08/22/2022_1018	29.60	TOC
SHF-101G	SHF-101G	4" PVC	Upper RGA	322.43	318.8	754685.75	1957635.07	Active	32	37.3	290.43	285.13	304.39	18.04	08/22/2022_1107	29.60	TOC
Ohio River Elevation						831.9815	14996.63							301.5	08/22/2022_1120	29.60	TVA Inlet

LEGEND:

TOC: Top of Casing

DTW: Depth to Water

National Geodetic Vertical Datum of 1929 (NGVD 29).

Attachment 3

Presentation: 2023 Groundwater Model Update

2023 Sitewide Groundwater Flow (GW) Model Update

October 5, 2022

DRAFT Work Product – For Discussion Only

Paducah Modeling Team

DOE

- Rich Bonczek
- Dave Dollins

DOE/ETAS

- Martin Clauberg
- Tracy Taylor

DOE/SRNL

- Juan Morales
- Brian Looney
- Carol Eddy-Dilek

FRNP/Geosyntec Consultants

- Stefanie Fountain –Project Manager
- Ken Davis – Lead Geologist
- Denise Tripp - Lead Groundwater (GW) modeler
- Josue Gallegos – Environmental Visualization System (EVS) and GW Modeler
- Dawit Yifru – Data Management (GW Strategy Program)

FRNP/Clemson University

- Ron Falta – Modeling Strategy and Peer Review

Project Schedule

Activity	Target Start	Target Finish
~~Preliminary Meeting with DOE, FRNP, SRNL~~	-	~~7/27/2022~~
~~SRNL Review model data compilation~~	~~8/26/2022~~	~~9/21/2022~~
~~Kickoff Meeting with DOE, FRNP, SRNL~~		~~9/22/2022~~
Flow Model Build	9/23/2022	10/21/2022
Groundwater Modeling Working Group Quarterly Meeting Q1 FY23		10/5/2022
Meeting with DOE, FRNP, SRNL to present/discuss modeling strategy		10/13/2022
Preliminary Flow Model Calibration	10/22/2022	12/20/2023
Transport Model Calibration (inlcudes adjustment to flow model calibration)	12/21/2022	2/20/2023
Groundwater Modeling Working Group Quarterly Meeting Q2 FY23		1/11/2023
Meeting with DOE, FRNP, SRNL to Discuss Calibration		2/20/2023
Submit Draft D1 2023 Groundwater Model Update Report to DOE*		5/17/2023
Submit Draft Final D1 2023 Groundwater Model Update Report and CRS to DOE for Approval*		6/29/2023
Groundwater Modeling Working Group Quarterly Meeting Q4 FY23		7/12/2023
Submit Final D1 Groundwater Modeling Report to Regulators*		7/14/2023
Regulator Review of Informal Draft D1 2023 Groundwater Model Update Report	7/17/2023	8/14/2023
Meeting to Discuss D1 Report with Regulators		7/17/2023
Submit Final D2 2023 Groundwater Model Update Report and CRS to Regulators for Approval*		9/26/2023
Regulator Review and Approve D2 2023 Groundwater Model Update Report and CRS	9/27/2023	10/10/2023
Groundwater Modeling Working Group Quarterly Meeting Q1 FY24		10/5/2023
Regulator Approval of Final D2 2023 Groundwater Model Update Report and CRS to Regulators for Approval		10/10/2023

🟩	Submittal Date
🟪	Concurrence/acknowledgement date
🟦	MWG Meeting
🟨	SRNL

Model Recommendation GWSP Cross Reference

Recommendation	GWSP Activity #	AOC	Data Collection Description	Status*	Notes
(1) Install additional monitoring wells (MWs) to better define the Terrace Gravel/Upper Continental Recharge System (UCRS) interface along the southern model boundary.	10	Characterize Underflow from the Terrace Area	Desktop study planned for FY 2023 (to assess data for additional MWs and field data collection). Field data collection planned beyond FY 2023. Desktop study planned beyond FY 2023 (to characterize underflow). KRCEE database current version (R10) updated with additional boring data and revised interpretation of Terrace Gravel/UCRS interface.	IA	KRCEE database version R11 is in progress; completion planned for the end of September.
(2) Conduct additional slug tests to better define hydraulic conductivity (K) distribution across the model domain.	16	Additional Slug Testing	Evaluation of historical slug test data concluded that a more rigorous site assessment of the validity of slug tests in the RGA would be needed before the method could be considered for use at the Paducah Site. However, new pumping test data is available for EW234 and EW235.	IE	Evaluation of historical data concluded slug testing in the RGA is not an accurate method due to relatively high K values (DRAFT Measurement of Hydraulic Conductivity in the RGA Aquifer Using Monitoring Wells at the Paducah Site, FRNP-RPT-0010 included in the Final Compilation of Meeting Summaries and White Papers (2017-2018, DOE-LX-07-2437andD1, Attachment 3). Findings from the Northeast Plume Optimization Hydraulic Monitoring Pumping Test was presented in Appendix G of the U.S. Department of Energy Paducah Gaseous Diffusion Plant Federal Facility Agreement Semiannual Progress Report for the Second Half of Fiscal Year 2018, issued October 2018.
(3) Conduct stream gaging during sitewide synoptic water level (WL) measurement event to quantify stream discharge/recharge in Bayou Creek (BC) and Little Bayou Creek (LBC).	4	Nature and Extent of Contaminants Currently Contributed by LBC Seeps	Data collection and White Paper planned beyond FY 2023 (includes hydraulic and water quality analysis to revise the conceptual site model). Interim stream gaging was conducted during August 2022 synoptic.	IE	August 2022 synoptic water level data will be used for steady-state dry period simulation because stream gage data was also collected in August 2022.
(4) Evaluate a more accurate method to quantify Terrace Gravel underflow to the RGA.	10	Characterize Underflow from the Terrace Area	Desktop study planned for FY 2023 (to assess data for additional MWs and field data collection). Field data collection planned beyond 2023.	NI	No new data available at this time.

* Model update status: IE=Implement with existing GWSP data; IA = Implement with additional data from another project; NI = not implemented

NA = Not Applicable

GWSP = Groundwater Strategy Project

DRAFT Work Product – For Discussion Only

Model Recommendation GWSP Cross Reference (cont'd)

Recommendation	GWSP Activity #	AOC	Data Collection Description	Status*	Notes
(5) Record continuous RGA water level data along a transect extending from Ohio River to Paducah Gaseous Diffusion Plant (PGDP) industrial area for a 1 year period to assess the impact of bank storage and transient conditions during wet periods.	13	Continuous RGA Water Level Monitoring	Pressure transducer data was collected along north-south transects in FY 2021 and in areas of plume delineation uncertainty in FY 2022. Pressure transducer data collection is planned in FY 2023 and a White Paper planned beyond 2023 (includes transects with select TVA wells, synoptic event will coincide with peak river elevation).	IE	FY 2021 data will be used for simulating wet conditions for transient calibration period. Note: TVA collects pressure transducer data and if available for 2021 could supplement PGDP data used for the transient calibration period.
(6) Monitor and document (including dates) the enacted utility optimization program (performed by others) to evaluate changes in post closure operations that may affect anthropogenic recharge.	12	Water Balance Study	Desktop study and White Paper planned beyond FY 2023. Other studies at the site provide relevant data/information.	IA	VI study noted widespread detections of chloroform supporting occurrence of widespread potable water leaks. The HPFW system was taken offline in November 2021. (DOE 2022. Plant Industrial Area Vapor Intrusion Preliminary Risk Assessment Report, Paducah Gaseous Diffusion Plant, Paducah, Kentucky, DOE/LX/07-2471&D2).
(7) Conduct seasonal synoptic WL events to provide information regarding seasonal variation in groundwater (GW) flow patterns and the inferred GW divide within the plant area (data may be considered for calibration targets in a subsequent model update).	14	Synoptic Water Level Measurement	Several synoptic WL events (quarterly since November 2021) completed. Quarterly events planned in FY 2023.	IE	August 2022 synoptic will be used for steady-state dry period simulation and stream gage data was also collected in August 2022.
(8) Measure Metropolis Lake WL during synoptic events. Consider of characterizing the thickness and K of the lake sediments if the lake is to be modeled as a boundary condition.	14 and 16	Synoptic Water Level Measurement Hydraulic conductivity	Visual observations in July 2019 during period of flooding provided to MWG. WL measurements at boat ramp collected since 2019. Characterization of the thickness and hydraulic conductivity of the Metropolis Lake sediments (Activity 16) and white paper planned beyond FY 2023.	NI	No sediment data available; simulating the lake with high K zone remains an acceptable approximation. Lake measurements will be included in model calibration.

* Model update status: IE=Implement with existing GWSP data; IA = Implement with additional data from another project; NI = not implemented
NA = Not Applicable
GWSP = Groundwater Strategy Project

Model Recommendation GWSP Cross Reference (cont'd)

Recommendation	GWSP Activity #	AOC	Data Collection Description	Status*	Notes
(9) Assess WL and WQ data from new transect of wells east of C-400 to assess GW divide.	15	Water Level Divide Study	Pressure transducer data was collected in 2022 (MW526 to MW529). Preliminary evaluation of Colloidal Borescope (CB) data collected by FRNP was inconclusive, no additional CB data collection planned for GWSP, white paper planned for FY 2023. The NE Plume Optimization Study (ongoing) data collection is relevant. WL data assessment of the 2016 Model was conducted in 2018.	IE	Available data will be incorporated (e.g., new MWs added as calibration targets). WL data assessment of the 2016 Model was conducted (*DRAFT Assessment of Sitewide GW Flow Model Using Data from the NE Plume Optimization Project, FRNP-RPT-0013* included in the MWG Meeting Compilation (2017 -2018) - Attachment 4).
(10) Compile and verify TVA monitoring system data to better understand GW flow north of the site.	11	Expansion of GW Monitoring Network	In Progress. TVA MW data has been compiled and water level data included in select synoptic potentiometric maps when available. A desktop study planned beyond 2023 that is limited to compilation and verification of TVA system data (especially reference point datum).	IA	In progress, incorporate data if available by November 2022. Also see Note for Item 5.
(11) Assess the remaining water supply systems in the plant area (recirculating cooling water and waste heat system, sanitary water system, and the plant (non-sanitary) water system) to evaluate potential for contribution to anthropogenic recharge.	12	Water Balance Study	Desktop study and White Paper planned beyond FY 2023.	IA	See Note for Item 6.
(12) Deploy continuous water level recorders in select monitoring wells/piezometers within the plant area to assess recharge and its impact on nearby water levels and to assess anthropogenic recharge rates.	13, 14	Continuous RGA Water Level Monitoring Synoptic WL Data	Pressure transducer data was collected along north-south transects in FY 2021. Quarterly synoptic data has been collected since November 2020.	IE	Available data will be assessed for use in evaluating relative recharge trends.

* Model update status: IE=Implement with existing GWSP data; IA = Implement with additional data from another project; NI = not implemented
NA = Not Applicable
GWSP = Groundwater Strategy Project

Model Recommendation GWSP Cross Reference (cont'd)

Recommendation	GWSP Activity #	AOC	Data Collection Description	Status*	Notes
(13) Install piezometers w/dataloggers beneath several of the large buildings to define the thickness of the gravel base and temporal WLs beneath the buildings.	13	Continuous RGA Water Level Monitoring	No current plan for piezometer installation.	NI	Ongoing; white paper submitted to the MWG (Evaluation of Anthropogenic Recharge Associated with the Process Buildings in Support of the Sitewide GW Flow Model, FRNP-RPT-0224, February 2022); next steps are being evaluated.
(14) Consider potential mass flux from the McNairy to the RGA resulting from back diffusion in future transport models.	NA	NA	McNairy data collected from historical investigations and C-400 Remedial Investigation/Feasibility Study; monitoring wells, WL/pot maps, K estimates.	IA	Layer(s) will be added to the model to simulate transport in the RGA and McNairy.
(15) Consider evaluation of the calibrated model using a synoptic data set collected under steady conditions at the higher (dry period) river stage anticipated post-Olmsted Dam completion in 2018.	14	Synoptic Water Level Measurement	Several synoptic WL events completed since completion of Olmsted Dam (quarterly since November 2021). More events planned for FY 2023.	IE	Post -Olmsted dam synoptic will be used for calibration. Evaluation of pre- and post-Olmsted Dam water levels is provided in DRAFT Comparison of Regional Groundwater Flow Pre- and Post-Construction and Operation of Olmsted Locks and Dam (FRNP-RPT-0260), August 2022.
(16) Consider transient seasonal conditions at high Ohio River stages in the use of the model for evaluating remedial strategies.	13	Continuous RGA Water Level Monitoring	Pressure transducer data has been collected along north-south transects between September 2020 and September 2021. Additional data collection planned along north-south transects in FY 2023.	IE	2021 datalogger data will be used to calibrate transient period; see Note for Item 5.
(17) Conduct a Water Balance Study to identify significant sources of anthropogenic recharge in the model domain may to provide a better understanding of key components of anthropogenic recharge and reduce uncertainty in recharge estimates for future model updates.	12	Water Balance Study	Utility optimization program, roof drain repair compilation/assessment, and expanded assessment of water supply and storm water systems desktop study and white paper is planned beyond FY 2023.	NI	Available information from the ongoing Utility Optimization Study will be compiled and evaluated to inform updates to anthropogenic model recharge. Also, See Note for Item 6.

* Model update status: IE=Implement with existing GWSP data; IA = Implement with additional data from another project; NI = not implemented
NA = Not Applicable
GWSP = Groundwater Strategy Project

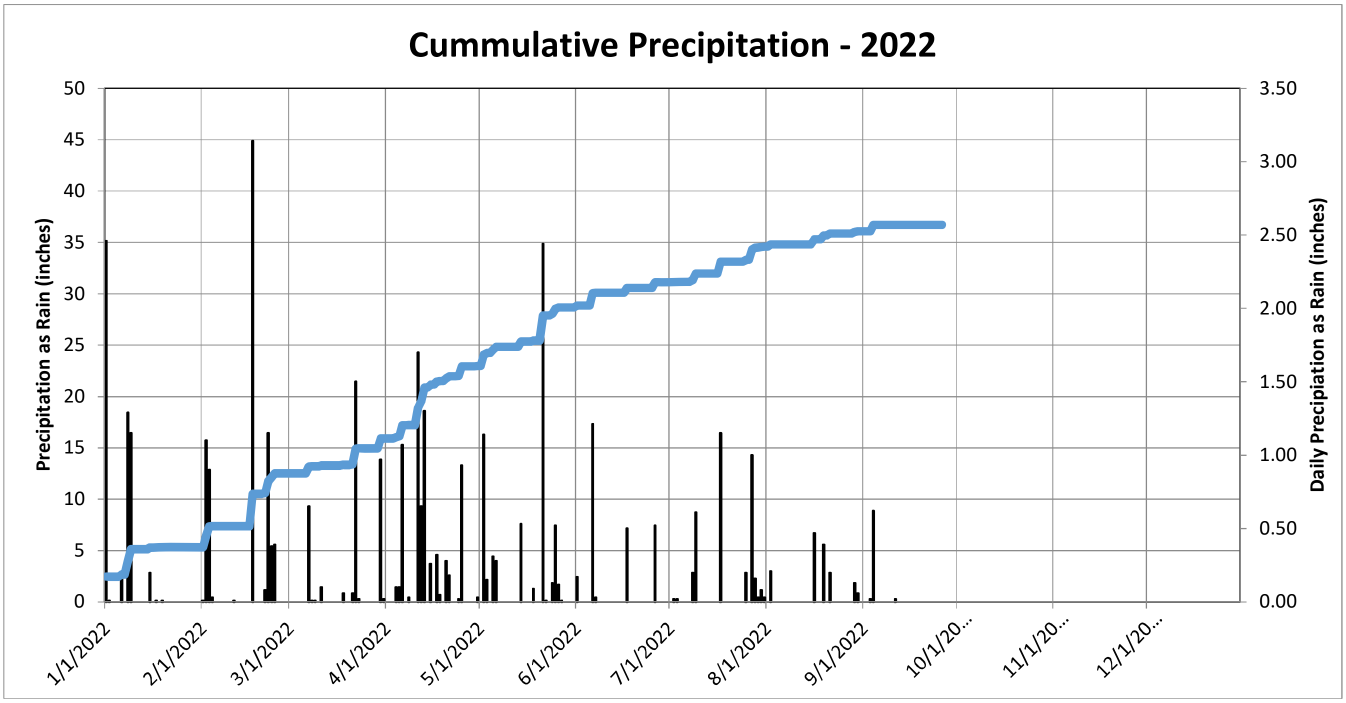
Model Recommendation GWSP Cross Reference (cont'd)

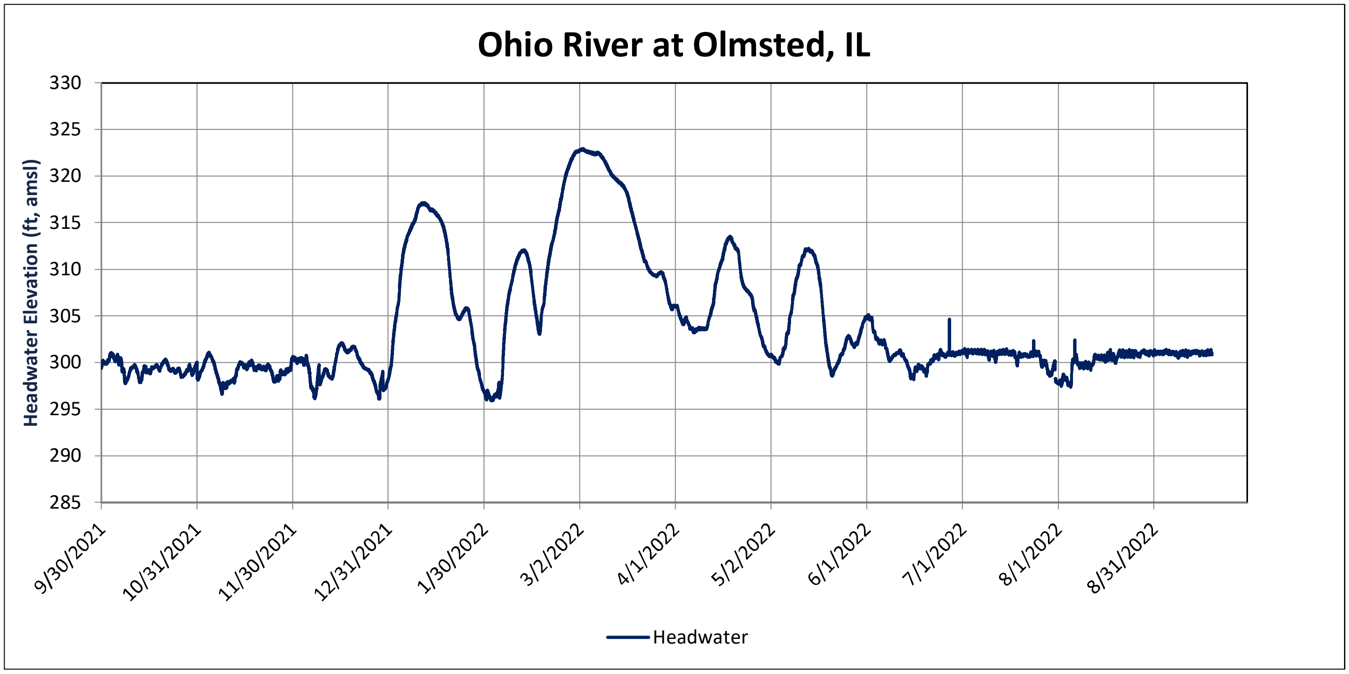
Recommendation	GWSP Activity #	AOC	Data Collection Description	Status*	Notes
(18) Future model efforts should compile available information regarding the chronology of roof drain repair to better understand temporal variability and reduce uncertainty in recharge estimates.	12	Water Balance Study	Roof drain repair has been summarized in a white paper completed in 2022.	IA	Revise large building and C-400 Building recharge zones based on findings of the interim white paper (Evaluation of Anthropogenic Recharge Associated with the Process Buildings in Support of the Sitewide Groundwater Flow Model, FRNP-RPT-0224, February 27, 2022.)
(19) Install additional monitoring wells, inside and outside of the plants industrial area to reduce uncertainty regarding groundwater flow direction, contaminant distribution, and potential source areas for future model updates.	11	Expansion of Groundwater Monitoring Network	C-400 wells and NE Plume divide MWs have been installed.	IE	C-400 and other newly installed well data will be incorporated into model calibration and F&T model source estimates as appropriate.
(20) Conduct tracer tests near apparent groundwater divide east of the C-400 Building to refine understanding of groundwater flow should be considered for future model update efforts.	15	Water Level Divide Study	A tracer test is not planned for Activity #15.	NI	Data from the NE Plume Optimization Study will be evaluated to improve understanding of the apparent GW divide.

* Model update status: IE=Implement with existing GWSP data; IA = Implement with additional data from another project; NI = not implemented
NA = Not Applicable
GWSP = Groundwater Strategy Project

Attachment 4

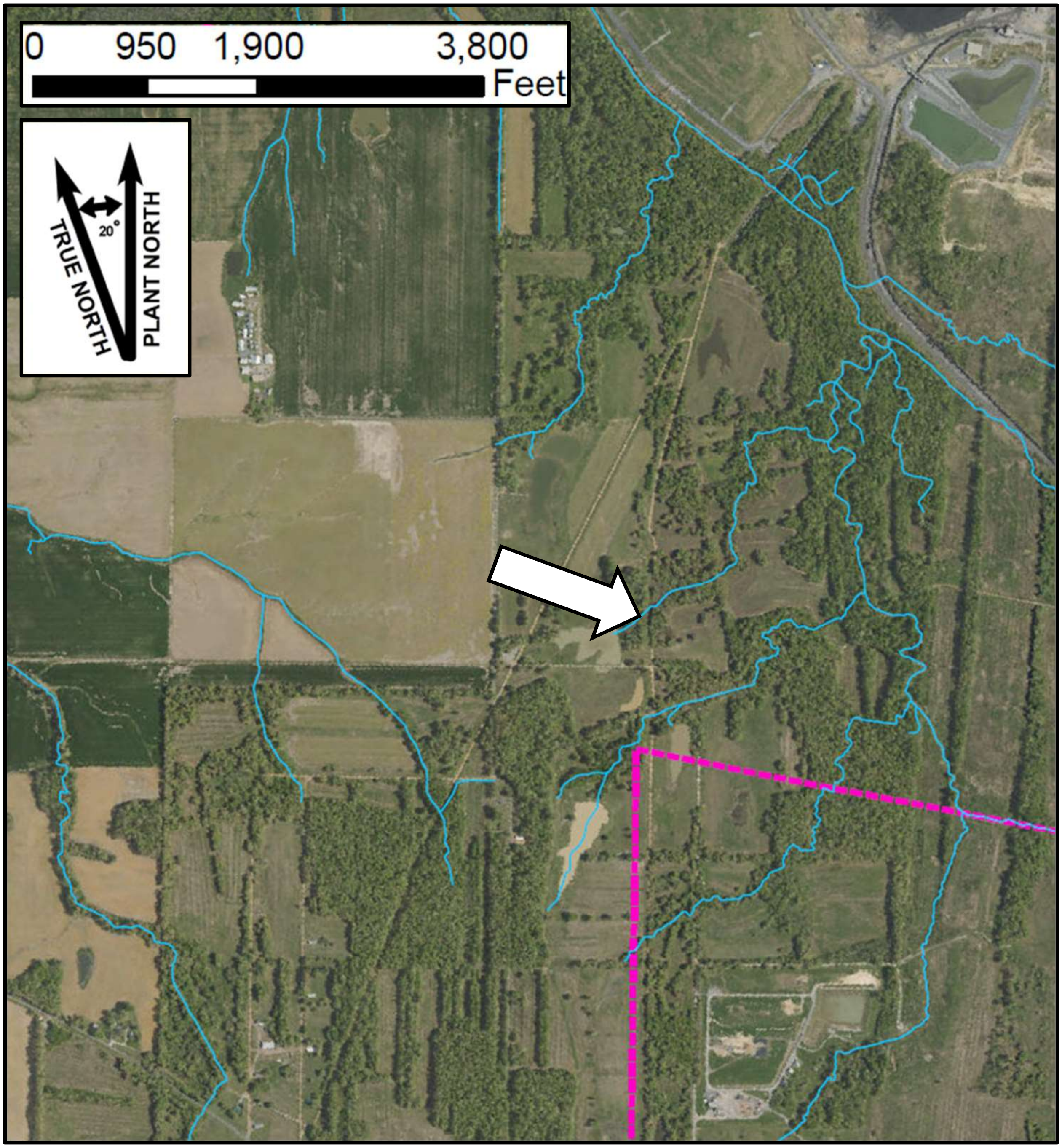
Precipitation and Ohio River Stage Data


Cummulative Precipitation - 2022
Precipitation as Rain (inches)
Daily Precipitation as Rain (inches)
50
45
40
35
30
25
20
15
10
5
0
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1/1/2022
2/1/2022
3/1/2022
4/1/2022
5/1/2022
6/1/2022
7/1/2022
8/1/2022
9/1/2022
10/1/20…
11/1/20…
12/1/20…


Ohio River at Olmsted, IL
Headwater Elevation (ft, amsl)
330
325
320
315
310
305
300
295
290
285
9/30/2021
10/31/2021
11/30/2021
12/31/2021
1/30/2022
3/2/2022
4/1/2022
5/2/2022
6/1/2022
7/1/2022
8/1/2022
8/31/2022
Headwater

Attachment 5

Water Line Leak Location Map



Apparent Pipe Leak Source of Water near Little Bayou Creek

- Located ~0.5 mile south of "daylight" of PGDP water pipes on west side of road
- Landmark is yellow Area 5 sign on east side of road

APPENDIX B

GROUNDWATER MODELING WORKING GROUP MEETING SUMMARY—JANUARY 18, 2023

Paducah Site Groundwater Modeling Working Group
Meeting Summary—January 18, 2023

MWG Attendees:

DOE
Rich Bonczek ✓
Brian Looney (SRNL) ✓

ETAS
Martin Clauberg ✓
Bruce Stearns ✓
Tracy Taylor ✓

KRCEE
Steve Hampson ✓

TVA
Tabitha Ester ✓
Anna Fisher
Dominic Norman
Jeffrey Frazier ✓

EPA and Contractors
Noman Ahsanuzzaman ✓
Ben Bentkowski ✓
Eva Davis ✓
Mac McRae
Victor Weeks ✓

Kentucky
Brian Begley ✓
Stephanie Brock
Nathan Garner ✓
Brian Lainhart
Bart Schaffer ✓
Chris Travis

FRNP
Bryan Clayton
Ken Davis ✓
Rob Flynn ✓
Bruce Ford ✓
Stefanie Fountain ✓
LeAnne Garner
Todd Powers ✓
Denise Tripp ✓
Dawit Yifru ✓
Bruce Meadows
Evan Clark ✓
Jason Orr ✓

✓ Indicates the Attendee was present

Original meeting agenda items are provided followed by meeting notes; the meeting notes are provided in italics with action items noted in green. Additions or revisions to the agenda items are noted in [].

1. Call for Issues from Groundwater Modeling Working Group (MWG) Members

No comments were received to the October 5, 2022 Meeting Summary (sent to participants on 11/14/2022). This summary will be considered final.

No comments were received to the October 5, 2022 Meeting Summary. The meeting summary is now final.

As a general business rule, materials presented at a given meeting do not need to be reproduced for other meetings and may be discussed by referencing the original meeting they were presented in.

The next meeting is scheduled for April 5, 2023. Topics of discussion to include an update on the TVA groundwater model and potentially a review of the prior EarthCon work and plan for FY 2023.

2. Draft FY 2023 Work Plan/Schedule

Activity	Date
~~Provide Draft Agenda Including FY 2023 Work Plan/Schedule (October/FY23Q1) to MWG~~	~~9/28/2022~~
~~Quarterly Meeting (October/FY23Q1)~~	~~10/5/2022~~

Activity	Date
~~Submit Final Lithologic Technical Paper to EPA and KY~~	~~10/7/2022~~
~~Provide Olmsted Dam White Paper to MWG for Review~~	~~10/19/2022~~
~~Submit Draft MWG Compilation (FY 2022) to MWG~~	~~1/5/2023~~ ~~Actual 12/21/2022~~
~~Submit "Assessment of Northwest Plume Capture at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky" (Capture White Paper) to MWG for Review~~	~~1/10/2023~~
~~Submit Final Lithologic Technical Paper to EPA and KY~~	~~1/13/2023~~
Submit Revised FY 2023 Work Plan (included in this summary)	1/18/2023
Quarterly Meeting (January/FY23Q2)	1/18/2023
MWG Provide Comments on Capture White Paper	1/27/2023 (schedule tied to FYR)
MWG Provide Comments on Olmsted Dam White Paper	2/1/2023
MWG Concurs with FY 2023 Work Plan	2/1/2023
MWG Provide Comments on Draft MWG Compilation (FY 2022)	2/3/2023
Submit Draft TCE Degradation Rate White Paper to MWG	2/16/2023 (Planning Date)
Submit Final MWG Compilation (FY 2022)	3/2/2023
MWG Provide Comments on Draft TCE Degradation Rate White Paper	3/23/2023 (Planning Date)
Quarterly Meeting (April/FY23Q3)	4/5/2023
Quarterly Meeting (July/FY23Q4)	7/12/2023
Provide Draft Agenda Including FY 2024 Work Plan/Schedule (October/FY24Q1) to MWG	9/27/2023

The MOA stipulates that the final Lithologic Technical Paper is to be submitted 30 days following the submittal of the D1 C-400 RI/FS Report. The schedule for the D1 C-400 RI/FS Report has been revised to January 5, 2023 by the FFA parties. This would result in a submittal date for the Lithologic Technical Paper of February 4, 2023 (FFA processes for submittals due on weekend days apply, which would result in submittal by February 4, 2023).

EPA and KY to send acknowledgement of receipt of the final Lithologic Technical Paper to close out the MOA action. (Both email acknowledgements were sent to DOE during this meeting, thereby closing the action and the topic will be removed from future agendas.)

3. Draft FY 2023+ Work Plan/Schedule

Activity	Date
Quarterly Meeting (October/FY24Q1)	10/4/2023 (Planning date)

4. Update on Water Levels

Synoptic water level events are being collected quarterly. As part of each quarterly synoptic water level event, the TVA well water levels are reviewed for inclusion on the potentiometric maps. FRNP continues to coordinate with KY on the AIP monitoring wells sampling schedule. Tabitha Ester (TVA) continues to coordinate with Brian Lainhart (KY) on collection of water level measurements and monitoring well abandonment plans.

The potentiometric map for the synoptic water level event for August 22-25, 2022 is included in Attachment 1. A synoptic water level event was conducted November 14-16, 2022 and the resulting potentiometric map will be discussed during the April 2023 MWG meeting. November 2022 groundwater elevation data for TVA wells collected by KY are included as Attachment 2. FRNP provided the new Paducah Site monitoring well survey data to KY on November 10, 2022.

The potentiometric maps from FY 2022 are included in Appendix E of the FY 2022 MWG compendium document. FY 2023 potentiometric maps will be included in the FY 2023 MWG compendium.

Possible localized impacts on water levels due to the TVA sheet pile wall installation are an ongoing topic of discussion (see Agenda Item 11, Projects on the "Watch Topics" List, TVA Changes).

The group discussed that the plume shape does not always follow the potentiometric contours for a given synoptic event. This may be a result of having fewer monitoring wells further from the site and thus more interpolation closer to the Ohio River or may be due to an undefined influence or feature. The potentiometric maps, including any anomalies, are reviewed in the context of the sitewide groundwater model.

5. Update on Paducah Site Groundwater Strategy

The overall objective for the Groundwater Strategy Project (GWSP) is to develop a groundwater strategy that closes out various issues for the site:

- Change status of two Environmental Indicator Performance Measures to "Yes"
    - Human exposure under control
    - Groundwater migration under control
- Resolution of data needs
- Groundwater Modeling Working Group (MWG) recommended [model] maintenance and updates

The GWSP is a multi-year plan with multiple activities planned. The specific timing and scope of each activity are developed by DOE based on data collected in the prior year(s). The GWSP and the C-400 OU Remedial Investigation projects are separate, but where activities overlap they are coordinated and the relevant information obtained from the remedial investigation will be incorporated into the GWSP. The final Olmsted Dam White Paper was provided to the MWG on October 19, 2022.

EPA did not have any comments on the Olmsted Dam White Paper. KY will provide any comments in email by February 1, 2023.

FRNP and KY continue to develop information related to the leak in the main raw water line from the Ohio River to the site. The location of the water line leak along Water Line Road about a mile from the creek crossing is indicated on the figure in Attachment 3. Photographs and a map of the area from the KY walkdown on December 13 are also included in Attachment 3. This area stays wet year round.

KY noted that the flow of water from the water line leak is approximately 1/3 the flow observed during walkdowns earlier in 2022. The area of the water line leak is upgradient of the beaver dam. Tributaries *in general, and specifically the leak and leak area, should be considered in the context of future stream gauging.*

Seeps. There have been no seep results above the maximum concentration limit (MCL) for trichloroethene (TCE) for many years. During the October 6, 2021 meeting, the group discussed that LBCSP5 routinely has flow and is able to be sampled, whereas many of the other previously identified seeps do not have flow consistently. KY reported that they have revised their stream walkdowns to go further up and downgradient of LBCSP5. KY also suggested the use of thermal imaging for seep identification in the winter months.

A beaver dam and elevated water levels behind the dam were noted by KDEP on Little Bayou Creek off of DOE property during a seep walkdown. KY performs a walkdown of the beaver dam area every 2-3 weeks and has attempted water level measurements behind the beaver dam and at the waterline crossing at the entry to Little Bayou Creek. Photographs and water level measurements from the December 13, 2022 walkdown are included in Attachment 3.

A recent heavy rain event has disturbed the beaver dam. The group discussed that the beavers will continually rebuild their dam to the prior location and levels if disturbed. KY relayed that the stream measurements are challenging because the floor of the stream is dynamic. KY is walking down the area weekly.

KRCEE has a task (contingent on funding) to look at seeps using a drone equipped with FLIR (Forward Looking InfraRed). The project will look at other project sites then apply what is learned to the Paducah site. The project intends to provide a proof-of-concept and an understanding of whether the seeps have or have not shifted. The drones will be tied to GPS, potentially also with LiDAR.

KRCEE is drafting a work plan for the 2023 DOE funding; this activity is planned to be included in the work plan for DOE review.

"No Go" Areas for Monitoring Well Installations. There is no change to this topic from the prior meeting. Corridors where overhead transmission lines have been removed have been considered for monitoring well placement, especially with respect to the west side of the NE Plume. No additional changes to the power line configurations are planned at this time. Other medium and low voltage lines around the plant would need to be accounted for in any project, including monitoring well installation. Generally these lines would have 50 ft buffer. A figure of the current high-voltage overhead power lines has been included in prior meeting summaries. Any future changes to facility overhead lines that may impact environmental scopes or data collection will be shared with the MWG.

This topic will be retained, but will be restructured to provide a look–ahead at planned or potential changes rather than a backward look at changes. Discussions from the quarterly meetings with Fish & Wildlife will be reviewed for applicability to this discussion/group. Several standing questions on this topic will be developed and included in future MWG meeting agendas.

Sitewide Groundwater Model Update. The update to the Paducah Site groundwater is in progress. Savannah River National Laboratory (SRNL) is participating in the update and has reviewed the 2008 and 2016 model updates and is providing input to the 2023 update. Modeling will be performed and discussions will be held following submittal of the draft model report. The overarching goal of the model update is to develop a model to support remedial decision making. Review and "approval" or "acknowledgement" of the model will be discussed following transmittal of the model report.

The flow model has been developed and calibrated and the fate & transport model is now in development.

D. Tripp gave an update on the sitewide groundwater model update:

- *Referenced Attachment 3 of the October 5, 2022 Modeling Working Group Meeting Summary for and cross reference between recommendations on the 2016 GW model and GWSP activities*
- *Model construction*
    - *RGA surfaces and boundaries (KRCEE R11 Lithology Database)*
        - *Use of the new database resulted in some modification on southern boundary of the model compared to the prior model*
    - *10 layers*
        - *RGA – 3 layers of equal thickness*
        - *McNairy – 7 layers representing the upper 50 feet with increasing thickness with depth (0.82 ft thick near the RGA interface)*
        - *This layer approach produced results comparable with the semi-analytic REMChlor-MD model performed by R. Falta to help simulate matrix diffusion*
    - *Simplified recharge zonation within plant boundary*
        - *Maximum recharge rate constrained to 22 in/yr (except in pond areas where recharge can be higher)*
        - *Recharge under buildings minimized based on findings from the large process building white paper (thinner gravel base than originally understood) and C-400 RI findings (dry)*
    - *Three stress periods (SP)*
        - *Two transient SPs – February 2021 to April 2021 transducer data – have data from site extending to river*
        - *One steady-state SP – August 2022 WL synoptic – have stream gauge data*
- *Calibration in progress*
    - *Flow model*
        - *MODFLOW and PEST with manual parameter adjustments*
            - *PEST simulations take on order of 24 hours to run*
        - *Preliminary calibration will be refined iteratively with the F&T model calibration*
    - *Fate & Transport (F&T) Model (MT3D)*
        - *Simulation period – 2011 to 2020 to reflect the more extensive monitoring well network and better understanding of plumes after 2010 (also, there is uncertainty of timing of original sources). Plume reports will be used as initial concentrations in 2010 with later reports used as targets.*
        - *Initial concentrations from 2010 Plume Assessment Report (TCE and Tc99) in groundwater and constant concentration of source areas in RGA. There is some evidence of decreasing overall concentrations over time, and this will be a focus of calibration of the F&T model. Predicted 2012-2020 plumes from model will visually compared to the published plumes.*

    - *C-400 RIFS data are being used to refine source zones*
    - *4 SPs capture changing hydraulic stresses (extraction well pumping and Olmsted Dam completion/operation)*
    - *Model will be calibrated to the 2012, 2024, 2016, 2018, 2020 plume maps*
    - *Simulations take 15-18 hours to run each scenario*

Following the update, the group discussed a number of items.

- *What parameters were changed to provide a more representative model when compared to field observations?*
  - *New water level and depth of water data from Little Bayou Creek.*
  - *Post-Olmsted Dam groundwater elevations and Ohio River elevations.*
  - *The recharge under the larger buildings has been revised, reflecting new information on foundation construction and field observations from under the C-400 foundation.*
  - *The recharge from the terrace is relatively unchanged (some modification as noted during the update discussion).*
- *Was the 2008 model more representative of the plumes?*
  - *The 2016 model did not simulate the plumes but was hydraulically similar to the 2008 model.*
  - *The 2008 model fit recharge and artificial sources to output model plumes that were representative of observed plume concentrations.*
  - *The 2016 model addressed some uncertainties with the 2008 model with newer data and assumptions developed by the MWG; it was acknowledged at the time that some uncertainties remained and some inputs were selected to make the model perform as expected.*
- *How does the overall recharge in the new model compare to the 2016 model?*
  - *The recharge distribution has been simplified and there are fewer zones based on a review of current utility densities.*
  - *Recharge is still being finalized as part of calibration.*
- *Will there be additional discussion on the model before the report is issued?*
  - *FRNP will provide updates on the model during the MWG meetings.*
- *When will the model be ready for review?*
  - *The current schedule:*
    - *Calibration through mid-February*
    - *Initial, informal draft report provided to DOE in 3/20/2023.*
    - *Comments from DOE on the informal draft report are expected 4/3/2023.*
    - *The formal draft is planned to be submitted to DOE in 5/17/2023.*
    - *DOE to provide comments on the draft report by 6/1/2023.*
    - *The draft report will be finalized and submitted to DOE on 6/29/2023.*
    - *DOE to approve the draft report and submit the report to EPA and KY 7/14/2023.*
    - *Comments from EPA and KY will be requested 8/14/2023.*
    - *The final report is to be submitted to DOE for approval 9/12/2023.*
    - *DOE to approve the final report and submit the report to EPA and KY 9/26/2023.*
    - *The group will discuss the final review and "approval" of the report (scheduled for 10/10/2023) at a future MWG meeting.*

6. Anthropogenic Recharge

This sub-topic will capture discussion on site changes, such as the recent changes to the high pressure fire water system. Understanding of the recharge associated with the process buildings was identified as a data need during the 2016 groundwater model update.

The paper *Evaluation of Anthropogenic Recharge Associated with the Process Buildings in Support of the Sitewide Groundwater Model* (Large Building PZ White Paper) is included in the *FY 2022 Meeting Summaries and White Papers Compilation.* During prior meetings, the group agreed to discuss whether the approaches included in the paper are needed for near-term projects and if field implementation should be pursued. There is currently no funding for this investigation and likely this work would need to be performed as part of the GWSP.

The group discussed developing a timeline to track changes to site operations that could impact the water balance at the site (e.g., removal of the high pressure fire water line from service, removal of the second raw water line from service, etc.).

7. Plant-Wide Seismic Update

DOE and FRNP periodically review whether there are any ways to further reduce (temporarily) sources of noise to facilitate new testing without disrupting site activities. Seismic investigation is not currently a project (either DOE or KRCEE). The group discussed that this topic may be informed by the McNairy Lithologic Technical Paper and that seismic information will be needed for the selection of the on-site waste disposal facility and potentially for the Groundwater Operable Unit Dissolved Phase Plume project.

During the April 6, 2022 meeting, the group discussed that there was no evidence of faulting encountered during the C-400 remedial investigation. The group also discussed whether this topic should follow the lithology paper discussions or if this topic could be advanced independently. KY’s understanding is that the current level of plant operations with updated technology may provide a possibility for seismic studies in the plant area. S. Hampson (KRCEE) is willing to discuss with Dr. Woolery if that is the appropriate next step. There is no funding currently for this type of work, but could be discussed for FY 2023.

During the October 5, 2022 meeting, Steve Hampson noted that KGS is working on regional compilation of seismic data focused on extents of the New Madrid centroid and on the northwest leg along the Mississippi River and that KGS plans to generate a report this year to summarize information compiled to date. The group discussed that there is no new on-site information and Steve reported that KRCEE/KGS is updating some testing equipment. The current plan for seismic information is to look at this topic on a project-specific basis going forward and that seismic information will be most relevant for the Waste Disposal Alternatives project or the Groundwater Operable Unit dissolved phase plume projects.

There is no specific KRCEE project on this topic planned for 2023. During the site tour in 2022, the Waste Disposal Alternatives project was discussed, specifically that items such as this would be considered for early implementation and that the candidate siting may be revisited. Prior discussions on seismic evaluation for siting an on-site waste disposal facility (OSWDF) concluded adequate *information existed for a Remedial Investigation/Feasibility Study, but that additional seismic evaluation would be needed for actual siting of an OSWDF.*

8. CSM for the McNairy in the C-400 Complex Area

A lithology white paper has been prepared as part of the resolution of dispute on the CERCLA Five Year Review. DOE will issue the final technical paper within one month of submittal of the D1 C-400 Complex OU RI/FS Report to support the review and comment of the C-400 specific data interpretation as part of the C-400 Complex OU RI/FS Report review process and the performance of the FY 2023 Five-Year Review revised protectiveness determinations for the Northeast, Northwest, and Water Policy response actions. The D1 C-400 Complex OU RI/FS Report was submitted on January 5, 2023.

The draft paper was issued to the MWG for review on June 30, 2022. During the July 13, 2022 meeting, EPA discussed that for C-400, they believe the paper has enough data and agreed that faulting was not observed and although other parts of the site do not have as high a resolution of data as the C-400 area, that the risk of faulting is low. They acknowledge that some projects may use the McNairy Formation as a vertical [flow or transport] boundary. This paper should be factored into the CERCLA Five Year Review (FYR) with a strong conclusion that faulting was not observed in the primary area of concern at the site and that this issue from the 2018 FYR should be closed out. EPA discussed use of a FYR addenda to the 2023 FYR for this process and noted that there is good risk control due to good evidence of no faulting at C-400. KDEP recommended that the FYR addenda not go beyond the conclusions presented in the paper.

This paper was issued on January 13, 2023. This agenda item will be retained for the next meeting to discuss comments to the paper, if any.

9. Precipitation and Ohio River Stage

Attachment 4 includes precipitation and Ohio River stage charts through December 31, 2022.

The charts show that the latter part of 2022 was dry, with a very flat Ohio River stage. Precipitation for 2022 was 5 inches less than normal. There was a significant rain event last week that resulted in a brief, approximately 10 ft rise in Ohio River stage.

10. Synoptic Water Level Events and Ohio River Levels

In coordination with the KRCEE stream gauging project, FRNP/DOE provided KRCEE with a map with potential stream gauge locations and times for data collection for coordination of this effort in support of the Groundwater Strategy Project on June 27, 2022 KRCEE performed the stream gauging event for portions of Bayou Creek and Little Bayou Creek in August 2022. The findings of the gauging are included as Attachment 5, Report on Stream Gauging along Bayou Creek, Little Bayou Creek, and Tributaries, August 16–17, 2022.

Data from gauge stations 12 and 13 are being used for calibration of the sitewide groundwater flow model update. The group discussed whether the location where the creeks shift from gaining to losing impacts the flow model and that the model is not very sensitive to this parameter. It may be *advantageous to have Dr. Alan Fryar attend either the July or October MWG meeting to discuss this study and any future similar studies.*

11. 2022 Plume Map Document Update

The 2022 update to the Plume Map Document is in progress. Scoping with DOE occurred in December 2022 and final data for the document update are expected in late January 2023.

This topic will be discussed in more detail during the July and October MWG meetings.

12. Capture White Paper

This white paper provides an additional review of the contaminant trends in the area of the optimized NWPGS EW field in order to better assess the capture of the Northwest Plume.

This paper was prepared to address questions raised during the previous CERCLA Five Year Review. EPA suggested that the paper would benefit from a conclusions statement that ties or closes out the earlier paper recommendations to the recommendations included in this paper. The group discussed whether lowering the pumps is still under consideration and the risk of unintended consequences to changing the system while it is meeting goals. The status of the system and any proposed changes to the system will be discussed in the CERCLA Five Year Review.

13. Projects on the "Watch Topics" List

- **TVA Changes.** TVA has completed construction of a 3,800 ft sheet pile wall in close proximity to Little Bayou Creek and several seeps in December 2021. The wall is intended to stabilize the creek's bank, as opposed to control groundwater. KY/TVA provided as-built drawings showing the installation depth of the wall. Based on the information available in the TVA drawings, the sheet pile wall extends a significant depth into the RGA. The wall joints are not sealed, and the sheet piles themselves are solid (not perforated).

  During the July 13, 2022 meeting, the group discussed that some portions of the sheet pile wall extend into the McNairy Formation and that restriction of flow in the RGA may result in new seeps in Little Bayou Creek (LBC). KY noted that there have been decreases in TCE concentrations in the LBC seeps over time, and that they are interested in understanding the impacts of the wall on groundwater flow and whether the wall will result in a shift in the plume(s). The group noted that there is not pressure data on both sides of the wall and the impact of the wall on the groundwater flow model is not currently known. KDEP continues to do creek walkdowns to look for seeps.

  Tabitha Ester (TVA) shared the 2018 Terracon TVA report with the groundwater modeling team and is checking on whether the TVA Discharge and Intake channels are lined and the connection of the canal to the Ohio River. Tabitha also shared with the group that TVA is updating their groundwater model and that they are looking at the data collected during construction of the sheet pile wall. There were areas of refusal and areas where the targeted depth of the wall was not achieved. TVA will be reviewing the logs and will look to provide a summary of those findings.

TVA is compiling and reviewing available data to support their groundwater model update, which is planned to be performed this spring. An update on the model is planned to be provided during the April MWG meeting.

- **Emerging Contaminants**
    - PFAS
        - PFAS is discussed as part of the Risk Assessment Working Group and has ties to this working group as well.
        - The Paducah Site continues to participate in the DOE HQ PFAS Working Group Meetings (last meeting held November 17, 2022). Rich is a member of the DOE PFAS Coordinating Committee. DOE reported that the Coordination Committee is developing several guidance documents.
            - *The PFAS Coordinating Committee last met on January 10, 2023.*
            - *The DOE HQ PFAS Working Group last met on January 11, 2023.*
        - The DOE Preliminary Assessment was released in late November.
            - *The template for the annual assessment update is in review.*
        - The preliminary assessment (PA) guidance is anticipated to be finalized in January 2023; the Paducah Site is already beyond the PA stage. Currently the draft refers sites to the EPA guidance. The group acknowledged that action levels currently are guidance and are not regulatory requirements.
            - *The guidance is anticipated to be released in February.*
        - The draft DOE PFAS Environmental Sampling Guide is in review. This guide is expected to be final in late spring 2023.
            - *The guide is anticipated to be provided to DOE sites for review later in January.*
        - The Paducah Implementation Plan was provided to DOE HQ by December 31, 2022.
        - For Paducah, the main PFAS activity for 2023 is the in-progress PFAS screening assessment project. The final scope for the Site-wide PFAS Screening Assessment was included in the FY 2023 Environmental Monitoring Plan. Drinking water samples were collected in November and results are being verified. Groundwater sampling is anticipated to begin this quarter and the other water samples in January-February 2023.
            - During the Risk Assessment Working Group meeting in December 2022, that group discussed the use of standard sampling procedures and the potential for cross-contamination of samples. DOE relayed that the potential for cross-contamination from the samplers themselves is thought to be minimal based on newer literature.
            - FRNP and DOE are putting the 2023 schedule of sampling together for the PFAS screening assessment project and will share that with EPA/KY once finalized.
            - *The Second Round of PFAS drinking water samples have been collected with results anticipated to be received late-January. These samples were collected based on a question on the potential for cross-contamination of samples derived from clothing or products worn by the samplers.*

        - *The schedule for sampling of other waters under this project is in development and will be shared pending conclusion of the cross-contamination considerations. Sampling is planned to be completed this fiscal year with a Performance Assessment (PA)-type report or technical report that could form the basis of a PA to be written in the fall of 2023.*
    - In December 2022, EPA issued EPA's PFAS Strategic Roadmap: A Year of Progress
    - *The DOE disposal guidance is currently in review by the DOE sites with comments due back at the end of January.*
    - *KY shared that there is a new study on PFAS in fish tissue available as well as the link for an interactive map (https://www.ewg.org/interactive-maps/pfas_in_US_fish/).*
    - *The group discussed that interactions with FFA parties is being managed at the site level as opposed to the HQ level.*
- *1,4-Dioxane*
    - *The site is responding to a DOE HQ survey on 1,4-dioxane, with responses due mid-February.*
    - *The group discussed that 1,4-dioxane was historically used as a stabilizer in 1,1,1-trichloroethane and dichloroethane. The group plans to discuss fate & transport characteristics of 1,4-dioxane (compared to TCE) during the April MWG meeting.*

14. Meeting Presentations

FY 2023 Presentations:

- October 2022: Summary of the 2023 Sitewide Groundwater Model Update team, schedule, and crosswalk of recommendations from the 2016 model update.
- January 2022: Discussion of groundwater model revision progress.

MWG members should provide any presentation requests to Stefanie. Potential topics for future meetings:

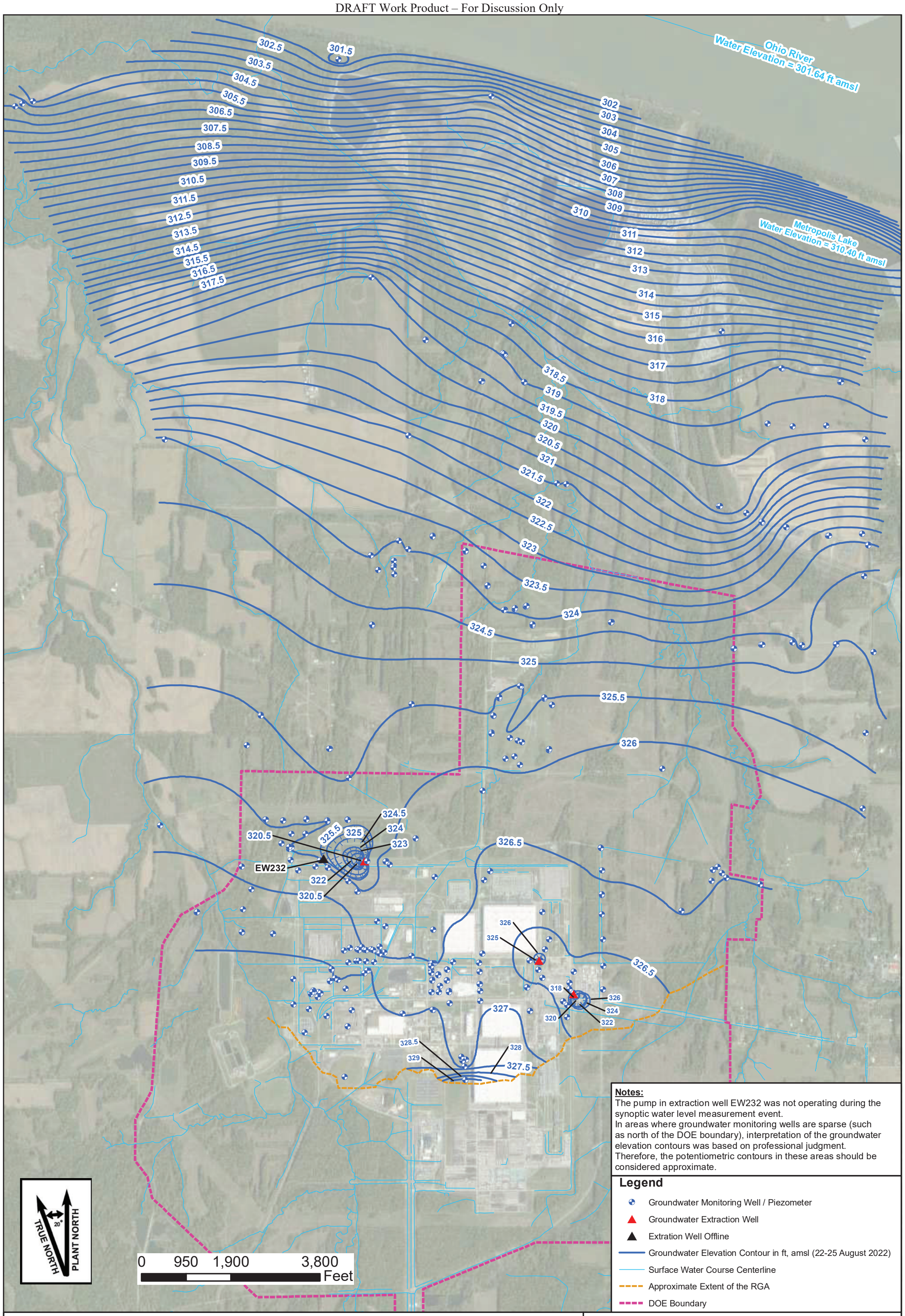
- C-400 Complex remedial investigation
- Lithology
- TCE degradation rates
- Site water balance items (e.g., leaks from piping, above and below ground piping, building foundation gravel layers, etc.)
- EarthCon (following contracting and completion of evaluation). The EarthCon report shows more detail on plume remediation than what plume map update document shows.
- Groundwater model updates
- Topics from the Site Management Plan

15. Poll MWG Members/Open Discussion

The EarthCon contract has been approved by DOE and the specific scope of work is in development. Once contracted, EarthCon will present their prior work at one of the MWG meetings.

Attachment 1

Groundwater Strategy Potentiometric Map
August 2022



Notes:
The pump in extraction well EW232 was not operating during the synoptic water level measurement event.
In areas where groundwater monitoring wells are sparse (such as north of the DOE boundary), interpretation of the groundwater elevation contours was based on professional judgment. Therefore, the potentiometric contours in these areas should be considered approximate.

MAP SOURCE INFORMATION

Map Generation Date and Location - 10/11/2022 Geosyntec\\fedprojects-01\paducah$\Knoxville\GW Strategy\GIS\MXDs\2021-2022 Potentiometric Surface Maps
Map Layer Location: Geosyntec\\fedprojects-01\paducah$\Knoxville\GW Strategy\GIS\MXDs\2021-2022 Potentiometric Surface Maps\August 2022 Potentiometric Surface Map 9_28_22.mxd
Image Source: Aerial 2021: http://pegasis.pad.pppo.gov:6080/arcgis/services; and
Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.
Shapefile for Surface Water Course Centerline was obtained from Pegasis (https://pegasis.pad.pppo.gov/), downloaded on 6/27/2022.
DOE Property Boundary provided by FRNP 2/4/2021.
Northing and easting of wells obtained from Pegasis, downloaded on 6/14/2022.
Groundwater elevation was based on the 8/22/2022 - 8/25/2022 measurements. Ohio River elevation was estimated as the average of elevations measured by the USGS at Paducah Station USGS 0361100 and Olmsted, IL Station (USGS 03612600) between 8/22/2022 - 8/25/2022.
Groundwater elevation for the TVA wells were provided by the Kentucky Division of Waste Management on 9/1/2022. Water elevation at Metropolis Lake was provided by FRNP on 8/30/2022.
amsl = above mean sea level

U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

FOUR RIVERS
NUCLEAR PARTNERSHIP, LLC

Figure 1. August 2022 RGA Potentiometric Surface Map

Att1-2

2/13/2023

Attachment 2

Groundwater Elevation Data for TVA Wells
November 2022

OREIS Name	Well	Description	Aquifer	Top of Casing	Top of Ground	xconv Easting (Ft)	yconv Northing (Ft)	Status	Screen Top Depth (Ft)	Screen Bot Depth (Ft)	tscreenelev (Ft)	bscreenelev (Ft)	GW Elev. (Datum - DTW)	Water Level	Date & Time	Barometric Pressure (inHg)	Measuring Point
TVAGW-6D	TVAGW-6D	4" PVC	Upper RGA	372.77	369.38	760787.88	1946731.54	Active	65.2	75.2	307.57	297.57	317.67	55.1	11/15/2022_1244	29.70	TOC
TVAGW-5D	TVAGW-5D	4" PVC	Upper RGA	372.55	369.14	760131.63	1947315.95	Active	66.9	76.9	305.65	295.65	316.22	56.33	11/15/2022_1247	29.70	TOC
TVAGW-4D	TVAGW-4D	4" PVC	Upper RGA	369.26	365.84	759456.72	1947561.73	Active	63.3	73.3	305.96	295.96	317.32	51.94	11/15/2022_1249	29.70	TOC
TVAGW-3D	TVAGW-3D	4" PVC	Upper RGA	366.9	363.42	758982.49	1947793.86	Active	71.3	81.3	295.6	285.6	315.36	51.54	11/15/2022_1251	29.70	TOC
TVAGW-2D	TVAGW-2D	4" PVC	Upper RGA	372.82	369.24	759966.78	1944870.47	Active	61.2	71.2	311.62	301.62	321.55	51.27	11/15/2022_1241	29.70	TOC
TVAGW-1D	TVAGW-1D	4" PVC	Upper RGA	374.94	371.56	757847.05	1946203.79	Active	63.4	73.4	311.54	301.54	317.85	57.09	11/15/2022_1304	29.70	TOC
TVA-D74B	SHF-D74B	2" PVC	Upper RGA	332.16	329	756125.35	1956489.82	Active	42.3	52.3	289.86	279.86	304.87	27.29	11/15/2022_1025	29.70	TOC
TVA-D30B	SHF-D30B	2" PVC	Upper RGA	324.36	320.6	757594	1955563.41	Active	42.7	52.7	281.66	271.66	297.97	26.39	11/15/2022_1029	29.70	TOC
TVA-D17	SHF-D17	2" PVC	Upper RGA	365.43	362.8	758809.17	1950015.71	Active	14	17	351.43	348.43	314.43	51	11/15/2022_1054	29.70	TOC
TVA-D11B	SHF-D11B	2" PVC	Upper RGA	321.79	319.2	753434.76	1958481.44	Active	32	42	289.79	279.79	301.34	20.45	11/15/2022_1037	29.70	TOC
SHF-201C	SHF-201C	4" PVC	Upper RGA	323.75	320	746799.24	1960068.889	Active	44.5	54.5	279.25	269.25	303.86	19.89	11/15/2022_0938	29.71	TOC
SHF-201B	SHF-201B	4" PVC	Upper RGA	323.75	320.2	746641.107	1960082.768	Active	32	37	291.75	286.75	303.98	19.77	11/15/2022_0937	29.71	TOC
SHF-201A	SHF-201A	4" PVC	Upper RGA	323.75	320	747030.226	1960036.252	Active	14.5	24.5	309.25	299.25	303.91	19.84	11/15/2022_0936	29.71	TOC
SHF-102G	SHF-102G	4" PVC	Upper RGA	362.85	359.1	845764.387	1927473.284	Active	47.1	57.4	315.75	305.45	318.26	44.59	11/15/2022_0927	29.71	TOC
SHF-101G	SHF-101G	4" PVC	Upper RGA	322.43	318.8	754685.75	1957635.07	Active	32	37.3	290.43	285.13	304.16	18.27	11/15/2022_1034	29.70	TOC
Ohio River Elevation						831.9815	14996.63							300.55	11/15/2022_1012	29.70	TVA Inlet

LEGEND:

TOC: Top of Casing

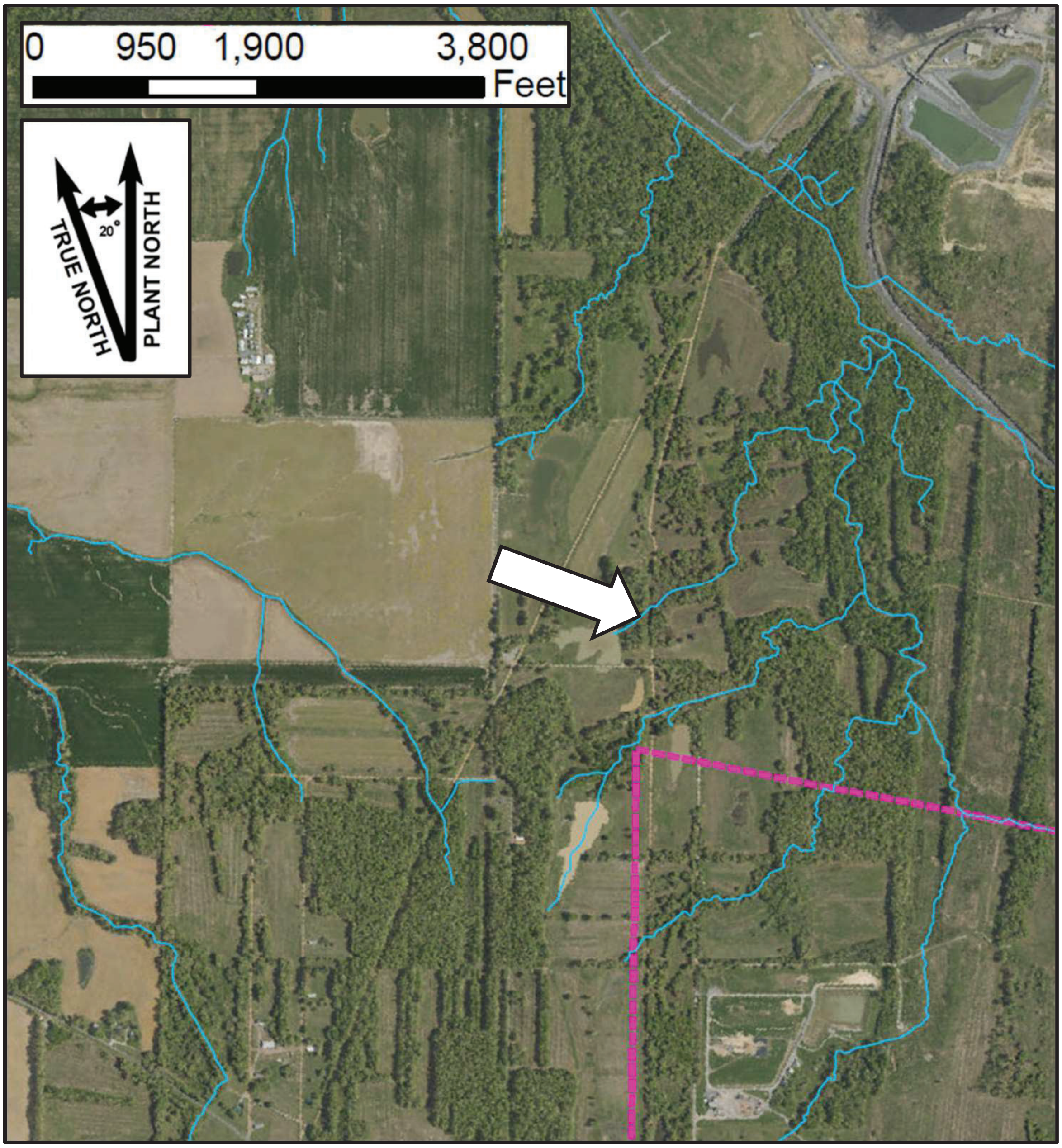
DTW: Depth to Water

National Geodetic Vertical Datum of 1929 (NGVD 29).

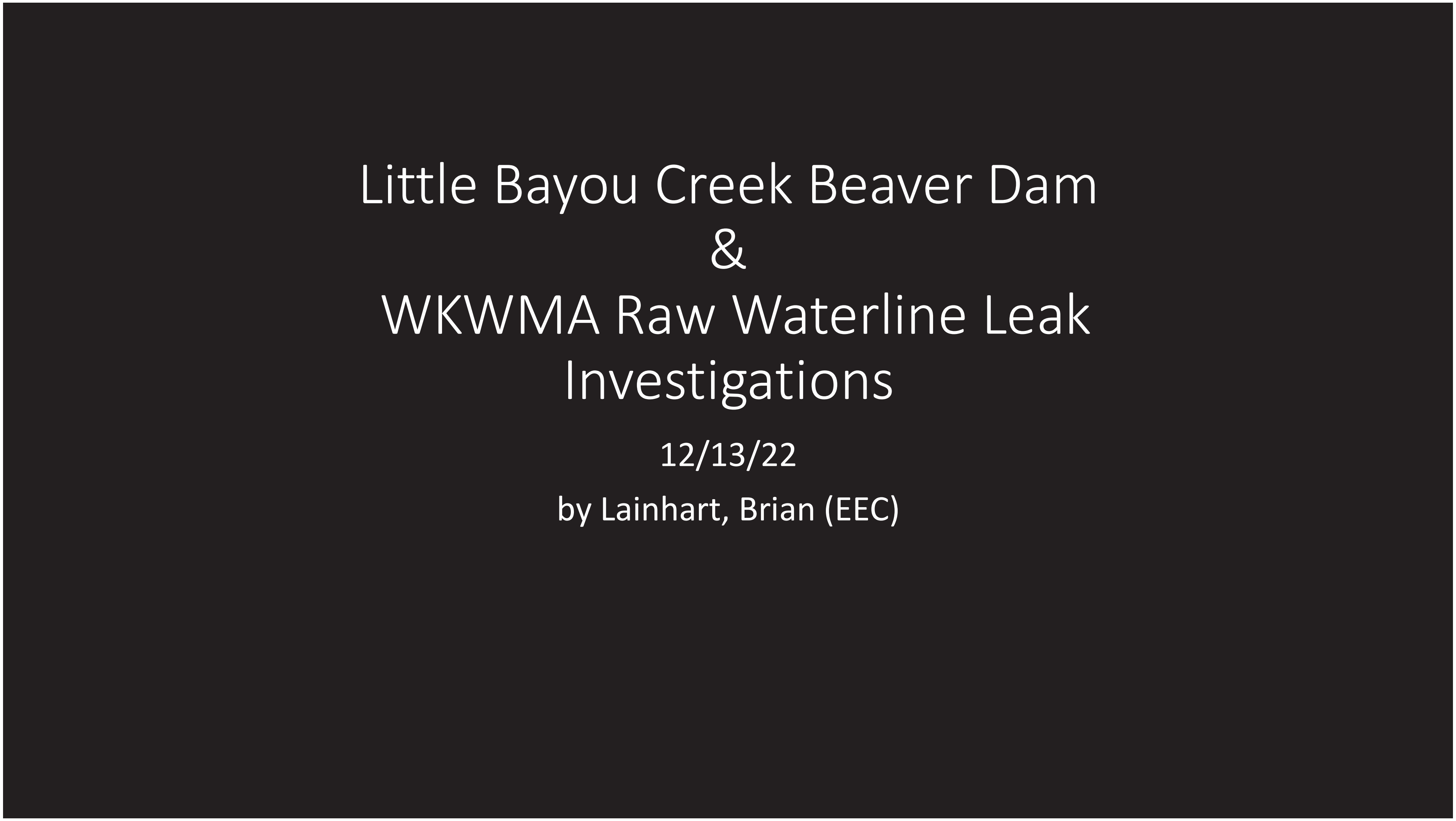
Note: Barometric pressure readings at the Paducah, Barkley Regional Airport office of the National Weather Service for November 15, 2022 were 30.15 inches of mercury at 08:53 and 30.14 inches of mercury for the period 09:53 through 12:53.

Attachment 3

Water Line Leak Location Map and KDEP Walkdown Photographs



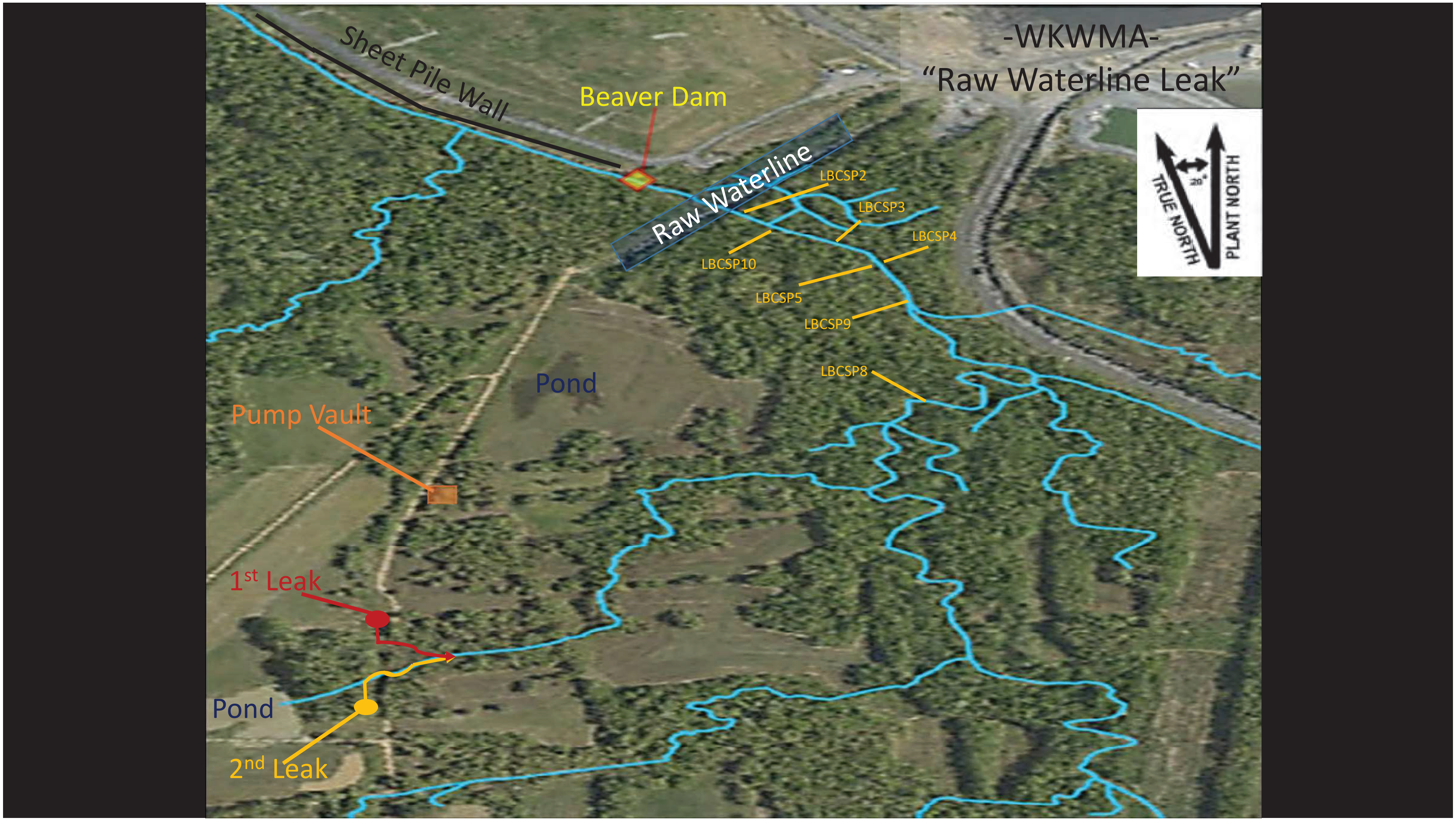
Apparent Pipe Leak Source of Water near Little Bayou Creek
- Located ~0.5 mile south of "daylight" of PGDP water pipes on west side of road
- Landmark is yellow Area 5 sign on east side of road



Little Bayou Creek Beaver Dam & WKWMA Raw Waterline Leak Investigations

12/13/22

by Lainhart, Brian (EEC)


-WKWMA-
“Raw Waterline Leak”
Sheet Pile Wall
Beaver Dam
Raw Waterline
LBCSP2
LBCSP3
LBCSP4
LBCSP10
LBCSP5
LBCSP9
LBCSP8
TRUE NORTH
20°
PLANT NORTH
Pond
Pump Vault
1st Leak
Pond
2nd Leak

Little Bayou Creek Beaver Dam Investigation

12/13/22

Little Bayou Creek Access Point

The overall beaver activity in Little Bayou Creek has decreased since the last AIP investigation on November 16, 2022.

DOE Sign


Little Bayou Creek Access Point
During this investigation fewer down trees were observed.
Measuring Location
Raw Waterlines


Little Bayou Creek
Access Point
Collecting
Measurement

Little Bayou Creek Access Point

LBC Access Point	
Date	Water Depth (in)
9/28/22	~ 28”
10/05/22	~ 27”
10/18/22	~ 27”
11/03/22	~ 34”
11/16/22	~ 32.5”
12/13/22	~ 29

Water Depth ~ 29 in.


Little Bayou Creek
Beaver Trail
Underground Waterlines By-Pass

2/13/2023

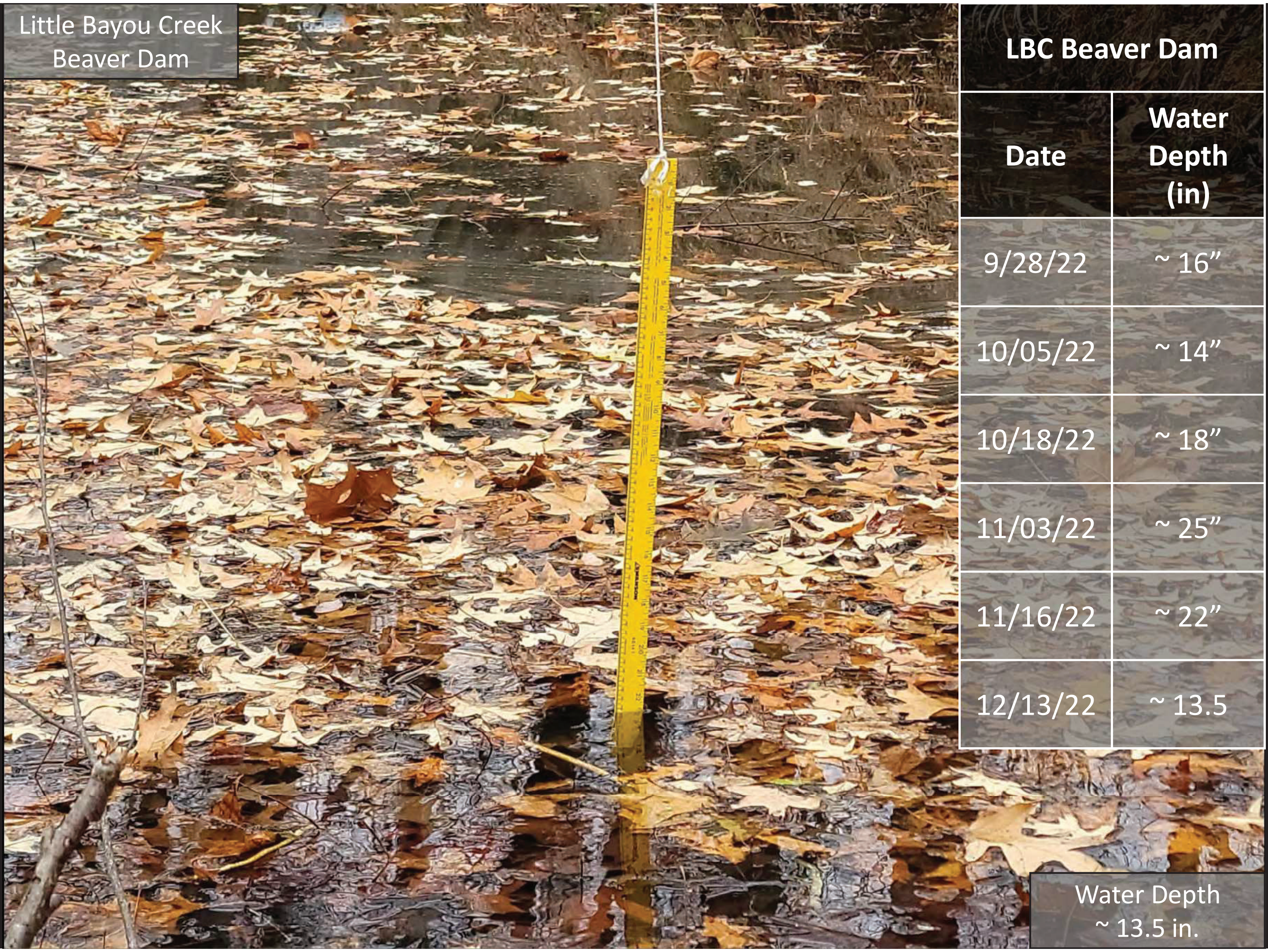

Little Bayou Creek Beaver Dam
Accumulating debris on the upgradient side of the dam.
Measuring Location
Above Dam


Little Bayou Creek
Beaver Dam
Facing Upstream

Little Bayou Creek Beaver Dam

The beavers have reinforced and expanded the dam.

Facing Upstream



Little Bayou Creek Beaver Dam

LBC Beaver Dam	
Date	Water Depth (in)
9/28/22	~ 16”
10/05/22	~ 14”
10/18/22	~ 18”
11/03/22	~ 25”
11/16/22	~ 22”
12/13/22	~ 13.5

Water Depth
~ 13.5 in.

LBC Access Point

Date	Water Depth (in)
8/25/22	~ 30”
9/14/22	N/A
9/28/22	~ 28”
10/05/22	~ 27”
10/18/22	~ 27”
11/03/22	~ 34”
11/16/22	~ 32.5”
12/13/22	~ 29

The next investigation has been tentatively scheduled during the week of January 9, 2023.

LBC Beaver Dam

Date	Water Depth (in)
8/25/22	N/A
9/14/22	~ 14.5”
9/28/22	~ 16”
10/05/22	~ 14”
10/18/22	~ 18”
11/03/22	~ 25”
11/16/22	~ 22”
12/13/22	~ 13.5

WKWMA Raw Waterline Leak Investigation

12/13/2022


-WKWMA-
Waterline Rd.
Facing West
Leak #1

-WKWMA-
Waterline Rd.

Facing Southwest
Leak #1 Drainage

-WKWMA-
Waterline Rd.

~ 25,000 gal. per day

Facing East
Leak #1 Drainage

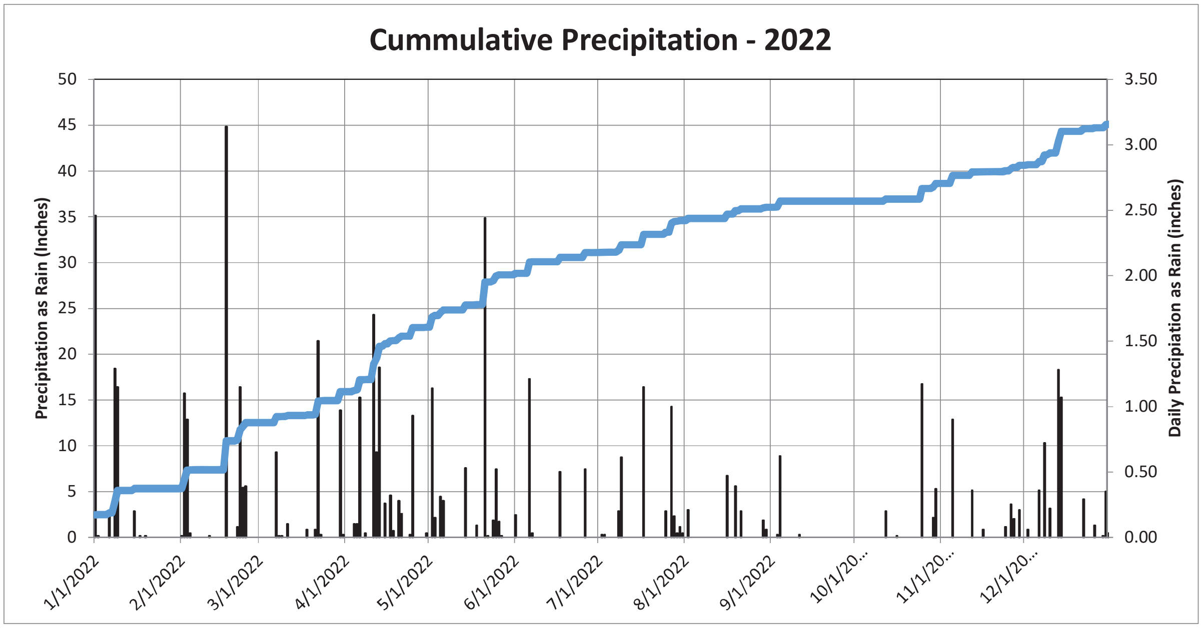

-WKWMA-
Waterline Rd.
Facing West
Leak #2

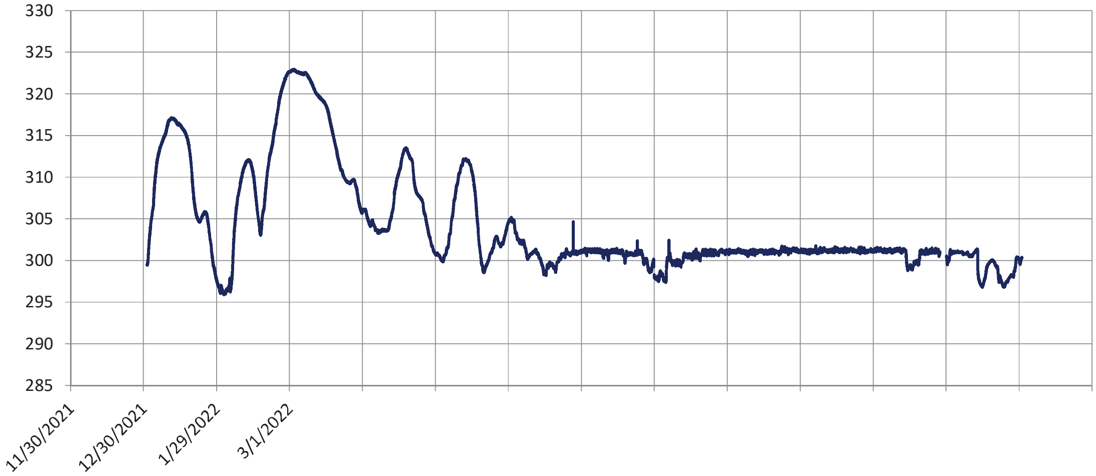

-WKWMA-
Waterline Rd.
Culvert
Facing North
Leak #2 Drainage


-WKWMA-
Waterline Rd.
Culvert
~ 10,000 gal. per day
Facing East
Leak #2 Drainage

Attachment 4

Precipitation and Ohio River Stage Data


Cummulative Precipitation - 2022
Precipitation as Rain (Inches)
Daily Precipiation as Rain (inches)
50
45
40
35
30
25
20
15
10
5
0
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1/1/2022
2/1/2022
3/1/2022
4/1/2022
5/1/2022
6/1/2022
7/1/2022
8/1/2022
9/1/2022
10/1/20…
11/1/20…
12/1/20…


330
325
320
315
310
305
300
295
290
285
11/30/2021
12/30/2021
1/29/2022
3/1/2022

Attachment 5

KRCEE Report on Stream Gauging along Bayou Creek, Little Bayou Creek, and Tributaries, August 16–17, 2022

Report on Stream Gauging along Bayou Creek, Little Bayou Creek, and Tributaries, August 16–17, 2022

Alan Fryar, Department of Earth and Environmental Sciences, University of Kentucky
November 23, 2022

Introduction and Methods

With Brian Begley, Brian Lainhart, and Christopher Travis (Kentucky Energy and Environment Cabinet [EEC]), I gauged discharge by wading with a digital current meter (Marsh-McBirney Flo-Mate) and top-setting rods at two locations along Bayou Creek and six locations along Little Bayou Creek. In addition, I recorded stage heights at three Parshall flumes on outfalls to Bayou Creek (K001, K008, and K015), and I measured discharge volumetrically along the North-South Diversion Ditch. Except for the three farthest-downstream locations, which were gauged on August 17, all measurements were made on August 16, 2022. Measurement locations, which are shown on Figure 1 and listed in Table 1, were identified based on recommendations from site personnel and were geolocated. Gauging locations were selected depending on local conditions (i.e., along relatively straight stream reaches without obstacles).

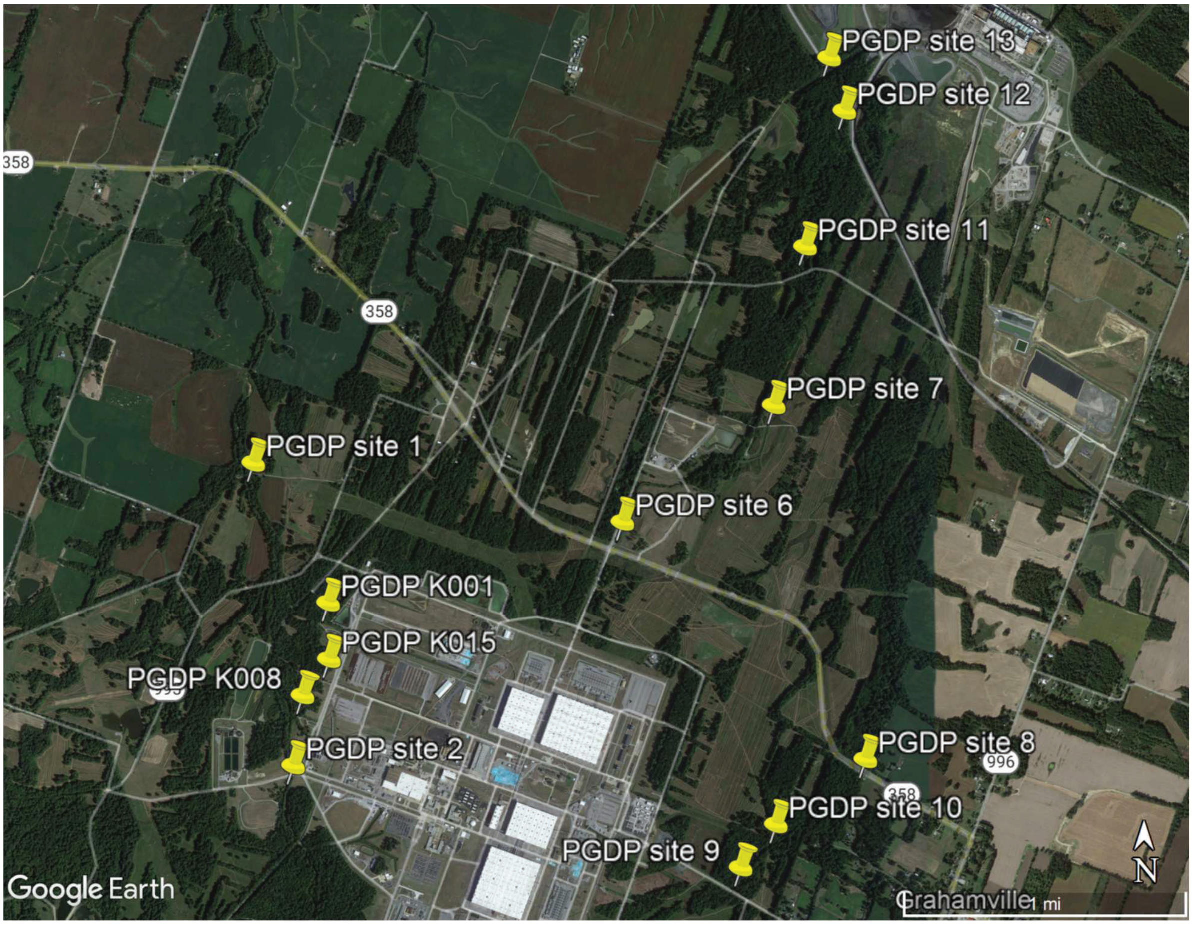


Figure 1. Discharge measurement sites (numbered in order of measurement; see Table 1 for locations). Note K008 is site 3, K001 is site 4, and K015 is site 5.

For gauging, velocity and depth were typically measured at 0.5-ft to 1-ft intervals along a transect across the stream, which was marked by a measuring tape staked to each bank. Depth was visually estimated to within 0.01 ft. Stream discharge was calculated using the midsection method of Rantz (1982) in Excel. No single segment contained more than 10% of the total discharge along a gauging transect. Calculation of error bounds on gauging calculations followed previous work at the site (Mukherjee et al. 2005, LaSage et al. 2008, Tripathi et al. 2021). Velocity was varied by ± 0.01 ft/s (the precision of the current meter) and depth by ±0.05 ft (half the increment of the top-setting rod), and negative (physically nonsensical) values were taken as 0. Discharge values for the 9-inch Parshall flumes were calculated using standard empirical formulas (Justin Riley, Four Rivers Nuclear Partnership, personal communication, September 19, 2022). Discharge exiting the culvert along the North-South Diversion Ditch (site 7) was averaged using four measurements made with a bucket, a 1-L measuring cup graduated in 50-mL increments, and a stopwatch. A fifth measurement was disregarded as an outlier.

Results and Discussion

As expected, discharge increased along Bayou Creek from upstream to downstream of the outfalls. Discharge was 2.37 ft^3/sec (cfs) at site 2 above Water Works Road and 6.29 cfs at site 1 above the downstream low-water crossing (Table 1). Outfall discharge was 2.88 cfs at K008, <0.003 cfs at K015, and 2.02 cfs at K001; total outfall discharge (4.90 cfs) exceeded the gain in discharge between sites 2 and 1 (3.92 cfs). The North-South Diversion Ditch was dry at site 6 (below Ogden Landing Road) and discharge was 0.145 cfs at site 7 (at the downstream end of culvert below the C-746-U landfill). Discharge along Little Bayou Creek increased from 1.44 cfs below McCaw Road (site 9) to 1.48 cfs upstream of the K002 confluence (site 10) to 2.69 cfs above Ogden Landing Road (site 8), decreased to 0.95 cfs below Anderson Road (site 11), then increased to 1.50 cfs above the head of the channelized reach (site 12) and 1.80 cfs above the water-line crossing (site 13). Estimated errors in gauging calculations, which were lowest at site 1 (-9.8 to 10.3%) and highest at site 13 (-19.3 to +21.3%), fell within ranges reported in previous studies of the site. Individual discharge measurements at site 7 (excluding the outlier) were within ± 8.3% of the overall average measurement.

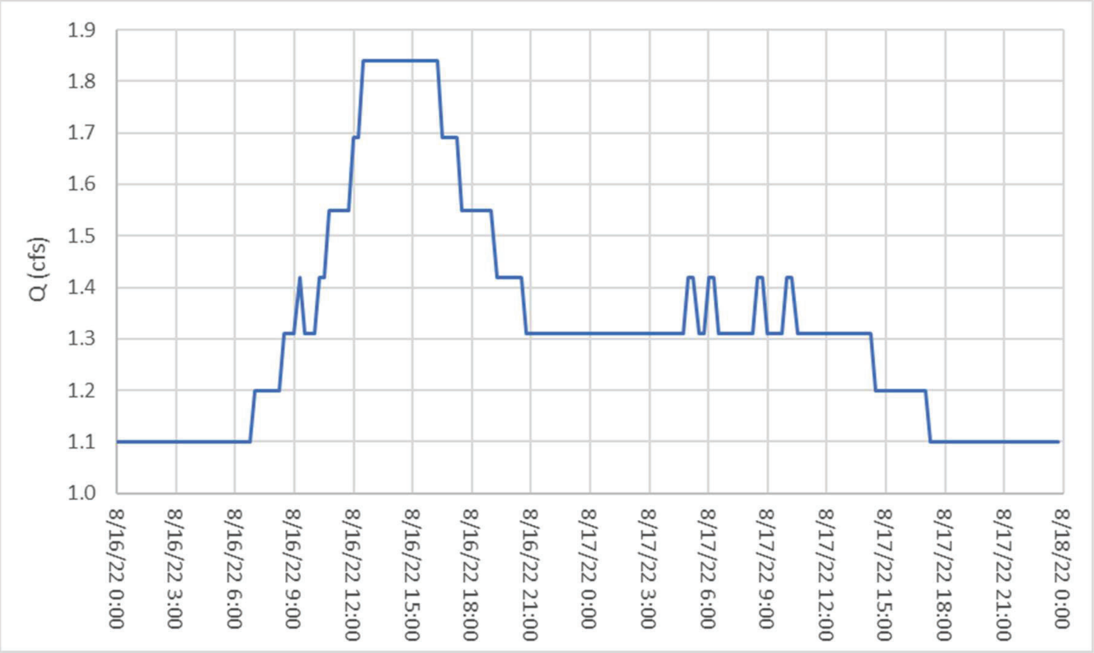


Figure 2. Discharge hydrograph for stream gauge along Massac Creek (USGS 2022b).

Site #	Latitude	Longitude	Date	Time (approx.)	Q (cfs)	Lower-bound Q (cfs)	Upper-bound Q (cfs)	Historical Q (cfs)	Date
1	N 37° 07.7322'	W 88° 49.5527'	8/16/2022	8:20 AM	6.29	5.68	6.94	5.5 - 5.6	8/16/1989
2	N 37° 06.8050'	W 88° 49.3993'	8/16/2022	9:30 AM	2.37	2.07	2.69		
3 (K008)			8/16/2022	10:30 AM	2.88			1.6	8/16/1989
4 (K001)			8/16/2022	10:45 AM	2.02			1.8	8/16/1989
5 (K015)			8/16/2022	11:00 AM	<0.003			2.3	8/16/1989
6			8/16/2022	12:50 PM	0				
7	N 37° 07.9087'	W 88° 47.5544'	8/16/2022	1:10 PM	0.145	0.133	0.157		
8	N 37° 06.8245'	W 88° 47.2022'	8/16/2022	1:30 PM	2.69	2.41	2.99	0.65	8/15/1989
9	N 37° 06.4930'	W 88° 47.6818'	8/16/2022	3:00 PM	1.44	1.25	1.64		
10	N 37° 06.6252'	W 88° 47.5462'	8/16/2022	3:30 PM	1.48	1.26	1.71		
11	N 37° 08.3945'	W 88° 47.4341'	8/17/2022	9:15 AM	0.95	0.78	1.14	0.62	8/15/1989
12	N 37° 08.8101'	W 88° 47.2831'	8/17/2022	10:15 AM	1.50	1.30	1.72	0.85	8/15/1989
								0.97	8/26/2000
13	N 37° 08.9729'	W 88° 47.3415'	8/17/2022	11:15 AM	1.80	1.45	2.18	0.75	8/17/2000
								1.01	8/12/2002
								1.29	8/23/2002

Table 1. Gauging locations, date, approximate time, discharge, lower- and upper-bound ranges of Q, and historical values with dates of gauging. 1989 dates from Evaldi and McClain (1989); 2000 dates from LaSage (2004); 2002 dates from Mukherjee (2003).

Discharge values were probably affected by runoff: 0.47 in. rainfall was recorded at the Paducah airport on August 16 (UK Ag Weather Center 2022). The nearest active U.S. Geological Survey stream gauge is on Massac Creek ~ 7 mi southeast of the Paducah Gaseous Diffusion Plant (USGS 2022b). The discharge hydrograph for this gauge (Figure 2) indicates that runoff occurred from 06:30 August 16 to 17:30 August 17, with peak discharge (1.84 cfs) being 67% greater than baseflow discharge (1.10 cfs). The timing and magnitude of the discharge response varies between gauging sites because of variations in the amount and intensity of rainfall, in land use and land cover, and in the area of the basin upstream of the site. For example, the drainage area upstream of the Massac Creek gauge is 14.6 mi^2, whereas the entire basin areas for Bayou Creek and Little Bayou Creek are 18.4 mi^2 and 9.3 mi^2, respectively (Fryar et al. 2000). Nonetheless, the discharge values measured along Bayou Creek, Little Bayou Creek, and their tributaries probably exceeded baseflow values, particularly on August 16.

Discharge values at the two farthest-downstream sites along Little Bayou Creek were probably also affected by water-line leaks identified by Kentucky EEC personnel (Figure 3; Brian Begley and Brian Lainhart, personal communication, October 20, 2022). However, the magnitude of those leaks appears to have been overestimated. Based on field observations, the total discharge was estimated as ~ 1.5 million gallons/day (Mgd) (~ 1 Mgd for leak 1 and ~ 0.5 Mgd for leak 2), which is equivalent to 2.3 cfs. The tributary receiving the leaks enters between sites 11 and 12; the gain in calculated discharge between those sites was 0.55 cfs. Incorporating error calculations, the difference between the low-bound discharge at site 11 and the high-bound discharge at site 12 was 0.93 cfs.

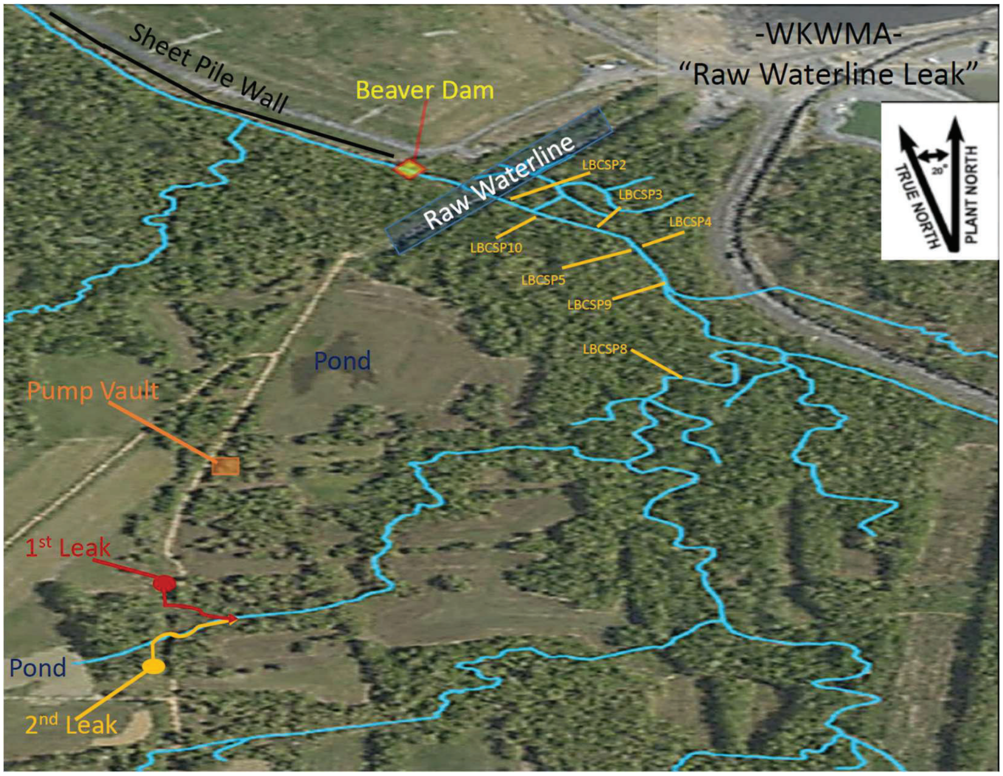
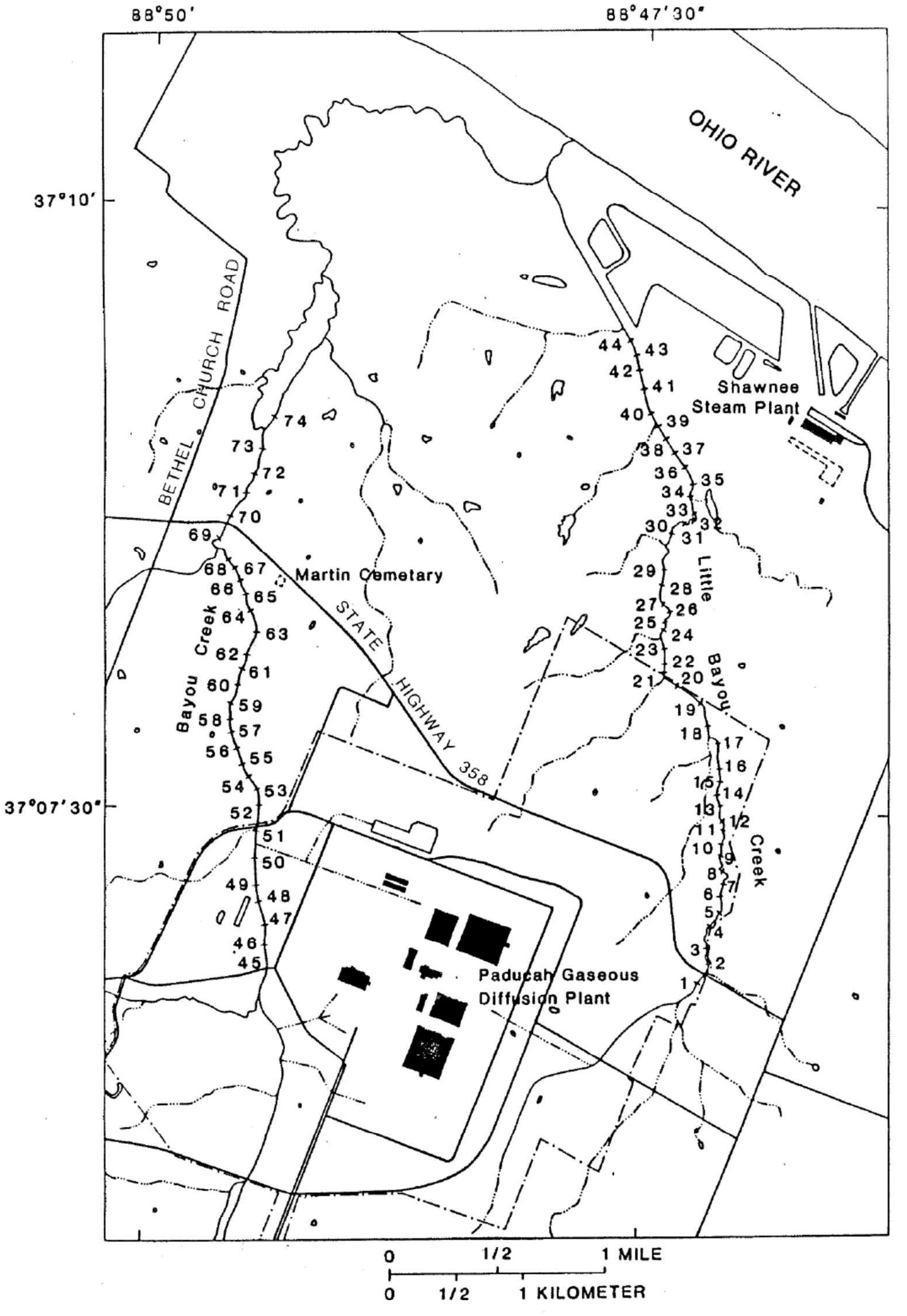


Figure 3. Map showing locations of water-line leaks along tributary to Little Bayou Creek (Brian Begley and Brian Lainhart, Kentucky EEC, personal communication, October 20, 2022).



Base from U.S.Geological Survey 1:24,000, Heath, 1978, Joppa, 1982.

EXPLANATION

1 - Measurement site and number

Figure 4. Measurement sites along Bayou Creek and Little Bayou Creek (Evaldi and McClain 1989).

In general, discharge values in this study exceed values reported in previous studies for similar locations and dates. Evaldi and McClain (1989) gauged discharge at 39 sites along Little Bayou Creek on August 15, 1989, and at 30 sites along Bayou Creek on August 16, 1989 (Figure 4). Discharge values were greater at our sites 1, 3 (outfall K008), 4 (outfall K001), 8, 11, 12, and 13 (Table 1). For outfall K015, discharge was not detectable in this study but was reported by Evaldi and McClain (1989). Downstream of the outfalls, along some segments of Bayou Creek, Evaldi and McClain (1989) observed decreases in discharge (Figure 5), which were attributed to groundwater recharge by the stream or unmeasured subsurface (hyporheic-zone) flow. Such processes may explain the observation that the increase in discharge between our sites 2 and 1 was less than the total outfall discharge along the same reach. Increases in discharge along the lower ~ 8600 ft of the monitored reach of Little Bayou Creek (Figure 5) were attributed to seepage from the bank. Evaldi and McClain (1989) reported a spring between their sites 35 and 37, consistent with subsequent observations (LaSage 2004, LaSage et al. 2008, Tripathi et al. 2021, and this study). A USGS stream gauge was maintained from 1991 to 2010 at the bridge ~ 140 ft upstream of our site 11 (USGS 2022a). During each year of operation, daily discharge values at that gauge for August 17 ranged from 0.57 to 2.00 cfs; the median value (1.00 cfs) slightly exceeds the value for site 11 in this study. Discharge values measured by LaSage (2004) at sites 12 and 13 and by Mukherjee (2003) at site 13 (on two dates) were less than in this study (Table 1). In all the instances of prior gauging reported here except for August 17, 1991, and August 17, 2005, total rainfall for the day of gauging and the preceding day was less than the rainfall that occurred during this study.

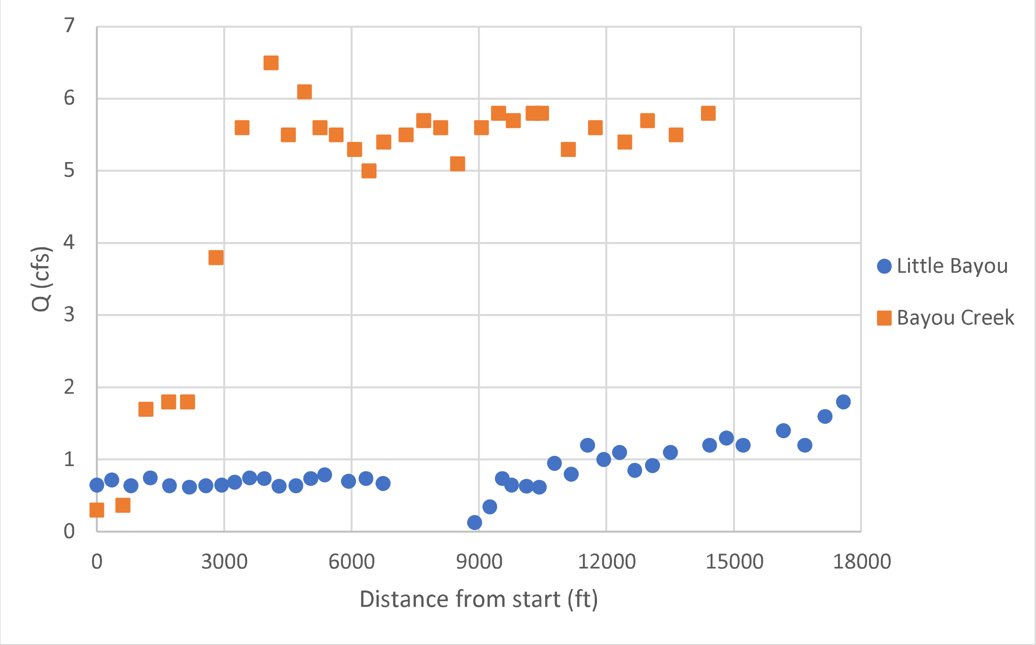


Figure 5. Gauged discharge along Bayou Creek and Little Bayou Creek (Evaldi and McClain 1989). Farthest-upstream location along each creek defined here as 0 ft.

References

Evaldi, R.D., and D.L. McClain. 1989. Streamflow, specific-conductance, and temperature data for Bayou and Little Bayou Creeks near Paducah, Kentucky, August 15 and 16, 1989. U.S. Geological Survey Open-File Report 89-582. Louisville, Kentucky: USGS.

Fryar, A.E., E.J. Wallin, and D.L. Brown, 2000. Spatial and temporal variability in seepage between a contaminated aquifer and tributaries to the Ohio River. Ground Water Monitoring & Remediation 20, 129–146.

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LaSage, D.M., J.L. Sexton, A. Mukherjee, A.E. Fryar, and S.F. Greb. 2008. Groundwater discharge along a channelized Coastal Plain stream. Journal of Hydrology 360, 252–264.

Mukherjee, A. 2003. Identification of natural attenuation of trichloroethene and technetium-99 along Little Bayou Creek, McCracken County, Kentucky. MS thesis, University of Kentucky, Lexington, Kentucky, 163 p.

Mukherjee, A., A.E. Fryar, and D.M. LaSage. 2005. Using tracer tests to assess natural attenuation of contaminants along a channelized Coastal Plain stream. Environmental & Engineering Geoscience 11, 371–382.

Rantz, S.E. 1982. Measurement and computation of streamflow, volume 1, measurement of stage and discharge. U.S. Geological Survey Water-Supply Paper 2175. Washington, D.C.: U.S. Government Printing Office.

Tripathi, G.N., A.E. Fryar, S.K. Hampson, and A. Mukherjee. 2021. Seasonal to decadal variability in focused groundwater and contaminant discharge along a channelized stream: Groundwater Monitoring & Remediation 41, 32–45.

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U.S. Geological Survey. 2022a. Little Bayou Creek near Grahamville, KY. Available at https://waterdata.usgs.gov/monitoring-location/03611900/ (accessed November 23, 2022).

U.S. Geological Survey. 2022b. Massac Creek near Paducah, KY. Available at https://waterdata.usgs.gov/monitoring-location/03611260/ (accessed November 23, 2022).

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APPENDIX C

GROUNDWATER MODELING WORKING GROUP MEETING SUMMARY—APRIL 5, 2023

Paducah Site Groundwater Modeling Working Group
Meeting Summary—April 5, 2023

MWG Attendees:

DOE
Rich Bonczek ✓
Brian Looney (SRNL)

ETAS
Martin Clauberg
Bruce Stearns ✓
Tracy Taylor ✓

KRCEE
Steve Hampson ✓

TVA
Tabitha Ester ✓
Anna Fisher
Dominic Norman
Jeffrey Frazier ✓

EPA and Contractors
Noman Ahsanuzzaman ✓
Ben Bentkowski ✓
Eva Davis ✓
Mac McRae ✓
Victor Weeks ✓

Kentucky
Brian Begley ✓
Stephanie Brock
Mary Evans ✓
Nathan Garner ✓
Will Grasch ✓
Brian Lainhart
Bart Schaffer
Chris Travis ✓

FRNP
Bryan Clayton
Sarah Cronk ✓
Ken Davis ✓
Rob Flynn
Bruce Ford ✓
Stefanie Fountain ✓
LeAnne Garner
Todd Powers
Denise Tripp ✓
Dawit Yifru ✓
Bruce Meadows
Evan Clark ✓
Jason Orr

✓ Indicates the Attendee was present

Original meeting agenda items are provided followed by meeting notes; the meeting notes are provided in italics with action items noted in green. Additions or revisions to the agenda items are noted in [].

1. Call for Issues from Groundwater Modeling Working Group (MWG) Members

No comments were received to the January 18, 2023 Meeting Summary (sent to participants on 2/13/2023). This summary will be considered final.

No comments were received to the January 18, 2023 Meeting Summary. The meeting summary is now final.

2. Draft FY 2023 Work Plan/Schedule

Activity	Date
~~Provide Draft Agenda Including FY 2023 Work Plan/Schedule (October/FY23Q1) to MWG~~	~~9/28/2022~~
~~Quarterly Meeting (October/FY23Q1)~~	~~10/5/2022~~
~~Submit Final Lithologic Technical Paper to EPA and KY~~	~~10/7/2022~~
~~Provide Olmsted Dam White Paper to MWG for Review~~	~~10/19/2022~~
~~Submit Draft MWG Compilation (FY 2022) to MWG~~	~~1/5/2023~~ ~~Actual 12/21/2022~~
~~Submit "Assessment of Northwest Plume Capture at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky" (Capture White Paper) to MWG for Review~~	~~1/10/2023~~
~~Submit Final Lithologic Technical Paper to EPA and KY~~	~~1/13/2023~~

Activity	Date
~~Submit Revised FY 2023 Work Plan (included in this summary)~~	~~1/18/2023~~ ~~Actual 2/13/2023~~
~~Quarterly Meeting (January/FY23Q2)~~	~~1/18/2023~~
~~MWG Provide Comments on Capture White Paper~~	~~1/27/2023~~ ~~(schedule tied to FYR)~~
~~MWG Provide Comments on Olmsted Dam White Paper~~	~~2/1/2023~~ ~~Actual 2/2/2023~~
~~MWG Concurs with FY 2023 Work Plan~~	~~2/1/2023~~
~~MWG Provide Comments on Draft MWG Compilation (FY 2022)~~	~~1/27/2023~~ ~~Actual 2/3/2023~~
~~Submit Draft TCE Degradation Rate White Paper to MWG~~	~~2/16/2023 (Planning Date)~~ ~~Actual 3/1/2023~~
~~Submit Final MWG Compilation (FY 2022)~~	~~3/2/2023~~ ~~Actual 2/13/2023~~
MWG Provide Comments on Draft TCE Degradation Rate White Paper	4/7/2023 (Previously 3/23/2023)
Quarterly Meeting (April/FY23Q3)	4/5/2023
Quarterly Meeting (July/FY23Q4)	7/12/2023
Provide Draft Agenda Including FY 2024 Work Plan/Schedule (October/FY24Q1) to MWG	9/27/2023

The group discussed the Draft TCE Degradation Rate White Paper:

- *EPA provided comments vie email during the meeting.*
- *Kentucky will provide any comments although they note that they have no comments so far.*
- *There is a need to finalize the document as it is employed in the in progress 2023 site wide groundwater modeling update.*

3. Draft FY 2023+ Work Plan/Schedule

Activity	Date
Quarterly Meeting (October/FY24Q1)	10/4/2023 (Planning date)

The group did not have questions on the schedule.

4. Update on Water Levels

Synoptic water level events are being collected quarterly. As part of each quarterly synoptic water level event, the TVA well water levels are reviewed for inclusion on the potentiometric maps. FRNP continues to coordinate with KY on the AIP monitoring wells sampling schedule. Tabitha Ester (TVA) continues to coordinate with Brian Lainhart (KY) on collection of water level measurements and monitoring well abandonment plans.

The potentiometric map for the synoptic water level event for November 14-16, 2022 is included in Attachment 1. A synoptic water level event is planned for March 2023 and the resulting potentiometric map will be discussed during the July 2023 MWG meeting. Potentiometric maps will be included in the FY 2023 MWG compendium. The plume shape does not always follow the potentiometric contours for a given synoptic event. This may be a result of having fewer monitoring wells further from the site and thus more interpolation closer to the Ohio River or may be due to an undefined influence or feature. The potentiometric maps, including any anomalies, are reviewed in the context of the sitewide groundwater model.

Possible localized impacts on water levels due to the TVA sheet pile wall installation are an ongoing topic of discussion (see Agenda Item 11, Projects on the "Watch Topics" List, TVA Changes).

The group did not have comments on the update for water levels.

5. Update on Paducah Site Groundwater Strategy

The overall objective for the Groundwater Strategy Project (GWSP) is to develop a groundwater strategy that closes out various issues for the site:

- Change status of two Environmental Indicator (EI) Performance Measures to "Yes"
    - Human exposure under control
    - Groundwater migration under control
- Resolution of data needs
- Groundwater Modeling Working Group (MWG) recommended [model] maintenance and updates

The GWSP is a multi-year plan with multiple activities planned. The specific timing and scope of each activity are developed by DOE based on data collected in the prior year(s). The GWSP and the C-400 OU Remedial Investigation projects are separate, but where activities overlap they are coordinated and the relevant information obtained from the remedial investigation will be incorporated into the GWSP. The final Olmsted Dam White Paper was provided to the MWG on October 19, 2022. EPA noted during the January 18 meeting that they did not have any comments on the white paper; comments on the white paper were provided by KY on 2/2/2023. The final white paper will be included in the FY 2023 MWG compendium.

FRNP and KY continue to develop information related to the leak in the main raw water line from the Ohio River to the site. The location of the water line leak along Water Line Road about a mile from the creek crossing was provided during prior meetings, most recently the January 18, 2023 meeting. KY performed walkdowns of the area on January 17, 2023; February 15, 2023; and March 8, 2023. During the January 18, 2023 meeting, KY noted:

- the flow of water from the water line leak is approximately 1/3 the flow observed during walkdowns earlier in 2022;
- the area of the water line leak is upgradient of the beaver dam;
- tributaries in general, and specifically the leak and leak area, should be considered in the context of future stream gauging.

DOE requested that the goal of the GWSP, particularly closure of the EIs, be discussed at the next meeting.

B. Begley (KY) asked the group if there are any groundwater detections outside of the known plume because his team noted an anomalous concentration of TCE at 3 ppb on the western boundary of the

water policy box (WPB) from a February 2023 sampling event. Vinyl chloride has also been detected in low amounts in late-2022 sampling events. The detections were on the far west of WPB, about 1 mile south of R90. KY would like the group to consider if additional wells should be installed in this area. K. Davis (FRNP) responded that their team has noted low levels of TCE in this area but rarely vinyl chloride. This area is monitored routinely and is a focus area of the GWSP.
DOE noted that the group will discuss this area moving forward and, as part of GWSP, and additional information needs are being evaluated.

B. Begley (KY) noted that the history with EIs has evolved. KY will review the EIs after optimization of the pump & treat (P&T) systems is complete. There has been particular interest on the western side of the NE Plume. This area is a focus of the GWSP and a new monitoring well location may be considered. KY noted there are challenges with installation of a new monitoring well due to the power lines in this area. In the interim, they have noted anomalous concentrations of TCE on west side of the NW Plume. KY is monitoring anomalies with vinyl chloride detections over the past year, but note that these may not be site related. DOE clarified that they are not asking to close the EIs at the next MWG meeting, but they would like the group to discuss the GWSP to ensure progress is being made and data gaps are being addressed in a way that will facilitate closure of the EIs. There are multiple white papers in progress and the 2022 plume map update is in review. KY notes the GWSP is the most commitment they have seen to getting this information and noted that all parties are working to a common goal.

K. Davis (FRNP) also noted that the CERCLA Five Year Review (FYR) is in progress and trends documented in the FYR are moving in the right direction.

DOE mentioned the fate and transport model is challenged to match the reality of the plumes and that it would be good to close as much as possible before the next site contractor change. DOE will provide historical EI assessments (2015-2017 EI presentations and the 2019 EPA materials) before the next MWG meeting.

Seeps. There have been no seep results above the maximum concentration limit (MCL) for trichloroethene (TCE) for many years. LBCSP5 routinely has flow and is able to be sampled, whereas many of the other previously identified seeps do not have flow consistently. KY reported that they have revised their stream walkdowns to go further up and downgradient of LBCSP5. KY also suggested the use of thermal imaging for seep identification in the winter months.

A beaver dam and elevated water levels behind the dam were noted by KDEP on Little Bayou Creek off of DOE property during a seep walkdown. KY performed walkdowns of the area on January 17, 2023; February 15, 2023; and March 8, 2023.

KRCEE has a task (contingent on funding) to look at seeps using a drone equipped with FLIR (Forward Looking InfraRed). The project will look at other project sites then apply what is learned to the Paducah site. The project intends to provide a proof-of-concept and an understanding of whether the seeps have or have not shifted. The drones will be tied to GPS, potentially also with LiDAR.

S. Hampson (KRCEE) shared with the group that the drone FLIR equipment order is out and is expected on site any day. Scoping for the Lower Bayou Creek survey will start once the equipment arrives, with the survey planned for winter.

B. Begley (KY) discussed the monthly walk downs his team is doing in the area of the seeps and the beaver dam and offered to provide the group PowerPoint summaries to those that want to be on the list. S. Hampson will be added to the distribution list.

The status of work on the raw water line and leaks were updated by B. Ford (FRNP); the equipment has been mobilized to the work area to repair the line and backfill the holes.

"No Go" Areas for Monitoring Well Installations.
This topic is retained, but restructured to provide a look–ahead at planned or potential changes rather than a backward look at changes. Several standing questions on this topic will be developed and included in future MWG meeting agendas.

Recognizing there may be new "No Go" Areas over time, the group agreed to add a third standing question to this topic for future meetings: Have any changes to the "No Go" Areas map occurred since the last meeting or map revision?

- **Planned site activities with potential to impact?** None known at this time. Reprioritization of remedial projects is being considered by the FFA parties.
- **Applicable Quarterly Kentucky Department Fish & Wildlife Resources (KDFWR) meeting discussions?**
    - Due to illegal disposal of trash and off-roading that damages Wildlife Management Aare (WMA) habitat, KDFWR is planning to erect a barricade on Transport Road. This will limit access to MW426 and MW427, but the samplers have keys to the KDFWR locks.
    - KDFWR was made aware that the site plans to repair the leaks in the raw water line and backfill the holes created by the leaks.

Sitewide Groundwater Model Update. The update to the Paducah Site groundwater is in progress. Savannah River National Laboratory (SRNL) is participating in the update and has reviewed the 2008 and 2016 model updates and is providing input to the 2023 update. The overarching goal of the model update is to develop a model to support remedial decision making.

SRNL (B. Looney) is under contract through DOE and their scope includes review of the older models as well as providing formal review of the updated model. R. Falta is contracted to FRNP and is working directly with the modeling team.

The flow model and the fate & transport models have been developed and the report is being developed with a first draft of the D1 due to DOE May 17, 2023.

The REMChlor model was discussed recently during a C-400 RI/FS meeting. The 2023 groundwater model update compares REMChlor-MD results to the results of a multi-layered MT3DMS contaminant transport model to determine the McNairy layer thickneses in the model update. REMChlor-MD differs from the older EPA REMChlor model; the original REMChlor model did not include matrix diffusion and was also verified by comparison with analytical solutions in the attached paper from 2008. REMChlor-MD was verified with analytical and numerical solutions for matrix diffusion, and validated with experimental matrix diffusion data (references provided separately). REMChlor-MD was also used for the C-400 RI/FS.

The group discussed how the REMChlor-MD model will be used in the sitewide groundwater model update and also discussed how the model was used for the C-400 RI/FS. The discussions and questions regarding the use of the model for the C-400 project were tabled to a C-400 project meeting planned for April 24. Generally, these discussions and questions involved:

- *the purpose/goal of use of this model for the project;*
- *the capabilities of the model with respect to flow (1-dimensional), dispersion (2-dimensional), biodegradation (up to nine zones for different decay rates;*
- *model handling of multiple conductive zones (i.e., the RGA vs the McNairy) and back-diffusion;*
- *model boundaries; and*
- *definition/assignment of source term(s) in the model*

Review and "approval" or "acknowledgement" of the model will be discussed with the MWG. A meeting to brief the MWG is planned for June (date to be determined).

The meeting to brief the MWG on the model will be coordinated with the Risk Assessment Working Group (RAWG) meeting on June 7, 2023.

6. Anthropogenic Recharge

This sub-topic will capture discussion on site changes, such as the recent changes to the high pressure fire water system.

The paper *Evaluation of Anthropogenic Recharge Associated with the Process Buildings in Support of the Sitewide Groundwater Model* (Large Building PZ White Paper) is included in the *FY 2022 Meeting Summaries and White Papers Compilation.* During prior meetings, the group agreed to discuss whether the approaches included in the paper are needed for near-term projects and if field implementation should be pursued. There is currently no funding for this investigation and likely this work would need to be performed as part of the GWSP.

Development of a timeline to track changes to site operations that could impact the water balance at the site (e.g., removal of the high pressure fire water line from service, removal of the second raw water line from service, etc.) is under consideration.

New information on anthropogenic recharge is available since the 2016 sitewide groundwater model update and has been incorporated into this model update. A white paper/summary of the anthropogenic recharge information will be included as an appendix to the modeling report. Generally, recharge across the site is as high as 36 inches but the average across the site is much lower.

7. Plant-Wide Seismic Update

This topic has been discussed during multiple meetings, most recently the January 18, 2023 meeting. DOE and FRNP periodically review whether there are any ways to further reduce (temporarily) sources of noise to facilitate new testing without disrupting site activities. Seismic investigation is not currently a project (either DOE or KRCEE).

There was no evidence of faulting encountered during the C-400 remedial investigation. KGS is working on regional compilation of seismic data focused on extents of the New Madrid centroid and on the northwest leg along the Mississippi River and that KGS plans to generate a report this year to summarize information compiled to date. KRCEE/KGS is updating some testing equipment.

The current plan for seismic information is to look at this topic on a project-specific basis going forward and that seismic information will be most relevant for the Waste Disposal Alternatives project or the Groundwater Operable Unit dissolved phase plume projects. The Waste Disposal Alternatives project is being considered by the FFA parties for early implementation and that the candidate siting may be revisited. Prior discussions on seismic evaluation for siting an on-site waste disposal facility (OSWDF) concluded adequate information existed for a Remedial Investigation/Feasibility Study, but that additional seismic evaluation would be needed for actual siting of an OSWDF.

DOE shared with the group that project sequencing discussions are in progress. Previously, the independent technical review of the Waste Disposal Alternatives RI/FS commented that the seismic information available for the site was sufficient to make a decision on whether an on-site waste disposal facility (OSWDF) was feasible for the site, but that there was not sufficient data to site an OSWDF.

8. CSM for the McNairy in the C-400 Complex Area

A lithology white paper has been prepared as part of the resolution of dispute on the CERCLA Five Year Review. The paper is intended to support the review and comment of the C-400 specific data interpretation as part of the C-400 Complex OU RI/FS Report review process and the performance of the FY 2023 Five-Year Review revised protectiveness determinations for the Northeast, Northwest, and Water Policy response actions. The D1 C-400 Complex OU RI/FS Report was submitted on January 5, 2023. This paper was issued on January 13, 2023. This agenda item is being retained for this meeting to discuss comments to the paper, if any.

KY noted that there is no back diffusion from McNairy included in the discussion in the report.

9. Precipitation and Ohio River Stage

Attachment 2 includes precipitation and Ohio River stage charts through mid-March 2023.

The group discussed that there was a drought in 2022 (as indicated on the chart), but that the Ohio River has now returned to normal stage.

10. Synoptic Water Level Events and Ohio River Levels

KRCEE performed a stream gauging event for portions of Bayou Creek and Little Bayou Creek in August 2022. The findings of the gauging were included in the January 18, 2023 meeting summary.

Data from gauge stations 12 and 13 are being used for calibration of the sitewide groundwater flow model update. The group discussed whether the location where the creeks shift from gaining to losing impacts the flow model and that the model is not very sensitive to this parameter. It may be advantageous to have Dr. Alan Fryar attend either the July or October MWG meeting to discuss this study and any future similar studies.

S. Hampson is stepping back and Dr. Fryar is stepping into his role.
Dr. Fryar will be added to these meeting invites going forward (July or October).

11. 2022 Plume Map Document Update

The 2022 update to the Plume Map Document is in progress. Scoping with DOE occurred in December 2022 and final data for the document update were received in March 2023. The first draft of the document was submitted to DOE for review and is due to EPA and KY June 15, 2023.

There were no additional comments from the group on the plume map document update.

12. Capture White Paper

This white paper provides an additional review of the contaminant trends in the area of the optimized NWPGS EW field in order to better assess the capture of the Northwest Plume. This paper was prepared to address questions raised during the previous CERCLA Five Year Review. The group discussed whether lowering the pumps is still under consideration and the risk of unintended consequences to changing the system while it is meeting goals. The status of the system and any proposed changes to the system will be discussed in the CERCLA Five Year Review.

The draft white paper was provided to the MWG for review on January 10, 2023; comments were received January 25 and January 27, 2023; and the revised paper was provided to the MWG on February 9, 2023.

The group agreed this item is closed out and can be deleted from the agenda.

13. Projects on the "Watch Topics" List

- **TVA Changes.** TVA has completed construction of a 3,800 ft sheet pile wall in close proximity to Little Bayou Creek and several seeps in December 2021. The wall is intended to stabilize the creek's bank, as opposed to control groundwater. Based on the information available in the TVA drawings, the sheet pile wall extends a significant depth into the RGA. The wall joints are not sealed, and the sheet piles themselves are solid (not perforated).

  During the July 13, 2022 meeting, the group discussed that some portions of the sheet pile wall extend into the McNairy Formation and that restriction of flow in the RGA may result in new seeps in Little Bayou Creek (LBC). KDEP continues to do creek walkdowns to look for seeps.

  TVA is compiling and reviewing available data to support their groundwater model update, which is planned to be performed this spring. An update on the model is planned to be provided during a future MWG meeting. There were areas of refusal and areas where the targeted depth of the wall was not achieved. TVA will be reviewing the logs and will look to provide a summary of those findings.

T. Ester (TVA) noted that there are no changes to update the group with at this time.

- **Emerging Contaminants**
    - PFAS
        - PFAS is discussed as part of the Risk Assessment Working Group and has ties to this working group as well.
        - The Paducah Site continues to participate in the DOE HQ PFAS Working Group Meetings.
            - The PFAS Coordinating Committee last met on March 8, 2023.
            - The DOE HQ PFAS Working Group last met on March 23, 2023.
            - The DOE Preliminary Assessment was released in late November and the template for the annual assessment update is being finalized.
            - The preliminary assessment (PA) guidance is final and expected to be released soon. The Paducah Site is already beyond the PA stage. Currently the draft refers sites to the EPA guidance. The group acknowledged that action levels currently are guidance and are not regulatory requirements. New MCLs and MCLGs have been proposed that will be used in screening versus the health advisory values. Additionally, there are RSLs that may be used pending RAWG decisions.
            - The site provided comments on the DOE disposal guidance in January.
            - The site is reviewing the DOE sampling guidance with comments due to DOE HQ on April 4, 2023. This guide is expected to be final in late spring 2023.
        - PFAS topic interactions with FFA parties are being managed at the site level as opposed to the HQ level.
        - For Paducah, the main PFAS activity for 2023 is the in-progress PFAS screening assessment project. The final scope for the Site-wide PFAS Screening Assessment was included in the FY 2023 Environmental Monitoring Plan.
            - During the Risk Assessment Working Group meeting in December 2022, that group discussed the use of standard sampling procedures and the potential for cross-contamination of samples. DOE relayed that the potential for cross-contamination from the samplers themselves is thought to be minimal based on newer literature.
                - The revisions to the PFAS QAPP worksheets will be shared with EPA and KY (possibly during a Routine Paducah Groundwater Update call) once finalized. The revised worksheets will be included with the planned update to the 2023 EMP.
            - Drinking water samples were collected in November 2022 and January 2023 and results are being verified. The January 2023 samples were collected based on a question on the potential for cross-contamination of samples derived from clothing or products worn by the samplers
            - Sampling is planned to be completed this fiscal year with a Performance Assessment (PA)-type report or technical report that could form the basis of a PA to be written in the fall of 2023.
            - Sampling resumed March 20, 2023 and is currently planned:

        - Groundwater sampling March-August
        - Surface Water sampling April (pending procedure revisions)
        - Groundwater and Treated Groundwater sampling May
        - Leachate and Treated Wastewater sampling TBD (pending procedure revisions)

The revisions to the EMP include updates reflecting the new KPDES permit parameters. The updates to the PFAS QAPP worksheets include minor changes to the PFAS sampling locations consistent with the monitoring wells planned for sampling in the EMP. The changes to the PFAS QAPP worksheets will be discussed during a future Routine Paducah Groundwater Update calls. DOE is starting to hear questions on PFAS related to sources and soils; DOE anticipates that site discussions on these are about 6-8 months out.

- 1,4-Dioxane
    - 1,4-dioxane was historically used as a stabilizer in 1,1,1-trichloroethane and dichloroethane.
    - The site responded to a DOE HQ survey on 1,4-dioxane in mid-February.
    - The group plans to discuss fate & transport characteristics of 1,4-dioxane (compared to TCE) during a MWG meeting.

14. Meeting Presentations

FY 2023 Presentations:

- October 2022: Summary of the 2023 Sitewide Groundwater Model Update team, schedule, and crosswalk of recommendations from the 2016 model update.
- January 2022: Discussion of groundwater model revision progress.

MWG members should provide any presentation requests to Stefanie. Potential topics for future meetings:

- C-400 Complex remedial investigation
- Lithology
- TCE degradation rates
- Site water balance items (e.g., leaks from piping, above and below ground piping, building foundation gravel layers, etc.)
- EarthCon (following contracting and completion of evaluation). The EarthCon report shows more detail on plume remediation than what plume map update document shows.
- Groundwater model updates
- Topics from the Site Management Plan

15. Poll MWG Members/Open Discussion

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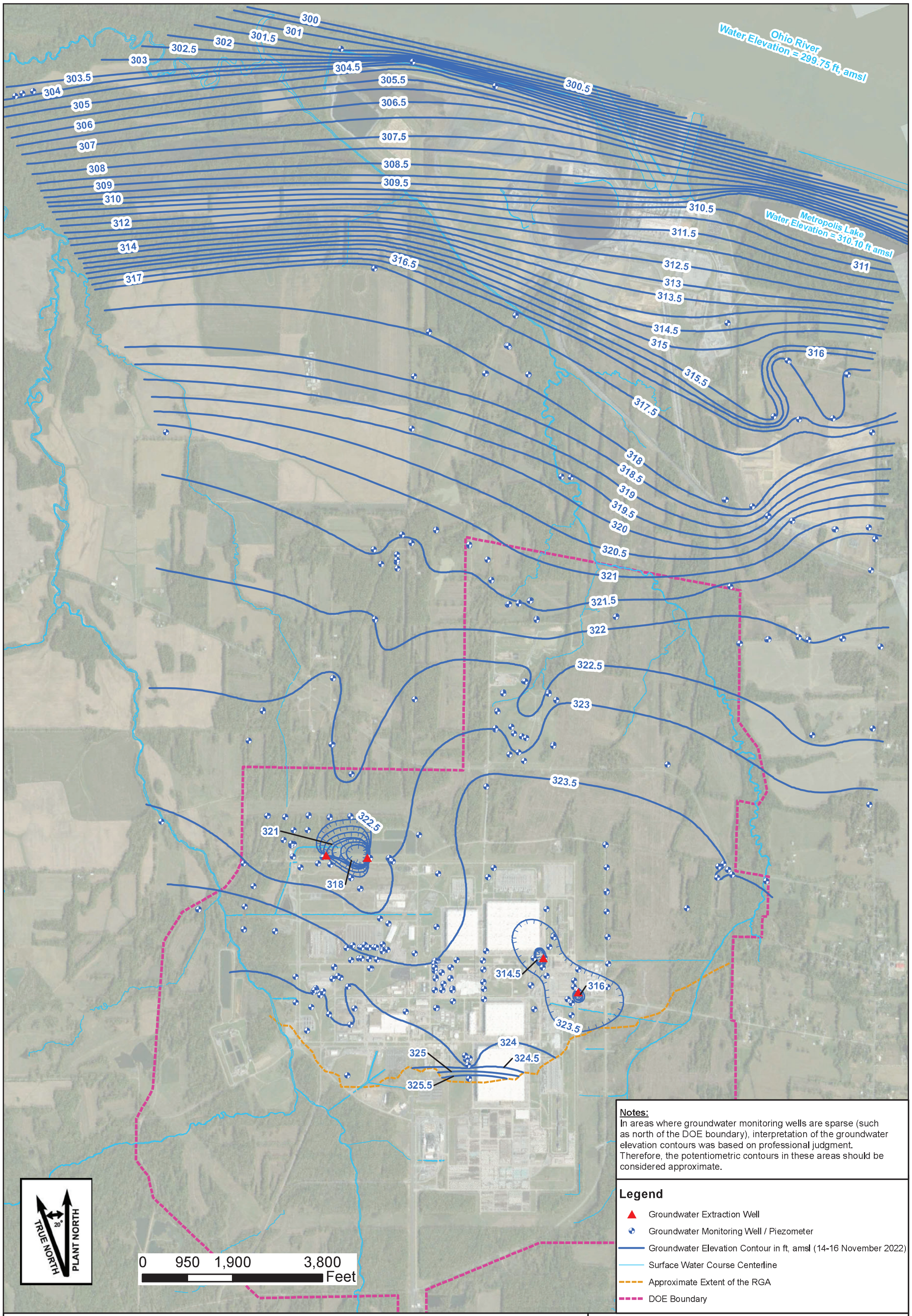
Attachment 1

Groundwater Strategy Potentiometric Map
November 2022



Notes:
In areas where groundwater monitoring wells are sparse (such as north of the DOE boundary), interpretation of the groundwater elevation contours was based on professional judgment. Therefore, the potentiometric contours in these areas should be considered approximate.

Legend

- ▲ Groundwater Extraction Well
- ● Groundwater Monitoring Well / Piezometer
- — Groundwater Elevation Contour in ft, amsl (14-16 November 2022)
- — Surface Water Course Centerline
- - - Approximate Extent of the RGA
- - - DOE Boundary

MAP SOURCE INFORMATION

Map Generation Date and Location - 1/27/2023 Geosyntec\\fedprojects-01\paducah$\Knoxville\GW Strategy\GIS\MXDs\2021-2022 Potentiometric Surface Maps
Map Layer Location: Geosyntec\\fedprojects-01\paducah$\Knoxville\GW Strategy\GIS\MXDs\2021-2022 Potentiometric Surface Maps\November 2022 Potentiometric Surface Map.mxd
Image Source: Aerial 2021: http://pegasis.pad.pppo.gov:6080/arcgis/services; and
Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.
Shapefile for Surface Water Course Centerline provided by FRNP on 11/8/2022.
DOE Property Boundary provided by FRNP on 2/4/2021.
Northing and easting of wells obtained from Pegasis, downloaded on 6/14/2022.
Groundwater elevation was based on the 11/14/2022 - 11/16/2022 measurements. Ohio River elevation was estimated as the average of elevations measured by the USGS at Paducah Station USGS 0361100 and Olmsted, IL Station (USGS 03612600) between 11/14/2022 - 11/16/2022.
Groundwater elevation for the TVA wells were provided by the Kentucky Division of Waste Management on 11/22/22. Water elevation at Metropolis Lake was provided by FRNP on 11/15/2022.
Due to erroneous measurement of depth to groundwater in EW235 on 11/14/2022, measurement from 11/21/2022 was used to prepare this map.
amsl = above mean sea level

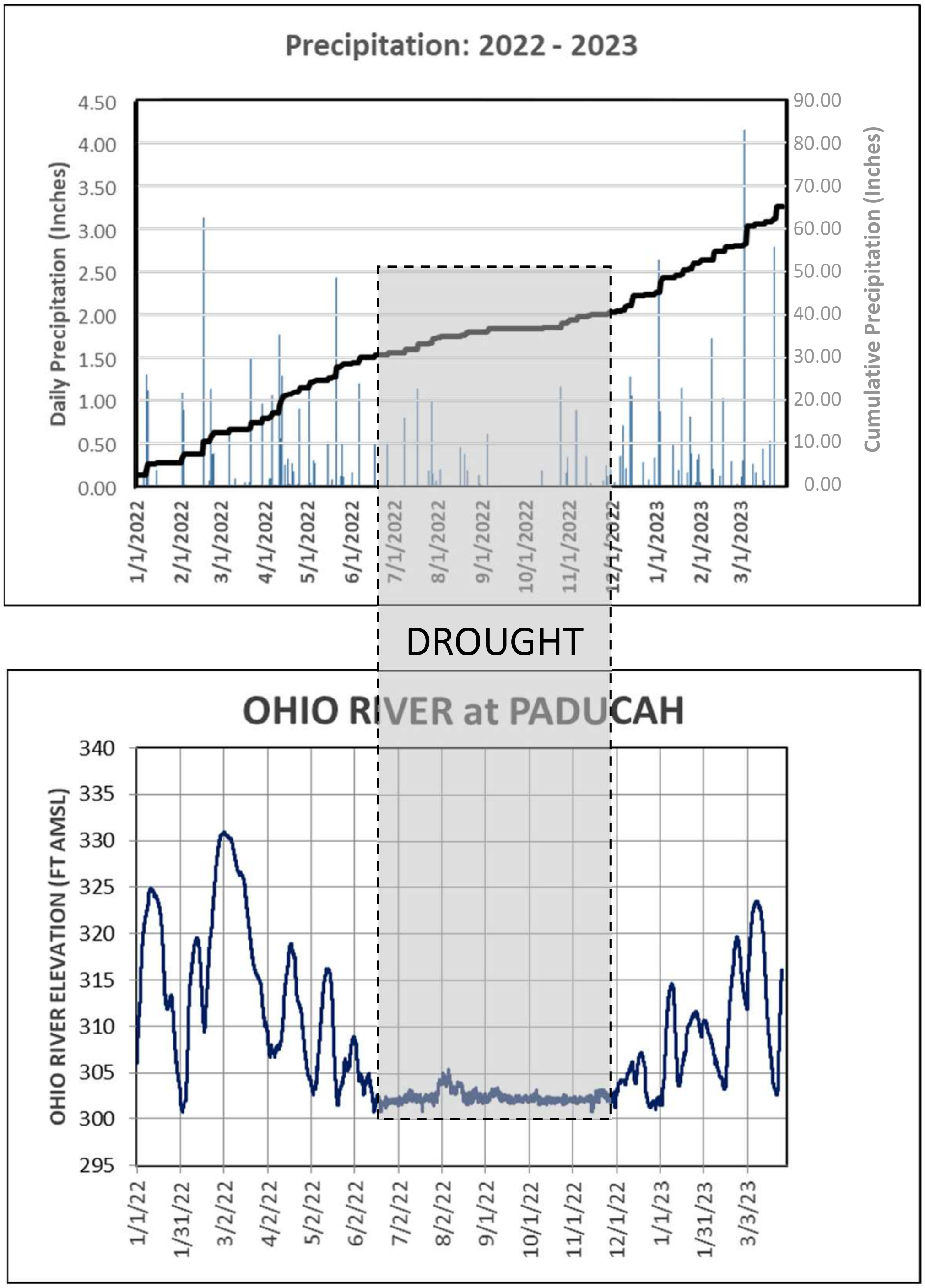
U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

FOUR RIVERS NUCLEAR PARTNERSHIP, LLC

Figure 1. November 2022 RGA Potentiometric Surface Map

Attachment 2

Precipitation and Ohio River Stage Data


Precipitation: 2022 - 2023
Daily Precipitation (Inches)
Cumulative Precipitation (Inches)
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
1/1/2022
2/1/2022
3/1/2022
4/1/2022
5/1/2022
6/1/2022
7/1/2022
8/1/2022
9/1/2022
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11/1/2022
12/1/2022
1/1/2023
2/1/2023
3/1/2023
DROUGHT
OHIO RIVER at PADUCAH
OHIO RIVER ELEVATION (FT AMSL)
340
335
330
325
320
315
310
305
300
295
1/1/22
1/31/22
3/2/22
4/2/22
5/2/22
6/2/22
7/2/22
8/2/22
9/1/22
10/1/22
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3/3/23

APPENDIX D

GROUNDWATER MODELING WORKING GROUP MEETING SUMMARY—JULY 19, 2023

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Paducah Site Groundwater Modeling Working Group
Meeting Summary—July 19, 2023

MWG Attendees:

DOE
Rich Bonczek ✓
Brian Looney (SRNL) ✓

ETAS
Martin Clauberg ✓
Bruce Stearns ✓
Tracy Taylor ✓

KRCEE
Steve Hampson ✓
Alan Fryer ✓

TVA
Tabitha Ester ✓
Anna Fisher
Dominic Norman
Jeffrey Frazier ✓

EPA and Contractors
Noman Ahsanuzzaman
Ben Bentkowski ✓
Eva Davis ✓
Jonathan Dziekan ✓
Mac McRae ✓
Victor Weeks ✓

Kentucky
Brian Begley ✓
Stephanie Brock
Mary Evans ✓
Nathan Garner ✓
Will Grasch ✓
Brian Lainhart
Todd Mullins ✓
Bart Schaffer ✓
Chris Travis
Elizabeth Walton ✓

FRNP
Evan Clark ✓
Bryan Clayton ✓
Sarah Cronk ✓
Ken Davis ✓
Rob Flynn
Bruce Ford ✓
Stefanie Fountain ✓
Josue Gallegos
LeAnne Garner ✓
Jeffrey King ✓
Bruce Meadows
Allison Millspargh ✓
Todd Powers ✓
Denise Tripp ✓
Corey Wallace ✓
Dawit Yifru ✓

WSP
Joe Ricker (WSP) ✓
David Winchell (WSP) ✓

✓ Indicates the Attendee was present

Original meeting agenda items are provided followed by meeting notes; the meeting notes are provided in italics with action items noted in green. Additions or revisions to the agenda items are noted in [].

1. Call for Issues from Groundwater Modeling Working Group (MWG) Members

No comments were received to the April 5, 2023 Meeting Summary (sent to participants on 5/23/2023). This summary will be considered final.

No comments were received to the April 5, 2023 Meeting Summary. During the meeting, Victor Weeks (EPA) mentioned 3rd party review of the site-wide model report, which was agreed to be addressed in a later section of this July 19, 2023 Meeting Summary. The meeting summary for the April 5, 2023 Meeting is now final.

Participants were requested to confirm or revise their meeting participant lists.

2. Draft FY 2023 Work Plan/Schedule

Activity	Date
~~Provide Draft Agenda Including FY 2023 Work Plan/Schedule (October/FY23Q1) to MWG~~	~~9/28/2022~~
~~Quarterly Meeting (October/FY23Q1)~~	~~10/5/2022~~
~~Submit Final Lithologic Technical Paper to EPA and KY~~	~~10/7/2022~~
~~Provide Olmsted Dam White Paper to MWG for Review~~	~~10/19/2022~~
~~Submit Draft MWG Compilation (FY 2022) to MWG~~	~~1/5/2023~~ ~~Actual 12/21/2022~~
~~Submit "Assessment of Northwest Plume Capture at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky" (Capture White Paper) to MWG for Review~~	~~1/10/2023~~
~~Submit Final Lithologic Technical Paper to EPA and KY~~	~~1/13/2023~~
~~Submit Revised FY 2023 Work Plan (included in this summary)~~	~~1/18/2023~~ ~~Actual 2/13/2023~~
~~Quarterly Meeting (January/FY23Q2)~~	~~1/18/2023~~
~~MWG Provide Comments on Capture White Paper~~	~~1/27/2023~~ ~~(schedule tied to FYR)~~
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~~MWG Provide Comments on Draft MWG Compilation (FY 2022)~~	~~1/27/2023~~ ~~Actual 2/3/2023~~
~~Submit Draft TCE Degradation Rate White Paper to MWG~~	~~2/16/2023 (Planning Date)~~ ~~Actual 3/1/2023~~
~~Submit Final MWG Compilation (FY 2022)~~	~~3/2/2023~~ ~~Actual 2/13/2023~~
~~MWG Provide Comments on Draft TCE Degradation Rate White Paper~~	~~4/7/2023~~ ~~(Previously 3/23/2023)~~
~~Quarterly Meeting (April/FY23Q3)~~	~~4/5/2023~~
Quarterly Meeting (July/FY23Q4)	7/19/2023 (Previously 7/12/2023)
Provide Draft Agenda Including FY 2024 Work Plan/Schedule (October/FY24Q1) to MWG	9/27/2023

The date for the Quarterly Meeting (July/FY23Q4) was adjusted from 7/12/2023 to 7/19/2023.

The group discussed the following changes to the meeting participants listing:

- *Denise Tripp (Geosyntec/FRNP) is retiring in July.*
- *Brian Begley (KDEP) is retiring, but plans to continue working elsewhere.*
- *Steve Hampson (KRCEE) is reducing his role at KRCEE.*
- *Alan Fryer (KRCEE) will be increasing his participation in these meetings.*
- *Jeffrey King (Geosyntec/FRNP) was announced as the new Senior Modeler.*

3. Draft FY 2023+ Work Plan/Schedule

Activity	Date
Quarterly Meeting (October/FY24Q1)	10/4/2023 (Planning date)

The group did not have any commnets on the schedule.

4. Update on Water Levels

Synoptic water level events are being collected quarterly. The potentiometric map for the synoptic water level event for March 27-30, 2023 is included in Attachment 1. March 2023 groundwater elevation data for TVA wells collected by KY are also included in Attachment 1. Potentiometric maps will be included in the annual MWG compendia.

The group did not have comments on the update for water levels and the potentiometric map.

5. Update on Paducah Site Groundwater Strategy

The GWSP is a multi-year plan with multiple activities planned. The specific timing and scope of each activity are developed by DOE based on data collected in the prior year(s).

The overall objective for the Groundwater Strategy Project (GWSP) is to develop a groundwater strategy that closes out various issues for the site:

- Change status of two Environmental Indicator (EI) Performance Measures to "Yes"
    - Human exposure under control
    - Groundwater migration under control
- Resolution of data needs
- Groundwater Modeling Working Group (MWG) recommended [model] maintenance and updates

Attachment 2 includes background information on EIs for the Paducah Site. During the April 5, 2023 meeting, KY requested the group discuss the GWSP to ensure progress is being made and data gaps are being addressed in a way that will facilitate closure of the EIs. There are multiple white papers in progress and the 2022 plume map update has been finalized and provided to the MWG on July 12, 2023.

FRNP discussed there are multiple white papers planned for FY2023 and the FY2024 PMP is in development.

DOE requested the group review the EIs in advance of a discussion during the October meeting. EPA noted they will review and provide information on what is needed to close actions related to EIs. DOE discussed that the vapor intrusion studies resolve the human health component of the EIs. KY discussed MW463/MW464 and the Northeast Plume and extent to west and noted odd observations of outlier concentrations west of the Northwest Plume. KY also discussed the potential for a pumping well in the C-400 vicinity.

Water Line Leaks. FRNP and KY continue to develop information related to the leak in the main raw water line from the Ohio River to the site. The location of the water line leak along Water Line Road about a mile from the creek crossing. Repairs to the line and backfilling of the holes are in progress.

The group did not have any updates on the water line leaks or repairs but agreed to keep this topic on the agenda.

Seeps. There have been no seep results above the maximum concentration limit (MCL) for trichloroethene (TCE) for many years. LBCSP5 routinely has flow and is able to be sampled, whereas many of the other previously identified seeps do not have flow consistently.

KRCEE has a task (contingent on funding) to look at seeps using a drone equipped with FLIR (Forward Looking InfraRed). The project will look at other project sites then apply what is learned to the Paducah site. The project intends to provide a proof-of-concept and an understanding of whether the seeps have or have not shifted. The drones will be tied to GPS, potentially also with LiDAR.

KRCEE FY2024 proposal(s) are due to DOE and DOE plans to have grants in place by October. KRCEE is reviewing associated equipment capabilities for seeps identification, including hand held meters and fiber optic. Physical access and determining temperature gauging/gradients are also being evaluated.

KY discussed the TVA Sheet Pile wall in this regard, stating that the assumption is that there is an "expected change with the sheet pile wall that TVA put in where portions of it appear to either cut off part of the RGA or severely diminish the ability to flow through there, so the thought is that that water would back up and try to find outlets from that bank into the creek.." KY also described physical access using temperature readings to find locations of seeps and testing those for TCE (see also Agenda Item 11, Watch Topics, TVA Changes).

KRCEE noted a drone has been purchased but there are concerns with flying the drone below the tree canopy. A test flight is scheduled for September.

"No Go" Areas for Monitoring Well Installations. The topic is retained, but restructured to provide a look-ahead at planned or potential changes rather than a backward look at changes. Several standing questions on this topic will be developed and included in future MWG meeting agendas.

- **Planned site activities with potential to impact Monitoring Well Installations?** None known at this time. Reprioritization of remedial projects is being considered by the FFA parties.
- **Applicable Quarterly Kentucky Department Fish & Wildlife Resources (KDFWR) meeting discussions?**
    - Meetings held 3/15/2023 and 5/3/2023. The next meeting is scheduled for 8/2/2023. Discussion topics included:
        - AOC 112 (a berm/dam for a fish pond in the WKWMA)
        - AOC 113 (the rubble pile near the iron bridge in the WKWMA)
    - KDFWR is aware that the site is repairing the leaks in the raw water line and will backfill the holes created by the leaks.

- **Have any changes to the "No Go" Areas map occurred since the last meeting or map revision?** None known at this time.

The group discussed that the AOC 113 rubble pile/bank near the iron bridge has washed out. FRNP and the FFA members are discussing a proposal to remove the rubble pile as a maintenance action.

Sitewide Groundwater Model Update. The overarching goal of the model update is to develop a model to support remedial decision making. The update to the Paducah Site groundwater is in progress and the draft report has been submitted to DOE for review and responses to comments are in progress. KRCEE and Savannah River National Laboratory (SRNL) have also reviewed the model and report and have provided their feedback.

Review and "approval" or "acknowledgement" of the model will be discussed with the MWG. A meeting to brief the MWG will be scheduled and held before the model is sent to the MWG for review.

At the time of the meeting, the D1 report was expected by the end of July or early August, with a briefing to follow. EPA noted it plans to acknowledge and accept the Sitewide Groundwater Model Update. EPA requested that the external reviewer comments be shared as part of the deliverable to EPA and KY.

6. Anthropogenic Recharge

This sub-topic will capture discussion on site changes, such as the recent changes to the high pressure fire water system. Development of a timeline to track changes to site operations that could impact the water balance at the site (e.g., removal of the high pressure fire water line from service, removal of the second raw water line from service, etc.) is being maintained. A water balance study is included as an appendix to the 2023 modeling report.

K. Davis noted that the intake water volume was historically around 4 million gallons per day (mgd) and is now closer to 1 mgd as shown in the water balance study.

7. Plant-Wide Seismic Update

DOE and FRNP periodically review whether there are any ways to further reduce (temporarily) sources of noise to facilitate new testing without disrupting site activities. Seismic investigation is not currently a project (either DOE or KRCEE).

There was no evidence of faulting encountered during the C-400 remedial investigation. Kentucky Geological Survey (KGS) is working on regional compilation of seismic data focused on extents of the New Madrid centroid and on the northwest leg along the Mississippi River and that KGS plans to generate a report this year to summarize information compiled to date. KRCEE/KGS is updating some testing equipment.

The Waste Disposal Alternatives project is being considered by the FFA parties for early implementation and that the candidate siting may be revisited. Prior discussions on seismic evaluation for siting an on-site waste disposal facility (OSWDF) concluded adequate information existed for a

Remedial Investigation/Feasibility Study, but that additional seismic evaluation would be needed for actual siting of an OSWDF.

The group did not have comments on this topic.

8. Precipitation and Ohio River Stage

Attachment 3 includes precipitation and Ohio River stage charts through mid-May 2023.

The group discussed that the Ohio River stage is at base level and the rainfall had been at an average level until week of July 19, 2023.

9. Synoptic Water Level Events and Ohio River Levels

The location where the creeks shift from gaining to losing may impact the flow model (although the model is not very sensitive to this parameter) and is an area of interest to the group going forward. Dr. Alan Fryar will be invited to attend these meetings starting in October to discuss this study and any future similar studies.

There were not additional comments from the group on this topic. Dr. Fryar has been added to the distribution for this group and was in attendance at this meeting.

10. 2022 Plume Map Document Update

The 2022 update to the Plume Map Document has been finalized and provided to the MWG on July 12, 2023.

The group discussed high concentration plume separation as delineated using new data from the C-400 RI.

11. Projects on the "Watch Topics" List

- **TVA Changes.** TVA has completed construction of a 3,800 ft sheet pile wall in close proximity to Little Bayou Creek and several seeps in December 2021. The wall is intended to stabilize the creek's bank, as opposed to control groundwater. Based on the information available in the TVA drawings, the sheet pile wall extends a significant depth into the RGA. The wall joints are not sealed, and the sheet piles themselves are solid (not perforated).

  TVA has compiled and reviewed available data to support their groundwater model update, which is planned to be performed in 2023. TVA has provided to FRNP relevant as-built information and boring logs.

  TVA provided details on TVA cutoff wall, specifically that the wall is not as deep as originally thought. The group will reevaluate the influence of the wall on controlling groundwater.

- **Emerging Contaminants**
  - PFAS

- PFAS is discussed as part of the Risk Assessment Working Group and has ties to this working group as well.
- The Paducah Site continues to participate in the DOE HQ PFAS Working Group Meetings.
    - The PFAS Coordinating Committee last met on July 12, 2023.
    - The DOE HQ PFAS Working Group last met on June 1, 2023. The next meeting is scheduled for August 3, 2023.
    - The DOE Preliminary Assessment was released in late November and the template for the annual assessment update is being finalized. An update to the Preliminary Assessment is planned for first quarter FY2024.
    - The preliminary assessment (PA) guidance (Guide for Investigating Historical and Current Uses of Per-and Polyfluoroalkyl Substances at Department of Energy Sites) is final and available at: https://www.energy.gov/sites/default/files/2023-02/Final%20PFAS%20Investigation%20Guide%20Final%20%28002%29_0.pdf
    - The site provided comments on the DOE disposal guidance in May. The final version of this guidance should be available by August 2023.
    - The site provided comments on the DOE sampling guidance in May and June. This guidance should be final and available by the end of FY2023.
    - The site provided comments on a DOE LFRG guidance memo in March. The final version of the memo is expected by the end of July 2023.
- For Paducah, the main PFAS activity for 2023 is the in-progress PFAS screening assessment project. The final scope for the Site-wide PFAS Screening Assessment was included in the FY 2023 Environmental Monitoring Plan and is in the process of being update as discussed during the Routine Paducah Groundwater Update calls
    - Potable water samples were collected in November 2022 and January 2023 and results are being verified. The January 2023 samples were collected based on a question on the potential for cross-contamination of samples derived from clothing or products worn by the samplers.
    - Sampling is planned to be completed this fiscal year with a technical report available to the MWG in the second quarter of FY2024.
    - Environmental sampling began on March 20, 2023. Status as of 7/9/2023:

Sample Type and Planned Month	Planned	Sampled	% Complete
MWs (April-August)	191	77	40%
Drinking Water (Complete)	5	5	100%
Surface Water (May)	16	10	63%
Treated Wastewater (May)	1	0	0%
Leachate (TBD)	3	3	33%
GW and Treated GW (TBD)	6	0	0%
Total	**222**	**95**	**43%**

The group discussed several PFAS updates from the last week including:

- *Final release of the Historical Review Guidance,*
- *Publication on the DOE website of Disposal Guidance*

The final Sampling Guidance is expected to be available in several weeks (published on the DOE website following the meeting). The DOE LFRG disposal memorandum is final and awaiting signatures. There is no information in this memo on Subtitle D disposal of PFAS because the DOE LFRG regulates DOE Order 435.1 (as opposed to DOE Order 458.1). This memo is most applicable to the Portsmouth site now, but will be considered for the proposed on-site waste disposal facility (OSWDF) at Paducah.

The schedule of post-sampling activities will be added to the next meeting agenda.

- 1,4-Dioxane
  - 1,4-dioxane was historically used as a stabilizer in 1,1,1-trichloroethane and dichloroethane.
  - The group plans to discuss fate & transport characteristics of 1,4-dioxane (compared to TCE) during a MWG meeting in FY2024.

The group discussed the recent New York regulation on 1,4-Dioxane and use restrictions regarding detergents. It was also noted that at Paducah only scattered detections have been observed. The current groundwater treatment systems do not include treatment units to address 1,4-dioxane.

12. Meeting Presentations

FY 2023 Presentations:

- July 2023: Summary of EarthCon (now WSP) 2016 plume stability analysis and plans for 2023 plume stability analysis. The presentation file is provided separately.

MWG members should provide any presentation requests to Stefanie. Potential topics for future meetings:

- Environmental Indicator analyses
- C-400 Complex remedial investigation
- Lithology
- TCE degradation rates
- Site water balance items (e.g., leaks from piping, above and below ground piping, building foundation gravel layers, etc.)
- Summary of WSP 2023 plume stability analysis
- Groundwater model updates
- Topics from the Site Management Plan

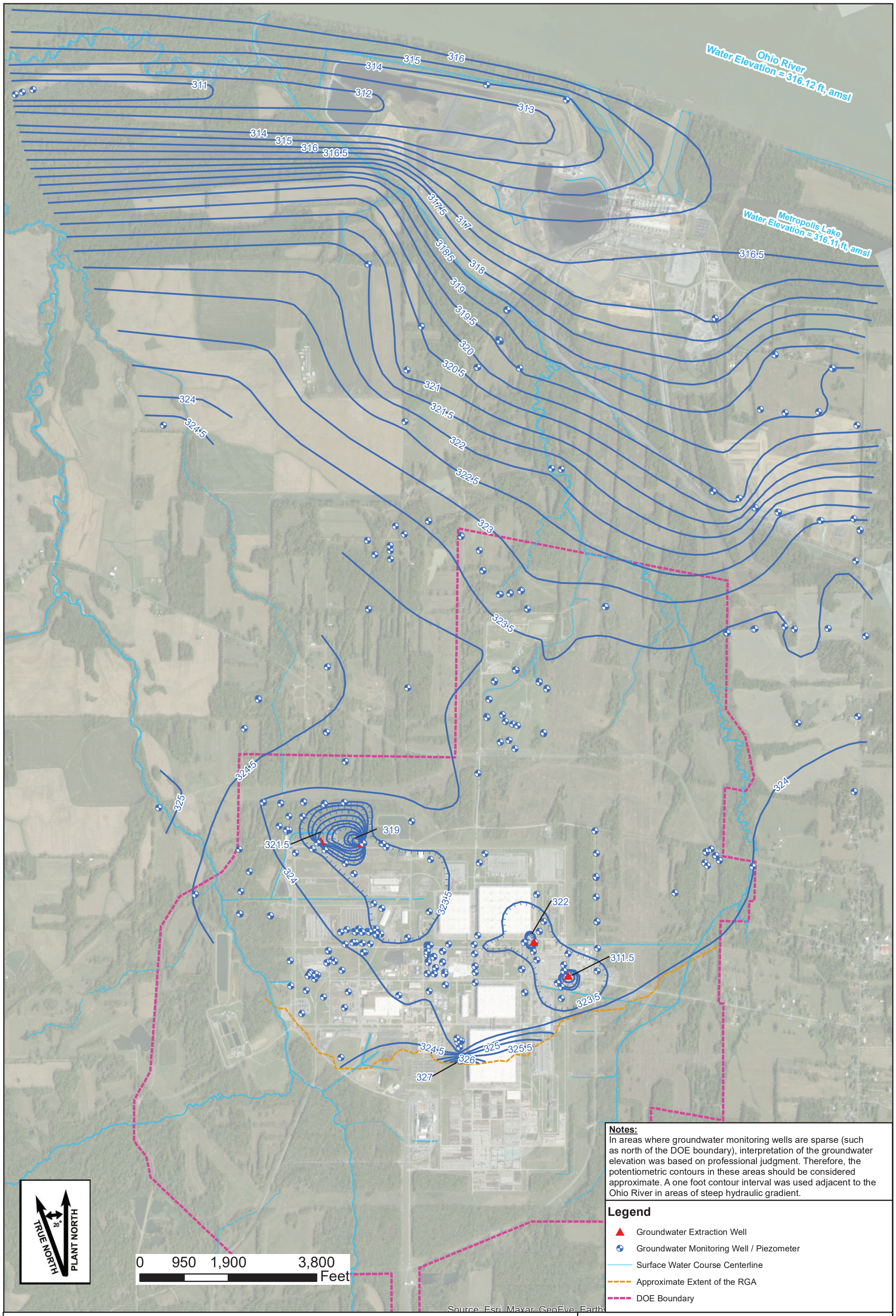
For the next meeting, a discussion of the Site Management Plan (SMP) discussion will be added to the agenda.

13. Poll MWG Members/Open Discussion

Attachment 1

Groundwater Strategy Potentiometric Map
March 2023

Groundwater Elevation Data for TVA Wells
March 2023



Notes:
In areas where groundwater monitoring wells are sparse (such as north of the DOE boundary), interpretation of the groundwater elevation was based on professional judgment. Therefore, the potentiometric contours in these areas should be considered approximate. A one foot contour interval was used adjacent to the Ohio River in areas of steep hydraulic gradient.

Legend

- ▲ Groundwater Extraction Well
- ● Groundwater Monitoring Well / Piezometer
- — Surface Water Course Centerline
- - - Approximate Extent of the RGA
- - - DOE Boundary

MAP SOURCE INFORMATION

Map Generation Date and Location - 5/15/2023 Geosyntec\\fedprojects-01\paducah$\Knoxville\GW Strategy\GIS\MXDs\2022-2023 Potentiometric Surface Maps
Map Layer Location: Geosyntec\\fedprojects-01\paducah$\Knoxville\GW Strategy\GIS\MXDs\2022-2023 Potentiometric Surface Maps\March 2023 Potentiometric Surface Map_05152023.mxd
Image Source: Aerial 2021: http://pegasis.pad.pppo.gov:6080/arcgis/services; and
Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.
Shapefile for Surface Water Course Centerline provided by FRNP on 11/8/2022.
DOE Property Boundary provided by FRNP on 2/4/2021.
Northing and easting of wells obtained from Pegasis, downloaded on 6/14/2022.
Groundwater elevation was based on the 3/27/2023 - 3/30/2023 measurements. Ohio River elevation was estimated as the average of elevations measured by the USGS at Paducah Station USGS 0361100 and Olmsted, IL Station (USGS 03612600) between 03/27/2023 - 03/30/2023.
Groundwater elevation for the TVA wells were provided by the Kentucky Division of Waste Management on 4/7/2023. Water elevation at Metropolis Lake was provided by FRNP on 4/4/2023.
amsl = above mean sea level

U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

FOUR RIVERS
NUCLEAR PARTNERSHIP, LLC

Figure 1. March 2023 RGA Potentiometric Surface Map

OREIS Name	Well	Description	Aquifer	Top of Casing	Top of Ground	xconv Easting (Ft)	yconv Northing (Ft)	Status	Screen Top Depth (Ft)	Screen Bot Depth (Ft)	tscreenelev (Ft)	bscreenelev (Ft)	GW Elev. (Datum - DTW)	Water Level	Date & Time	Barometric Pressure (inHg)	Measuring Point
TVAGW-6D	TVAGW-6D	4" PVC	Upper RGA	372.77	369.38	760787.88	1946731.54	Active	65.2	75.2	307.57	297.57	319.86	52.91	3/28/2023_1020	30.26	TOC
TVAGW-5D	TVAGW-5D	4" PVC	Upper RGA	372.55	369.14	760131.63	1947315.95	Active	66.9	76.9	305.65	295.65	319.55	53	3/28/2023_1025	30.26	TOC
TVAGW-4D	TVAGW-4D	4" PVC	Upper RGA	369.26	365.84	759456.72	1947561.73	Active	63.3	73.3	305.96	295.96	309.51	59.75	3/28/2023_1027	30.26	TOC
TVAGW-3D	TVAGW-3D	4" PVC	Upper RGA	366.9	363.42	758982.49	1947793.86	Active	71.3	81.3	295.6	285.6	319.42	47.48	3/28/2023_1033	30.26	TOC
TVAGW-2D	TVAGW-2D	4" PVC	Upper RGA	372.82	369.24	759966.78	1944870.47	Active	61.2	71.2	311.62	301.62	322.96	49.86	3/28/2023_1015	30.26	TOC
TVAGW-1D	TVAGW-1D	4" PVC	Upper RGA	374.94	371.56	757847.05	1946203.79	Active	63.4	73.4	311.54	301.54	319.67	55.27	3/28/2023_1039	30.26	TOC
TVA-D74B	SHF-D74B	2" PVC	Upper RGA	332.16	329	756125.35	1956489.82	Active	42.3	52.3	289.86	279.86	313.69	18.47	3/28/2023_1133	30.28	TOC
TVA-D30B	SHF-D30B	2" PVC	Upper RGA	324.36	320.6	757594	1955563.41	Active	42.7	52.7	281.66	271.66	313.28	11.08	3/28/2023_1123	30.28	TOC
TVA-D17	SHF-D17	2" PVC	Upper RGA	365.43	362.8	758809.17	1950015.71	Active	14	17	351.43	348.43	316.88	48.55	3/28/2023_1145	30.28	TOC
SHF-201C	SHF-201C	4" PVC	Upper RGA	323.75	320	746799.24	1960068.889	Active	44.5	54.5	279.25	269.25	310.7	13.05	3/28/2023_0950	30.26	TOC
SHF-201B	SHF-201B	4" PVC	Upper RGA	323.75	320.2	746641.107	1960082.768	Active	32	37	291.75	286.75	310.75	13	3/28/2023_0951	30.26	TOC
SHF-201A	SHF-201A	4" PVC	Upper RGA	323.75	320	747030.226	1960036.252	Active	14.5	24.5	309.25	299.25	310.65	13.1	3/28/2023_0952	30.26	TOC
SHF-102G	SHF-102G	4" PVC	Upper RGA	362.85	359.1	845764.387	1927473.284	Active	47.1	57.4	315.75	305.45	320.83	42.02	3/28/2023_1000	30.26	TOC
Ohio River Elevation						831.9815	14996.63							317.14	3/28/2023_1200	30.28	TVA Inlet

LEGEND:

TOC: Top of Casing

DTW: Depth to Water

National Geodetic Vertical Datum of 1929 (NGVD 29).

Attachment 2

Environmental Indicator Information

- KDEP letter dated 8/27/2007: Environmental Indicators, Paducah Gaseous Diffusion Plant, Paducah, Kentucky (DOE/LX/07-0004&D1), McCracken County, Kentucky, KY8-890-008-982. (10 pages)

- DOE letter dated 4/1/2008: Response to Proposed Actions for Environmental Indication Reclassification for the Paducah Gaseous Diffusion Plant (4 pages)

- KDEP letter dated 11/7/2008: EI Memo Update for DOE Paducah Gaseous Diffusion Plant, Paducah, Kentucky, McCracken County, Kentucky, KY8-890-008-982. (18 pages)

- Environmental Indicators (as of April 1, 2010) (1 page)

- EPA letter dated 9/20/2018: EPA Comments: Community Relations Plan under the Federal Facility Agreement at the U.S. Department of Energy Paducah Gaseous Diffusion Plant, Paducah, Kentucky, (DOE/LX/07-2413&D1), Primary Document, transmittal dated June 26, 2018 (PPPO-02-4930994-18A) (9 pages)

- EPA letter dated 12/11/2018: EPA Approval: Community Relations Plan under the Federal Facility Agreement at the U.S. Department of Energy Paducah Gaseous Diffusion Plant, Paducah, Kentucky, (DOE/LX/07-2413&D2), transmittal dated November 20, 2018 (PPPO-02-5278854-19A). (5 pages)

- Environmental Indicators - Frequent Questions (8 pages)

FACSIMILE TRANSMITTAL

KENTUCKY HAZARDOUS WASTE BRANCH
14 Reilly Road
Frankfort, Kentucky 40601
Phone: (502) 564-6716
Fax: (502) 564-2705

To: Rob Seifert

Fax #:

From: Todd Mullins

Date: 9/5/07

Subject: EI PATH FORWARD

Pages Including This Cover Sheet: 10

For Verification, Call (502) 564-6716, And Ask For

Comments:

Rob,

This letter was signed prior to our learning that DOE wanted to change NSDD sign language. We are still open to the proposed language change

TODD

ERNIE FLETCHER
GOVERNOR

ENVIRONMENTAL AND PUBLIC PROTECTION CABINET
DEPARTMENT FOR ENVIRONMENTAL PROTECTION
DIVISION OF WASTE MANAGEMENT
HAZARDOUS WASTE BRANCH
14 REILLY ROAD
FRANKFORT, KENTUCKY 40601
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LAJUANA S. WILCHER
SECRETARY

August 27, 2007

Mr. William E. Murphie, Manager
US Department of Energy
Portsmouth/ Paducah Project Office
PO Box 1410
Paducah KY 42002

Mr. Russ Boyd, Paducah Manager of Projects
Paducah Remediation Services LLC
101 Liberty Drive, Suite #3
Kevil KY 42053

RE: Environmental Indicators
Paducah Gaseous Diffusion Plant, Paducah, Kentucky (DOE/LX/07-0004&D1)
McCracken County, Kentucky
KY8-890-008-982

Gentlemen:

In a recent FFA manager's meeting, Kentucky's FFA manager committed to providing the lead agency with the necessary steps they should take to receive a "Yes" with regard to the GPRA milestone of having Human Health Exposures Under Control. Please find attached these steps.

If you have any questions or require additional information, please contact Mike Guffey at (502) 564-6716.

Sincerely,

Bill Schneider

for April J. Webb, P.E., Manager
Hazardous Waste Branch

AJW: jmg;ew;gtm;kr

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edward.winner@ky.gov
john.morgan@prs-llc.net
DOE Reading File/ DWM File #5000

DOE Path Forward to Achieving 'YES' for EI

1. Place signage along Little Bayou Creek, including a small defined stretch of Bayou Creek and along Section 5 of the North South Diversion Ditch in accordance with criteria as set forth in Attachment A.
   - Criteria in Attachment
     - i. Map presenting sign placement
     - ii. Sign language
     - iii. Maintenance plan for signs per Fish and Wildlife

2. Stay on track with Site Evaluations in accordance w/ February 2007 letter and the schedules attached to the subject letter.

3. Submit an acceptable white paper (including a flow chart) for review by EPA Region 4 and KDWM that describes the uncertainties in non-worker exposures associated with the entire PDGP property including property leased or licensed to Fish and Wildlife known generally as the Western Kentucky Wildlife Area (WKWMA). The submittal should be easily understood by the various stakeholders and present the lead agency's case on reducing uncertainty with regard to any as yet to be discovered areas and provide a decision tree for any necessary early removal actions required to address risks found that exceeds the 10^{-4} threshold.

4. Provide an enforceable commitment and discussion of necessary scope of work (acceptable to the parties of the FFA) under the Site Management Plan for a work plan and report that fulfills the requirements of Part IX of the FFA and by inclusion Conditions T-216, T-217, T-218 and T-219 under Part IV. of the hazardous waste permit, with respect to discoveries of previously unaccounted for areas of contamination. The work plan shall consider all reasonable means to discover unknown areas of contamination. Tools such as field investigations, environmental audits, surveillance walkovers, fly-over surveys (singly or in combination) shall be given full consideration.

Attachment A

Posting of Signs Along Bayou and Little Bayou Creeks
and Along Section 5 of the North South Diversion Ditch

Significant uncertainty exists regarding the levels of contamination currently present in Little Bayou and Bayou creeks. In addition, offsite portions of Section 5 of the North South Diversion Ditch (NSDD) have recently been shown to be contaminated. Various site related contaminants have been detected above background and at levels in excess of site-specific risk-based numbers (action and no-action levels for the child recreator - wading) in soils and sediments associated with the creeks and ditch.

As a condition of granting DOE a GPRA EI determination of "YES" for Human Exposures Controlled, institutional controls in the form of signs must be placed along the creeks and along Section 5 of the NSDD at specific locations as explained in the attached instructions. These signs must remain in place until such time as sufficient analytical data exists, has been presented to the state, and has been accepted by the state as confirming that the risk levels are below an ELCR of 10^{-6} and the HIs are less than or equal to 1 as determined by a reasonable risk scenario agreed to by the state. Placement of signs along the creeks and ditch will insure, to the degree possible, that inadvertent human exposure to potentially harmful contamination does not occur.

DOE must place signs at all easily accessible points to the creeks (e.g., horse trail crossings or road intersections) and at 500 and 1000 foot intervals along those stretches of Little Bayou Creek located on privately owned, state, TVA or DOE leased property (see attached map and instructions). Only signs located along the deeply incised sections of Little Bayou Creek would be placed at 1000 foot intervals. All others must be placed at 500 foot intervals in order to increase the likelihood that they will be seen by recreational users attempting to cross the creek. Although the 1000 and 500 foot intervals should generally be adhered to, sign spacing will need to be somewhat flexible in order to insure that each sign is as visible as possible. No signs would be required on the Warren Smith property due to existing fencing that prevents creek access or along other stretches of the creeks or ditch that may be fenced. However, signs would become necessary if this fencing were to be removed or become severely damaged. Signage along Bayou Creek must be placed at the low-water crossing, at Ogden Landing Road/ Rossington Bridge and at up to seven (7) locations located near the northwest corner of the facility where horse trails cross the creek. The five signs to be located near the horse crossings would be placed at 500 foot intervals. Approximately three additional signs must be placed along Section 5 of the NSDD. Each sign location will need to be surveyed using GPS so that the signs can be easily located in the future.

Installation and maintenance of all signs will be the responsibility of the U.S. Department of Energy. Guidelines, if not already in place, must be established in order to prevent damage to habitat and/or crops by any vehicles required to access the sign locations. Periodic maintenance of all sign locations (e.g., mowing, weed eating, and/or herbicide treatment) will be necessary in order to help maintain sign visibility. A failure to maintain the areas surrounding the signs may result in a revocation of the "Yes" determination.

Each sign is to be double-sided in order to improve its visibility and must contain the U.S. Department of Energy insignia as well as a contact phone number. This phone number should be capable of receiving or recording requests for information 24 hours a day, 7 days a week. Signs should be large enough and of sufficient height so as to be visible from a distance. Similarly, sign coloring should be selected so as to insure that the signs stand out from the surrounding vegetation. Signs must display the following area dependent language:

For the North/South Diversion Ditch, Section 5:

"WARNING: The U.S. Federal Government has determined that this ditch is contaminated and should not be used for drinking, recreational, or fishing purposes. For more information, call (270) 441-5023."

For Bayou Creek:

"Sediments in this creek may be contaminated. Use of this waterway for drinking, swimming or other forms of recreation may expose you to unnecessary health risk. For more information, call (270) 441-5023."

For Little Bayou Creek:

"Sediments in this creek may be contaminated. Use of this waterway for drinking, fishing, swimming or other forms of recreation may expose you to unnecessary health risk. Do not eat fish caught in this body of water. For more information, call (270) 441-5023."

Locations for Signs (Double-Sided w/ DOE emblem) to be Placed Along Big Bayou Creek, Little Bayou Creek and Section 5 of the North South Diversion Ditch:

1. This location is at the intersection of Bayou Creek the Low Water Crossing. The sign should be placed just south of the creek and west of the access road and should face away from (and toward) the creek.

2. Two signs are to be located where the Rossington Bridge crosses Bayou Creek, one each end of the bridge. The signs should face north/south (toward and away from the road). The signs should be visible to those crossing the bridge by car.

3. This location is on the west side of Bayou Creek at the weir used for surface water sampling. Monitoring Well 194 is in close proximity. The location is near a tree that was flagged and marked with orange spray paint. Seven (7) signs should be placed using a 500 foot spacing beginning at this location and continuing to the south along the western stream bank. In addition, a single sign should be placed at the intersection of Bayou Creek and Transport Road. Signs located south of this intersection must be 500 feet distant from the last sign placed north of this location. All signs should face away from (and toward) the creek. The GPS coordinates (+/- 90 feet accuracy) for this location are as follows.

N 37° 07' 44.9"
W 088° 49' 34.1"

4. This location is on the west side of Little Bayou Creek (LBC) in Tract No. 9 of the Wildlife Management Area (WMA). Access to this location is by the gravel/dirt road that turns to the right (when heading north) off of the main WMA road. A large amount of concrete has been disposed of on the bank of the creek at this location and there is a corn field immediately to the south. The location is near a tree that was flagged and marked with orange spray paint. Beginning at this location and continuing to the south, signs must be spaced at 1000 foot intervals until the point that the addition of another sign would place this sign closer than 500 feet from the first of the LBC seeps (estimate of 6 signs required). All signs should face away from (and toward) the creek. The GPS coordinates (+/- 90 feet accuracy) for this location are as follows.

N 37° 09' 45.7"
W 088° 47' 51.4"

5. This location is on the southwest side of LBC downstream of the seeps. It is situated at an access point that allows someone to easily enter the creek. The two water supply pipelines for the PGDP are in close proximity. The location was flagged, but was not marked with orange spray paint. A single sign should be placed at this location. All signs located to the south of this location should be spaced at 500 foot intervals along the western creek bank. In addition to the other signs, a single sign should be placed at the intersection of LBC and Anderson Road (the ICM sign will suffice assuming it is to remain in place). Signs located south of this intersection must be 500 feet distant from the last sign placed north of this location. Signs should face away from (and toward) the creek. The GPS coordinates (+/- 90 feet accuracy) for this location are as follows.

N 37° 08' 58.7"
W 088° 47' 21.3"

6. This location is at the point where the gravel road located just to the north of the U Landfill crosses the North South Diversion Ditch (NSDD) beneath some large power lines. The location is near a piece of rock that was flagged and marked with orange spray paint. Appropriate signage should be placed along the western bank of the ditch beginning at this point and continuing to the north using 500 foot spacing until the confluence with LBC has been reached. A single sign utilizing the language selected for LBC should be placed at the confluence of the NSDD and LBC if there are no other signs located within 50 feet of this intersection. Signs located south of the confluence and along LBC must be 500 feet distant from the last sign placed north of this location. Signs should face away from (and toward) the NSDD. Any sign placed at the confluence of the ditch at LBC should face away from (and toward) the creek. The GPS coordinates (+/- 90 feet accuracy) for this location are as follows.

N 37° 07' 54.2"
W 088° 47' 33.0"

7. This sign is to be located at the point where Warren Smith's property ends on the west side of LBC and within the WMA. The location was a large wooden fence post that was flagged and marked with orange spray paint. The sign should face away from (and toward) the creek. The GPS coordinates (+/- 90 feet accuracy) for this location are as follows.

N 37° 07' 04.9"
W 088° 47' 07.4"

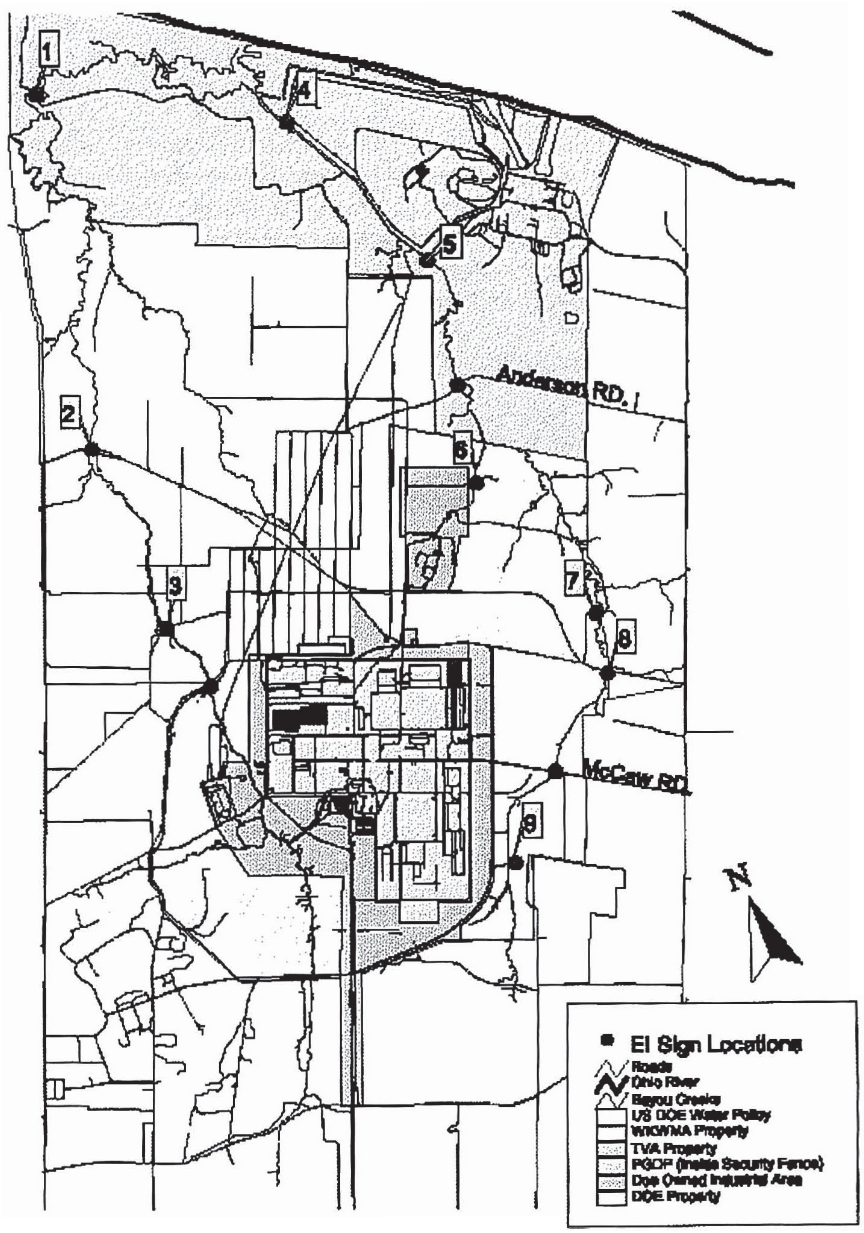
8. This sign is to be located at the point where Warren Smith's property begins on the west side of LBC and at Ogden Landing Road (north of the road). The location surveyed was a chain link fence post that was flagged and marked with orange spray paint. All signs located to the south of this position should be spaced at 500 foot intervals. However, a single sign should be placed at the intersection of LBC and McCaw Road (the ICM sign will suffice assuming it is to remain in place). The sign to be posted at the surveyed location should face toward Ogden Landing Road. The GPS coordinates (+/- 90 feet accuracy) for this location are as follows.

N 37° 06' 50.4"
W 088° 47' 11.5"

9. This location is at the confluence of the Outfall 013 ditch and LBC. The location is on the south side of the ditch near a tree that was flagged and marked with orange spray paint. A sign should be placed at this location only if there are no other signs located within 50 feet of this location. This sign should face away from (and toward) the creek. The GPS coordinates (+/- 90 feet accuracy) for this location are as follows.

N 37° 06' 09.3"
W 088° 48' 08.4"

EI SIGN LOCATIONS



Department of Energy

Portsmouth/Paducah Project Office
1017 Majestic Drive, Suite 200
Lexington, Kentucky 40513
(859) 219-4000

APR 01 2008

PPPO-02-130-08

Ms. April Webb, P.E., Manager
Hazardous Waste Branch
Division of Waste Management
Kentucky Department for Environmental Protection
14 Reilly Road
Frankfort Office Park
Frankfort, Kentucky 40601

Dear Ms. Webb:

RESPONSE TO PROPOSED ACTIONS FOR ENVIRONMENTAL INDICATOR RECLASSIFICATION FOR THE PADUCAH GASEOUS DIFFUSION PLANT

Reference: Letter to R. Knerr from A. Webb, "Environmental Indicators Paducah Gaseous Diffusion Plant, Paducah, Kentucky (DOE/LX/07-0004&D1), McCracken County, Kentucky, KY8-890-008-982," dated August 27, 2007

The U.S. Department of Energy (DOE) received your letter (Reference) outlining the conditions to be met for DOE to receive an Environmental Indicator of "Yes" with regard to the Government Performance and Results Act milestone of having human exposures under control.

DOE believes that actions have been taken to satisfy all four conditions outlined in your letter. DOE has reached agreement with Kentucky Division of Waste Management (KDWM), Kentucky Cabinet for Health Services and Tennessee Valley Authority on the language for signs that will be placed in specific locations (as designated in your letter) along Little Bayou Creek, Bayou Creek, and the North South Diversion Ditch (Condition 1). DOE has submitted sampling and analysis plans to KDWM and U.S. Environmental Protection Agency for review and/or approval in accordance with the schedule established for the soil and rubble pile investigations (Condition 2). Additionally, DOE has included a discussion and an enforceable milestone in the draft Fiscal Year 2008 Site Management Plan for the Scoping Survey Plan (Condition 4).

DOE is providing an annotated flow chart (Enclosure). The flowchart applies to newly identified areas of contamination that may be identified in the future on DOE-owned property licensed for use at the Paducah Gaseous Diffusion Plant, which are outside the controlled area and not currently assigned to an operable unit under the Federal Facility Agreement. The flowchart describes uncertainty management for non-worker exposures associated with DOE-owned property described above. DOE believes that the enclosure meets Condition 3. With your acceptance of our response, all conditions set forth in your letter are met.

If you have any questions or require additional information, please call Rob Seifert at (270) 441-6823.

Sincerely,

Reinhard Knerr
Paducah Site Lead
Portsmouth/Paducah Project Office

Enclosure:
Flow Chart

cc w/enclosure:
DCC/Kevil
EIC/PAD
R. Seifert, PPPO/PAD

e-copy w/enclosure:
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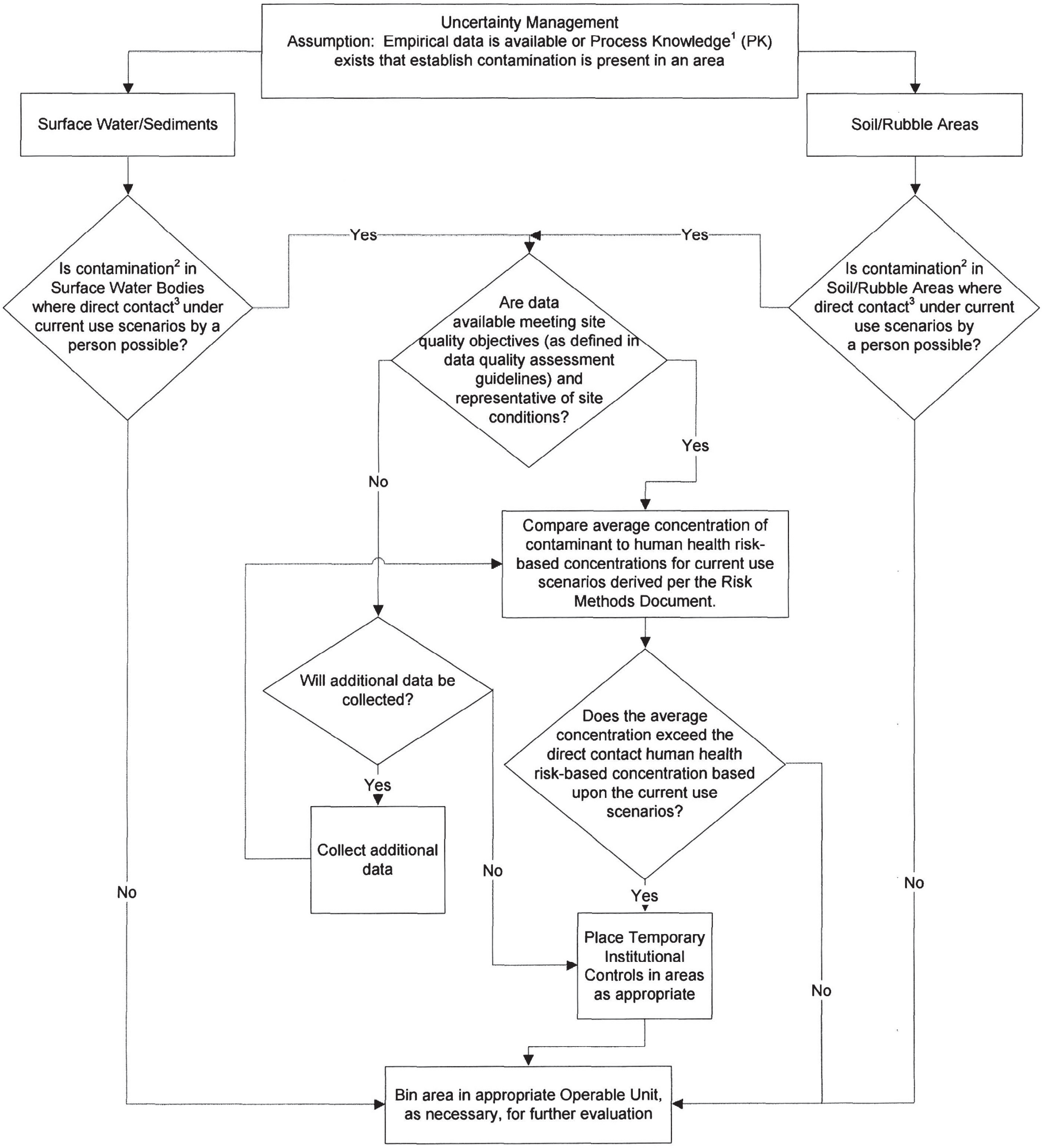
Enclosure

Flow Chart for Uncertainty Management

This flowchart applies to newly identified areas of contamination that may be identified in the future on DOE-owned property licensed for use at the Paducah Gaseous Diffusion Plant, which are outside the controlled area and not currently assigned to an operable unit under the federal Facility Agreement. The flowchart describes uncertainty management for non-worker exposures associated with DOE-owned property described above.



1 “Process Knowledge” is defined as information identifying releases from past or current processes at the PGDP.

2 “Contamination” is defined in the Risk Methods Document as the presence of a constituent at a concentration greater than background.

3 “Direct contact” is exposure by a human to environmental medium [i.e., surface soil, sediment, debris (e.g., rubble), and surface water] through ingestion, dermal contact, inhalation (particulates and vapors), or external exposure.

Enclosure
(Cont)
Further Explanation of Flow Chart Steps

Uncertainty Management Assumption: Empirical data is available or Process Knowledge[1] (PK) exists that establish contamination is present in an area	This flowchart applies to newly identified areas of contamination that may be identified in the future on DOE-owned property licensed for use at the Paducah Gaseous Diffusion Plant, which are outside the controlled area and not currently assigned to an operable unit under the federal Facility Agreement. The flowchart describes uncertainty management for non-worker exposures associated with DOE-owned property described above. Sufficient data or credible Process Knowledge must exist for this process to be activated.
Is contamination[2] in Surface Water Bodies or Soil/Rubble Areas where direct contact[3] under current use scenarios by a person possible?	Contamination definition is identified in Footnote 2. This process focuses on areas of surface soil, sediment, debris (e.g., rubble), and surface water that are located in the licensed area and available for direct contact exposure. Examples of exposure scenarios are riding horses or ATVs in the creek and bank areas, walking or hiking through wildlife habitat, or hunting.
Are data available meeting site quality objectives (as defined in data quality assessment guidelines) and representative of site conditions?	An evaluation of the available data will be performed to determine if data are of sufficient quality to be used for risk assessment. Additional data may be collected to determine appropriate protective actions.
Compare average concentration of contaminant to human health risk-based concentrations for current use scenarios derived per the Risk Methods Document.	Average concentrations from existing data will be compared to the human health risk-based concentrations. Risk-based concentrations used will be based on guidance in the current site Risk Methods Document.
Place Temporary Institutional Controls in areas as appropriate	Temporary institutional controls may vary depending on the nature of contamination. DOE may place temporary institutional controls under CERCLA, perform a maintenance action, or post under 10 *CFR* 835.
Bin area in appropriate Operable Unit, as necessary, for further evaluation	DOE, EPA, and KY will determine the appropriate Operable Unit under which the area may be placed for future evaluation in accordance with the FFA. These agencies will determine if immediate actions such as sampling or removal actions are warranted based on potential risk and exposure to the public.

ENERGY AND ENVIRONMENT CABINET

Steven L. Beshear
Governor

Leonard K. Peters
Secretary

Department for Environmental Protection
Division of Waste Management
200 Fair Oaks, 2nd Floor
Frankfort, Kentucky 40601-1190
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November 7, 2008

Mr. William E. Murphie, Manager
US Department of Energy
Portsmouth/Paducah Project Office
Post Office Box 1410
Paducah, KY 42002

Mr. Russ Boyd, Paducah Manager of Projects
Paducah Remediation Services LLC
101 Liberty Drive, Suite #3
Kevil, Kentucky 42053

RE: EI MEMO UPDATE FOR DOE PADUCAH GASEOUS DIFFUSION PLANT
Paducah Gaseous Diffusion Plant, Paducah, Kentucky
McCracken County, Kentucky
KY8-890-008-982

Gentlemen:

The Division of Waste Management recently completed a re-evaluation of its Environmental Indicators (EI) determination for the Paducah Gaseous Diffusion Plant. U.S. EPA has set a mandate for the states to periodically perform these determinations for sites undergoing environmental restoration. EIs are EPA defined interim milestones that contaminated sites should attempt meet in the near term if possible, prior to final cleanup. The two environmental indicators are "CA-725 - Current Human Exposures Controlled" and "CA-750 - Migration of Contaminated Groundwater Under Control." In order for human exposures to be considered under control, a site must take action to insure that current human exposures to known site-related contaminants are below appropriate risk-based levels of concern. If a site has already performed such actions then it must demonstrate that it has done so to the regulators performing the determination. In order for a site to get a "yes" determination for "Migration of Contaminated Groundwater Under Control" it must first demonstrate that any existing groundwater contaminant plumes are no longer expanding (i.e., have reached steady-state) and that monitoring will be conducted to insure that the plumes remain within their current boundaries.

Attachment 1 contains the latest "Current Human Exposures Controlled" determination for the PGDP. The determination begins by identifying those contaminants believed to be present in the environment at concentrations in excess of appropriate risk-based levels. The contaminants listed were identified through document searches and through queries of the OREIS database. Risk-based levels were taken from action and no-action levels found in *Methods for Conducting Human Health Risk Assessments and Risk Evaluations at the Paducah Gaseous Diffusion Plant* (DOE/OR/07-1506&D2) and are listed in tables found in this submittal (pages 16-20). The text identifies what are believed to be currently plausible pathways for human exposure and the significance of any pathways deemed to be complete. Lastly, a determination is made as to whether any currently known or reasonably expected human exposures can be considered to be within acceptable limits.

Attachment 2 contains the "Migration of Contaminated Groundwater Under Control" portion of the assessment. Here, contaminants commonly detected above MCLs in the site's three groundwater contaminant plumes are identified and a determination is made as to whether plume migration has stabilized. There is also an assessment of the magnitude and significance of discharge of contaminated groundwater to surface water.

The Division's conclusions are presented near the end of each attachment and are as follows. There is uncertainty surrounding current levels of specific contaminants in offsite soils and sediments. Consequently, there is a concern that a recreational user or resident may unknowingly be exposed to contaminants present in ditches, creeks, or soil located in areas easily accessed by the public. There is also a concern that individuals may consume PCB contaminated fish taken from Little Bayou Creek. To address these concerns, DOE has placed signs along segments of Little Bayou and Bayou Creeks that inform the public of the potential to be exposed to contamination in the creeks. In addition, DOE has roped off soil piles known to contain contamination (uranium and PCBs) and is actively investigating other soil piles. Lastly, DOE has agreed to perform a site walkover in an attempt to locate areas containing contaminated soils and has a plan in place to address these types of areas if they are found in the future. Attachment 3 contains a map showing the locations of signs that have been placed along portions of the creeks and an EI Flowchart that will direct any future actions tied to any as yet unidentified areas containing contaminated soil. The Division has concluded that these actions taken by DOE to control uncertainty effectively control human exposure.

In the case of the groundwater migration controlled determination, the Division must conclude that migration is not currently under control. This conclusion is based primarily on data obtained from MW 99 that clearly indicates continued expansion of the Northeast Plume.

If you have any questions or require additional information, please contact Todd Mullins at (502)564-6716 or email todd.mullins@ky.gov.

Sincerely,

April J. Webb, P.E., Manager
Hazardous Waste Branch

Enclosures
Attachment 1: CA 725 – Current Human Exposures Under Control
Attachment 2: CA 750 – Migration of Contaminated Groundwater Under Control
Attachment 3: Controls in Place to Limit Human Exposure

AJW: ew:tm:lw

Cc:
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Reading File; DWM File# 5000
AI 3059; Graybar AIN20050005

Attachment 1

CA 725 – Current Human Exposures Under Control

DOCUMENTATION OF ENVIRONMENTAL INDICATOR DETERMINATION

Interim Final 2/5/99

RCRA Corrective Action
Environmental Indicator (EI) RCRIS code (CA725)

Current Human Exposures Under Control

Facility Name: U.S. DOE Paducah Gaseous Diffusion Plant
Facility Address: 5600 Hobbs Road, West Paducah, KY 42086
Facility EPA ID #: KY8-890-008-982

1. Has **all** available relevant/significant information on known and reasonably suspected releases to soil, groundwater, surface water/sediments, and air, subject to RCRA Corrective Action (e.g., from Solid Waste Management Units (SWMU), Regulated Units (RU), and Areas of Concern (AOC)), been **considered** in this EI determination?

X____ If yes - check here and continue with #2 below.

_____ If no - re-evaluate existing data, or

_____ If data are not available skip to #6 and enter "IN" (more information needed) status code.

BACKGROUND

Definition of Environmental Indicators (for the RCRA Corrective Action)

Environmental Indicators (EI) are measures being used by the RCRA Corrective Action program to go beyond programmatic activity measures (e.g., reports received and approved, etc.) to track changes in the quality of the environment. The two EI developed to-date indicate the quality of the environment in relation to current human exposures to contamination and the migration of contaminated groundwater. An EI for non-human (ecological) receptors is intended to be developed in the future.

Definition of "Current Human Exposures Under Control" EI

A positive "Current Human Exposures Under Control" EI determination ("YE" status code) indicates that there are no "unacceptable" human exposures to "contamination" (i.e., contaminants in concentrations in excess of appropriate risk-based levels) that can be reasonably expected under current land- and groundwater-use conditions (for all "contamination" subject to RCRA corrective action at or from the identified facility (i.e., site-wide)).

Relationship of EI to Final Remedies

While Final remedies remain the long-term objective of the RCRA Corrective Action program the EI are near-term objectives which are currently being used as Program measures for the Government Performance and Results Act of 1993, GPRA). The "Current Human Exposures Under Control" EI are for reasonably expected human exposures under current land- and groundwater-use conditions ONLY, and do not consider potential future land- or groundwater-use conditions or ecological receptors. The RCRA Corrective Action program's overall mission to protect human health and the environment requires that Final remedies address these issues (i.e., potential future human exposure scenarios, future land and groundwater uses, and ecological receptors).

Duration / Applicability of EI Determinations

EI Determinations status codes should remain in RCRIS national database ONLY as long as they remain true (i.e., RCRIS status codes must be changed when the regulatory authorities become aware of contrary information).

2. Are groundwater, soil, surface water, sediments, or air **media** known or reasonably suspected to be **"contaminated"**[1] above appropriately protective risk-based "levels" (applicable promulgated standards, as well as other appropriate standards, guidelines, guidance, or criteria) from releases subject to RCRA Corrective Action (from SWMUs, RUs or AOCs)?

	Yes	No	?	Rationale / Key Contaminants
Groundwater	X			^{99}Tc, TCE (and degradation products)
Air (indoors)[2]		X		
Surface Soil (e.g., <2 ft)	X			Radionuclides, inorganics, PCBs, PAHs, uranium
Surface Water	X			Inorganics, uranium, TCE
Sediment	X			Radionuclides, inorganics, PCBs, PAHs, uranium, TCE (at Outfall 011)
Subsurf. Soil (e.g., >2 ft)	X			Radionuclides, inorganics, PCBs, PAHs, TCE, uranium
Air (outdoors)		X		

____ If no (for all media) - skip to #6, and enter "YE," status code after providing or citing appropriate "levels," and referencing sufficient supporting documentation demonstrating that these "levels" are not exceeded.

X___ If yes (for any media) - continue after identifying key contaminants in each "contaminated" medium, citing appropriate "levels" (or provide an explanation for the determination that the medium could pose an unacceptable risk), and referencing supporting documentation.

____ If unknown (for any media) - skip to #6 and enter "IN" status code.

Rationale and Reference(s):
TCE (w/ degradation products) and ^{99}Tc are the primary contaminants found in groundwater at the site. MCLs established for TCE and vinyl chloride in groundwater are 5 µg/L and 2 µg/L, respectively. Vinyl chloride has the lowest MCL of any of the TCE degradation products present. The currently accepted drinking water standard for ^{99}Tc is 900 pCi/L. This figure equates to the 4 mrem/year MCL established by EPA for beta particle and photon radioactivity from man-made radionuclides in drinking water. TCE and ^{99}Tc levels in onsite groundwater and in offsite (i.e., outside the security fence) plumes continue to exceed relevant MCLs and risk (or dose) based levels. Vinyl chloride and several other TCE degradation products generally only exceed MCLs within the plant's security fence.

Certain heavy metals are known to exist in the groundwater at the site at levels that exceed MCLs but detects are somewhat random in nature. A groundwater metals study was originally to be performed in order to determine the full nature and extent of this potential problem. However, the study was never performed. Therefore, there is still some uncertainty surrounding this issue.

Numerous contaminants are found in onsite (i.e., inside the security fence) surface soils and in onsite subsurface soils. Beryllium, cadmium and chromium are some of the more common inorganics detected above site-specific background numbers. Several others are also present above these levels. Other key contaminants found in soils are PCBs, dioxins, PAHs, TCE (w/ degradation products) and the radionuclides ^{99}Tc and ^{238}U. In addition, some transuranic elements such as ^{239}Pu , ^{137}Cs and ^{237}Np are present in much smaller quantities. A comprehensive investigation of site soils has not been conducted. However, several focused investigations have determined that onsite soils present a risk to current as well as future industrial workers (assumes no PPE worn). Procedures exist to protect workers from potential exposure to radiologically and non-radiologically contaminated soils and sediments. In offsite soils, Uranium and PCBs have been identified at levels in excess of site-specific risked-based concentrations in a soil pile (Soil Pile I) located near and south of the confluence of Outfall 002 and Little Bayou Creek. An investigation revealed that much of this contamination is surficial and is confined to a few "hot spots." Other similar piles are presently under investigation.

Much of the contaminated sediments that present an unacceptable risk to human receptors are located within the plant's security fence and within outfall ditches. Historically, the most highly contaminated sediments were located in the North South Diversion Ditch, which flowed through the center of the plant and exited to the north, eventually discharging to Little Bayou Creek. In 2004, the section of this ditch located inside the plant's security fence was excavated and backfilled to original grade with clean soil. Contaminants associated with the excavated ditch soils/sediments and several other outfall ditches are very similar to those found in soils (listed above). Sediments present in the creeks are also contaminated (e.g., PCBs in Little Bayou Creek sediments). However, this contamination is less well defined than that present inside the security fence.

Preliminary site-specific risk-based levels (see attached tables) are available for contaminants in soils and sediments. Action Levels equate to an ELCR risk of 10^{-4} or greater (or HI>=3) whereas No Action-Levels equate to an ELCR risk of 10^{-6} or smaller or HI<=0.1 (0.1 selected in order to assure cumulative risk remains at or below HI=1).

Those contaminants that have exceeded the preliminary Action Level criteria in sediments for a particular receptor are as follows:

> For the Industrial Worker – antimony; beryllium; U-238; Cs-137; vanadium; chromium; uranium; and benzo (a) pyrene
>
> For the Child Recreator – antimony (background elevated); vanadium (background elevated); uranium; U-238; and beryllium (background elevated)

Those contaminants that have exceeded the preliminary No-Action Level in sediments but did not exceed the Action Level for a particular receptor are as follows:

> For the Industrial Worker – ^{99}Tc; benzo(a) anthracene; benzo (b) fluoranthene; TCE; Np-237; benzo (k) fluoranthene; and indeno (1,2,3cd) pyrene
>
> For the Child Recreator –chromium; benzo (b) fluoranthene; benzo (a) pyrene; benzo(a) anthracene; Pu-239; Np-237; Cs-137; and indeno (1,2,3 cd) pyrene

Those contaminants that have exceeded the preliminary Action Level criteria in soils for a particular receptor are as follows:

> For the Excavation Worker – TCE; uranium; benzo (a) anthracene; indeno (1,2,3-cd) pyrene; benzo (b) fluoranthene; benzo (a) pyrene; antimony; beryllium; Np-237; Cs-137; vanadium; and U-238
>
> For the Industrial Worker – U-238; Cs-137; uranium; benzo (a) anthracene; benzo (b) fluoranthene; benzo (a) pyrene; indeno (1,2,3-cd) pyrene; antimony; vanadium; beryllium; and benzo (k) fluoranthene
>
> For the Child Recreator – U-238 (at 011/ LBC confluence); uranium (at 011/ LBC and Soil Pile I); PCBs (Soil Pile I) and vanadium

Those contaminants that have exceeded the preliminary No-Action Level in soils but did not exceed the Action Level for a particular receptor are as follows:

For the Excavation Worker – chromium; ^{99}Tc; and benzo (k) fluoranthene

For the Industrial Worker –chromium; Np-237; and ^{99}Tc

For the Child Recreator – U-238 (at Soil Pile I), Np-237 and beryllium

The PGDP outfall ditches discharge to two streams, known as Little and Bayou Creek that flow along the eastern and western sides of the plant, respectively. These streams flow north through recreational and rural residential areas before eventually discharging into the Ohio River. Numerous contaminants have been detected in surface water at varying levels both inside and outside the plant's security fence.

Contaminants detected in surface water were compared to the preliminary Human Health Risk –Based Action Levels and No-Action Levels. Action Levels equate to an ELCR risk of 10^{-4} or greater (or HI>=3) whereas No Action-Levels equate to an ELCR risk of 10^{-6} or smaller or HI<=0.1 (0.1 selected in order to assure cumulative risk remains at or below HI=1).

Those contaminants that have exceeded the preliminary Action Level criteria for surface water for a particular receptor are as follows:

For the Industrial Worker – vanadium.

For the Child Recreator – None known

Those contaminants that have exceeded the preliminary No-Action Level for surface water but did not exceed the Action Level for a particular receptor are as follows:

For the Industrial Worker –Arsenic; TCE; and chromium.

For the Child Recreator - Uranium; TCE; arsenic (elevated background); and cadmium

Footnotes:

[1] "Contamination" and "contaminated" describes media containing contaminants (in any form, NAPL and/or dissolved, vapors, or solids, that are subject to RCRA) in concentrations in excess of appropriately protective risk-based "levels" (for the media, that identify risks within the acceptable risk range).

[2] Recent evidence (from the Colorado Dept. of Public Health and Environment, and others) suggest that unacceptable indoor air concentrations are more common in structures above groundwater with volatile contaminants than previously believed. This is a rapidly developing field and reviewers are encouraged to look to the latest guidance for the appropriate methods and scale of demonstration necessary to be reasonably certain that indoor air (in structures located above (and adjacent to) groundwater with volatile contaminants) does not present unacceptable risks.

Primary References:

CH2M HILL 1991. *Results of the Site Investigation, Phase I, at the Paducah Gaseous Diffusion Plant,* KY/ER-4, CH2M HILL Southeast, Inc., Oak Ridge, TN, March.

CH2M HILL 1992. *Results of the Site Investigation, Phase II, Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* KY/SUB/13B-97777C P-03/1991/1, CH2M HILL Southeast, Inc., Oak Ridge, TN, April.

DOE 1996. *Resource Conservation and Recovery Act/ Facility Investigation/ Remedial Investigation Report for Waste Area Groupings 1 and 7 at Paducah Gaseous Diffusion Plant ,Paducah, Kentucky ,* Volume 1-4, DOE/OR/07-1404/V4&D2, United States Department of Energy, Paducah, Ky, April.

DOE 1996.*Background Concentrations and Human Health Risk-based Screening Criteria for Metals in Soil at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/OR/07-1417&D2, United States Department of Energy, Paducah, Ky, September.

DOE 1997. *Background Levels of Selected Radionuclides and Metals in Soils and Geologic Media at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/OR/07-1586&D2, United States Department of Energy, Paducah, Ky, June.

DOE 1998. *Remedial Investigation Report for Solid Waste Management Units 7 and 30 of Waste Area Grouping 22 at the Paducah Gaseous Diffusion Plant ,Paducah, Kentucky,* DOE/OR/07-1604/V2&D2, United States Department of Energy, Paducah, Ky, January.

DOE 1999. *Remedial Investigation Report for Waste Area Grouping 6 at the Paducah Gaseous Diffusion Plant ,Paducah, Kentucky ,* Volumes 1-4, DOE/OR/07-1727/V1&D2, United States Department of Energy, Paducah, Ky, May.

DOE 1999. *Remedial Investigation Report for Waste Area Grouping 27 at the Paducah Gaseous Diffusion Plant ,Paducah, Kentucky ,* DOE/OR/07-1777/V1&D2, United States Department of Energy, Paducah, Ky, June.

DOE 1999. *Risk Evaluation Report for Waste Area Grouping 23 and Solid Waste Management Unit 1 of Waste Area Grouping 27 at the Paducah Gaseous Diffusion Plant ,Paducah, Kentucky ,* DOE/OR/07-1781&D1, February.

DOE 2000. *Remedial Investigation Report for Waste Area Grouping 28 at the Paducah Gaseous Diffusion Plant ,Paducah, Kentucky ,*Volumes 1-4, DOE/OR/07-1846/V1&D2, United States Department of Energy, Paducah, Ky, August.

DOE 2000. *Feasibility Study for the Groundwater Operable Unit at the Paducah Gaseous Diffusion Plant,* DOE/OR/07-1857&D1, United States Department of Energy, Paducah, Ky, July.

DOE 2000. *Methods for Conducting Human Health Risk Assessments and Risk Evaluations at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/OR/07-1506&D2, United States Department of Energy, Paducah, Ky.

DOE 2008. *Site Evaluation Report for Soil Pile I at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-0108&D1, United States Department of Energy, Paducah, Ky, July.

Current Human Exposures Under Control
Environmental Indicator (EI) RCRIS code (CA725)

3. Are there **complete pathways** between "contamination" and human receptors such that exposures can be reasonably expected under the current (land- and groundwater-use) conditions?

Summary Exposure Pathway Evaluation Table

Potential **Human Receptors** (Under Current Conditions)

Contaminated Media	Residents	Workers	Day-Care	Construction	Trespassers	Recreation	Food[3]
Groundwater	no	no	no	no	no	no	no
Air (indoors)	no	no	no	no	no	no	no
Soil (surface, e.g., <2 ft)	no	no[1]	no	no[1]	no	no[3]	no
Surface Water	no	no[1]	no	no[1]	no	no[2]	no
Sediment	no[2]	no[1]	no	no[1]	no	no[2]	no[2]
Soil (subsurface e.g., >2 ft)	no	no	no	no[1]	no	no	no
Air (outdoors) (other than rad)	no	no	no	no	no	no	X

[1] Pathway does not exist as long as current worker protection procedures remain in place.

[2] Pathway does not exist as long as signage along Bayou and Little Bayou Creeks remains in place.

[3] Pathway does not exist as long as contaminanted offsite soils are clearly identifiable by the public and a mechanism remains in place to insure that contaminated offsite soils identified in the future are addressed in an expeditious manner according to the EI Flowchart (see Attachment 3).

Instructions for Summary Exposure Pathway Evaluation Table:

1. Strike-out specific Media including Human Receptors' spaces for Media which are not "contaminated" as identified in #2 above.

2. enter "yes" or "no" for potential "completeness" under each "Contaminated" Media – Human Receptor combination (Pathway).

Note: In order to focus the evaluation to the most probable combinations some potential "Contaminated" Media - Human Receptor combinations (Pathways) do not have check spaces ("___"). While these combinations may not be probable in most situations they may be possible in some settings and should be added as necessary.

no___ If no (pathways are not complete for any contaminated media-receptor combination) -skip to #6, and enter "YE" status code, after explaining and/or referencing condition(s) in-place, whether natural or man-made, preventing a complete exposure pathway from each contaminated medium (e.g., use optional Pathway Evaluation Work Sheet to analyze major pathways).

_____ If yes (pathways are complete for any "Contaminated" Media - Human Receptor combination) - continue after providing supporting explanation.

____ If unknown (for any "Contaminated" Media - Human Receptor combination) - skip to #6 and enter "IN" status code

Rationale and Reference(s):

Contaminated groundwater at this site -- with the exception of where it discharges to a section of Little Bayou Creek -- exists several tens of feet beneath the surface and can only be accessed by drilling a well. Exposures to contaminated groundwater are controlled through a DOE initiative known as the Water Policy. The foundation of the Water Policy is an agreement between DOE and local residents wherein DOE provides municipal water to residents free of charge in exchange for the resident allowing DOE sole access to the resident's well. The resident also agrees to forego the use of any water from their well. For some time this policy has effectively insured that local residents are not exposed to contaminated groundwater emanating from the facility.

For surface soils, the recreational user is the potential contaminant receptor. In the absence of controls, a child recreator may be at risk of coming into contact with contaminated surface soils located on DOE property (e.g., near the creeks, ditches or offsite NSDD) currently leased to the WKWMA. DOE has recently taken actions to protect recreational users from inadvertent exposure to contamination identified in surface soils located near Little Bayou Creek and is continuing to evaluate in an expeditious manner whether other offsite soils may be contaminated. Given the pace at which DOE is moving forward to identify and characterize offsite areas of potentially contaminated surface soil, it is highly unlikely that an individual would receive an exposure to such soil that would be detrimental to their health.

For surface water, the recreational user is the potential receptor. In the absence of controls, a recreational user may be exposed to contaminated surface water via the creeks. However, signage (see Attachment 3) recently placed along Bayou Creek, Little Bayou Creek and offsite portions of the NSDD will serve to inform the public of potential risks associated with creek or ditch exposure. The signs effectively control inadvertent exposure to contamination by members of the public.

For sediment, the resident, recreational user and food consumer are all potential receptors. In the absence of controls, the possibility exists for residents living near the creeks to be exposed to contaminated sediments. Recreational users may be exposed if they enter the creeks or contaminated ditches. Food consumers might catch and eat bottom dwelling PCB contaminated fish obtained from the creeks. The recently installed signs will serve to prevent inadvertent exposures by members of the public until such time as the creeks and offsite ditches can be fully investigated and remediated, as necessary.

The state has confirmed that offsite radionuclide air emissions do not appear to be a problem and continues to monitor for these emissions. Recent work performed by EPA would seem to suggest that intrusion of TCE vapor into homes overlying groundwater plumes is not an issue.

[3] Indirect Pathway/Receptor (e.g., vegetables, fruits, crops, meat and dairy products, fish, shellfish, etc.)

Current Human Exposures Under Control
Environmental Indicator (EI) RCRIS code (CA725)

4. Can the **exposures** from any of the complete pathways identified in #3 be reasonably expected to be **"significant"**[4] (i.e., potentially "unacceptable" because exposures can be reasonably expected to be: 1) greater in magnitude (intensity, frequency and/or duration) than assumed in the derivation of the acceptable "levels" (used to identify the "contamination"); or 2) the combination of exposure magnitude (perhaps even though low) and contaminant concentrations (which may be substantially above the acceptable "levels") could result in greater than acceptable risks)?

____ If no (exposures can not be reasonably expected to be significant (i.e., potentially "unacceptable") for any complete exposure pathway) - skip to #6 and enter "YE" status code after explaining and/or referencing documentation justifying why the exposures (from each of the complete pathways) to "contamination" (identified in #3) are not expected to be "significant."

____ If yes (exposures could be reasonably expected to be "significant" (i.e., potentially "unacceptable") for any complete exposure pathway) - continue after providing a description (of each potentially "unacceptable" exposure pathway) and explaining and/or referencing documentation justifying why the exposures (from each of the remaining complete pathways) to "contamination" (identified in #3) are not expected to be "significant."

____ If unknown (for any complete pathway) - skip to #6 and enter "IN" status code

Rationale and Reference(s):

Not applicable, since pathways are incomplete.

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[4] If there is any question on whether the identified exposures are "significant" (i.e., potentially "unacceptable") consult a human health Risk Assessment specialist with appropriate education, training and experience.

Current Human Exposures Under Control
Environmental Indicator (EI) RCRIS code (CA725)

5. Can the "significant" **exposures** (identified in #4) be shown to be within **acceptable** limits?

____ If yes (all "significant" exposures have been shown to be within acceptable limits) -continue and enter "YE" after summarizing and referencing documentation justifying why all "significant" exposures to "contamination" are within acceptable limits (e.g., a site-specific Human Health Risk Assessment).

____ If no (there are current exposures that can be reasonably expected to be "unacceptable") – continue and enter "NO" status code after providing a description of each potentially "unacceptable" exposure.

____ If unknown (for any potentially "unacceptable" exposure) - continue and enter "IN" status code

Rationale and Reference(s):
Not applicable, since pathways are incomplete.

Current Human Exposures Under Control
Environmental Indicator (EI) RCRIS code (CA725)

6. Check the appropriate RCRIS status codes for the Current Human Exposures Under Control EI event code (CA725), and obtain Supervisor (or appropriate Manager) signature and date on the EI determination below (and attach appropriate supporting documentation as well as a map of the facility):

YE YE - Yes, "Current Human Exposures Under Control" has been verified. Based on a review of the information contained in this EI Determination, "Current Human Exposures" are expected to be "Under Control" at the U.S. DOE Paducah Gaseous Diffusion Plant, EPA ID # KY8-890-008-982, located at 5600 Hobbs Road, West Paducah, Kentucky 42001 under current and reasonably expected conditions. This determination will be re-evaluated when the Agency/State becomes aware of significant changes at the facility.

____ NO - "Current Human Exposures" are NOT "Under Control."

____ IN - More information is needed to make a determination.

Completed by (signature) Todd Mullins Date 11-7-08
(print) Todd Mullins and Brian Begley
(title) Geologist Registered

Supervisor (signature) Date 11/10/08
(print) April J. Webb
(title) Hazardous Waste Branch Manager
(EPA Region or State) Kentucky

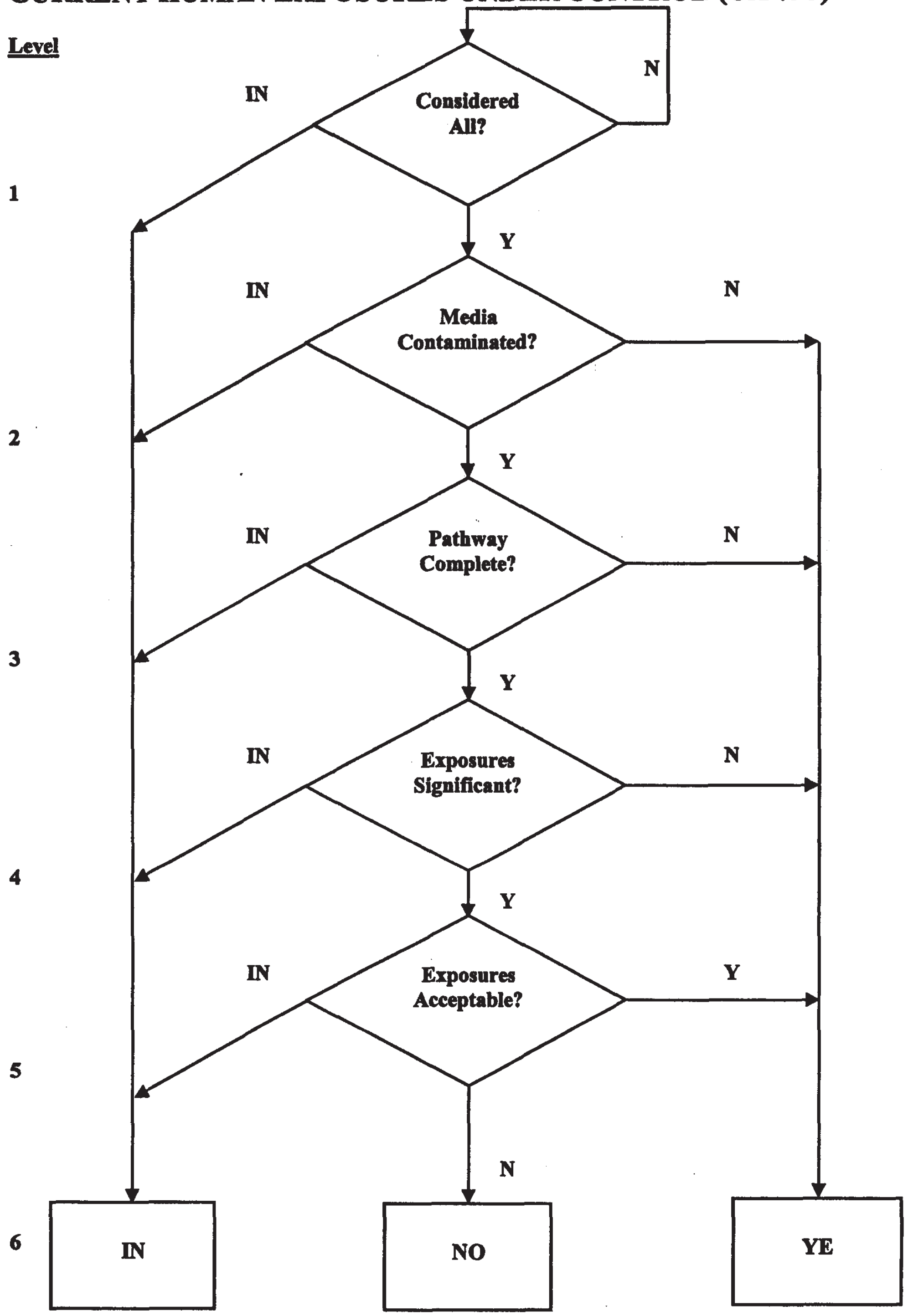
Locations where References may be found:
KY Division of Waste Management, 200 Fair Oaks Lane, Frankfort, Ky 40601

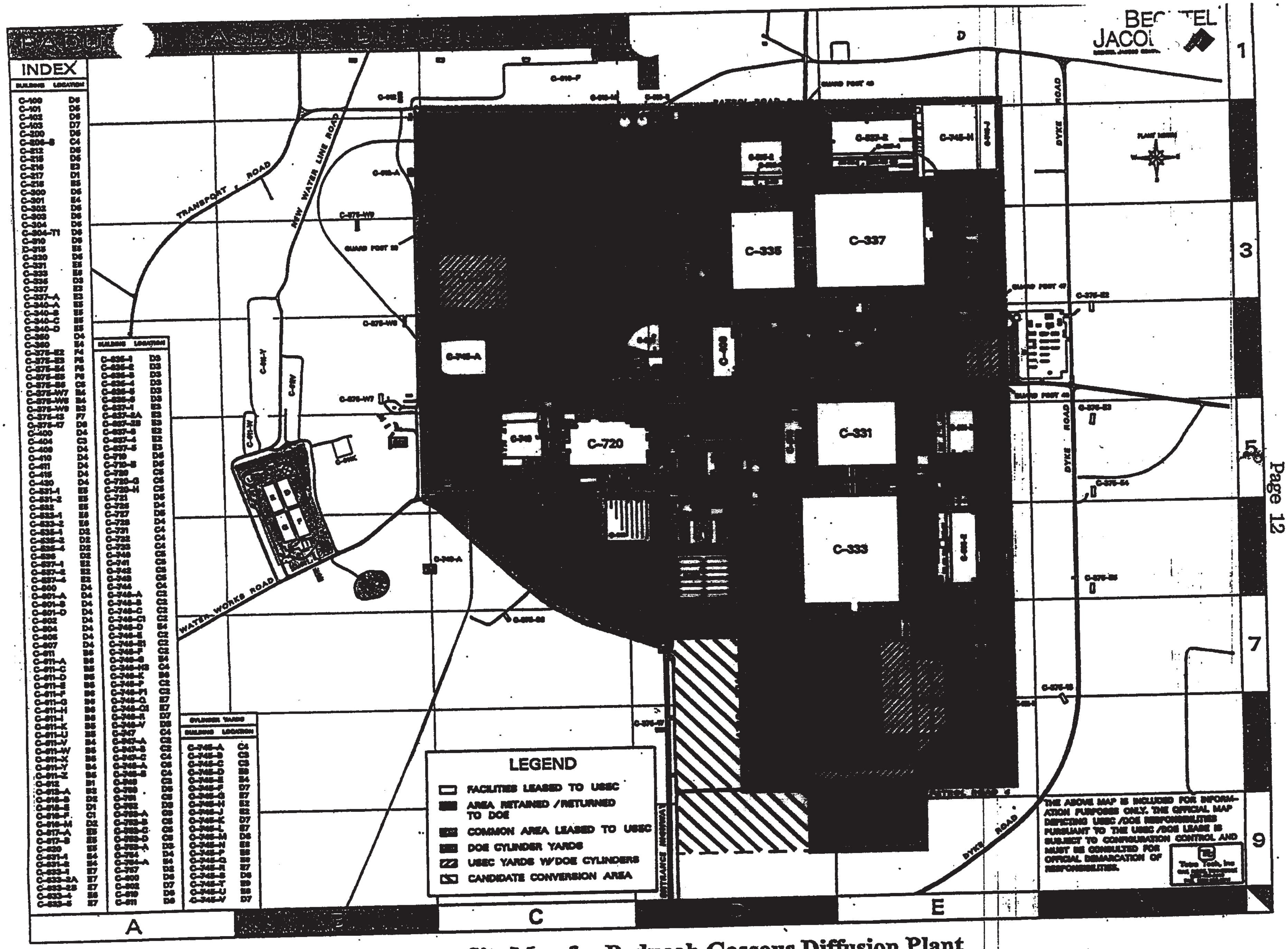
Contact telephone and e-mail numbers
(name) Todd Mullins
(phone #) (502) 564-6716
(e-mail) todd.mullins@ky.gov

FINAL NOTE: THE HUMAN EXPOSURES EI IS A QUALITATIVE SCREENING OF EXPOSURES AND THE DETERMINATIONS WITHIN THIS DOCUMENT SHOULD NOT BE USED AS THE SOLE BASIS FOR RESTRICTING THE SCOPE OF MORE DETAILED (E.G., SITE-SPECIFIC) ASSESSMENTS OF RISK.

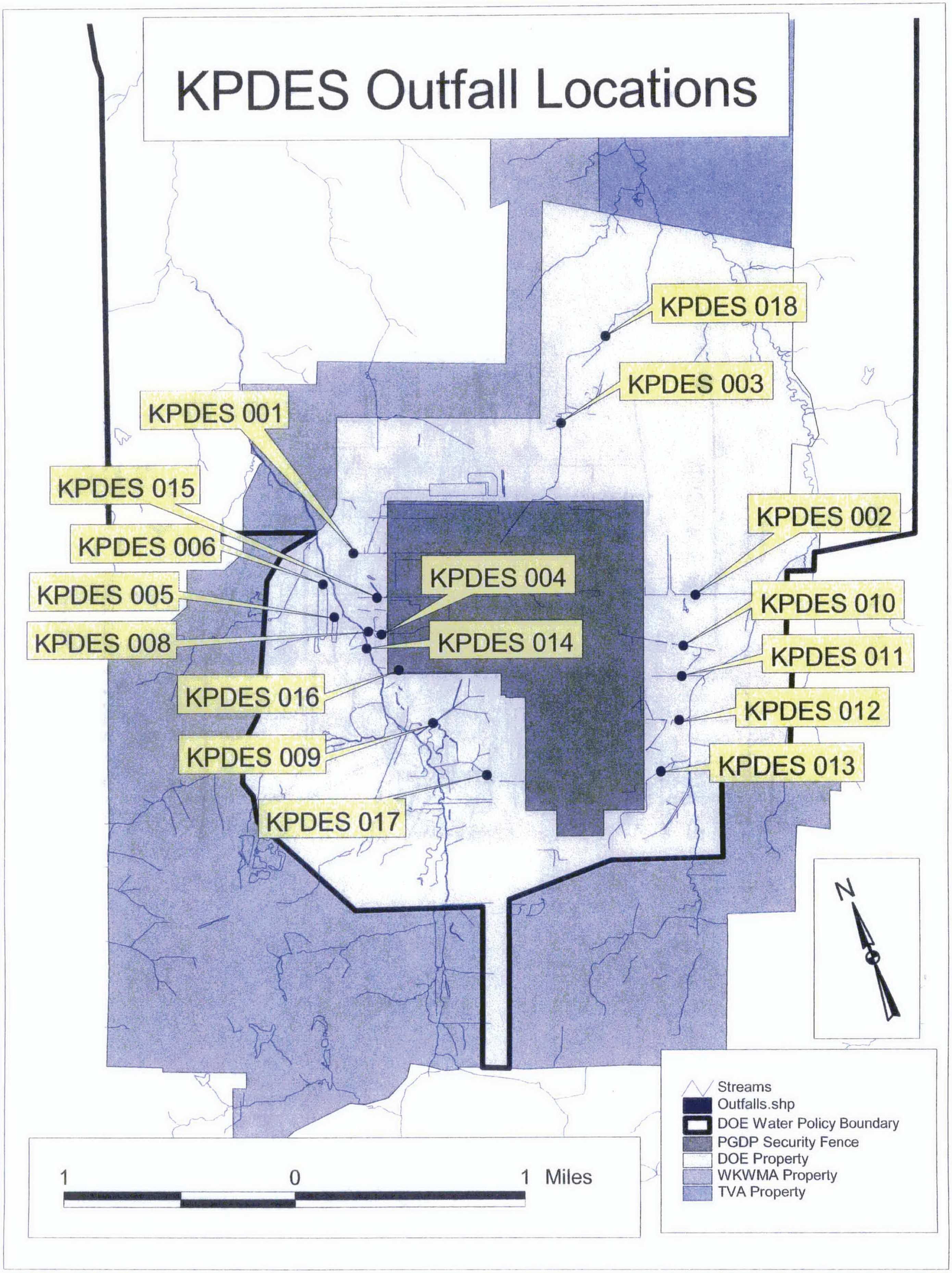
Facility Name: U.S. DOE Paducah Gaseous Diffusion Plant
EPA ID#: KY8-890-008-982
City/State: West Paducah, KY

CURRENT HUMAN EXPOSURES UNDER CONTROL (CA 725)

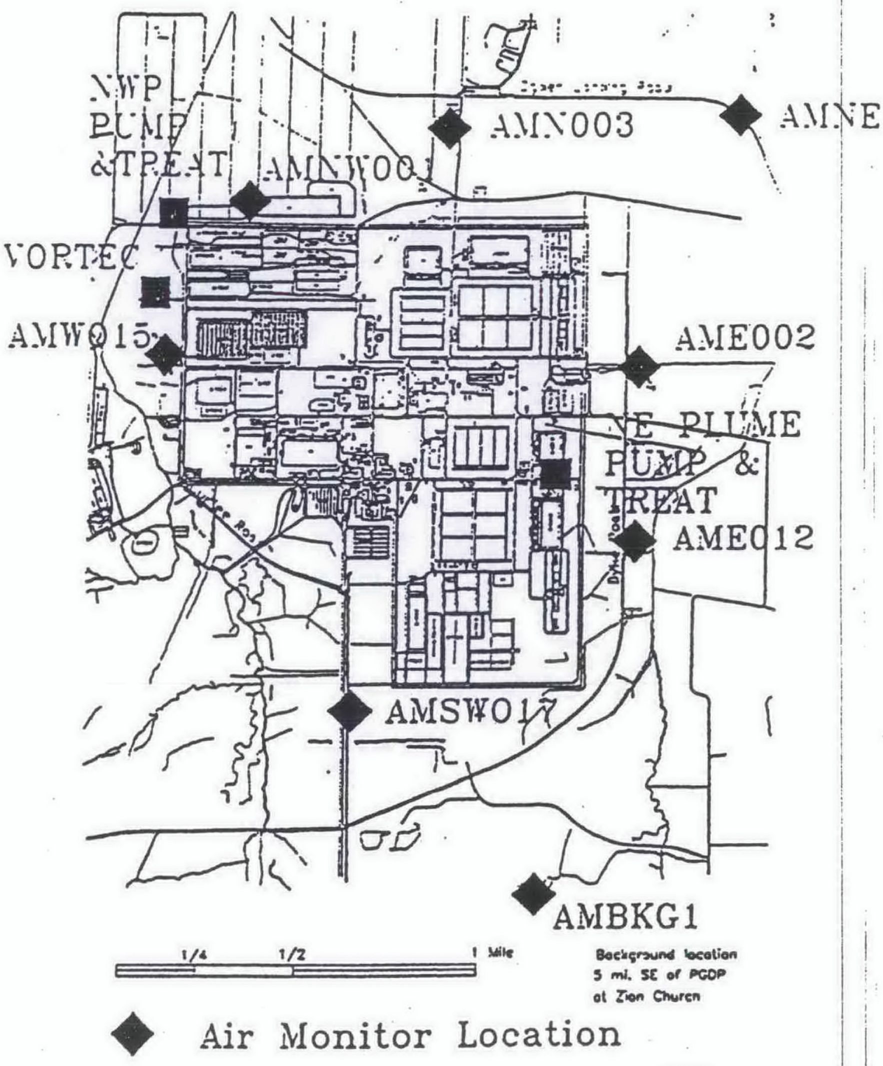




Site Map for Paducah Gaseous Diffusion Plant


KPDES Outfall Locations
KPDES 018
KPDES 003
KPDES 001
KPDES 015
KPDES 006
KPDES 005
KPDES 008
KPDES 004
KPDES 014
KPDES 016
KPDES 009
KPDES 017
KPDES 002
KPDES 010
KPDES 011
KPDES 012
KPDES 013
N
Streams
Outfalls.shp
DOE Water Policy Boundary
PGDP Security Fence
DOE Property
WKWMA Property
TVA Property
1
0
1 Miles

Kentucky CHS-RCB Air Monitor Locations



ENVIRONMENTAL INDICATORS (as of April 1, 2010)

DEPARTMENT OF ENERGY (DOE)					
EPA REGION	STATE	FACILITY NAME	NPL STATUS	HUMAN EXPOSURE	GROUNDWATER MIGRATION
02	NJ	MIDDLESEX SAMPLING PLANT (USDOE)	FINAL	HE UNDER CONTROL	GM UNDER CONTROL
02	NJ	W.R. GRACE & CO., INC./WAYNE INTERIM STORAGE SITE (USDOE)	FINAL	HE UNDER CONTROL	GM UNDER CONTROL
02	NY	BROOKHAVEN NATIONAL LABORATORY (USDOE)	FINAL	HE UNDER CONTROL	GM NOT CONTROLLED
04	KY	PADUCAH GASEOUS DIFFUSION PLANT (USDOE)	FINAL	HE UNDER CONTROL	GM NOT CONTROLLED
04	SC	SAVANNAH RIVER SITE (USDOE)	FINAL	HE UNDER CONTROL	GM NOT CONTROLLED
04	TN	OAK RIDGE RESERVATION (USDOE)	FINAL	HE UNDER CONTROL	GM NOT CONTROLLED
05	OH	FEED MATERIALS PRODUCTION CENTER (USDOE)	FINAL	HE CONTROLLED, PROT. REM.	GM UNDER CONTROL
05	OH	MOUND PLANT (USDOE)	FINAL	HE UNDER CONTROL	GM UNDER CONTROL
06	TX	PANTEX PLANT (USDOE)	FINAL	LONG TERM PROTECT	GM UNDER CONTROL
07	MO	WELDON SPRING QUARRY/PLANT/PITS (USDOE/ARMY)	FINAL	HE CONTROLLED, PROT. REM.	GM UNDER CONTROL
08	CO	ROCKY FLATS PLANT (USDOE)	FINAL	HE CONTROLLED, PROT. REM.	GM UNDER CONTROL
08	UT	MONTICELLO MILL TAILINGS (USDOE)	FINAL	HE UNDER CONTROL	GM UNDER CONTROL
09	CA	LABORATORY FOR ENERGY-RELATED HEALTH RESEARCH/OLD CAMPUS LANDFILL (USDOE)	FINAL	HE UNDER CONTROL	GM UNDER CONTROL

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 4
ATLANTA FEDERAL CENTER
61 FORSYTH STREET
ATLANTA, GEORGIA 30303-8960

September 20, 2018

Ms. Tracey Duncan
Federal Facility Agreement Manager
United States Department of Energy
Portsmouth/Paducah Project Site Office
5501 Hobbs Road
Kevil, KY 42053

RE: EPA Comments: Community Relations Plan under the Federal Facility Agreement at the U.S. Department of Energy Paducah Gaseous Diffusion Plant, Paducah, Kentucky, (DOE/LX/07-2413&D1), Primary Document, transmittal dated June 26, 2018 (PPPO-02-4930994-18A)

Dear Ms. Duncan,

EPA has reviewed the 2018 update to the Community Relations Plan for the cleanup of the Paducah Gaseous Diffusion Plant Superfund Site (EPA ID KY8890008982). Limited comments for discussion and document revision are enclosed.

If you have any questions about this correspondence, please do not hesitate to contact me at (404) 562-8547 or via electronic mail at corkran.julie@epa.gov.

Sincerely,

Julie L. Corkran, Ph.D.
Federal Facility Agreement Manager
Superfund Division

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United States Environmental Protection Agency (EPA) Region 4
Comments on:

Community Relations Plan
under the Federal Facility Agreement
at the U. S. Department of Energy Paducah Gaseous Diffusion Plant,
Paducah, Kentucky, (DOE/LX/07-2413&D1), Primary Document,
transmittal dated June 26, 2018 (PPPO-02-4930994-18A)

General Comments

1. Transparency regarding Site Management Plan references and the strategic approach for cleanup. Section 2 (*Capsule Site Summary*) Section 2.2 (*Environmental Challenges*) advises the community that the strategic approach for achieving cleanup under the Federal Facility Agreement (FFA) is outlined in the 2018 Site Management Plan (SMP). The last time DOE, EPA and the Kentucky Department for Environmental Protection agreed on a strategic approach for the cleanup of the Paducah Gaseous Diffusion Plant Superfund Site was the Fiscal Year 2015 SMP. An approved SMP was not achieved in FY2016 or FY2017 and the FY 2018 SMP is in Formal Dispute with less than two weeks until the close of the 2018 fiscal year (September 30th). Thus, the Community Relations Plan update may be approved before agreement on a new strategic plan for cleanup is reached in an approved SMP.

   Please revise the CRP to clarify that the currently approved strategic approach for cleanup of PGDP is available in the 2015 SMP and DOE's new cleanup plan, proposed in the FY2018 SMP, is pending EPA and KDEP approval. Revise the CRP to make conforming changes throughout the document when referencing the SMP to distinguish between the approved 2015 SMP and the proposed FY2018 SMP. Since the CRP is anticipated to be updated less frequently than SMPs, an Erratum or page changes to the CRP may be issued once the FFA parties agree on a new strategic plan for cleanup of the Superfund site in an approved SMP.

2. Scope and Intent of the C-400 Complex FFA Senior Managers Memorandum of Agreement (MOA). Section 2.3 *Long-Term Strategy* does not accurately present to the community the scope and intent of the C-400 Complex FFA Senior Managers MOA (August 8, 2017). The MOA directs creation of the new C-400 Complex Operable Unit with schedules for work for EPA and KDEP approval. Specifically:

   a. The C-400 Complex MOA does not "…*document a new strategy that provides for a comprehensive approach that integrates the pre- and post-GDP scope, including decommissioning of the GDP, and reprioritizes all cleanup projects to focus near-term efforts on the C-400 Complex*". Revise the first paragraph to strike this language.

   b. In the bullet list, consider spelling out the CSOU acronym for the reader (Comprehensive Site OU).

   c. As of the date of this letter, EPA and DOE are in Formal Dispute over DOE's proposal to delay all environmental media cleanup (including Burial Grounds, groundwater and vapor intrusion projects) until after a decision is made regarding on-site versus off-site waste disposal. Please revise the third paragraph generally as follows:

      In 2016, DOE determined that uranium enrichment building Deactivation activities and infrastructure optimization projects would be the DOE's top priorities at PGDP over the next ten years. Therefore, DOE proposed in the 2018 SMP to delay a decision regarding the CERCLA Waste Disposal Alternatives (WDA) project until after completion of the C-400 Complex OU. In the meantime, disposal options for wastes generated as a result of implementing removal and remedial actions include closing and capping *wastes in place, disposal in the KDEP permitted solid waste landfill operated at PGDP, and disposal of wastes at off-facility waste repositories. Due to significant public interest in the WDA project, frequent interactions with the public have occurred and are expected to continue through the WDA project life cycle. Previous public outreach activities for this project are documented in Appendix A.*

d. Revise the CRP to make conforming changes throughout the document when referencing the cleanup strategy and/or the C-400 Complex MOA. Since the CRP is anticipated to be updated less frequently than SMPs, an Erratum or page changes to the CRP may be issued once the FFA parties agree on a new strategic plan for cleanup of the Superfund site in an approved SMP.

3. Government Performance and Results Act (GPRA): Status and path forward for achieving "yes" for Superfund Environmental Indicators (EI)

   a. In Section 2.3 - *Long Term Strategy Outlook* (paragraph 2 of page 6), DOE advises the community that PGDP is "yes" for the Human Exposures under Control EI. Currently, and for the last several years, EPA has designated PGDP as "insufficient data" for this EI. A copy of the PGDP EI Status webpage extracted on September 18, 2018, is provided as Attachment 1 to this letter. The plant industrial area is ground zero for the TCE releases that have contributed to the massive groundwater contamination plumes that lie below the industrial area of PGDP and extend beyond the plant boundary. Therefore, pending an agreement from DOE for execution and reporting of a Plant Industrial Area Vapor Intrusion Remedial Investigation for potential worker exposure, the EI will remain "insufficient data" or may be revised to "no". EPA reviews and updates Superfund EIs whenever a change in site conditions warrant, but no less frequently than on an annual basis. Revise this paragraph to report that the human exposure EI status is currently "insufficient data" at PGDP.

   b. In the fourth paragraph on page 6, DOE has included a paragraph that does not clearly present the results of the separate Water Policy Box and C-400 Building Vapor intrusion studies and does not make the connection for the reader between the vapor intrusion studies and the PGDP's GPRA EI status for Human Exposures under Control". Revise the text to advise the reader that DOE is "insufficient data" for this EI. State that DOE has made progress toward "yes" by conducting vapor intrusion studies in the Water Policy Box area beyond the plant boundary and the C-400 Building within the plant industrial area. Report the results of the Water Policy Box and C-400 VI studies in separate sentences (as written, the reader is led to conclude that the vapor intrusion pathway for C-400 was incomplete: that conclusion is inconsistent with the draft report submitted to EPA). Describe the actions needed to make progress toward "yes" (see Attachment 1).

   c. The text directs the community to the EPA Superfund Web page for PGDP's GPRA status. However, the link provided is incorrect and directs the reader to a generic Superfund Remedial Performance Measures splash page. Replace the generic link with the hyperlink to the PGPD EI status page (provided below). https://cumulis.epa.gov/supercpad/SiteProfiles/index.cfm?fuseaction=second.Healthenv&id=0404794

4. Maps should clearly illustrate for the community all DOE owned property that comprises PGDP.
   In Section 3.1 *Site and Community Overview*, DOE advises the community that approximately 1,986 acres of DOE land are licensed to the Kentucky Department for Fish and Wildlife as part of the West Kentucky Wildlife Management Area (WKWMA). A community member should be able to read the text in Section 3.1, then go to a figure in the CRP to understand which PGDP acreage is part of the WKWMA.

   a. Revise Figure 2, *Local Communities and Community Gathering Areas*, to clearly illustrate (using a different color or hatching) the 1,986 DOE-owned acreage that is available for use by the community as part of the WKWMA. Add the notation to the figure legend. Revise the text on to refer the reader to Figure 2.

   b. Restore the deleted text (from page 15, top of page) describing the WKWMA as an important recreational resource in the community to Section 3.1.

Specific Comments

1. Section 2.2, *Environmental Challenges*. The fourth bullet on page 4 should be revised to better describe KDEP's oversight role as a signatory to the PGDP FFA: KDEP's role is broader than suggested by the current text.

2. Section 2.3, *Long-Term Outlook*.
   a. Page 6, 1st paragraph. Revise sentence to read "*DOE's proposed* long- term strategy…"

   b. Page 6, 4th paragraph. Revise the text to direct the reader to Figure 1 for an illustration of the Water Policy Box and PGDP Site boundaries.

3. Section 2.4, *Current Activities*, page 7. In the Five Year Review discussion of current activities, replace the phrase "…all human health and ecological risks are under control" with "…the cleanup actions taken remain protective of human health and the environment."

4. Section 3.1, *Site and Community Overview*.
   a. Page 9, 3rd paragraph. What is a "universal water supply"?

   b. Page 14, 3rd paragraph. The text states that "*The Plant also designated a contact person to handle all telephone inquiries and make personal visits to concerned residents."* Add a sentence with the DOE contact number community members may use to get answers to their questions about the Water Policy Box (whether their home is in the Water Policy Box, if their home is eligible for free water, questions about use of wells on their property).

5. Figure 1. *Groundwater Plumes*. The figure would be more useful to the community if major roads were labelled and the DOE-Boundary notation (dashed black line) continued to the south and inside of the Water Policy Box line (red solid line) to clearly illustrate the entire DOE facility boundary for the reader.

6. Section 3.2, *A History of Public Involvement*.
   a. Revise the text in the introductory paragraph to advise the community whether the Neighborhood Council (chartered in 1992) is still active. If the Neighborhood Council is still active, provide the community with contact information for that organization in the CRP.
   b. The term "water policy holder" as used in Section 3.2.3 is not clear to EPA and would not be clear to the general community. Evaluate use of the phrase "water policy holder" and revise this paragraph for clarity.
   c. For clarity, consider using the word "electronically" or "online" in lieu of "digitally" in the first paragraph on page 16.

7. Section 5.2, *Decision Making and Public Involvement*. Delete the word "appropriate" from the first sentence of this section: *"The FFA establishes a procedural framework and schedule for developing, implementing, and monitoring ~~appropriate~~ cleanup actions at PGPD…".*

8. Section 6, *References*.
   a. The most recent SMP approved by KDEP and EPA is the 2015 SMP. Revise Section 6 to include the 2015 SMP reference and a hyperlink to the plan for use by the community.

   b. Consider adding a hyperlink to the proposed FY2018 SMP to the citation in Section 6 for use by the community.

9. *Appendix C*, *Key Contacts for the Paducah Gaseous Diffusion Plant*. Please consider adding the DOE-PGDP Federal Facility Agreement Manager, Ms. Tracey Duncan, to the appropriate list in this Appendix.

10. Hyperlinks. Please evaluate the following hyperlinks and revise as needed.

    Presented as hyperlinks (blue text) but did not function as such during review of the document:
    a. Page 14, "Site-Specific Advisory Board (SSAB)" and "Paducah Citizens Advisory Board (CAB)"
    b. Page 37, the title for Garland (2008).
    c. Page B-5, "Community Interviews - 174740" (two occurrences).

    Hyperlink did not return the anticipated webpage:
    d. Page 19, the fourth bullet titled "DOE Portsmouth/Paducah Project office/PGDP Cleanup". The hyperlink provided only takes the reader to a page describing Deactivation contracting activities through 2017.
    e. Page 37 - DOE (2015).

Attachment

1. EPA Superfund Website for Paducah Gaseous Diffusion Plant: Health and Environment - Performance Measures. GPRA EI Status pages (extracted September 18, 2018). https://cumulis.epa.gov/supercpad/SiteProfiles/index.cfm?fuseaction=second.Healthenv&id=0404794

PADUCAH GASEOUS DIFFUSION PLANT (USDOE) PADUCAH, KY

Health & Environment

On this page:

- What Are the Risks at the Site?
- Contaminant Information
- Performance Measures

What Are the Risks at the Site?

Site investigations found contamination in groundwater,soils, surface water and sediments, both on-site and beyond the site boundaries.

- In 1988, DOE found technetium-99 in an off-site drinking water well north of PGDP. DOE also found VOCs in nearby private wells and in on-site monitoring wells. DOE placed affected residences and businesses on an alternate water supply. After finding PCBs in on-site surface water and downstream of the plant in Big Bayou Creek and in Little Bayou Creek, DOE took steps to prevent the spread of contaminated groundwater and restrict the use of surface water.
- Since several schools are located near the site, DOE and KDEP evaluated whether potential radioactive contamination posed a risk to children’s health in 2009. The parties did not find any site-related risks.
- The site's contamination is not a threat to nearby residents and businesses. The West McCracken Water District, a municipal utility, provides water supplies to residents and businesses in the area. The district’s water source is the Ohio River. Some residents with groundwater wells unaffected by the site’s contamination also continue to use their wells. Warning signs have been posted along creeks where contamination is present.
- More data is needed, however, to ensure that the site's contamination is not a threat to workers at the site. DOE is evaluating whether vapors are migrating from the groundwater contamination into buildings, potentially posing a threat to workers in the PGDP industrial area (i.e., more data are needed to ensure that human exposure is under control). DOE will report the results of that study in 2018.

Contaminant Information

View a full list of contaminants of concern for this site.

Performance Measures

EPA uses performance measures to track environmental results at Superfund sites. If you have any questions or concerns about the measures at this site, please contact the site team members listed under Site Contacts.

Read more about Superfund Remedial Performance Measures.

Performance Measure	**Status at this Superfund Site**	**What does this mean?**
Human Exposure Under Control	Insufficient Data	**Yes** means assessments indicate that across the entire site: 1. There are currently no unacceptable human exposure pathways; and 2. EPA has determined the site is under control for human exposure. **No** means an unsafe level of contamination has been detected at the site and a reasonable expectation exists that people could be exposed. **Insufficient data** means that, due to uncertainty regarding exposures, one cannot draw conclusions as to whether human exposures are controlled, typically because: 1. Response to the contamination has not begun; or 2. The response has begun, but it has not yet generated information sufficiently reliable to evaluate whether there are currently any unacceptable human exposure pathways at the site.
Groundwater Migration Under Control	No	**Yes** means EPA reviewed all information on known and reasonably expected groundwater contamination. EPA concluded the migration of contaminated groundwater is stabilized and there is no unacceptable discharge to surface water. EPA will conduct monitoring to confirm that affected groundwater remains in the original area of contamination. **No** means EPA has reviewed all information on known and reasonably expected groundwater contamination, and the migration of contaminated groundwater is not stabilized. **Insufficient data** means that due to uncertainty regarding contaminated groundwater migration, EPA cannot draw conclusions as to whether the migration of contaminated groundwater is stabilized.

Performance Measure	**Status at this Superfund Site**	**What does this mean?**
Construction Complete	No	**Yes** means the physical construction of the cleanup is complete for the **entire site**. **No** means either physical construction is not complete or actions are still needed to address contamination.
Sitewide Ready for Anticipated Use	No	**Yes** means: 1. All cleanup goals affecting current and reasonably anticipated future land uses of the entire site have been achieved, so there are no unacceptable risks; 2. All required land-use restrictions or other controls have been put in place; and 3. The site has achieved Construction Complete status. **No** means that one or more of these three criteria have **not** been met. However, a site listed as **no** may still have redevelopment occurring on portions of the site and may be eligible for additional redevelopment.

SEPTEMBER 18, 2018

RECEIVED
By morrisc at 6:19 am, Jan 16, 2019

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 4
ATLANTA FEDERAL CENTER
61 FORSYTH STREET
ATLANTA, GEORGIA 30303-8960

December 11, 2018

Ms. Tracey Duncan
Federal Facility Agreement Manager
United States Department of Energy
Portsmouth/Paducah Project Site Office
5501 Hobbs Road
Kevil, KY 42053

RE: EPA Approval: **Community Relations Plan under the Federal Facility Agreement at the U. S. Department of Energy Paducah Gaseous Diffusion Plant, Paducah, Kentucky**, **(DOE/LX/07-2413&D2)**, transmittal dated November 20, 2018 (PPPO-02-5278854-19A).

ENV 1.A-01618

Dear Ms. Duncan,

The United States Environmental Protection Agency (EPA) Region 4 has reviewed the revised 2018 Community Relations Plan (CRP) update for the Paducah Gaseous Diffusion Plant (PGDP) Superfund site and has no additional comments. The DOE/LX/07-2413&D2 CRP revision dated November 20, 2018, is approved as submitted.

Under the Government Performance and Results Act (GPRA), EPA has established Environmental Indicators (EI) for reporting Superfund site cleanup progress to Congress. In EPA comments on the D1 CRP, this Agency offered a comment correcting text (Section 2.3, *Long Term Strategy Outlook*) regarding the PGDP cleanup program status for one Superfund Environmental Indicator (EI): Human Exposure Under Control. EPA has designated PGDP as "Insufficient Data" for this measure and has sought a commitment from DOE under the PGPD Federal Facility Agreement (FFA) for a Plant Industrial Area Vapor Intrusion Remedial Investigation (RI) for potential worker exposure to TCE vapors. EPA's request for DOE commitment to the RI and progress towards "yes" for Human Exposure Under Control at PGDP is currently in FFA Formal Dispute under on the Fiscal Year 2018 Site Management Plan. The plant industrial area is "ground zero" for the historical TCE releases that contribute to the groundwater contamination plumes below the industrial area buildings of the PGDP and extend beyond the plant boundary.

EPA reviews and updates Superfund EIs whenever a change in site conditions warrant, but no less frequently than on an annual basis. PGPD's status for the Superfund GPRA EIs is provided as an enclosure to this letter. General information regarding the Superfund cleanup performance measures, including the GPRA EIs, is also available on the EPA website: https://www.epa.gov/superfund/superfund-remedial-performance-measures.

EPA notes that inclusion of sections on Environmental Justice and GPRA status had been previously negotiated among the Federal Facility Agreement (FFA) Parties in support of the 2015 CRP update. Rather than provide current information to the community, DOE elected to delete the PGDP GPRA status discussion from the 2018 Community Relations Plan, stating *"…nothing in CERCLA, the NCP, the FFA, or EPA Guidance, including EPA's Handbook, requires such information to be included in a CRP*". PGDP Federal Facility Agreement (FFA) Section XXXIII, *Public Participation*, states that work conducted under the FFA *"shall comply with the public participation requirements of CERCLA, including…the principles of the Federal Facility Environmental Dialogue Committee Final report dated April 1996. This shall be achieved through implementation of the approved Community Relations Plan (CRP) prepared and implemented by DOE.*"

EPA did not issue a Condition for approval of the 2018 CRP related to DOE's removal of the PGDP's status summary for these Superfund cleanup performance measures from the public participation document. However, it is EPA's interpretation that the FFA requires DOE to adhere to the Federal Facility Environmental Dialogue Committee (FFERDC) report expectations that "*the federal government must make a sustained commitment to completing environmental cleanups at its facilities at a reasonable and defensible pace that is protective of human health and the environment and allows closing federal facilities to return to economic use as promptly as possible*" and that community involvement processes regarding the cleanup (such as updates to the CRP) are "*transparent, interactive, inclusive and responsive*."

If you have any questions about this correspondence, please do not hesitate to contact me at (404) 562-8547 or via electronic mail at corkran.julie@epa.gov.

Sincerely,

Julie L Corkran

Julie L. Corkran, Ph.D.
Federal Facility Agreement Manager
Superfund Division

Enclosure (as stated)

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PADUCAH GASEOUS DIFFUSION PLANT (USDOE)
PADUCAH, KY

Health & Environment

Source:https://cumulis.epa.gov/supercpad/SiteProfiles/index.cfm?fuseaction=second.Healthenv&id=0404794#Perform

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Performance Measures

EPA uses performance measures to track environmental results at Superfund sites. If you have any questions or concerns about the measures at this site, please contact the site team members listed under Site Contacts.

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Performance Measure	Status at this Superfund Site	What does this mean?
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Groundwater Migration Under Control	No	**Yes** means EPA reviewed all information on known and reasonably expected groundwater contamination. EPA concluded the migration of contaminated groundwater is stabilized and there is no

Performance Measure	Status at this Superfund Site	What does this mean?
		unacceptable discharge to surface water. EPA will conduct monitoring to confirm that affected groundwater remains in the original area of contamination. **No** means EPA has reviewed all information on known and reasonably expected groundwater contamination, and the migration of contaminated groundwater is not stabilized. **Insufficient data** means that due to uncertainty regarding contaminated groundwater migration, EPA cannot draw conclusions as to whether the migration of contaminated groundwater is stabilized.
Construction Complete	No	**Yes** means the physical construction of the cleanup is complete for the **entire site**. **No** means either physical construction is not complete or actions are still needed to address contamination.
Sitewide Ready for Anticipated Use	No	**Yes** means: 1. All cleanup goals affecting current and reasonably anticipated future land uses of the entire site have been achieved, so there are no unacceptable risks; 2. All required land-use restrictions or other controls have been put in place; and 3. The site has achieved Construction Complete status. **No** means that one or more of these three criteria have **not** been met. However, a site listed as **no** may still have redevelopment occurring on portions of the site and may be eligible for additional redevelopment.

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Environmental Indicators - Frequent Questions

General

1. **What are the RCRA Corrective Action Environmental Indicators (EIs)?**

   The RCRA Corrective Action Environmental Indicators (EIs) are:

   - A means of evaluating and reporting on the acceptability of current site conditions (i.e., they are interim milestones and not final remedy or site closure goals).
   - An opportunity for facilities and regulators to show meaningful progress that is achievable in the near future.
   - A high priority within EPA and the #1 priority for the RCRA program.
   - Adopted by ECOS and equivalent to ASTSWMO cleanup measures.

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2. **How many RCRA CA EIs are there?**

   There are two:

   - Current Human Exposures Under Control (a.k.a. "Human Exposure EI")
   - Migration of Contaminated Groundwater Under Control (a.k.a. "Groundwater EI")

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3. **What are the possible results (determinations) for the EIs?**

   "YES" - conditions are "Under Control"
   "NO" - conditions are NOT "Under Control"
   "IN" - Insufficient information is available to determine if conditions are "Under Control"

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4. **What are the RCRA CA EI used for?**

These EIs are used to summarize and report on the site-wide environmental conditions at the RCRA CA Program's highest priority sites (i.e., those on RCRA Cleanup Baseline). These EIs are being used to track the RCRA program's progress on getting our highest priority contaminated sites under control and report to the Office of Management and Budget (OMB), U.S. Congress, and the public.

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5. **How are sites evaluated to see if they meet the RCRA CA EI?**

   Known and suspected site (-wide) conditions are evaluated using a series of simple questions and flow-chart logic to arrive at a reasonably defensible determination (YES, NO, or IN). These questions (EI forms) were issued on Feb. 5, 1999 as Interim Final Guidance (PDF) (17 pp, 52K, About PDF)

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6. **Who makes the EI determinations and fills out the EI forms?**

   The lead regulators for the site (Authorized State or EPA) make the EI determination. However, facilities or their consultants may assist EPA in the evaluation by providing information on the current environmental conditions and may even assist by filling out the EI forms and making recommendations for the determination.

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7. **How does the Human Exposures EI relate to traditional Risk Assessments?**

   The Human Exposure EI is an assessment of actual current human risks and would typically take the form of a qualitative assessment of the completeness of exposure pathways, but may include a traditional Quantitative Risk Assessment.

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8. **How does the Groundwater EI differ from the Human Exposures EI?**

   The Groundwater EI is strictly a resource protection measure and not a direct measure of human risk, and may include the assessment of the impacts of groundwater discharges to surface waters and surface water ecosystems.

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9. **Will EIs require additional investigations (beyond that typically required for CA)?**

   No, since the EIs are small components of typical site corrective action final remedies, the EI should not require any additional investigations to be conducted.

Although, the timing of when investigations, or stabilization actions, occur may be altered in order to demonstrate that site conditions are "Under Control" as soon a possible.

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10. **Is it necessary to complete an entire site investigation to show that human exposures are under control?**

    No, human exposures can be considered "under control" if adequately protective controls are in place to prevent unacceptable exposures (i.e., cut pathways between humans and contamination) for the reasonably-expected worst-case conditions (in the un-investigated areas).

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11. **Are EI determinations a point-in-time determination, or do they have to be maintained to ensure they remain true through time?**

    Yes, they are made in a point in time, and Yes, we are responsible to ensure that the EI determinations accurately report site conditions through time.

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12. **How do the Environmental Indicator determinations for Current Human Exposure under Control and Migration of Contaminated Groundwater relate to final remedy decisions at a RCRA corrective action facility?**

    The environmental indicator determinations are a snapshot reflecting current conditions at a facility. The Human Exposure EI focuses on current exposure scenarios, and the Groundwater EI addresses the question of whether existing plumes of contaminated groundwater are continuing to expand above levels of concern. These determinations do not address whether corrective action is "complete" at the site, whether remedial long-term goals are met, or whether a site will be safe if land uses change in the future.

    As a result, overseeing agencies should not look at EI determinations at a facility as the "final" decision, and facility owner/operators should not interpret positive EI determinations as indicating that all corrective action obligations are met. In some cases, a facility that meets both Environmental Indicators may well need no further corrective action. But in many other cases, substantial work will be needed before a cleanup is complete. At some facilities, for example, current exposures may be cut off through interim measures, and groundwater migration may be under control, but more permanent measures (or more extensive site characterization) are needed to ensure that the site is safe for reasonably anticipated future uses. These measures would be addressed as part of longer term cleanup at the site.

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13. **How do I consider future land use in making an EI determination?**

    An EI determination reflects current land use (and patterns of exposure). Potential future land uses are not relevant to the determination; instead, a positive EI determination is appropriate when current exposures are adequately under control. (Of course, when it's known that patterns of exposure or land use are about to change, the overseeing agency will likely take a more conservative approach, but this would be a special case.)

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Groundwater-to-Surface Water Interaction

1. **For the purpose of making a Groundwater Environmental Indicator determination, how do I address groundwater-to-surface-water interaction?**

    In cases where groundwater is being discharged to surface water, you should, as a general matter, focus your groundwater environmental indicator evaluation on the question of whether or not contaminated groundwater is significantly impairing the quality of the surface water body. A positive environmental indicator determination would generally be appropriate where the groundwater is not significantly affecting the surface water body in a way that leads it to fail basic water-quality criteria.

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2. **What does the Groundwater Environmental Indicator deal with?**

    The "Migration of Contaminated Groundwater Under Control" environmental indicator pertains to the physical migration (i.e., further spread) of contaminated groundwater and contaminants within groundwater (e.g., non-aqueous phase liquids or NAPLs). It also includes the interaction of contaminated groundwater with surface water.

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3. **What do we mean by a stabilized plume?**

    A plume is stabilized if it remains within the "existing area of contaminated groundwater." A plume of contaminated groundwater could remain in its existing area if it is no longer expanding above levels of concern in the vertical or horizontal dimensions due to, for example, natural attenuation or engineered controls such as hydraulic containment and/or physical barriers. Alternatively, the plume of groundwater contamination might not be expanding within the geologic formation, but it might be discharging into a hydraulically connected surface water body. In such a situation, the plume of contaminated groundwater is not getting any bigger (i.e., the plume has "stabilized"), but it might or might not be "under control." The environmental indicator determination in such a setting would be based on whether or not the continued discharge of groundwater represented an unacceptable impact to the receiving surface water body.

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4. **Is the discharge of "contaminated" groundwater into surface water likely to be "insignificant?"**

   In some cases, overseeing agencies are likely to be able to conclude that a release from groundwater into surface water will be "insignificant" - and therefore "under control" - based on the levels of contaminants in the groundwater, without consideration of the volume or flow of the surface water body. As a rule of thumb, we have found that, if the groundwater concentrations for all constituents are less than 10 times the appropriate surface water quality criteria for both human health and aquatic life, the current groundwater discharge should be "insignificant" for environmental indicator purposes. In this case, the regulator would conclude that the groundwater environmental indicator had been met (at least with respect to the discharge to surface water).

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5. **How do I deal with issues of historic sediment contamination when assessing the groundwater-to-surface-water pathway?**

   In cases where groundwater is being discharged to surface water, you should, as a general matter, focus your groundwater environmental indicator evaluation on the question of whether or not contaminated groundwater is significantly impairing the quality of the surface water body. A positive environmental indicator determination would generally be appropriate where the groundwater is not affecting the surface water body in a way that leads it to fail basic water-quality criteria.

   In many cases, RCRA facilities are located near rivers or other water bodies characterized by historic sediment contamination. In such situations, the potential contribution of current groundwater discharge to sediment quality (and similarly, to the hyporrheic zone) would be beyond the scope of a groundwater environmental indicator determination. Instead, sediment quality issues would be dealt with as a part of the final remedy (or perhaps more broadly as part of an area-wide investigation).

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Contaminated Sediment

1. **In making a human health EI determination, how do I deal with releases to surface water that may be associated with contamination of fish above safe levels? How about contaminated sediment from runoff, direct discharges, etc., to which people may be exposed?**

   It will generally be possible (for the purposes of a human health EI) to address concerns over possible contaminated fish consumption or direct human exposure to contaminated sediments through some combination of source control and exposure controls. For example, some RCRA facilities have been found to directly discharge contaminants into relatively small water bodies, leading to potential fish contamination. At some of these facilities, human health EIs were achieved through control of the discharges (e.g., water outflows and runoff), combined with access restrictions and signs warning against fishing. Other facilities may have contributed to broader water quality or sediment problems, which may have led to bioaccumulation of contaminants in fish. Again, we expect that measures to achieve the human health EI would focus on cutting off significant releases from the RCRA facility, perhaps combined with fish advisories or similar methods to reduce exposure where it is a concern.

   Again, it should be emphasized that achieving EIs does not necessarily mean that a facility has completed its corrective action obligations. In the situations described here, the final remedy is likely to require substantially more aggressive remedies, perhaps including direct cleanup of the contaminated sediment. In some cases, the remedy will likely take place as part of a broader area-wide cleanup.

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Contamination From off-Site Sources

1. **How do I address plumes of contaminated groundwater that originate from off-site sources in making a Migration of Contaminated Groundwater under Control EI determination at a RCRA facility?**

As stated in the February 5, 1999 guidance from the Office of Solid Waste, OSW (renamed Office of Resource Conservation and Recovery, ORCR, on January 18, 2009) on how to determine if a facility has met the RCRA Environmental Indicators, the Migration of Contaminated Groundwater under Control EI determination apples site-wide for all contaminated groundwater "subject to corrective action at or from the identified facility." Therefore, plumes that originate from off-site sources would not be subject to a RCRA groundwater EI determination for the RCRA facility in question. The overseeing agency, however, should ensure that such plumes are addressed as necessary through other regulatory actions.

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Vapor Intrusion

1. **What does USEPA recommend as the best way to address Vapor Intrusion for EI determinations in the time remaining before 2005?**

   EPA recommends that its November 2002 Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils be used to assess this pathway for the purpose of making RCRA EI determinations. Specifically, this would involve the use of the preliminary screening criteria in Tiers 1 and 2, and, if necessary, Tier 3 site-specific modeling for EI determinations. If scientific, site-specific models (such as the Johnson & Ettinger (1991) model spreadsheets found on the Superfund Program's website(www.epa.gov/superfund) or other appropriate models) do not indicate that the site has a potential to cause exposures above the applicable EI criteria (using site-appropriate input parameters), then this pathway should be considered to have been adequately screened for EI exposure assessment purposes. In such cases, we do not believe that confirmatory sampling will be necessary, for the purpose of making an EI determination.

   If Tier 3 models indicate a potential for exposure at levels above the applicable criteria, additional data gathering (e.g., sub-slab sampling or indoor air monitoring) or remediation may be needed to meet the human health environmental indicator.

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2. **What are the applicable criteria to use in determining whether the human health environmental indicator has been met for the vapor intrusion pathway?**

   For the purpose of making Current Human Exposure under Control EI determinations with respect to vapor intrusion, EPA generally recommends the use of 10-5 levels for carcinogens (incremental individual lifetime cancer risk), and a Hazard Quotient (HQ) of 1 for non-cancer risks.) (For occupational settings, see question 3 below.)

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3. **How is vapor intrusion into occupational and other non-residential settings to be evaluated for RCRA EI determinations?**

   Occupational settings where persons are in a working situation: Such settings could include workplaces where workers are handling hazardous chemicals (e.g., manufacturing facilities) similar to or different from those in the subsurface contamination, as well as other workplaces, such as administrative and other office buildings where chemicals are not routinely handled in daily activities. OSHA and EPA have agreed that OSHA generally will take the lead role in addressing occupational exposures. Therefore, EPA does not expect the November 2002 Vapor Intrusion Guidance to be used in such settings (i.e., primarily occupational). Nevertheless, we recommend that such facilities be notified of the potential for this exposure pathway and that they consider any potential exposure that may result.

   Nonresidential settings where persons are in a non-working situation: Nonresidential buildings may need to be evaluated where people (typically non-workers) may be exposed to hazardous constituents entering into the air space from the subsurface. This would include, for example, buildings where the general public may be present, e.g., schools, libraries, hospitals, hotels, and stores. In these situations we believe the November 2002 Vapor Intrusion Guidance may be appropriate, although we recommend appropriate adjustments be made for nonresidential exposure durations, the building specific air volumes and air exchange rates, as well as other relevant factors to be considered.

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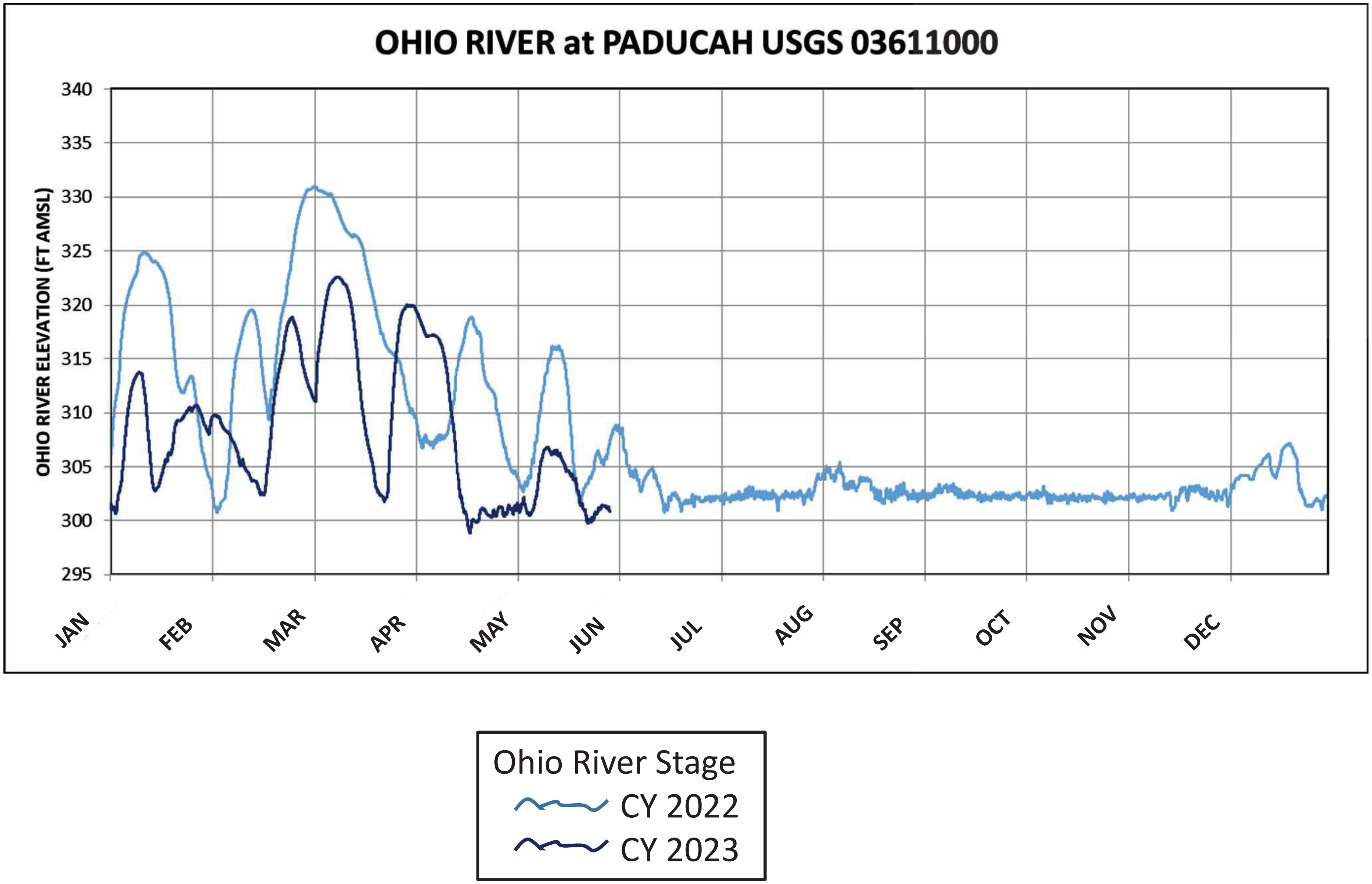
4. **How is future land use considered in making a RCRA Current Human Exposure Under Control EI determination for vapor intrusion?**

   Environmental Indicators reflect *current*, not future or potential, conditions. See response 13 in the "General" section above.

Attachment 3

Precipitation and Ohio River Stage Data


OHIO RIVER at PADUCAH USGS 03611000
OHIO RIVER ELEVATION (FT AMSL)
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Ohio River Stage
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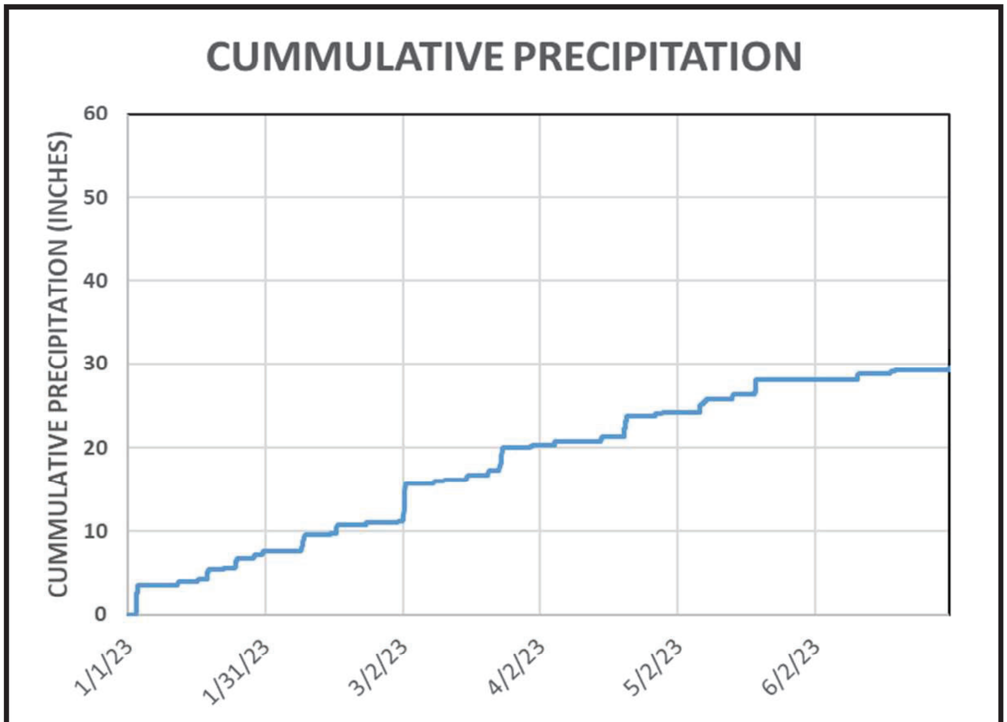
CUMMULATIVE PRECIPITATION
CUMMULATIVE PRECIPITATION (INCHES)
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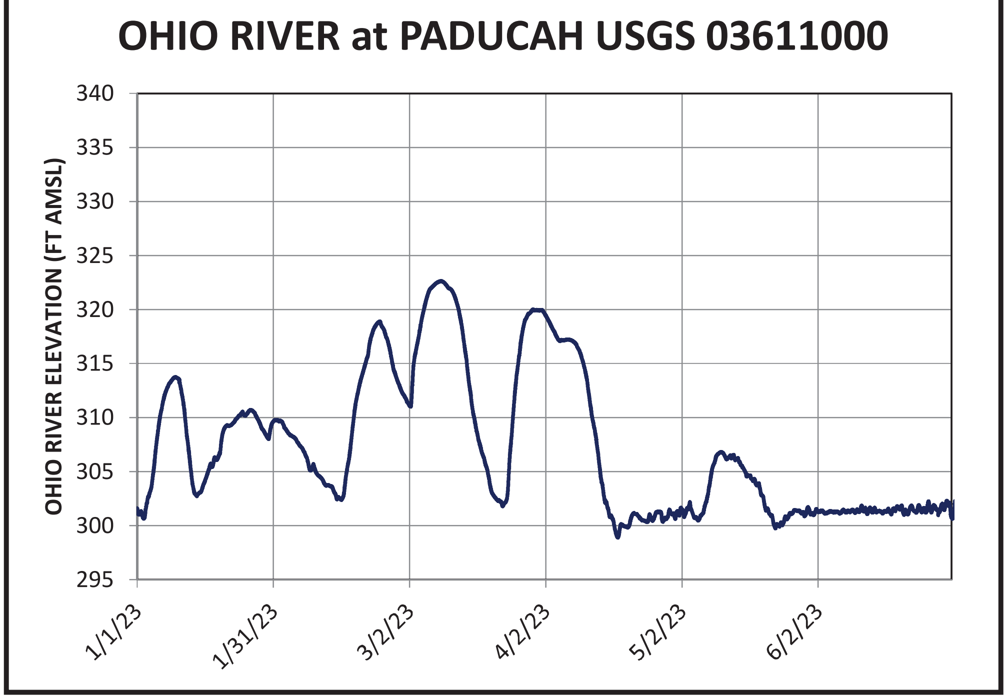
5/2/23
6/2/23


OHIO RIVER at PADUCAH USGS 03611000
OHIO RIVER ELEVATION (FT AMSL)
340
335
330
325
320
315
310
305
300
295
1/1/23
1/31/23
3/2/23
4/2/23
5/2/23
6/2/23

APPENDIX E

POTENTIOMETRIC MAPS

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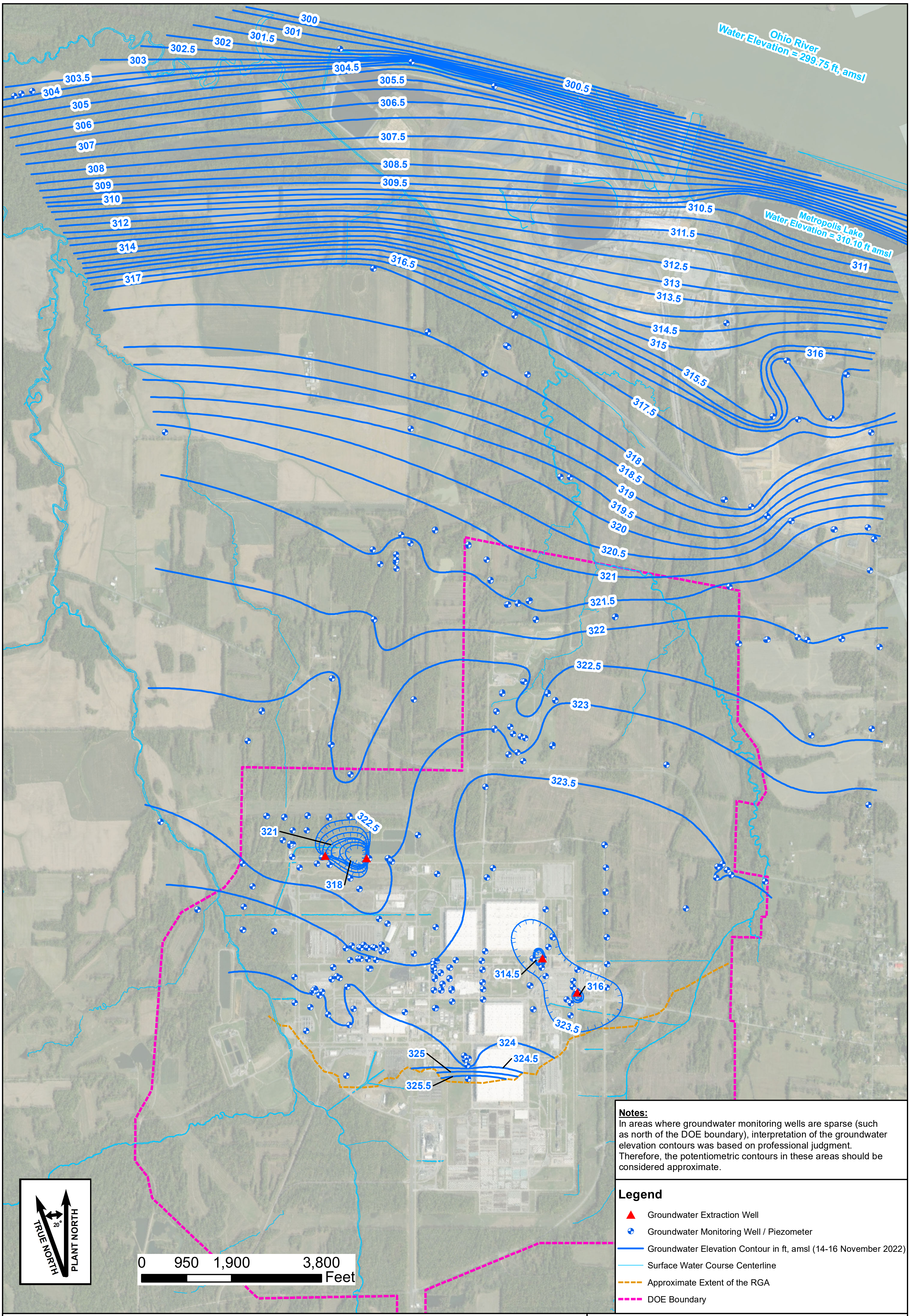


Notes:
In areas where groundwater monitoring wells are sparse (such as north of the DOE boundary), interpretation of the groundwater elevation contours was based on professional judgment. Therefore, the potentiometric contours in these areas should be considered approximate.

Legend

- ▲ Groundwater Extraction Well
- ● Groundwater Monitoring Well / Piezometer
- — Groundwater Elevation Contour in ft, amsl (14-16 November 2022)
- — Surface Water Course Centerline
- - - Approximate Extent of the RGA
- - - DOE Boundary

MAP SOURCE INFORMATION

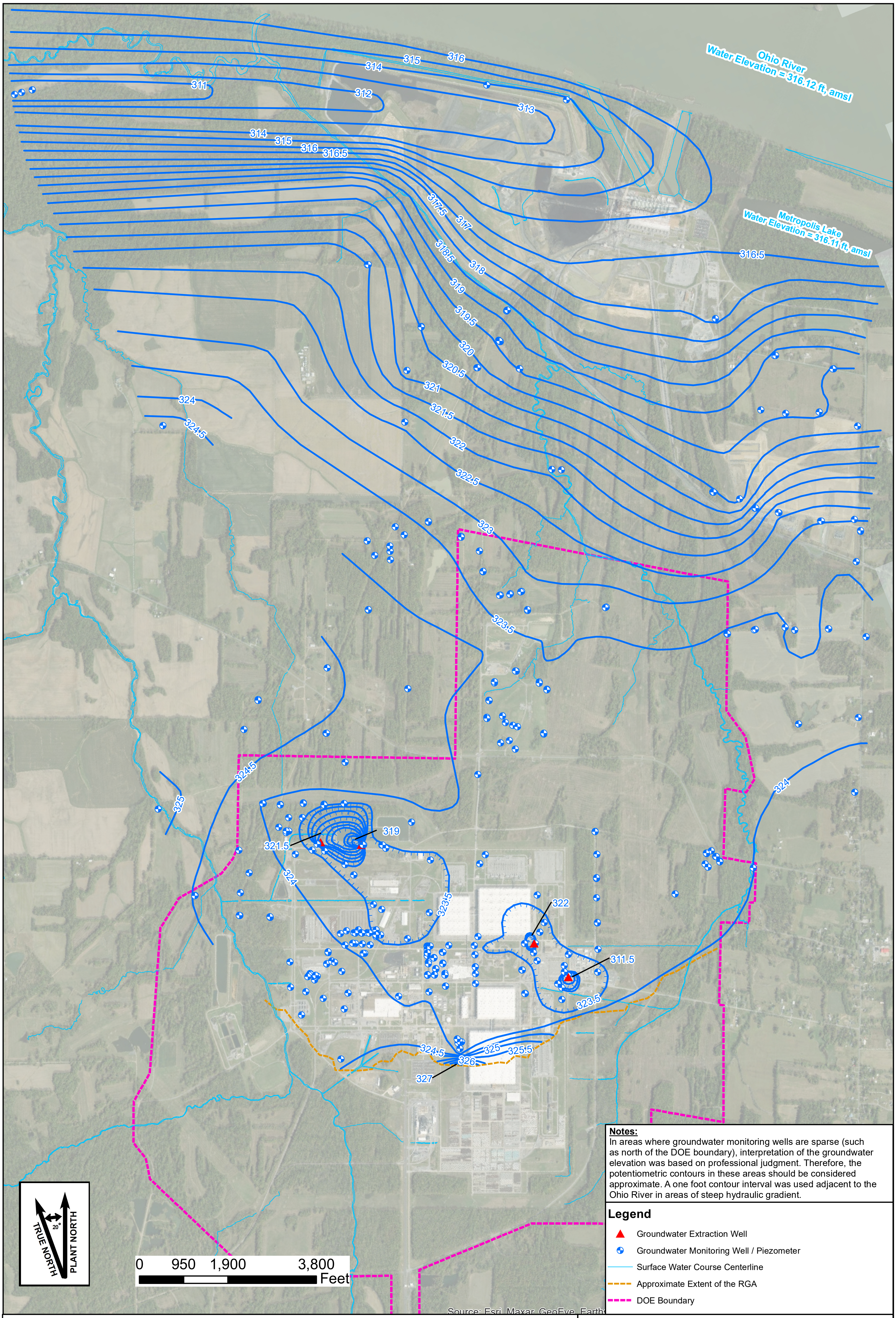
Map Generation Date and Location - 1/27/2023 Geosyntec\\fedprojects-01\paducah$\Knoxville\GW Strategy\GIS\MXDs\2021-2022 Potentiometric Surface Maps
Map Layer Location: Geosyntec\\fedprojects-01\paducah$\Knoxville\GW Strategy\GIS\MXDs\2021-2022 Potentiometric Surface Maps\November 2022 Potentiometric Surface Map.mxd
Image Source: Aerial 2021: http://pegasis.pad.pppo.gov:6080/arcgis/services; and
Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.
Shapefile for Surface Water Course Centerline provided by FRNP on 11/8/2022.
DOE Property Boundary provided by FRNP on 2/4/2021.
Northing and easting of wells obtained from Pegasis, downloaded on 6/14/2022.
Groundwater elevation was based on the 11/14/2022 - 11/16/2022 measurements. Ohio River elevation was estimated as the average of elevations measured by the USGS at Paducah Station USGS 0361100 and Olmsted, IL Station (USGS 03612600) between 11/14/2022 - 11/16/2022.
Groundwater elevation for the TVA wells were provided by the Kentucky Division of Waste Management on 11/22/22. Water elevation at Metropolis Lake was provided by FRNP on 11/15/2022.
Due to erroneous measurement of depth to groundwater in EW235 on 11/14/2022, measurement from 11/21/2022 was used to prepare this map.
amsl = above mean sea level

U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

FOUR RIVERS
NUCLEAR PARTNERSHIP, LLC

Figure 1. November 2022 RGA Potentiometric Surface Map

DRAFT Work Product For Review



Notes:
In areas where groundwater monitoring wells are sparse (such as north of the DOE boundary), interpretation of the groundwater elevation was based on professional judgment. Therefore, the potentiometric contours in these areas should be considered approximate. A one foot contour interval was used adjacent to the Ohio River in areas of steep hydraulic gradient.

Legend

- ▲ Groundwater Extraction Well
- ● Groundwater Monitoring Well / Piezometer
- — Surface Water Course Centerline
- - - Approximate Extent of the RGA
- - - DOE Boundary

MAP SOURCE INFORMATION

Map Generation Date and Location - 5/15/2023 Geosyntec\\fedprojects-01\paducah$\Knoxville\GW Strategy\GIS\MXDs\2022-2023 Potentiometric Surface Maps
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Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.
Shapefile for Surface Water Course Centerline provided by FRNP on 11/8/2022.
DOE Property Boundary provided by FRNP on 2/4/2021.
Northing and easting of wells obtained from Pegasis, downloaded on 6/14/2022.
Groundwater elevation was based on the 3/27/2023 - 3/30/2023 measurements. Ohio River elevation was estimated as the average of elevations measured by the USGS at Paducah Station USGS 0361100 and Olmsted, IL Station (USGS 03612600) between 03/27/2023 - 03/30/2023.
Groundwater elevation for the TVA wells were provided by the Kentucky Division of Waste Management on 4/7/2023. Water elevation at Metropolis Lake was provided by FRNP on 4/4/2023.
amsl = above mean sea level

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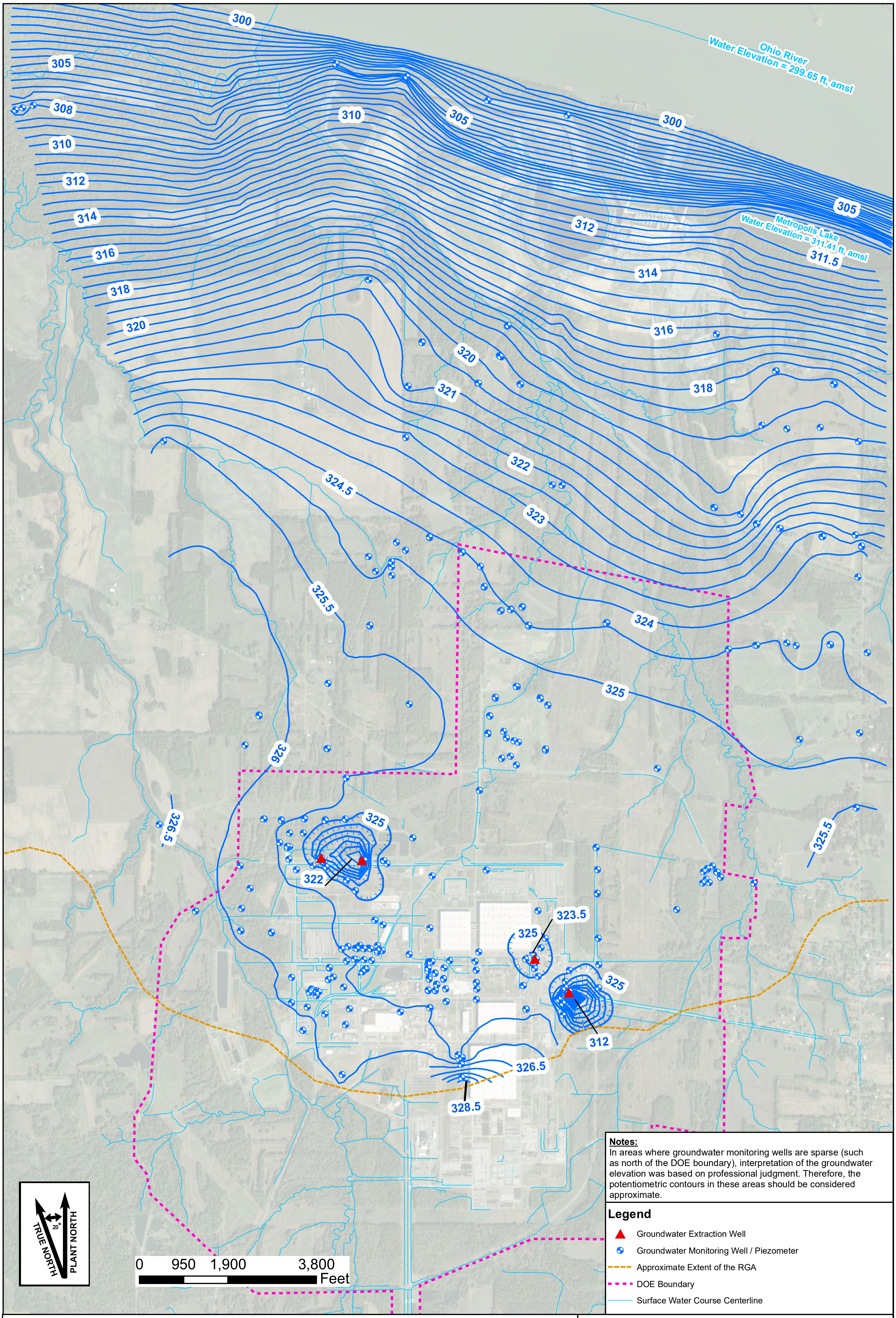
Figure 1. March 2023 RGA Potentiometric Surface Map



Notes:
In areas where groundwater monitoring wells are sparse (such as north of the DOE boundary), interpretation of the groundwater elevation was based on professional judgment. Therefore, the potentiometric contours in these areas should be considered approximate.

Legend

- ▲ Groundwater Extraction Well
- ● Groundwater Monitoring Well / Piezometer
- Approximate Extent of the RGA
- DOE Boundary
- Surface Water Course Centerline

MAP SOURCE INFORMATION

Map Generation Date and Location - 10/07/2023 Geosyntec\\fedprojects-01\paducah$\Knoxville\GW Strategy\GIS\MXDs\2022-2023 Potentiometric Surface Maps
Map Layer Location: Geosyntec\\fedprojects-01\paducah$\Knoxville\GW Strategy\GIS\MXDs\2022-2023 Potentiometric Surface Maps\May 2023 Potentiometric Surface Map_10062023.mxd
Image Source: Aerial 2021: http://pegasis.pad.pppo.gov:6080/arcgis/services; and
Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.
Shapefile for Surface Water Course Centerline provided by FRNP on 11/8/2022.
DOE Property Boundary provided by FRNP on 2/4/2021.
Northing and easting of wells obtained from Pegasis, downloaded on 6/14/2022.
Groundwater elevation was based on the 5/22/2023 - 5/26/2023 measurements. Ohio River elevation was estimated as the average of elevations measured by the USGS at Paducah Station USGS 0361100 and Olmsted, IL Station (USGS 03612600) between 5/22/2023 - 5/26/2023.
Groundwater elevation for the TVA wells were provided by the Kentucky Division of Waste Management letter to DOE (#KY8-890-008-982) dated 06/12/2023. Water elevation at Metropolis Lake was provided by FRNP on 5/30/2023.
amsl = above mean sea level

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PADUCAH GASEOUS DIFFUSION PLANT

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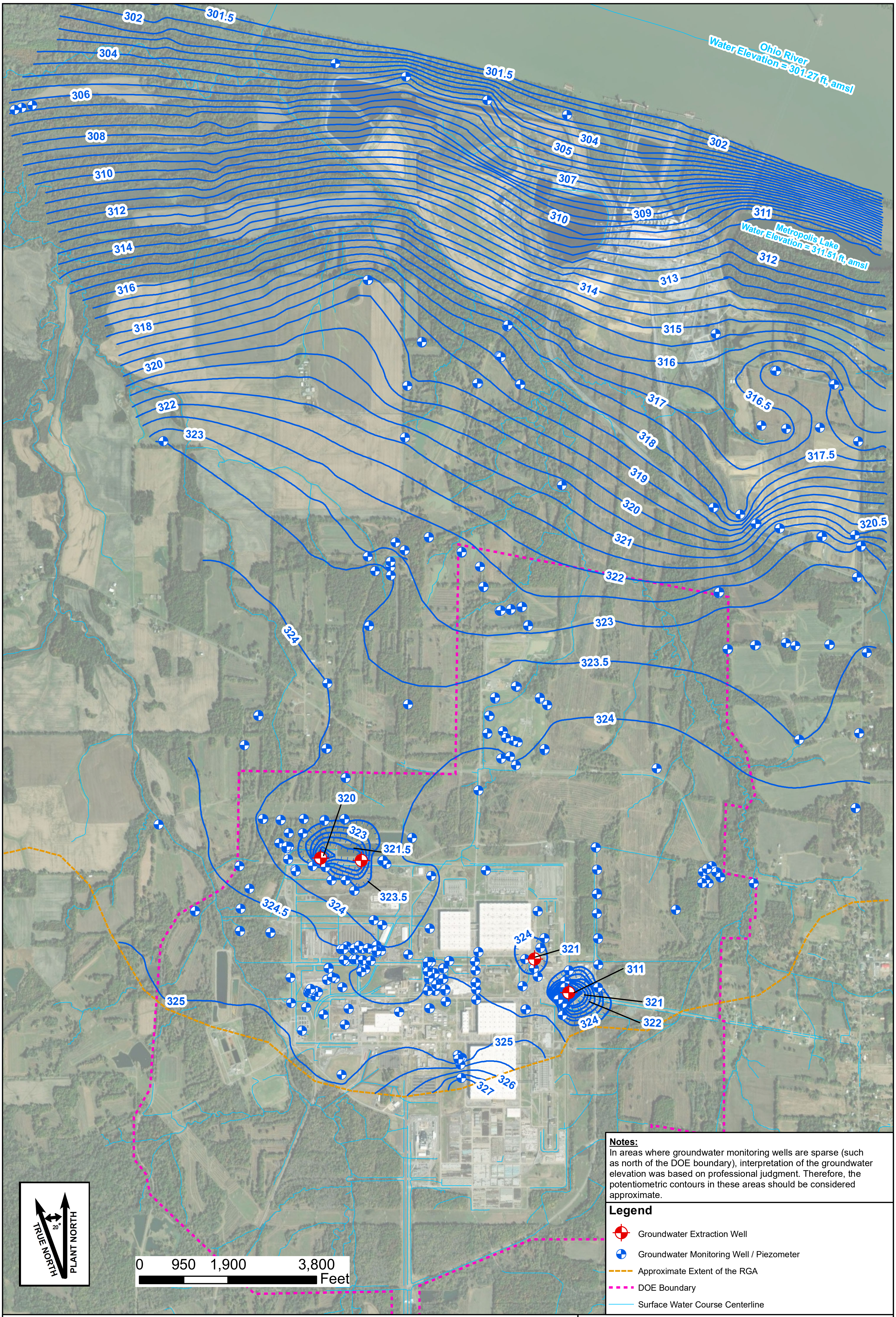
Figure 1. May 2023 RGA Potentiometric Surface Map



Notes:
In areas where groundwater monitoring wells are sparse (such as north of the DOE boundary), interpretation of the groundwater elevation was based on professional judgment. Therefore, the potentiometric contours in these areas should be considered approximate.

Legend

- Groundwater Extraction Well
- Groundwater Monitoring Well / Piezometer
- Approximate Extent of the RGA
- DOE Boundary
- Surface Water Course Centerline

MAP SOURCE INFORMATION

Map Generation Date and Location - 10/08/2023 Geosyntec\\fedprojects-01\paducah$\Knoxville\GW Strategy\GIS\MXDs\2022-2023 Potentiometric Surface Maps
Map Layer Location: Geosyntec\\fedprojects-01\paducah$\Knoxville\GW Strategy\GIS\MXDs\2022-2023 Potentiometric Surface Maps\August 2023 Potentiometric Surface Map_10082023.mxd
Image Source: Aerial 2021: http://pegasis.pad.pppo.gov:6080/arcgis/services; and
Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.
Shapefile for Surface Water Course Centerline provided by FRNP on 11/8/2022.
DOE Property Boundary provided by FRNP on 2/4/2021.
Northing and easting of wells obtained from Pegasis, downloaded on 6/14/2022.
Groundwater elevation was based on the 8/21/2023 - 8/24/2023 measurements. Groundwater elevation of extraction wells was measured on 08/28/2023 and was provided by FRNP on 9/14/2023.
Ohio River elevation was estimated as the average of elevations measured by the USGS at Paducah Station
USGS 0361100 and Olmsted, IL Station (USGS 03612600) between 5/22/2023 - 5/26/2023.
Groundwater elevation for the TVA wells were provided by the Kentucky Division of Waste Management letter to DOE (#KY8-890-008-982) dated 08/30/2023. Water elevation at Metropolis Lake was provided by FRNP on 8/24/2023.
amsl = above mean sea level

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Figure 1. August 2023 RGA Potentiometric Surface Map

APPENDIX F

DETAILED CORRELATIONS BETWEEN LITHOLOGIC UNITS IN THE MCNAIRY FORMATION ACROSS THE PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY, FRNP-RPT-0249

Department of Energy

Portsmouth/Paducah Project Office
1017 Majestic Drive, Suite 200
Lexington, Kentucky 40513
(859) 219-4000

January 13, 2023

PPPO-02-10021514-23B

Mr. Brian Begley
Federal Facility Agreement Manager
Division of Waste Management
Kentucky Department for Environmental Protection
300 Sower Boulevard, 2nd Floor
Frankfort, KY 40601

Mr. Victor Weeks
Federal Facility Agreement Manager
U.S. Environmental Protection Agency, Region 4
61 Forsyth Street
Atlanta, GA 30303

Dear Mr. Begley and Mr. Weeks:

TRANSMITTAL OF DETAILED CORRELATIONS BETWEEN LITHOLOGIC UNITS IN THE MCNAIRY FORMATION ACROSS THE PADUCAH GASEOUS DIFFUSION PLANT, FRNP-RPT-0249

Please find enclosed the *Detailed Correlations between Lithologic Units in the McNairy Formation across the Paducah Gaseous Diffusion Plant*, FRNP-RPT-0249. The subject document presents an assessment of the utility of existing soil boring logs to identify faulting in the McNairy Formation at the Paducah Site. This final version of the subject document incorporates informal review comments from the Paducah Gaseous Diffusion Plant Groundwater Modeling Working Group, and responses to these comments are included in Appendix F.

If you have any questions or require additional information, please contact Richard Bonczek at (859) 321-7127.

Sincerely,

TRACEY
DUNCAN
Digitally signed by
TRACEY DUNCAN
Date: 2023.01.13
07:48:49 -06'00'

Tracey Duncan
Federal Facility Agreement Manager
Portsmouth/Paducah Project Office

Enclosure:
Detailed Correlations between Lithologic Units in the McNairy Formation across the Paducah Gaseous Diffusion Plant, FRNP-RPT-0249

General Reference Compendium

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weeks.victor@epa.gov, EPA

FRNP-RPT-0249

Detailed Correlations between Lithologic Units in the McNairy Formation across the Paducah Gaseous Diffusion Plant

FOUR RIVERS
NUCLEAR PARTNERSHIP, LLC

This document is approved for public release per review by:

David Hayden
FRNP Classification Support

8-24-2022
Date

FRNP-RPT-0249

Detailed Correlations between Lithologic Units in the McNairy Formation across the Paducah Gaseous Diffusion Plant

Date Issued—August 2022

U.S. DEPARTMENT OF ENERGY
Office of Environmental Management

Prepared by
FOUR RIVERS NUCLEAR PARTNERSHIP, LLC,
managing the
Deactivation and Remediation Project at the
Paducah Gaseous Diffusion Plant
under Contract DE-EM0004895

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CONTENTS

FIGURES

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ACRONYMS

amsl	above mean sea level
DNAPL	dense non-aqueous phase liquid
DOE	U.S. Department of Energy
DQO	data quality objective
EPA	U.S. Environmental Protection Agency
FS	feasibility study
KRCEE	Kentucky Research Consortium for Energy and the Environment
MOA	Memorandum of Agreement
OU	operable unit
PGDP	Paducah Gaseous Diffusion Plant
RGA	Regional Gravel Aquifer
RI	remedial investigation
TVA	Tennessee Valley Authority

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EXECUTIVE SUMMARY

The McNairy Formation is an Upper Cretaceous age sequence of unconsolidated/non-lithified fine sands, silts, and clays that underlies the Regional Gravel Aquifer (RGA) at the Paducah Gaseous Diffusion Plant (PGDP). Regional geologic investigations in Illinois and seismic and electrical conductivity surveys conducted near PGDP (i.e., within 0.5 to 1.5 miles) demonstrate the presence of faults in the McNairy Formation (Blits et al. 2008). If present in the PGDP area, fault zones could be preferential flow paths of groundwater contaminants from the relatively high hydraulic conductivity RGA into the lower hydraulic conductivity McNairy Formation, and perhaps to the Mississippi limestone bedrock below.

The Memorandum of Agreement for the most recent Five-Year Review (DOE 2020) and planning agreements in support of the C-400 Complex Operable Unit (OU) Remedial Investigation/Feasibility Study have identified faulting in the McNairy Formation as a significant uncertainty.

This white paper is a review of the available lithologic information for PGDP to assess the presence and displacement of faulting in the McNairy Formation. In general, the distances between the available soil borings and the depositional heterogeneity are too great to correlate small-scale sedimentary units between the soil borings with confidence. Based on review of the lithologic information, no evidence of faulting is apparent from the correlation of soil borings; however, this white paper concludes that the deep PGDP soil borings with available lithologic logs are spaced too far apart to identify the occurrence of faults with offsets of approximately 25 ft or less in the McNairy Formation. Closely-spaced soil borings of the C-400 Complex OU remedial investigation did not identify faulting in the upper McNairy Formation.

Additional field study using the available investigation techniques is unlikely to provide enough data to resolve the following identified uncertainties in the Memorandum of Agreement for the 2018 Five-Year Review regarding protectiveness for the Northwest Plume, Northeast Plume, and Water Policy response actions (DOE 2020):

- The presence of unknown contamination in off-site areas; and
- The presence of unknown migration of contamination due to pathways not understood.

Detailed study of the upper-most McNairy Formation in the area of the C-400 Complex determined that faulting is not present locally and trichloroethene (TCE)-contamination levels in soils and groundwater decline rapidly with increasing depth. Thus, the area of the primary source of TCE contamination to groundwater at PGDP is unlikely to contribute significantly to off-site groundwater contamination in the McNairy Formation.

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1. INTRODUCTION

1.1 PURPOSE

The McNairy Formation is an Upper Cretaceous age sequence of unconsolidated/non-lithified fine-grained clastic sediments (i.e., sedimentary beds of fine sand, silt, and clay) that disconformably underlays the highly conductive Regional Gravel Aquifer (RGA) at the Paducah Gaseous Diffusion Plant (PGDP). The lower hydraulic conductivity of the upper and middle members of the McNairy Formation limits vertical groundwater flow and vertical extent of dissolved-phase groundwater contamination plumes that originate at PGDP, which principally consist of trichloroethene (TCE) and technetium-99 (Tc-99).

Geologic investigations of nearby areas in Illinois (Nelson 1998), which includes the area of a study conducted at Barnes Creek, Illinois, by PGDP (DOE 2004), have identified faults in the McNairy and older formations, as well as limited occurrences in younger geologic units. These faults generally trend in a northeast-southwest direction and potentially extend beneath the vicinity of PGDP, with McNairy Formation displacements of as much as 30 ft (KRCEE 2006) to 45 ft (Almayahi and Woolery 2018). Similar faulting is largely unknown in western Kentucky, due in part to younger loess deposits (i.e., wind-blown silt units) that blanket older formations. If faulting exists in the McNairy Formation beneath PGDP, the fault zones may be structures of enhanced hydraulic conductivity that allow dissolved-phase contamination to migrate below the RGA. Moreover, where TCE exists as dense non-aqueous phase liquid (DNAPL) in the RGA, fault planes could provide a conduit for deeper DNAPL penetration. The Memorandum of Agreement (MOA) for the most recent Five-Year Review (DOE 2020) and planning agreements in support of the C-400 Complex Operable Unit (OU) Remedial Investigation/Feasibility Study (RI/FS) have identified faulting in the McNairy Formation as a significant uncertainty.

1.2 OBJECTIVES

Characterization of site faulting and the potential for fault-controlled plume migration from the RGA into the McNairy Formation at PGDP, which includes the Water Policy-affected area,[1] are needed to better understand the following:

- the presence of unknown contamination in off-site areas; and
- the presence of unknown migration of contamination due to pathways[2] not understood.

The primary objective of this white paper is to develop two lithological cross sections of the McNairy Formation; one along a north-south transect and the other along an east-west transect within the PGDP and Water Policy-affected area (see Figure 1). The cross sections are used to assess the presence of fault displacement and, if present, the magnitude of fault displacement.

Inputs into the lithological correlations include a combination of PGDP historical soil boring logs and recent soil boring logs of the C-400 Complex OU RI/FS at the PGDP, for soil borings that extend into the McNairy Formation, and reports of McNairy Formation soil borings of the adjacent Tennessee Valley Authority (TVA) Shawnee Fossil Plant.

---

[1] The MOA regarding the 2018 Five-Year Review recognizes fault-related concerns with regard to protectiveness determinations for the Northeast and Northwest Groundwater Plumes and the Water Policy response actions (DOE 2020).

[2] The term “pathways” is used synonymously with “preferential pathways for contaminant migration.”

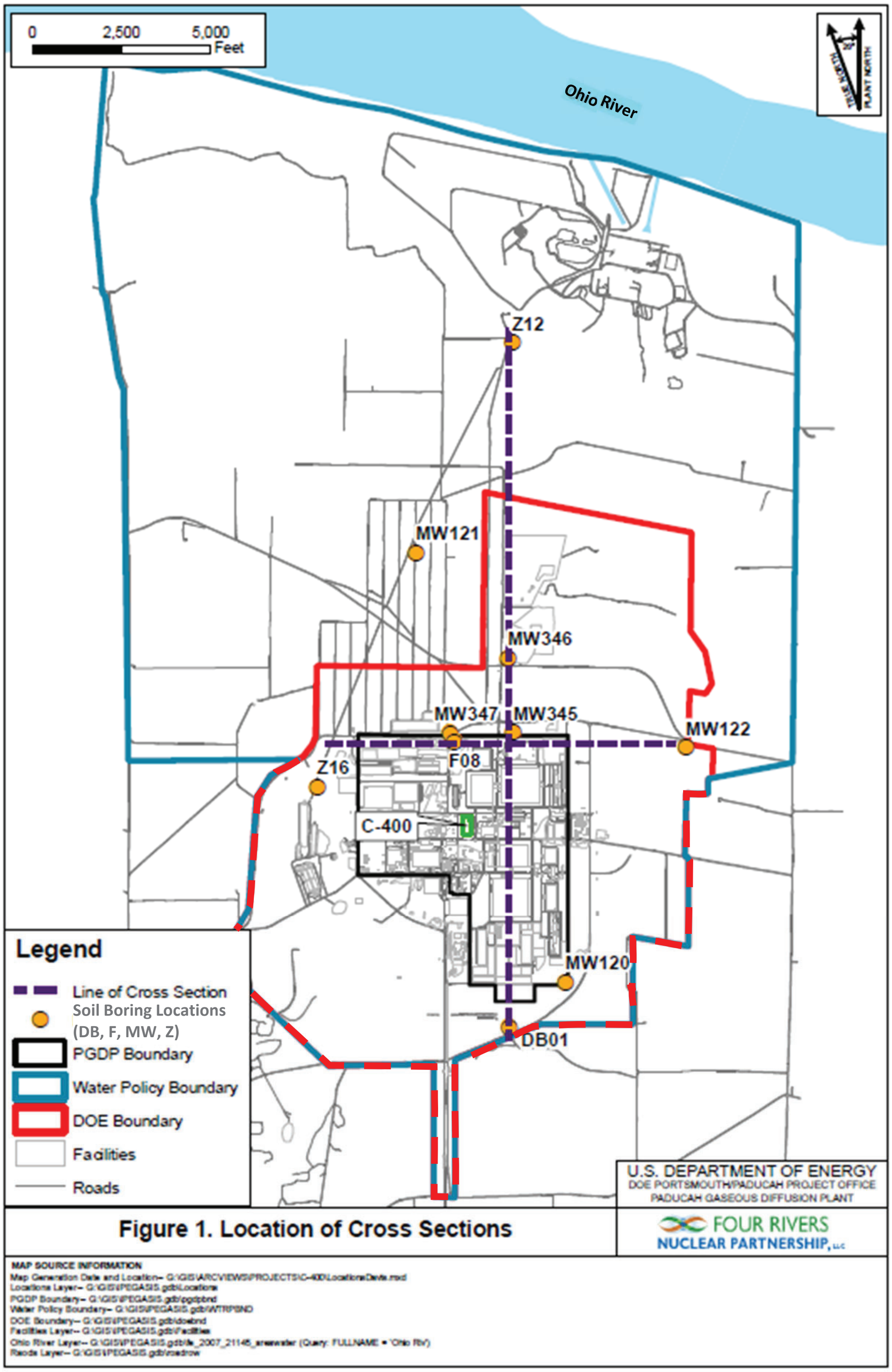

Figure 1. Location of Cross Sections

1.2.1 Memorandum of Agreement for Informal Dispute of the Five-Year Review

The MOA for resolution of informal dispute concerning the latest Five-Year Review included the following requirements (DOE 2020):

> As part of the U.S. Environmental Protection Agency's (EPA's) independent assessment of the FY 2018 Five-Year Review, EPA made a protectiveness deferred determination for the Northeast Plume, the Northwest Plume, and Water Policy response actions, until additional data are collected to verify that human exposures are not occurring. EPA determined additional actions are needed, specifically the collection of additional geological data at the C-400 Complex OU and the development of detailed correlations between lithologic units in the McNairy Formation across the entire Paducah site, to support an accurate characterization of site faulting and the potential for fault-controlled plume migration across the Plant and beyond the Plant boundaries, (including the Water Policy Affected Area). EPA requested that the detailed correlations of the McNairy Formation be reported not later than the C-400 Complex OU D1 Remedial Investigation/Feasibility Study (RI/FS) Report.
>
> The following uncertainties were identified regarding protectiveness for the Northwest Plume, Northeast Plume, and Water Policy response actions:
>
> - The presence of unknown contamination in off-site areas.
> - The presence of unknown migration of contamination due to pathways not understood.
>
> To help manage these uncertainties in regard to protectiveness, EPA proposed additional characterization of site faulting and the potential for fault-controlled plume migration across the Paducah Site, including the Water Policy Affected Area, as part of the 2023 Five-Year Review.
>
> DOE will develop a technical paper discussing two lithological correlations of the McNairy Formation; one along a north-south transect and the other along an east-west transect (see Figure 1). The transects will be developed using the existing data from previously drilled 8 deeper soil borings and from 6 discrete locations, that extend near/through the base of the McNairy Formation (which occurs at elevations of -2 ft to 66 ft amsl beneath the Paducah Site).
>
> - A north-south transect (relative to the Plant coordinate system) of 5 previously drilled soil borings/4 locations over ~ 19,200 ft (~ 3.6 miles), extending from immediately south of the Paducah Site industrial complex to near TVA's Shawnee Steam Plant.
>
> - An east-west transect (relative to the Plant coordinate system) of 4 previously drilled soil borings/3 locations over ~ 5,500 ft (~ 1.0 miles) across the north side of the Plant.
>
> Inputs into the lithological correlations will include a combination of the historical soil boring logs from both the deeper and shallower McNairy Formation within the Paducah Site and the adjacent TVA Shawnee Steam Plant and soil boring logs of the McNairy Formation from the C-400 Complex OU RI/FS (currently underway) that fall along the north-south and east-west transects.

1.2.2 Collaboration of Groundwater Model Working Group

The PGDP Groundwater Modeling Working Group includes representatives from EPA, Kentucky Department for Environmental Protection, Commonwealth of Kentucky Radiation Health Branch, Kentucky Research Consortium for Energy and the Environment (KRCEE), TVA, and DOE and its technical consultants. The PGDP Groundwater Modeling Working Group identified the main contents and structure of this white paper (an outline was approved during the January 13, 2021, PGDP Groundwater Model Working Group meeting), and will provide peer review.

2. BACKGROUND

Seismicity and related faulting are long-standing interests for safety analysis of PGDP and for siting studies of a potential on-site disposal facility for wastes generated from future environmental restoration activities implemented under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980. Related studies and deep groundwater monitoring for PGDP included seven deep soil borings with both lithologic descriptions and geophysical logs that penetrate to near the base of the McNairy Formation at depths of 315 ft to 369 ft, and three shallower McNairy Formation monitoring wells, MW120, MW121, and MW122, at depths of 158 ft to 212 ft.

2.1 McNAIRY FORMATION GEOLOGIC SETTING

PGDP, located in McCracken County, Kentucky, lies near the northern limit of the Mississippi Embayment. In the area, the ancestral Tennessee River eroded through the Paleocene Porters Creek Clay and deposited Tertiary and Quaternary sands and gravels disconformably on the Cretaceous McNairy Formation. The Tertiary and Quaternary sand and gravel deposits constitute the uppermost aquifer in the area of the buried valley fill.

The McNairy Formation consists of approximately 270 ft of fine-grained, clastic sediments overlying a thin rubble zone (Tuscaloosa Formation?) and Mississippian-age limestone bedrock in the PGDP area. Collectively, the McNairy Formation derives from lagoonal-to-shallow marine environments, which have frequent lateral and vertical depositional discontinuities. Geologic studies have identified three members within the McNairy Formation in the northern end of the Mississippi Embayment: (1) an upper member of sand, silt, and clay; (2) a middle member of greater silt and clay content (informally named the "Levings Member"); and (3) a lower member predominately consisting of sand.

2.1.1 Summary of Historical PGDP Information and Studies

The earliest deep McNairy Formation soil borings at PGDP, Z-12 and Z-16, are derived from studies of seismic properties of the soils underlying PGDP. Geophysical and lithologic logs for these borings are provided in the following two reports.

- *Final Data Package, Geophysical Study of Subsurface Conditions in the Vicinity of the Paducah Gaseous Diffusion Plant* (Selfridge et al. 1991); and

- *Assessment and Interpretation of Cross- and Down-Hole Seismograms at the Paducah Gaseous Diffusion Plant*, K/GDP/SAR-9 (Staub, Wang, and Selfridge 1991).

Northeast Plume Preliminary Characterization Summary Report, includes both gamma ray activity and lithologic logs for deep McNairy Formation soil boring F-08 (DOE 1995).

Gamma ray activity and lithologic logs for rubble zone monitoring wells MW345, MW346, and MW347 are found in *Data Report for the Sitewide Remedial Evaluation for Source Areas Contributing to Off-Site Groundwater Contamination at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1845&D0 (DOE 1999a).

Seismic Investigation Report for Siting of a Potential On-Site CERCLA Waste Disposal Facility at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky, provides geophysical and lithologic logs for soil borings DB-01 and DB-02 (DOE 2004). These are twinned (i.e., closely-spaced) soil borings with similar sampling results. Only DB-01 is discussed further in this white paper.

Lithologic logs of the three shallower McNairy Formation monitoring wells, MW120, MW121, and MW122, are found in *Results of the Site Investigation, Phase I, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (CH2M HILL 1991).

Lithologic logs, gamma ray activity logs, and other geophysical logs are available for an additional 79 soil borings completed in the upper member of the McNairy Formation (among the McNairy Formation soil borings identified in Appendix A). *Northeast Plume Preliminary Characterization Summary Report* (DOE 1995), and *Data Report for the Sitewide Remedial Evaluation for Source Areas Contributing to Off-Site Groundwater Contamination at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 1999a), provide 56 of the log suites.

2.1.2 Concerns

As the shallow aquifer and primary pathway for off-site groundwater migration, the RGA is the focus of groundwater monitoring for PGDP. Grab groundwater sample results in *Northeast Plume Preliminary Characterization Summary Report* (DOE 1995), and *Remedial Investigation Report for Waste Area Grouping 6 at Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 1999b), indicate that dissolved TCE levels rapidly decline with depth in the McNairy Formation. PGDP has few monitoring wells completed in the McNairy Formation. The McNairy Formation monitoring wells include MW102, MW120, MW121, MW122, MW133, MW140, MW239, MW247, and MW356; multi-port wells MW405, MW406, MW407, and MW408; and MW345, MW346, and MW347 screened in the lower McNairy Formation member and the rubble zone located below the base of the McNairy Formation. Even with a much greater number of McNairy Formation monitoring wells, monitoring for contaminant migration along a fault zone could not avert significant uncertainty.

Concern exists that dissolved TCE plumes that originate at PGDP may be present in the McNairy Formation and impact groundwater quality in the Water Policy Box to the north of PGDP (see Figure 1). Potential dissolved-phase TCE plumes in the deep McNairy Formation could migrate to drinking water supply wells on the north side of the Ohio River, specifically those in the city of Metropolis, Illinois, although there is no evidence that such migration has happened. Moreover, TCE is known to be present as DNAPL in several PGDP spill and burial sites. By its nature, DNAPL has the potential to penetrate to significant depths and serve as a source to secondary dissolved-phase plumes.

Faults of the Fluorspar Area Fault Complex of southern Illinois generally trend in a northeast/southwest direction that project into the area of PGDP.[3] Several geophysical investigations, primarily seismic surveys,

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[3] Seismic and electrical conductivity surveys demonstrate the presence of faults in the McNairy Formation within 0.5 to 1.5 miles of PGDP (Blits et al. 2008).

have demonstrated the presence of buried high-angle faults with McNairy Formation displacements of as much as 30 ft (KRCEE 2006) to 45 ft (Almayahi and Woolery 2018) that are interpreted to extend upwards into the Tertiary and Quaternary sand and gravel deposits of the RGA. Relevant fault-related geophysical studies of the PGDP area include the following.

- *Shallow High-Resolution Seismic Reflection Studies Near the Paducah Gaseous Diffusion Plant* (Speece et al. 1991)
- *Geologic Features Relevant to Ground-Water Flow in the Vicinity of the Paducah Gaseous Diffusion Plant* (Drahovzal and Hendricks 1997)
- *Acquisition of SH-wave Seismic Reflection and Refraction Data in the Area of the Northeastward Trending Contaminant Plume at the PGDP*, final report, (Langston and Street 1998)
- *Seismic Investigation Report for Siting of a Potential On-Site CERCLA Waste Disposal Facility at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 2004)
- *Investigation of Holocene Faulting at Proposed C-746-Landfill Expansion* (KRCEE 2006)
- "Integrated Geophysical Imaging Techniques for Detection Neotectonic Deformation in the Fluorspar Area Fault Complex of Western Kentucky" (Blits et al. 2008)
- "Fault-controlled contaminant plume migration: Inferences from SH-wave reflection and electrical resistivity experiments" (Almayahi and Woolery 2018)

2.1.2.1 Potential for fault-controlled plume migration

A particular concern related to faulting in the McNairy Formation in the vicinity of PGDP is the potential for fault-controlled plume migration. Specifically, do fault zones exist that significantly enhance local porosity and permeability of the McNairy Formation sediments? If so, such features could be pathways for vertical and lateral migration of dissolved-phase and DNAPL contaminants.

2.1.2.2 Potential for east-west fault-controlled structure

The PGDP area may have several generations of seismic activities with overprinting of seismicity and the occurrence of east-west faulting. Faulting may have formed the buried terrace slope of the ancestral Tennessee River floodplain under PGDP and may influence local groundwater flow directions.

3. HYDROGEOLOGY OF THE McNAIRY FORMATION

Subsurface Geology and Ground-Water Resources of the Jackson Purchase Region, Kentucky reports on the regional hydrogeology of the Jackson Purchase Region of Kentucky (Davis, Lambert, and Hansen 1973). The summary includes regional maps of geologic structure, water quality and yield, and potentiometric surfaces. Water level data suggests "the Paleozoic rocks [Mississippian-age limestone] and the McNairy Formation act as a single, interconnected hydraulic unit" (Davis, Lambert, and Hansen 1973, page 34). The McNairy potentiometric surface indicates that the regional McNairy flow system discharges to the Ohio River Valley in the area of PGDP.

Hydrogeology and Preliminary Assessment of Regional Flow in the Upper Cretaceous and Adjacent Aquifers in the Northern Mississippi Embayment modeled groundwater flow in the Upper Cretaceous formations of the northern Mississippi Embayment as part of the U.S. Geological Survey Regional Aquifer-System Analysis Program (Brahana and Mesko 1988). In the model, McNairy groundwater flows to the Ohio River Valley and either discharges directly to the Ohio River or flows parallel with the river to discharge further downstream. Aquifer tests in areas of the Mississippi Embayment where the McNairy Formation is used as an aquifer (i.e., southwestern Kentucky, western Tennessee, southeastern Missouri) define the range of hydraulic conductivity of the McNairy Formation to be 10^{-3} to 10^{-2} cm/sec. Model calibration yielded a hydraulic conductivity value of 10^{-2} cm/sec.

Documentation for the Olmsted Lock and Dam Project, *Foundation Design Memorandum, Supplement to Design Memorandum No. 5*, includes a report of a pumping test in the upper member of the McNairy Formation at the Olmsted site, which is 12 miles northwest of PGDP (COE 1991). At Olmsted, the McNairy Formation consists of an upper member of interlensing sands, silts, and clays and a lower member (i.e., Levings equivalent) of indurated clayey silt. A straight line distance versus drawdown analysis of the test data delivered a hydraulic conductivity value of 10^{-3} cm/sec for the upper McNairy Formation member.

There is only limited data to assess the hydraulic connection of the McNairy Formation and Mississippian-age bedrock in the PGDP area. In 1996, three of the four municipal wells in Metropolis pumped from cavernous zones in the underlying Mississippian-age limestone. Domestic wells completed in Mississippian-age bedrock are present in McCracken County. This line of evidence indicates the Mississippian-age bedrock has significant permeability across the area. Water levels measured during drilling of the Allied-Signal Plant supply wells located in Metropolis, Illinois, indicate that both the McNairy Formation lower member and the underlying Mississippian-age limestone are confined aquifers (AWD Technologies 1992). A dense cherty zone at the top of the Mississippian-age limestone serves as an upper confining unit (fracturing likely breaches this dense cherty zone elsewhere).

The McNairy Formation in the Area of the Paducah Gaseous Diffusion Plant presents a review of site-specific characterization data including stratigraphy, hydrogeologic properties, and groundwater chemistry (Davis 1996). It is a basis for the current conceptual site model of the hydrogeology of the McNairy Formation at PGDP.

3.1 DEPOSITIONAL HISTORY

“Cretaceous Sedimentation in Upper Mississippi Embayment” reports on studies of the depositional setting of Cretaceous sediments in the northern margins of the Mississippi Embayment (Pryor 1960) . The paper presents research on stratigraphy, paleontology, textural analyses, petrography, and sedimentary structures. Pryor concludes the Cretaceous sequence originated as a deltaic deposit with a McNairy Formation delta system centered in the northeastern margin of the embayment. The analysis indicates that the McNairy Formation sediments were predominately of fluviatile origin grading to marine sands and clays to the southwest.

3.2 LITHOLOGIC MEMBERS

Three members are distinguishable within the McNairy Formation over most of the PGDP area. These include an upper silt and sand member; a middle silt, clay, and sand member (i.e., the Levings Member); and a lower sand-dominant member. The depositional environment was not conducive to laterally extensive, smaller scale, depositional units.

The upper member of the McNairy Formation primarily consists of interlensing, fine-grained sand and silt. Sand predominates in southern Illinois. Silt content increases to the south. Sand units comprise less than one-half of the thickness of the McNairy Formation upper member at PGDP.

A common middle interval of generally fine-grained clastic sediments exists in borings of the study area. The lithologic character and stratigraphic position are consistent with description of the Levings Member by Pryor and Ross in 1962. The texture of the Levings Member sediments in the area of the TVA Shawnee Fossil Plant and southern Illinois is predominately clay. In the area of PGDP, the Levings interval has a higher percentage of silt and sand.

The lower member of the McNairy Formation mainly consists of a well-sorted, fine sand with lesser silt and clay interbeds. The lower member thickens to the south and east. In Illinois locations, a thick bed of fine-clastic sediments commonly occurs at the base of the McNairy Formation. Drillers describe these sediments as blue-to-black gumbo. This interval is not present in some borings in the PGDP area. An abrupt facies transition occurs just 1.7 miles southeast of PGDP, where the lower sand member is replaced by a thick clay interval.

3.3 POST-DEPOSITIONAL EROSIONAL STRUCTURAL SETTING

The stratigraphic sequence of Mississippi Embayment sediments immediately south of PGDP consists of the Cretaceous McNairy Formation overlain by the Paleocene Porters Creek Clay and, in turn, overlain by undifferentiated Eocene sands and Miocene(?)-to-Pleistocene Continental Deposits (see Figure 2). The buried terrace slope marking the southern margin of the ancestral Tennessee River valley is located beneath PGDP. The Porters Creek Clay subcrops in the buried terrace slope. A Tertiary and Quaternary sand and gravel deposit directly overlies the McNairy Formation to the north of the buried terrace slope, and Porters Creek Clay overlies the McNairy Formation to the south of the buried terrace slope. The erosional surface of the top of the McNairy Formation north of the buried terrace slope occurs at a common elevation of 280 ft amsl. The top of the McNairy Formation in the buried terrace slope subcrop beneath PGDP is at approximately 285 ft elevation; it dips towards the Mississippi Embayment axis to the southwest with a slope of 30 ft to 35 ft per mile (Olive 1980).

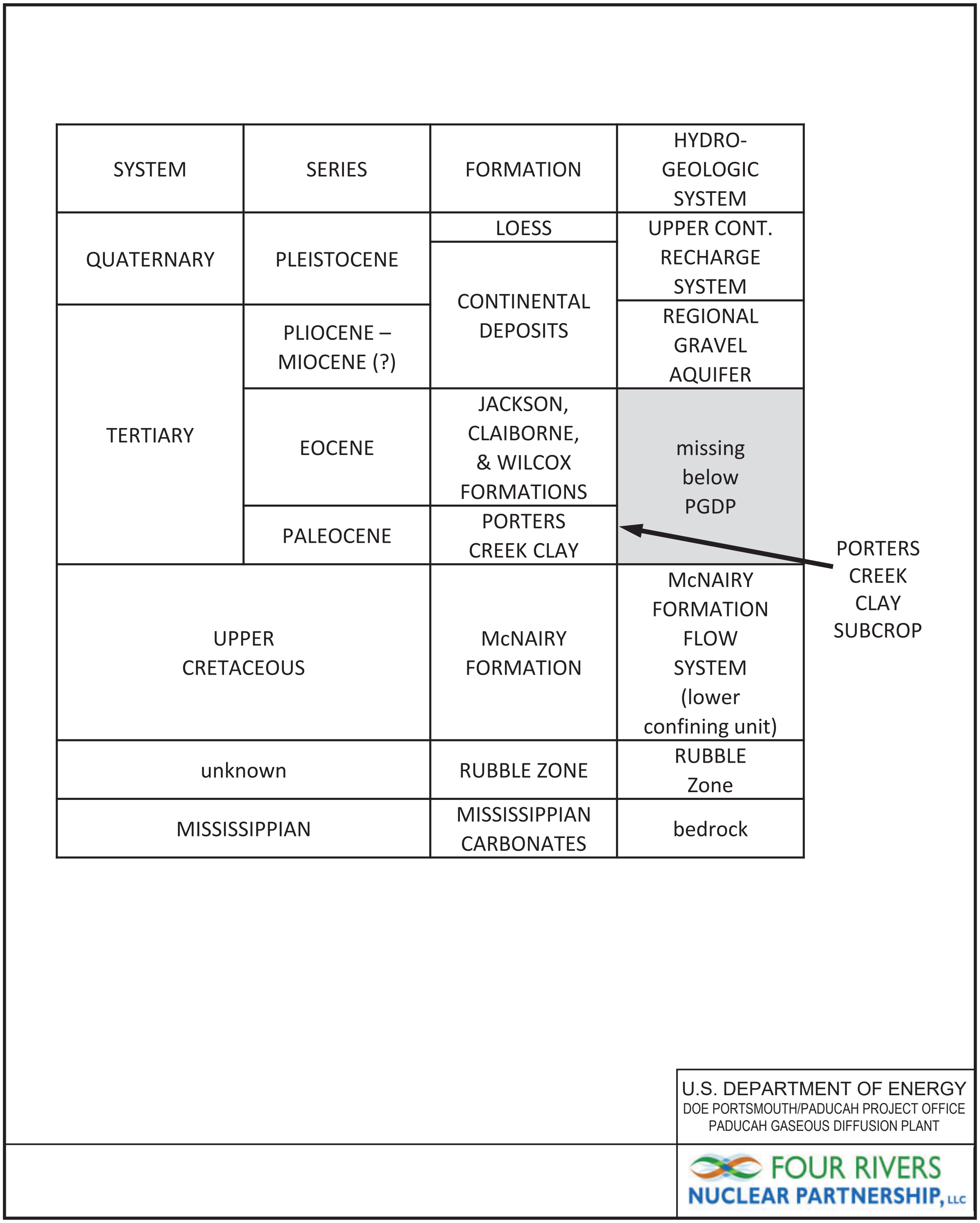
3.4 McNAIRY FORMATION GROUNDWATER FLOW SYSTEM

Groundwater flow in the McNairy Formation beneath PGDP originates in the Kentucky Lake area, near Murray, Kentucky. Hydraulic potential, as measured in McNairy Formation monitoring wells at PGDP, dips towards the Ohio River at approximately north 20-to-25º east relative to the plant coordinates system, with a gradient of approximately 4×10^{-5} ft/ft.

Hydraulic potential is slightly greater in the RGA beneath PGDP; however, the steeper hydraulic gradient of the RGA results in higher McNairy Formation hydraulic potential closer to the Ohio River.

4. RELEVANT FAULT STUDIES

PGDP is situated between the Fluorspar Area Fault Complex of southern Illinois and the New Madrid seismic zone of Arkansas, Missouri, and Tennessee. Numerous studies have delineated fault and seismicity trends that can be extrapolated into the PGDP area. The following sections summarize regional and local studies that have bearing on PGDP, as well as site-specific studies. Appendix B provides an April 2019 presentation on the PGDP seismic investigations for further reference.



SYSTEM	SERIES	FORMATION	HYDRO-GEOLOGIC SYSTEM
QUATERNARY	PLEISTOCENE	LOESS	UPPER CONT. RECHARGE SYSTEM
		CONTINENTAL DEPOSITS	
TERTIARY	PLIOCENE – MIOCENE (?)		REGIONAL GRAVEL AQUIFER
	EOCENE	JACKSON, CLAIBORNE, & WILCOX FORMATIONS	missing below PGDP
	PALEOCENE	PORTERS CREEK CLAY	
UPPER CRETACEOUS		McNAIRY FORMATION	McNAIRY FORMATION FLOW SYSTEM (lower confining unit)
unknown		RUBBLE ZONE	RUBBLE Zone
MISSISSIPPIAN		MISSISSIPPIAN CARBONATES	bedrock

PORTERS CREEK CLAY SUBCROP

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Figure 2. Paducah Site Stratigraphy

4.1 REGIONAL

The “Site-specific Fault Rupture Hazard Assessment—Fluorspar Area Fault Complex, Western Kentucky,” maps the major structural features in the central Mississippi Valley that are pertinent to regional geology and seismicity (Woolery et al. 2009) (see Figure 3). The *Bedrock Geology of the Paducah 1º x 2º CUSMAP Quadrangle*, notes that the Paducah quadrangle lies immediately north of the most active earthquake region of the North American Midcontinent, the New Madrid seismic zone (Nelson 1998). The New Madrid seismic zone is an ancient zone of weakness, the Reelfoot Rift, which has been reactivated repeatedly since Cambrian time. The present-day stress regime of the Paducah area is one of horizontal compression with a principal stress axis oriented east-west to 65º east. Cretaceous and younger faulting of the Paducah quadrangle is consistent with the contemporary stress regime and with active faults in the New Madrid area.

4.2 LOCAL

The authors of *Integrated Geophysical Imaging Techniques for Detecting Neotectonic Deformation in the Fluorspar Area Fault Complex of Western Kentucky* collected and assessed seismic reflection surveys and electrical resistivity surveys within and near the PGDP reservation and re-assessed some previous seismic reflection surveys of the area (Blits et al. 2008). The surveys imaged high-angle faults that extend upward into the Tertiary and Quaternary sand and gravel deposits and found that the structural features were preferentially oriented with groundwater and contaminant migration (see Figure 4).

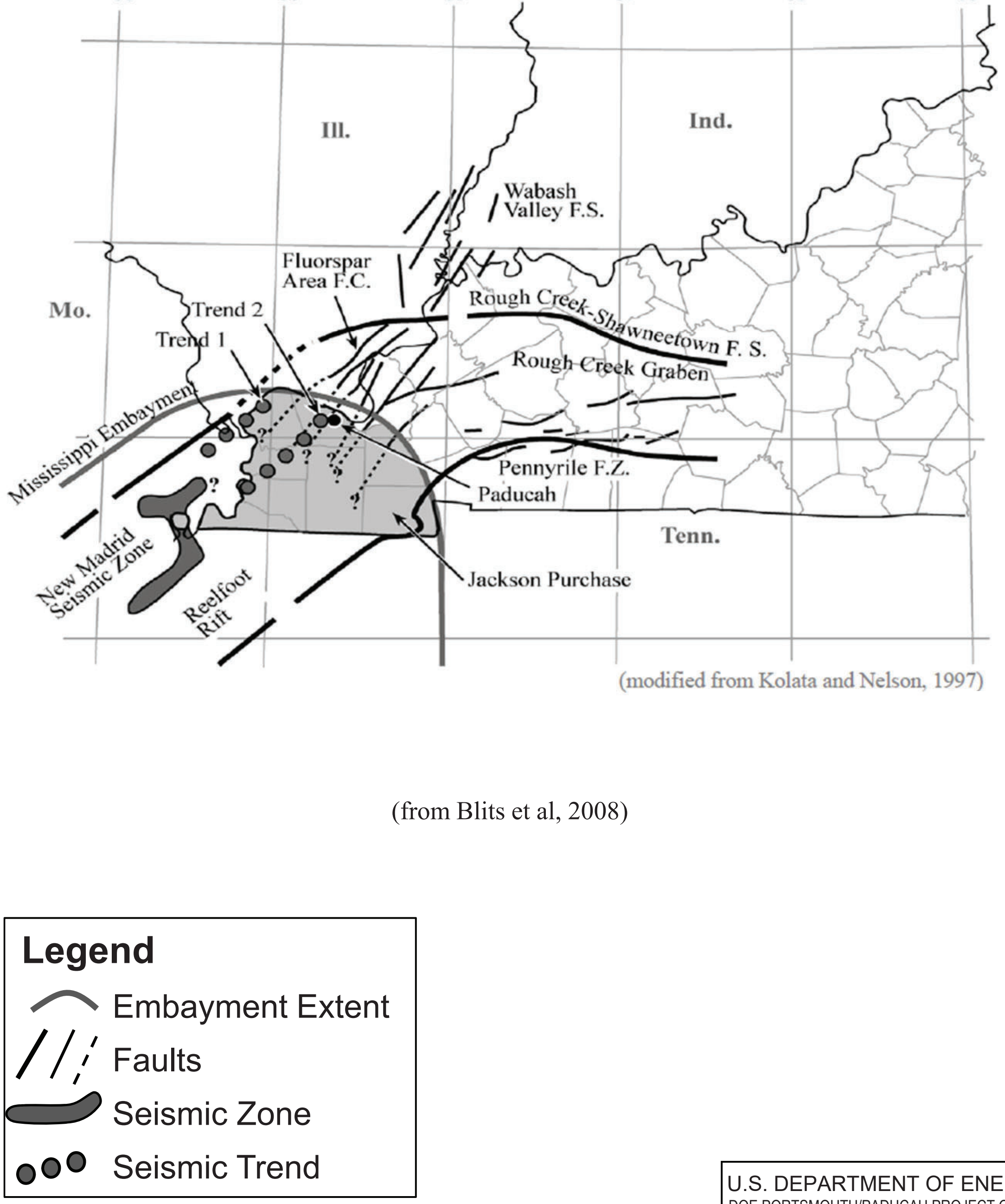
“Fault-controlled contaminant plume migration: Inferences from SH-wave reflection and electrical resistivity experiments” investigated elastic and electrical properties of the Tertiary and Quaternary sand and gravel deposits within and adjacent to a fault zone near PGDP with approximately 45 ft of displacement in the McNairy Formation (Almayahi and Woolery 2018). The study found geophysical anisotropies across and within the fault zone that likely relate to physical properties of the sediments and surmised that faults could locally influence hydraulic conductivity and act as a preferential pathway for fluid migration.

4.3 PADUCAH GASEOUS DIFFUSION PLANT

Acquisition of SH-Wave Seismic Reflection and Refraction Data in the Area of the Northeastward Trending Contaminant Plume at the PGDP, provides 17 km of shallow, high-resolution, S_H-wave reflection and refraction surveys adjacent to and north of the industrial area of PGDP (Langston and Street 1998). The study identified two major zones of faulting near the PGDP industrial area that were coincident with the edges of the Northeast Groundwater Plume.

Seismic Investigation Report for Siting of a Potential On-Site CERCLA Waste Disposal Facility at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky, assessed faulting of a site adjacent to the industrial area south of the buried terrace slope using shallow and deep borehole logs and Primary wave and S_H-wave seismic reflection surveys (DOE 2004). No faults were identified in the soil core samples, but the seismic surveys identified a series of normal faults and splays in a near north-south orientation relative to the plant coordinate system. The faults and splays form a series of narrow horst and graben features or divide the sediments into a series of rotated blocks. Several of the faults extend upwards through the McNairy Formation and the Porters Creek Clay.

Investigation of Holocene Faulting at Proposed C-746- Landfill Expansion (KRCEE 2006) used 30-ft deep soil borings and S_H-wave reflection profiles (Blackhawk Geosciences 2003) to investigate the occurrence



(modified from Kolata and Nelson, 1997)

(from Blits et al, 2008)

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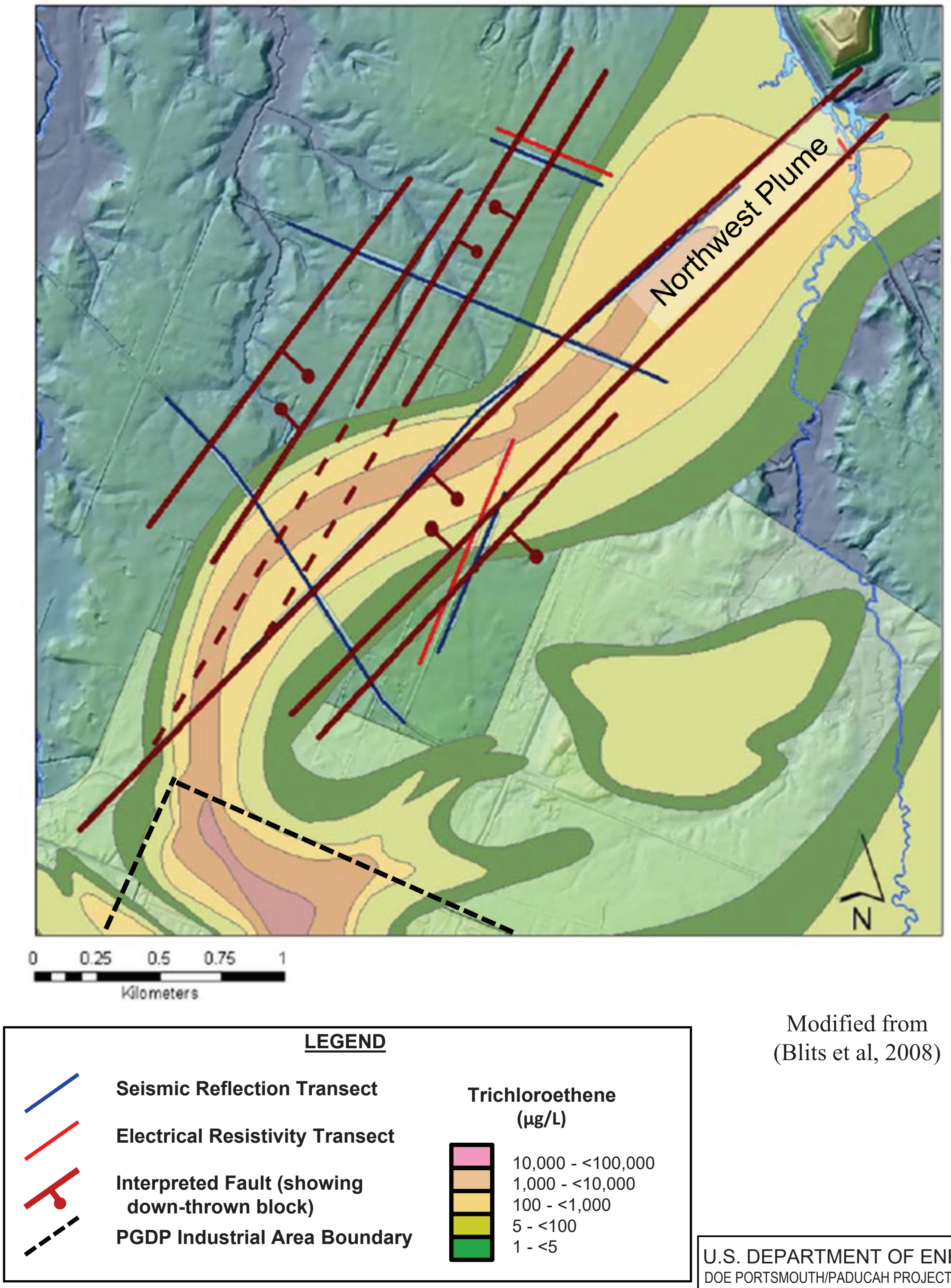
Figure 3. Structural Features in the Central Mississippi Valley



Modified from
(Blits et al, 2008)

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Figure 4. Structural Features in the Paducah Site Area

of faulting at a site located north of the PGDP industrial area. While three shallow loess units are generally flat-lying and mantle pre-existing topography, cross sections based on the lithologic logs identified undulations of deeper lithologic contacts that may be fault-related. The investigation interpreted two northeast-southwest trending faults relative to the plant coordinate system with oblique normal and reverse displacement.

5. APPROACH

This white paper summarizes existing data to evaluate the presence of faulting in the McNairy Formation beneath and in the vicinity of PGDP. The primary product is the development of cross sections of the McNairy Formation based on lithologic and geophysical logs of deep PGDP soil borings. Area seismic surveys provide additional context for development of the cross sections.

5.1 DATA QUALITY OBJECTIVES

The data quality objective (DQO) process is a planning tool based on the scientific method that identifies an environmental problem and defines the data collection process needed to support decisions in regard to that problem [*Guidance on Systematic Planning Using the Data Quality Objectives Process* (EPA 2006)].

The steps outlined in the DQO process were agreed upon by the PGDP Groundwater Modeling Working Group and have been used to develop the scope of this white paper. The DQO steps formulate a set of criteria to minimize uncertainty, which will allow conclusions to be made with the highest confidence possible.

5.1.1 State the Problem

The first step in the DQO process is to identify the problem to be resolved. The overall problem statement developed for this white paper is as follows:

An evaluation of the presence of faulting and the potential for fault-controlled plume migration across PGDP, including the Water Policy-affected area, are needed to better understand the following:

- the presence of unknown contamination in off-site areas; and
- the presence of unknown migration of contamination due to pathways not understood.

5.1.2 Identify the Decision

The correlation of lithologic units in the McNairy Formation is intended to assess whether there is faulting beneath PGDP that could be a contaminant migration pathway.

5.1.3 Identify the Inputs to the Decision

Inputs to this white paper will be descriptions of soils and gamma ray logs of the McNairy Formation from both historical soil borings at PGDP and recent soil borings of the C-400 Complex OU RI/FS at PGDP, and reports of McNairy Formation soil borings at the adjacent TVA Shawnee Fossil Plant.

5.1.4 Define the Study Boundaries

The study boundaries include the following:

- The McNairy Formation (vertical), and
- The vicinity of PGDP (aerial).

5.1.5 Develop a Decision Rule

This correlation will utilize the following decision rules:

1. If a lithologic contact disruption is identified, then assess if the discontinuity is fault-related. Nonfault-related factors that could create discontinuities include the following:

    a. The McNairy Formation consists of lagoonal-to-shallow marine deposits with frequent depositional discontinuities.

    b. The McNairy Formation consists of "soft" sediment deposition that may have resulted in diagenetic-related discontinuities (unrelated to faulting).

    c. Large bioturbation features are abundant.

2. If faulting is identified, then assess the orientation and continuity of the structure(s). The expected trend, consistent with the Fluorspar Area Complex of southern Illinois, is northeast-southwest.

5.1.6 Specify Limits on Decision Errors

Decision errors will be determined primarily by sample density and impacted by the quality of the data.

5.1.7 Optimize the Design for Obtaining Data

Where marker horizons can be identified, adjacent continuous geologic and geophysical logs may be used to identify small-scale discontinuities (i.e., on the order of 5 ft) with reasonable confidence. The resolution of faulting using lithologic logs based on grab samples at regular intervals will be governed by the sampling frequency depth-wise. Initial scrutiny of the available logs to identify candidate marker horizons will increase the effectiveness of the lateral comparison of the logs.

6. DATA SETS

Numerous investigation reports at PGDP provide lithologic and geophysical logs in the upper member of the McNairy Formation. Only seven borings exist that provide characterization to the base of the McNairy Formation (or deeper). Several seismic investigations provide transects of imaging of the McNairy Formation that can be used to assist the interpretation of the presence of faulting.

6.1 EXISTING DATA

6.1.1 Lithologic Logs

Soil boring logs are available from reports from individual projects in hard copy format and in a spreadsheet database, “R10 Hydrolitho Dbase posted 121620,” prepared by KRCEE in 2020.

Historical soil boring logs of PGDP consist of the following:

- Seven soil borings in six discrete locations that extend to, or through, the base of the McNairy Formation; and

- 133 soil borings that extend downward to an elevation of 240 ft amsl or deeper, which provides characterization of 40 ft or greater of the upper McNairy Formation. Soil boring depths range from 91 ft to 359 ft.

A cluster of shallow McNairy Formation soil borings is both within and near the industrial complex. This cluster includes most of the soil borings drilled by the air rotary method. Lithologic logs of these soil borings commonly are based on grab samples collected at regular intervals.

Additional soil borings at the TVA Shawnee Fossil Plant extend downward to an elevation of 240 ft amsl or deeper.

Several types of logs are available for PGDP soil borings. A few of the soil boring logs are based on geologists’ descriptions of continuous core. Others are geologists’ descriptions based on core samples collected at regular, frequent intervals. Many of the soil boring logs are geologists’ descriptions of cuttings collected by an air rotary drill rig, where grab samples are collected from the discharge of a cyclone separator. These samples are of limited use for detailed lithologic characterization; however, most of these same soil borings have strip logs of natural gamma activity and neutron porosity that can be used to interpret and correlate geology. Records from three of the deep soil borings include logs of downhole shear wave velocity.

Most of the original lithologic logs derive from project reports. With few exceptions (notably soil boring DB01), the geologic descriptions are assembled in the KRCEE spreadsheet database of Paducah lithologic logs, “R10 Hydrolitho Dbase posted 121620,” which was prepared by KRCEE.

6.1.2 Geophysical Logs

PGDP has geophysical logs extending into the McNairy Formation for 97 soil borings. Most of these soil borings were drilled for the RIs of Waste Area Groupings 3 (DOE 1993), 6 (DOE 1997), and 27 (DOE 1999c); the *Sitewide Remedial Evaluation for Source Areas Contributing to Off-Site Groundwater Contamination* (DOE 1999a); and the *Northeast Plume Preliminary Characterization Investigation* (DOE 1995). Some soil boring records include downhole logs for both gamma ray activity and neutron porosity.

6.2 C-400 COMPLEX OU REMEDIAL INVESTIGATION

Geologists of the C-400 Complex OU RI/FS logged continuous core in 21 soil borings to depths of at least 50 ft and another soil boring to 47 ft deep within the McNairy Formation (Figure 5). The RI/FS also characterized geotechnical properties of the McNairy Formation in 10 of the soil borings. Appendix C is an assessment of soil texture trends in the McNairy Formation at C-400; no faulting was evident.

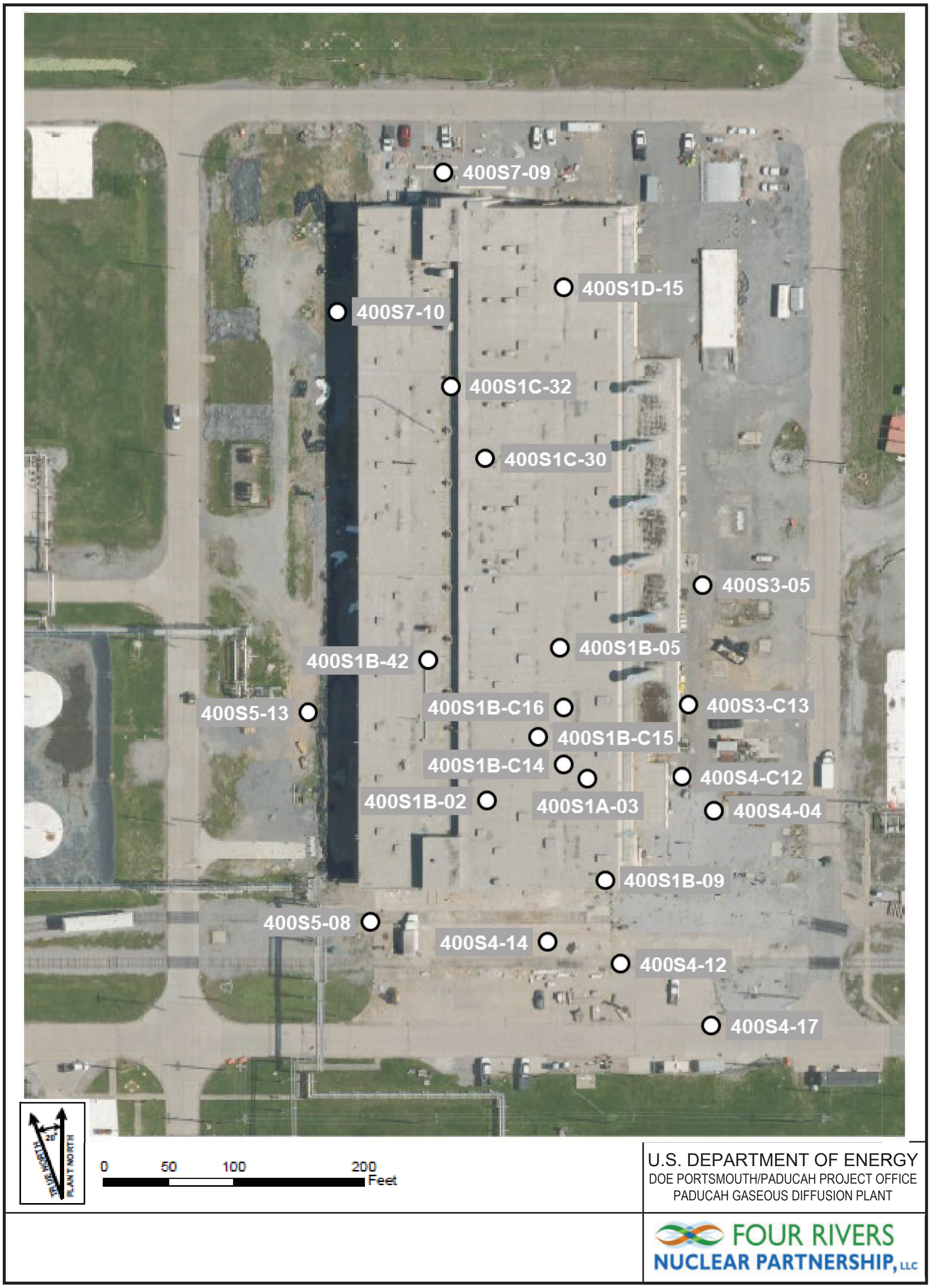

Figure 5. Deepest McNairy Soil Borings in C-400 Complex Remedial Investigation

7. DATA ADEQUACY

To support preparation of the two regional cross sections, geologists reformatted the lithologic and gamma ray activity logs of the seven deepest McNairy Formation soil borings in a standardized layout (see Appendix D). Only one of the lithologic logs, DB-01, is based on observation of continuous core. Continuous strip logs of gamma ray activity are available for all seven of the soil borings. When assessed collectively, the lithologic and gamma ray activity logs provide good characterization of the McNairy Formation geology in the seven deep McNairy Formation soil borings.

7.1 DEPTH OF DATA/THICKNESS OF McNAIRY INVESTIGATED

In the area of the PGDP industrial facility, the McNairy Formation is approximately 246 ft thick, as measured in soil boring F-08. In the soil boring, the upper member is 63 ft thick, the middle member is 62 ft thick, and the lower member is 121 ft thick.

PGDP has 133 historic soil borings that penetrate into the top of the McNairy Formation (Figure 6). In the vicinity of the industrial facility, where most of the soil borings are located, the base of the upper McNairy Formation member is at an approximate elevation of 217 ft amsl and at an approximate depth of 161 ft. Forty-nine of the historic soil borings penetrate the entire thickness of the upper McNairy Formation member. None of the soil borings drilled for the C-400 Complex OU RI/FS advanced to the base of the upper McNairy Formation member.[4]

The base of the middle member of the McNairy Formation in the vicinity of the PGDP industrial facility is at an approximate elevation of 155 ft elevation and an approximate depth of 223 ft. Only the seven deep McNairy Formation soil borings and one other historic soil boring of PGDP extend through the middle member of the McNairy Formation.

Five of the seven deep McNairy Formation soil borings extend into the Mississippian-age limestone that underlies the McNairy Formation. The remaining two deep McNairy Formation soil borings reached refusal depth (i.e., could not be advanced further) at the top of the underlying bedrock.

7.2 SPACING OF SAMPLE LOCATIONS

The spacing between neighboring, historic, upper McNairy Formation soil borings is commonly less than 500 ft (see Figure 6). Even at these relatively short distances, the depositional heterogeneity of the McNairy Formation soils prevails and no lithologic correlations can be made with confidence in the upper McNairy Formation member soils.

Electronic gamma ray activity logs are available for 47 of the historic soil borings that penetrate the upper member of the McNairy Formation, from *Northeast Plume Preliminary Characterization Investigation* (DOE 1995), and for MW122 that is of comparable depth (see Appendix E). Comparison of gamma ray activity trends with depth is a common correlation technique (in general, sand and gravel units yield relatively low gamma ray activity, and silt and clay units yield relatively high gamma ray activity). Where present, ash layers from volcanic events can result in definitive time-marker horizons.

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[4] Twenty-two soil borings of the C-400 Complex OU remedial investigation were completed within 10 ft to 15 ft of the base of the upper McNairy Formation member.

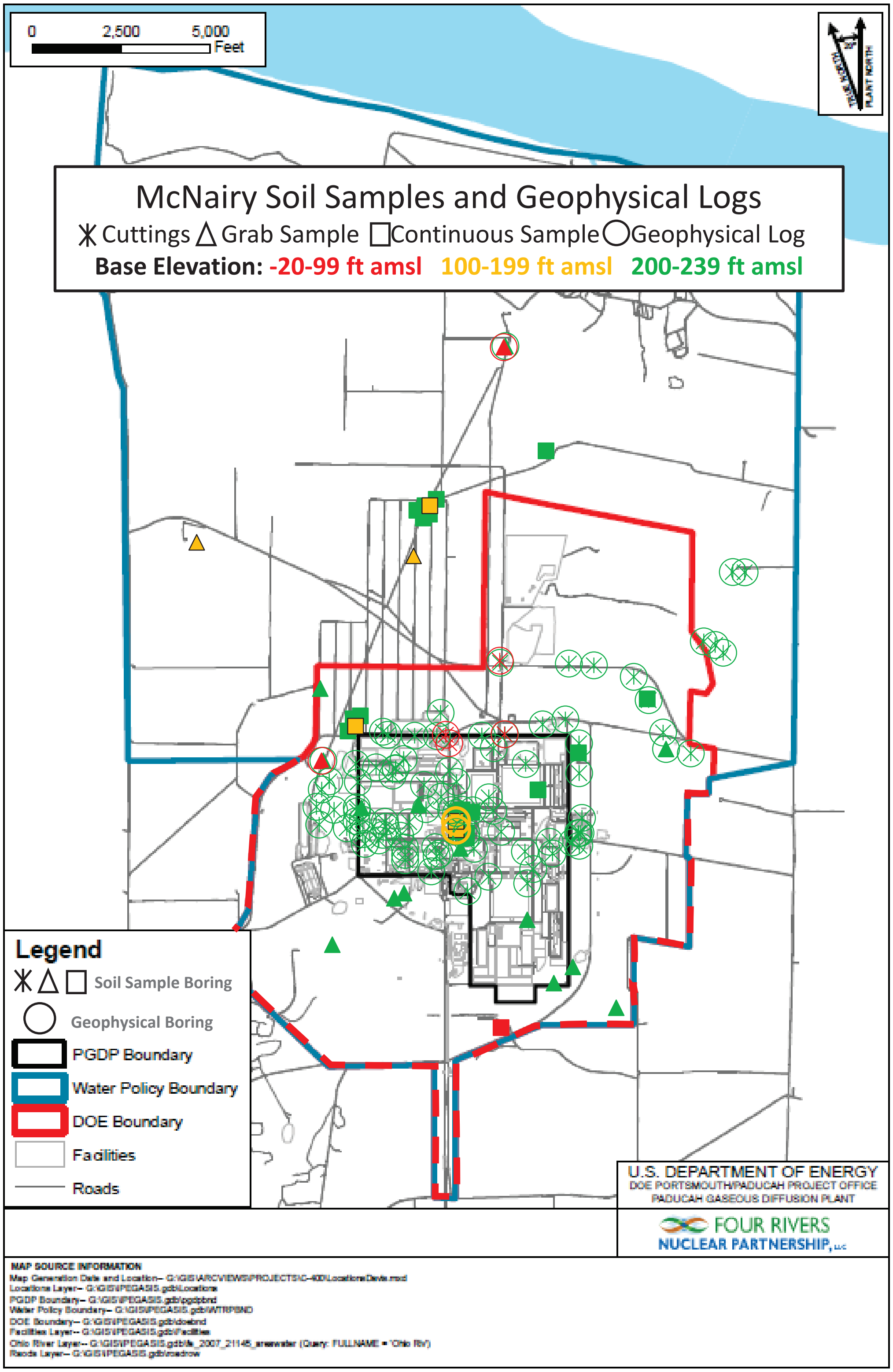

Figure 6. Location of Historic McNairy Formation Soil Borings

The Tertiary and Quaternary sand and gravel deposits are evident as a thick, low response interval on most of the gamma ray activity logs. No area-wide marker horizons or common lithologic units are evident in the gamma ray activity logs for the upper McNairy Formation member.

Soil borings F-08 and MW347 are located 257 ft apart, within and near the north boundary of the PGDP industrial area. Comparison of the gamma ray activity logs of these two soil borings identifies several common horizons in the upper and lower McNairy Formation members (see Figure 7) with distinctly different gamma ray responses in the upper and middle members at each borehole. The spacing between the other adjacent deep McNairy Formation soil borings ranges between 1,700 ft and 8,800 ft. Even at a significantly greater distance, the gamma ray activity trends define the upper, middle, and lower members of the McNairy Formation with reasonable confidence (see Figures 8 and 9).

7.3 DATA QUALITY

The assembled lithologic and gamma ray activity logs of the McNairy Formation for PGDP derive from many remedial and seismic investigations over a period of thirty-plus years. Drilling and sampling methods and gamma ray activity log equipment differ significantly.

7.3.1 Soil Sampling Methods and Sampling Frequency

The lithologic logs reviewed for this white paper primarily are based on three drilling methods summarized as follows:

- Most of the lithologic logs derive from soil cuttings of boreholes drilled with the reverse air rotary method. These cuttings are collected with a fine-mesh sieve held in the air discharge stream of a cyclone separator. The cuttings are typically disassociated soil grains. Clay fractions are poorly represented. Factors such as drill rate, downhole air pressure, and soil texture impact the travel time of soil cuttings in the borehole and cyclone separator. Although the geologists' descriptions are based on industry standards, this type of soil sample can be poorly representative of the interval being drilled. Commonly, only a single sample description is provided for each lithologic unit that is recognized. Of the drilling methods, reverse air rotary drilling provides the least representative samples for lithologic correlation.

- Deep soil borings Z-12 and Z-16 were drilled by mud rotary technique. McNairy soil cores were collected in sample tubes as drive samples. The sample interval in the McNairy Formation was commonly 20 ft. The sample tubes failed frequently or recovered only a small length of core. The soil sample results from this approach poorly represent the stratigraphic heterogeneity of the McNairy Formation.

- Deep soil boring DB-01 was drilled by rotary sonic method, which produced continuous soil core across the depth of the soil boring. The lithologic log of DB-01 provides frequent descriptions of the soil core and is well-representative of the soil textures and heterogeneity present in the McNairy Formation.

These lithologic logs were used to corroborate interpretations of the gamma ray logs used in the cross sections.

7.3.2 Gamma Ray Activity Logs

PGDP investigations, including the Waste Area Grouping 6 RI at C-400, provided continuous geophysical logs for most of the McNairy Formation soil borings, which includes all of the deep McNairy Formation

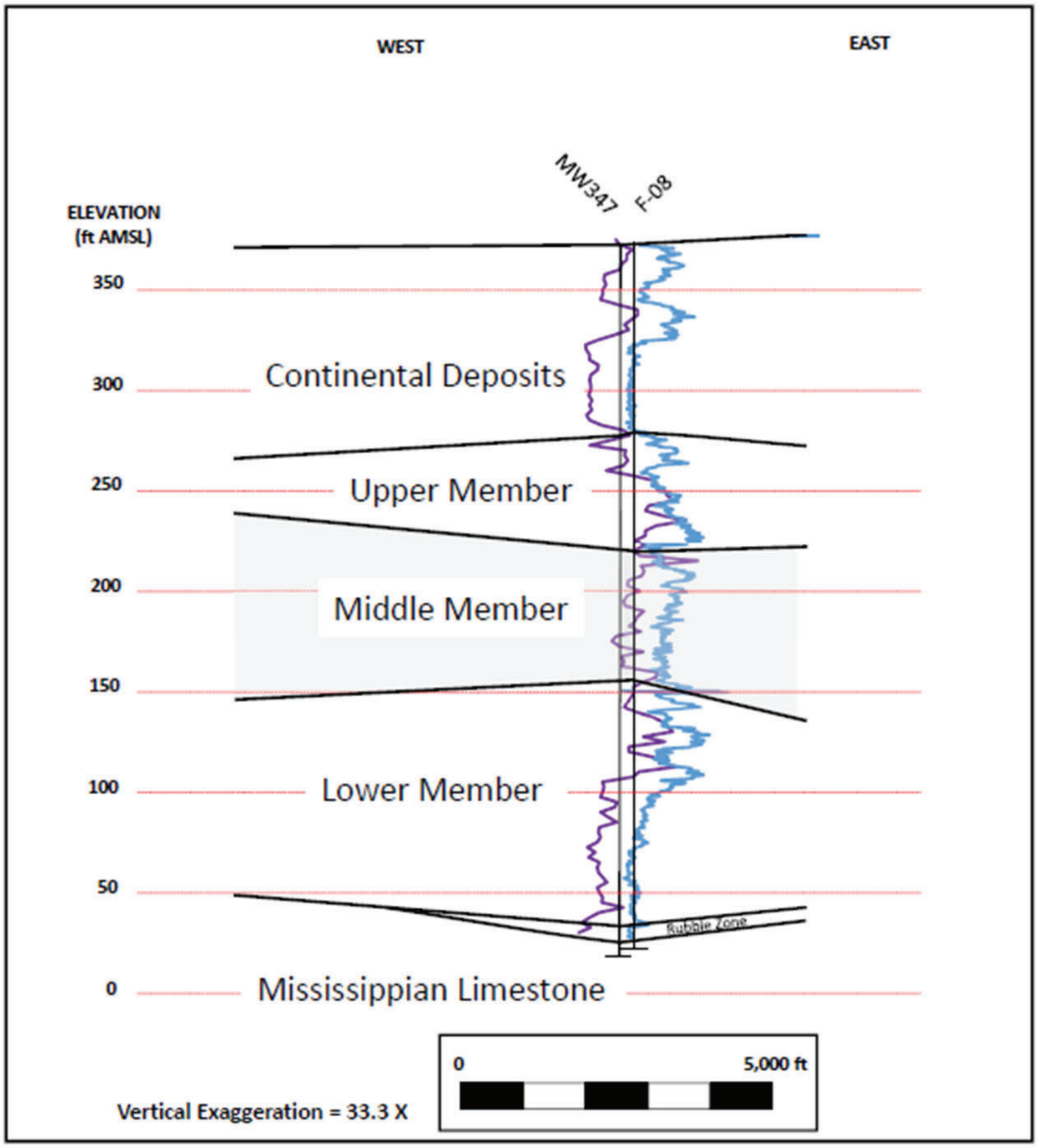

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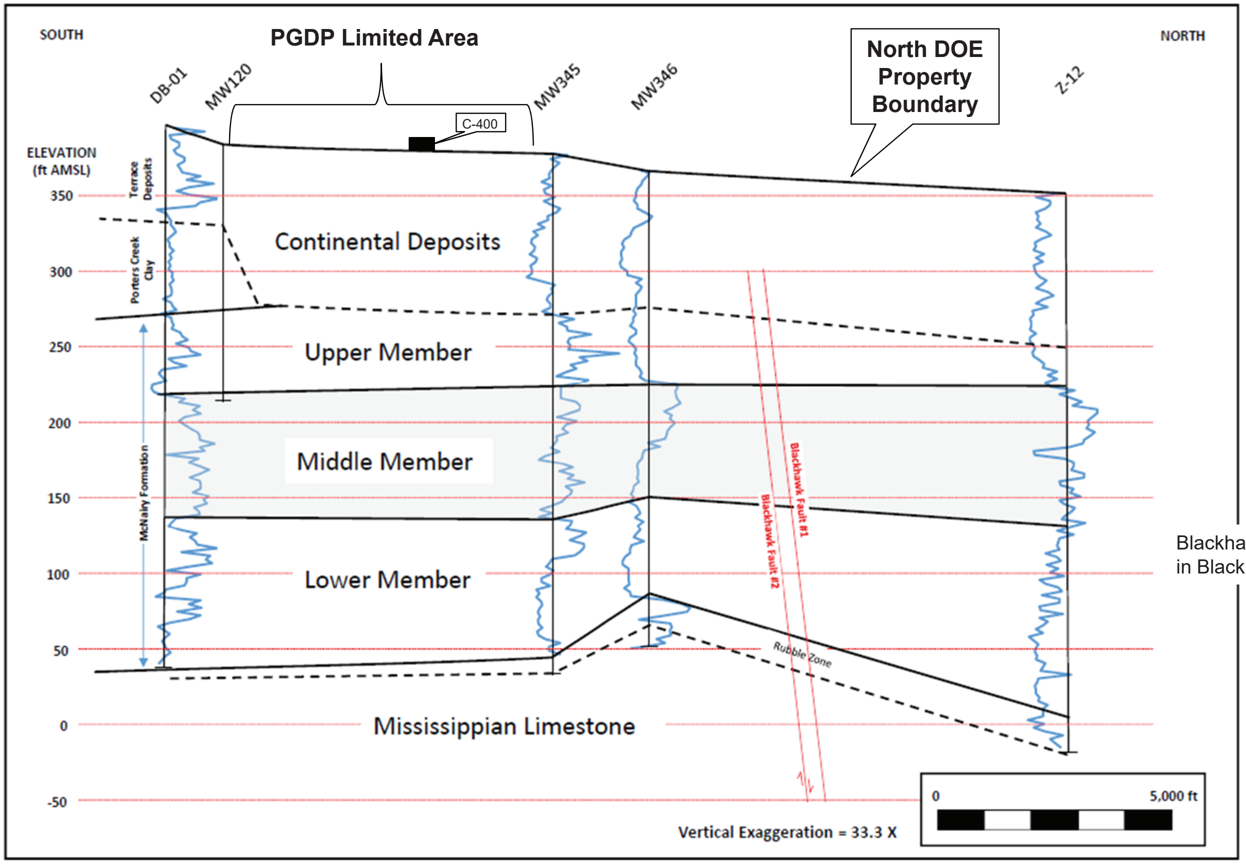
Figure 7. Comparison of F-08 and MW347 Gamma Ray Activity Logs



Blackhawk Faults are reported in Blackhawk Geoservices 2003

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Figure 8. North-South Cross Section of the McNairy Formation in the Area of the PGDP

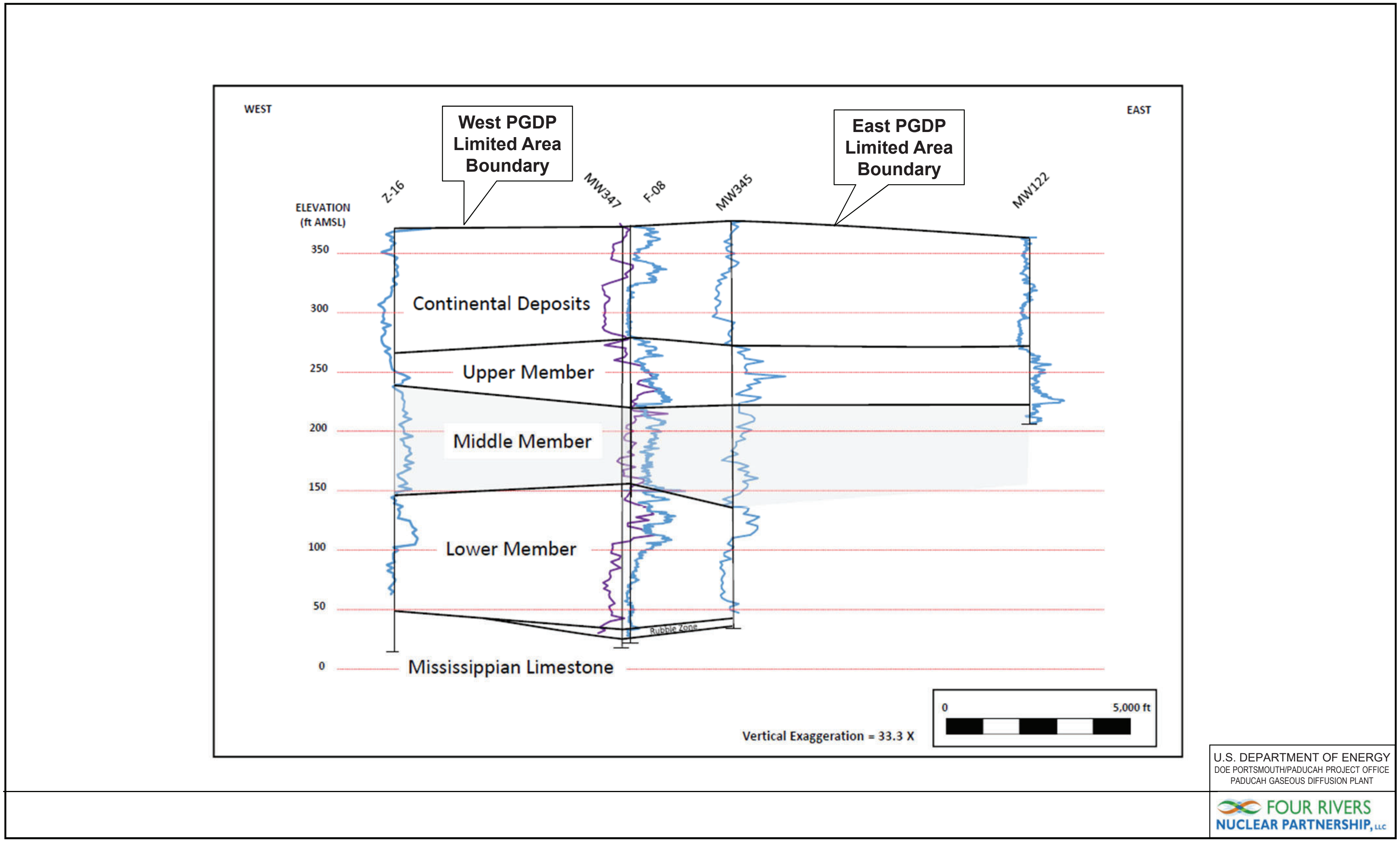

Figure 9. East-West Cross Section of the McNairy Formation in the Area of the PGDP

soil borings. Geophysical log suites commonly included logs of gamma ray activity, either as American Petroleum Institute units or as counts per second.

Gamma ray activity is a common industry measure of downhole lithology in soil and rock borings. In general, and also true for PGDP, sand and gravel produce relatively low gamma ray activity and silt and clay produce relatively high gamma ray activity in the downhole logs.

Used in concert with the soil boring sample descriptions in each soil borings, the gamma ray activity logs provide the primary basis for interpreting the soil texture and vertical extent of depositional units within the McNairy Formation. Gamma ray activity can be shielded to a small measure by the casing, temporary casing, and casing grout used for the soil boring; however, the trends descriptive of soil texture (i.e., sands and gravels yield low activities; silts and clays yield high activities) remain valid.

The cross sections of the McNairy Formation in this white paper primarily are based on the gamma ray activity logs. Attributes of the gamma ray logs include: (1) reliable interpretation of the gamma ray activity logs; (2) frequent characterization of gamma ray activity (i.e., several gamma ray activity measurements per foot); and (3) continuous record of the gamma ray activity.

With the exception of soil boring F-08, the gamma ray activity trends shown in the standardized logs presented in Appendix D are a smoothed (i.e., low fidelity) response. Strip logs of the gamma ray activity surveys with greater detail are available for all of the deep McNairy Formation soil borings (only F-08 has an electronic log of the original gamma ray activity survey). Original gamma ray activity strip logs were manually re-digitized to standardize the lithology logs and facilitate comparisons (see Appendix D). The re-digitization collected values for gamma ray activity on 2.5 ft intervals. The logs were reviewed to ensure the re-digitized logs retained the lithology-descriptive trends of the original logs.

8. ASSESSMENT METHODS

The intent of this white paper is to develop two lithological cross sections of the McNairy Formation to assess the presence of fault displacement and, if present, the magnitude of fault displacement. Research for this white paper identified little continuity of geologic units and no marker horizons that could be used to identify fault displacement.

8.1 CROSS SECTIONS

This white paper identifies common stratigraphic sequences across each of the seven deep McNairy Formation soil borings of PGDP that correlate with the regional occurrence of upper, middle, and lower members of the McNairy Formation (see Figures 8 and 9). As described in Illinois, the middle Levings Member contains a greater percentage of clays and silts (Pryor and Ross 1962).

Where available, seismic surveys provide another line of evidence to identify faulting in the McNairy Formation. The transect of the north-south cross section passes immediately west of the area of the C-746-U Landfill fault investigation (KRCEE 2006) (see Figure 8). The cross section includes the projection of the two faults that the investigation identified.

Geologic Map of Part of the Joppa Quadrangle, McCracken County, Kentucky, provides cross sections in a fence diagram of the Clayton and McNairy Formations at the TVA Shawnee Fossil Plant (Finch 1967). Finch wrote, “At the Shawnee steam plant data from carefully sampled and closely spaced drill holes indicate many vertical and horizontal variations in the lithology of the upper half of these combined formations [Clayton and McNairy] in the Joppa quadrangle."

8.1.1 Post Cretaceous Sedimentary Units

The shallow depths of the cross sections include sedimentary units deposited during the Tertiary and Quaternary Periods. Sand and gravel deposits that make up the RGA directly overlie the McNairy Formation across all but the south-most end of the study area. The Paleocene-age Porters Creek Clay occurs above the McNairy Formation in soil borings DB-01 and MW120.

8.1.2 Upper McNairy Formation Member

As evidenced in the north–south cross section (see Figure 8 and Appendix D), in soil borings DB-01 and MW345, the upper McNairy Formation member in the south half of PGDP consists of an upper clay-dominant facies and a lower sand-dominant facies. Both facies are present, although reversed, immediately to the north in soil boring MW346, with clay facies dominating the upper McNairy Formation member in soil boring Z-12 at the north end of the cross section.

In the east-west cross section (see Figure 9 and Appendix D), the upper McNairy Formation member is dominantly a fining-downward transition from sand to clay with a distinct coarse-clastic member at the base (gravel with sand in soil boring Z-16 and sandstone in soil boring F-08). The percentage of clayey units increases eastward with the basal unit grading from a silty sand in soil boring MW345 to a sandy clay in soil boring MW122.

8.1.3 Middle McNairy Formation Member

Across PGDP, the middle McNairy Formation member has a greater percentage of clayey units but with a common transition from clay and silty clay at the top of the member to silty sand and sand at the base of the member. A gravel with sand unit at approximately 180 ft amsl elevation in soil boring Z-12 marks a common horizon of coarse-clastic beds (sand units are also evident in gamma ray response of DB-01 and MW345; see Figure 8).

8.1.4 Lower McNairy Formation Member

The lower McNairy Formation member generally consists of a top sequence of interbedded sands and silts with clays locally present, overlying a 30 ft to 65 ft-thick fine sand deposit at the bottom.

8.1.5 Rubble Zone

A thin horizon of cherty gravel and limestone fragments, locally termed the "rubble zone," commonly occurs between the McNairy Formation and the underlying Mississippian-age limestone bedrock. In soil boring MW346, the horizon consists of 15 ft of clay, which likely is a preserved knoll of limestone residuum. Discrete occurrences of thick residual clay on top of the Mississippian Limestone would possess a significantly different S_H-wave velocity which could account for discontinuities interpreted as faults in seismic surveys.

8.2 GAMMA RAY ACTIVITY LOGS OF THE NORTHEAST PLUME PRELIMINARY CHARACTERIZATION INVESTIGATION

The gamma ray activity logs in *Northeast Plume Preliminary Characterization Investigation* support a three-dimensional assessment of soil texture trends in the upper McNairy Formation member (DOE 1995). In general, depositional heterogeneity precludes attempts to laterally correlate units in the upper McNairy Formation member based on gamma ray activity. The few exceptions where comparable intervals are present in adjacent soil borings include the following.

- a broad low-activity response over 230 ft to 255 ft amsl; elevation in soil borings B-03, B-04, and B-05; and

- a distinct, thin, high-activity response between 256 ft and 265 ft amsl elevation in soil borings D-09, D-10, D-11, D-12, and D-12A (also possibly in C-07, E-07, F-01, F-04 and MW122).

Appendix E provides the McNairy Formation section of the gamma ray activity logs from *Northeast Plume Preliminary Characterization Investigation*.

9. UNCERTAINTIES

Significant uncertainties abound towards the interpretation of the presence of faults based on the available lines of evidence. With the exception of the thick sand deposit at the base of the McNairy Formation, there were few sedimentary units that could be reliably correlated between the available soil borings.

9.1 DEPOSITIONAL HETEROGENEITY

The lagoonal-to-shallow marine environment of deposition of the McNairy Formation is highly heterogeneous. Examples of comparable levels of heterogeneity are well-documented in geologic studies of similar, modern-day settings. Although continuous core was unavailable for six of the seven deep McNairy soil borings, continuous gamma ray activity logs of these borings provide a good basis for correlation. With few exceptions, no correlations of distinct sedimentary units could be made between adjacent soil borings.

9.2 RESOLUTION OF FAULT OFFSET

The available soil boring logs are insufficient to identify the presence of faulting at PGDP. General soil texture trends, as interpreted from gamma ray activity logs, were sufficient to identify all three members of the McNairy Formation in all seven deep McNairy soil borings. The top and bottom elevations of the middle McNairy Formation member are nearly planar in the north-south cross section. Based on the lateral spacing between soil borings in the cross sections, a vertical fault offset of approximately 25 ft would create an obvious discontinuity.

10. CONCLUSIONS AND RECOMMENDATIONS

No evidence of faulting was apparent from the cross sections of soil borings completed for this white paper. Based on the lateral spacing between soil borings in the cross sections, a vertical fault offset of approximately 25 ft would create an obvious discontinuity. The distances between the available soil borings and depositional heterogeneity are too great to correlate between soil borings with confidence.

Seismic S_H-wave surveys at PGDP and adjacent areas have imaged apparent fault zones extending upwards through the McNairy Formation with displacements of up to 30 ft (KRCEE 2006) to 45 ft (Almayahi and Woolery 2018). Additional geophysical surveys (notably electrical resistivity and S_H-wave splitting studies) provide corroborative evidence of the presence of faulting.

Additional field study using the available investigation techniques is unlikely to provide enough data to resolve the following identified uncertainties in the Memorandum of Agreement for the 2018 Five-Year Review regarding protectiveness for the Northwest Plume, Northeast Plume, and Water Policy response actions (DOE 2020):

- The presence of unknown contamination in off-site areas; and
- The presence of unknown migration of contamination due to pathways not understood.

A detailed study of the upper-most McNairy Formation located in the area of the C-400 Complex determined that faulting is not present locally and that TCE-contamination levels in soils and groundwater decline rapidly with increasing depth. Thus, the primary source area where TCE contamination occurs in groundwater located at PGDP is an unlikely source to contribute significantly to off-site groundwater contamination in the McNairy Formation.

A preponderance of the mapped faults in the Precambrian bedrock, faults and lineaments in younger formations, and the sediments of the PGDP region all trend northeast-southwest, which is consistent with the structural trends of the Fluorspar Area Fault Complex of southern Illinois. Little, if any, vertical offset in the McNairy Formation is evident at the south end of the north-south PGDP cross-section (Figure 8). The southern boundary of the RGA (i.e., Porters Creek Clay subcrop in the buried terrace slope under PGDP) is consistent with the erosional history of the region and likely is unrelated to faulting.

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APPENDIX A

SUMMARY OF HISTORIC McNAIRY FORMATION SOIL BORING LOGS (ON CD)

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APPENDIX A

SUMMARY OF HISTORIC McNAIRY FORMATION SOIL BORING LOGS (CD)

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APPENDIX B

APRIL 2019 PRESENTATION: PGDP SEISMIC INVESTIGATIONS

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Paducah Site Seismic Investigations

The characterization of the seismicity of the Paducah area has been of significant interest to design of structures at the Paducah Site.

December 1982, *Recommended Seismic Hazard Levels for the Oak Ridge, Tennessee; Paducah, Kentucky; Fernald, Ohio; and Portsmouth, Ohio, Department of Energy Reservations*, K/BD-1025/R1

November 1989, *Seismic Issues at the Paducah Gaseous Diffusion Plant, Report of the Seismic Expert Workshop Held at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky, March 13-15, 1989*, KY/H-111

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August 1993, *Site-Specific Earthquake Response Analysis for Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, Waterways Experiment Station, Vicksburg, MS, Miscellaneous Paper GL-93-14

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June 2007, *Final Report: Seismic Hazard Assessment of the Paducah Gaseous Diffusion Plant*, Wang, Z. and Woolery, E.W., UK/KRCEE Doc #: P11.6 2007.

Paducah Site Seismic Response Investigations/Reports

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Previous seismic design studies and recent investigations provide data to assess the potential for fault rupture at the Paducah Site.

November 1990, *Recommended Soil Columns for Use in Amplification Studies, Paducah Gaseous Diffusion Plant, Paducah, Kentucky, ERCE File No. B672*

February 1991, *Final Data Package, Geophysical Study of Subsurface Conditions in the Vicinity of the Paducah Gaseous Diffusion Plant*, ASG/U-101

April 1991, *Shallow High-Resolution Seismic Reflection Studies Near the Paducah Gaseous Diffusion Plant*, KY/E-104

September 1991, *Assessment and Interpretation of Cross- and Down-Hole Seismograms at the Paducah Gaseous Diffusion Plant*, K/GDP/SAR-9

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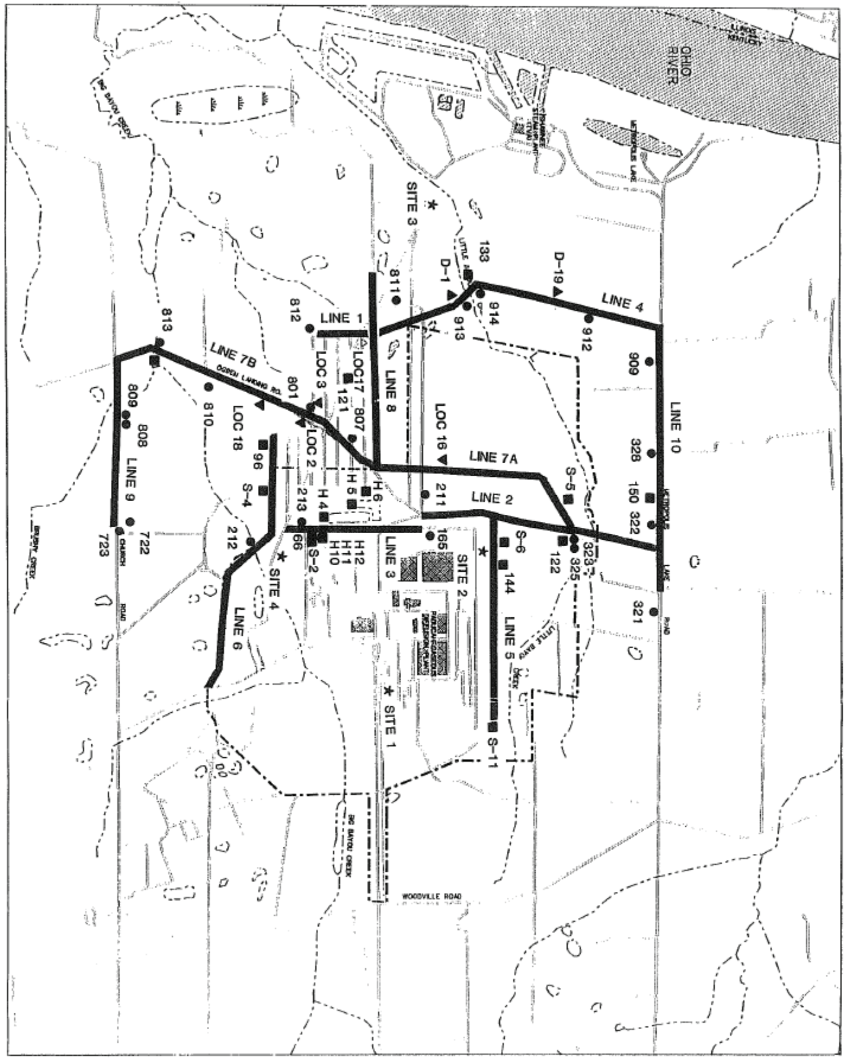
Almayahi, A. and Woolery, E., 2018. *Fault-controlled contaminant plume migration: Inferences from SH-wave reflection and electrical resistivity experiments*, Journal of Applied Geophysics 158 (2018) 57-64.

Location of Seismic Lines and Well Control Points



- Approximately 15 miles of P-wave reflection data
- 10 survey lines
- 3-fold data
- Shows configuration of the RGA and subsurface terrace features
- Imaged internal layering in RGA topographic depressions
- Topographic depressions in the RGA continue downward

Speece, M.A., Early T.O., Switek, J., Hanson, J.A., and Williams, R.T., 1991. Shallow High-Resolution Seismic Reflection Studies Near the Paducah Gaseous Diffusion Plant

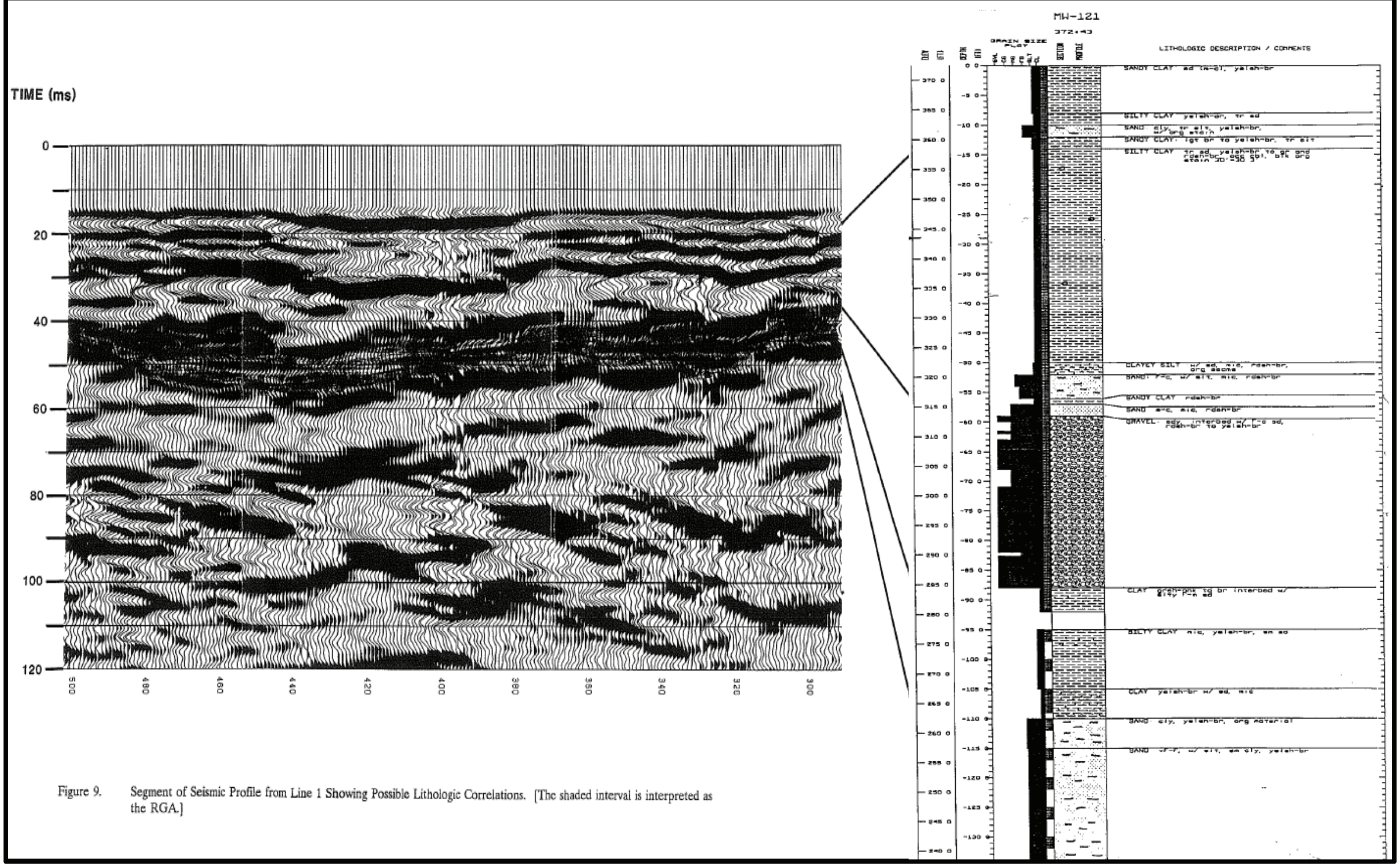


Figure 9. Segment of Seismic Profile from Line 1 Showing Possible Lithologic Correlations. [The shaded interval is interpreted as the RGA.]

Speece, M.A., Early T.O., Switek, J., Hanson, J.A., and Williams, R.T., 1991. Shallow High-Resolution Seismic Reflection Studies Near the Paducah Gaseous Diffusion Plant

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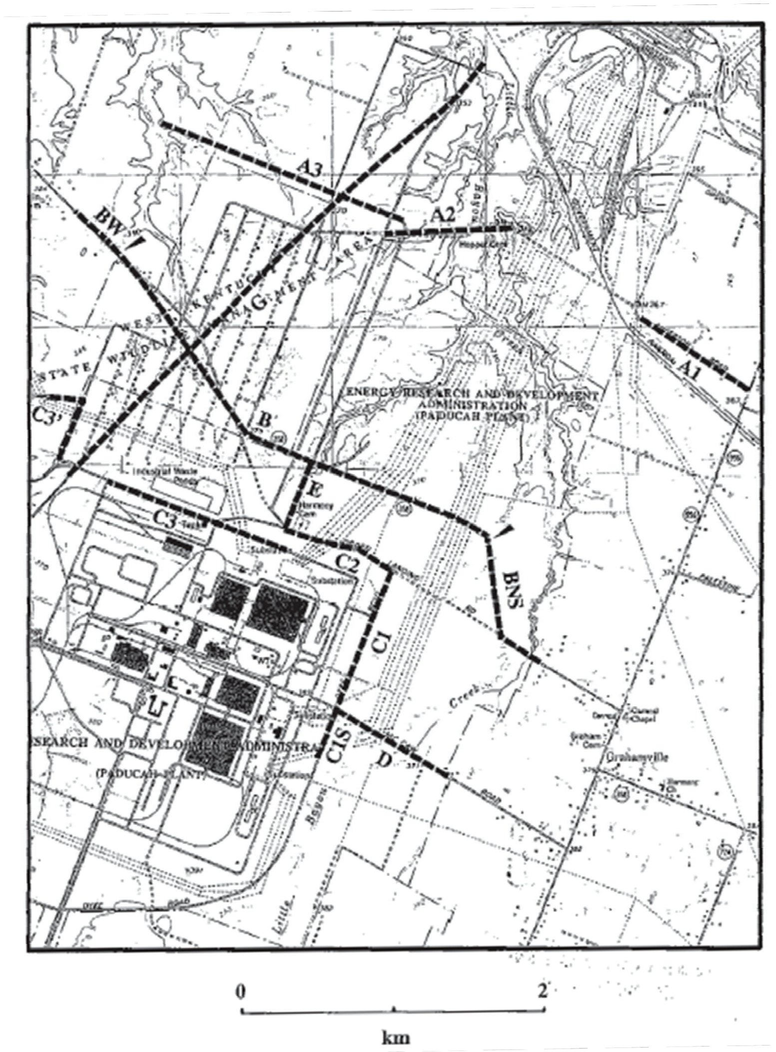


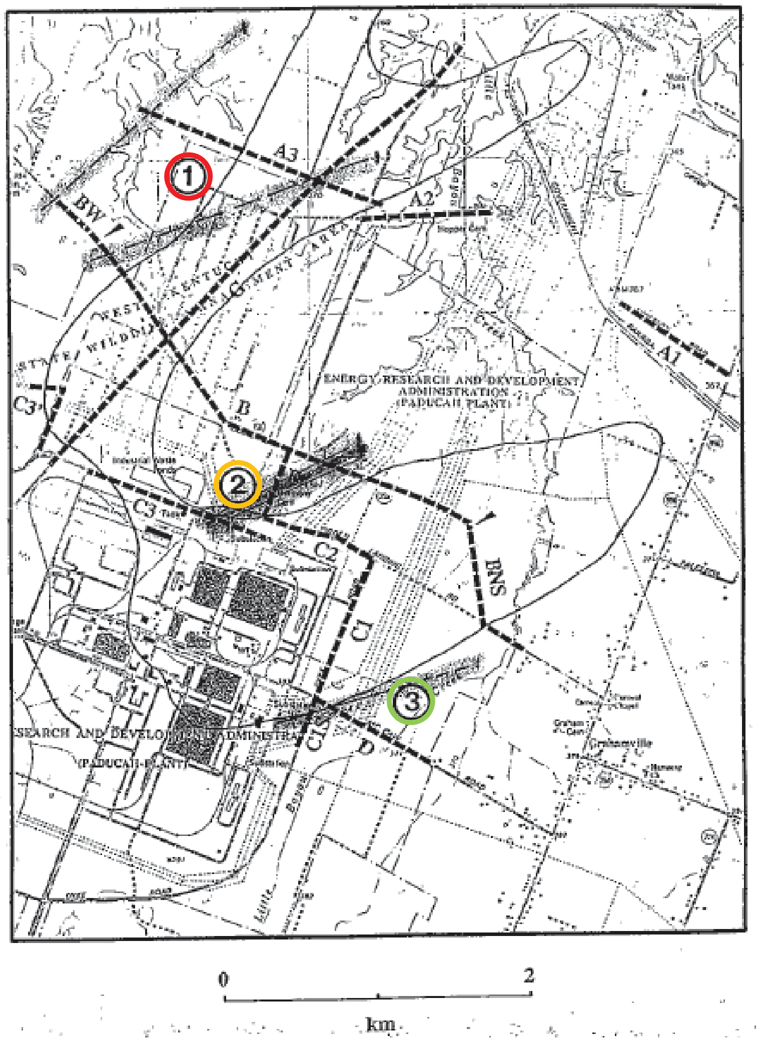
2 objectives:

- Seismically image the top of RGA, top of the Clayton and McNairy Formations, and the top of the limestone bedrock
- Find evidence of faulting or other aspects of the subsurface that could be controlling migration of the contaminant plumes

Approach:

- high-resolution, S_H-wave seismic CDP data using a seismic hammer
- 17 KM of shallow, high-resolution S_H-wave reflection and refraction data
- 12-fold CDP data

Langston, C. and Street, R., 1998. Acquisition of SH-Wave Seismic Reflection and Refraction Data in the Area of the Northeastward Trending Contaminant Plume at the PGDP



Preliminary results indicated the presence of two fault zones near the northwest corner of the plant ①.

Two major zones of faulting (② and ③) have been identified in the north-eastern part of the DOE reservation and are coincident with the direction of migration and edges of the northeast contaminant plume.

“The trend of the faults, and the fact that many of these faults appear to propagate from the bedrock into the RGA, strongly suggests that faulting is controlling the migration of the contaminant plumes associated with the PGDP.”

Langston, C. and Street, R., 1998. Acquisition of SH-Wave Seismic Reflection and Refraction Data in the Area of the Northeastward Trending Contaminant Plume at the PGDP

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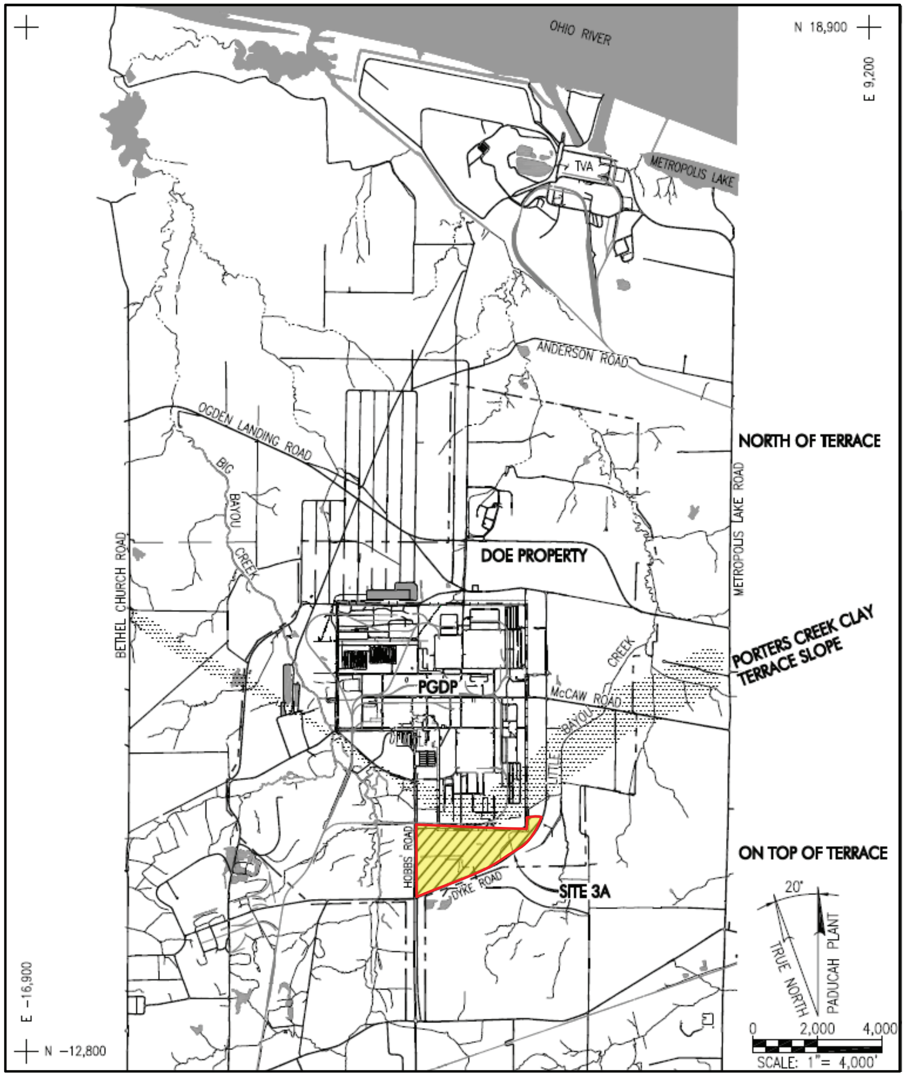

Site 3A Investigation:

- Deep borehole
- Suspension P & S_H-wave velocities
- P-wave seismic reflection survey
- S_H-wave seismic reflection survey
- DPT survey

DOE 2003. Seismic Investigation Report for Siting of a Potential On-Site CERCLA Waste Disposal Facility at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky (DOE/OR/07-2038&D2

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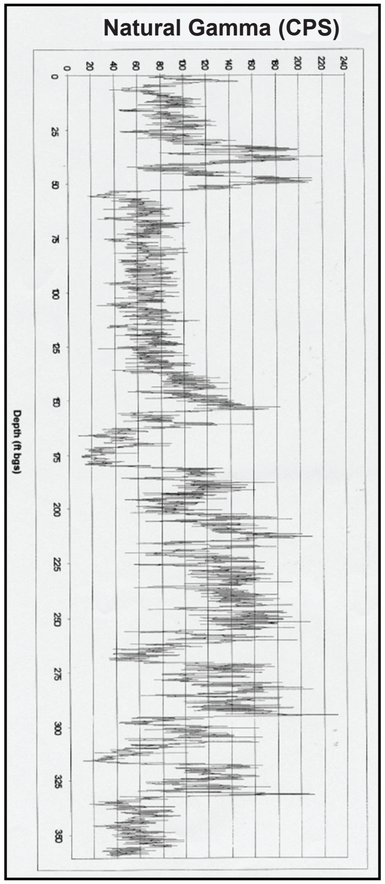

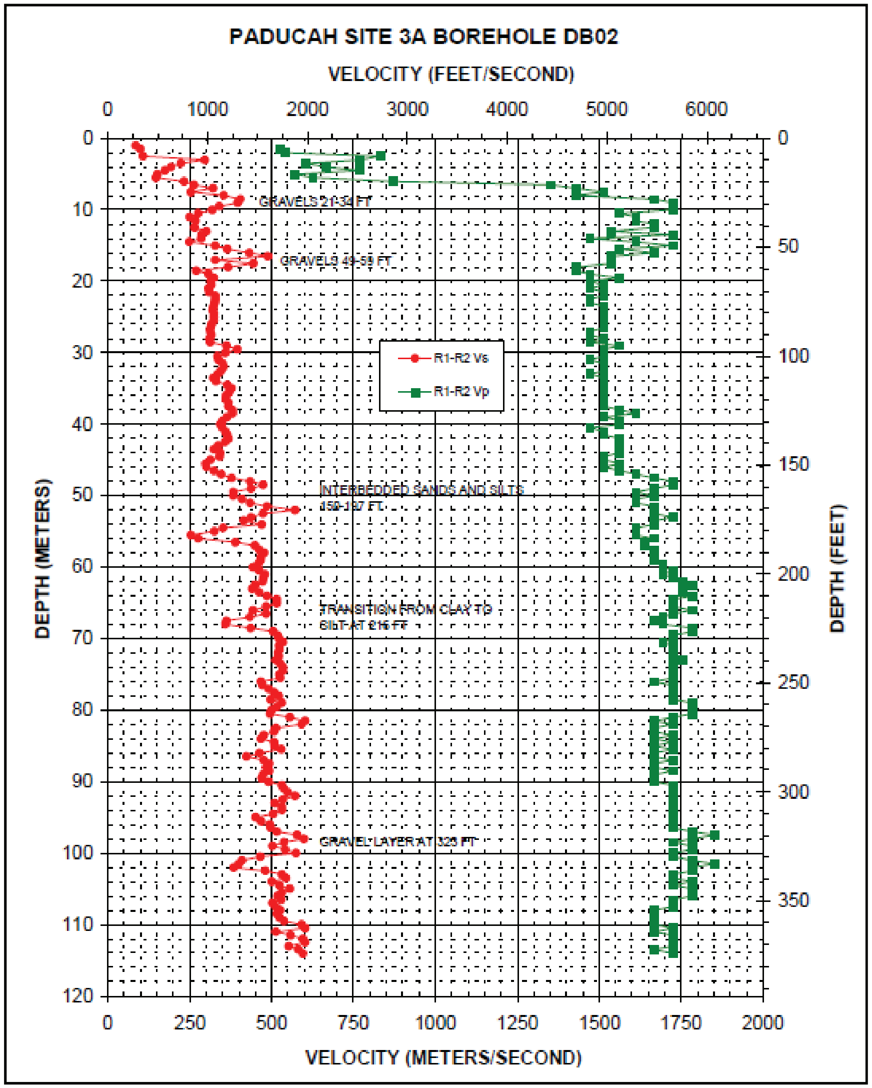

Deep borehole with P- and S_H-wave velocities study

DOE 2003. Seismic Investigation Report for Siting of a Potential On-Site CERCLA Waste Disposal Facility at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky (DOE/OR/07-2038&D2

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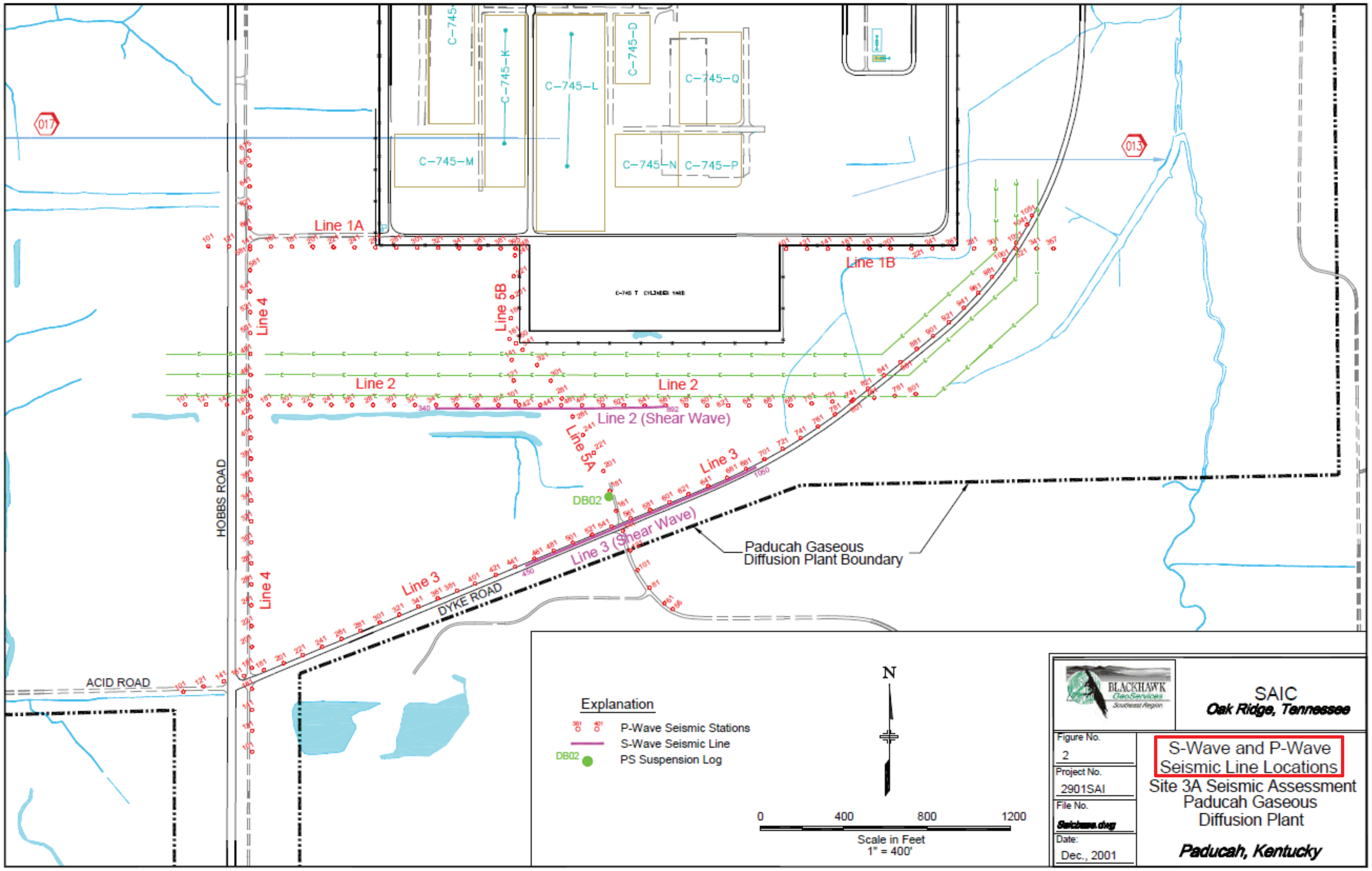

DOE 2003. Seismic Investigation Report for Siting of a Potential On-Site CERCLA Waste Disposal Facility at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky (DOE/OR/07-2038&D2

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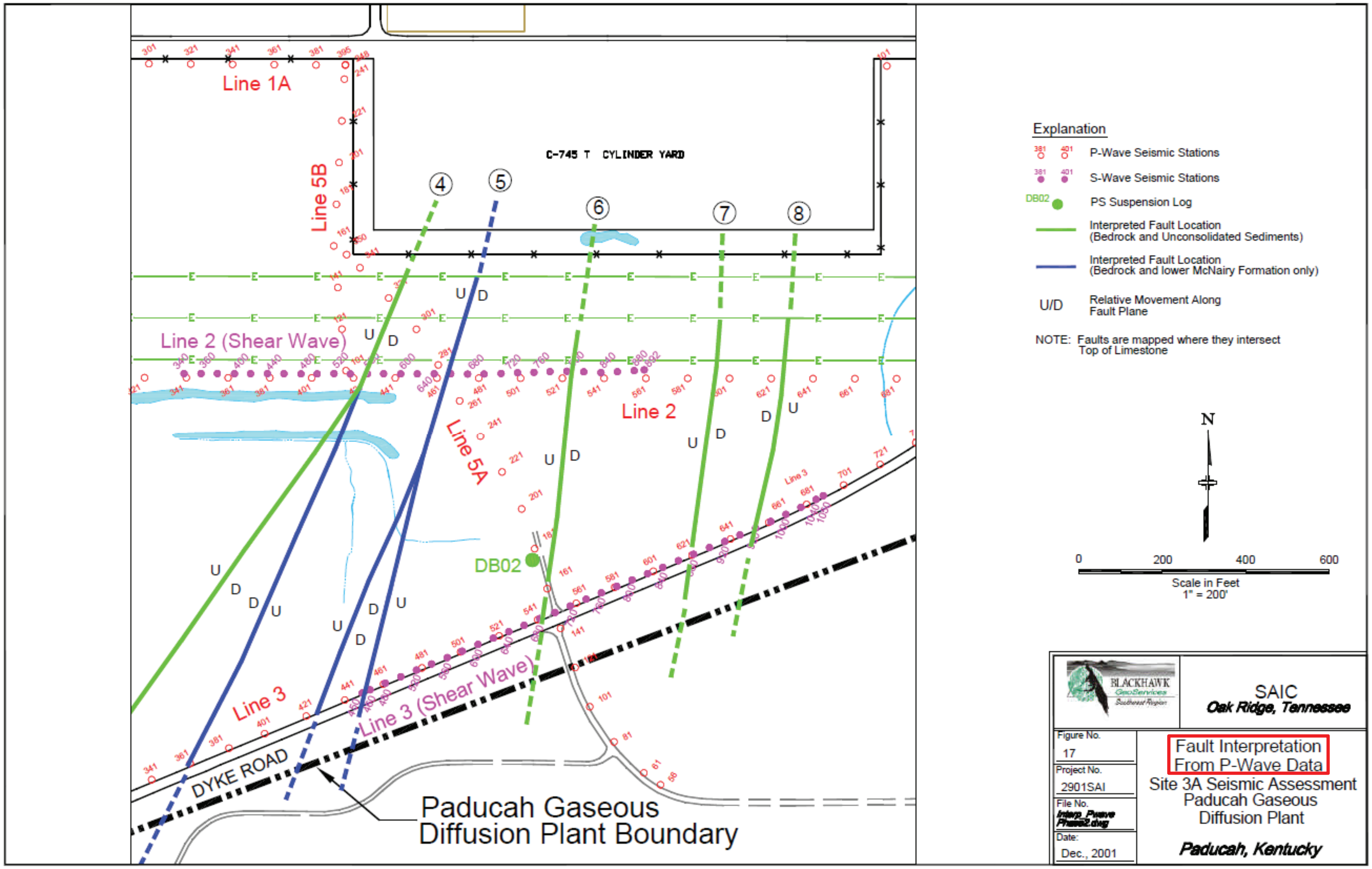
PADUCAH GASEOUS DIFFUSION PLANT



DOE 2003. Seismic Investigation Report for Siting of a Potential On-Site CERCLA Waste Disposal Facility at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky (DOE/OR/07-2038&D2

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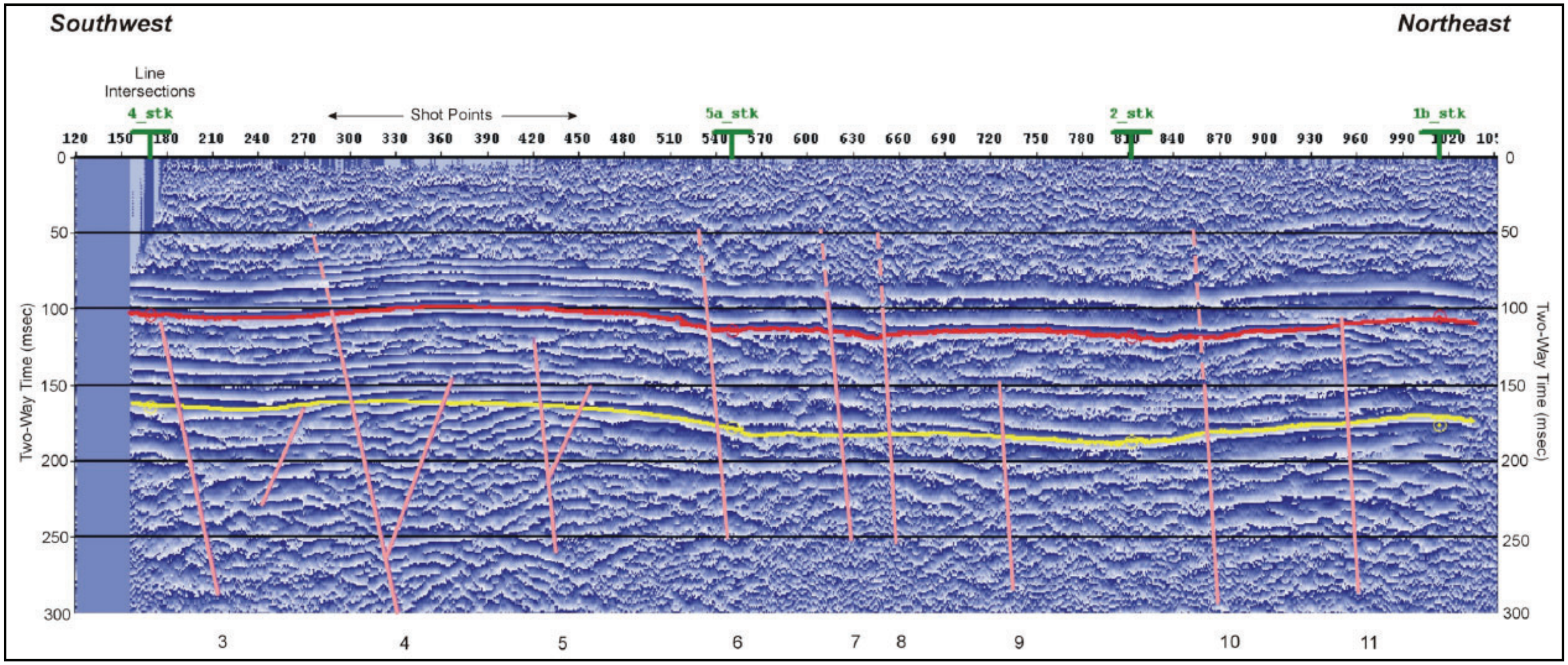
Line 3 interpreted instantaneous phase section – P-wave survey



LEGEND

🟥 Interpreted top of McNairy Formation (lower sand facies)
🟨 Interpreted top of limestone
▬ Interpreted fault

DOE 2003. Seismic Investigation Report for Siting of a Potential On-Site CERCLA Waste Disposal Facility at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky (DOE/OR/07-2038&D2

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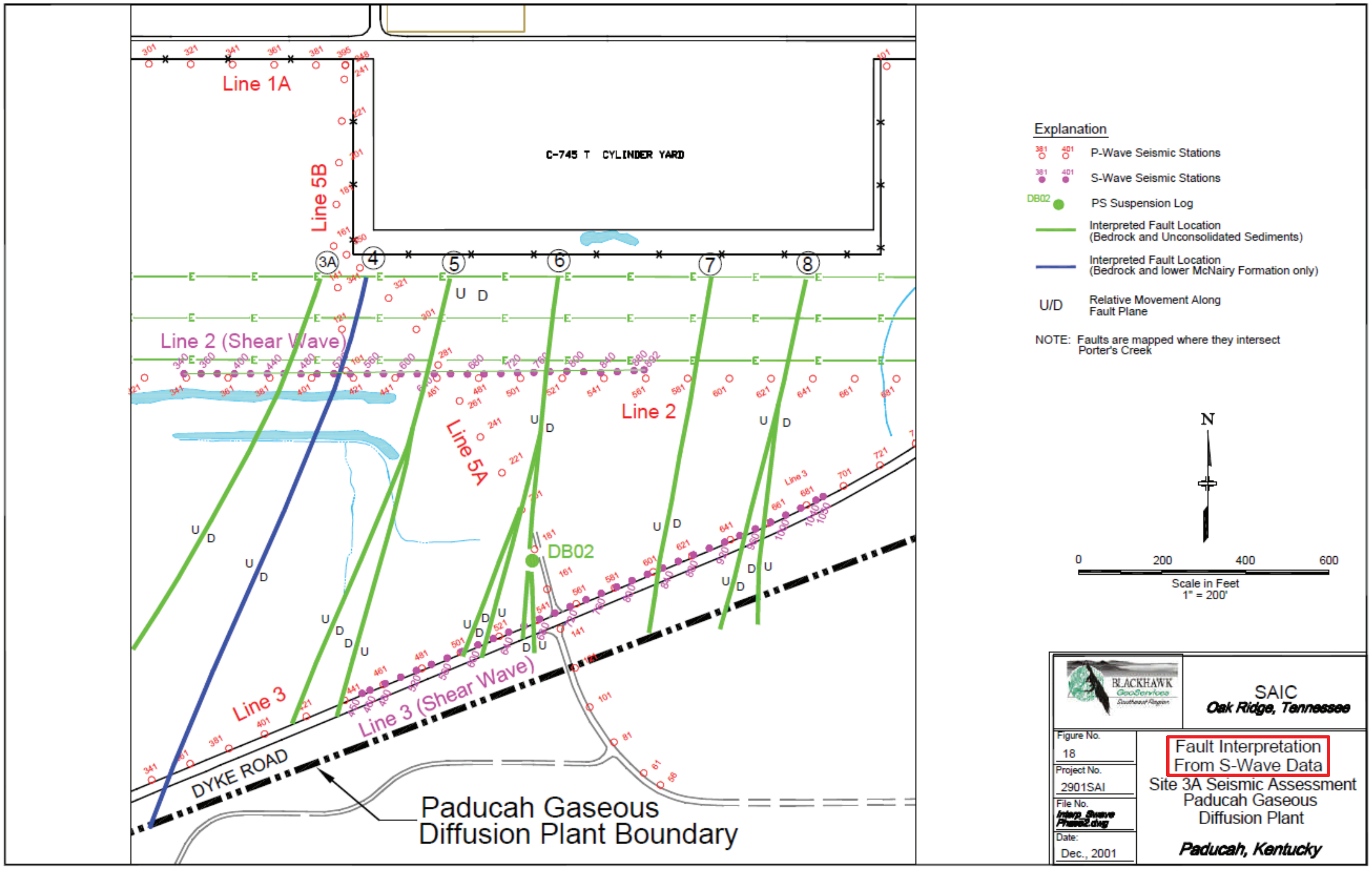

DOE 2003. Seismic Investigation Report for Siting of a Potential On-Site CERCLA Waste Disposal Facility at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky (DOE/OR/07-2038&D2

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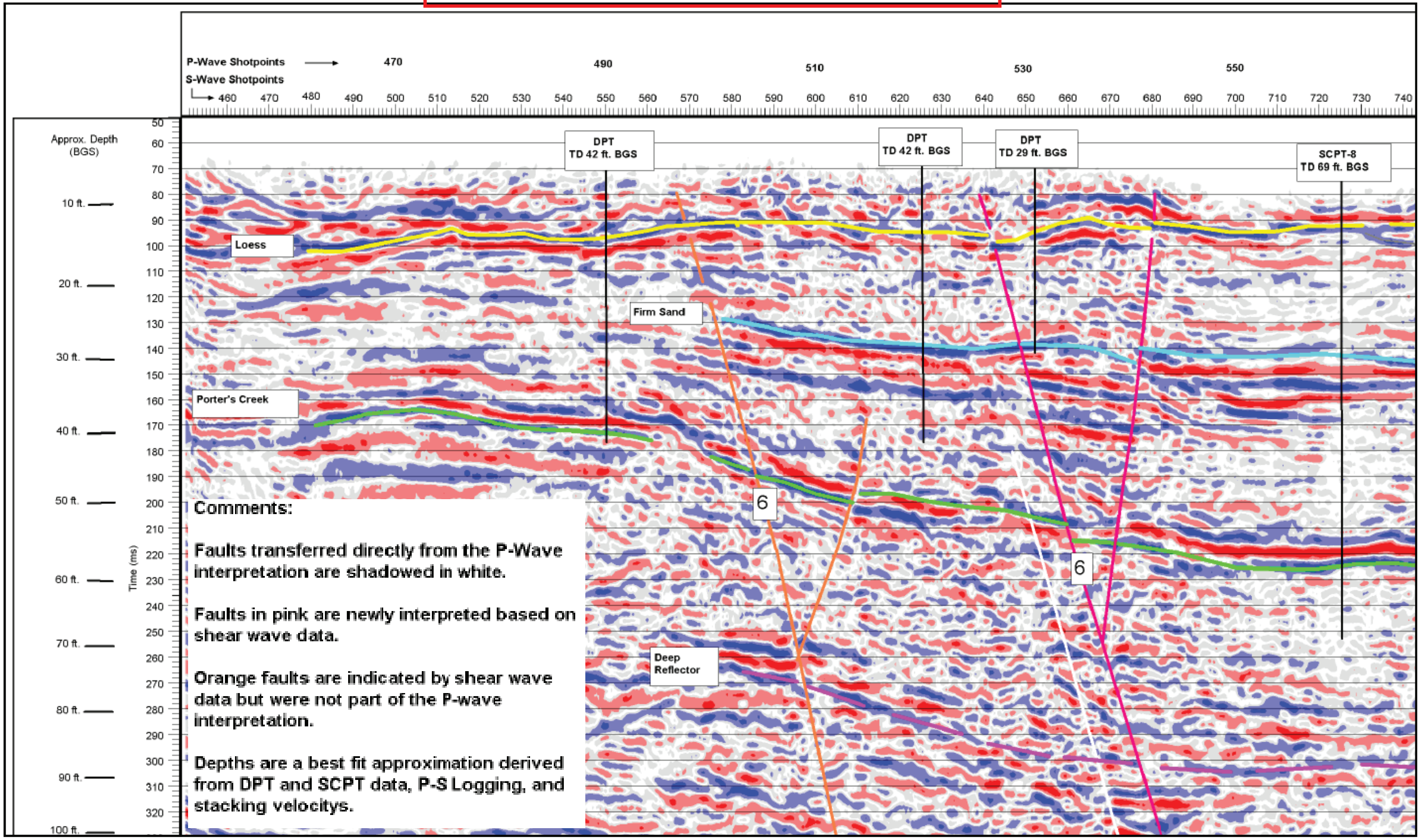
Line 3S S_H-wave migrated section



Comments:

Faults transferred directly from the P-Wave interpretation are shadowed in white.

Faults in pink are newly interpreted based on shear wave data.

Orange faults are indicated by shear wave data but were not part of the P-wave interpretation.

Depths are a best fit approximation derived from DPT and SCPT data, P-S Logging, and stacking velocitys.

DOE 2003. Seismic Investigation Report for Siting of a Potential On-Site CERCLA Waste Disposal Facility at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky (DOE/OR/07-2038&D2

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Summary answers to Project Core Team questions to address seismic issues at Site 3A (excerpted)

Is there evidence of Holocene displacement of faults at PGDP?

This study did not find Holocene displacement of faults at Site 3A. Several faults identified in seismic reflection data at Site 3A have been confirmed to extend through the Porters Creek Clay and into the materials underlying the surficial loess deposits. Three of these faults are interpreted to extend to within approximately 20 ft of the ground surface. One deeper DPT borehole encountered three fault planes at depths between 22 ft and 28 ft. Tightly spaced, shallower DPT boreholes at these locations found no faults in the overlying loess. The radiocarbon dating at Site 3A found that the loess is late Pleistocene in age, and the deposits are at least as old as the oldest roots that grew into them (17,100 years old).

Are there faults underlying the potential disposal facility site?

The site-specific Fault Study identified a series of faults beneath Site 3A. For most of the faults beneath Site 3A, relative movement along the main fault plane is normal, with the downthrown side to the east. These normal faults, along with their associated splays, either form a series of narrow horst and graben features, or divide the local sediments into a series of rotated blocks. Several of the faults extend through the Porters Creek Clay and into the materials underlying the surficial loess. Three of these faults extend to within approximately 20 ft of the ground surface. Tightly spaced shallower DPT boreholes found no evidence that these faults extend upward into the Pleistocene loess deposits and, therefore, are not Holocene in age.

DOE 2003. Seismic Investigation Report for Siting of a Potential On-Site CERCLA Waste Disposal Facility at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky (DOE/OR/07-2038&D2

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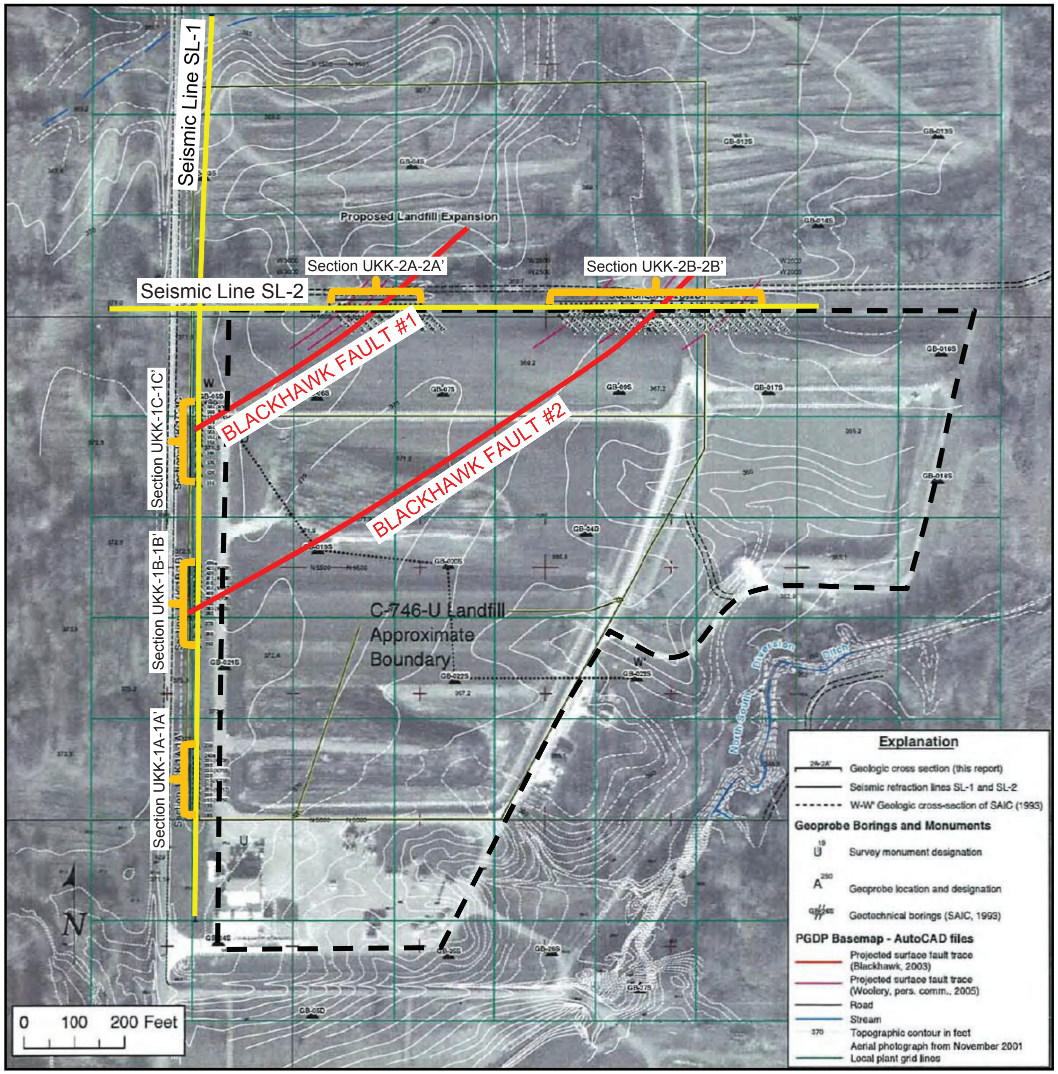
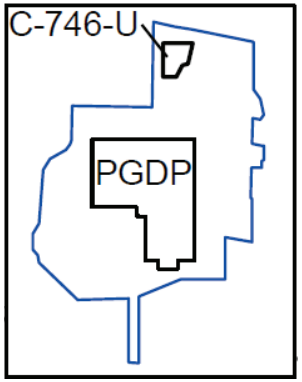


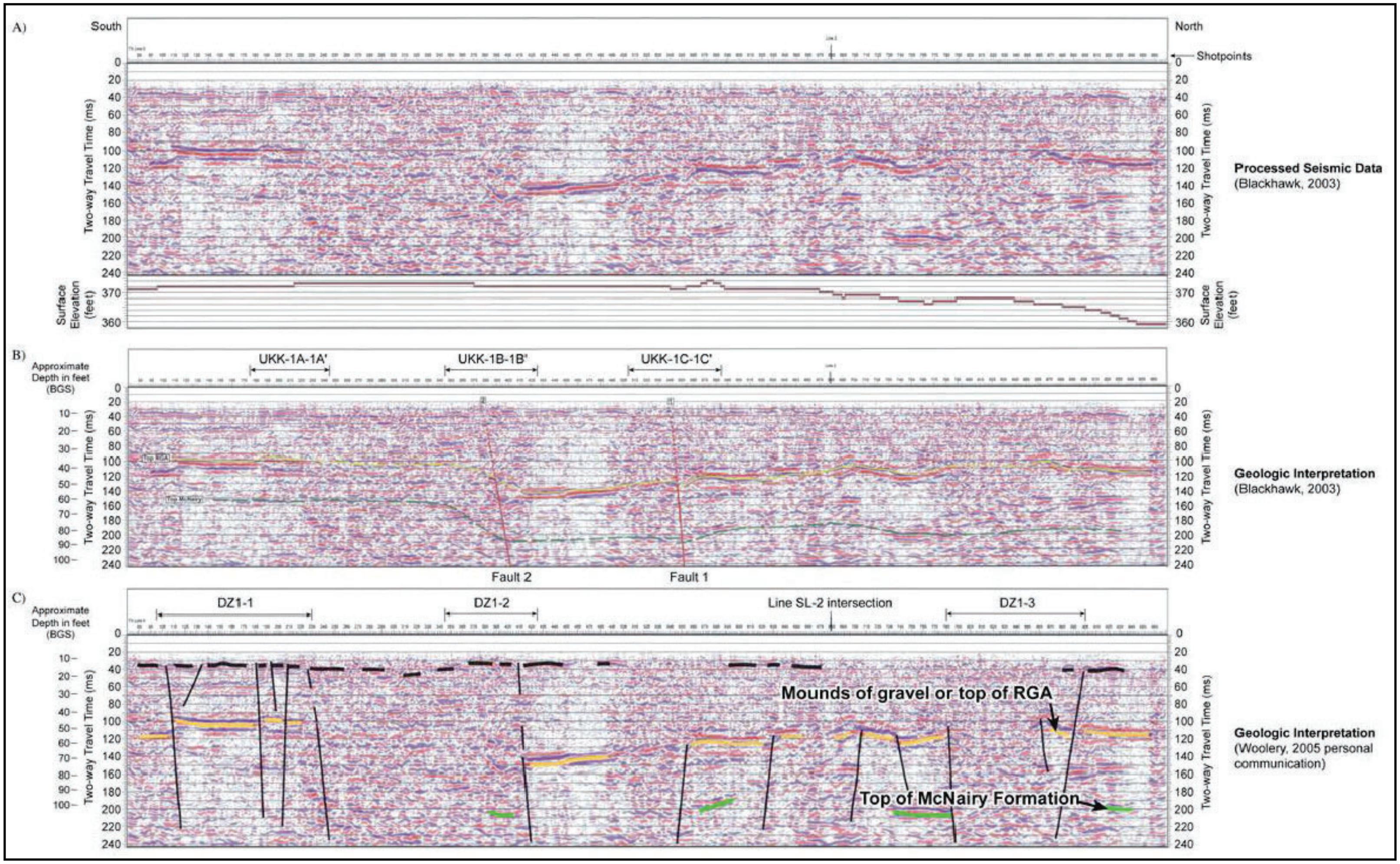
Seismic reflection profiles (Blackhawk Geosciences, 2003) image at least two faults offsetting Quaternary to Tertiary (Mounds Gravel) deposits beneath the project area.

- Subsurface exploration to confirm existence, locations and ages of the inferred faults.



William Letis & Associates, Inc., 2006. Investigation of Holocene Faulting, Proposed C-746-U Landfill Expansion

S$_H$-Wave Seismic Reflection Profile SL-1



William Letis & Associates, Inc., 2006. Investigation of Holocene Faulting, Proposed C-746-U Landfill Expansion

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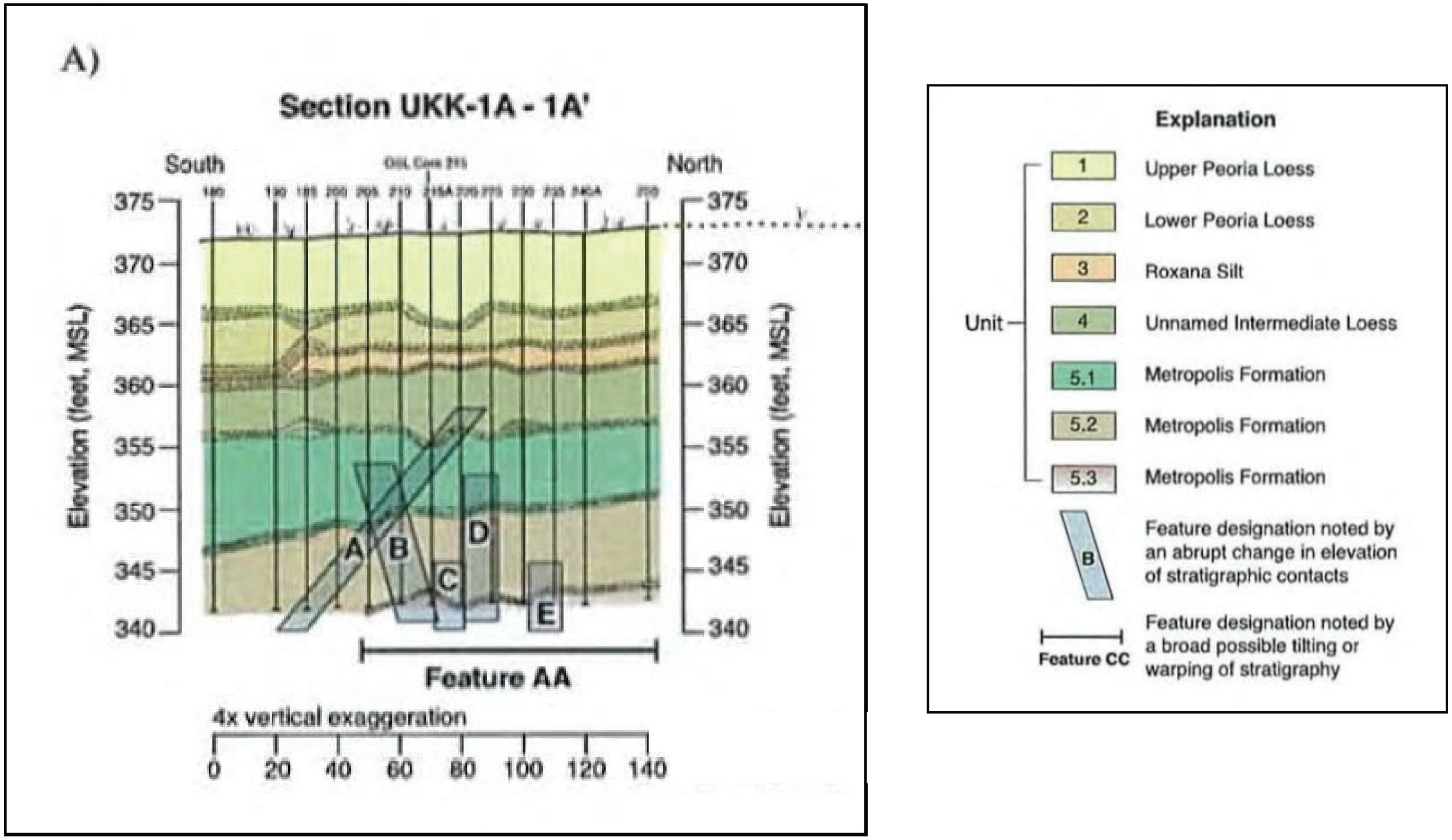
Selected Features Interpreted from the DPT Data



William Letis & Associates, Inc., 2006. Investigation of Holocene Faulting, Proposed C-746-U Landfill Expansion

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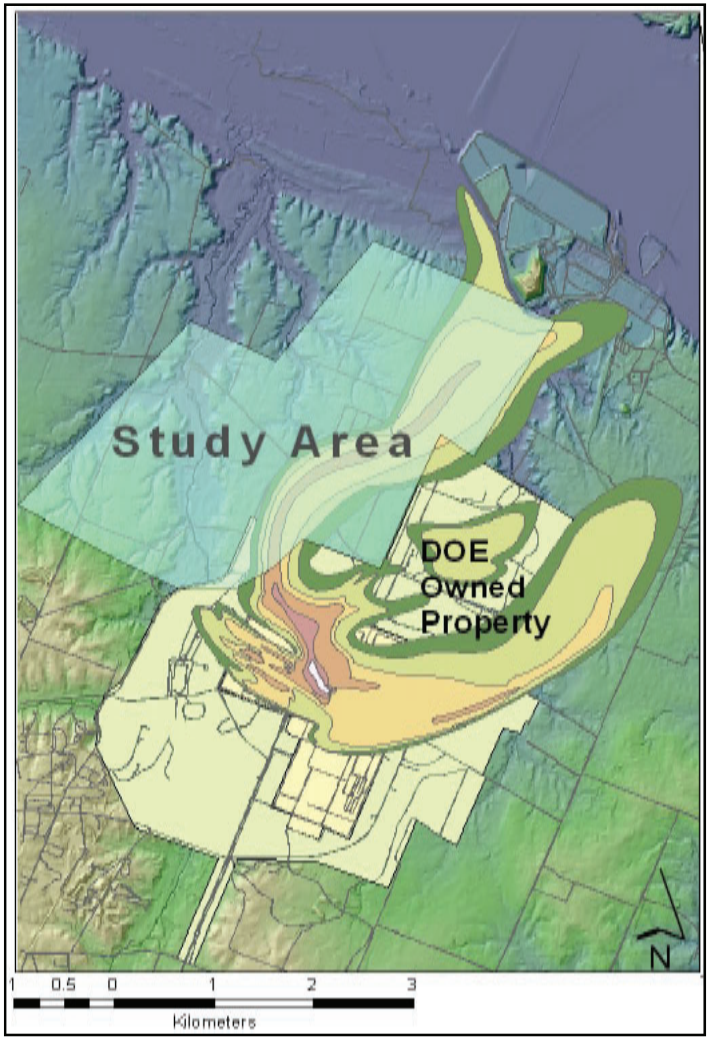
Summary

Methodology:
- 1 km of seismic reflection data
- (86) 30-ft deep continuous soil cores
- OSL age-dating of loess

Conclusions:
- Geophysical data exhibit northeast-trending faults with oblique normal and reverse displacement.
- Upper (3) loess units generally flat-lying and mantle pre-existing topography.
- Lower older units exhibit subtle to abrupt undulations of basal contacts.
- Most recent fault displacement, if present at the site, is constrained to post-date deposition of the Unnamed Intermediate Silt (53.6 to 75.5 thousand years ago).



Over 7.8 Km of S_H-wave reflection data and 2 km of electrical resistivity data.

Imaged high-angle faults extending into Pleistocene horizons.

Structural features preferentially oriented with groundwater and contaminant migration.

Blits, C.A., Woolery, E.W., Macpherson, K.A., and Hampson, S. 2008. Integrated Geophysical Imaging Techniques for Detecting Neotectonic Deformation in the Fluorspar Area Fault Complex of Western Kentucky

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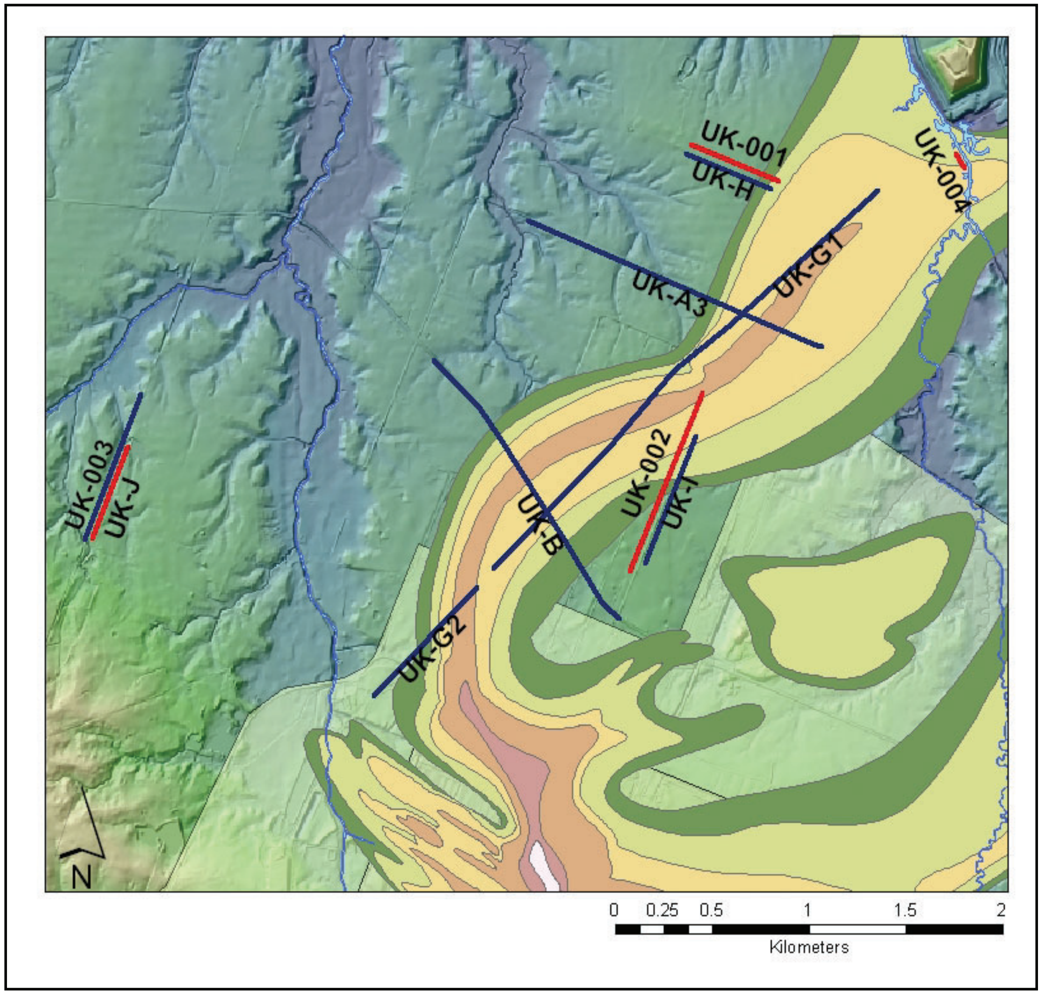

Geophysical Surveys

Line Name	Survey Type
Seismic Reflection	
UK-A3$_1$	S$_H$-wave
UK-B$_1$	S$_H$-wave
UK-G1$_1$	S$_H$-wave
UK-G2$_1$	S$_H$-wave
UK-H	S$_H$-wave
UK-I	S$_H$-wave
UK-J$_2$	S$_H$wave
Electrical Resistivity	
UK-001	Dipole-Dipole
UK-002	Dipole-Dipole
UK-003	Dipole-Dipole
UK-004	Dipole-Dipole

[1] Collected by Langston and Street (1997)

[2] Collected by Wood, McDowell, Woolery and Wang (2000-2001)

Blits, C.A., Woolery, E.W., Macpherson, K.A., and Hampson, S. 2008. Integrated Geophysical Imaging Techniques for Detecting Neotectonic Deformation in the Fluorspar Area Fault Complex of Western Kentucky

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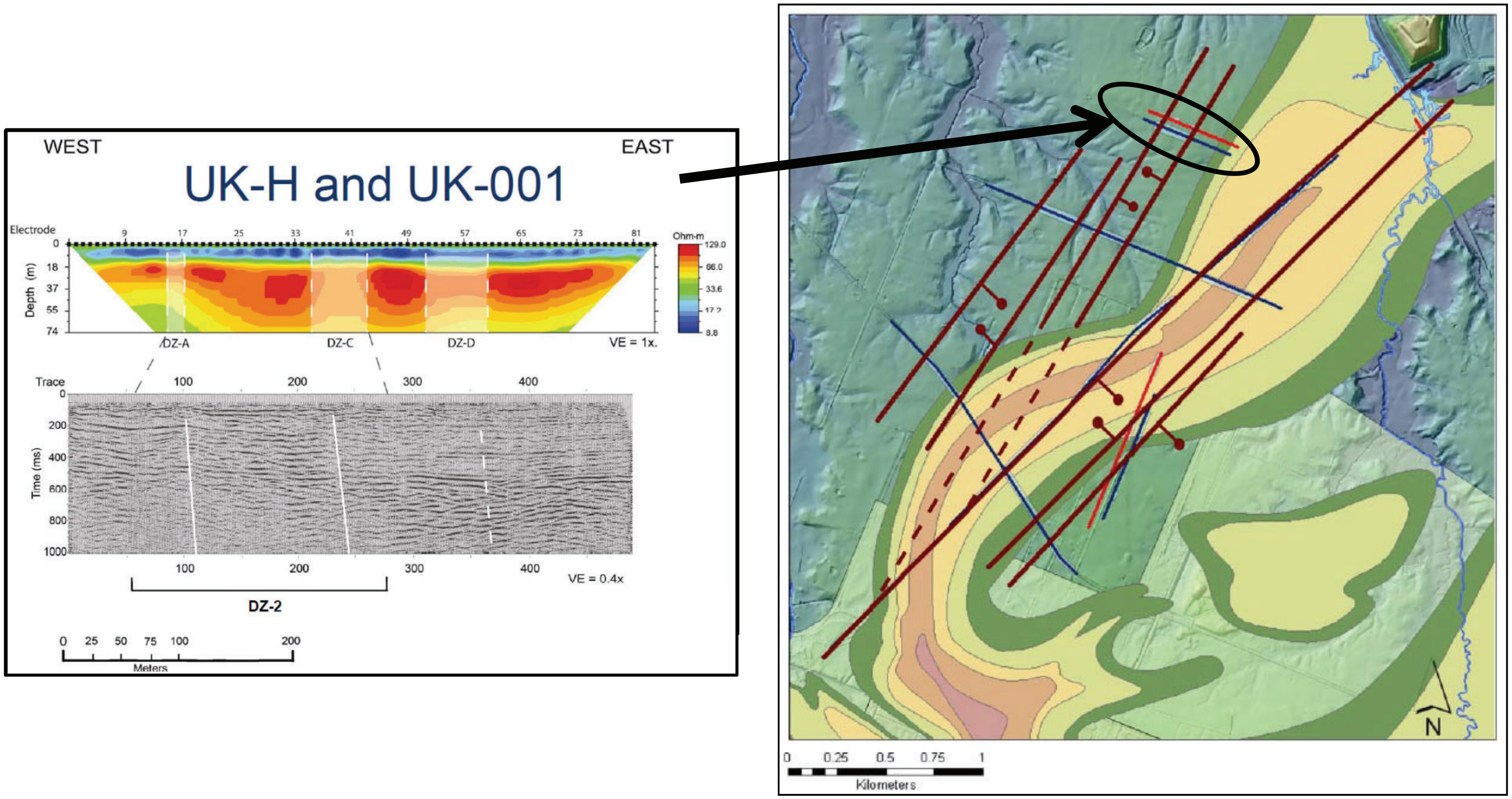

Blits, C.A., Woolery, E.W., Macpherson, K.A., and Hampson, S. 2008. Integrated Geophysical Imaging Techniques for Detecting Neotectonic Deformation in the Fluorspar Area Fault Complex of Western Kentucky

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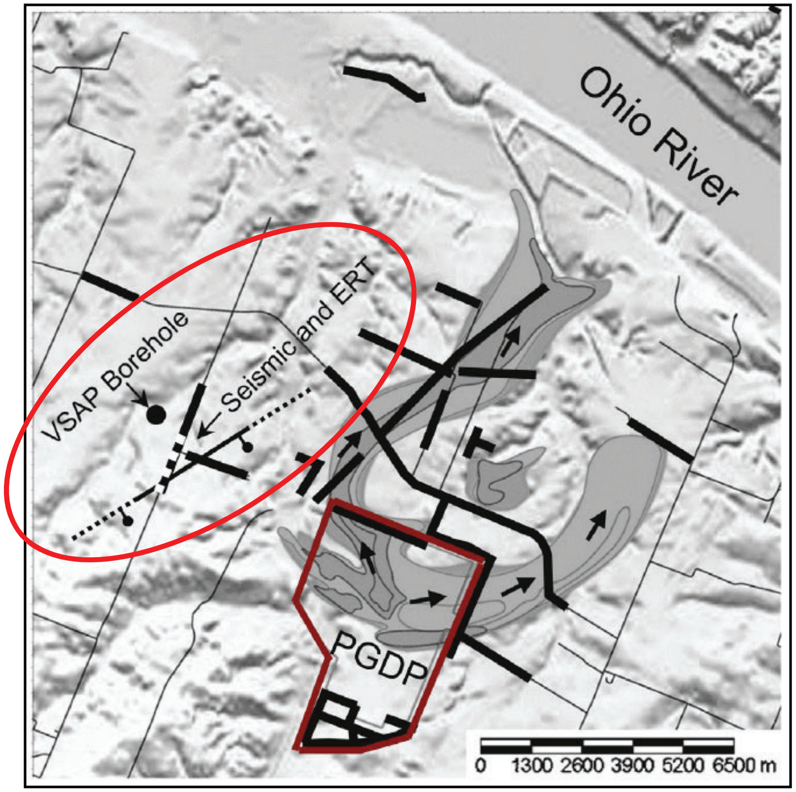


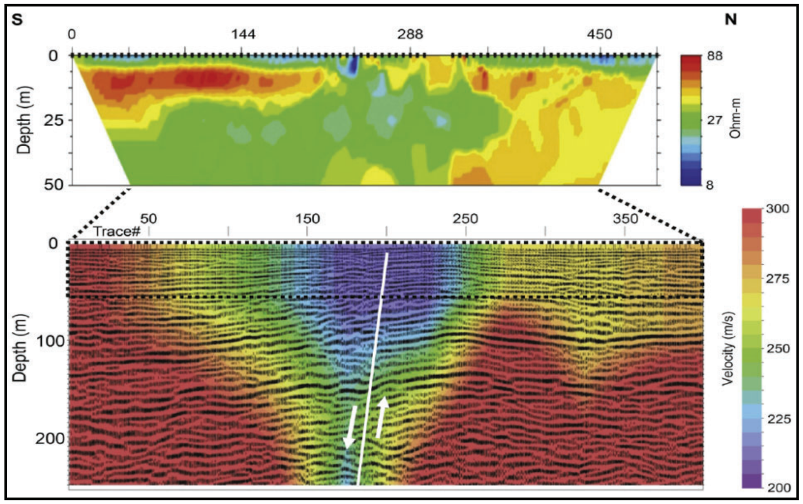
Can near-surface structural features within unlithified sediment locally influence hydraulic conductivity and act as a preferential pathway for fluid migration?

(The answer is "Yes".)

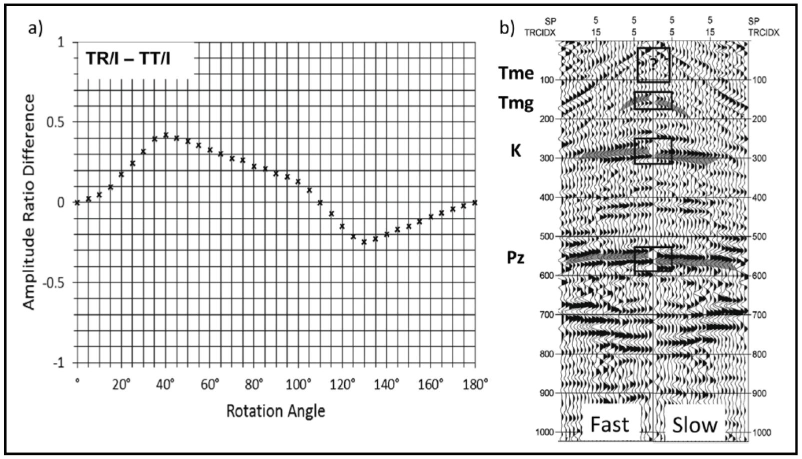
Based on:

- One seismic reflection line (of ~17.5 km of seismic reflection lines),
- one electrical-resistivity tomography survey line, and
- the single S_H-wave splitting survey (to determine structural orientation)

Ali Almayahi and Edward Woolery, 2018. Fault-controlled contaminant plume migration: Inferences from SH-wave reflection and electrical resistivity experiments



- The S_H-wave velocity in the fault zone is ~100 m/s slower than the surrounding area.
- As much as 80 Ω-m reduction in resistivity within the fault zone relative to the surrounding undeformed sediments.



S-wave splitting experiment

a) Fast and slow driections

b) Symmetric mirror view of a field-file seismogram from the same shot point that has been rotated into the fast and slow directions.

Integrated geophysical measurements show significant variation in the elastic and electrical properties between deformed and undeformed sediments

Ali Almayahi and Edward Woolery, 2018. Fault-controlled contaminant plume migration: Inferences from SH-wave reflection and electrical resistivity experiments

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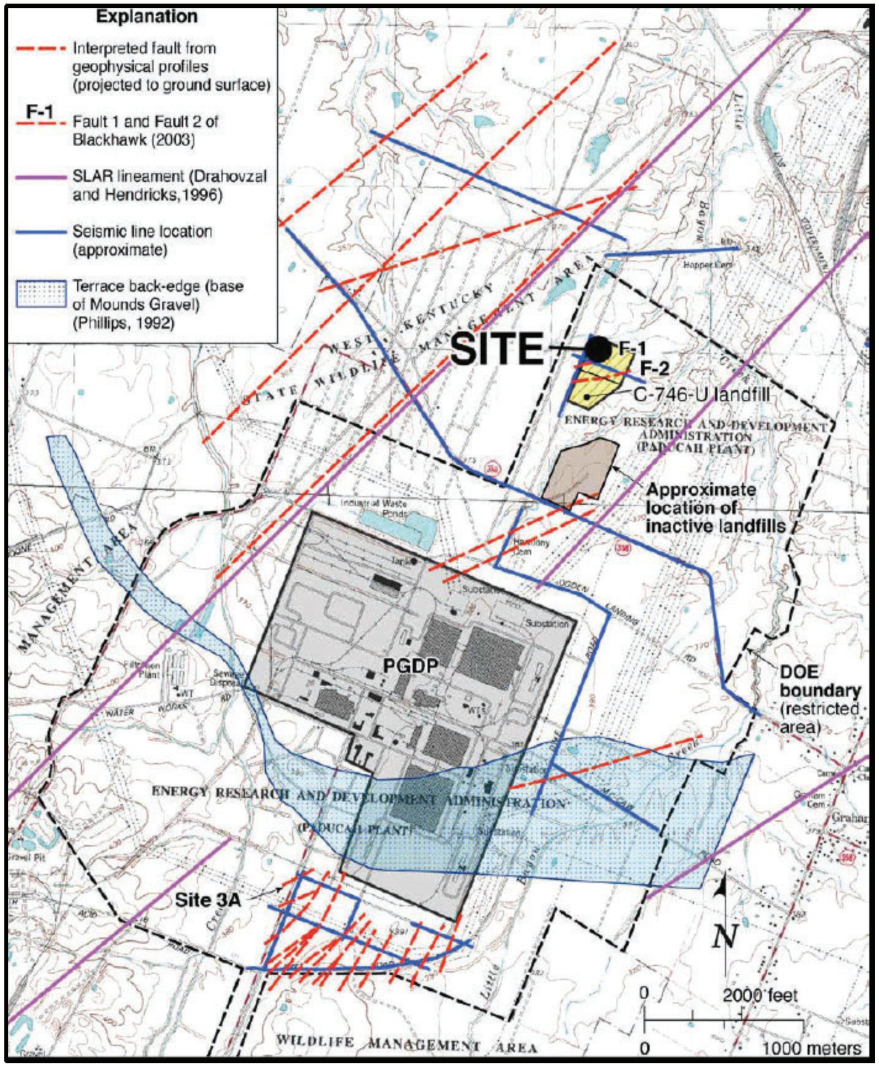

SUMMARY

- Seismic investigations provide good coverage of the area of the Paducah Site outside of the industrial area.
- Seismic investigations (principally S_H-wave) have identified numerous high-angle faults within and adjacent to the Paducah Site, consistent with trends of the Fluorspar Area Fault Complex of southern Illinois.
- Seismic surveys image faults extending upwards through the lower Continental Deposits.

Local Faulting and Related Features in the Vicinity of the Paducah Site

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APPENDIX C

ASSESSMENT OF THE McNAIRY FORMATION SECTION IN THE C-400 REMEDIAL INVESTIGATION SOIL BORINGS

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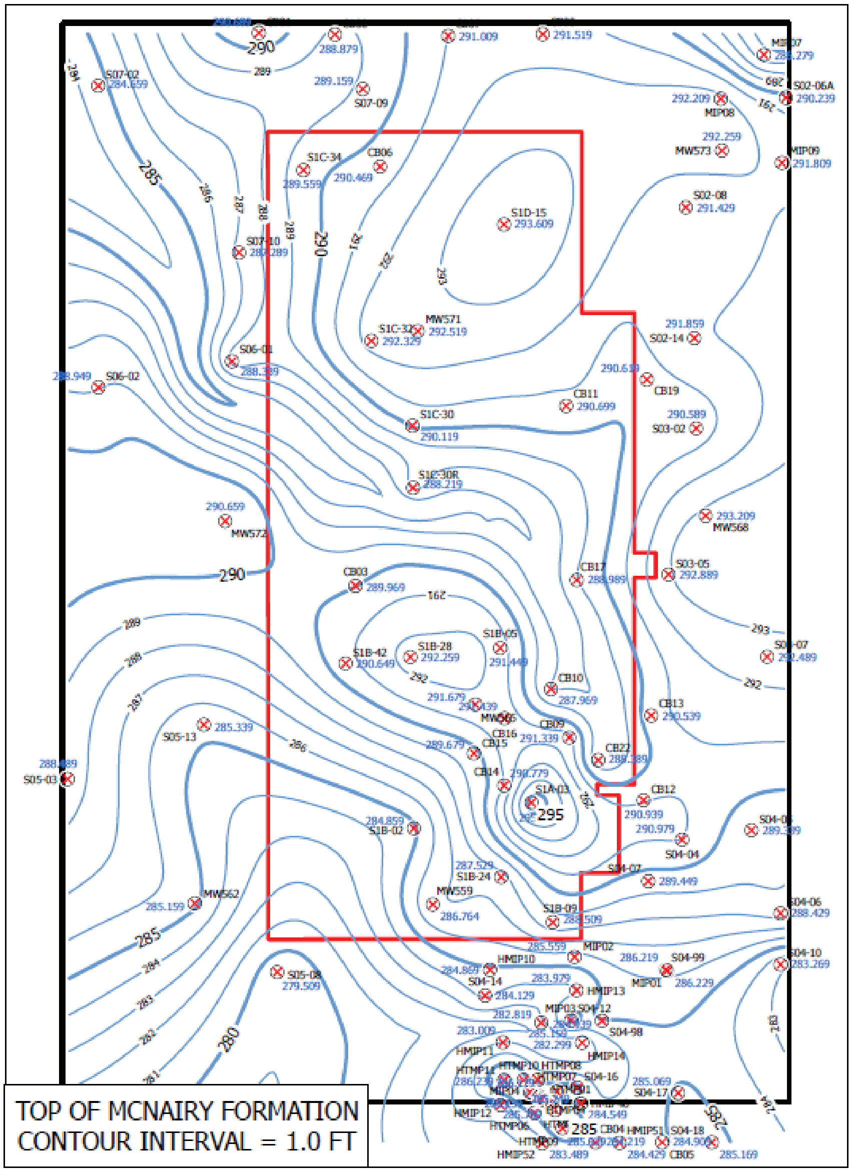
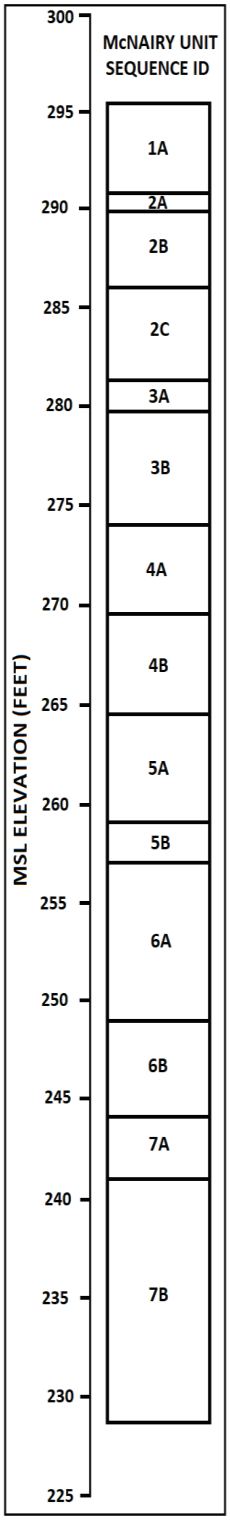
THE McNAIRY SURFACE

Below is the surface of the McNairy as it is estimated to appear beneath the Pleistocene gravel. The surface exhibits significant lithological heterogeneity, indicating that the observed structural irregularities may be erosional in nature. The red outline is the footprint of the C-400 building.



Although the structure could reflect deltaic sedimentary features such as channels or lobes, it is at least equally likely that said surface is an eroded paleotopography. The presence of the Tertiary and Quaternary sand and gravel deposit on top of the McNairy suggests an intense, high-energy erosional environment. Such a setting would have likely substantially affected the weak, unconsolidated materials comprising the McNairy Formation and contributed to its current form. The stratigraphic interpretation approach proposed below is based on the eroded paleotopography model.



C-400 STUDY AREA
UPPER McNAIRY SEQUENCE COLUMN
(SPECIFIC TO THE UPPER McNAIRY FORMATION AT C-400)
THIN-SECTION METHOD

Proposed Model: The upper 61 feet of the McNairy Formation penetrated by drilling in the C-400 study area have been speciated into 14 distinct, named sequences. The speciation is based solely elevation and sub-unit thickness similarities that occur laterally across space. The model assumes absence of faulting, minimal diagenesis, and relatively uncompacted, horizontal bedding. These latter assumptions are not unreasonable considering the relatively small areal extent of the study area. The speciated units are named in decending order, MU1A through MU7B (MU = McNairy Unit) as indicated in the scaled column on the left, with 1A being the youngest and 7B being the oldest. The sequences are correlated independently of lithology. The named sequences are restricted to the narrow elevation intervals indicated along the right side of column. Each named sequence can be composed of sub-units that remain unnamed.

Deltaic environments typically produce stratigraphic comlexity that increases, or at least does not decrease as drillhole spacing decreases. The McNairy environment encountered in the C-400 study area appears to exhibit such complexity.

Emergent Structures: The cardinal utility of this model is that it appears to reveal the different depositional (lithofacies) regimes that existed more or less simultaneously, spatially across the McNairy environment. This revealed structure can indicate among other things, the orientation of the paleoshoreline and direction from which of source stream may have flowed. It can also provide insight into potential hydrologic parameter trends. This is the only mapping method tried that appears to reduce complexity sufficiently such that structures extending across the entire study area emerge from the stratigraphic background noise and that are unlikely to dissipate with increased resolution.

The surface of the McNairy in the C-400 study area appears to exhibit the structure of an eroded paleotopography. The apparent paleotopography coupled with the overlying high-energy gravel indicates scouring, possibly related to massive flow events occurring after the melting of ice dams located several hundred miles to the east in pre-Illinoian time.

Paleosols: It is unclear if the apparent McNairy paleotopography was subjected to subareial exposure. However, indications exist that some of the horizons within the penetrated interval could have been exposed. Strongly colored iron oxide bands and the occurrence of manganese nodules may be indicators of paleosols that once existed but did not survive the HU5 gravel deposition event.

The common presence of ophiomorpha across the upper member of the McNairy Formation indicates shallow marine and/or fresh water environments, supporting conclusions made in previous studies.

SEQUENCE SUMMARIES

The 14 McNairy sequences penetrated by drilling are summarized below.

MU1A

HOLE NO.	SURF ELEV	UNIT	DESCRIP	MAP LITHOFACIES	TOP	BOT	TOP ELEV	THICK
MW-565	379.48	**MU1A**	CLAY	CLAY	87.79	88.67	291.69	0.88
MW-568	378.71	**MU1A**	CLAY INTRLAM W/ SAND	SILTY CLAY	85.50	87.00	293.21	1.50
MW-571	379.52	**MU1A**	SILTY CLAY/GRY BRN	CLAYEY SD	87.00	92.00	292.52	5.00
MW-573	376.46	**MU1A**	SILTY SAND	SANDY SILT	84.22	85.80	292.24	1.58
S1A-03	379.54	**MU1A**	INTRBED SILT, SAND,/CLAY	SILTY CLAY	84.10	88.80	295.44	4.70
S1B-28	379.26	**MU1A**	CLAY W/HOR PART	CLAY	87.00	92.00	292.26	5.00
S1C-32	379.53	**MU1A**	SILTY GRAV/CLAYEY SILT	CLAYEY SD	87.20	89.53	292.33	2.33
S1D-15	379.51	**MU1A**	CLAYEY SILT	CLAYEY SD	85.87	88.85	293.64	2.98
S02-14	378.46	**MU1A**	SILT INTRBD W/SAND	SANDY SILT	86.61	87.55	291.85	0.94
S03-05	378.99	**MU1A**	SANDY SILT	SANDY SILT	86.11	89.05	292.88	2.94
S03-07	378.29	**MU1A**	SILTY CLAY/SAND	SILTY CLAY	85.77	88.23	292.52	2.46
MIN	**376.46**				**84.10**	**85.80**	**291.69**	**0.88**
MAX	**379.54**				**87.79**	**92.00**	**295.44**	**5.00**
MEAN	**378.89**				**86.11**	**88.86**	**292.78**	**2.76**
RANGE	**3.08**				**3.69**	**6.20**	**3.75**	**4.12**
COUNT	**11**				**11**	**11**	**11**	**11**

MU2A

HOLE NO.	SURF ELEV	UNIT	DESCRIP	MAP LITHOFACIES	TOP	BOT	TOP ELEV	THICK
MW-572	378.66	**MU2A**	SILTY CLAY	CLAYEY SD	88.02	90.28	290.64	2.26
MW-573	376.46	**MU2A**	CLAY W/INTRBD SILT	CLAYEY SD	85.80	87.00	290.66	1.20
S1A-03	379.54	**MU2A**	INTRBED SAND/CLAY	SILTY CLAY	88.80	92.00	290.74	3.20
S1B-05	379.45	**MU2A**	CLAY	CLAY	87.98	92.81	291.47	4.83
S1B-28	379.26	**MU2A**	CLAY	CLAY	92.00	93.00	287.26	1.00
MW-565	379.48	**MU2A**	CLAYEY SILT	CLAYEY SD	88.67	92.00	290.81	3.33
S1B-42	379.55	**MU2A**	CLAYEY SILT	CLAYEY SD	88.92	90.00	290.63	1.08
S1C-30	379.52	**MU2A**	CLAY/SILT CLAY	CLAYEY SD	89.41	92.00	290.11	2.59
S1C-32	379.53	**MU2A**	CLAY/DK RED GRY	CLAY	89.53	90.00	290.00	0.47
S1D-15	379.51	**MU2A**	SILTY CLAY	CLAYEY SD	88.85	89.50	290.66	0.65
S02-06	376.14	**MU2A**	SILTY SAND	SILTY SD	85.87	86.72	290.27	0.85
S02-08	382.53	**MU2A**	SILTY SAND/STRG BRN	SILTY SD	91.09	92.00	291.44	0.91
S02-14	378.46	**MU2A**	SANDY SILT	SILTY SD	87.55	89.36	290.91	1.81
S03-02	378.09	**MU2A**	SAND/CLAY INTRBD	SILTY CLAY	87.63	89.77	290.46	2.14
S03-05	378.99	**MU2A**	SAND W/INTRBD SILT	SILTY SD	89.05	92.00	289.94	2.95
S03-07	378.29	**MU2A**	SAND	SAND	88.23	88.70	290.06	0.47
S04-04	379.48	**MU2A**	SILTY CLAY AND SAND	SILTY CLAY	88.50	92.00	290.98	3.50
MIN	**376.14**				**85.80**	**86.72**	**287.26**	**0.47**
MAX	**382.53**				**92.00**	**93.00**	**291.47**	**4.83**
MEAN	**379.00**				**88.58**	**90.54**	**290.41**	**1.96**
RANGE	**6.39**				**6.20**	**6.28**	**4.21**	**4.36**
COUNT	**17**				**17**	**17**	**17**	**17**

MU2B

HOLE NO.	SURF ELEV	UNIT	DESCRIP	MAP LITHOFACIES	TOP	BOT	TOP ELEV	THICK
MW-559	379.56	**MU2B**	SAND/GRAV INTRBD W/SILT	SANDY SILT	92.78	95.00	286.78	2.22
MW-572	378.66	**MU2B**	CLAY/CLAY W/SILTY BANDS	CLAYEY SD	90.28	93.95	288.38	3.67
S1A-03	379.54	**MU2B**	SAND GRAD TO GRAV	SAND	92.00	95.00	287.54	3.00
S1B-05	379.45	**MU2B**	CLAY W/INTRBER SAND/ GLAUCONITE	SILTY CLAY	92.81	96.05	286.64	3.24
S1B-09	379.41	**MU2B**	INTRBD SILT, SAND/GRAV SAND	--	90.89	96.10	288.52	5.21
S1B-24	379.53	**MU2B**	SAND/CLAY INTRBD	SILTY CLAY	92.00	96.17	287.53	4.17
S1B-28	379.26	**MU2B**	SANDY SILT	SANDY SILT	93.00	96.70	286.26	3.70
S1B-42	379.55	**MU2B**	CLAYEY SILT/DK GRY	CLAYEY SD	90.00	96.38	289.55	6.38
S1C-30	379.52	**MU2B**	SILTY CLAY/BLK	CLAYEY SD	92.00	95.12	287.52	3.12
S1C-30R	379.62	**MU2B**	CLAY W/SILT, DK RED GRY	CLAYEY SD	91.43	95.00	288.19	3.57
S1C-32	379.53	**MU2B**	SILTY CLAY/VRY DK GRY	CLAYEY SD	90.00	96.61	289.53	6.61
S1C-34	379.56	**MU2B**	CLAYEY SILT/DK RED GRY	CLAYEY SD	90.00	95.00	289.56	5.00
S1D-15	379.51	**MU2B**	CLAYEY SILT	CLAYEY SD	89.50	97.00	290.01	7.50
S02-06	376.14	**MU2B**	SAND INTRBD W/SILT	SANDY SILT	86.72	92.62	289.42	5.90
S02-08	382.53	**MU2B**	SAND INTRBD W/SILT	SANDY SILT	92.00	101.36	290.53	9.36
S02-14	378.46	**MU2B**	SILTY SAND	SANDY SILT	89.36	97.00	289.10	7.64
S03-02	378.09	**MU2B**	SAND W/TR CLAY LAM	SAND	89.77	94.23	288.32	4.46
S03-05	378.99	**MU2B**	SAND/SILT INTRBD	SANDY SILT	92.00	96.00	286.99	4.00
S03-07	378.29	**MU2B**	CLAY	CLAY	88.70	93.01	289.59	4.31
S04-04	379.48	**MU2B**	CLAY/SAND	SILTY CLAY	92.00	94.98	287.48	2.98
S04-05	378.74	**MU2B**	SAND/SILT INTRBD	SANDY SILT	89.41	95.32	289.33	5.91
S04-06	379.13	**MU2B**	SILT W/THINLY INTRBD SAND	SANDY SILT	90.67	95.17	288.46	4.50
S04-07	379.95	**MU2B**	SAND W/CLAY/SILTY PARTINGS	SILTY CLAY	90.53	94.53	289.42	4.00
S04-99	379.73	**MU2B**	CLAYEY SILT/SAND INTRBD	SILTY CLAY	93.47	95.00	286.26	1.53
S05-03	377.79	**MU2B**	CLAY W SILT, DK GRY W/IRON STAINS	CLAYEY SD	89.30	94.38	288.49	5.08
S06-01	374.94	**MU2B**	SILT W/THIN INTRBD SAND	SANDY SILT	86.60	90.00	288.34	3.40
S06-02	372.15	**MU2B**	SILTY CLAY/GRAV SILT	CLAYEY SD	83.15	85.54	289.00	2.39
S07-09	379.16	**MU2B**	SAND/SILT INTRBD, DK GRY	SANDY SILT	90.00	96.14	289.16	6.14
S07-10	374.99	**MU2B**	SILTY SAND	SANDY SILT	87.69	89.03	287.30	1.34
MIN	**372.15**				**83.15**	**85.54**	**286.26**	**1.34**
MAX	**382.53**				**93.47**	**101.36**	**290.53**	**9.36**
MEAN	**378.66**				**90.28**	**94.77**	**288.39**	**4.49**
RANGE	**10.38**				**10.32**	**15.82**	**4.27**	**8.02**
COUNT	**29**				**29**	**29**	**29**	**29**

MU2C

HOLE NO.	SURF ELEV	UNIT	DESCRIP	MAP LITHOFACIES	TOP	BOT	TOP ELEV	THICK
MW-562	378.36	**MU2C**	SILT W/LT CLAY//LAM	CLAYEY SD	93.18	97.00	285.18	3.82
MW-572	378.66	**MU2C**	CLAY	CLAY	93.95	97.00	284.71	3.05
S1A-03	379.54	**MU2C**	INTRBED SILT, SAND,/CLAY	SILTY CLAY	95.00	98.30	284.54	3.30
S1B-02	379.56	**MU2C**	SILT W/LT SAND	SANDY SILT	94.67	98.67	284.89	4.00
S1B-05	379.45	**MU2C**	SAND W/FEW CLAY INTRBD	SILTY CLAY	96.05	99.00	283.40	2.95
S1B-09	379.41	**MU2C**	INTRBD SANDY SILT/GRAV	SILTY CLAY	96.10	100.00	283.31	3.90
S1B-24	379.53	**MU2C**	INTRBD CLAY/SAND	SILTY CLAY	96.17	100.73	283.36	4.56
S1B-28	379.26	**MU2C**	SILTY SAND	SANDY SILT	96.70	99.60	282.56	2.90
S1B-42	379.55	**MU2C**	CLAYEY SILT	CLAYEY SD	96.38	99.23	283.17	2.85
S1C-30	379.52	**MU2C**	SILT/SILTY SAND	SANDY SILT	95.12	100.00	284.40	4.88
S1C-32	379.53	**MU2C**	SANDY SILT	SANDY SILT	96.61	99.29	282.92	2.68
S1C-34	379.56	**MU2C**	SAND/SILT INTRBD, DK RED GRY	SANDY SILT	95.00	99.17	284.56	4.17
S1D-15	379.51	**MU2C**	SAND W/BANDS OF CLAY	SILTY CLAY	97.00	103.90	282.51	6.90
S02-06	376.14	**MU2C**	SAND INTRBD W/SILT/DK GRY	SANDY SILT	92.62	97.05	283.52	4.43
S03-02	378.09	**MU2C**	CLAY W/INTRBD SAND	SILTY CLAY	94.23	98.79	283.86	4.56
S03-05	378.99	**MU2C**	SILTY SAND	SANDY SILT	96.00	98.11	282.99	2.11
S03-07	378.29	**MU2C**	SAND AND CLAYEY SAND	SILTY CLAY	93.01	98.67	285.28	5.66
S04-04	379.48	**MU2C**	CLAY	CLAY	94.98	99.00	284.50	4.02
S04-05	378.74	**MU2C**	SAND W/TR INTRBD SILT	SANDY SILT	95.32	98.65	283.42	3.33
S04-06	379.13	**MU2C**	SAND W/INTRBD SILT	SANDY SILT	95.17	98.83	283.96	3.66
S04-07	379.95	**MU2C**	CLAY W/SILT LAM	CLAYEY SD	94.53	99.78	285.42	5.25
S04-10	379.37	**MU2C**	SILT W/INTRBD SAND	SANDY SILT	96.14	100.71	283.23	4.57
S04-12	378.96	**MU2C**	CLAY W/INTRBD SAND	SILTY CLAY	93.75	97.00	285.21	3.25
S04-14	379.03	**MU2C**	SAND W/THIN-MED INTRBD SILT/TR MN STAIN	SANDY SILT	94.91	100.00	284.12	5.09
S04-16	378.95	**MU2C**	STRNG BRN SAND INTRBD W/SILT/CLAY	SILTY CLAY	93.68	98.11	285.27	4.43
S04-17	379.17	**MU2C**	SAND/CLAY INTRLAM	SILTY CLAY	94.13	97.67	285.04	3.54
S04-18	379.17	**MU2C**	SAND W/INTRBD SILT/STRG BRN	SANDY SILT	94.00	98.87	285.17	4.87
S04-98	379.04	**MU2C**	CLAYEY SILT W/INTRBD SAND	SILTY CLAY	94.13	98.10	284.91	3.97
S04-99	379.73	**MU2C**	CLAYEY SILT W/INTRBD SAND	SILTY CLAY	95.00	99.15	284.73	4.15
S05-03	377.79	**MU2C**	SILTY CLAY/DK GRY W/SAND	SILTY CLAY	94.38	100.09	283.41	5.71
S05-13	375.74	**MU2C**	SILTY CLAY/CLAY	CLAYEY SD	90.45	95.00	285.29	4.55
S06-01	374.94	**MU2C**	SILT/DK GRY	CLAYEY SD	90.00	98.75	284.94	8.75
S06-02	372.15	**MU2C**	SILTY CLAY	CLAYEY SD	85.54	94.46	286.61	8.92
S07-02	371.86	**MU2C**	CLAYEY SILT	CLAYEY SD	87.25	92.00	284.61	4.75
S07-09	379.16	**MU2C**	SAND W/INTRBD SILT	SANDY SILT	96.14	100.00	283.02	3.86
S07-10	374.99	**MU2C**	SILT/BLK	CLAYEY SD	89.03	95.45	285.96	6.42
MIN	**371.86**				**85.54**	**92.00**	**282.51**	**2.11**
MAX	**379.95**				**97.00**	**103.90**	**286.61**	**8.92**
MEAN	**378.34**				**94.06**	**98.50**	**284.28**	**4.44**
RANGE	**8.09**				**11.46**	**11.90**	**4.10**	**6.81**
COUNT	**36**				**36**	**36**	**36**	**36**

MU3A

HOLE NO.	SURF ELEV	UNIT	DESCRIP	MAP LITHOFACIES	TOP	BOT	TOP ELEV	THICK
S1A-03	379.54	**MU3A**	INTRBED SAND/CLAY	SILTY CLAY	98.30	102.33	281.24	4.03
S1B-02	379.56	**MU3A**	SILT/SAND	SANDY SILT	98.67	105.00	280.89	6.33
S1B-05	379.45	**MU3A**	SAND W/CLAY HORIZON	SILTY CLAY	99.00	102.40	280.45	3.40
S1B-09	379.41	**MU3A**	SAND W/SILT	SANDY SILT	100.00	103.77	279.41	3.77
S1B-24	379.53	**MU3A**	SAND	SAND	100.73	102.63	278.80	1.90
S1B-28	379.26	**MU3A**	SAND/CLAY INTRBD	SILTY CLAY	99.60	101.00	279.66	1.40
S1B-42	379.55	**MU3A**	CLAYEY SILT/SAND INTRBD	SILTY CLAY	99.23	104.29	280.32	5.06
S1C-30	379.52	**MU3A**	SAND W/TR CLAY	SILTY CLAY	100.00	103.61	279.52	3.61
S1C-32	379.53	**MU3A**	SAND/CLAY INTRBD	SILTY CLAY	99.29	101.70	280.24	2.41
S1C-34	379.56	**MU3A**	SILT/SAND, INTRBD	SANDY SILT	99.17	102.76	280.39	3.59
S1D-15	379.51	**MU3A**	CLAY/DK GRY	CLAY	103.90	105.67	275.61	1.77
S02-06	376.14	**MU3A**	SILTY SAND/DK GRY INTRBD SILT/SAND	SANDY SILT	97.05	100.00	279.09	2.95
S02-08	382.53	**MU3A**	SILT INTRBD W/THIN SAND	SANDY SILT	101.36	108.09	281.17	6.73
S02-14	378.46	**MU3A**	SILT INTRBD W/SAND LENS	SANDY SILT	97.00	99.43	281.46	2.43
S03-02	378.09	**MU3A**	SAND W/TR SILT LENS	SANDY SILT	98.79	102.45	279.30	3.66
S03-05	378.99	**MU3A**	SAND INTRBD W/SILT	SANDY SILT	98.11	102.40	280.88	4.29
S03-07	378.29	**MU3A**	SILTY SAND	SANDY SILT	98.67	100.38	279.62	1.71
S04-04	379.48	**MU3A**	SILTY SAND W/TR INTRBD SILT	SANDY SILT	99.00	103.55	280.48	4.55
S04-05	378.74	**MU3A**	SAND	SAND	98.65	101.36	280.09	2.71
S04-06	379.13	**MU3A**	SILTY SAND	SAND	98.83	113.70	280.30	14.87
S04-07	379.95	**MU3A**	SAND	SAND	99.78	104.03	280.17	4.25
S04-10	379.37	**MU3A**	SAND	SAND	100.71	103.95	278.66	3.24
S04-12	378.96	**MU3A**	CLAY W/INTRBD SILTY SAND	SILTY CLAY	97.00	102.65	281.96	5.65
S04-14	379.03	**MU3A**	SAND W/INTRBD SILT	SANDY SILT	100.00	102.10	279.03	2.10
S04-16	378.95	**MU3A**	SILT W/INTRBD SAND/CLAY LAY	SILTY CLAY	98.11	102.00	280.84	3.89
S04-17	379.17	**MU3A**	SANDY SILT SANDY CLAY PARTING	SILTY CLAY	97.67	102.83	281.50	5.16
S04-98	379.04	**MU3A**	SAND/SILTY SAND	SANDY SILT	98.10	102.91	280.94	4.81
S04-99	379.73	**MU3A**	SAND W/LT SILT	SANDY SILT	99.15	100.00	280.58	0.85
S05-03	377.79	**MU3A**	SANDY SILT/GRY BRN	SANDY SILT	100.09	103.96	277.70	3.87
S05-08	379.21	**MU3A**	SILTY SAND	SANDY SILT	99.65	103.68	279.56	4.03
S05-13	375.74	**MU3A**	CLAY/VRY DK GRY	CLAY	95.00	97.91	280.74	2.91
S06-01	374.94	**MU3A**	SAND/SILT INTRBD	SANDY SILT	98.75	103.46	276.19	4.71
S06-02	372.15	**MU3A**	SANDY SILT/BRN	SANDY SILT	94.46	97.93	277.69	3.47
S07-02	371.86	**MU3A**	CLAY W/SAND STRK/TR SH GRAV/DK GRY	SILTY CLAY	92.00	96.47	279.86	4.47
S07-09	379.16	**MU3A**	SILT W/INTRBD SAND	SANDY SILT	100.00	104.32	279.16	4.32
S07-10	374.99	**MU3A**	SANDY SILT	SANDY SILT	95.45	99.29	279.54	3.84
MIN	**371.86**				**92.00**	**96.47**	**275.61**	**0.85**
MAX	**382.53**				**103.90**	**113.70**	**281.96**	**14.87**
MEAN	**378.45**				**98.65**	**102.61**	**279.81**	**3.97**
RANGE	**10.67**				**11.90**	**17.23**	**6.35**	**14.02**
COUNT	**36**				**36**	**36**	**36**	**36**

MU3B

HOLE NO.	SURF ELEV	UNIT	DESCRIP	MAP LITHOFACIES	TOP	BOT	TOP ELEV	THICK
S1A-03	379.54	**MU3B**	INTRBED SILT/CLAY/SAND	SILTY CLAY	102.33	107.00	277.21	4.67
S1B-02	379.56	**MU3B**	SAND W/INTRBD SILT	SANDY SILT	105.00	108.95	274.56	3.95
S1B-05	379.45	**MU3B**	CLAY/SAND INTRBD	SILTY CLAY	102.40	107.50	277.05	5.10
S1B-09	379.41	**MU3B**	SILT W/INTRBD SAND		103.77	104.82	275.64	1.05
S1B-24	379.53	**MU3B**	INTRBD CLAY/SAND CLAY	SILTY CLAY	102.63	110.83	276.90	8.20
S1B-28	379.26	**MU3B**	SAND W/CLAY PARTINGS		101.00	107.00	278.26	6.00
S1B-42	379.55	**MU3B**	SAND/SILT INTRBD	SANDY SILT	104.29	107.36	275.26	3.07
S1C-30	379.52	**MU3B**	SAND/VRY DK GRY SILTY CLAY	SILTY CLAY	103.61	109.29	275.91	5.68
S1C-32	379.53	**MU3B**	SAND W/CLAY AND SILT PARTINGS	SILTY CLAY	101.70	107.50	277.83	5.80
S1C-34	379.56	**MU3B**	SILTY CLAYEY SAND, DK RED GRY	SILTY CLAY	102.76	108.86	276.80	6.10
S1D-15	379.51	**MU3B**	SAND/CLAY INTRBD, VRY DK GRY	SILTY CLAY	105.67	108.97	273.84	3.30
S02-06	376.14	**MU3B**	SAND INTRBD W/SILT	SANDY SILT	100.00	104.68	276.14	4.68
S02-08	382.53	**MU3B**	SILT/SAND INTRBD, DK RED GRY	SANDY SILT	108.09	110.68	274.44	2.59
S02-14	378.46	**MU3B**	SILT/SAND INTRBD, DK GRY	SANDY SILT	99.43	107.00	279.03	7.57
S03-02	378.09	**MU3B**	SAND/SILT INTRBD	SAND	102.45	107.00	275.64	4.55
S03-05	378.99	**MU3B**	SAND/SILT	SANDY SILT	102.40	107.89	276.59	5.49
S03-07	378.29	**MU3B**	SAND	SAND	100.38	112.00	277.91	11.62
S04-04	379.48	**MU3B**	SILTY SAND W/INTRBD SILT/TR GRAV	SANDY SILT	103.55	109.00	275.93	5.45
S04-05	378.74	**MU3B**	SILT, SAND/CLAY INTRBD	SILTY CLAY	101.36	107.55	277.38	6.19
S04-07	379.95	**MU3B**	SAND W/FEW CLAY LAM	SILTY CLAY	104.03	110.37	275.92	6.34
S04-10	379.37	**MU3B**	SAND W/INTRBD SILT	SANDY SILT	103.95	108.58	275.42	4.63
S04-12	378.96	**MU3B**	SAND/SILT INTRBD	SANDY SILT	102.65	106.76	276.31	4.11
S04-14	379.03	**MU3B**	SILT/INTRBD SAND	SANDY SILT	102.10	108.92	276.93	6.82
S04-16	378.95	**MU3B**	SANDY INTRBD SILT	SANDY SILT	102.00	108.42	276.95	6.42
S04-17	379.17	**MU3B**	SAND/SILTY SAND	SANDY SILT	102.83	109.94	276.34	7.11
S04-18	379.17	**MU3B**	SAND	SAND	98.87	107.84	280.30	8.97
S04-98	379.04	**MU3B**	SAND W/INTRBD SILT	SANDY SILT	102.91	108.54	276.13	5.63
S04-99	379.73	**MU3B**	SAND W/INTRBD SILT	SANDY SILT	100.00	110.00	279.73	10.00
S05-08	379.21	**MU3B**	SILT/SAND INTRBD	SANDY SILT	103.68	107.93	275.53	4.25
S05-13	375.74	**MU3B**	SILTY SAND/CLAY	SILTY CLAY	97.91	106.22	277.83	8.31
S06-01	374.94	**MU3B**	SILT W/INTRBD SAND	SANDY SILT	103.46	108.75	271.48	5.29
S06-02	372.15	**MU3B**	SANDY CLAYEY SILT/SFT SHALE	SILTY CLAY	97.93	101.32	274.22	3.39
S07-02	371.86	**MU3B**	CLAY W/SAND/GRAV, DK GRY	CLAY	96.47	101.11	275.39	4.64
S07-09	379.16	**MU3B**	SAND W/SILTY PARTING	SILTY CLAY	104.32	106.72	274.84	2.40
S07-10	374.99	**MU3B**	SILT/SAND INTRBD DK GRY	SANDY SILT	99.29	108.20	275.70	8.91
MIN	**371.86**				**96.47**	**101.11**	**271.48**	**1.05**
MAX	**382.53**				**108.09**	**112.00**	**280.30**	**11.62**
MEAN	**378.47**				**102.15**	**107.81**	**276.32**	**5.67**
RANGE	**10.67**				**11.62**	**10.89**	**8.82**	**10.57**
COUNT	**35**				**35**	**35**	**35**	**35**

MU4A

HOLE NO.	SURF ELEV	UNIT	DESCRIP	MAP LITHOFACIES	TOP	BOT	TOP ELEV	THICK
S1A-03	379.54	**MU4A**	SAND W/TR CLAY BLEB	SANDY SILT	107.00	114.38	272.54	7.38
S1B-02	379.56	**MU4A**	SAND/SILT	SANDY SILT	108.95	110.00	270.61	1.05
S1B-05	379.45	**MU4A**	CLAY/SILT W/INTRBD SAND	SILTY CLAY	107.50	110.90	271.95	3.40
S1B-09	379.41	**MU4A**	SAND W/TR INTRBD SILT	SANDY SILT	104.82	115.38	274.59	10.56
S1B-24	379.53	**MU4A**	SAND W/TR GRAV	SAND	110.83	112.00	268.70	1.17
S1B-42	379.55	**MU4A**	SILT/SAND INTRBD	SANDY SILT	107.36	112.25	272.19	4.89
S1C-30	379.52	**MU4A**	SILTY SANDY CLAY/DK GRY	SANDY SILT	109.29	114.22	270.23	4.93
S1C-32	379.53	**MU4A**	SAND W/CLAY PARTINGS	SILTY CLAY	107.50	111.24	272.03	3.74
S1C-34	379.56	**MU4A**	SAND W/INTRBD SILT	SANDY SILT	108.86	110.00	270.70	1.14
S1D-15	379.51	**MU4A**	SAND, SILT, DK GRY CLAY, INTRBD	SILTY CLAY	108.97	117.00	270.54	8.03
S02-06	376.14	**MU4A**	SILTY SAND/INTRBD SILT/SAND	SANDY SILT	104.68	110.00	271.46	5.32
S02-08	382.53	**MU4A**	SAND/SILT INTRBD, DK RED GRY	SANDY SILT	110.68	115.64	271.85	4.96
S03-05	378.99	**MU4A**	SILTY SAND/SILT	SANDY SILT	107.89	111.94	271.10	4.05
S04-04	379.48	**MU4A**	SILTY SAND	SANDY SILT	109.00	116.92	270.48	7.92
S04-05	378.74	**MU4A**	SAND/WHT	SAND	107.55	110.00	271.19	2.45
S04-06	379.13	**MU4A**	SILT W/INTRBD SAND/SOM PYR NOD	SANDY SILT	113.70	115.00	265.43	1.30
S04-07	379.95	**MU4A**	SAND W/SILT LAM	SANDY SILT	110.37	111.00	269.58	0.63
S04-10	379.37	**MU4A**	SAND W/TR SILT/WHT	SANDY SILT	108.58	111.42	270.79	2.84
S04-12	378.96	**MU4A**	SILTY SAND/CLAY	SILTY CLAY	106.76	112.95	272.20	6.19
S04-14	379.03	**MU4A**	SAND W INTRBD SILT	SANDY SILT	108.92	111.19	270.11	2.27
S04-16	378.95	**MU4A**	SILTY SAND INTRBD W/CLAY	SILTY CLAY	108.42	112.17	270.53	3.75
S04-17	379.17	**MU4A**	SILTY SAND	SANDY SILT	109.94	110.60	269.23	0.66
S04-18	379.17	**MU4A**	SAND INTRBD W/SILT	SANDY SILT	107.84	110.00	271.33	2.16
S04-98	379.04	**MU4A**	SAND W/INTRBD SILT/RED/STRG BRN	SANDY SILT	108.54	111.45	270.50	2.91
S04-99	379.73	**MU4A**	CLAYEY SILT W/INTRBD SAND	SILTY CLAY	110.00	119.00	269.73	9.00
S05-03	377.79	**MU4A**	SANDY CLAY	SILTY CLAY	103.96	109.00	273.83	5.04
S05-08	379.21	**MU4A**	SILT W/INTRBD SAND	SANDY SILT	107.92	110.00	271.29	2.08
S05-13	375.74	**MU4A**	SAND W/SILT/CLAY PARTINGS	SILTY CLAY	106.22	109.61	269.52	3.39
S06-01	374.94	**MU4A**	SILT W/INTRBD SAND/DK GRY	SANDY SILT	108.75	110.00	266.19	1.25
S06-02	372.15	**MU4A**	CLAYEY SILT	SILTY CLAY	101.32	102.00	270.83	0.68
S07-02	371.86	**MU4A**	CLAY INTRBD W/SAND/BLK		101.11	110.21	270.75	9.10
S07-09	379.16	**MU4A**	CLAYEY SILT W/TR INTRBD SAND	SILTY CLAY	106.72	110.00	272.44	3.28
S07-10	374.99	**MU4A**	SAND/BLK SILT	SANDY SILT	108.20	111.24	266.79	3.04
MIN	**371.86**				**101.11**	**102.00**	**265.43**	**0.63**
MAX	**382.53**				**113.70**	**119.00**	**274.59**	**10.56**
MEAN	**378.47**				**107.82**	**111.78**	**270.64**	**3.96**
RANGE	**10.67**				**12.59**	**17.00**	**9.16**	**9.93**
COUNT	**33**				**33**	**33**	**33**	**33**

MU4B

HOLE NO.	SURF ELEV	UNIT	DESCRIP	MAP LITHOFACIES	TOP	BOT	TOP ELEV	THICK
S1B-02	379.56	**MU4B**	SILT W/INTRBD SAND	SANDY SILT	110.00	116.28	269.56	6.28
S1B-05	379.45	**MU4B**	SILTY SAND	SANDY SILT	110.90	118.43	268.55	7.53
S1B-09	379.41	**MU4B**	SAND W/LT SILT	SANDY SILT	115.38	119.23	264.03	3.85
S1B-42	379.55	**MU4B**	CLAY, SAND/SILT INTRBD	SILTY CLAY	112.25	118.75	267.30	6.50
S1C-30	379.52	**MU4B**	CLAY/SAND INTRBD, DK GRY	SILTY CLAY	114.22	120.97	265.30	6.75
S1C-32	379.53	**MU4B**	CLAYEY SILT/VRY DK BRN	CLAYEY SD	111.24	117.31	268.29	6.07
S1D-15	379.51	**MU4B**	CLAYEY SILTY SAND, DK GRY - BLK	SILTY CLAY	117.00	118.81	262.51	1.81
S02-08	382.53	**MU4B**	SILT/SAND INTRBD	SANDY SILT	115.64	120.00	266.89	4.36
S03-05	378.99	**MU4B**	SAND W/TR VRY THIN SILT BEDS	SANDY SILT	111.94	116.00	267.05	4.06
S04-10	379.37	**MU4B**	SAND W/INTRBD SILT	SANDY SILT	111.42	116.30	267.95	4.88
S04-12	378.96	**MU4B**	CLAY, SAND, SILTY SAND	SILTY CLAY	112.95	117.03	266.01	4.08
S04-14	379.03	**MU4B**	SILTY SAND	SANDY SILT	111.19	115.00	267.84	3.81
S04-16	378.95	**MU4B**	SILTY SAND	SANDY SILT	112.17	117.00	266.78	4.83
S04-17	379.17	**MU4B**	SAND	SAND	110.60	118.82	268.57	8.22
S04-18	379.17	**MU4B**	SAND W/THIN INTRBD SILT LENS	SANDY SILT	110.00	119.03	269.17	9.03
S04-98	379.04	**MU4B**	SILTY SAND	SANDY SILT	111.45	116.18	267.59	4.73
S04-99	379.73	**MU4B**	CLAYEY SILT/DK GRY	SILTY CLAY	119.00	120.00	260.73	1.00
S05-08	379.21	**MU4B**	SAND/SILT INTRBD	SANDY SILT	110.00	115.78	269.21	5.78
S05-13	375.74	**MU4B**	SAND W/CLAYEY SILT PARTINGS	SILTY CLAY	109.61	113.16	266.13	3.55
S06-02	372.15	**MU4B**	SILT W/VRY DK GRY, GREEN-GRY BNDS	SANDY SILT	102.00	112.00	270.15	10.00
S07-09	379.16	**MU4B**	CLAYEY SILT W/INTRBD SAND/RED BLK	SILTY CLAY	110.00	117.58	269.16	7.58
S07-10	374.99	**MU4B**	CLAYEY SILT W/TR SAND/BLK	SILTY CLAY	111.24	116.33	263.75	5.09
MIN	**372.15**				**102.00**	**112.00**	**260.73**	**1.00**
MAX	**382.53**				**119.00**	**120.97**	**270.15**	**10.00**
MEAN	**378.76**				**111.83**	**117.27**	**266.93**	**5.45**
RANGE	**10.38**				**17.00**	**8.97**	**9.42**	**9.00**
COUNT	**22**				**22**	**22**	**22**	**22**

MU5A

HOLE NO.	SURF ELEV	UNIT	DESCRIP	MAP LITHOFACIES	TOP	BOT	TOP ELEV	THICK
S1A-03	379.54	**MU5A**	SAND	SAND	114.38	127.20	265.16	12.82
S1B-02	379.56	**MU5A**	SAND W/INTRBD SILT	SANDY SILT	116.28	121.23	263.28	4.95
S1B-05	379.45	**MU5A**	SAND INTRBD W/SILT	SANDY SILT	118.43	125.67	261.02	7.24
S1B-09	379.41	**MU5A**	SAND W/INTRBD SILT	SANDY SILT	119.23	123.12	260.18	3.89
S1B-42	379.55	**MU5A**	SAND SILT DK GRY	SANDY SILT	118.75	120.00	260.80	1.25
S1C-30	379.52	**MU5A**	SAND	SAND	120.97	127.90	258.55	6.93
S1C-32	379.53	**MU5A**	CLAYEY LIG SILT/SAND, VRY DK GRY TO BLK	SILTY CLAY	117.31	121.72	262.22	4.41
S1D-15	379.51	**MU5A**	CLAYEY SANDY SILT/DK GRY	SILTY CLAY	118.81	128.76	260.70	9.95
S03-05	378.99	**MU5A**	SILTY SAND	SANDY SILT	116.00	122.81	262.99	6.81
S04-04	379.48	**MU5A**	SILT W/INTRBD SAND	SANDY SILT	116.92	122.25	262.56	5.33
S04-10	379.37	**MU5A**	SILT W/INTRBD SAND/DK RED GRY	SANDY SILT	116.30	120.00	263.07	3.70
S04-12	378.96	**MU5A**	SILTY SAND	SANDY SILT	117.03	121.11	261.93	4.08
S04-14	379.03	**MU5A**	SAND	SAND	115.00	119.44	264.03	4.44
S04-17	379.17	**MU5A**	SILT INTRBD W/SAND/DK GRY	SANDY SILT	118.82	124.08	260.35	5.26
S04-18	379.17	**MU5A**	SILT/DK GRY	SILT	119.03	120.00	260.14	0.97
S04-98	379.04	**MU5A**	SILTY SAND	SANDY SILT	116.18	120.00	262.86	3.82
S05-08	379.21	**MU5A**	SILTY SAND	SANDY SILT	115.78	123.43	263.43	7.65
S05-13	375.74	**MU5A**	CLAYEY SILT/BLK	CLAYEY SD	113.16	120.66	262.58	7.50
S07-02	371.86	**MU5A**	CLAY W/TR CLAY	CLAY	110.21	112.00	261.65	1.79
S07-09	379.16	**MU5A**	SAND/RED BLK	SAND	117.58	120.00	261.58	2.42
S07-10	374.99	**MU5A**	SAND/SILT INTRBD/BLK	SANDY SILT	116.33	122.25	258.66	5.92
MIN	**371.86**				**110.21**	**112.00**	**258.55**	**0.97**
MAX	**379.56**				**120.97**	**128.76**	**265.16**	**12.82**
MEAN	**378.58**				**116.79**	**122.08**	**261.80**	**5.29**
RANGE	**7.70**				**10.76**	**16.76**	**6.61**	**11.85**
COUNT	**21**				**21**	**21**	**21**	**21**

MU5B

HOLE NO.	SURF ELEV	UNIT	DESCRIP	MAP LITHOFACIES	TOP	BOT	TOP ELEV	THICK
S1B-02	379.56	**MU5B**	SAND	SAND	121.23	126.23	258.33	5.00
S1B-05	379.45	**MU5B**	SILTY SAND	SANDY SILT	125.67	129.00	253.78	3.33
S1B-42	379.55	**MU5B**	SILTY SAND	SANDY SILT	120.00	128.00	259.55	8.00
S1C-32	379.53	**MU5B**	SAND	SAND	121.72	124.74	257.81	3.02
S03-05	378.99	**MU5B**	SANDY SILT W/INTRBD THIN SAND BEDS/DK GRY	SANDY SILT	122.81	126.00	256.18	3.19
S04-04	379.48	**MU5B**	SILTY SAND/DK GRY	SANDY SILT	122.25	128.06	257.23	5.81
S04-14	379.03	**MU5B**	SAND W/VRY DK GRY BAND	SAND	119.44	126.32	259.59	6.88
S04-17	379.17	**MU5B**	SAND/SILT, DK GRY	SANDY SILT	124.08	127.00	255.09	2.92
S05-08	379.21	**MU5B**	SILTY SAND W/INTRBD SILT	SANDY SILT	123.43	130.00	255.78	6.57
S07-09	379.16	**MU5B**	SILT W/TR SAND LENS/RED BLK	SANDY SILT	120.00	124.80	259.16	4.80
MIN	**378.99**				**119.44**	**124.74**	**253.78**	**2.92**
MAX	**379.56**				**125.67**	**130.00**	**259.59**	**8.00**
MEAN	**379.31**				**122.06**	**127.02**	**257.25**	**4.95**
RANGE	**0.57**				**6.23**	**5.26**	**5.81**	**5.08**
COUNT	**10**				**10**	**10**	**10**	**10**

MU6A

HOLE NO.	SURF ELEV	UNIT	DESCRIP	MAP LITHOFACIES	TOP	BOT	TOP ELEV	THICK
S1A-03	379.54	**MU6A**	SILT W/SAND PARTS/DK GR	SANDY SILT	127.23	137.00	252.31	9.77
S1B-02	379.56	**MU6A**	SAND W/INTRBD SILT	SANDY SILT	126.23	130.00	253.33	3.77
S1B-05	379.45	**MU6A**	NO RECOVRY	--	129.00	139.00	250.45	10.00
S1B-09	379.41	**MU6A**	CLAYEY SILT W/INTRBD SAND	SILTY CLAY	123.12	137.01	256.29	13.89
S1B-42	379.55	**MU6A**	SAND DK GRY	SAND	128.00	132.18	251.55	4.18
S1C-30	379.52	**MU6A**	SILTY CLAY, DK GRY	SILTY CLAY	127.90	140.05	251.62	12.15
S1C-32	379.53	**MU6A**	CLAYEY SILT W/SAND LAM/DK GRY	SILTY CLAY	124.74	135.29	254.79	10.55
S1D-15	379.51	**MU6A**	SILTY SAND/CLAY W/TR PYRITE, DK GRY	SILTY CLAY	128.76	133.89	250.75	5.13
S03-05	378.99	**MU6A**	SANDY SILT INTRBD W/SAND/DK GRY	SANDY SILT	126.00	136.00	252.99	10.00
S04-04	379.48	**MU6A**	SILT W/INTRBD SAND	SANDY SILT	128.06	133.84	251.42	5.78
S04-12	378.96	**MU6A**	CLAY W/INTRBD SILTY SAND/DK GRY	SILTY CLAY	121.11	130.94	257.85	9.83
S04-14	379.03	**MU6A**	SILT W/THIN INTRBD SAND LENS/VRY DK GRY	SANDY SILT	126.32	130.00	252.71	3.68
S04-17	379.17	**MU6A**	SILT INTRBD W/SAND/DK GRY	SANDY SILT	127.00	132.60	252.17	5.60
S05-08	379.21	**MU6A**	SILTY SAND W/INTRBD SILT/DK GRY	SANDY SILT	130.00	138.40	249.21	8.40
S05-13	375.74	**MU6A**	SAND/DK GRY	SAND	120.66	129.62	255.08	8.96
S07-09	379.16	**MU6A**	SILT W/INTRBD SAND/RED BLK/DK GRY	SANDY SILT	124.80	131.64	254.36	6.84
S07-10	374.99	**MU6A**	CLAYEY SILT/SAND VRY DK GRY TO BLK	CLAYEY SD	122.25	126.02	252.74	3.77
MIN	**374.99**				**120.66**	**126.02**	**249.21**	**3.68**
MAX	**379.56**				**130.00**	**140.05**	**257.85**	**13.89**
MEAN	**378.87**				**125.95**	**133.73**	**252.92**	**7.78**
RANGE	**4.57**				**9.34**	**14.03**	**8.64**	**10.21**
COUNT	**17**				**17**	**17**	**17**	**17**

MU6B

HOLE NO.	SURF ELEV	UNIT	DESCRIP	MAP LITHOFACIES	TOP	BOT	TOP ELEV	THICK
S1B-02	379.56	**MU6B**	SAND W/INTRBD SILT, DARK GRAY	SANDY SILT	130.00	135.31	249.56	5.31
S1B-42	379.55	**MU6B**	CLAYEY SILT/SAND INTRBD, DK GRY	SILTY CLAY	132.18	137.61	247.37	5.43
S1D-15	379.51	**MU6B**	CLAYEY SILT/DK GRY	CLAYEY SD	133.89	137.00	245.62	3.11
S04-04	379.48	**MU6B**	SILT/VRY DK GRY/PYR NOD	SILT	133.84	137.78	245.64	3.94
S04-12	378.96	**MU6B**	CLAY W/INTRBD SILTY SAND/VRY DK GRY	CLAYEY SD	130.94	137.23	248.02	6.29
S04-14	379.03	**MU6B**	SANDY SILT/BLK	SANDY SILT	130.00	136.12	249.03	6.12
S04-17	379.17	**MU6B**	CLAYEY SILT/BLK	CLAYEY SD	132.60	137.25	246.57	4.65
S05-08	379.21	**MU6B**	SILT W/INTRBD SAND/DK GRY	SANDY SILT	138.40	140.00	240.81	1.60
S05-13	375.74	**MU6B**	SAND/VRY DK GRY STREAKS	SAND	129.62	131.00	246.12	1.38
S07-09	379.16	**MU6B**	SAND	SAND	131.64	135.36	247.52	3.72
S07-10	374.99	**MU6B**	CLAYEY SILT W/TR SAND/BLK	SILTY CLAY	126.02	137.02	248.97	11.00
MIN	**374.99**				**126.02**	**131.00**	**240.81**	**1.38**
MAX	**379.56**				**138.40**	**140.00**	**249.56**	**11.00**
MEAN	**378.58**				**131.74**	**136.52**	**246.84**	**4.78**
RANGE	**4.57**				**12.38**	**9.00**	**8.75**	**9.62**
COUNT	**11**				**11**	**11**	**11**	**11**

MU7A

HOLE NO.	SURF ELEV	UNIT	DESCRIP	MAP LITHOFACIES	TOP	BOT	TOP ELEV	THICK
S1B-02	379.56	**MU7A**	SILT W/INTRBD SAND	SANDY SILT	135.31	140.00	244.25	4.69
S1B-05	379.45	**MU7A**	CLAY W/SAND, VRY DK GRY	SILTY CLAY	139.00	147.50	240.45	8.50
S1B-09	379.41	**MU7A**	CLAYEY SILT W/INTRBD SAND W/LIGNITE	SILTY CLAY	137.01	142.00	242.40	4.99
S1B-42	379.55	**MU7A**	CLAYEY SILT DK GRY	SILTY CLAY	137.61	140.00	241.94	2.39
S1C-30	379.52	**MU7A**	SILTY SAND/CLAY	SILTY CLAY	140.05	142.00	239.47	1.95
S1C-32	379.53	**MU7A**	SILTY SAND/CLAY, DK GRY	SILTY CLAY	135.29	137.50	244.24	2.21
S04-04	379.48	**MU7A**	SILT	SILT	137.78	139.00	241.70	1.22
S04-12	378.96	**MU7A**	CLAY/BLK	CLAY	137.23	141.40	241.73	4.17
S04-14	379.03	**MU7A**	SILT W/SOM SAND	SANDY SILT	136.12	140.62	242.91	4.50
S04-17	379.17	**MU7A**	SILT W/SOM SAND/GRY/BLK	SANDY SILT	137.25	144.00	241.92	6.75
S05-08	379.21	**MU7A**	SILTY SAND W/INTRBD SILT/DK GRY	SANDY SILT	140.00	148.80	239.21	8.80
S05-13	375.74	**MU7A**	SAND/DK GREEN TO DK GRY	SAND	131.00	134.19	244.74	3.19
S07-09	379.16	**MU7A**	SILTY SAND/DK GRY	SANDY SILT	135.36	140.00	243.80	4.64
S07-10	374.99	**MU7A**	SAND	SAND	137.02	139.00	237.97	1.98
MIN	**374.99**				**131.00**	**134.19**	**237.97**	**1.22**
MAX	**379.56**				**140.05**	**148.80**	**244.74**	**8.80**
MEAN	**378.77**				**136.86**	**141.14**	**241.91**	**4.28**
RANGE	**4.57**				**9.05**	**14.61**	**6.77**	**7.58**
COUNT	**14**				**14**	**14**	**14**	**14**

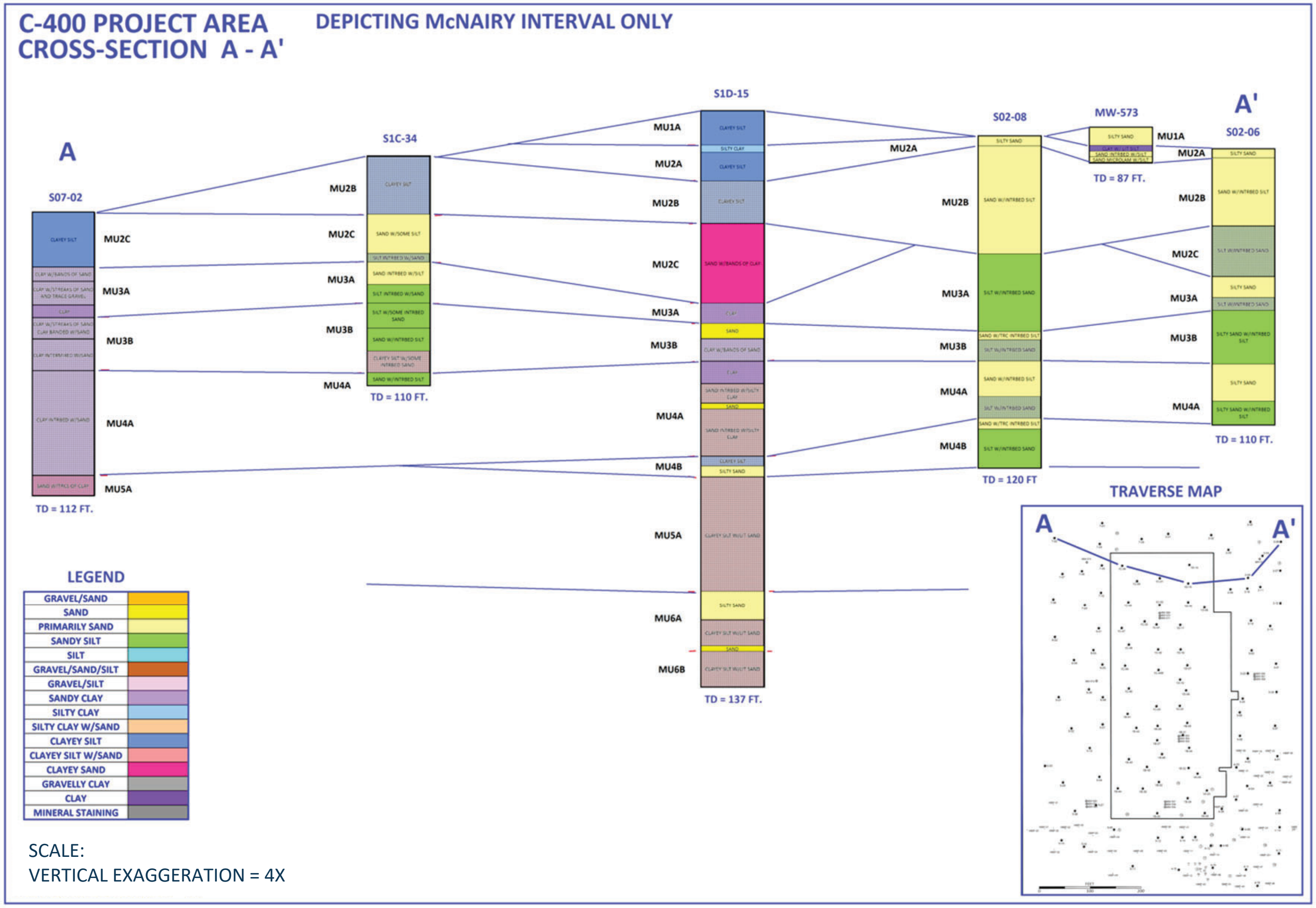
MU7B

HOLE NO.	SURF ELEV	UNIT	DESCRIP	MAP LITHOFACIES	TOP	BOT	TOP ELEV	THICK
S1B-02	379.56	**MU7B**	SILT, DARK GRAY AND BLACK	SILT	140.00	145.00	239.56	5.00
S1B-05	379.45	**MU7B**	CLAY W/SAND, GLAUCONITE	SILTY CLAY	147.50	149.00	231.95	1.50
S04-12	378.96	**MU7B**	CLAY	CLAY	141.40	144.00	237.56	2.60
S04-14	379.03	**MU7B**	CLAYEY SILT/BLK	CLAYEY SD	140.62	145.00	238.41	4.38
S05-08	379.21	**MU7B**	SILT W/INTRBD SAND/DK GRY	SANDY SILT	148.80	150.00	230.41	1.20
S05-13	375.74	**MU7B**	BLK CLAY W/GRY STREAKS	CLAY	134.19	141.00	241.55	6.81
MIN	**375.74**				**134.19**	**141.00**	**230.41**	**1.20**
MAX	**379.56**				**148.80**	**150.00**	**241.55**	**6.81**
MEAN	**378.66**				**142.09**	**145.67**	**236.57**	**3.58**
RANGE	**3.82**				**14.61**	**9.00**	**11.14**	**5.61**
COUNT	**6**				**6**	**6**	**6**	**6**

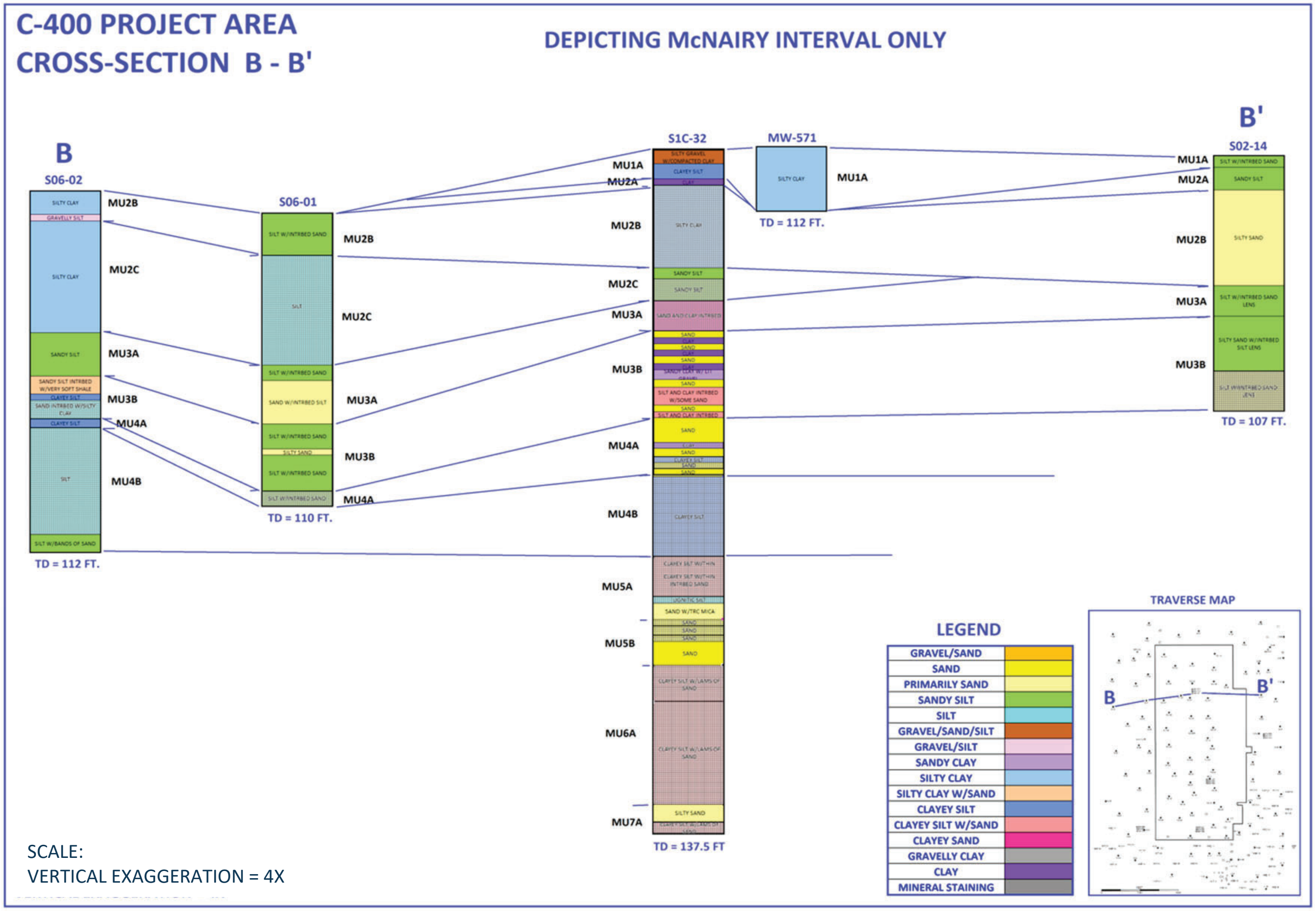
OVERALL SUMMARY

SEQUENCE	MAX TOP ELEV	MIN TOP ELEV	AVG THICK	OCCURRENCE
MU1A	295.4	291.7	2.76	11
MU2A	291.5	287.3	1.96	17
MU2B	290.5	286.3	4.49	29
MU2C	286.6	282.5	4.44	36
MU3A	281.9	275.6	3.97	36
MU3B	280.3	271.5	5.67	35
MU4A	274.6	265.4	3.96	33
MU4B	270.2	260.7	5.45	22
MU5A	265.2	258.6	5.29	21
MU5B	259.6	253.8	4.95	10
MU6A	257.9	249.2	7.78	17
MU6B	249.6	240.8	4.78	11
MU7A	244.7	238.0	4.28	14
MU7B	241.6	230.4	3.58	6

CROSS SECTION A-A'



CROSS SECTION B-B'

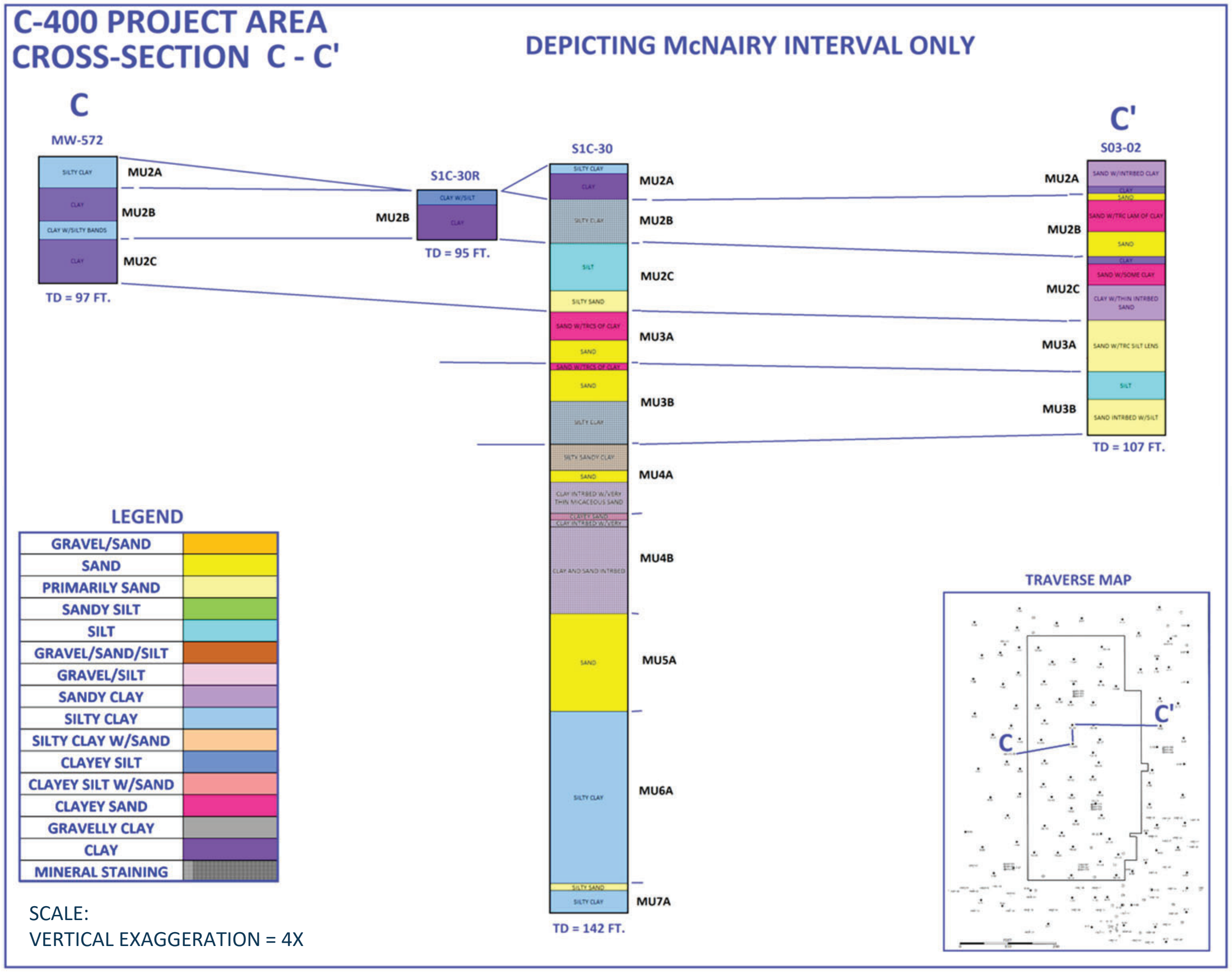

C-400 PROJECT AREA
CROSS-SECTION B - B'

DEPICTING McNAIRY INTERVAL ONLY

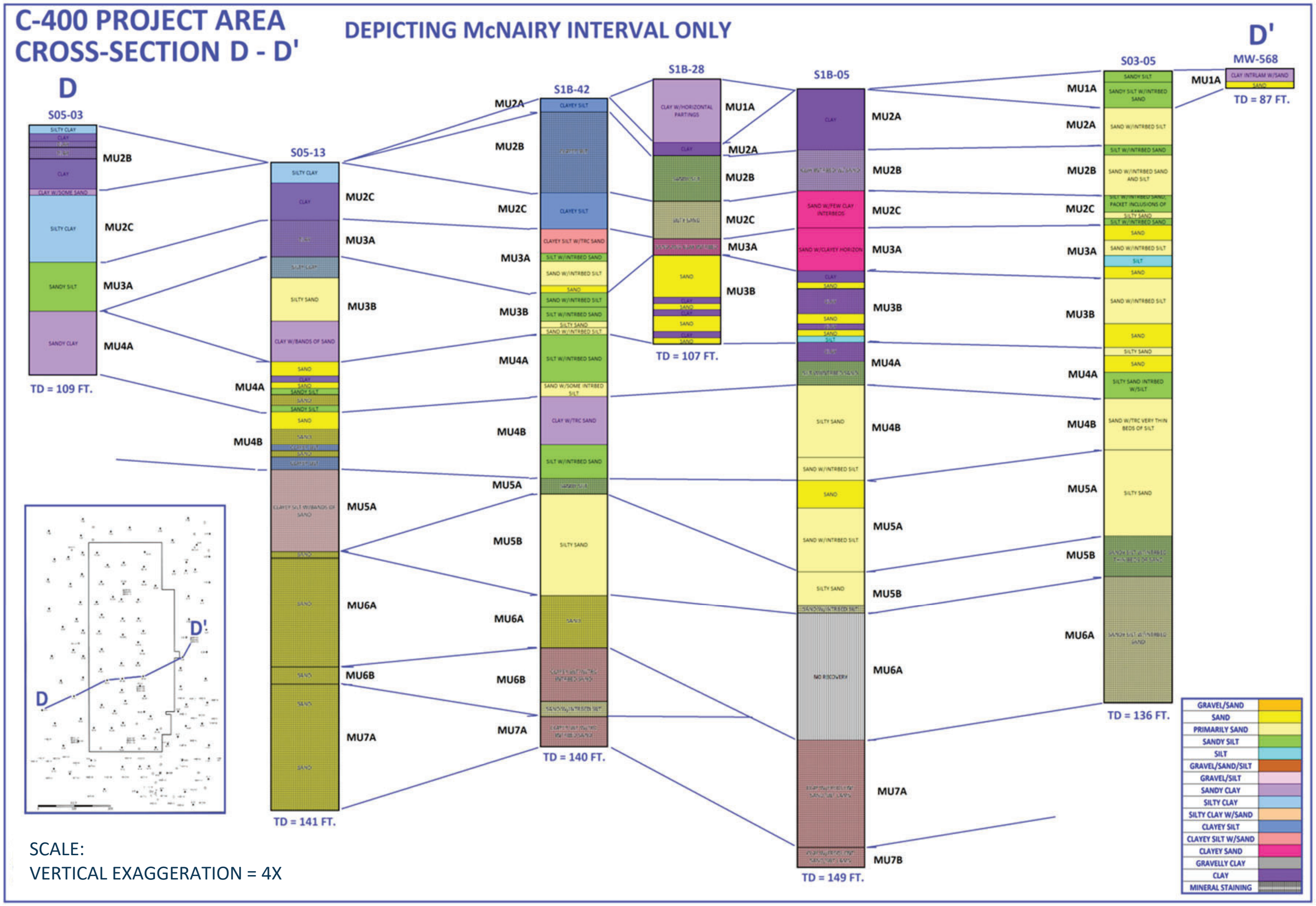
SCALE:
VERTICAL EXAGGERATION = 4X

C-400 PROJECT AREA
CROSS-SECTION C - C'

DEPICTING McNAIRY INTERVAL ONLY



SCALE:
VERTICAL EXAGGERATION = 4X



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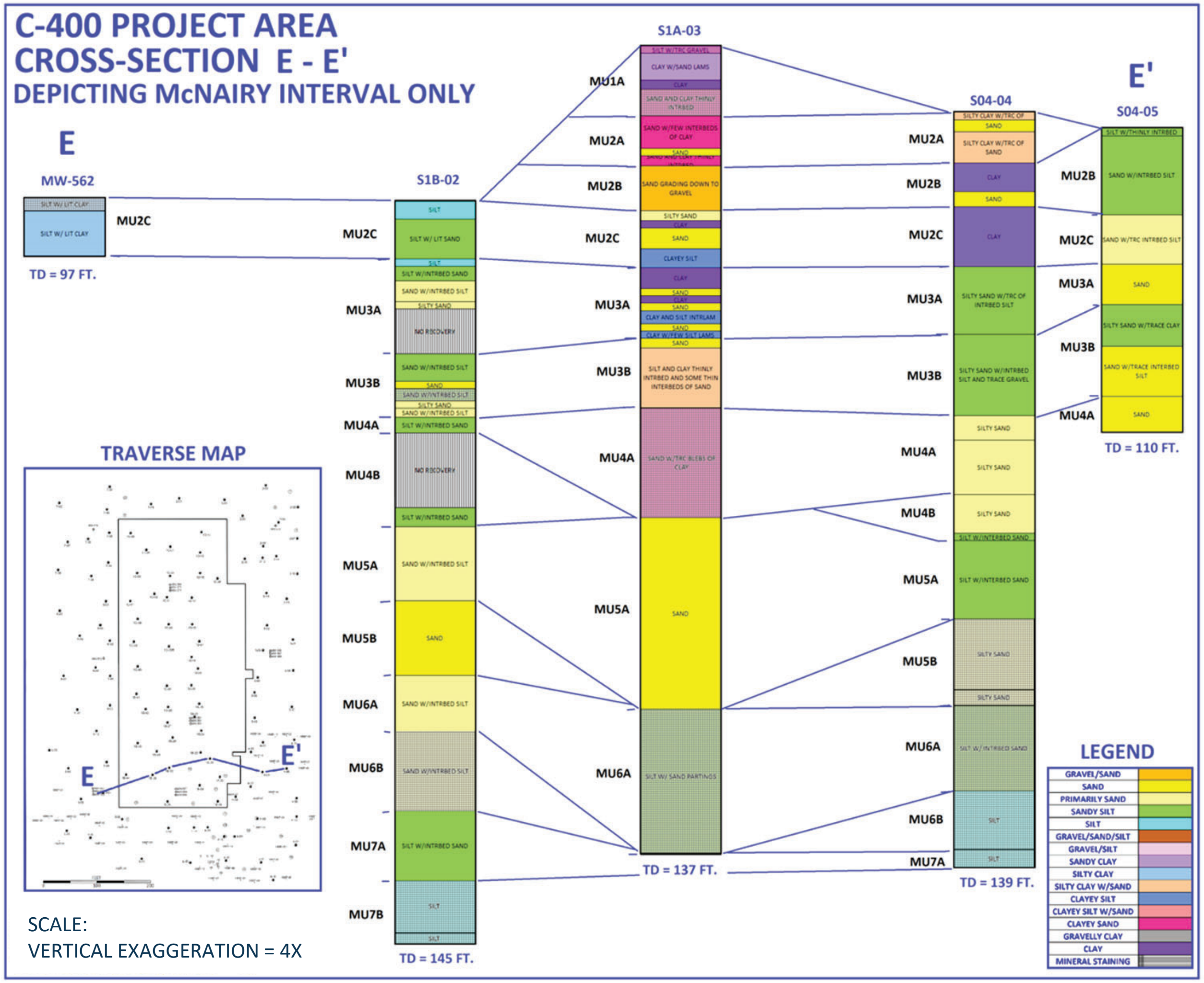
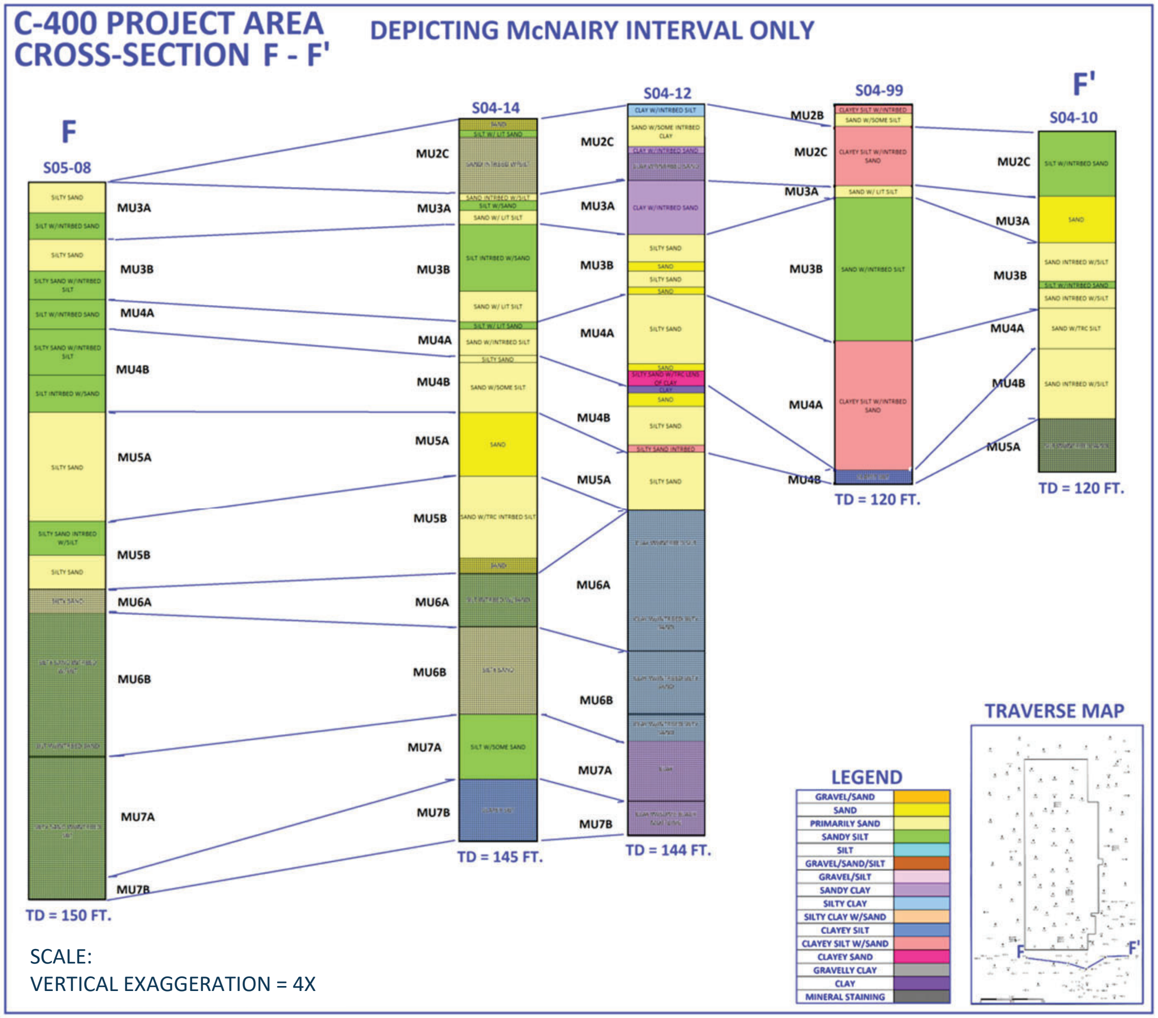
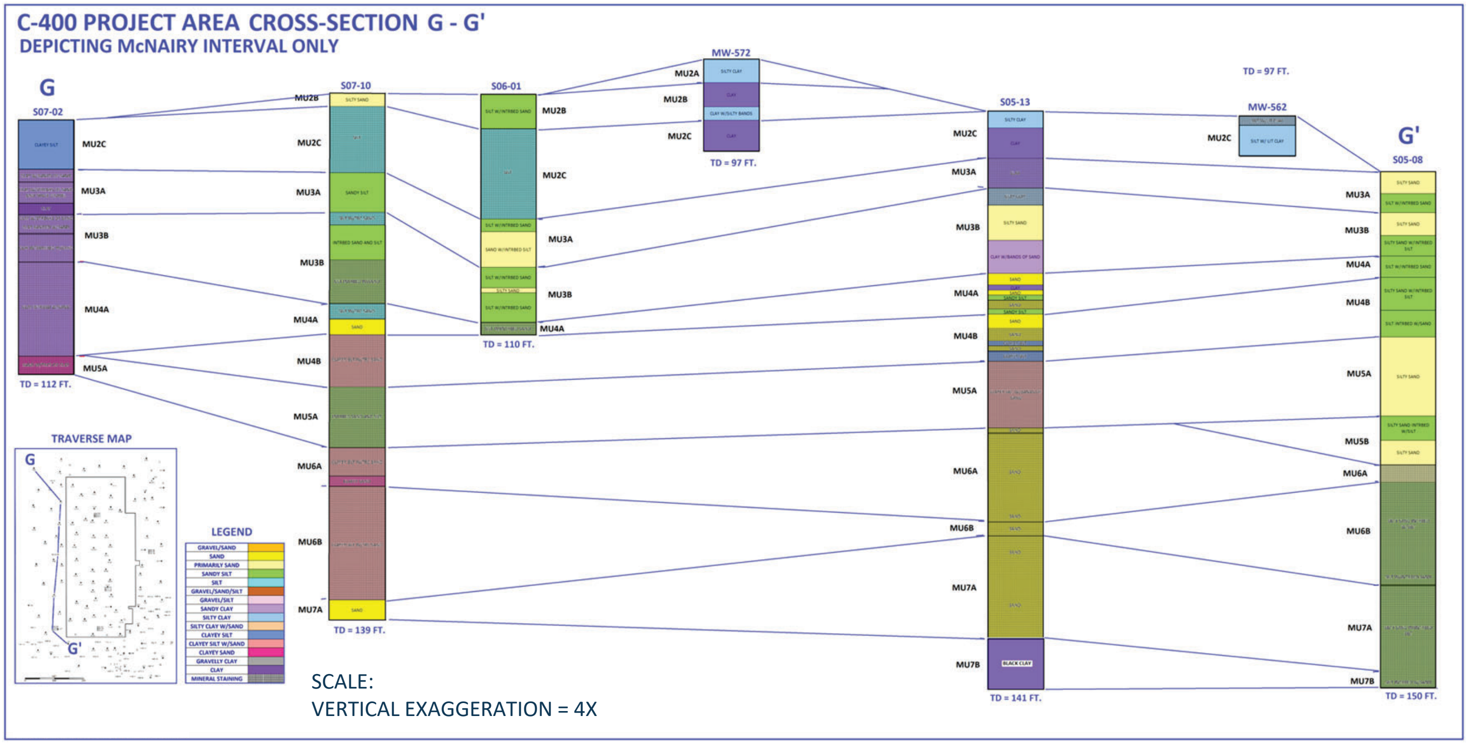


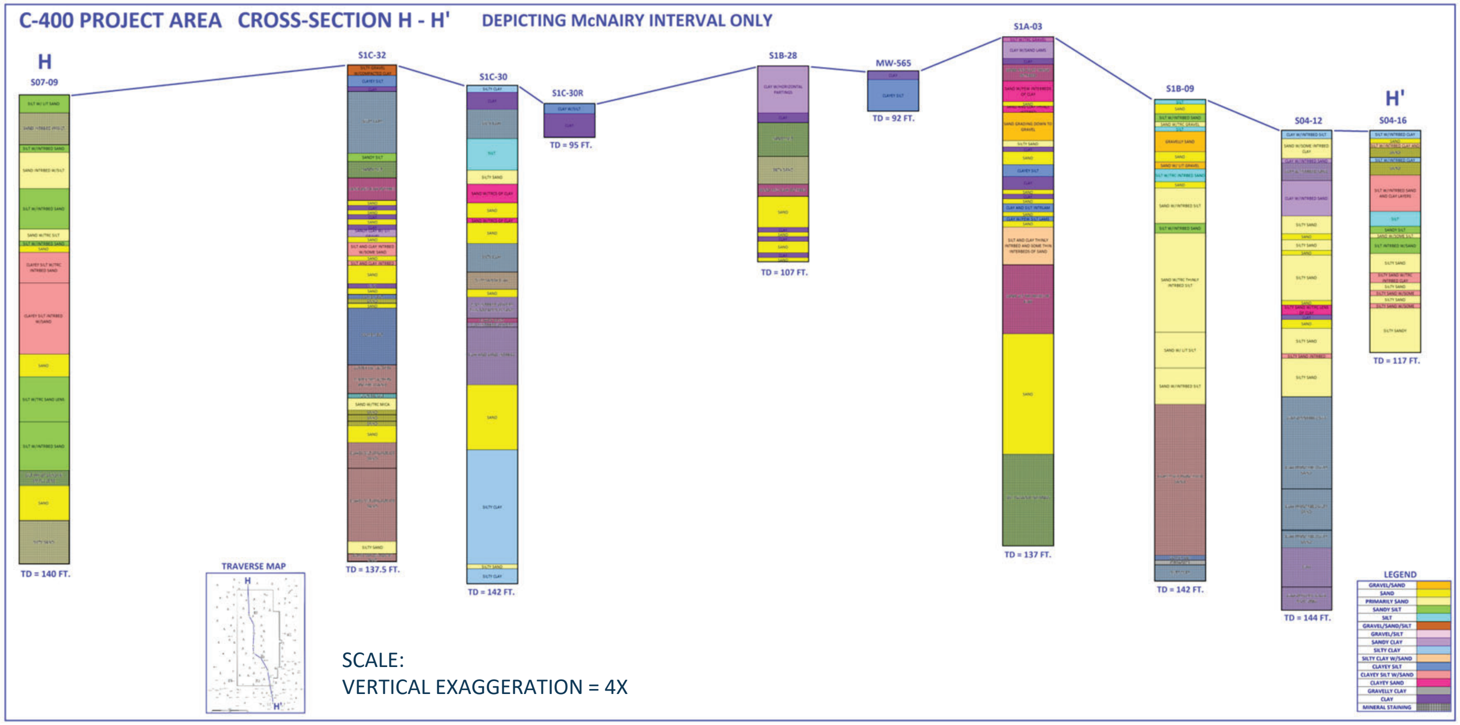
CROSS SECTION E-E'


C-400 PROJECT AREA
CROSS-SECTION F - F'
DEPICTING McNAIRY INTERVAL ONLY
F
S05-08
S04-14
S04-12
S04-99
F'
S04-10
MU2B
MU2C
MU3A
MU3B
MU4A
MU4B
MU5A
MU5B
MU6A
MU6B
MU7A
MU7B
TD = 150 FT.
TD = 145 FT.
TD = 144 FT.
TD = 120 FT.
TD = 120 FT.
SCALE:
VERTICAL EXAGGERATION = 4X
LEGEND
GRAVEL/SAND
SAND
PRIMARILY SAND
SANDY SILT
SILT
GRAVEL/SAND/SILT
GRAVEL/SILT
SANDY CLAY
SILTY CLAY
SILTY CLAY W/SAND
CLAYEY SILT
CLAYEY SILT W/SAND
CLAYEY SAND
GRAVELLY CLAY
CLAY
MINERAL STAINING
TRAVERSE MAP
F
F'

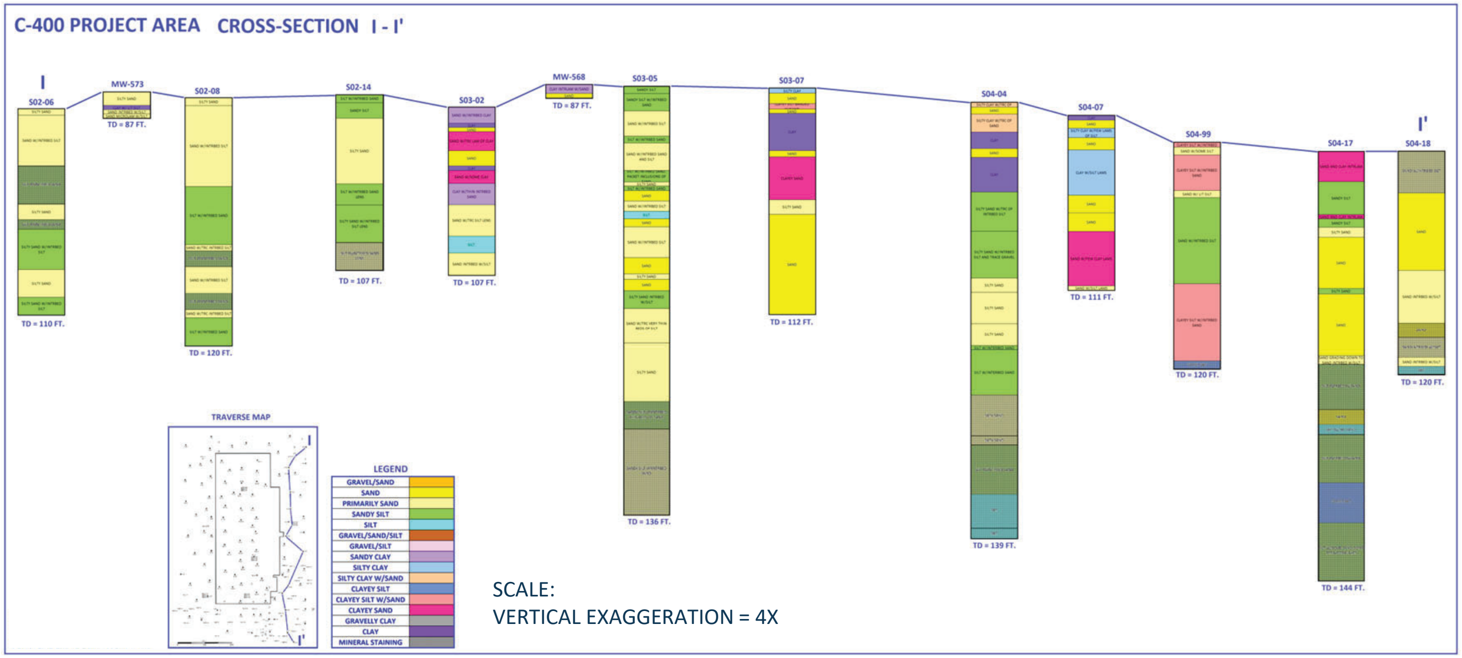
CROSS SECTION G-G'



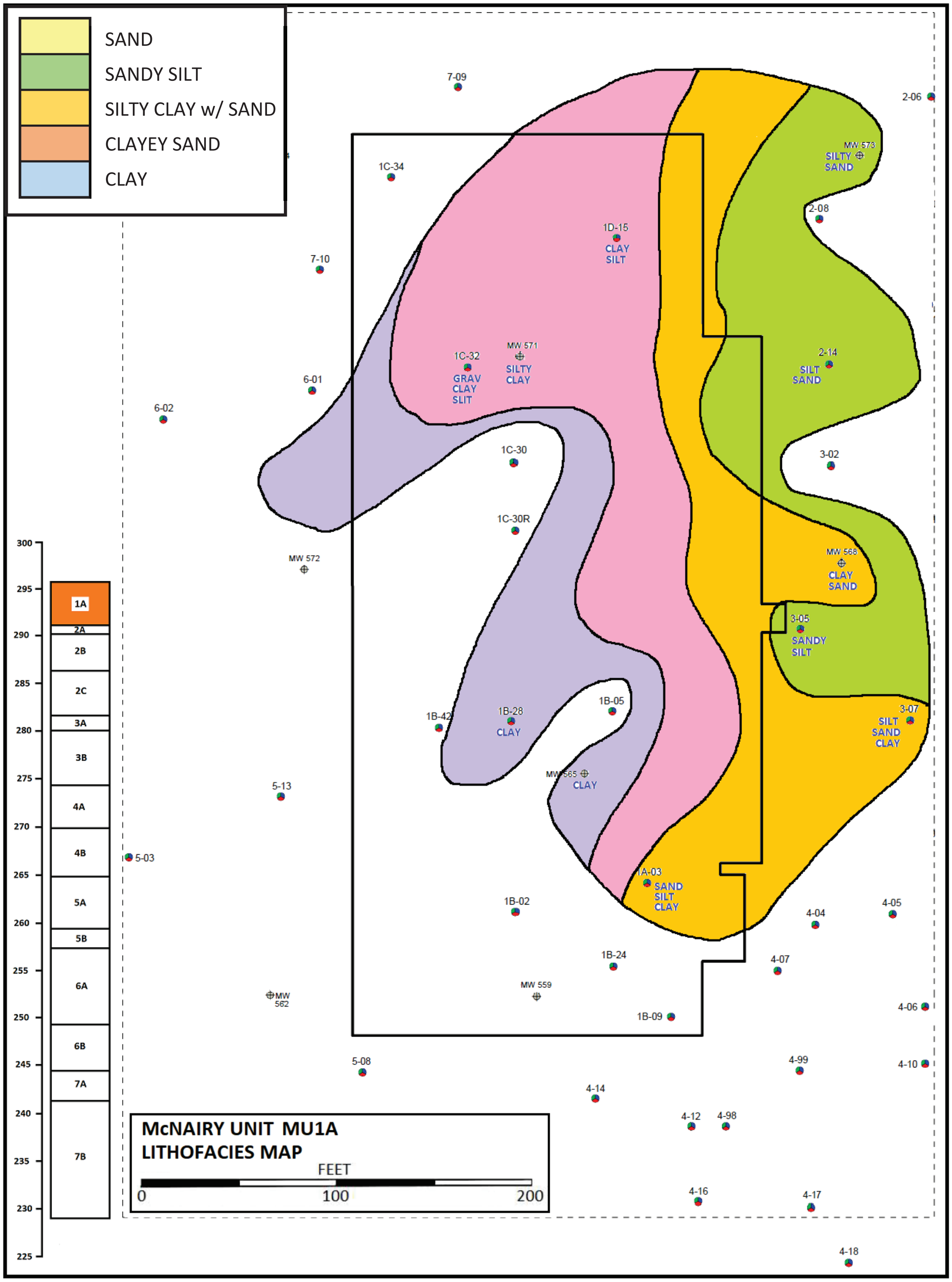
CROSS SECTION H-H'



CROSS SECTION I-I'



LITHOFACIES MAP: SEQUENCE MU1A



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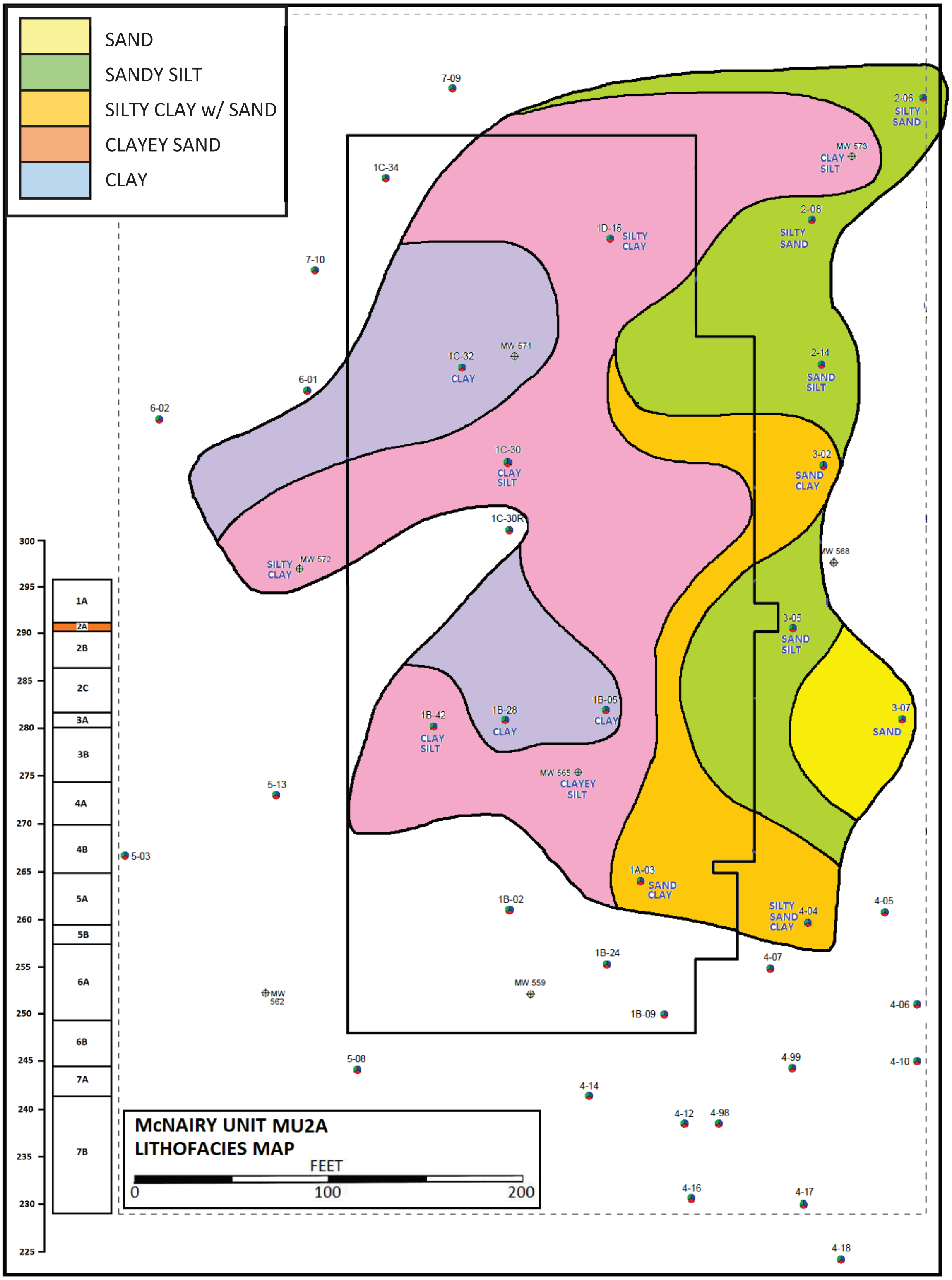

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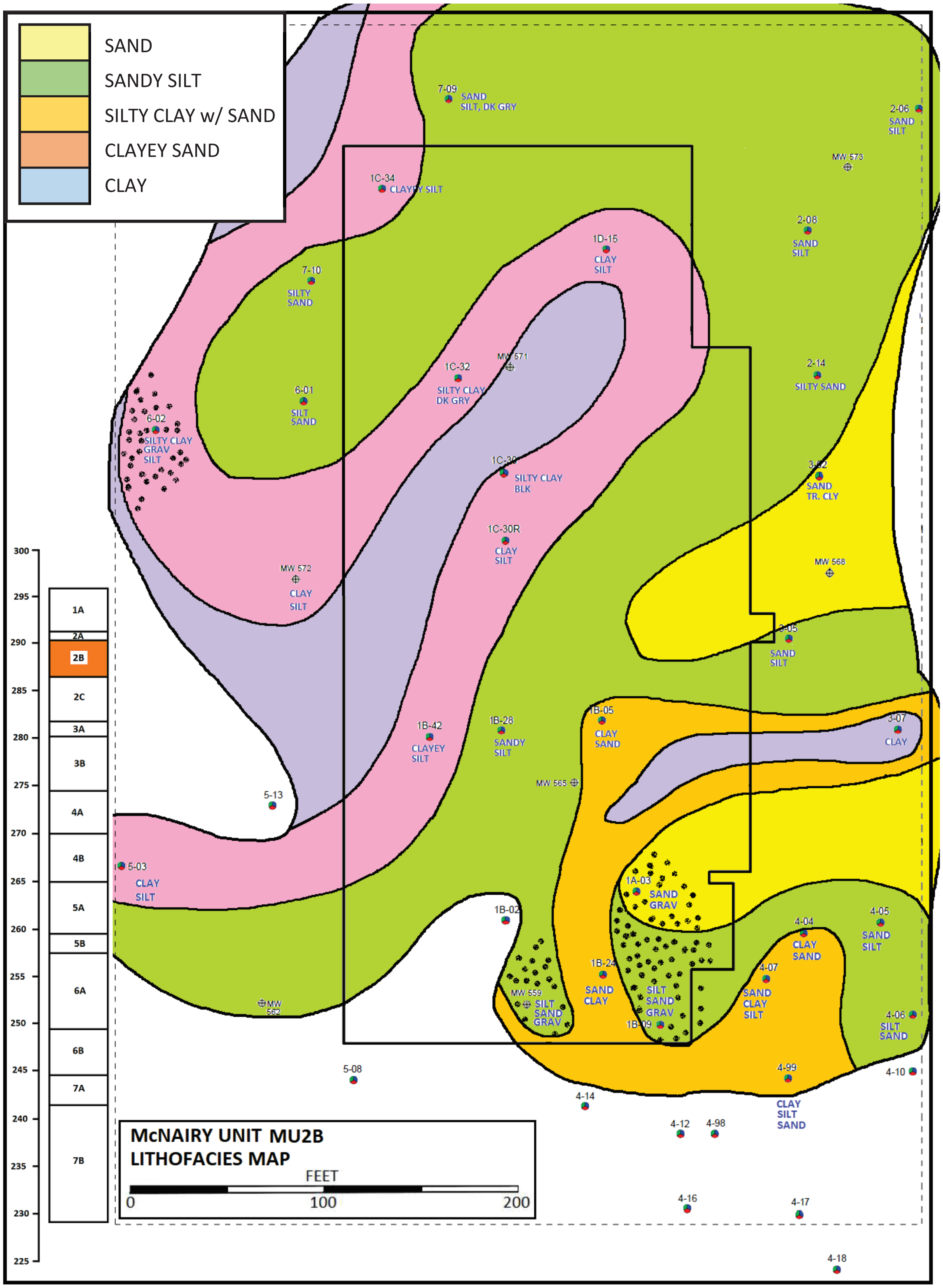
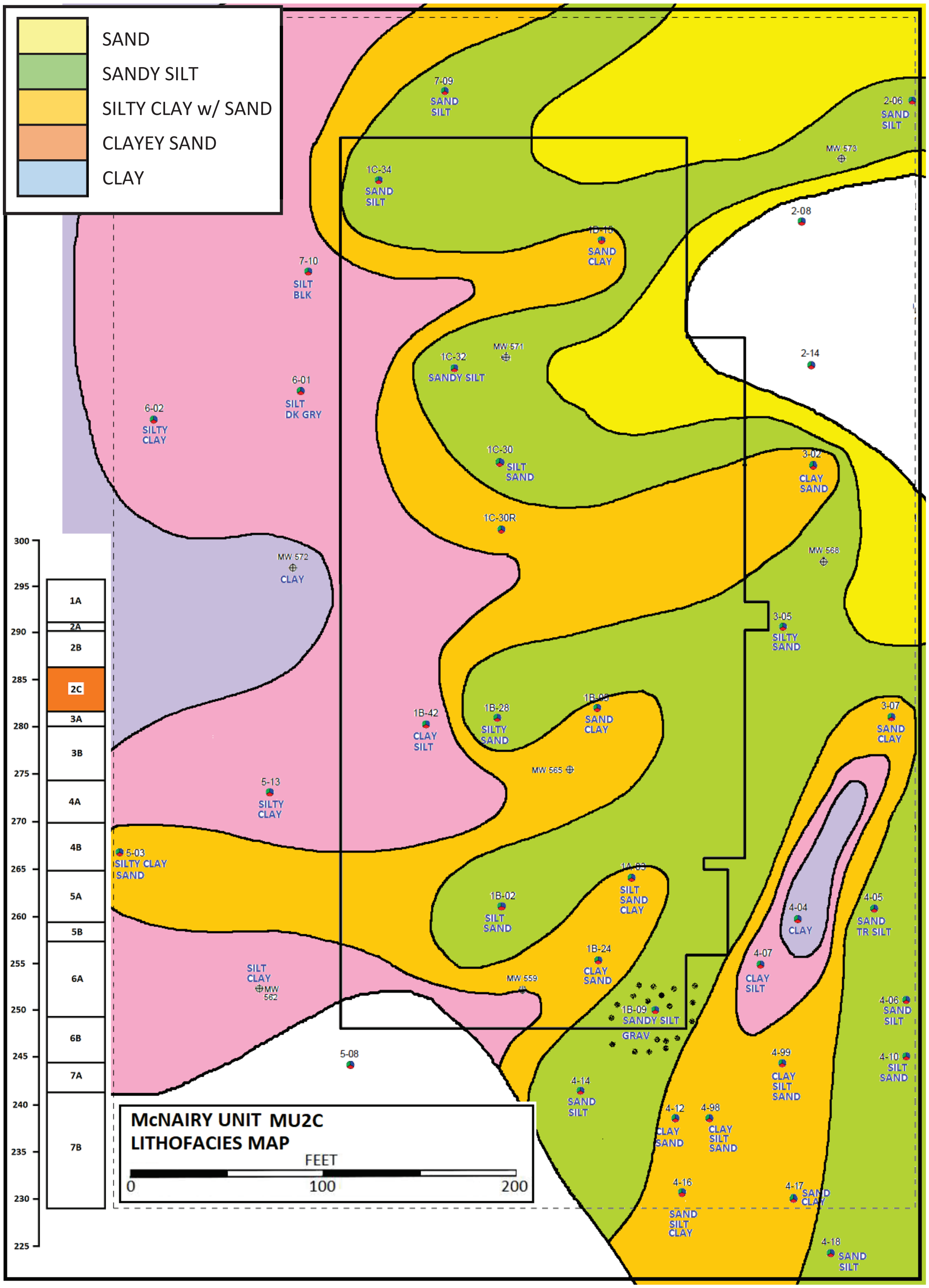
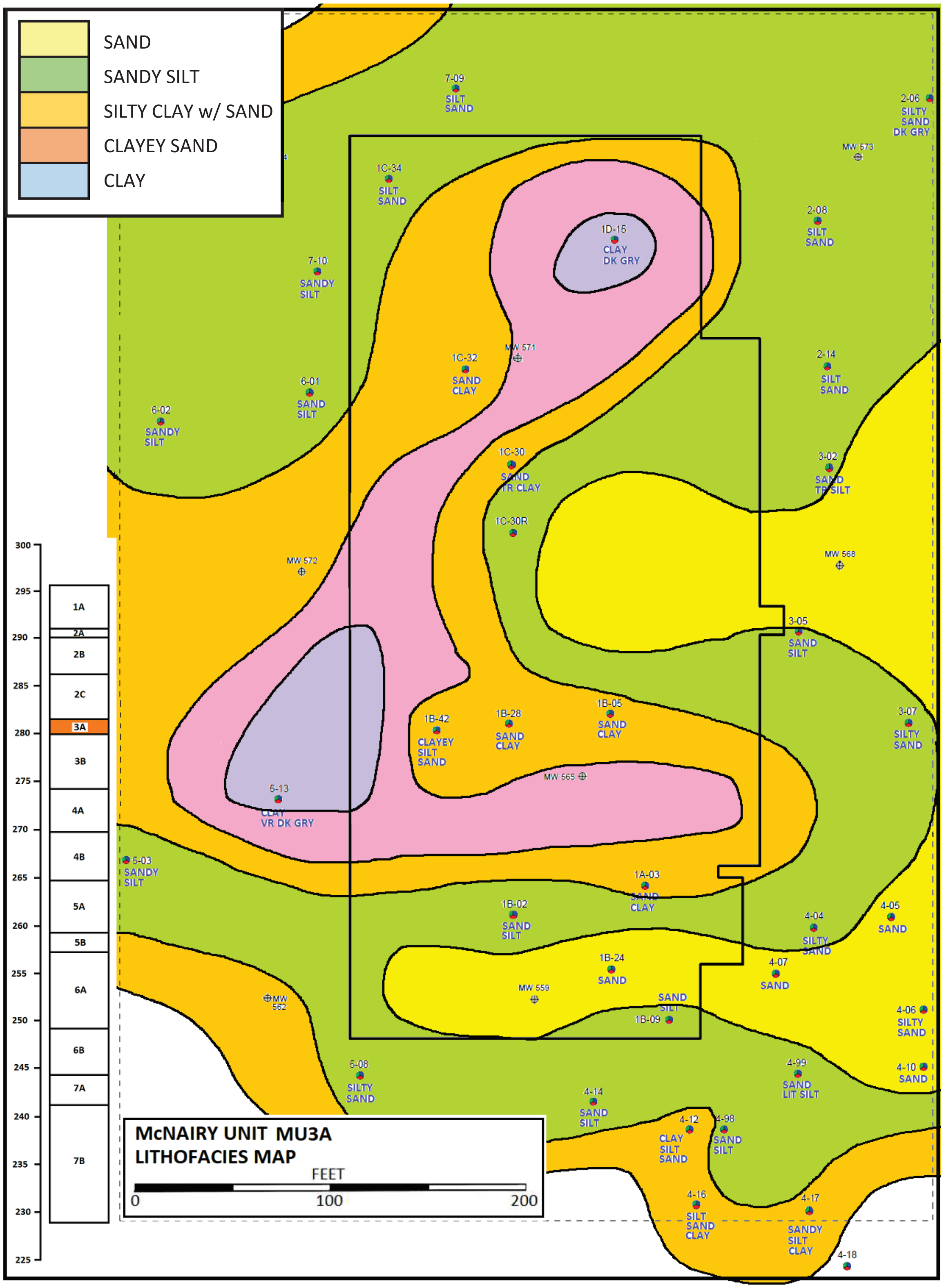


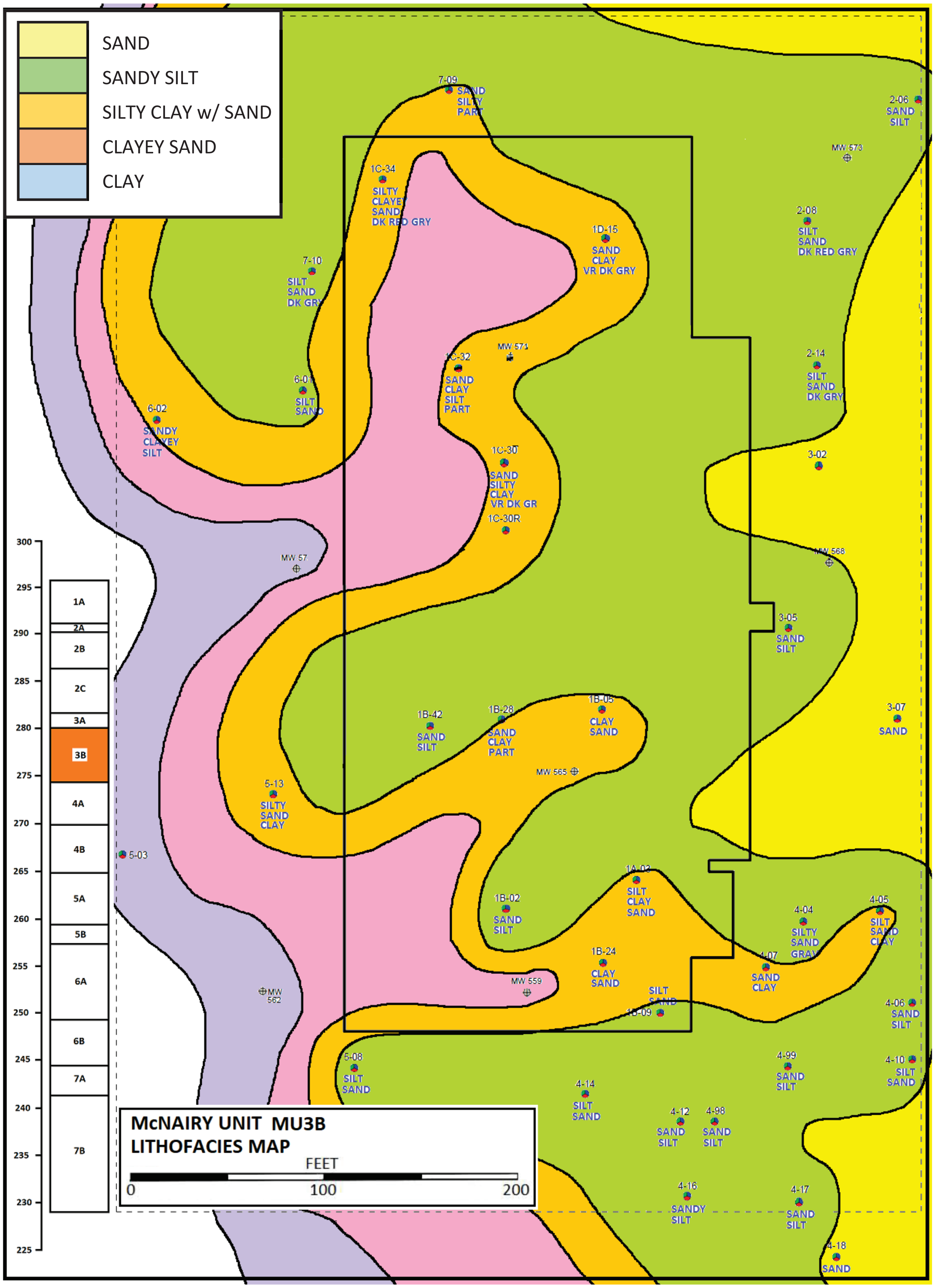
LITHOFACIES MAP: SEQUENCE MU2C



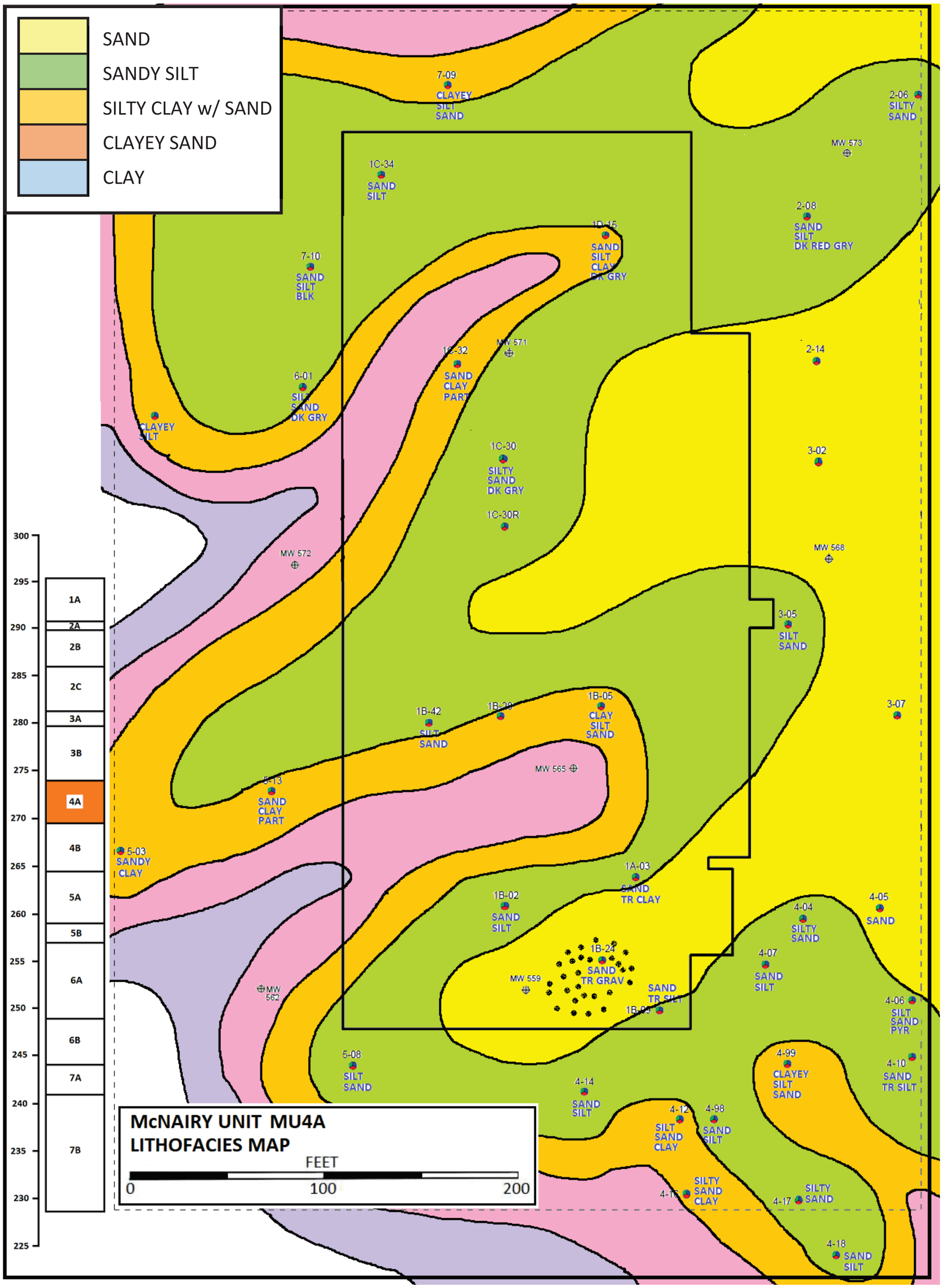
LITHOFACIES MAP: SEQUENCE MU3A



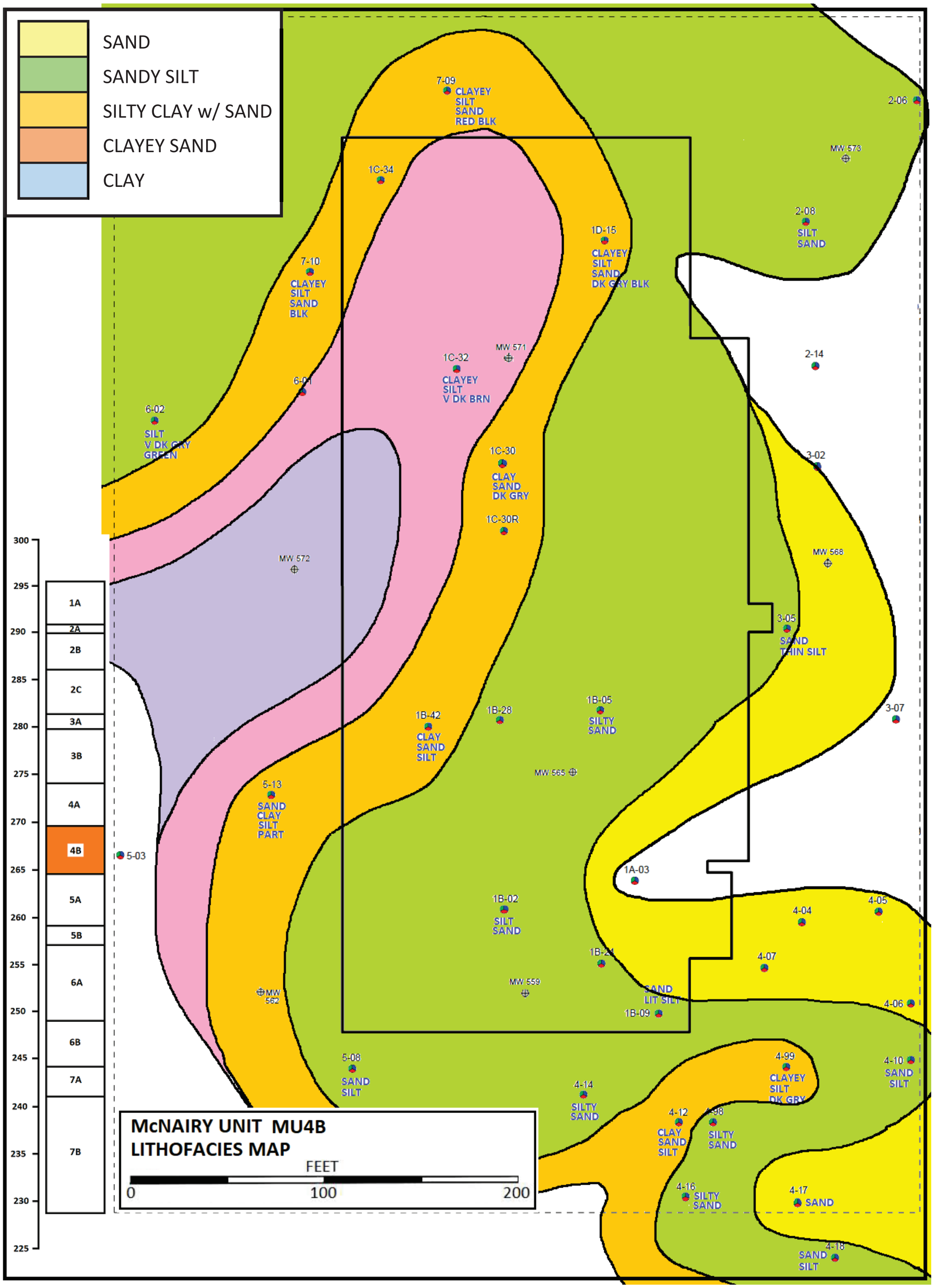
LITHOFACIES MAP: SEQUENCE MU3B



LITHOFACIES MAP: SEQUENCE MU4A



LITHOFACIES MAP: SEQUENCE MU4B



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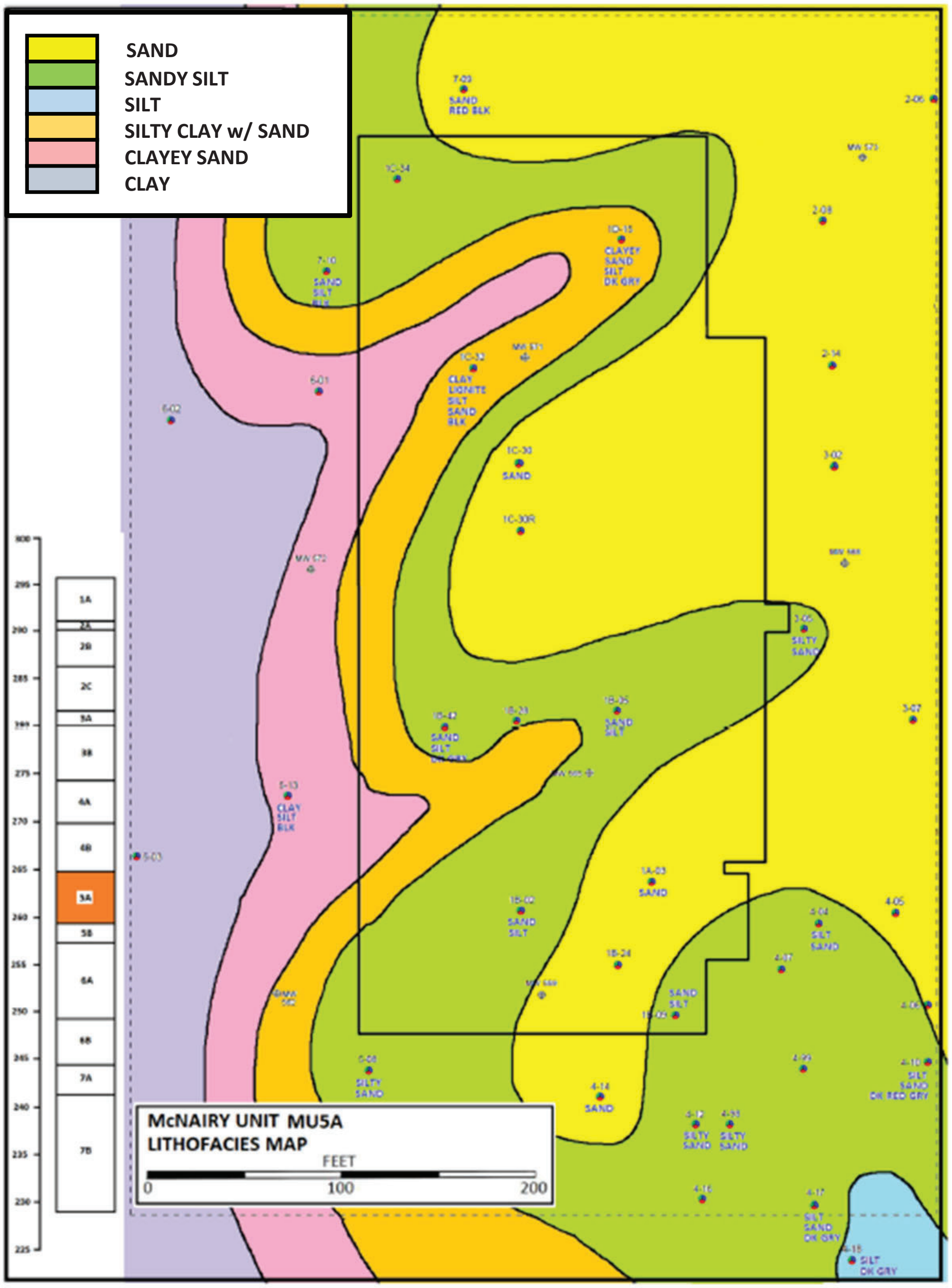
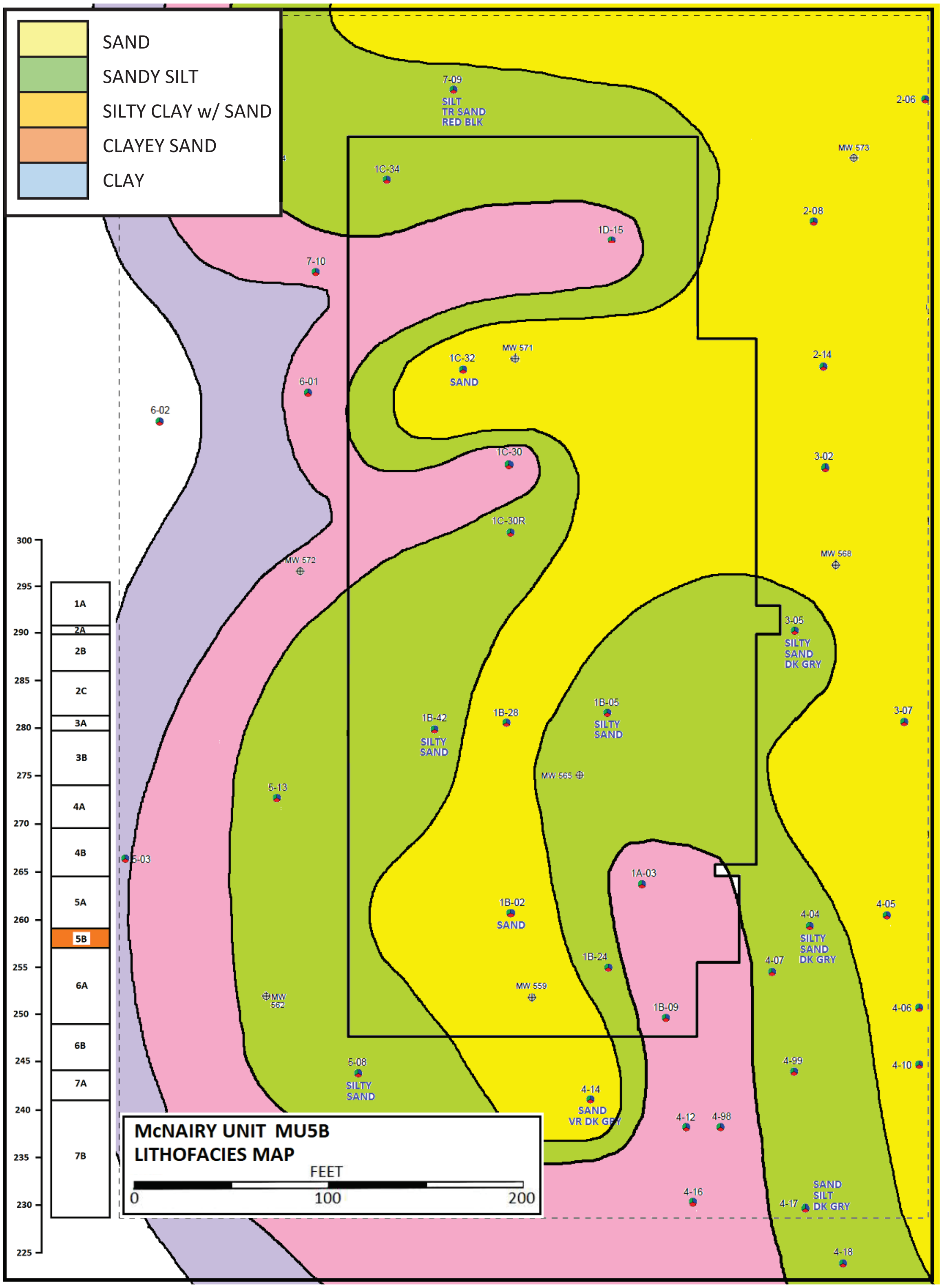


LITHOFACIES MAP: SEQUENCE MU5B



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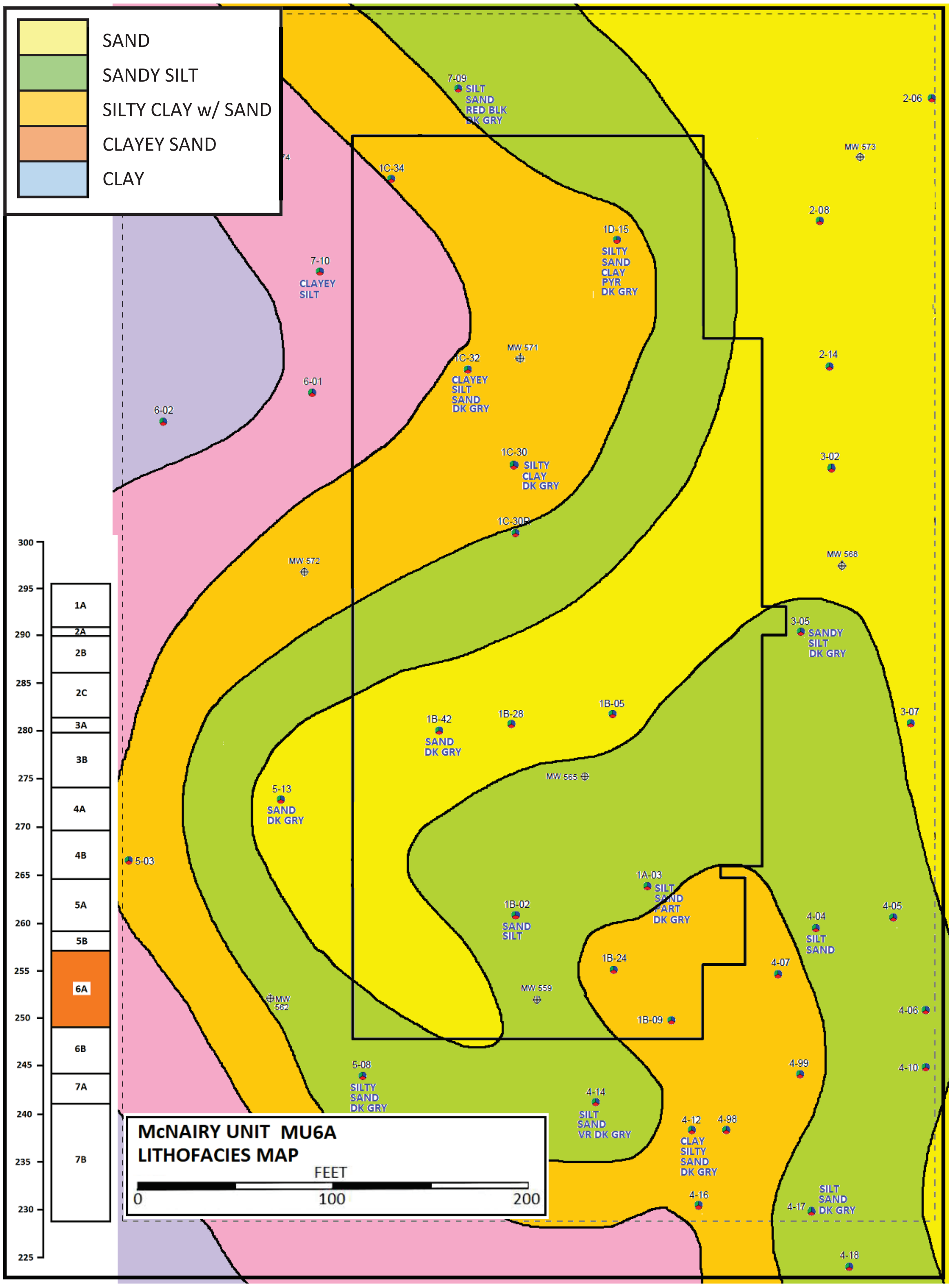

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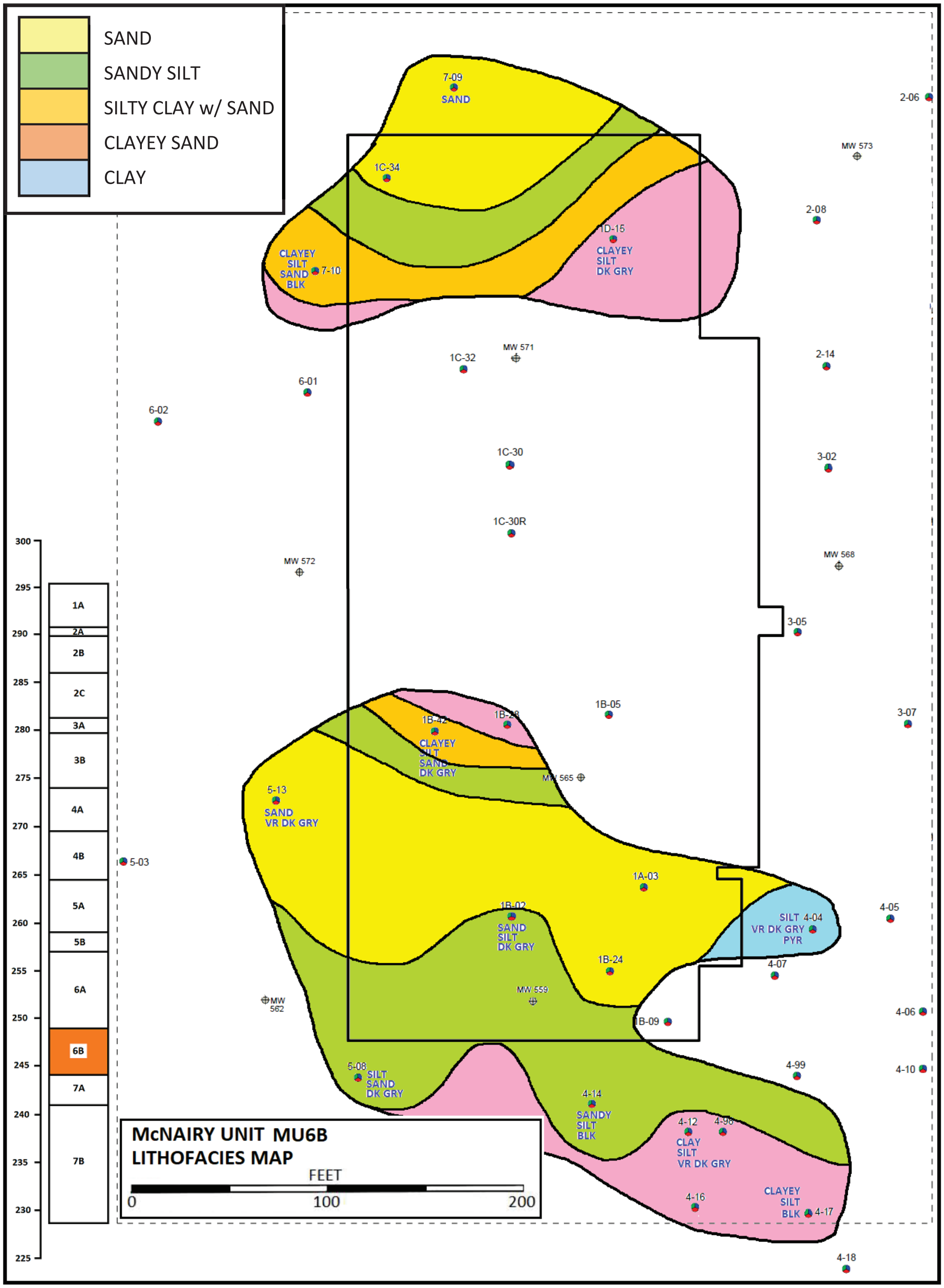

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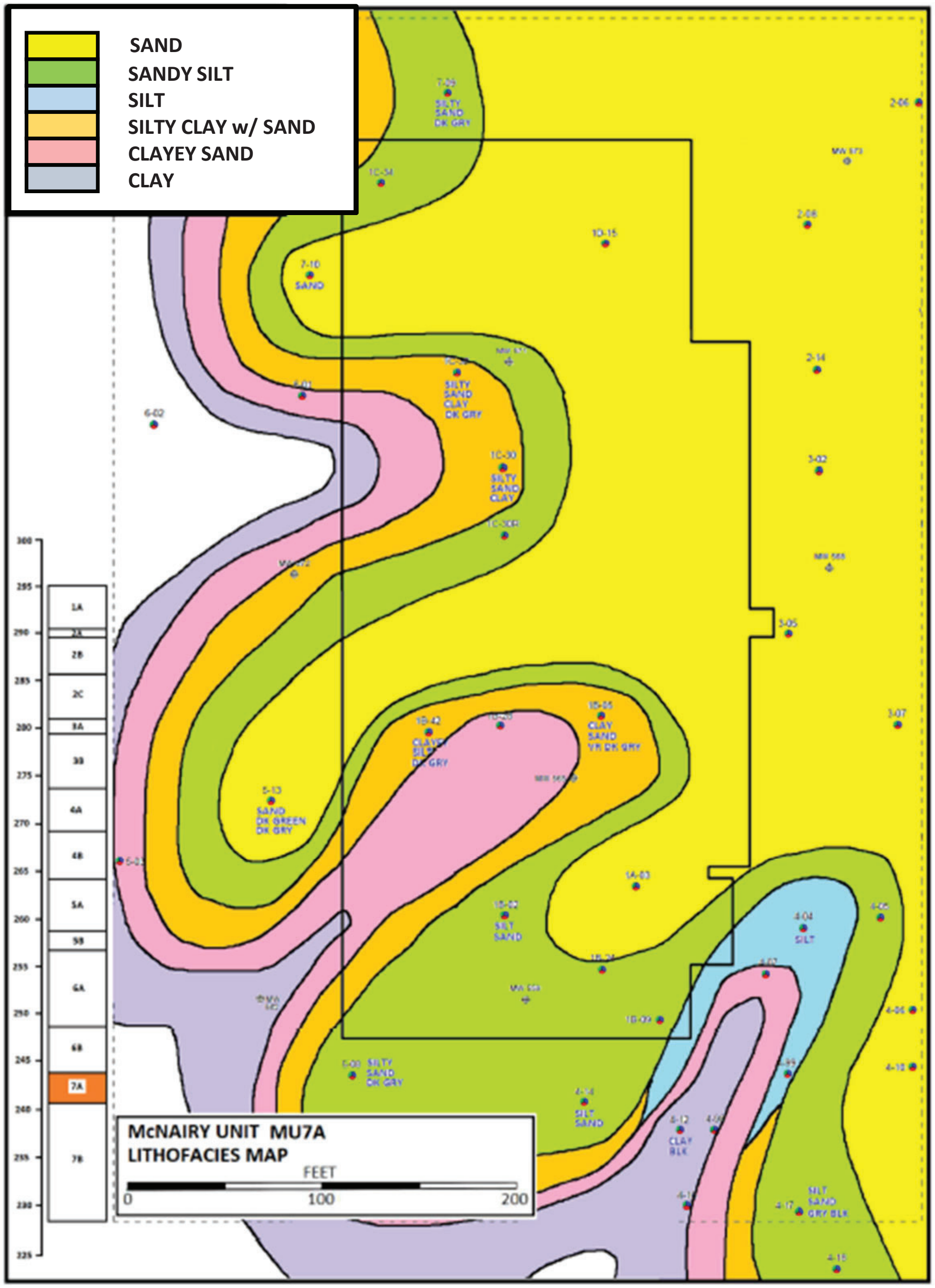
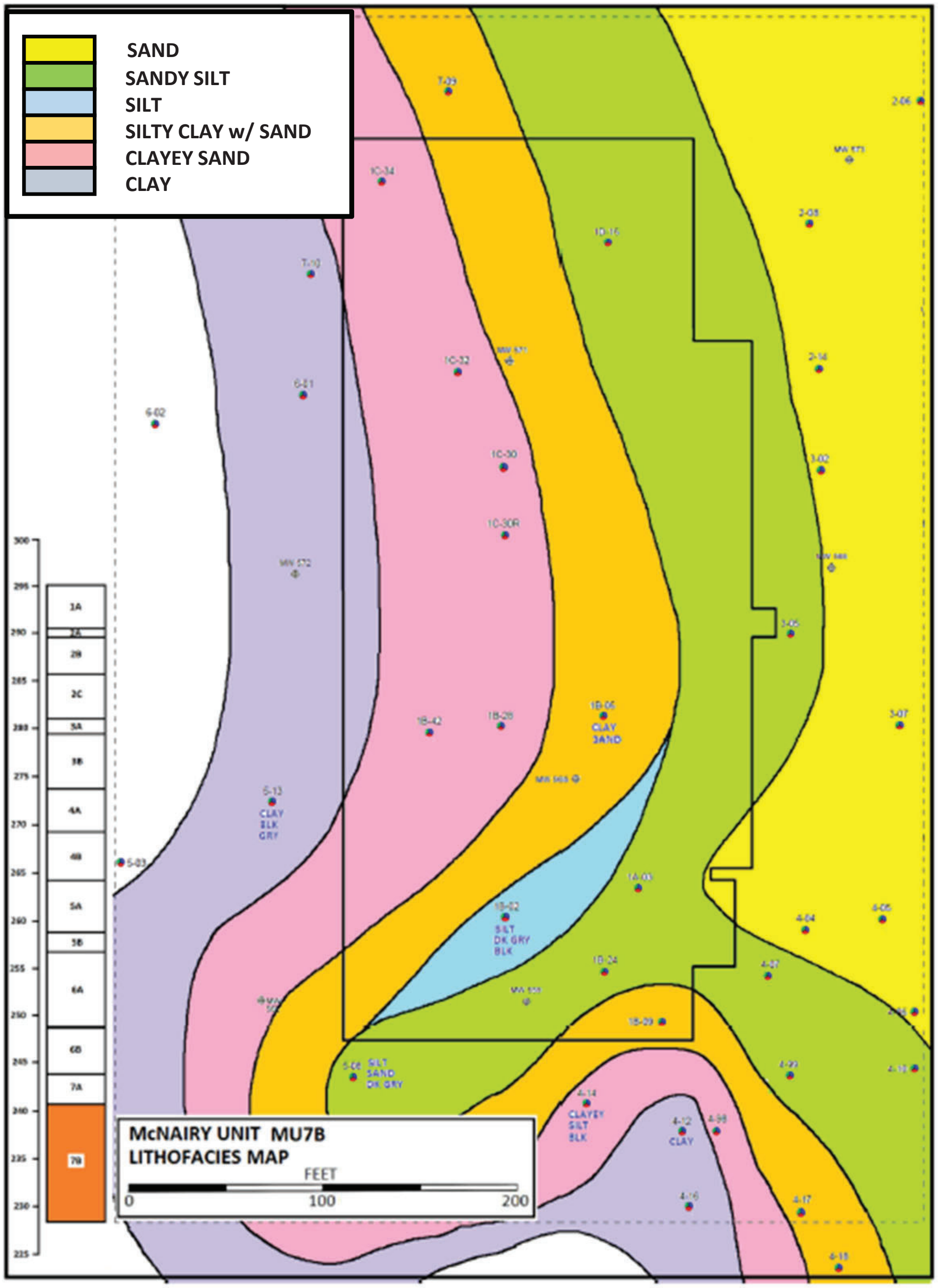


LITHOFACIES MAP: SEQUENCE MU7B



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APPENDIX D

LOGS OF PGDP DEEP McNAIRY SOIL BORINGS

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FOUR RIVERS NUCLEAR PARTNERSHIP, LLC

BORING NUMBER DB-01

PAGE 1 OF 3

PROJECT NAME **Seismic Investigation for Siting of a Potential On-Site CERCLA Waste Disposal Facility - Site 3A**

METHOD **Versa-Sonic**

CONTRACTOR **Miller Government Services**

DATE STARTED **2/18/2002**

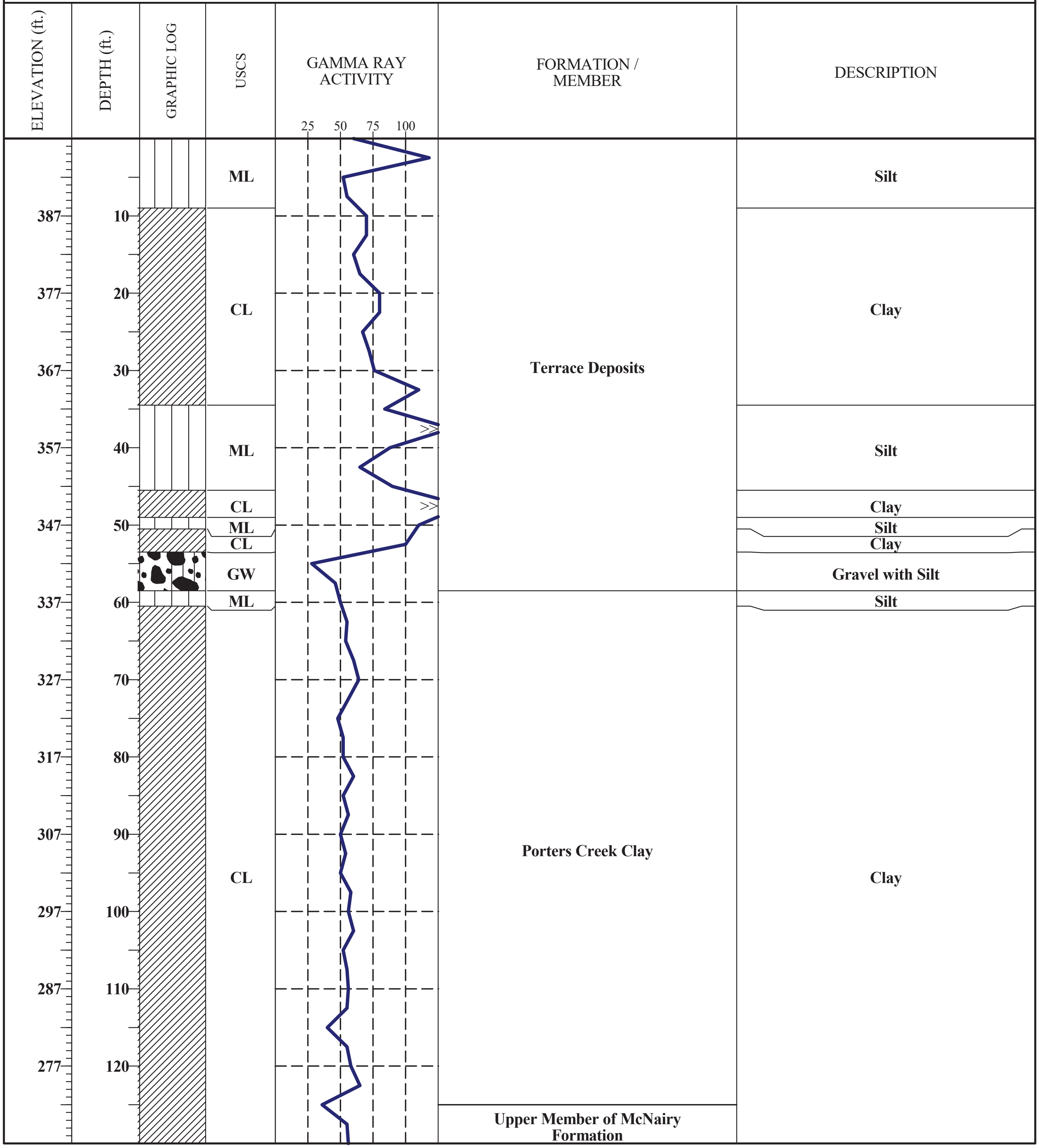
DATE FINISHED **2/21/2002**

TOTAL DEPTH **359 ft.**

NORTHING **-7132.19**

EASTING **-3062.74**

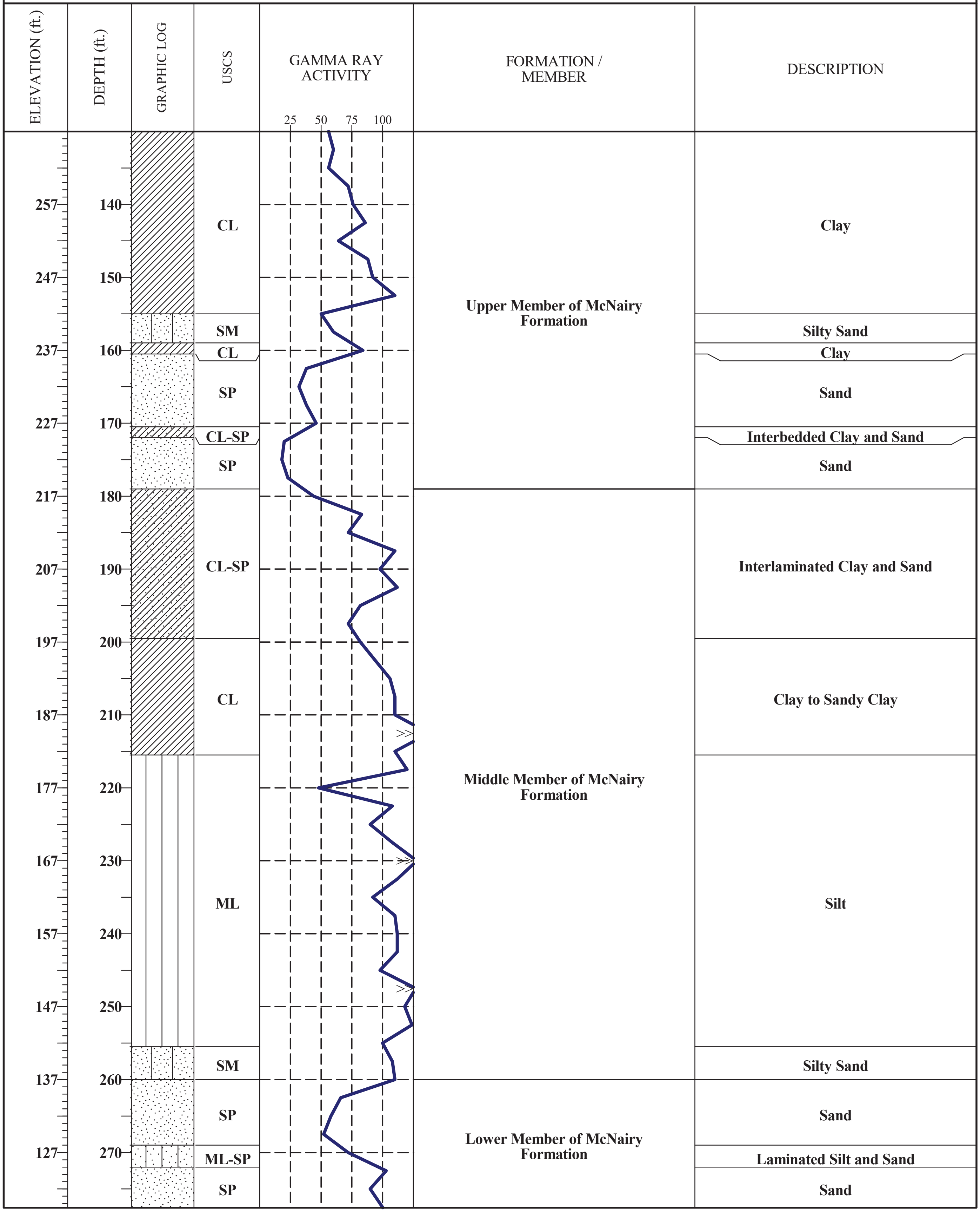
ELEVATION **397.4 ft.**



FOUR RIVERS NUCLEAR PARTNERSHIP, LLC

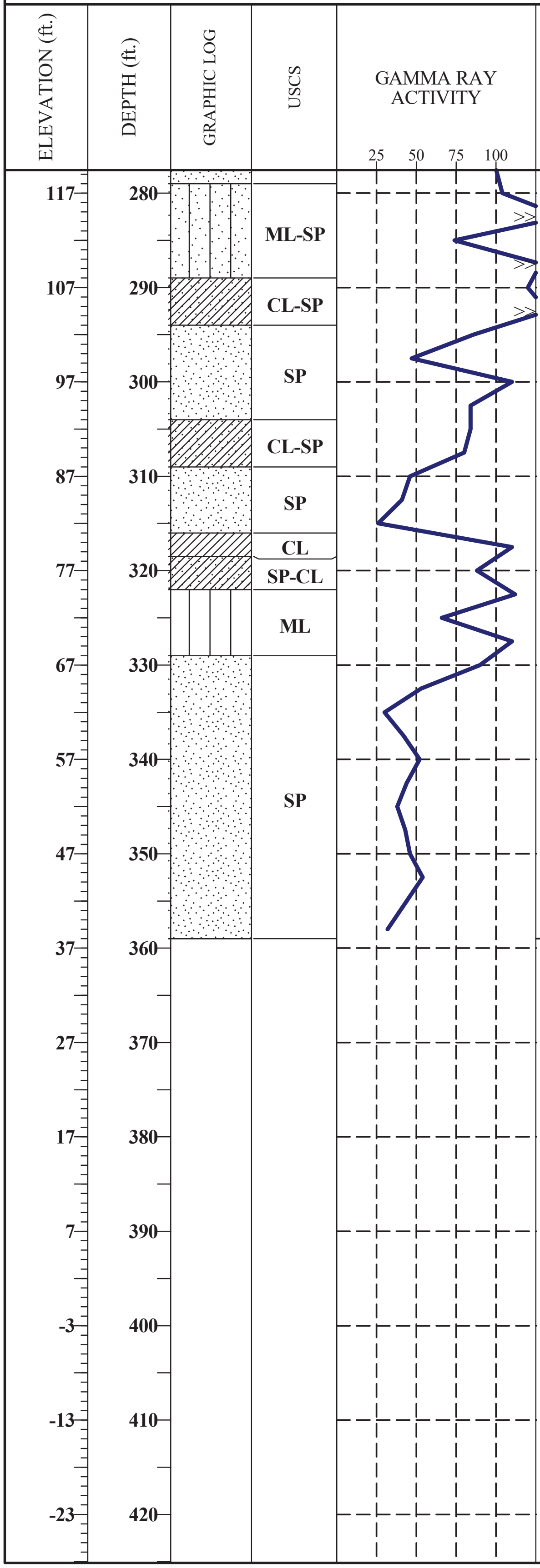
BORING NUMBER DB-01

PAGE 2 OF 3



MCNAIRY GAMMA LOG - C-400 RIFS.GDT - 3/23/22 14:42 - S:\ENV SERVICES\ENVIRONMENTAL REMEDIATION\C-400 RIFS\SOIL BORING LOGS\GINT\PROJECT\C-400 MCNAIRY GAMMA.GPJ

BORING NUMBER DB-01



USCS	FORMATION / MEMBER	DESCRIPTION
ML-SP	Lower Member of McNairy Formation	Laminated Silt and Sand
CL-SP		Interlaminated Clay and Sand
SP		Sand
CL-SP		Interbedded Clay and Sand
SP		Sand
CL		Clay
SP-CL		Interbedded Sand and Clay
ML		Silt
SP		Sand

Boring Terminated at 359 ft.

MCNAIRY GAMMA LOG - C-400 RIFS.GDT - 3/23/22 14:42 - S:\ENV SERVICES\ENVIRONMENTAL REMEDIATION\C-400 RIFS\SOIL BORING LOGS\GINT\PROJECT\C-400 MCNAIRY GAMMA.GPJ

BORING NUMBER F-08

PAGE 1 OF 3

PROJECT NAME **NE Plume Preliminary Characterization - Phase IV Site Investigation**

METHOD **Dual-wall Reverse Circulation with Overshot Casing**

CONTRACTOR **Layne-Northwest**

DATE STARTED **9/27/1994**

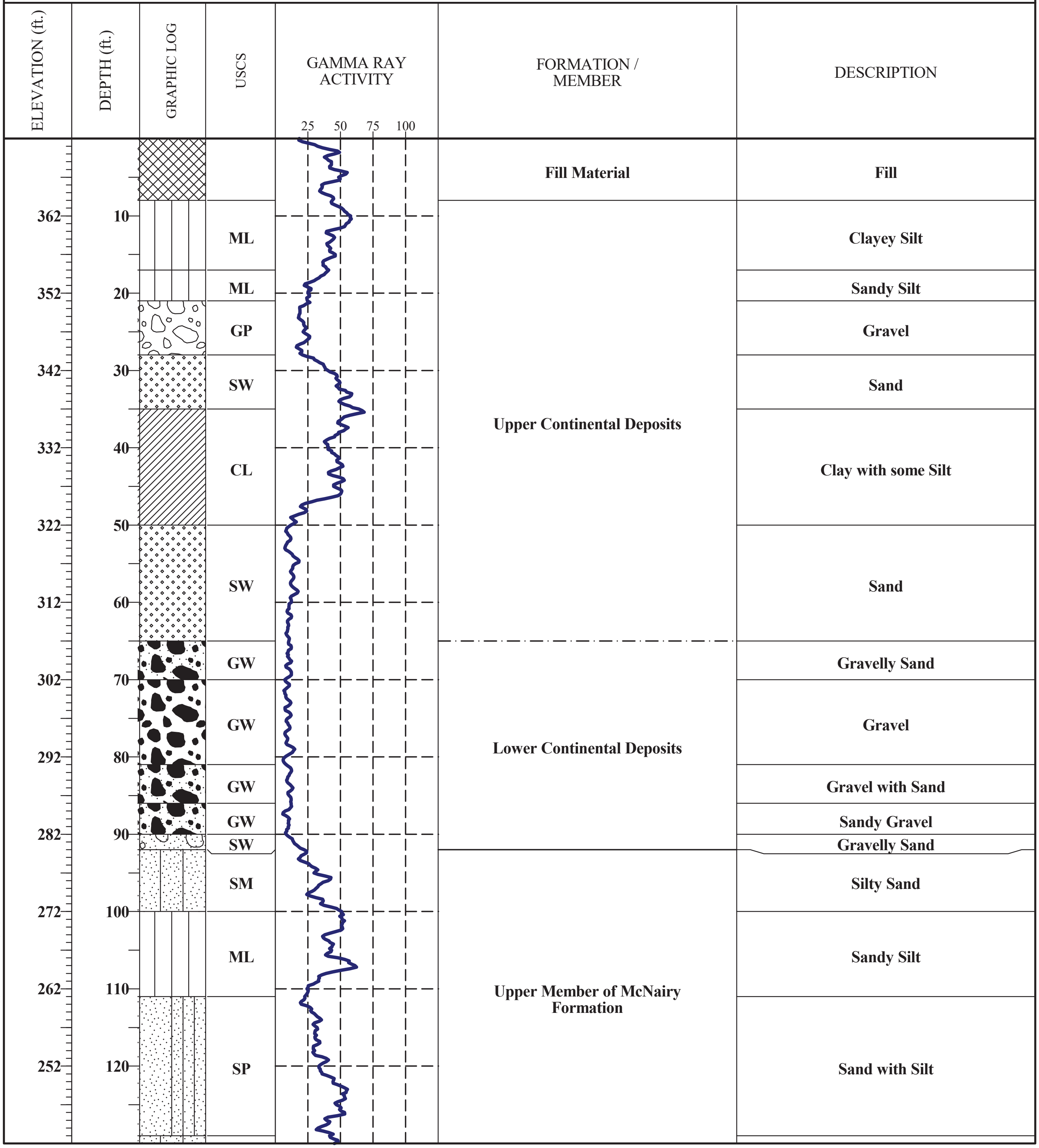
DATE FINISHED **9/29/1994**

TOTAL DEPTH **350 ft.**

NORTHING **880**

EASTING **-4614**

ELEVATION **372 ft.**



USCS	FORMATION / MEMBER	DESCRIPTION
	Fill Material	**Fill**
ML	**Upper Continental Deposits**	**Clayey Silt**
ML		**Sandy Silt**
GP		**Gravel**
SW		**Sand**
CL		**Clay with some Silt**
SW		**Sand**
GW	**Lower Continental Deposits**	**Gravelly Sand**
GW		**Gravel**
GW		**Gravel with Sand**
GW		**Sandy Gravel**
SW		**Gravelly Sand**
SM	**Upper Member of McNairy Formation**	**Silty Sand**
ML		**Sandy Silt**
SP		**Sand with Silt**

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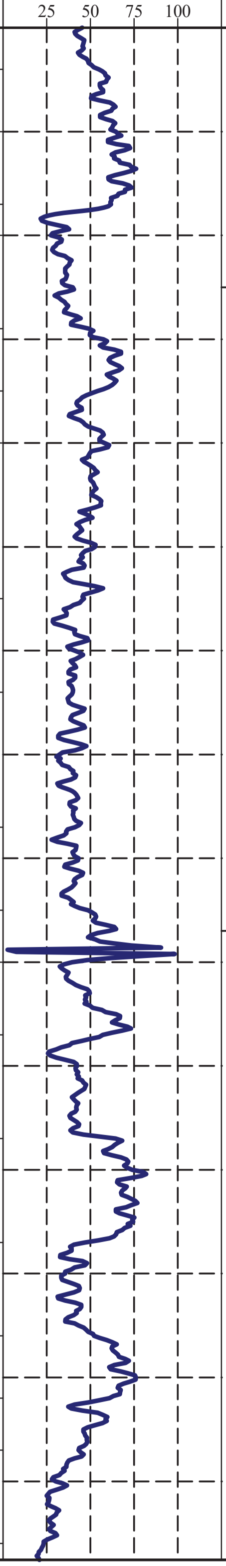
NUCLEAR PARTNERSHIP, LLC

BORING NUMBER F-08

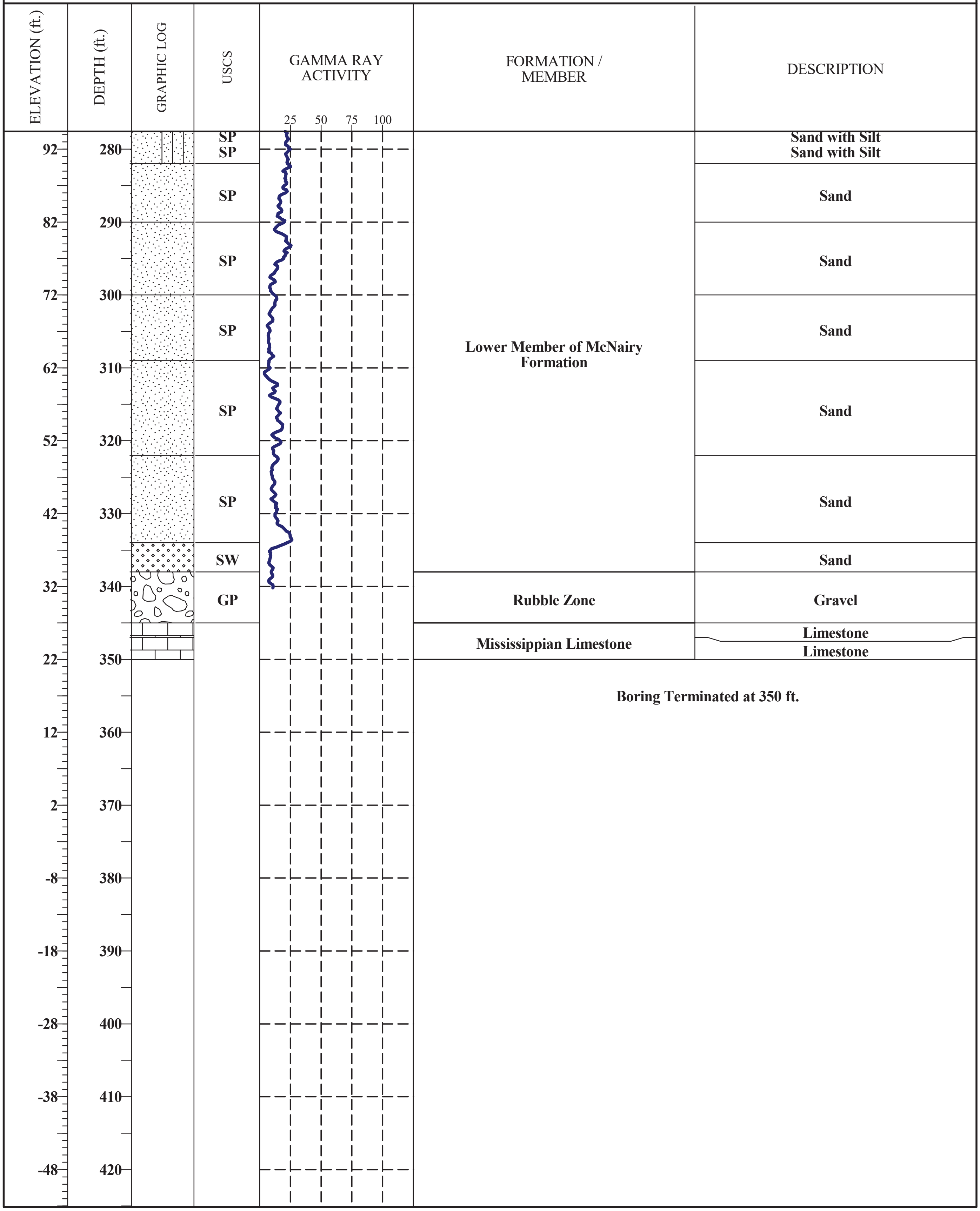
ELEVATION (ft.)	DEPTH (ft.)
232	140
222	150
212	160
202	170
192	180
182	190
172	200
162	210
152	220
142	230
132	240
122	250
112	260
102	270

GAMMA RAY ACTIVITY



USCS	FORMATION / MEMBER	DESCRIPTION
SM	Upper Member of McNairy Formation	Silty Sand
CL		Silty Clay
CL		Silty Clay
		Sandstone
SP		Sand with Silt
CL	Middle Member of McNairy Formation	Clay
CL		Silty Clay
ML		Sandy Silt
SM		Silty Sand
SP		Sand
SP		Sand with Silt
SP		Sand
ML	Lower Member of McNairy Formation	Sandy Silt
ML		Sandy Silt
ML		Clayey Silt
ML		Silt with some Sand
CL		Silty Clay
ML		Clayey Silt
ML		Silt with some Sand

BORING NUMBER F-08



USCS	FORMATION / MEMBER	DESCRIPTION
SP	Lower Member of McNairy Formation	Sand with Silt
SP		Sand with Silt
SP		Sand
SP		Sand
SP		Sand
SP		Sand
SP		Sand
SW		Sand
GP	Rubble Zone	Gravel
	Mississippian Limestone	Limestone
		Limestone

Boring Terminated at 350 ft.

MCNAIRY GAMMA LOG - C-400 RIFS.GDT - 3/23/22 14:42 - S:\ENV SERVICES\ENVIRONMENTAL REMEDIATION\C-400 RIFS\SOIL BORING LOGS\GINT\PROJECT\C-400 MCNAIRY GAMMA.GPJ

FOUR RIVERS NUCLEAR PARTNERSHIP, LLC

BORING NUMBER MW120

PAGE 1 OF 2

PROJECT NAME **Phase I Site Investigation**

METHOD **Hollow Stem Auger Drill Method / Mud Rotary Drill Method**

CONTRACTOR **Geotek Engineering**

DATE STARTED **11/18/1989**

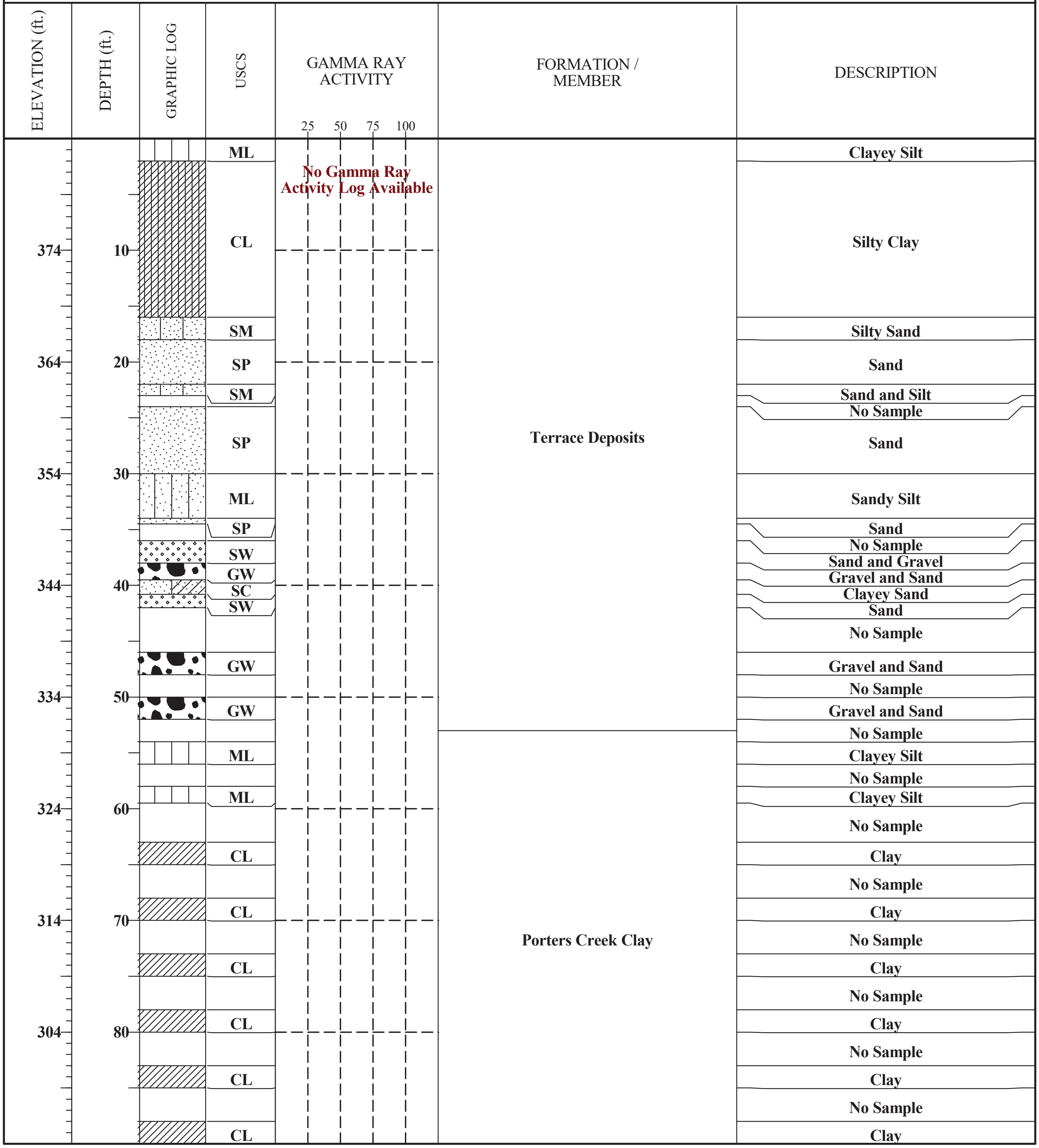
DATE FINISHED **1/23/1990**

TOTAL DEPTH **170 ft.**

NORTHING **-5865.15**

EASTING **-1606.97**

ELEVATION **384.1 ft.**

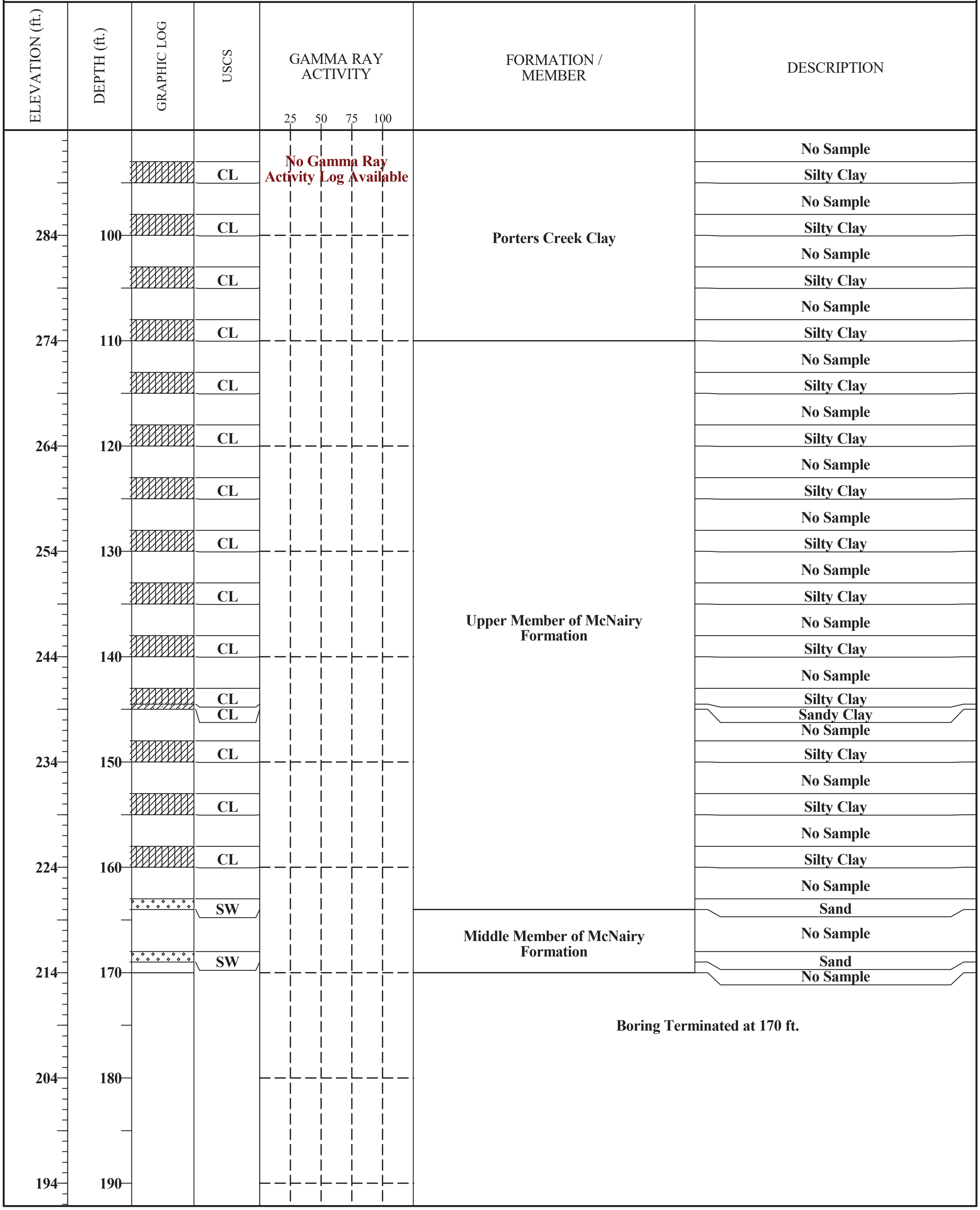


USCS	FORMATION / MEMBER	DESCRIPTION
ML	Terrace Deposits	Clayey Silt
CL		Silty Clay
SM		Silty Sand
SP		Sand
SM		Sand and Silt
		No Sample
SP		Sand
ML		Sandy Silt
SP		Sand
		No Sample
SW		Sand and Gravel
GW		Gravel and Sand
SC		Clayey Sand
SW		Sand
		No Sample
GW		Gravel and Sand
		No Sample
GW		Gravel and Sand
	Porters Creek Clay	No Sample
ML		Clayey Silt
		No Sample
ML		Clayey Silt
		No Sample
CL		Clay
		No Sample
CL		Clay
		No Sample
CL		Clay
		No Sample
CL		Clay
		No Sample
CL		Clay
		No Sample
CL		Clay

FOUR RIVERS NUCLEAR PARTNERSHIP, LLC

BORING NUMBER MW120

PAGE 2 OF 2



MCNAIRY GAMMA LOG - C-400 RIFS.GDT - 3/23/22 14:43 - S:\ENV SERVICES\ENVIRONMENTAL REMEDIATION\C-400 RIFS\SOIL BORING LOGS\GINT\PROJECT\C-400 MCNAIRY GAMMA.GPJ

BORING NUMBER MW121

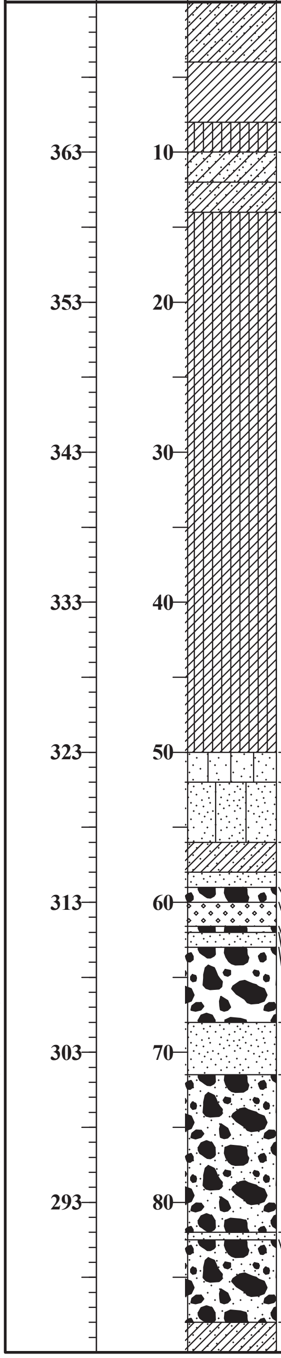
PAGE 1 OF 3

PROJECT NAME **Phase I Site Investigation**

METHOD **Hollow Stem Auger Drill Method / Mud Rotary Drill Method**
CONTRACTOR **Geotek Engineering**

DATE STARTED **11/14/1989**
DATE FINISHED **1/6/1990**
TOTAL DEPTH **211.5 ft.**

NORTHING **6161.61**
EASTING **-5677.61**
ELEVATION **372.6 ft.**



GAMMA RAY ACTIVITY: 25 50 75 100

No Gamma Ray Activity Log Available

USCS	FORMATION / MEMBER	DESCRIPTION
CL	**Upper Continental Deposits**	**Sandy Clay**
CL		**Fat Clay with Sand**
CL		**Silty Clay**
SC		**Clayey Sand**
CL		**Sandy Clay**
CL		**Silty Clay**
ML		**Clayey Silt with Sand**
SM		**Sand with Silt**
CL		**Sandy Clay**
SP		**Sand**
GW	**Lower Continental Deposits**	**Gravel**
SW		**Sand**
GW		**Gravel**
SP		**Sand**
GW		**Gravel**
SP		**Sand**
GW		**Sandy Gravel**
SP		**Sand**
GW		**Sandy Gravel**
CL-SM		**Interbedded Clay and Silty Sand**

MCNAIRY GAMMA LOG - C-400 RIFS.GDT - 3/23/22 14:43 - S:\ENV SERVICES\ENVIRONMENTAL REMEDIATION\C-400 RIFS\SOIL BORING LOGS\GINT\PROJECT\C-400 MCNAIRY GAMMA.GPJ

BORING NUMBER MW121

ELEVATION (ft.)	DEPTH (ft.)	GRAPHIC LOG	USCS	GAMMA RAY ACTIVITY 25 50 75 100	FORMATION / MEMBER	DESCRIPTION
			CL-SM			Interbedded Clay and Silty Sand
				No Gamma Ray Activity Log Available		No Sample
			CL			Silty Clay
						No Sample
273	100		CL			Silty Clay
						No Sample
			CL		Upper Member of McNairy Formation	Clay with Sand
						No Sample
263	110		SC			Clayey Sand
						No Sample
			SP-SM			Sand with Silt
						No Sample
253	120		SP-SM			Sand with Silt
						No Sample
			SP-SM			Sand with Silt
						No Sample
243	130		SP-CL		Middle Member of McNairy Formation	Interbedded Sand and Sandy Clay
						No Sample
			ML			Silt
						No Sample
233	140		ML			Silt
						No Sample
			ML			Silt
						No Sample
223	150		ML			Silt
						No Sample
			ML			Silt
						No Sample
213	160		ML			Silt
						No Sample
			ML-SP			Interbedded Silt and Sand
						No Sample
203	170		ML			Silt
						No Sample
			ML			Silt
						No Sample
193	180		ML			Silt
						No Sample
			ML			Clayey Silt
						No Sample
183	190		ML-SP			Silt and Sand

MCNAIRY GAMMA LOG - C-400 RIFS.GDT - 3/23/22 14:43 - S:\ENV SERVICES\ENVIRONMENTAL REMEDIATION\C-400 RIFS\SOIL BORING LOGS\GINT\PROJECT\C-400 MCNAIRY GAMMA.GPJ

BORING NUMBER MW121

ELEVATION (ft.)	DEPTH (ft.)	GRAPHIC LOG	USCS	GAMMA RAY ACTIVITY 25 50 75 100	FORMATION / MEMBER	DESCRIPTION
				No Gamma Ray Activity Log Available	**Middle Member of McNairy Formation**	**No Sample**
			ML			**Silt**
						No Sample
			ML			**Silt**
173	200				**Lower Member of McNairy Formation**	**No Sample**
			SM			**Silty Sand**
						No Sample
163	210					
					Boring Terminated at 211.5 ft.	
153	220					
143	230					
133	240					
123	250					
113	260					
103	270					
93	280					
83	290					

MCNAIRY GAMMA LOG - C-400 RIFS.GDT - 3/23/22 14:43 - S:\ENV SERVICES\ENVIRONMENTAL REMEDIATION\C-400 RIFS\SOIL BORING LOGS\GINT\PROJECT\C-400 MCNAIRY GAMMA.GPJ

FOUR RIVERS NUCLEAR PARTNERSHIP, LLC

BORING NUMBER MW122

PAGE 1 OF 2

PROJECT NAME **Phase I Site Investigation**

METHOD **Hollow Stem Auger Drill Method / Mud Rotary Drill Method**

CONTRACTOR **Geotek Engineering**

DATE STARTED **11/18/1989**

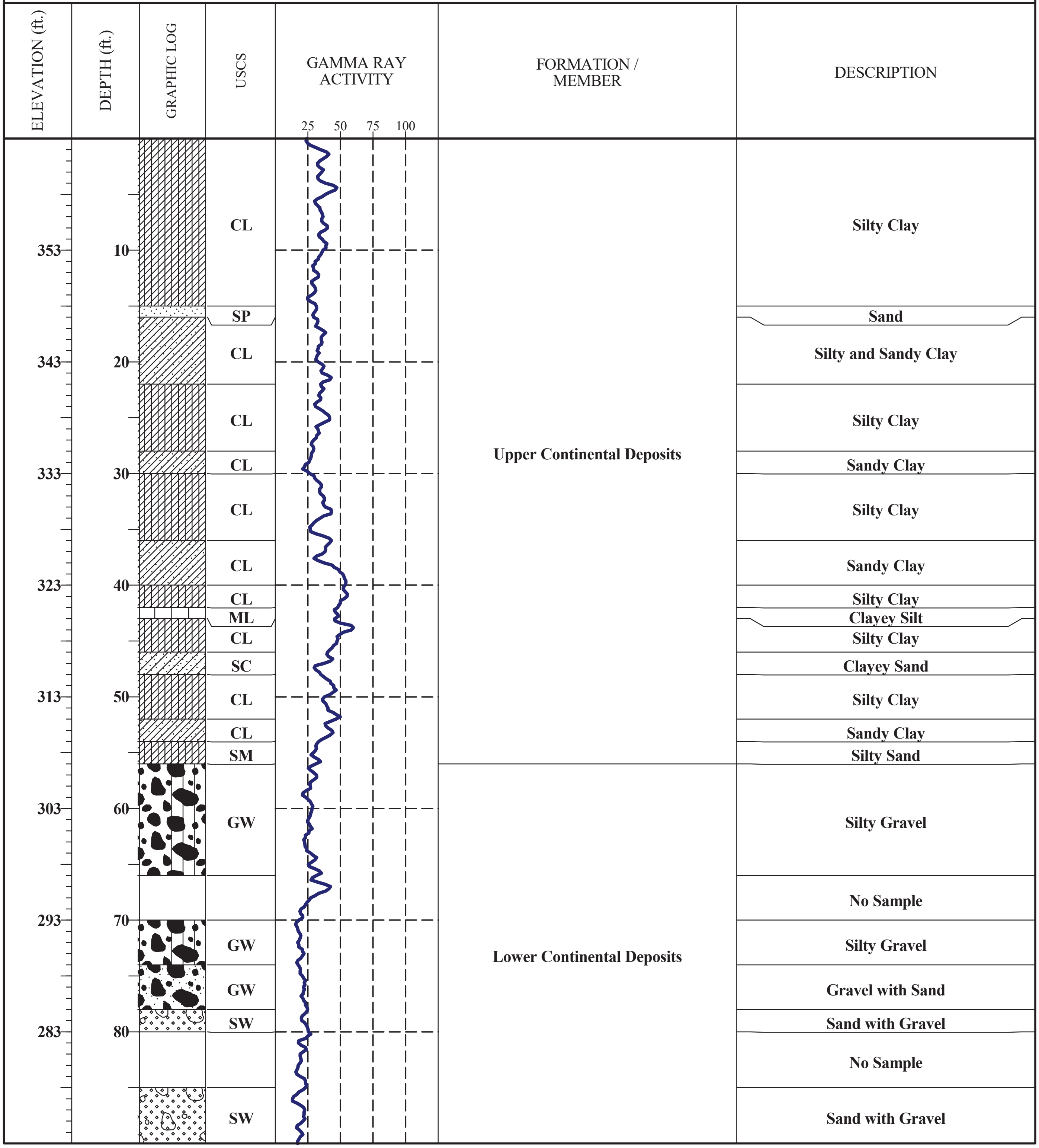
DATE FINISHED **1/5/1990**

TOTAL DEPTH **158 ft.**

NORTHING **718.405**

EASTING **1876.33**

ELEVATION **363.0 ft.**



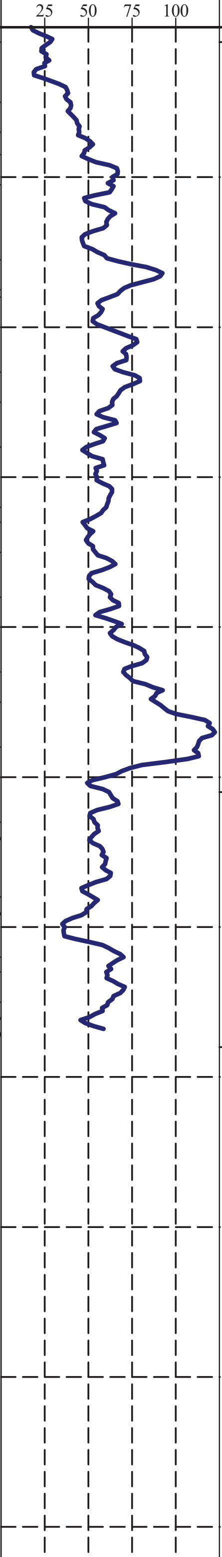
USCS	FORMATION / MEMBER	DESCRIPTION
CL	Upper Continental Deposits	Silty Clay
SP		Sand
CL		Silty and Sandy Clay
CL		Silty Clay
CL		Sandy Clay
CL		Silty Clay
CL		Sandy Clay
CL		Silty Clay
ML		Clayey Silt
CL		Silty Clay
SC		Clayey Sand
CL		Silty Clay
CL		Sandy Clay
SM		Silty Sand
GW	Lower Continental Deposits	Silty Gravel
		No Sample
GW		Silty Gravel
GW		Gravel with Sand
SW		Sand with Gravel
		No Sample
SW		Sand with Gravel

MCNAIRY GAMMA LOG - C-400 RIFS.GDT - 3/23/22 14:43 - S:\ENV SERVICES\ENVIRONMENTAL REMEDIATION\C-400 RIFS\SOIL BORING LOGS\GINT\PROJECT\C-400 MCNAIRY GAMMA.GPJ

BORING NUMBER MW122

ELEVATION (ft.)	DEPTH (ft.)
263	100
253	110
243	120
233	130
223	140
213	150
203	160
193	170
183	180
173	190

GAMMA RAY ACTIVITY



USCS	FORMATION / MEMBER	DESCRIPTION
	Upper Member of McNairy Formation	No Sample
CL		Clay
		No Sample
CL		Clay
		No Sample
CL		Clay
		No Sample
CL		Clay
		No Sample
CL		Sandy Clay
		No Sample
CL		Sandy Clay
		No Sample
CL		Sandy Clay
		No Sample
CL		Sandy Clay
		No Sample
CL		Sandy Clay
		No Sample
CL		Sandy Clay
	Middle Member of McNairy Formation	No Sample
SP		Sand
		No Sample
CL		Sandy Clay
SP		Sand
		No Sample
CL		Sandy Clay
SP		Sand
CL		Sandy Clay
		No Sample

Boring Terminated at 158 ft.

MCNAIRY GAMMA LOG - C-400 RIFS.GDT - 3/23/22 14:43 - S:\ENV SERVICES\ENVIRONMENTAL REMEDIATION\C-400 RIFS\SOIL BORING LOGS\GINT\PROJECT\C-400 MCNAIRY GAMMA.GPJ

FOUR RIVERS NUCLEAR PARTNERSHIP, LLC

BORING NUMBER MW345

PAGE 1 OF 3

PROJECT NAME **Sitewide Remedial Evaluation for Source Areas Contributing to Off-Site Groundwater Contamination**

METHOD **Barber: Dual-wall Reverse Circulation (Air) with Overshot Casing**

CONTRACTOR **Miller Drilling**

DATE STARTED **6/7/1999**

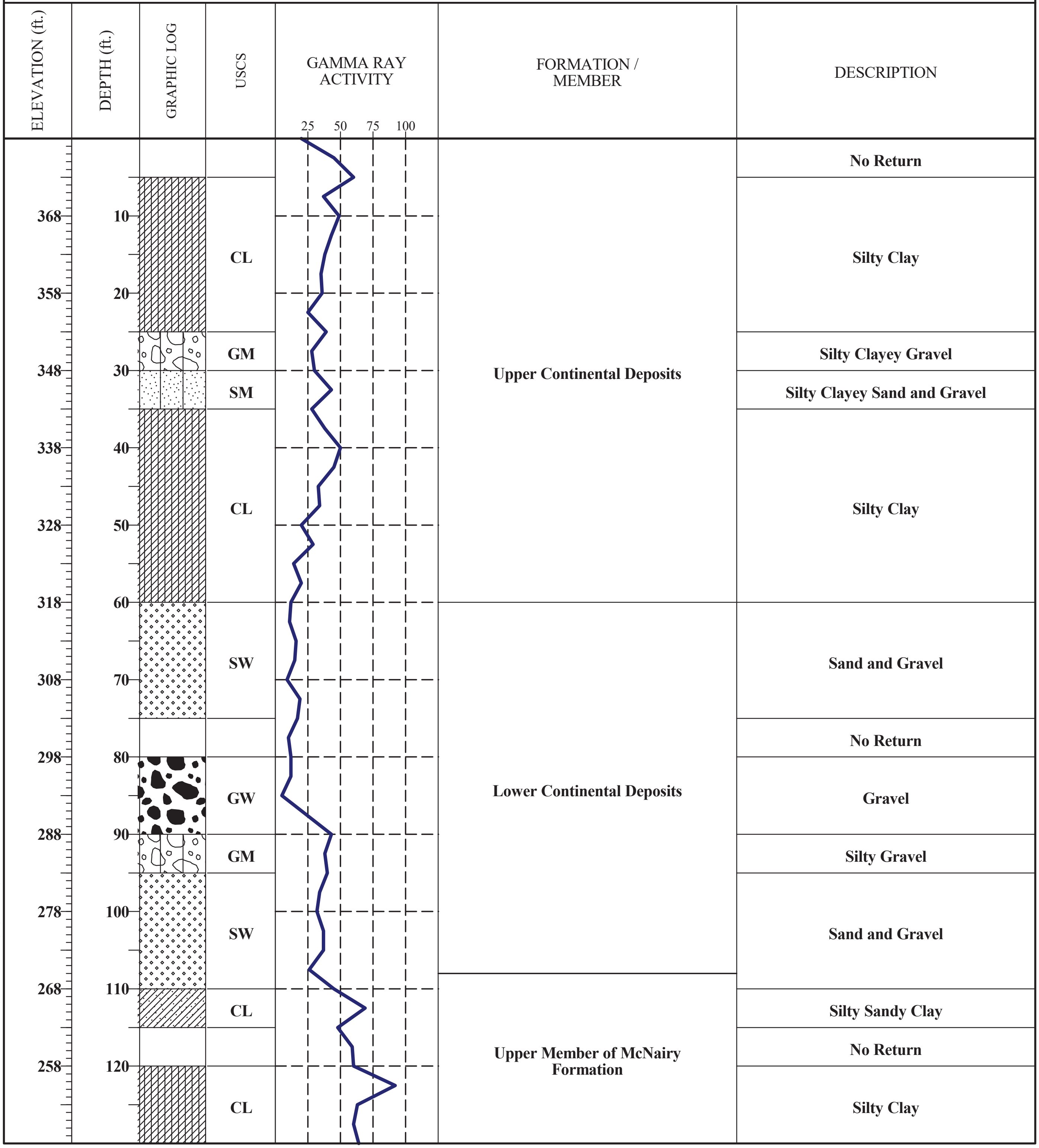
DATE FINISHED **6/20/1999**

TOTAL DEPTH **344 ft.**

NORTHING **1133.14**

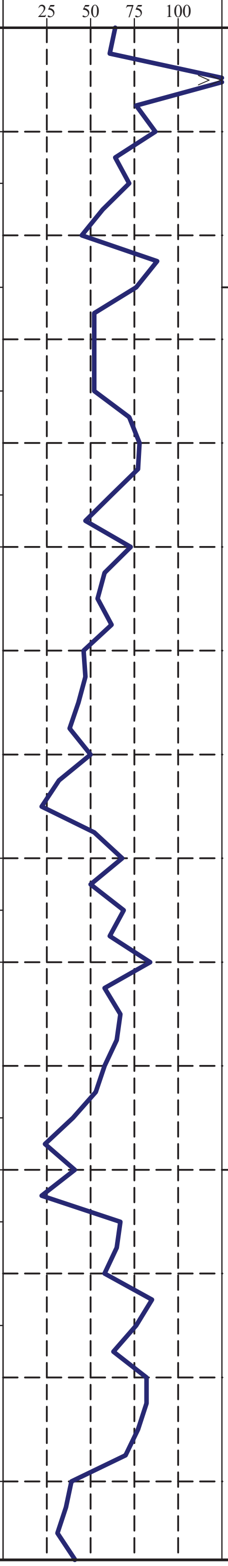
EASTING **-2955.61**

ELEVATION **378.1 ft.**



USCS	FORMATION / MEMBER	DESCRIPTION
	Upper Continental Deposits	**No Return**
CL		**Silty Clay**
GM		**Silty Clayey Gravel**
SM		**Silty Clayey Sand and Gravel**
CL		**Silty Clay**
SW	Lower Continental Deposits	**Sand and Gravel**
		No Return
GW		**Gravel**
GM		**Silty Gravel**
SW		**Sand and Gravel**
CL	Upper Member of McNairy Formation	**Silty Sandy Clay**
		No Return
CL		**Silty Clay**

BORING NUMBER MW345

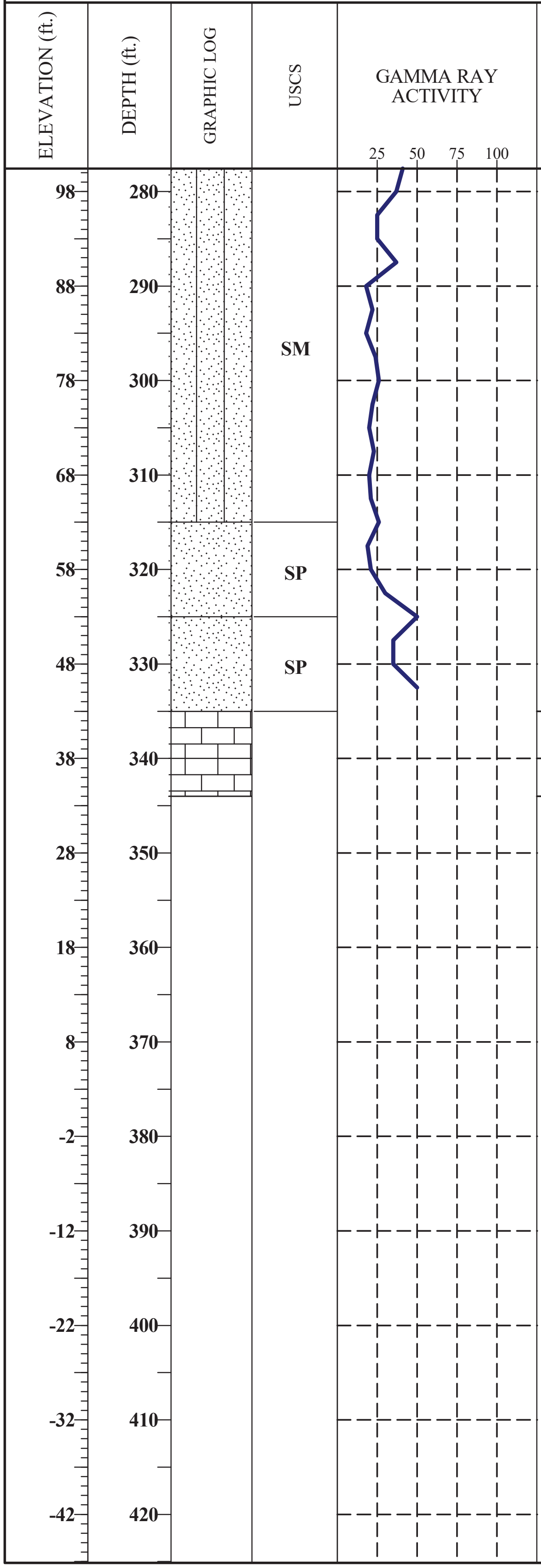


ELEVATION (ft.)	DEPTH (ft.)	GRAPHIC LOG	USCS	GAMMA RAY ACTIVITY	FORMATION / MEMBER	DESCRIPTION
			CL		Upper Member of McNairy Formation	Silty Clay
238	140					No Return
228	150		SM			Silty Sand
218	160		CL		Middle Member of McNairy Formation	Silty Clay
208	170					No Return
			CL			Silty Clay
198 188 178	180 190 200		SM			Silty Sand
168	210		CL			Silty Clay
			CL-SP			Clay and Sand
158 148	220 230		CL			Clay with Sand
			CL			Clay
138	240		SP		Lower Member of McNairy Formation	Silty Clayey Sand
128	250		CL			Silty Clay
118	260		CL			Clay
108	270		SM			Silty Sand

FOUR RIVERS
NUCLEAR PARTNERSHIP, LLC

BORING NUMBER MW345

PAGE 3 OF 3



USCS	FORMATION / MEMBER	DESCRIPTION
SM	Lower Member of McNairy Formation	Silty Sand
SP		Fine Sand
SP		Fine to Medium Sand
	Rubble Zone	Limestone Fragments
	Mississippian Limestone	Limestone

Boring Terminated at 344 ft.

MCNAIRY GAMMA LOG - C-400 RIFS.GDT - 3/23/22 14:43 - S:\ENV SERVICES\ENVIRONMENTAL REMEDIATION\C-400 RIFS\SOIL BORING LOGS\GINT\PROJECT\C-400 MCNAIRY GAMMA.GPJ

BORING NUMBER MW346

PAGE 1 OF 3

PROJECT NAME **Sitewide Remedial Evaluation for Source Areas Contributing to Off-Site Groundwater Contamination**

METHOD **Barber: Dual-wall Reverse Circulation (Air) with Overshot Casing**

CONTRACTOR **Miller Drilling**

DATE STARTED **6/30/1999**

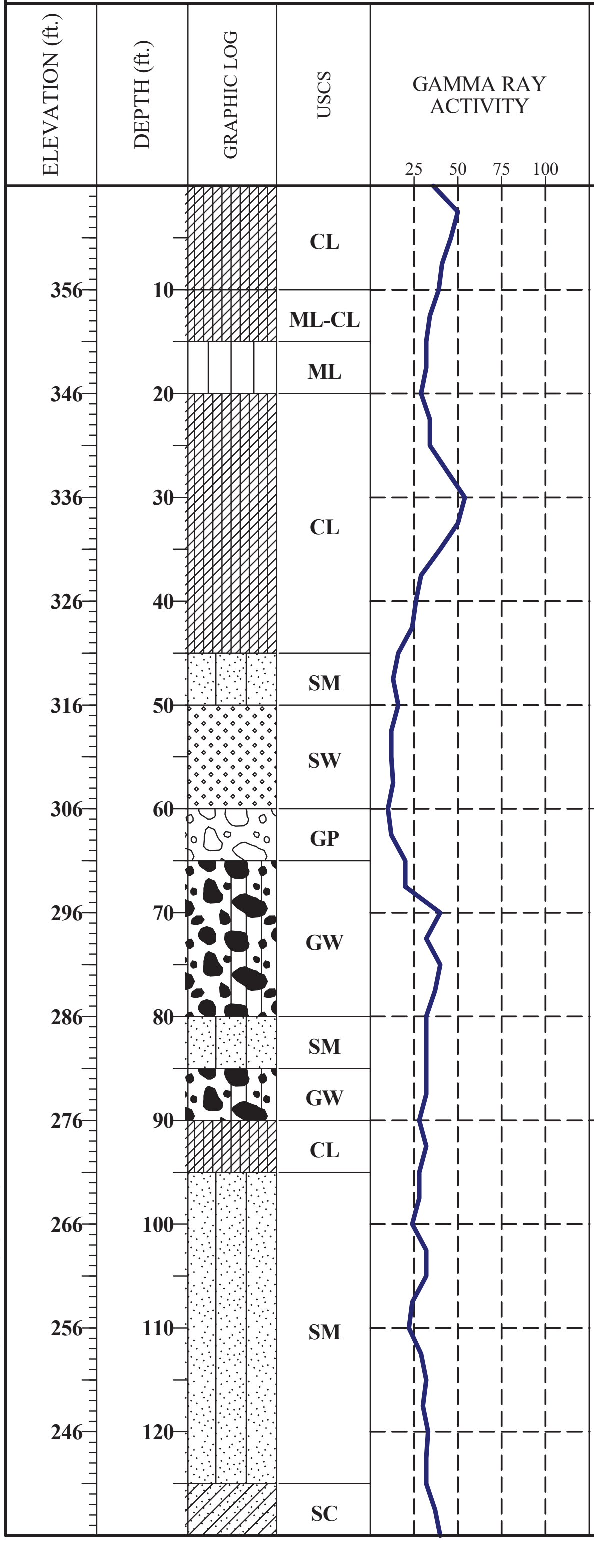
DATE FINISHED **7/15/1999**

TOTAL DEPTH **315 ft.**

NORTHING **3210.44**

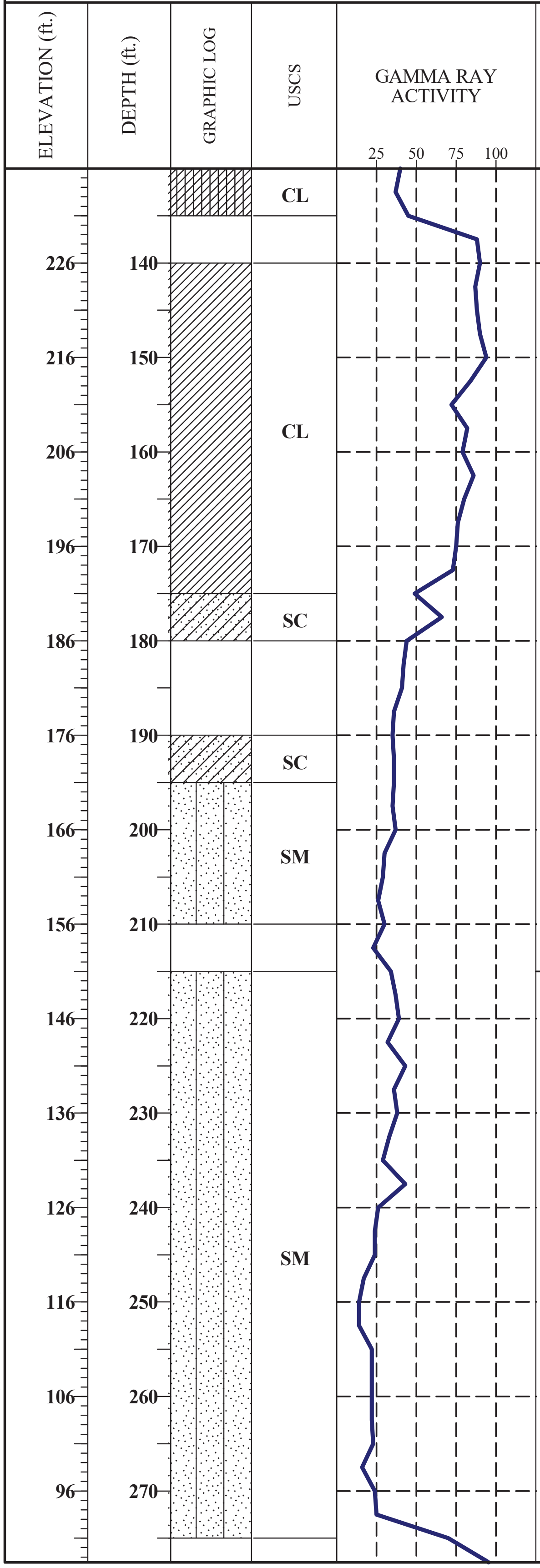
EASTING **-3099.9**

ELEVATION **365.9 ft.**



USCS	FORMATION / MEMBER	DESCRIPTION
CL	**Upper Continental Deposits**	**Silty Clay**
ML-CL		**Silt and Clay**
ML		**Clayey Silt**
CL		**Silty Clay**
SM		**Silty Sand**
SW		**Sand and Gravel**
GP	**Lower Continental Deposits**	**Gravel**
GW		**Silty Sand and Gravel**
SM		**Silty Sand**
GW		**Silty Sand and Gravel**
CL	**Upper Member of McNairy Formation**	**Silty Clay**
SM		**Silty Sand**
SC		**Clayey Sand**

BORING NUMBER MW346



USCS	FORMATION / MEMBER	DESCRIPTION
CL	Upper Member of McNairy Formation	Silty Clay
		No Return
CL	Middle Member of McNairy Formation	Clay
SC		Clayey Sand
		No Return
SC		Clayey Sand
SM		Silty Sand
		No Return
SM	Lower Member of McNairy Formation	Silty Sand
		No Recovery

MCNAIRY GAMMA LOG - C-400 RIFS.GDT - 3/23/22 14:43 - S:\ENV SERVICES\ENVIRONMENTAL REMEDIATION\C-400 RIFS\SOIL BORING LOGS\GINT\PROJECT\C-400 MCNAIRY GAMMA.GPJ

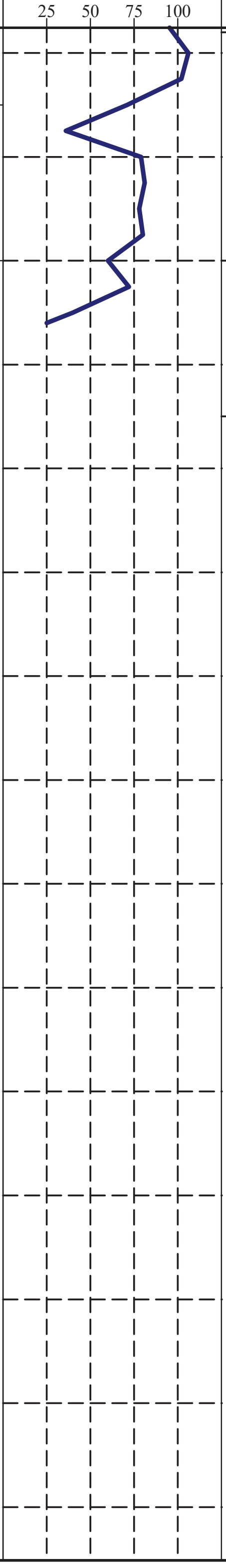
BORING NUMBER MW346

GRAPHIC LOG	USCS	FORMATION / MEMBER	DESCRIPTION
		Rubble Zone	**No Recovery**
▨	CL		**Clay**
Limestone		**Mississippian Limestone**	**Limestone**

Boring Terminated at 315 ft.

ELEVATION (ft.)	DEPTH (ft.)
86	280
76	290
66	300
56	310
46	320
36	330
26	340
16	350
6	360
-4	370
-14	380
-24	390
-34	400
-44	410
-54	420

GAMMA RAY ACTIVITY



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FOUR RIVERS
NUCLEAR PARTNERSHIP, LLC

BORING NUMBER MW347

PROJECT NAME **Sitewide Remedial Evaluation for Source Areas Contributing to Off-Site Groundwater Contamination**

METHOD **Barber: Dual-wall Reverse Circulation (Air) with Overshot Casing**

CONTRACTOR **Miller Drilling**

DATE STARTED **5/17/1999**

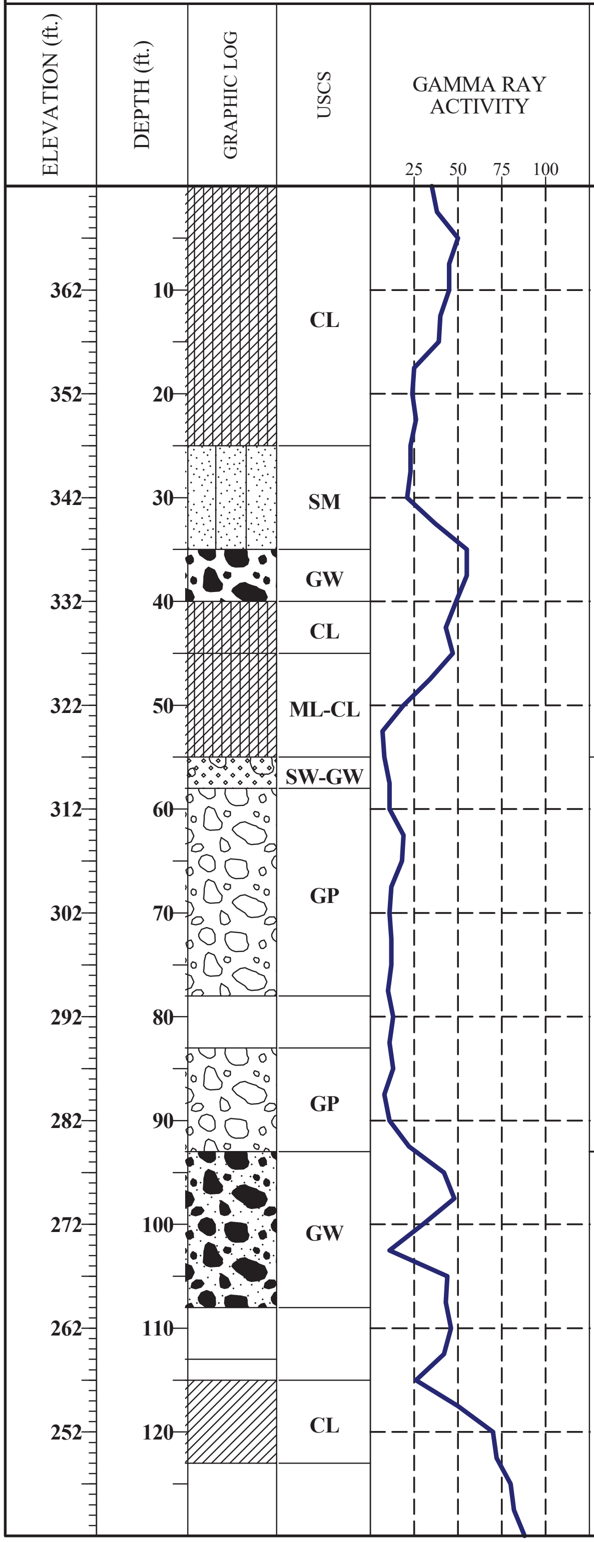
DATE FINISHED **5/26/1999**

TOTAL DEPTH **353 ft.**

NORTHING **1116.54**

EASTING **-4713.34**

ELEVATION **371.8 ft.**

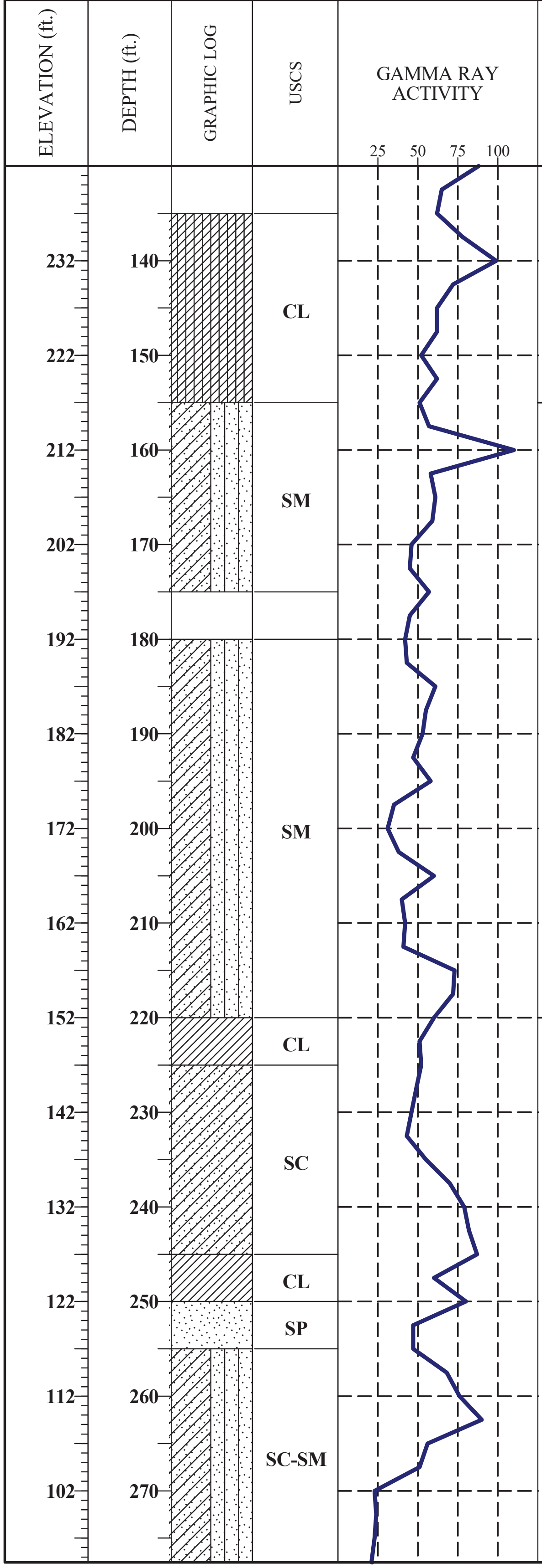


USCS	FORMATION / MEMBER	DESCRIPTION
CL	Upper Continental Deposits	Silty Clay
SM		Silty Sand
GW		Gravel
CL		Silty Clay
ML-CL		Silt and Clay
SW-GW	Lower Continental Deposits	Sand and Gravel
GP		Gravel
		No Return
GP		Gravel
GW	Upper Member of McNairy Formation	Sandy Gravel
		No Return
		No Return
CL		Clay
		No Return

MCNAIRY GAMMA LOG - C-400 RIFS.GDT - 3/23/22 14:43 - S:\ENV SERVICES\ENVIRONMENTAL REMEDIATION\C-400 RIFS\SOIL BORING LOGS\GINT\PROJECT\C-400 MCNAIRY GAMMA.GPJ

BORING NUMBER MW347

PAGE 2 OF 3

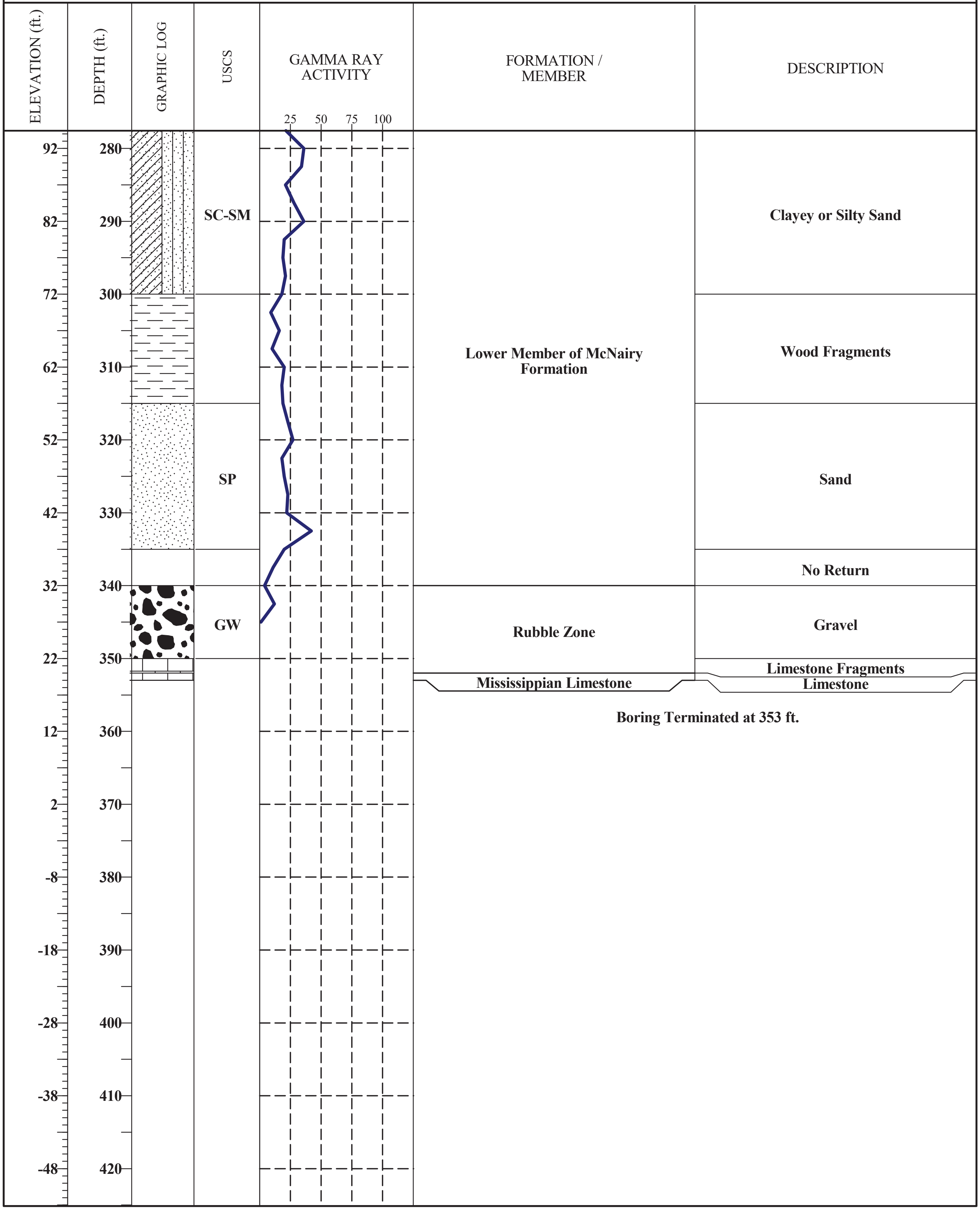


USCS	FORMATION / MEMBER	DESCRIPTION
	Upper Member of McNairy Formation	No Return
CL		Silty Clay
SM	Middle Member of McNairy Formation	Silty Clayey Sand
		No Return
SM		Silty Clayey Sand
CL	Lower Member of McNairy Formation	Clay
SC		Clayey Sand
CL		Clay
SP		Sand
SC-SM		Clayey or Silty Sand

FOUR RIVERS
NUCLEAR PARTNERSHIP, LLC

BORING NUMBER MW347

PAGE 3 OF 3



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FOUR RIVERS
NUCLEAR PARTNERSHIP, LLC

BORING NUMBER Z-12

PROJECT NAME **Recommended Soil Columns for Use in Amplification Studies**

METHOD **Mud Rotary**

CONTRACTOR **ERC Environmental & Energy**

DATE STARTED **1990**

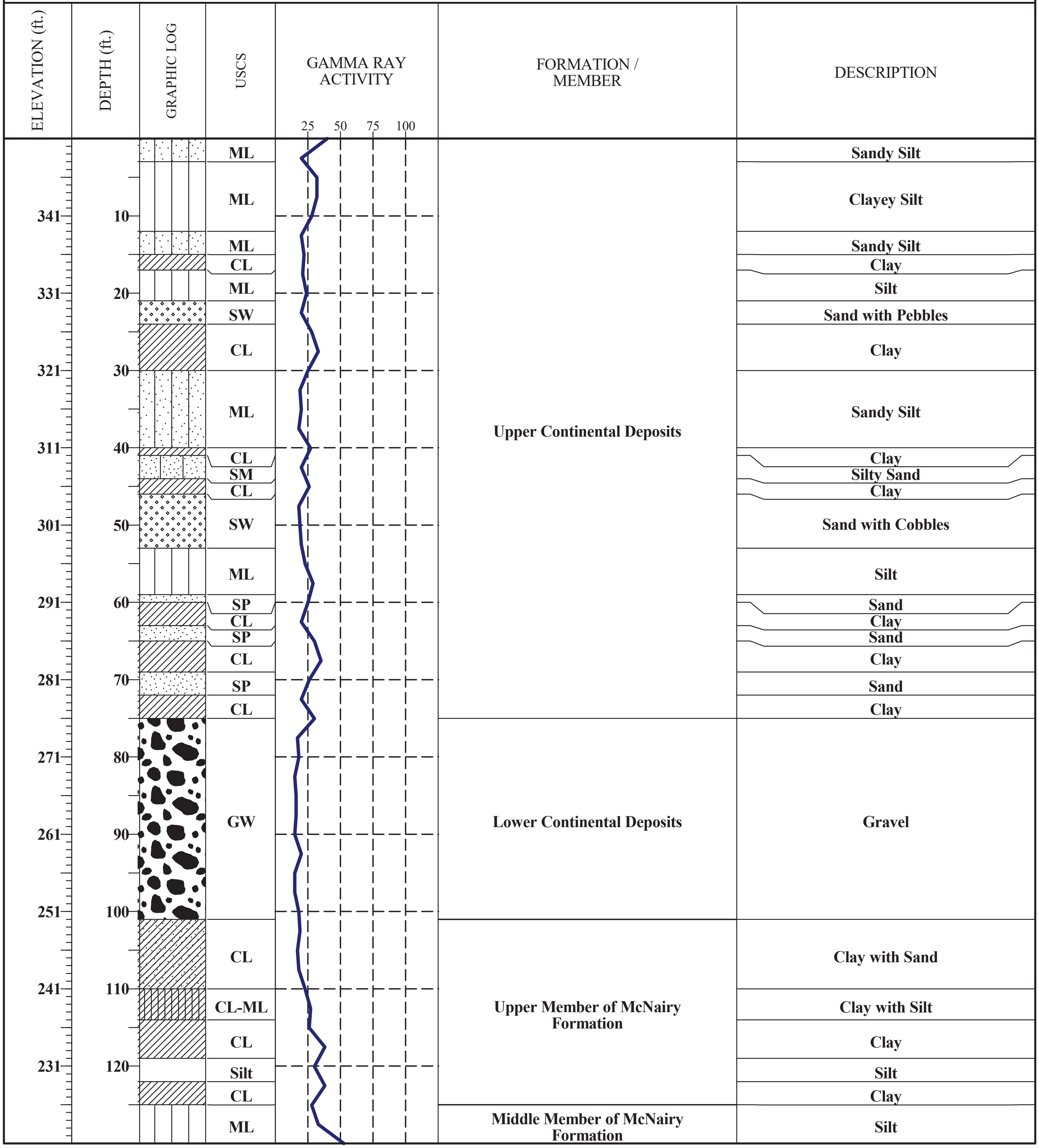
DATE FINISHED **1990**

TOTAL DEPTH **369 ft.**

NORTHING **12044.52**

EASTING **-2980.58**

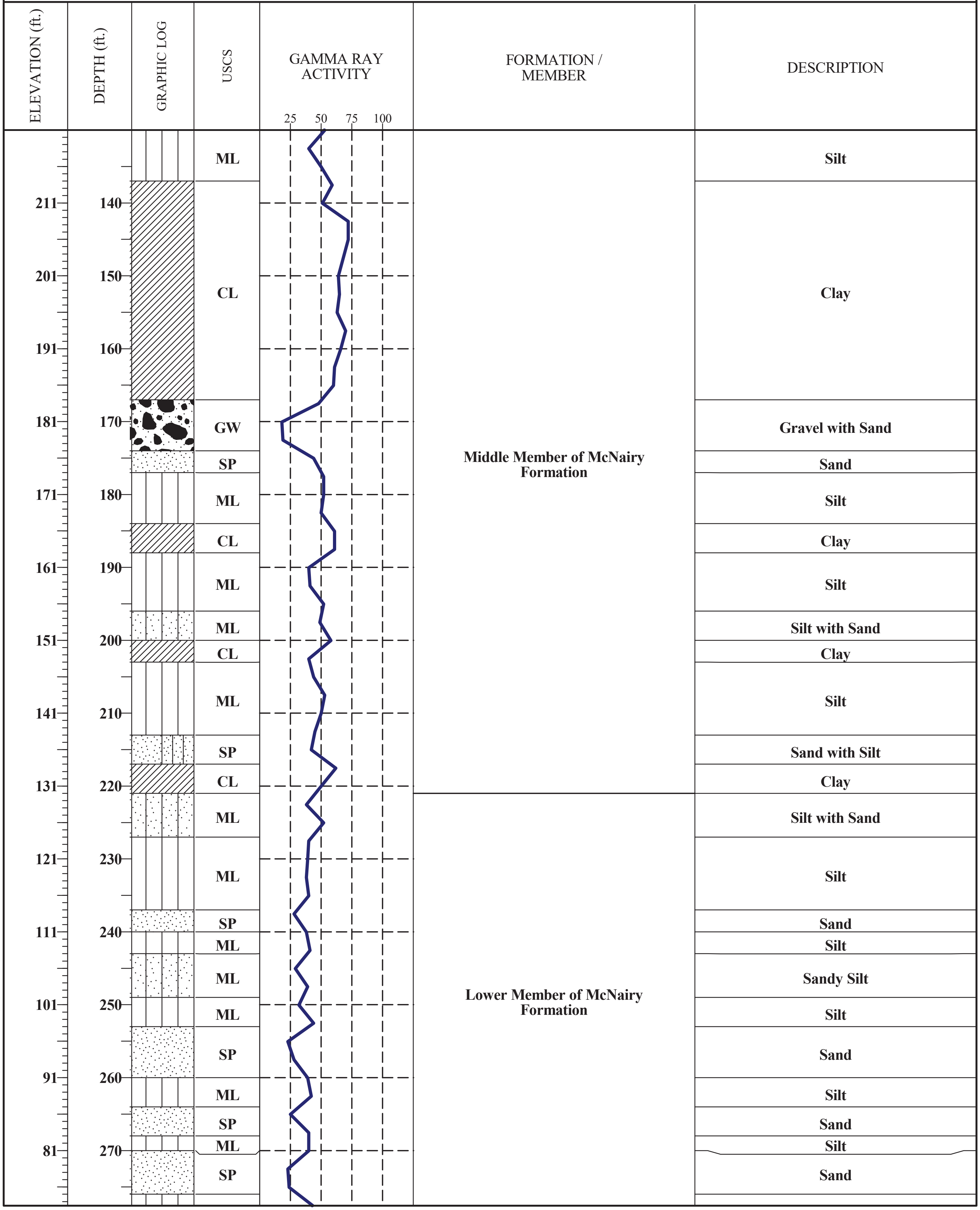
ELEVATION **351.1 ft.**



USCS	FORMATION / MEMBER	DESCRIPTION
ML	Upper Continental Deposits	Sandy Silt
ML		Clayey Silt
ML		Sandy Silt
CL		Clay
ML		Silt
SW		Sand with Pebbles
CL		Clay
ML		Sandy Silt
CL		Clay
SM		Silty Sand
CL		Clay
SW		Sand with Cobbles
ML		Silt
SP		Sand
CL		Clay
SP		Sand
CL		Clay
SP		Sand
CL		Clay
GW	Lower Continental Deposits	Gravel
CL	Upper Member of McNairy Formation	Clay with Sand
CL-ML		Clay with Silt
CL		Clay
Silt		Silt
CL		Clay
ML	Middle Member of McNairy Formation	Silt

BORING NUMBER Z-12

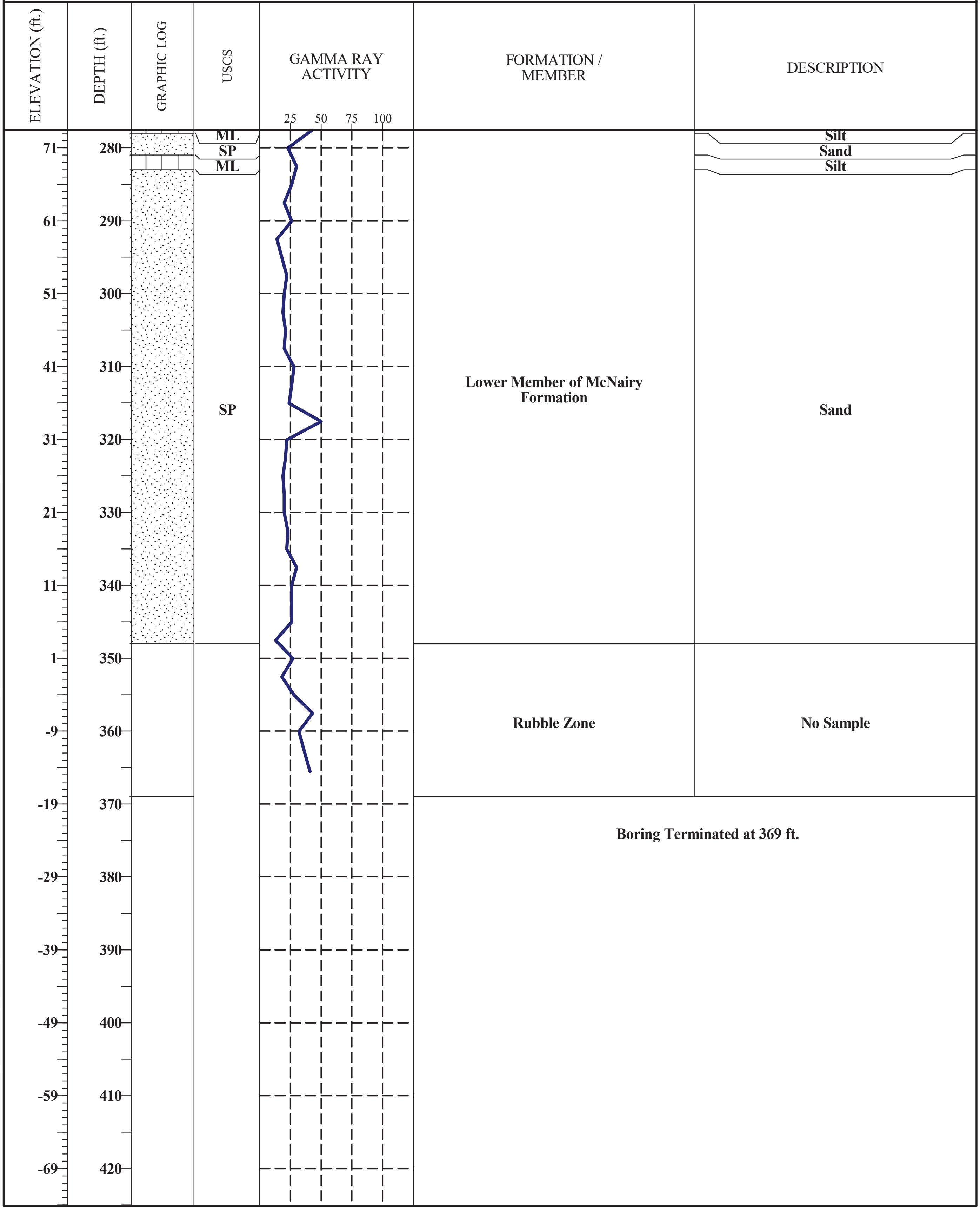
PAGE 2 OF 3



USCS	FORMATION / MEMBER	DESCRIPTION
ML		Silt
CL	Middle Member of McNairy Formation	Clay
GW		Gravel with Sand
SP		Sand
ML		Silt
CL		Clay
ML		Silt
ML		Silt with Sand
CL		Clay
ML		Silt
SP		Sand with Silt
CL		Clay
ML	Lower Member of McNairy Formation	Silt with Sand
ML		Silt
SP		Sand
ML		Silt
ML		Sandy Silt
ML		Silt
SP		Sand
ML		Silt
SP		Sand
ML		Silt
SP		Sand

BORING NUMBER Z-12

PAGE 3 OF 3



USCS	FORMATION / MEMBER	DESCRIPTION
ML		Silt
SP		Sand
ML		Silt
SP	Lower Member of McNairy Formation	Sand
	Rubble Zone	No Sample

Boring Terminated at 369 ft.

MCNAIRY GAMMA LOG - C-400 RIFS.GDT - 3/23/22 14:43 - S:\ENV SERVICES\ENVIRONMENTAL REMEDIATION\C-400 RIFS\SOIL BORING LOGS\GINT\PROJECT\C-400 MCNAIRY GAMMA.GPJ

BORING NUMBER Z-16

PAGE 1 OF 3

FOUR RIVERS NUCLEAR PARTNERSHIP, LLC

PROJECT NAME **Recommended Soil Columns for Use in Amplification Studies**

METHOD **Mud Rotary**

CONTRACTOR **ERC Environmental and Energy**

DATE STARTED **1990**

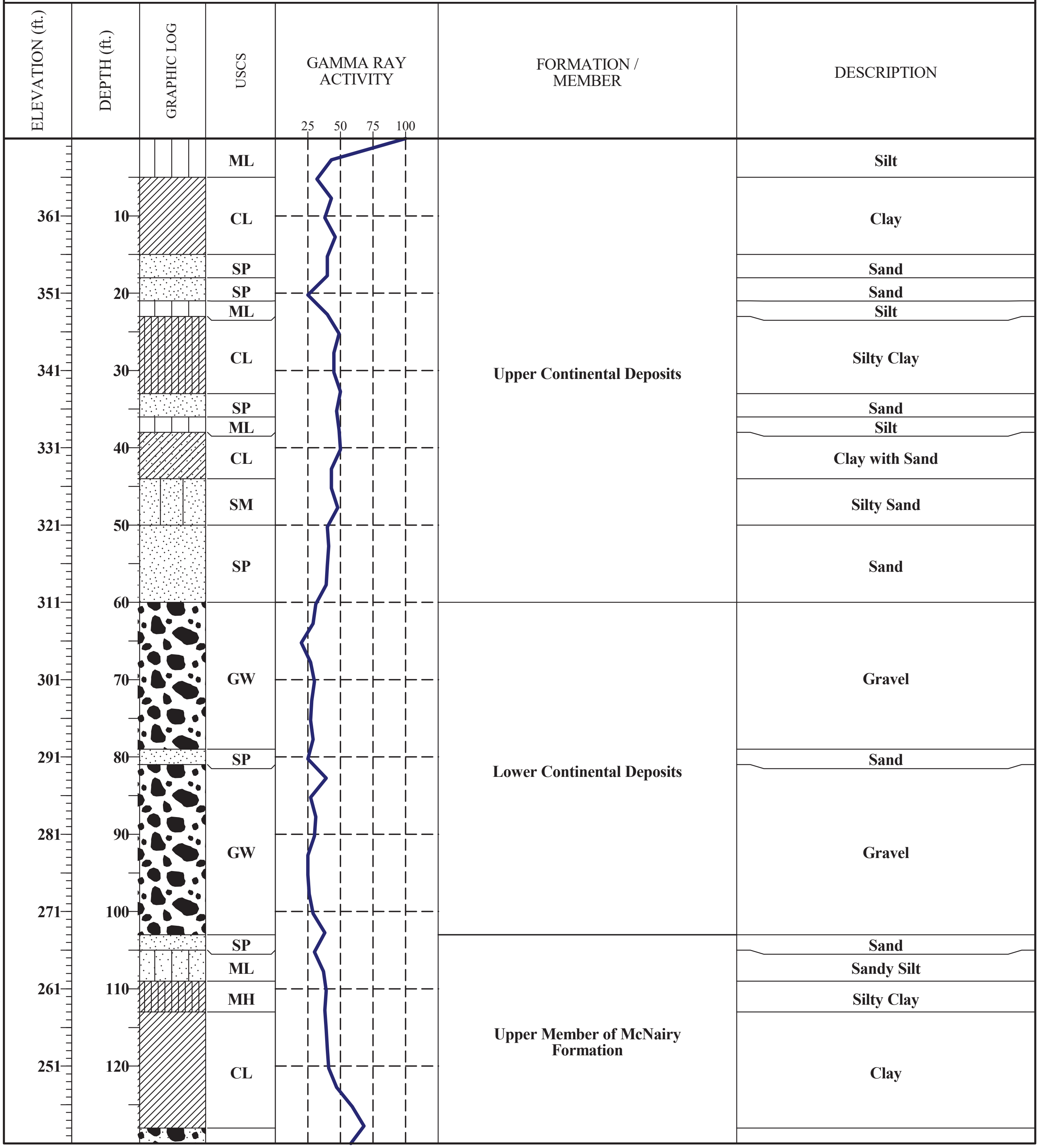
DATE FINISHED **1990**

TOTAL DEPTH **356.5 ft.**

NORTHING **-385.15**

EASTING **-8436.66**

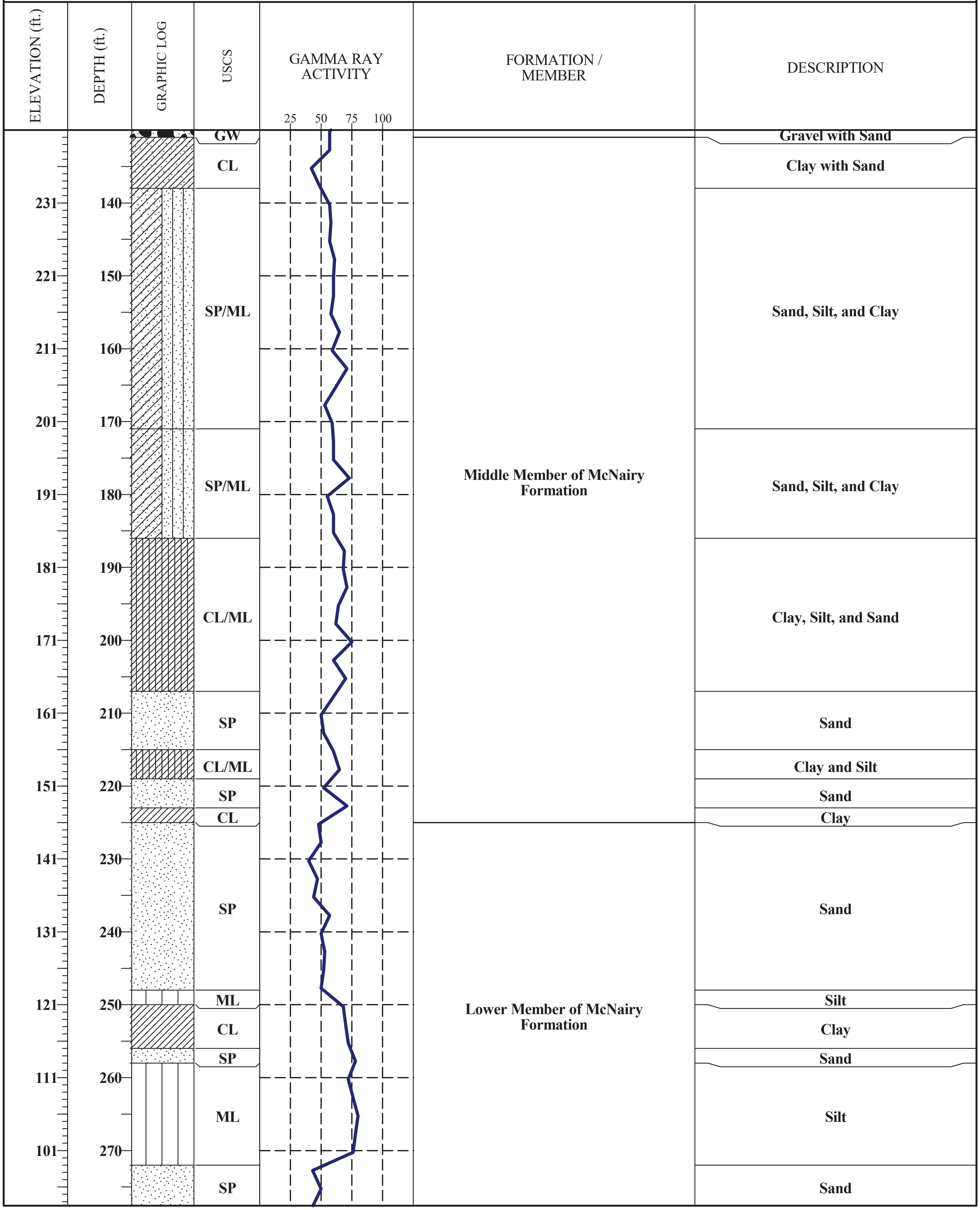
ELEVATION **370.9 ft.**



USCS	FORMATION / MEMBER	DESCRIPTION
ML	Upper Continental Deposits	Silt
CL		Clay
SP		Sand
SP		Sand
ML		Silt
CL		Silty Clay
SP		Sand
ML		Silt
CL		Clay with Sand
SM		Silty Sand
SP		Sand
GW	Lower Continental Deposits	Gravel
SP		Sand
GW		Gravel
SP	Upper Member of McNairy Formation	Sand
ML		Sandy Silt
MH		Silty Clay
CL		Clay

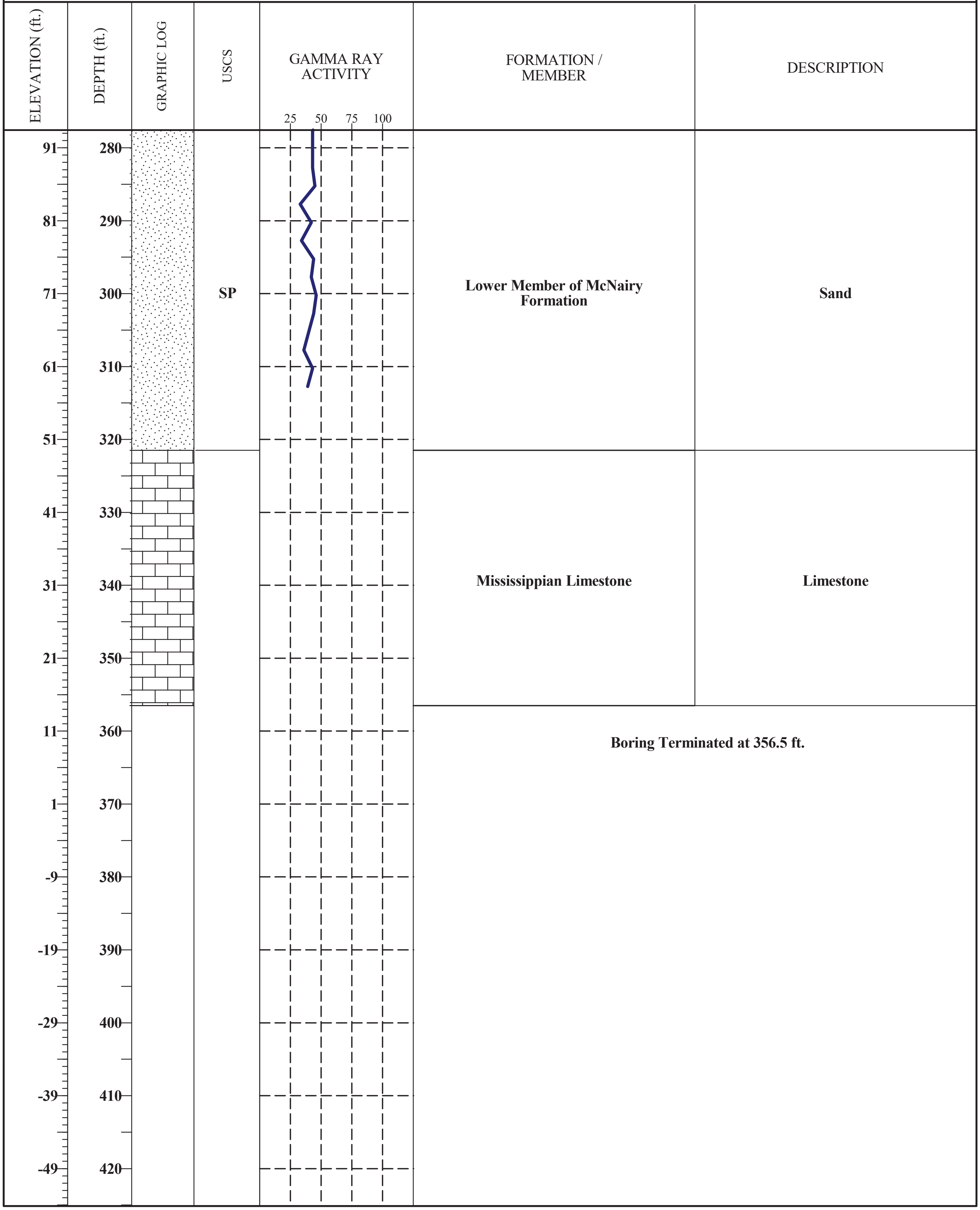
BORING NUMBER Z-16

PAGE 2 OF 3



USCS	FORMATION / MEMBER	DESCRIPTION
GW		Gravel with Sand
CL	Middle Member of McNairy Formation	Clay with Sand
SP/ML		Sand, Silt, and Clay
SP/ML		Sand, Silt, and Clay
CL/ML		Clay, Silt, and Sand
SP		Sand
CL/ML		Clay and Silt
SP		Sand
CL		Clay
SP	Lower Member of McNairy Formation	Sand
ML		Silt
CL		Clay
SP		Sand
ML		Silt
SP		Sand

BORING NUMBER Z-16



APPENDIX E

DIGITAL GAMMA RAY ACTIVITY LOGS FROM THE NORTHEAST PLUME PRELIMINARY CHARACTERIZATION INVESTIGATION (ON CD)

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APPENDIX E

DIGITAL GAMMA RAY ACTIVITY LOGS FROM THE NORTHEAST PLUME PRELIMINARY CHARACTERIZATION INVESTIGATION (DOE 1995) (CD)

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APPENDIX F

REGULATORY COMMENTS AND RESPONSES TO *DETAILED CORRELATIONS BETWEEN LITHOLOGIC UNITS IN THE McNAIRY FORMATION ACROSS THE PADUCAH GASEOUS DIFFUSION PLANT FOR THE U.S. DEPARTMENT OF ENERGY PADUCAH GASEOUS DIFFUSION PLANT SITE, PADUCAH, KENTUCKY*, FRNP-RPT-0249

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From: Weeks, Victor
Sent: Thursday, July 28, 2022 8:08 AM
To: Fountain, Stefanie
Cc: Bonczek, Richard; Dollins, Dave; Davis, Eva; Bentkowski, Ben; McRae, Mac; Begley, Brian (EEC); ; Ahsanuzzaman, Noman
Subject: [EXTERNAL SENDER] RE: Working Draft for MWG Peer Review: Detailed Correlations between Lithologic Units in the McNairy Formation across PGDP

These are the comments developed by TechLaw and presented on behalf of EPA:

TECHNICAL REVIEW OF THE DETAILED CORRELATIONS BETWEEN LITHOLOGIC UNITS IN THE MCNAIRY FORMATION ACROSS THE PADUCAH GASEOUS DIFFUSION PLANT FOR THE U.S. DEPARTMENT OF ENERGY PADUCAH GASEOUS DIFFUSION PLANT SITE, PADUCAH, KENTUCKY, FRNP-RPT-0249

DATED JUNE 2022

PADUCAH GASEOUS DIFFUSION PLANT
PADUCAH, KENTUCKY

The following observation comments were generated based on a low level technical review of the Detailed Correlations Between Lithologic Units in the McNairy Formation Across the Paducah Gaseous Diffusion Plant, Department of Energy Paducah Gaseous Diffusion Plant, Paducah (PGDP), Kentucky, FRNP-RPT-0249, dated June 2022 (the Report).

GENERAL OBSERVATION COMMENTS

1. According to the Report, the primary source area where trichloroethylene (TCE) contamination occurs in groundwater located at PGDP is an unlikely source to contribute significantly to off-site groundwater contamination in the McNairy Formation. However, it is uncertain if the high TCE concentrations (i.e., 10,000 micrograms per liter) in plume areas that are coincident with fault trends located outside the PGDP, and within the Water Policy Box, has the potential to serve as secondary sources contributing to off-site groundwater contamination in the McNairy Formation. For example, according to the information presented on Figure 4 (Interpreted Structural Features in the PGDP Area [Modified from Blits et al, 2008], Page 12), the Northwest Plume is trending with the faulting depicted in the historical figure and both plume and fault trace crosses the Ohio River

2. The Report concludes that a detailed study of the upper-most McNairy Formation in the area of the C-400 Complex determined that faulting is not present locally, which remains an uncertainty and requires further clarification. According to Section 4.3 (Paducah Gaseous Diffusion Plant, Page 10), the assessment of faulting of a site adjacent to the industrial area south of the buried terrace slope using shallow and deep borehole logs and Primary wave and SH-wave seismic reflection surveys indicated no faults were identified in the soil core samples, but the seismic surveys identified a series of normal faults and splays in a near north-south orientation relative to the plant coordinate system. The text states that the faults and splays form a series of narrow horst and graben features or divide the sediments into a series of rotated blocks. Several of the faults extend upwards through the McNairy Formation and the Porters Creek Clay. Seismic studies have not previously been conducted between the east and west fences and from the Porters Creek terrace to north fence. As such, it appears additional lines of evidence, including seismic survey data, are needed to address the

uncertainty in whether faulting is not present in the upper-most McNairy Formation in the area of the C-400 Complex.

3. The rubble zone located below the base of the McNairy Formation appears to thicken to the north, as seen in Figure 7 (North-South cross Section of the McNairy Formation in the Area of the PGDP, Page 20). According to Section 3 (Hydrogeology of the McNairy Formation, Page 6), the *Subsurface Geology and Ground-Water Resources of the Jackson Purchase Region, Kentucky* (Davis, Lambert, and Hansen 1973) suggests that, based on water level data, the Paleozoic rocks and the McNairy Formation act a single, interconnected hydraulic unit. Thus, it is unclear whether the gravel, rubble zone at the base of the McNairy Formation served as a source of drinking water either currently or historically north of the Ohio River.

4. The rubble zone located below the base of the McNairy Formation is not shown on Figure 2 (PGDP Stratigraphy, Page 9). Section 8.1.5 (Rubble Zone, Page 23) describes a thin horizon of cherty gravel and limestone fragments that was encountered in site soil borings and locally termed the "rubble zone," and which commonly occurs between the McNairy Formation and the underlying Mississippian-age limestone bedrock. The rubble zone is depicted in Figure 6 (Comparison of F-08 and MW347 Gamma ray Activity Logs, Page 19), Figure 7 (North-South Cross Section of the McNairy Formation in the Area of PGDP, Page 20), and Figure 8 (East-West Cross Section of the McNairy Formation in the Area of PGDP, Page 21).

5. In Figure 4 (Interpreted Structural Features in the PGDP Area, Page 12), the interpreted fault symbol with red dot is defined in the legend as "showing dip". However, it is noted the dot side of the interpreted fault symbol is intended to show the relative sense of movement and technically indicates the downthrown block or graben and not "dip".

End of TechLaw comments

From my Remedial Project Manager perspective, while there is uncertainty, given the findings in the C-400 area, the risk of McNairy fault controlled high concentration contaminant migration via faulting to the Mississippian bedrock formation is low. Thus, the risk of fault controlled migration is low and acceptable as it relates to groundwater remedy protectiveness determinations in support of the 5-Year Review Addendum.

I would like DOE/FRNP to arrange a meeting to discuss the TechLaw comments presented above and any other comments from other EPA team or KDEP team members produced on or before August 1, 2022.

Victor L. Weeks

U.S. EPA Region 4
Superfund and Emergency Management Division
Superfund Restoration and Site Evaluation Branch
Restoration & DOE Coordination Section
Atlanta Federal Center
61 Forsyth ST
Atlanta, Georgia 30303

Direct: 404-562-9189
Cell: 770-363-8201

Response to U.S. Environmental Protection Agency
Comments Submitted July 28, 2022,
Detailed Correlations between Lithologic Units in the McNairy Formation across the Paducah Gaseous Diffusion Plant,
FRNP-RPT-0249, June 30, 2022

General Comments:

Comment 1: According to the Report, the primary source area where trichloroethylene (TCE) contamination occurs in groundwater located at PGDP is an unlikely source to contribute significantly to off-site groundwater contamination in the McNairy Formation. However, it is uncertain if the high TCE concentrations (i.e., 10,000 micrograms per liter) in plume areas that are coincident with fault trends located outside the PGDP, and within the Water Policy Box, has the potential to serve as secondary sources contributing to off-site groundwater contamination in the McNairy Formation. For example, according to the information presented on Figure 4 (Interpreted Structural Features in the PGDP Area [Modified from Blits et al, 2008], Page 12), the Northwest Plume is trending with the faulting depicted in the historical figure and both plume and fault trace crosses the Ohio River

Response 1: Trichloroethene (TCE) concentrations outside the Paducah Gaseous Diffusion Plant (PGDP) are now significantly diminished below 10,000 micrograms per liter (µg/L). The 2020 TCE Plume Regional Gravel Aquifer map shows the Northwest Plume extraction wells are effectively containing the 1,000 µg/L centroid of the plume. (TCE concentrations outside the PGDP in the Northeast Plume are lower.) Note that the area within Figure 4 does not extend north to the Ohio River. (The Northwest Plume does not cross the Ohio River.) The water feature overlying the Northwest Plume is Little Bayou Creek.

Comment 2: The Report concludes that a detailed study of the upper-most McNairy Formation in the area of the C-400 Complex determined that faulting is not present locally, which remains an uncertainty and requires further clarification. According to Section 4.3 (Paducah Gaseous Diffusion Plant, Page 10), the assessment of faulting of a site adjacent to the industrial area south of the buried terrace slope using shallow and deep borehole logs and Primary wave and SH-wave seismic reflection surveys indicated no faults were identified in the soil core samples, but the seismic surveys identified a series of normal faults and splays in a near north-south orientation relative to the plant coordinate system. The text states that the faults and splays form a series of narrow horst and graben features or divide the sediments into a series of rotated blocks. Several of the faults extend upwards through the McNairy Formation and the Porters Creek Clay. Seismic studies have not previously been conducted between the east and west fences and from the Porters Creek terrace to north fence. As such, it appears additional lines of evidence, including seismic survey data, are needed to address the uncertainty in whether faulting is not present in the upper-most McNairy Formation in the area of the C-400 Complex.

Response 2: Faulting was not evident in the soil cores of the 23 soil borings of the C-400 Complex Remedial Investigation (RI) that penetrated a depth of 50 ft or greater into the McNairy Formation. This interval forms a significant barrier to contaminant migration from the C-400 Complex to the deeper McNairy Formation. Faulting at greater depths in the McNairy Formation remains uncharacterized.

Comment 3: The rubble zone located below the base of the McNairy Formation appears to thicken to the north, as seen in Figure 7 (North-South cross Section of the McNairy Formation in the Area of the PGDP, Page 20). According to Section 3 (Hydrogeology of the McNairy Formation, Page 6), the *Subsurface Geology and Ground-Water Resources of the Jackson Purchase Region, Kentucky* (Davis, Lambert, and

Hansen 1973) suggests that, based on water level data, the Paleozoic rocks and the McNairy Formation act a single, interconnected hydraulic unit. Thus, it is unclear whether the gravel, rubble zone at the base of the McNairy Formation served as a source of drinking water either currently or historically north of the Ohio River.

Response 3: The Rubble Zone may be a source of drinking water north of the Ohio River. The McNairy Formation and Mississippian-age limestone are sources of drinking water. The PGDP monitors three deep monitor wells that are screened in the lower McNairy Formation and the underlying Rubble Zone (MW345, MW346, and MW347).

Comment 4: The rubble zone located below the base of the McNairy Formation is not shown on Figure 2 (PGDP Stratigraphy, Page 9). Section 8.1.5 (Rubble Zone, Page 23) describes a thin horizon of cherty gravel and limestone fragments that was encountered in site soil borings and locally termed the "rubble zone," and which commonly occurs between the McNairy Formation and the underlying Mississippian-age limestone bedrock. The rubble zone is depicted in Figure 6 (Comparison of F-08 and MW347 Gamma ray Activity Logs, Page 19), Figure 7 (North-South Cross Section of the McNairy Formation in the Area of PGDP, Page 20), and Figure 8 (East-West Cross Section of the McNairy Formation in the Area of PGDP, Page 21).

Response 4: Agree that the Rubble Zone is missing from Figure 2. The figure has been revised.

Comment 5: In Figure 4 (Interpreted Structural Features in the PGDP Area, Page 12), the interpreted fault symbol with red dot is defined in the legend as "showing dip". However, it is noted the dot side of the interpreted fault symbol is intended to show the relative sense of movement and technically indicates the downthrown block or graben and not "dip".

Response 5: The symbol is incorrectly defined. It does demark the downthrown block. The figure has been revised.

Comment 6: (Victor Weeks) From my Remedial Project Manager perspective, while there is uncertainty, given the findings in the C-400 area, the risk of McNairy fault controlled high concentration contaminant migration via faulting to the Mississippian bedrock formation is low. Thus, the risk of fault controlled migration is low and acceptable as it relates to groundwater remedy protectiveness determinations in support of the 5-Year Review Addendum.

Response 6: The C-400 Complex RI provides high confidence that faulting is not present in the upper 50 ft of the McNairy Formation beneath the C-400 Cleaning Building.

From: Begley, Brian (EEC)
Sent: Monday, August 1, 2022 8:42 PM
To: Fountain, Stefanie; Dollins, Dave; Bonczek, Richard; 'SFountain@Geosyntec.com'; 'DTripp@Geosyntec.com'; Ford, Bruce; Davis, Ken; Clayton, Bryan; Powers, Todd; White, Jana; Clauberg, Martin (PPPO/CONTR); Taylor, Tracy (PPPO/CONTR); Stearns, Bruce (PPPO/CONTR); Duncan, Tracey; Garner, Nathan (CHFS DPH); 'Hampson, Steve'; Brock, Stephanie C (CHFS DPH); 'Bentkowski, Ben'; 'Ahsanuzzaman, Noman'; 'Davis, Eva'; 'Mac.McRae@TechLawInc.com'; Crabtree, Lisa; 'Weeks, Victor'; Flynn, Robert; Travis, Christopher (EEC); Lainhart, Brian (EEC); Tarantino, Joe; 'Steven Hampson'; Garner, LeAnne; 'Fisher, Anna Brodie'; 'dcnorman0@tva.gov'; Meadows, Bruce; Schaffer, Bart (EEC); Clark, Evan; 'Kristan.Avedikian@TechLawInc.com'; 'Quinn, James Roy III'; 'Thomas, Paul Robinson'; Bonczek, Richard; 'Esther, Tabitha'; Buckhalter, Austin; Orr, Jason D
Subject: [EXTERNAL SENDER] Re: Working Draft for MWG Peer Review: Detailed Correlations between Lithologic Units in the McNairy Formation across PGDP

Stefanie, Rich & GW Modeling Team,
KDEP acknowledges the conclusions and uncertainties expressed in the *Detailed Correlations between Lithologic Units in the McNairy Formation across the Paducah Gaseous Diffusion Plant* [FRNP-RPT-0249] white paper. These include the lack of evidence of faulting within the C-400 Complex OU boundary and the lack of evidence indicating that TCE contamination is likely to contribute significantly to off-site contamination by way of transport within the McNairy Formation. With that being said, KDEP asserts that faulting within the McNairy Formation remains an uncertainty for the Paducah Site, specific to the Limited Area. This assertion is based on several factors, including a nearby seismic study conducted that concluded 30-45 ft of displacement within the McNairy Formation is present, as well as anecdotal evidence from multiple sources, like the SW to NE groundwater plume trajectories and their orientation with the NE to SW trending faults that are present a few miles north in Illinois. KDEP recommends that seismic surveys conducted within the Limited Area will reduce uncertainty with faulting concerns regarding the McNairy Formation.

Thanks,
Brian Begley, PG
Registered Geologist Supervisor
KY Federal Facilities Agreement Manager
Energy and Environment Cabinet
Division of Waste Management
Hazardous Waste Branch
Paducah Gaseous Diffusion Plant Section
300 Sower Blvd., Frankfort, KY 40601
KY Paducah Site Section Web Page
Brian.Begley @ KY.GOV
office: (502) 782-6317
mobile: (502) 229-4703

Response to Kentucky Division of Waste Management Comments Submitted August 1, 2022, *Detailed Correlations between Lithologic Units in the McNairy Formation across the Paducah Gaseous Diffusion Plant*, FRNP-RPT-0249, June 30, 2022

General Comments:

Comment 1: KDEP acknowledges the conclusions and uncertainties expressed in the *Detailed Correlations between Lithologic Units in the McNairy Formation across the Paducah Gaseous Diffusion Plant* [FRNP-RPT-0249] white paper. These include the lack of evidence of faulting within the C-400 Complex OU boundary and the lack of evidence indicating that TCE contamination is likely to contribute significantly to off-site contamination by way of transport within the McNairy Formation.

Response 1: Both the C-400 Complex RI and the assessment of McNairy stratigraphy in PGDP's deep soil borings support a conclusion that faulting does not enhance contaminant migration from the C-400 Complex.

Comment 2: With that being said, KDEP asserts that faulting within the McNairy Formation remains an uncertainty for the Paducah Site, specific to the Limited Area. This assertion is based on several factors, including a nearby seismic study conducted that concluded 30-45 ft of displacement within the McNairy Formation is present, as well as anecdotal evidence from multiple sources, like the SW to NE groundwater plume trajectories and their orientation with the NE to SW trending faults that are present a few miles north in Illinois.

Response 2: The presence of faulting remains an uncertainty below the C-400 Complex at depths greater than 50 ft in the McNairy Formation and elsewhere in the McNairy Formation at the Paducah Site.

Comment 3: KDEP recommends that seismic surveys conducted within the Limited Area will reduce uncertainty with faulting concerns regarding the McNairy Formation.

Response 3: Seismic surveys are a common method for assessing the presence of faulting. Additional/alternative investigative approaches may be needed to reduce uncertainty regarding faulting and to assess contaminant migration.

APPENDIX G

COMPARISON OF REGIONAL GROUNDWATER FLOW PRE- AND POST-CONSTRUCTION AND OPERATION OF OLMSTED LOCKS AND DAM, FRNP-RPT-0260

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FRNP-RPT-0260

Comparison of Regional Groundwater Flow Pre- and Post-Construction and Operation of Olmsted Locks and Dam

FOUR RIVERS
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FRNP-RPT-0260

Comparison of Regional Groundwater Flow Pre- and Post-Construction and Operation of Olmsted Locks and Dam

Date Issued—February 2023

U.S. DEPARTMENT OF ENERGY
Office of Environmental Management

Prepared by
FOUR RIVERS NUCLEAR PARTNERSHIP, LLC,
managing the
Deactivation and Remediation Project at the
Paducah Gaseous Diffusion Plant
under Contract DE-EM0004895

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ACRONYMS

amsl	above mean sea level
DOE	U.S. Department of Energy
DQO	data quality objective
GWSP	groundwater strategy project
HU	hydrogeologic unit
MW	monitoring well
MWG	modeling working group
PGDP	Paducah Gaseous Diffusion Plant
RGA	Regional Gravel Aquifer
TVA	Tennessee Valley Authority
UCRS	Upper Continental Recharge System
USGS	United States Geological Survey

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EXECUTIVE SUMMARY

The Olmsted Locks and Dam (Olmsted Dam) were constructed to regulate the surface water elevation in the Ohio River by the U.S. Army Corps of Engineers and were put into service on September 6, 2018. This evaluation is based on a comparison of synoptic groundwater level measurements (referred to herein as synoptic events), precipitation records, and Ohio River elevations collected from September 2013 to February 2022. The comparisons of the various data and subsequent conclusions presented in this report are intended to be used for consideration when the Paducah Site groundwater model is updated.

Analysis of the groundwater elevation data showed spatial and temporal changes of groundwater flow at the Paducah Site. Based on an evaluation of historical potentiometric surface maps, steady groundwater elevations were observed in monitoring wells (MWs) during low river water elevations. This results in a consistent groundwater gradient between the Regional Gravel Aquifer (RGA) wells and the Ohio River and indicates flow from the Paducah Gaseous Diffusion Plant (PGDP) toward the Ohio River. Most of the time, hydraulic gradients generally increased toward the Ohio River and groundwater discharged from the RGA to the river. The pattern of groundwater elevation fluctuations in MWs generally mimics Ohio River surface water elevation fluctuations although the magnitude of the groundwater elevation fluctuations generally decreases with distance from the river. Due to storage capacity in the aquifer, the amplitude of the groundwater fluctuations is lower than the amplitude of the Ohio River surface water fluctuations.

After Olmsted Dam began operation in September 2018, the minimum elevation of the Ohio River increased to approximately 295 ft to 300 ft above mean sea level. When the Ohio River water level increased to the level of the RGA potentiometric surface north of PGDP, the RGA hydraulic gradient declined near the river and at PGDP. MWs located closer to the river fluctuated by as much as 7 ft while MWs located further from the river fluctuated by approximately 4 ft. When the Ohio River elevation rose above the RGA potentiometric surface, the Ohio River recharged the RGA; however, this groundwater flow reversal lasted for a short duration (e.g., January and February 2019). Increased river elevation consistently resulted in decreased hydraulic gradients.

Hydraulic gradients calculated between an equipotential surface in the northern part of the RGA and the Ohio River elevation were compared to evaluate the impact of the Olmsted Dam operation on groundwater. Groundwater elevation data collected from the same season (August and September) were evaluated. A statistically significant difference was calculated when comparing hydraulic gradient values from the pre-Olmsted Dam operation with hydraulic gradient values from post-Olmsted Dam operation. The mean hydraulic gradient of 0.005 ft/ft observed between the Ohio River and MWs in the northern part of the RGA before the dam operation declined to a mean gradient of 0.004 ft/ft after the dam operation. The lower hydraulic gradient after operation of the dam is attributed to the increase in river water elevation. Lower hydraulic gradient implies lower groundwater flow velocity, which consequently results in slower flow of groundwater.

Although no regional changes in groundwater flow direction due to operations of the Olmsted Dam are observed, an increase in river water elevation after operation of the Olmsted Dam created a decline in hydraulic gradient between the Ohio River and MWs located north of PGDP. Based on the findings of this evaluation, the use of the pre- and post-operation Olmsted Dam datasets are available (and appropriate) for groundwater model calibration; however, predictive modeling should be limited to Olmsted Dam post-operation conditions.

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1. INTRODUCTION

As part of the 2016 Sitewide Groundwater Model Update and as discussed by the Paducah Gaseous Diffusion Plant (PGDP) Site Groundwater Modeling Working Group (MWG) during the group quarterly meetings, the MWG identified the following recommendation related to a future sitewide groundwater model update (DOE 2017):

> The Olmsted Locks and Dam are scheduled to be operational in 2018. At that time, the lowest Ohio River stage at PGDP will be the upper pool height of the dam, 302 ft amsl. Seasonally low river stages at PGDP effectively will be increased 7 ft to 12 ft. Future groundwater modeling should consider evaluation of the calibrated model using a synoptic data set collected under steady conditions at the higher river stage anticipated to start in 2018.

This recommendation has been integrated into the Paducah Site[1] Groundwater Strategy Project (GWSP) as Activity 14 (FRNP 2021). The GWSP defined one of the primary tasks for Activity 14 as the collection of water level measurements to understand the impact to the plumes in response to the change in operations at the Olmsted Locks and Dam (Olmsted Dam).

This white paper documents the comparison of the synoptic groundwater level measurements (referred to herein as synoptic events) performed at the Paducah Site prior to and after operation of the Olmsted Dam, in conjunction with Ohio River water elevations and precipitation data, to provide an understanding of the impact, if any, of the operation of the Olmsted Dam on regional groundwater flow patterns at the Paducah Site. Based on the comparison, this white paper also provides a recommendation that the use of the pre- and post-operation Olmsted Dam datasets are available (and appropriate) for groundwater model calibration; however, predictive modeling should be limited to Olmsted Dam post-operation conditions.

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[1] References in this white paper to the Paducah Site generally mean the property, programs, and facilities at or near PGDP for which U.S. Department of Energy (DOE) has ultimate responsibility.

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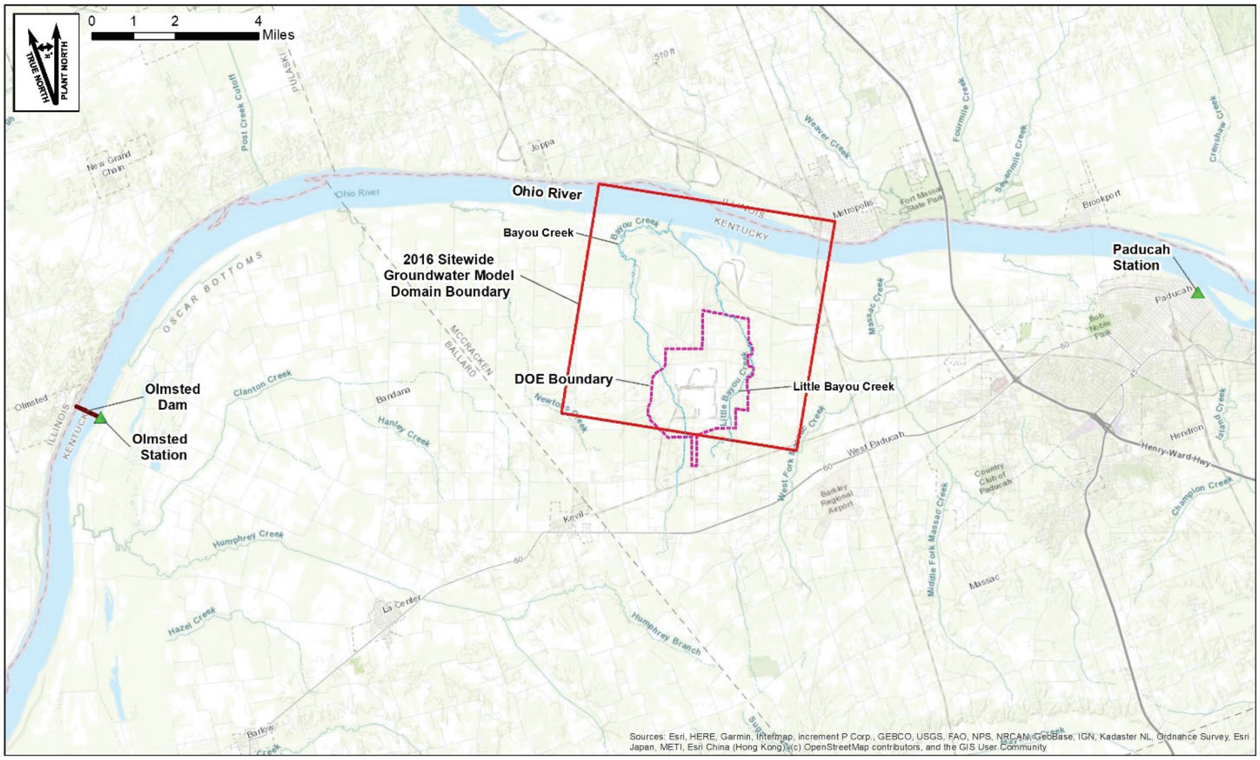
2. BACKGROUND

The DOE Paducah Site is located in a generally rural area of McCracken County, Kentucky, 10 miles west of Paducah, Kentucky, and 3.5 miles south of the Ohio River. The U.S. Geological Survey (USGS) maintains two Ohio River stations in the vicinity of the Paducah Site: USGS 03611000 Ohio River at Paducah, KY (Paducah Station) located approximately 8 miles east of the 2016 Sitewide Groundwater Model domain (model domain), and USGS 03612600 Ohio River at Olmsted, IL (Olmsted Station), located approximately 14 miles west of the model domain (Figure 1). The Olmsted Dam is also located approximately 14 miles downstream of the model domain, just downstream of the Olmsted Station.



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Figure 1. Location of the Olmsted Dam, Paducah Station, and Olmsted Station in Relation to the Paducah Site and the 2016 Sitewide Groundwater Model Domain Boundary

2.1. CLIMATE

The Paducah Site is located in the humid continental zone where summers are warm (July averages 79°F) and winters are moderately cold (January averages 34°F) (NOAA 2022). Historical yearly precipitation averages about 47.5 inches (NOAA 2022). The prevailing wind is from the south-southwest at approximately 10 miles per hour.

2.2. SURFACE WATER DRAINAGE

The Paducah Site is situated in the western part of the Ohio River Basin. The confluence of the Ohio River with the Tennessee River is about 15 miles upstream of the Paducah Site, and the confluence of the Ohio River with the Mississippi River is about 35 miles downstream. The Paducah Site is located on a local drainage divide. Surface water from the east side of the plant flows east-northeast toward Little Bayou Creek, and surface water from the west side of the Paducah Site flows west-northwest toward Bayou Creek, a perennial stream that flows toward the Ohio River along a nine-mile course. Little Bayou Creek is an intermittent stream that flows north toward the Ohio River along a seven-mile course. The two creeks converge three miles north of the Paducah Site before emptying into the Ohio River. Approximately two miles north of the plant, the lower reaches of Bayou Creek and Little Bayou Creek are hydraulically connected to the Regional Gravel Aquifer (RGA). Flooding in the area is associated with Bayou Creek, Little Bayou Creek, and the Ohio River.

Olmsted Dam was constructed to regulate the minimum surface water elevation in the Ohio River and began operation on September 6, 2018. Prior to operation of the dam, the Ohio River water elevation between the Paducah Station and the Olmsted Station in the vicinity of the Paducah Site was not locally constrained at Olmsted Station and fluctuated in response to precipitation. The Ohio River elevation in the vicinity of the Paducah Site was estimated as the average of the Paducah Station and Olmsted Station river water elevations. River elevation data collected from January 1, 2015, through April 5, 2022, was used to evaluate the river water elevation fluctuations. Prior to operation of the Olmsted Dam on September 6, 2018, the water elevation in the vicinity of the Paducah Site fluctuated between 290 ft above mean seal level (amsl) and 333 ft amsl.

Since becoming operational, the Olmsted Dam regulates the Ohio River to maintain a minimum water elevation at Olmsted Station of approximately 295 ft to 300 ft amsl (Byrne 2020). Following operation of the Olmsted Dam beginning September 6, 2018, and through April 5, 2022, the Ohio River elevation in the vicinity of the Paducah Site fluctuated between 296 ft amsl and 335 ft amsl.

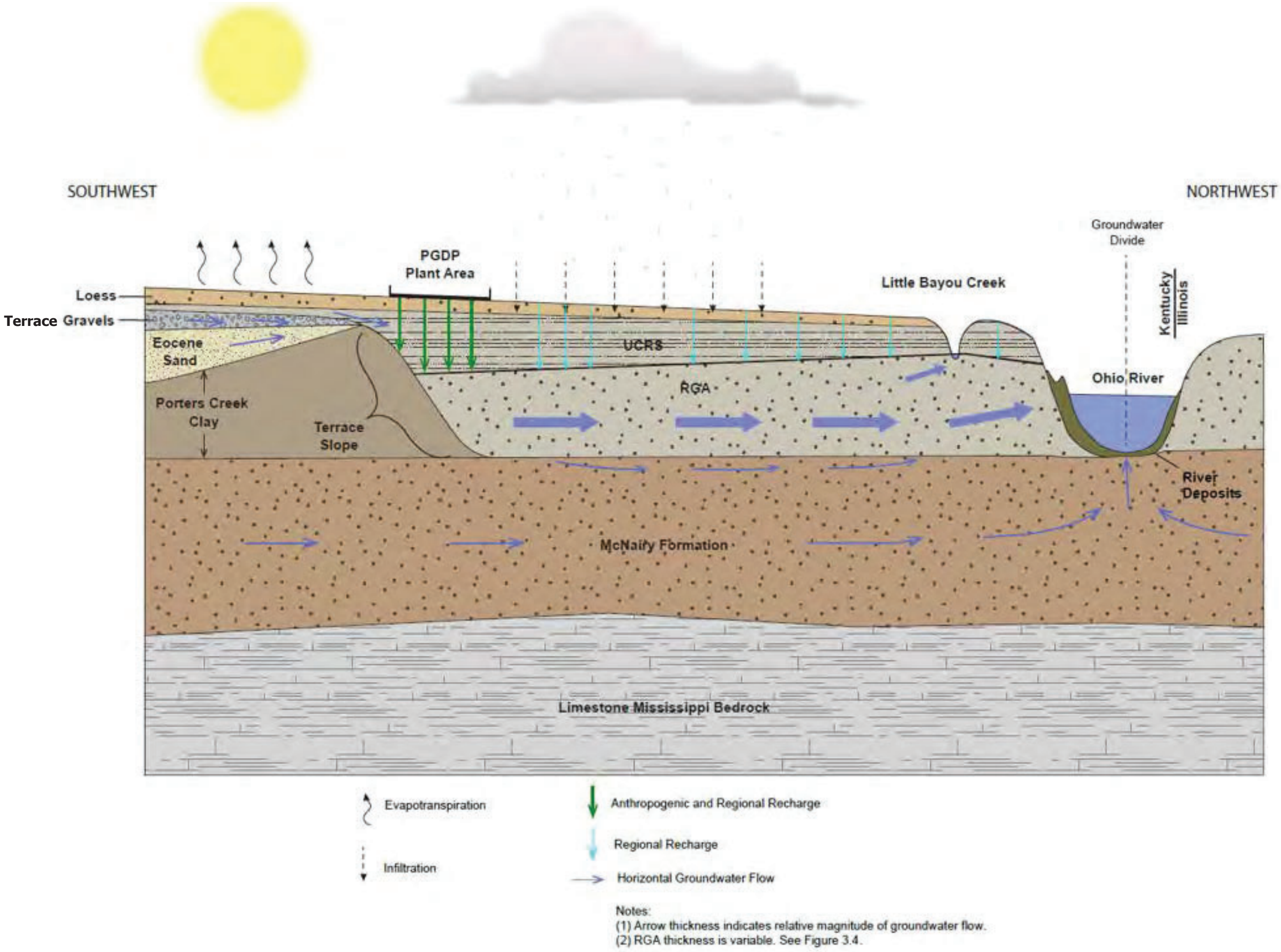
Due to hydraulic connection between the river and the RGA beneath the Paducah Site, river water level fluctuations may influence groundwater flow in the RGA beneath the Paducah Site.

2.3. GEOLOGIC AND HYDROGEOLOGIC SETTING

The local groundwater flow systems at the Paducah Site (Figure 2) include the following (from shallowest to deepest): (1) the Terrace Gravels flow system, (2) Upper Continental Recharge System (UCRS), (3) RGA, and (4) the McNairy flow system. Additional water-bearing zones monitored at the Paducah Site are the Eocene Sands and the Rubble Zone (i.e., the weathered upper portion of the Mississippian bedrock).

At depth beneath the Paducah Site, Cretaceous marine sediments of the Mississippian Embayment, comprising the McNairy Formation, unconformably overlie Mississippian-age carbonate bedrock. Buried Pleistocene fluvial deposits of the ancestral Tennessee River, in turn, unconformably overlie the Cretaceous marine sediments directly beneath and north of PGDP. The Pleistocene fluvial deposits in contact with the marine sediments (the McNairy Formation) consist of a gravel unit that ranges in thickness from 30 ft to 50 ft, with the top of the unit encountered at a general depth of 60 ft below ground surface at PGDP. This gravel unit is the primary member of the uppermost aquifer, the RGA, beneath the PGDP area and north to the Ohio River. The RGA pinches out to the south, southeast, and southwest along the buried slope of the Porters Creek Clay Terrace, which is overlain to the south by the Terrace Gravels flow system. The UCRS overlies the RGA and Terrace Gravels. Figure 2 presents a conceptual site model with local stratigraphy and groundwater flow directions (DOE 2017).

Groundwater flow originates south of the Paducah Site within the Eocene Sands and the Terrace Gravels. Groundwater within the Terrace Gravels discharges to local streams and recharges the RGA through infiltration through the UCRS (north of the Porters Creek Clay). Groundwater flow through the UCRS predominantly is downward, also recharging the RGA. From PGDP, groundwater generally flows



Notes:
(1) Arrow thickness indicates relative magnitude of groundwater flow.
(2) RGA thickness is variable. See Figure 3.4.

Adapted from: *2016 Update of the Paducah Gaseous Diffusion Plant Sitewide Groundwater Flow Model* (DOE/LX/07-2415&D2)—July 2017

Figure 2. Conceptual Site Model

northward in the RGA toward the Ohio River, which is the local base level for the system. Flow in the McNairy Formation beneath the Paducah Site also is northward to discharge into the Ohio River.

Hydrogeologic units (HUs) at the Paducah Site are divided into hydrostratigraphic units to explain local groundwater flows (Moore and Clausen 1997). The following is a list of the HUs:

- HU1 (UCRS): loess that covers the entire site;
- HU2 (UCRS): discontinuous sand and gravel lenses in a clayey silt matrix;
- HU3 (UCRS): relatively impermeable clay layer that acts as the confining layer for the RGA. The composition varies from clay to sand but is mostly clay or silt;
- HU4 (RGA): generally continuous sand unit with a clayey silt matrix; this unit is in hydraulic connection with HU5 and is a part of the RGA; and
- HU5 (RGA): gravel, sand and silt. This is the primary pathway for groundwater transport and is the uppermost aquifer in the area of the PGDP.

The horizontal hydraulic conductivities of the sands in HU2 and HU4 are typically two orders of magnitude or larger than those of the clays and silts in HU1 and HU3 (Clausen et al. 1992). Although the sand lenses within the UCRS are laterally extensive, they are not continuous beneath the Paducah Site and decrease in frequency toward the Ohio River. Lateral heterogeneity also exists within each hydrostratigraphic unit. Groundwater flow in the UCRS is primarily vertical (Clausen et al. 1992). The horizontal flow component within the UCRS occurs mostly in the coarser grained deposits of HU2.

The RGA is the main conduit for groundwater flow to the north, where groundwater discharges to Bayou Creek, Little Bayou Creek, and the Ohio River. The RGA has a predominantly horizontal flow, and the dominant control on the hydraulic potential field of the RGA is the Ohio River water elevation. In addition, the groundwater pump-and-treat systems in the Northeast Plume and Northwest Plume form local cones of depression in the RGA groundwater elevations. Hydraulic gradients generally increase toward the Ohio River when the river water elevation is lower than the aquifer. When the Ohio River elevation is higher than the potentiometric surface of the RGA, a short-term flow reversal occurs from the river into the northernmost part of the RGA (Clausen et al. 1995, Moore and Clausen 1997). When the Ohio River level drops, water moves back from the aquifer into the river.

3. TECHNICAL APPROACH

3.1. DATA SETS

The following data were used in the evaluation presented in this white paper.

- Groundwater elevation data was gathered from the synoptic events prior to Olmsted Dam operation.[2]

  - September 2013
  - September/October 2014
  - September 2015
  - August 2016
  - August 2017
  - August 2018

- Groundwater elevation data was gathered from the synoptic events following Olmsted Dam operation.

  - October through December (monthly) 2018
  - January through December (monthly) 2019
  - August and November 2020
  - February, May, August, and November 2021
  - February 2022

- Ohio River water elevation data from the Olmsted Station and the Paducah Station for 2013–2022 and 2014–2022 respectively, was obtained from the USGS National Water Information System from April 12, 2022, to April 28, 2022, and is typically reported in 15-minute intervals (USGS 2022). Because the Paducah Site is located between the two stations, the average river water elevations of the two stations were used to generate the potentiometric maps in order to represent the elevation of the Ohio River downgradient of PGDP. Ohio River elevation data is also available from a river gauge located at Tennessee Valley Authority's (TVA's) Shawnee Fossil Plant. The TVA river gauge data consists of a single measurement recorded during the synoptic events. Correlation of the average USGS data for the two stations with the TVA river gauge data indicate a high level of agreement between the two data sets (Table 1 and Figure 3). The correlation between the average USGS data and the TVA gauge data indicate that the use of the average USGS data between the two stations are appropriate for this evaluation. Additionally, the USGS data are available for the entire time period of interest in this evaluation and for the full duration of each synoptic event.

- Precipitation data from 2013 to 2022 was obtained for the Paducah Barkley Regional Airport weather station on April 23, 2022 (Meteostat 2022).

Groundwater pumping rate data from the PGDP Northeast Plume Containment System, the Northwest Plume Groundwater System, or from off-site properties, were not explicitly included in the data analysis; however, the pumping rate data are reflected in the synoptic event data when the extraction wells were operational during the synoptic events.

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[2] Synoptic water level data sets are available for 2013, 2014, and 2015; however, potentiometric maps were not finalized or published previously and, as such, are not included in Appendix B.

Table 1. Comparison of the Ohio River Elevations Measured at TVA's Shawnee Fossil Plant and Calculated as Average of the Elevations Measured at Olmsted and Paducah USGS Stations

Date	TVA Gauge (ft amsl)	USGS Olmsted—Paducah Station Average (ft amsl)
2/22/2021	303.40	303.30
5/24/2021	298.80	299.30
8/25/2021	301.18	301.80
11/16/2021	300.40	300.70
2/23/2022	320.21	318.00
5/25/2022	303.40*	302.15
8/22/2022	301.50	301.64
11/15/2022	300.55	299.75

*Note: Ohio River elevation data collected outside the duration of synoptic water level measurement event.

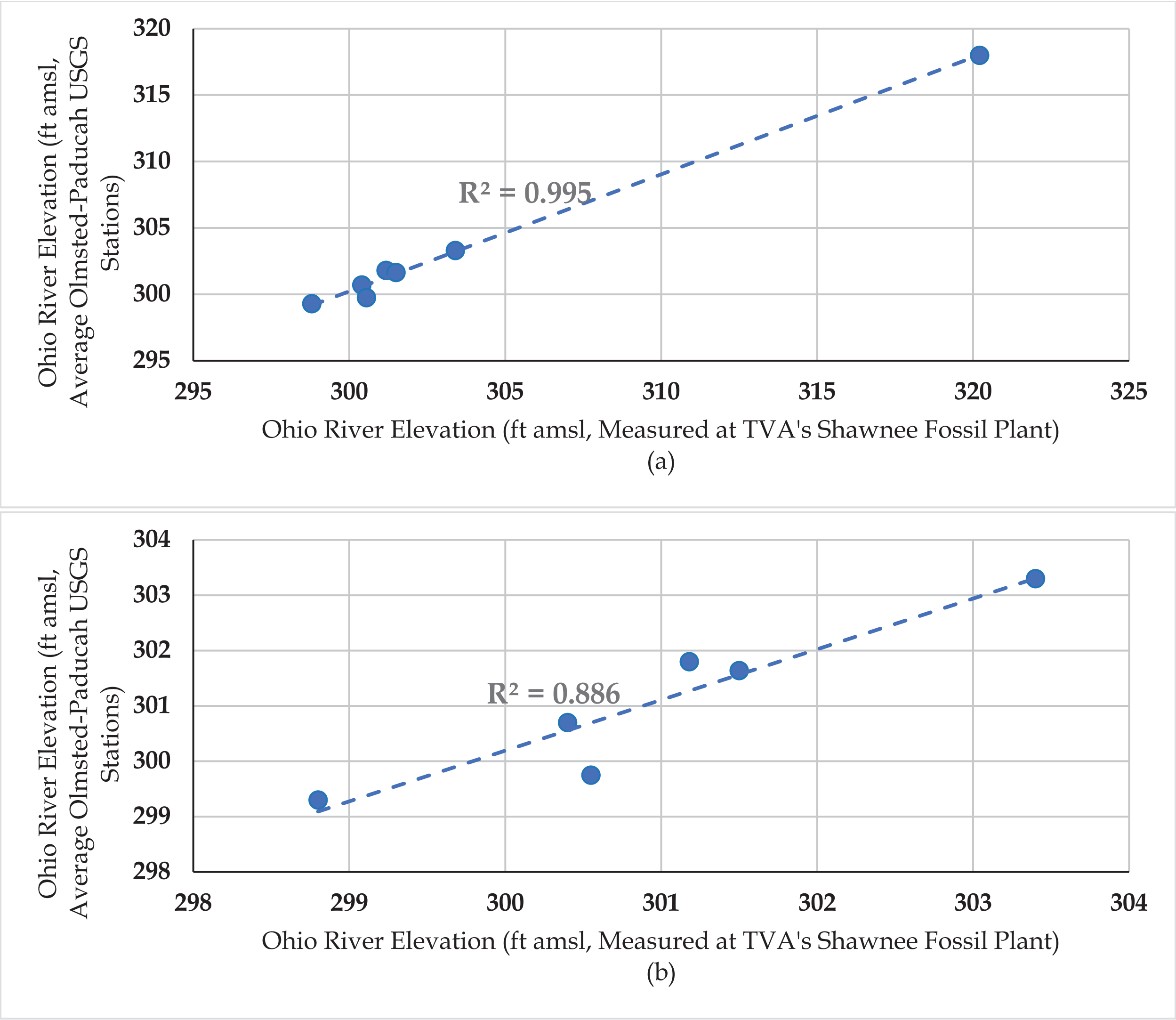

Figure 3. Correlation between Ohio River Elevation Measured at TVA's Shawnee Fossil Plant and Average Olmsted-Paducah USGS Stations [(a) Correlation Using Available Data Including High Ohio River Elevation in February 2022; (b) Correlation Not Including High Ohio River Elevation in February 2022]

3.2. WHITE PAPER DATA QUALITY OBJECTIVES

The data quality objective (DQO) process is a planning tool that is based on the scientific method used to identify an environmental problem and then define the data collection process needed to support decisions regarding that problem (EPA 2006). The steps outlined in the DQO process (Table 2) have been used to develop the scope of this white paper. The DQO steps formulate a set of criteria to minimize uncertainty, which allows for conclusions to be made with the highest confidence possible. The DQOs for this white paper are derived and adapted from the GWSP Activity 14 DQOs.

Table 2. White Paper Data Quality Objectives

<table>
<tr><td>1. State the Problem</td><td colspan="2">Prior groundwater modeling results have indicated uncertainty in how operational changes at Olmsted Dam may affect site groundwater.</td></tr>
<tr><td>2. Identify the Decision</td><td colspan="2">Are additional data related to the operation of the Olmsted Dam required to update the groundwater model?</td></tr>
<tr><td>3. Identify Inputs to the Decision</td><td colspan="2">• Ohio River water elevations
• Groundwater level measurements from synoptic events
• Precipitation data</td></tr>
<tr><td>4. Define the Study Boundaries</td><td>• Spatial: Paducah Site
• Temporal: 2013–2021</td><td>• Regulatory:
— Groundwater MWG
— GWSP</td></tr>
<tr><td>5. Develop a Decision Rule</td><td colspan="2">IF changing operations at Olmsted Dam result in different groundwater flow patterns at the Paducah Site (during low river water elevation) from what the groundwater model currently employs in such a way as to change the model outputs, THEN define actions to update the groundwater model.</td></tr>
<tr><td>6. Specify Limits on Decision Errors</td><td colspan="2">• Groundwater flow gradients during low river water elevation before and after Olmsted Dam operation
• Groundwater flow direction during low river water elevation before and after Olmsted Dam operation</td></tr>
<tr><td>7. Optimize the Design for Obtaining Data</td><td colspan="2">• A synoptic data set collected under steady conditions during post-Olmsted Dam operation
• Develop/review/revise conceptual model</td></tr>
</table>

3.3. DATA ADEQUACY

The available synoptic measurement events between 2013 and 2018 and prior to the operation of the Olmsted Dam occurred during the months of August and September each year, during historically drier months of the year, and when the Ohio River water elevations were typically low (Table 3, Figures 4 through 9); however, synoptic events performed post-operation of the Olmsted Dam include both historically wetter and drier months of the year which resulted in both high and low river elevations (Figures 10 through 14).[3] Figure 14 depicts the synoptic gauging events from 2013 to 2022 along with the 90-day running average precipitation and river stages measured at both the Paducah and the Olmsted stations.

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[3] For the purposes of this evaluation, based on visual review of long-term Ohio River water elevation data in Figure 14, low river conditions are characterized as having an Ohio River water elevation of less than 305 ft amsl at the Paducah Station.

Table 3. Summary of Ohio River Water Elevations for Synoptic Event Dates

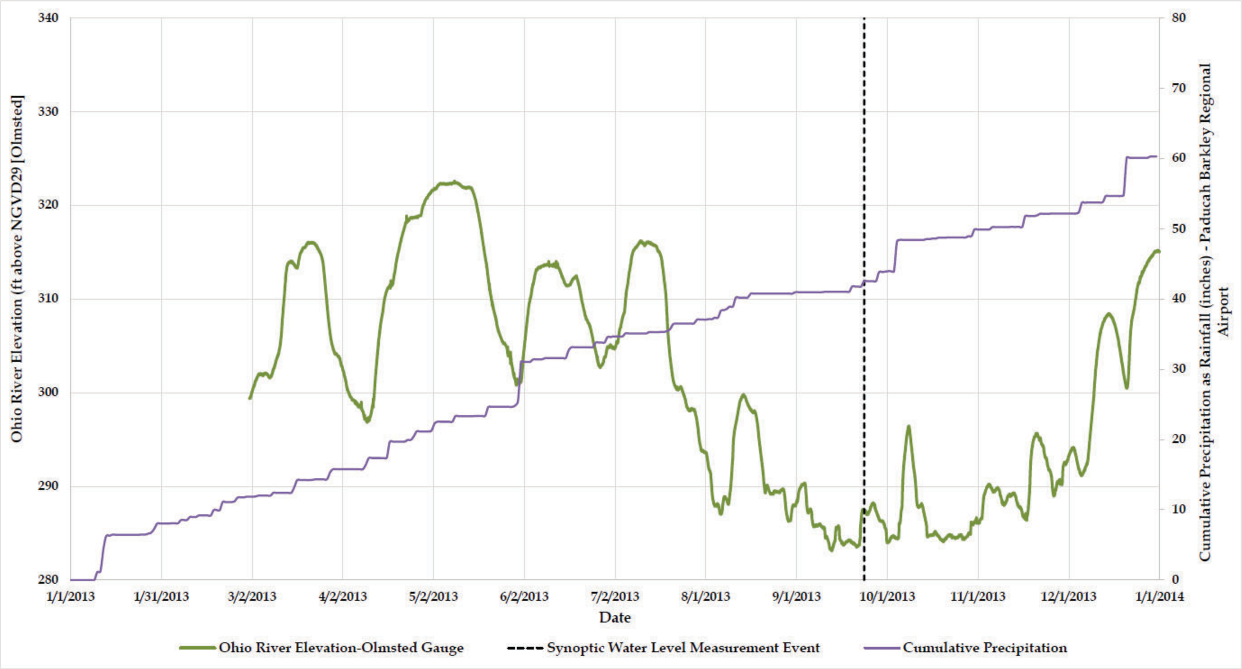
Synoptic Event	Event Date(s)	Ohio River Water Elevation (ft amsl)			Ohio River Water Level Designation[d]
		Olmsted Station[a]	Paducah Station[a]	Average[b]	
Pre-Olmsted Dam Operation					
September 2013	9/24/2013	287.2	NA	NA	Low
September 2014	9/29/2014–10/1/2014	288.44	302.06	295.25[b]	Low
September 2015	9/1/2015–9/2/2015	285.97	301.71	293.84[b]	Low
August 2017	8/28/2017	291.19	301.65	296.42[c]	Low
August 2018	8/20/2018–8/21/2018	293.13	302.63	297.88[c]	Low
Post-Olmsted Dam Operation (Minimum water elevation of approximately 295 ft amsl at Olmsted Station)					
October 2018	10/10/2018 – 10/11/2018	303.97	307.30	305.63	Mid
November 2018	11/7/2018	311.33	316.19	313.76	Mid
December 2018	12/5/2018	313.49	319.21	316.35	Mid
January 2019	1/9/2019	322.09	328.75	325.42	High
February 2019	2/13/2019	323.11	330.23	326.67	High
March 2019	3/13/2019	326.36	333.41	329.89	High
April 2019	4/2/2019	315.54	317.86	316.70	Mid
May 2019	5/8/2019	321.71	323.90	322.80	Mid
June 2019	6/5/2019	317.94	319.36	318.65	Mid
July 2019	7/3/2019	321.37	323.69	322[b]	Mid
August 2019	8/12/2019–8/15/2019	300.28	301.94	301.11[c]	Low
September 2019	9/4/2019	300.57	301.82	301.19	Low
October 2019	10/10/2019	300.70	301.80	301.25	Low
November 2019	11/7/2019	305.58	307.86	306.72	Mid
December 2019	12/16/2019–12/18/2019	307.36	313.15	310.26	Mid
August 2020	8/24/2020–8/26/2020	300.82	302.14	301.48[c]	Low
November 2020	11/11/2020–11/12/2020, 11/16/2020	299.74	302.63	301.19[c]	Low
February 2021	2/22/2021–2/24/2021	300.26	307.40	303.83[c]	Low
May 2021	5/24/2021–5/27/2021	298.67	300.49	299.58[c]	Low
August 2021	8/23/2021–8/25/2021	299.03	304.84	301.93[c]	Low
November 2021	11/15/2021—11/18/2021	299.71	301.70	300.70[c]	Low
February 2022	2/21/2022–2/23/2022	314.56	321.57	318.06[c]	Mid

[a] Average water elevation for the date of the synoptic event.

[b] Average of the average Olmsted Station and average Paducah Station water elevations for the date of the synoptic event.

[c] Ohio River water elevation included on potentiometric map.

[d] Ohio River water level designations are based on historic observations. Low is designated as less than 305 ft, high as greater than 325 ft, and mid as greater than 305 ft but less than 325 ft.



Note: Ohio River water elevation data from the Paducah Station for 2013 were not available.

Figure 4. Ohio River Hydrographs, Cumulative Precipitation, and Water Level Measurement Events—2013

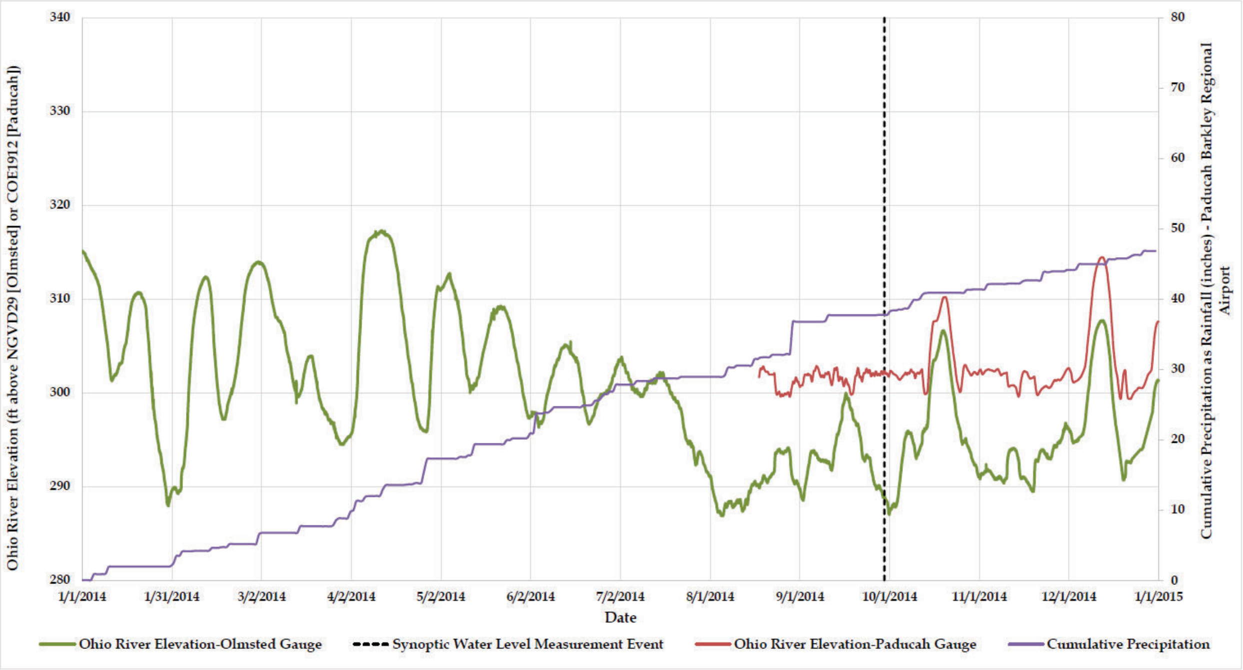


Figure 5. Ohio River Hydrographs, Cumulative Precipitation, and Water Level Measurement Events—2014

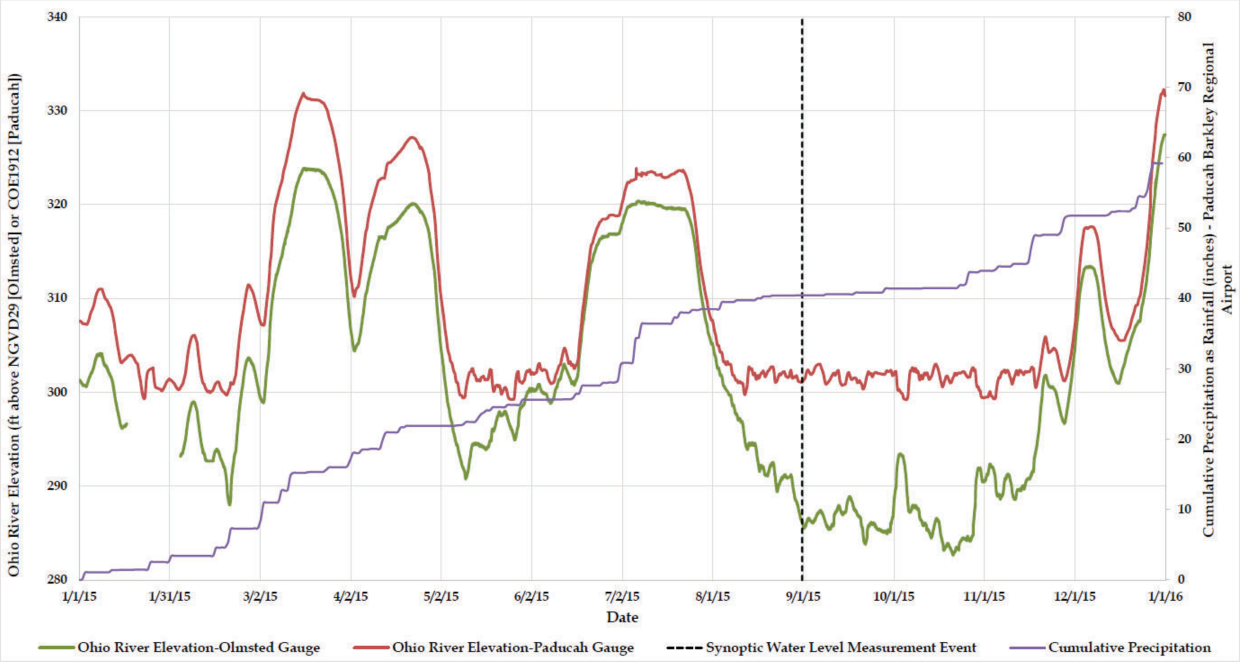


Figure 6. Ohio River Hydrographs, Cumulative Precipitation, and Water Level Measurement Events—2015

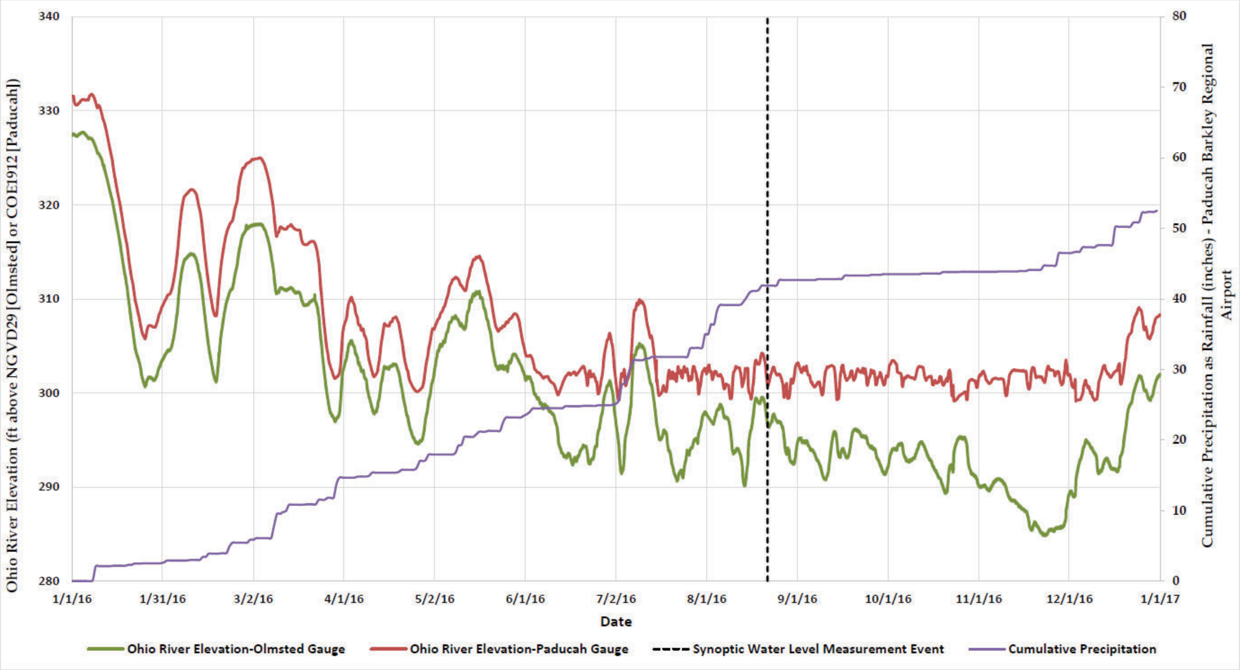


Figure 7. Ohio River Hydrographs, Cumulative Precipitation, and Water Level Measurement Events—2016

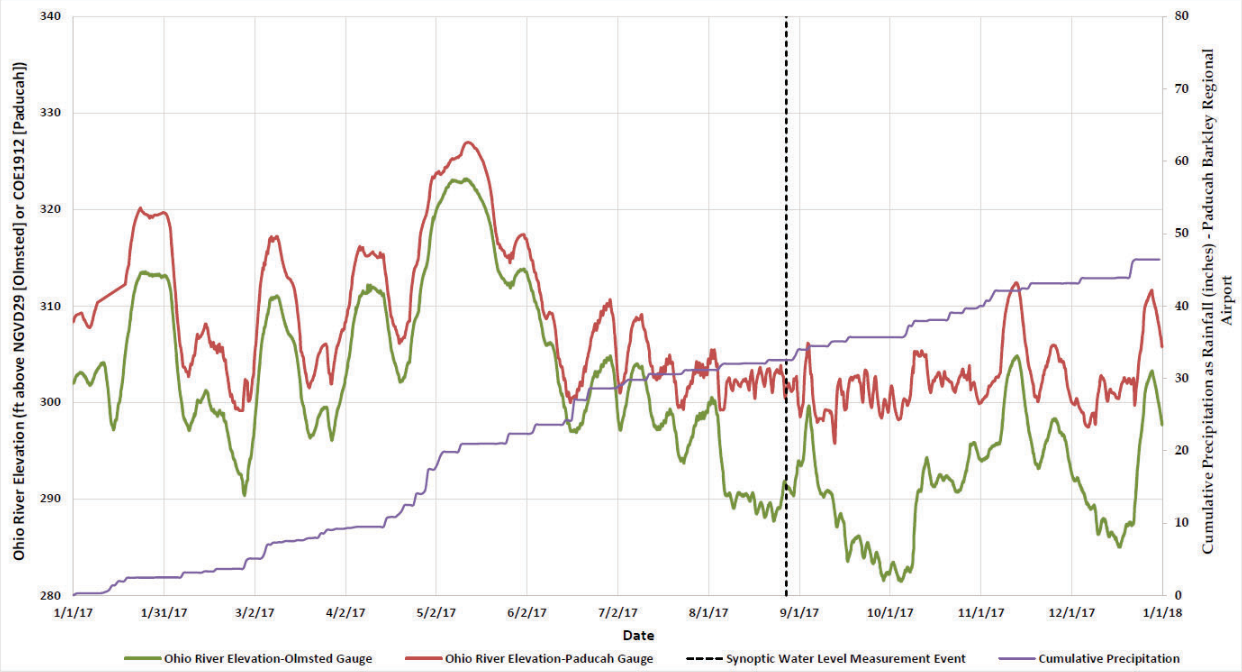


Figure 8. Ohio River Hydrographs, Cumulative Precipitation, and Water Level Measurement Events—2017

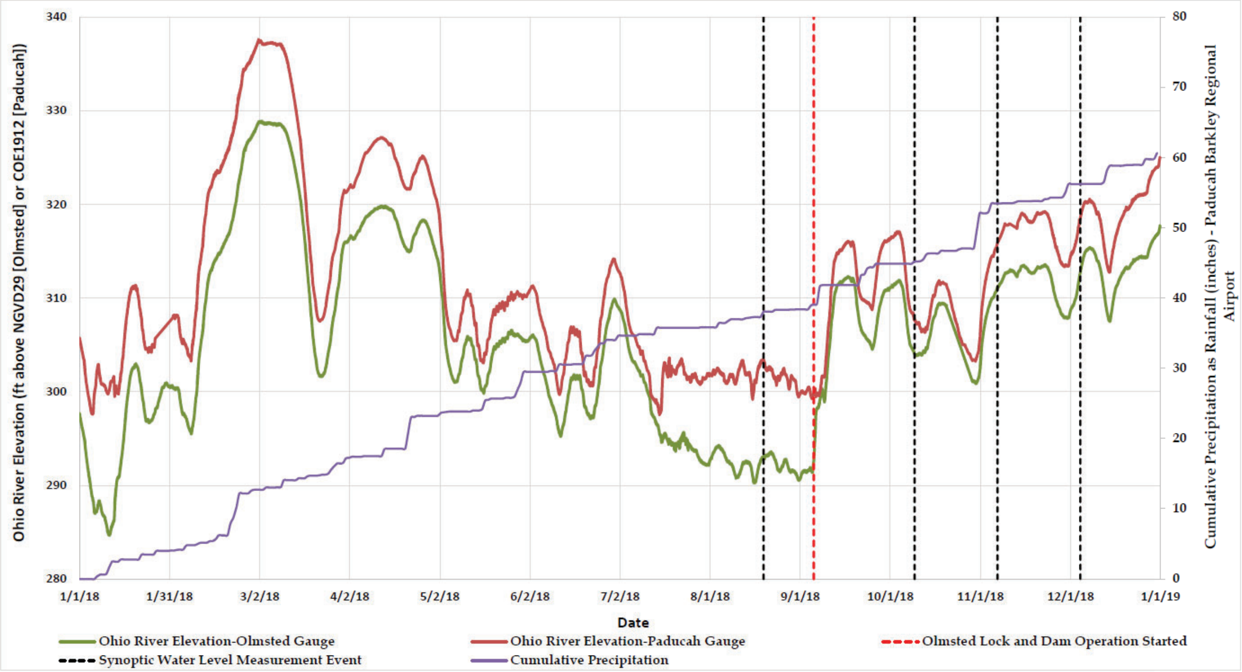


Figure 9. Ohio River Hydrographs, Cumulative Precipitation, and Water Level Measurement Events—2018

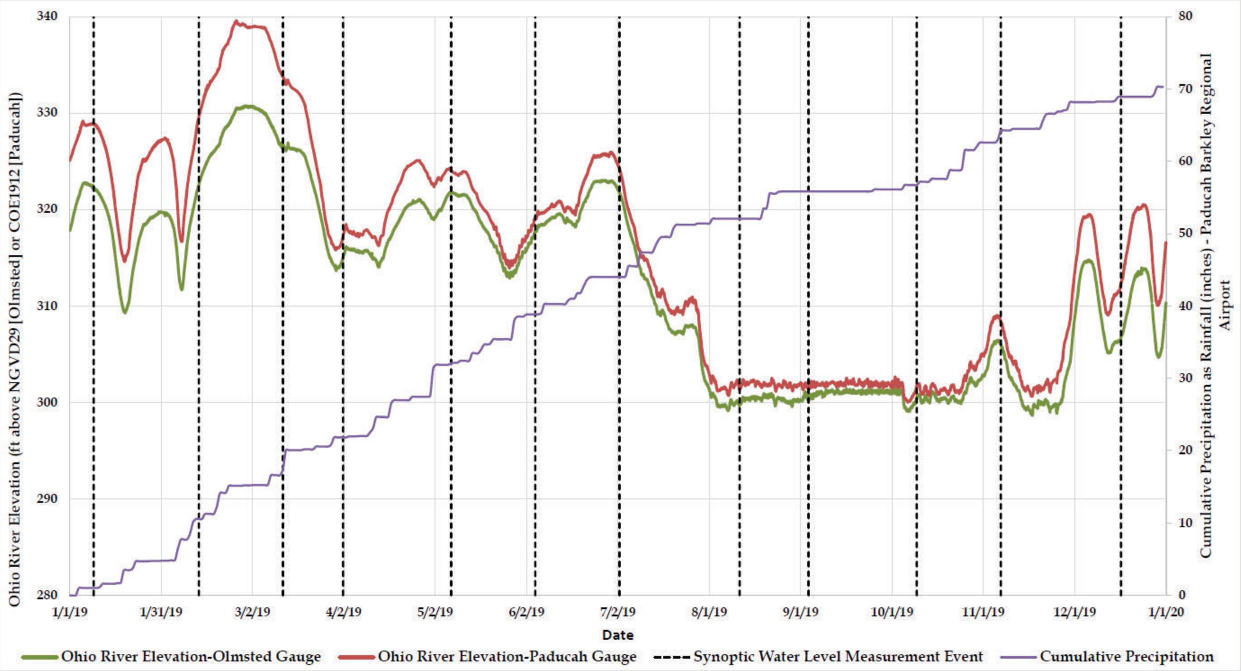


Figure 10. Ohio River Hydrographs, Cumulative Precipitation, and Water Level Measurement Events—2019

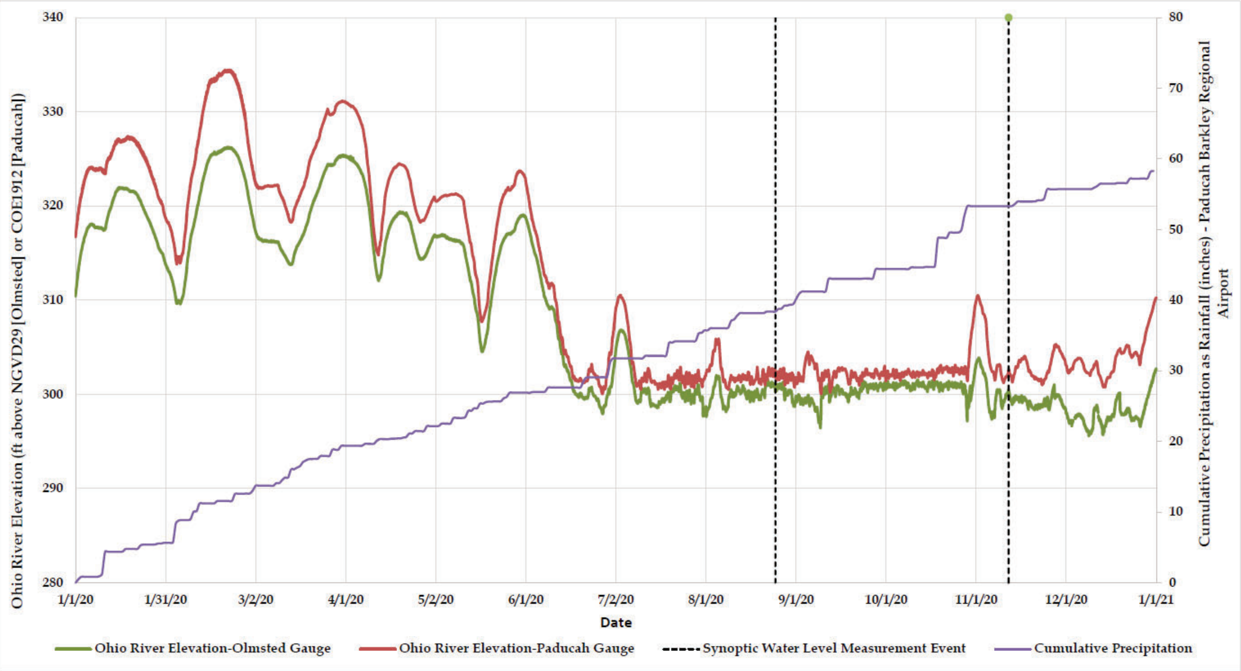


Figure 11. Ohio River Hydrographs, Cumulative Precipitation, and Water Level Measurement Events—2020

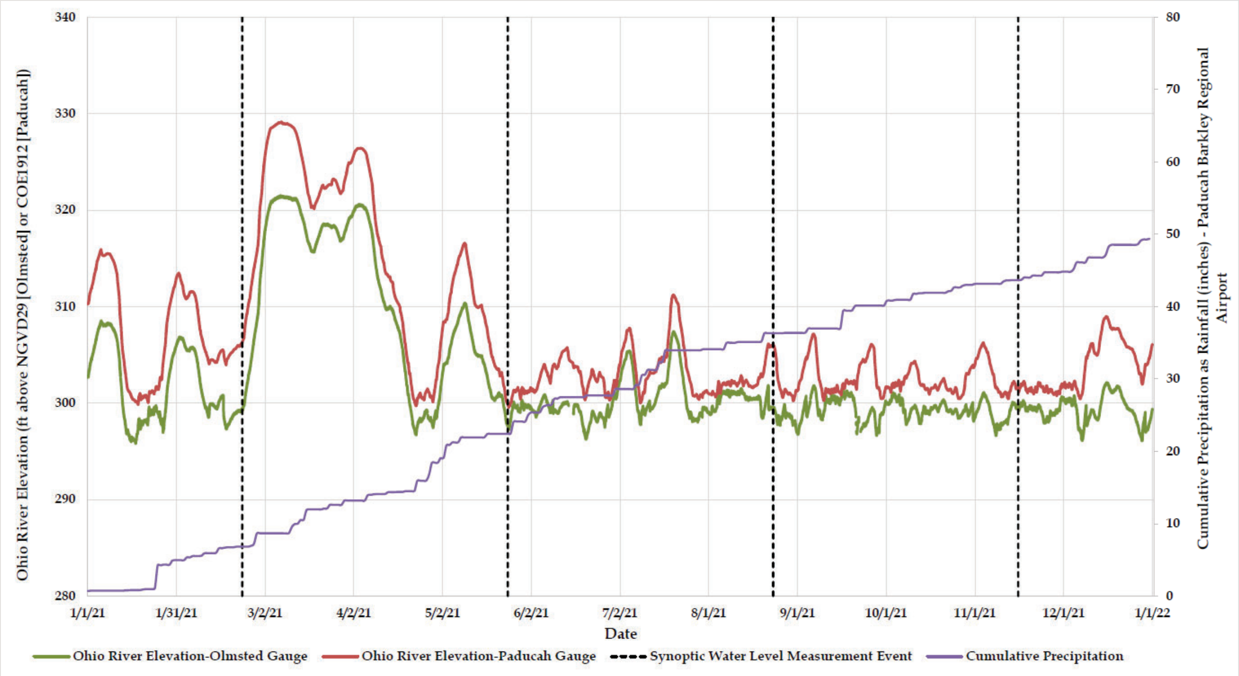


Figure 12. Ohio River Hydrographs, Cumulative Precipitation, and Water Level Measurement Events—2021

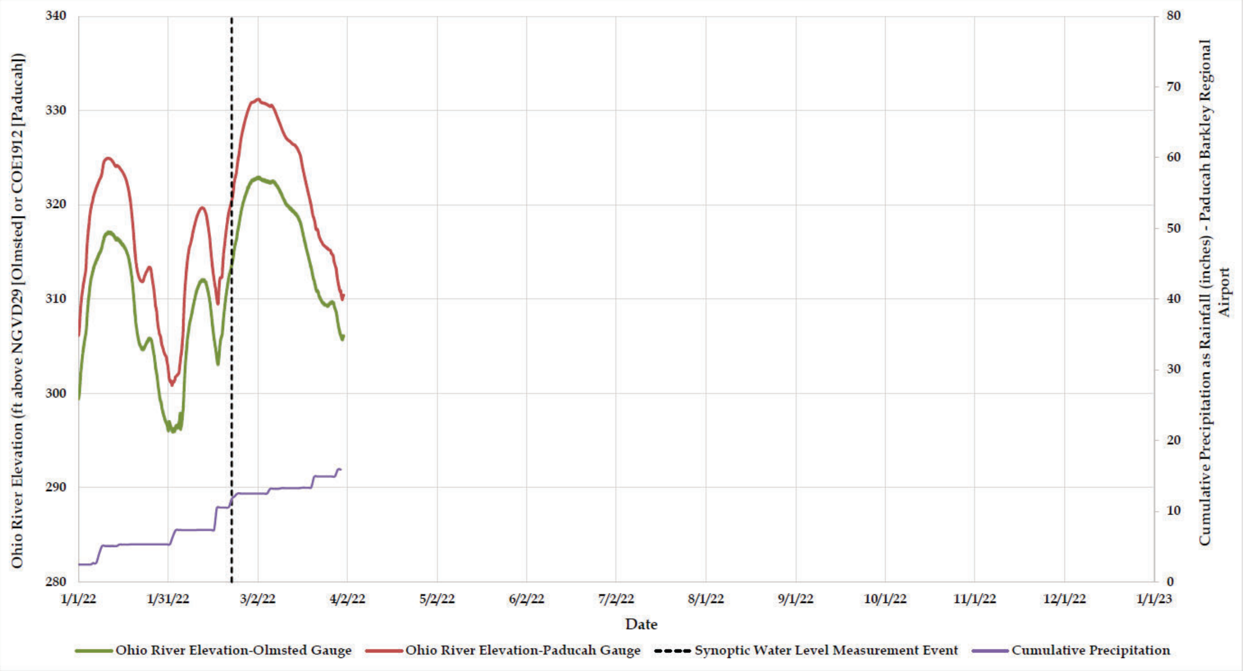


Figure 13. Ohio River Hydrographs, Cumulative Precipitation, and Water Level Measurement Events—2022

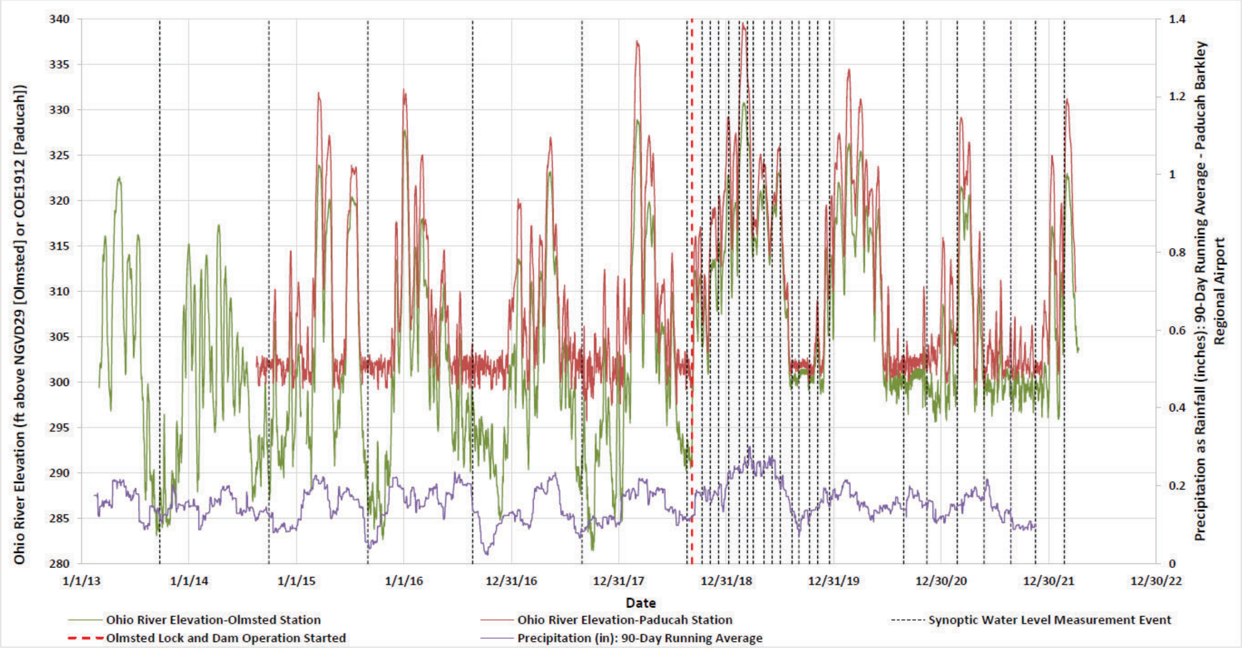


Figure 14. Comparison of Ohio River Water Elevations at Paducah Station and Olmsted Station from 2013 to 2022, with 90-Day Running Average Precipitation

As the datasets include Olmsted Dam pre- and post-operation synoptic events, the dataset satisfies the DQOs for this evaluation and a determination of the effects of the Olmsted Dam on the Paducah Site groundwater flow is possible. In addition, as there are synoptic events performed following the start of operation of the Olmsted Dam that include both high and low Ohio River water elevations, these datasets may provide insight as to seasonal effect or effect of fluctuations of the Ohio River on the Paducah Site groundwater flow.

4. DATA ASSESSMENT

To understand the impact of the Olmsted Dam operation on the groundwater flow gradients and the flow direction across the Paducah Site, comparisons and assessments were made of precipitation, Ohio River water elevations, and potentiometric surfaces from synoptic water level measurement events.

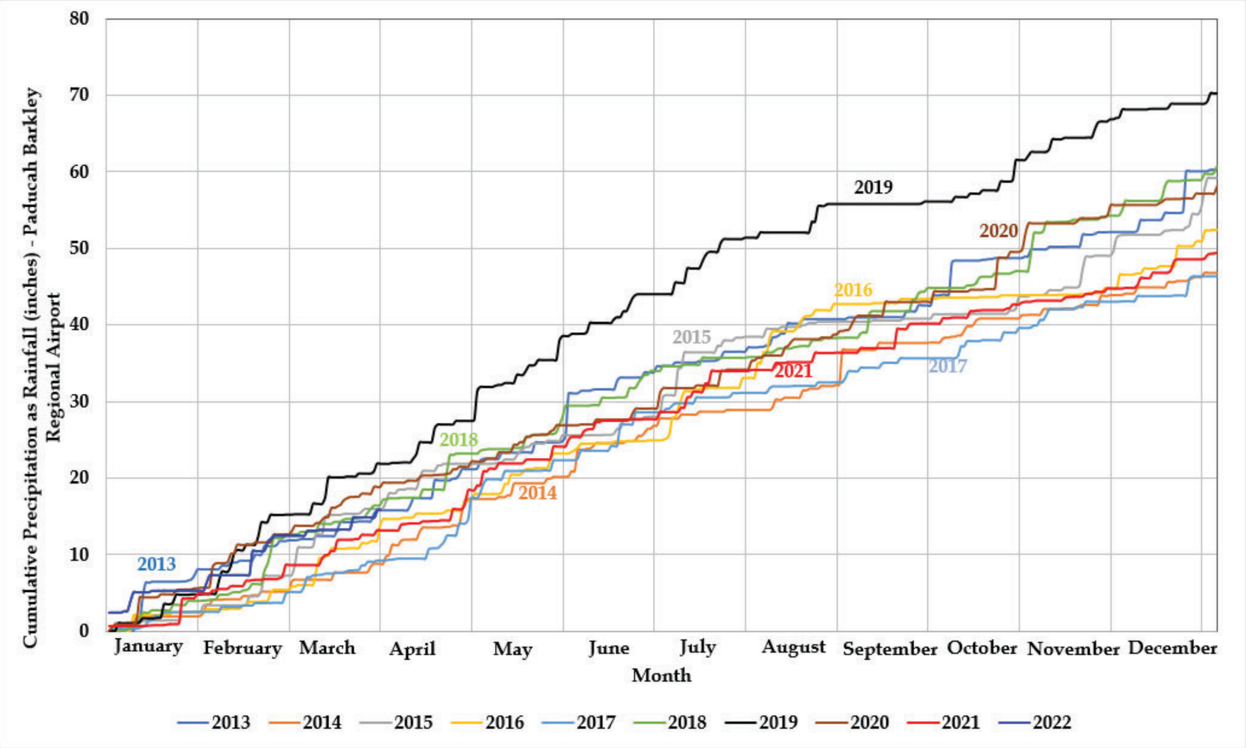
4.1. PRECIPITATION

Annual precipitation amounts from 2013 through 2021 are summarized in Table 4.

Table 4. Summary of Annual Precipitation Amounts

Year	Annual Precipitation (inches)
2013	60.29
2014	46.84
2015	59.17
2016	52.50
2017	46.41
2018	60.64
2019	70.27
2020	58.28
2021	49.38

The annual precipitation from 2013 through 2021 ranged from 46.41 inches in 2017 to 70.27 inches in 2019. Figure 15 presents the cumulative precipitation by year. As illustrated in Table 4 and in Figure 15, the precipitation amount in 2019 (70.27 inches) was statistically higher than the precipitation from the other years (Appendix A).



Source: https://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:USW00003816/detail

Figure 15. Cumulative Precipitation by Year

4.2. OHIO RIVER WATER ELEVATION

The Ohio River water elevation is directly related to precipitation (Figures 14 and 15). Prior to operation of the Olmsted Dam, the minimum water elevation at the Paducah Station was maintained between approximately 300 ft and 305 ft amsl and the maximum water elevation changed in response to precipitation. Similarly, prior to the dam operation, the maximum water elevation at Olmsted Dam fluctuated with precipitation; however, the minimum water elevation decreased to below 285 ft amsl during historically drier months in the year. Following operation of the Olmsted Dam, the maximum water elevations of both stations continued to fluctuate in response to precipitation, but the minimum water elevations are maintained at each station (between approximately 300 ft and 305 ft amsl at the Paducah Station and between approximately 295 ft and 300 ft amsl at the Olmsted Station) (Table 5).

Table 5. Summary of Ohio River Water Elevations*

Station	Pre-Operation			Post-Operation		
	Minimum Water Elevation (ft amsl)	Maximum Water Elevation (ft amsl)	Typical Minimum Water Elevation (ft amsl)	Minimum Water Elevation (ft amsl)	Maximum Water Elevation (ft amsl)	Typical Minimum Water Elevation (ft amsl)
Paducah	295.75	337.59	300-305	299.40	339.57	300–305
Olmsted	281.45	328.88	NA	295.75	337.59	295–300

NA = not applicable.

*Note: There was no typical minimum before the dam operation because the river elevation was not maintained at a minimum elevation. The river elevation fluctuated significantly before the dam operation, as shown on Figure 14.

The water levels are characterized by low and steady Ohio River water elevations during the summer months and higher and variable Ohio River water elevations during the fall, winter, and spring months. Flood events provide yearly water level spikes that impact water levels in the RGA near the Ohio River.

A comparison of the Ohio River surface water elevations at the two stations before and after the operation of the Olmsted Dam shows that the elevation differences between the two stations has been impacted by the operation of the dam. Prior to operation of the dam, the average difference between the two stations was 9.3 ft and trending upward. Since operation of the Olmsted Dam, the average difference has declined to 6.3 ft and is trending downward through 2022 (Figure 16).

4.3. RGA WATER LEVELS

Water levels in the RGA in the vicinity of the Paducah Site exhibit a yearly cycle of high and low stages, nearly synchronous and correlative with the overall stage of the Ohio River. Based on the 1992–1997 data, the annual peak of the RGA water levels typically was delayed when compared to Ohio River water elevation changes, and this delay increased with distance from the Ohio River (FRNP 2018). As illustrated in Figure 3 of the 2018 white paper, the delay varies from a matter of days (in wells near the Ohio River) to one or two months (in wells located at PGDP).[4]

4.3.1. Flow Direction

The potentiometric surfaces that were developed for the RGA at the Paducah Site prior to operation of Olmsted Dam (Appendix B) were performed in August or September and were representative of the dry or low Ohio River water elevation conditions. These potentiometric surfaces indicate consistent regional groundwater flow direction in the RGA from PGDP to the north toward the Ohio River. Comparisons among the pre-operation Olmsted Dam potentiometric surfaces, those obtained after operation began, and those that were collected in dry or low Ohio River water elevation conditions, exhibited similar regional and localized groundwater flow direction and patterns (Appendix A). The potentiometric surface maps also indicated temporal differences in hydraulic gradient due to recharge and discharge processes which included fluctuations in the water elevations of the Ohio River and the groundwater extraction system.

4.3.2. Hydraulic Gradients

To evaluate groundwater flow during different seasons, hydraulic gradients were calculated along three transects (A, B, and C) in the direction of groundwater flow. In addition, groundwater elevations were evaluated along four transects (D, E, F, and G) transverse to groundwater flow and in the direction of similar equipotential surfaces (Figure 17, Table 6). The hydraulic gradients were calculated using the following equation:

$$i = \frac{\Delta h}{\Delta l}$$

where:

i (ft/ft) = hydraulic gradient

Δh (ft) = hydraulic head difference between monitoring wells (MWs) or between MWs and the river water elevation

Δl (ft) = horizontal distance between MWs or between MWs and the river

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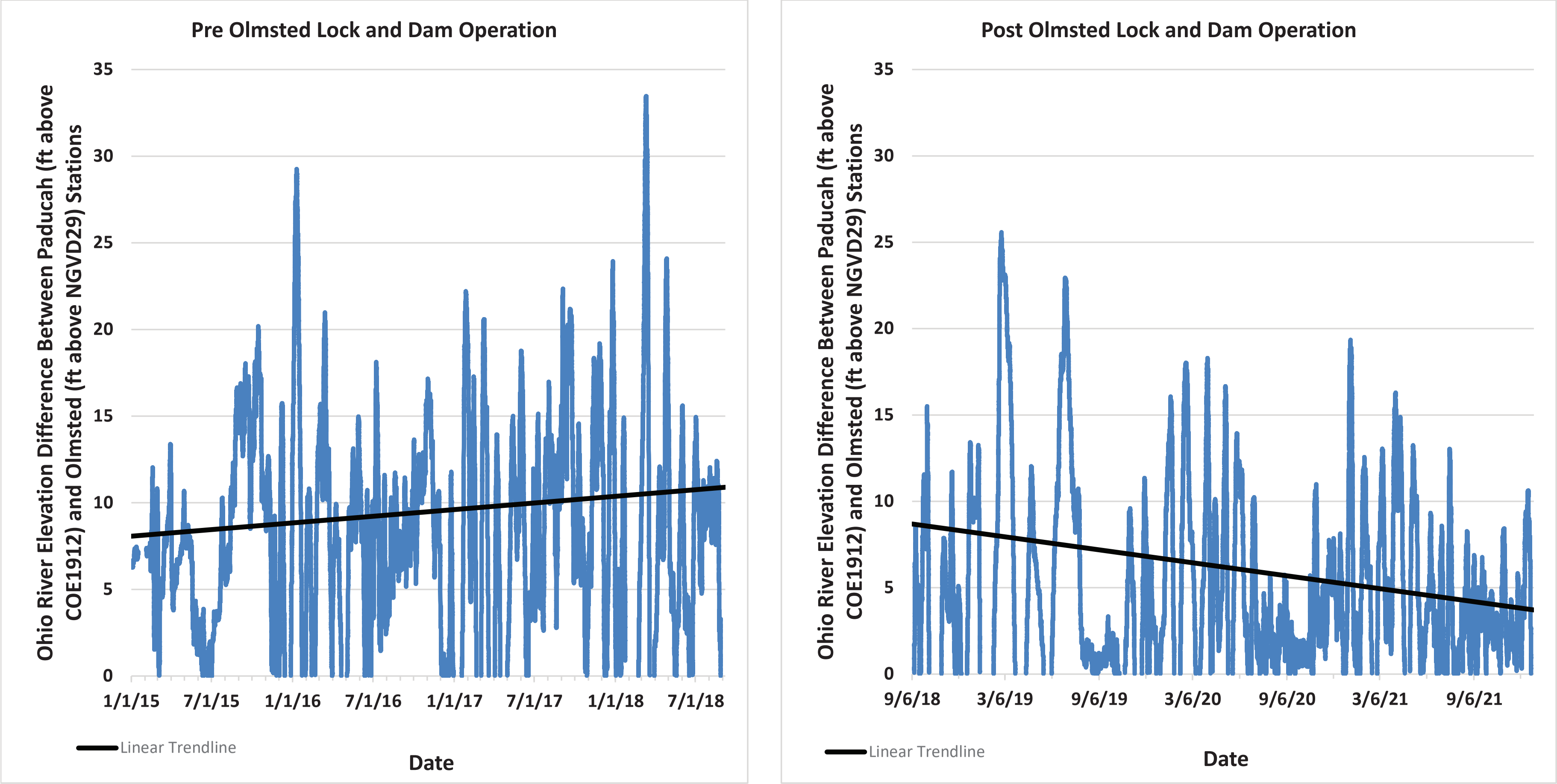
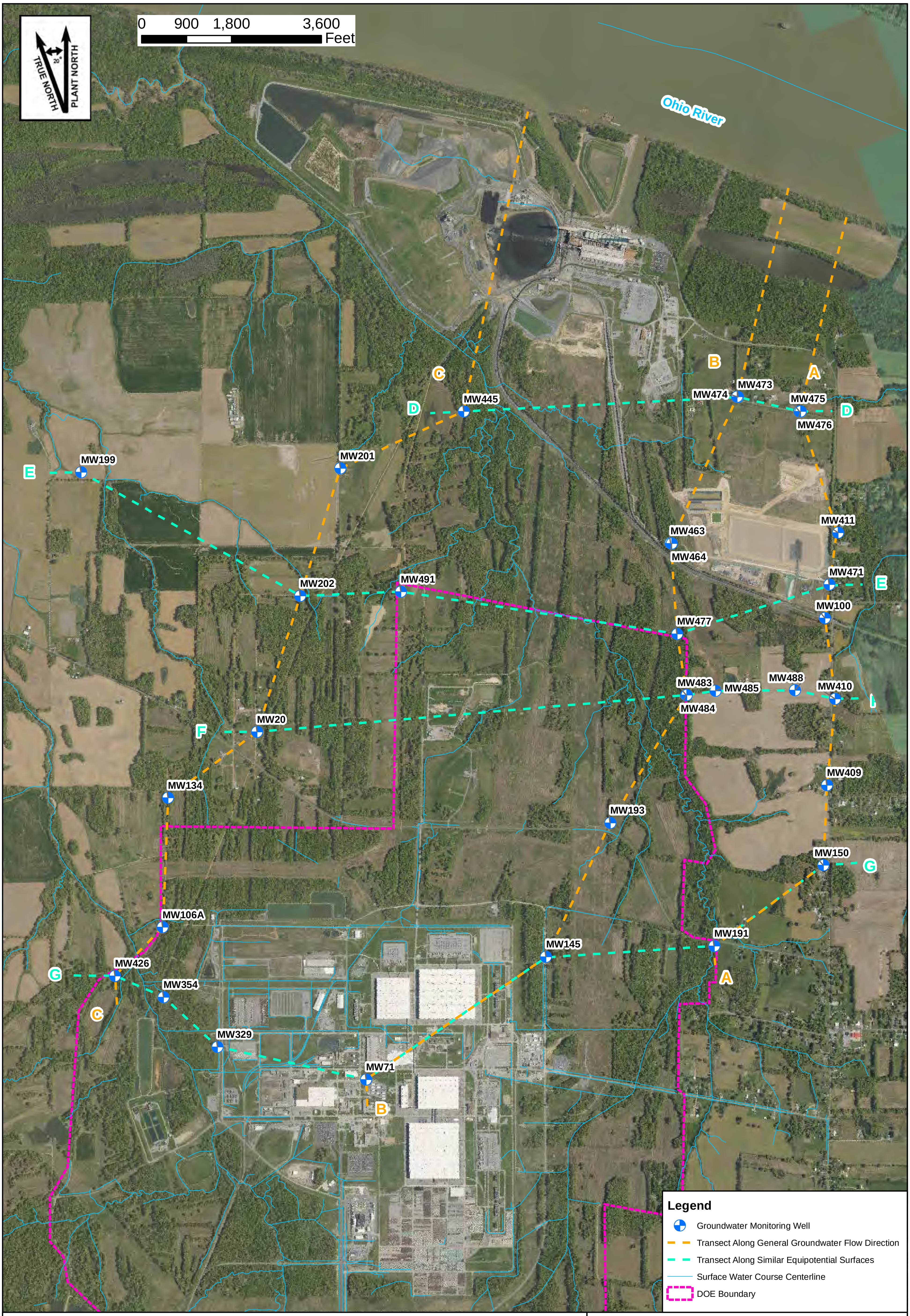
[4] The delay in the annual peak of RGA water level is due to gain and loss of storage: it is not due to transmission of kinetic energy.



Note: Data where the Olmsted Station water elevation was greater than the Paducah Station water elevation are excluded.

Figure 16. Comparison of Water Elevation Differences between the Paducah and Olmsted Stations



MAP SOURCE INFORMATION

Map Generation Date and Location - 8/4/2022 Geosyntec\\fedprojects-01\paducah$\Knoxville\GW Strategy\Activity #14 White Paper\GIS
Map Layer Location: Geosyntec\\fedprojects-01\paducah$\Knoxville\GW Strategy\Activity #14 White Paper\GIS\Figure 16. Location of Hydraulic Gradient Transects.mxd
Image Source: Aerial 2021: http://pegasis.pad.pppo.gov:6080/arcgis/services; and
Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.
Shapefile for Surface Water Course Centerline and DOE Property Boundary was obtained from Pegasis (https://pegasis.pad.pppo.gov/), downloaded on 5/11/2022.
Northing and easting of wells obtained from Pegasis, downloaded on 5/11/2022.
Transect Layer Location: \\fedprojects-01\paducah$\Knoxville\GW Strategy\Activity #14 White Paper\GIS\Transect.shp

U.S. DEPARTMENT OF ENERGY
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PADUCAH GASEOUS DIFFUSION PLANT

FOUR RIVERS
NUCLEAR PARTNERSHIP, LLC

Figure 17. Location of Hydraulic Gradient Transects

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Table 6. Summary of Transect Monitoring Wells

Transect	Monitoring Wells
A	MW191, MW150, MW409, MW410, MW100, MW471, MW411, MW475
B	MW71, MW145, MW193, MW483/MW484, MW477, MW463/MW464, MW473/MW474
C	MW426, MW106A, MW134, MW20, MW202, MW201, MW445
D	MW445, MW473/MW474, MW475/MW476
E	MW199, MW202, MW491, MW477, MW471
F	MW20, MW483/MW484, MW485, MW488, MW410
G	MW426, MW354, MW329, MW71, MW145, MW191, MW150

Computation of hydraulic gradient along each north-south transect was performed for the following four sections (Table 7 through Table 9):

- Sitewide gradient—uses the southern MW along each transect to the north MW along the transect;
- South gradient—uses MWs located on the south side of the transect;
- North gradient—uses MWs located on the north side of the transect; and
- River gradient—uses the north MWs of each transect and the Ohio River water elevation. The river elevation was calculated as the average of the Ohio River elevations measured at the Olmsted and Paducah stations (consistent with computation of river elevations during the drawing of potentiometric surface maps).

Table 7. Hydraulic Gradients Along Transect A

Date	Ohio River Elevation North of the PGDP[a]	Gradient Parameter	Transect A			
			Site-wide	South	North	North to Ohio River
			MW191 (h_1) to MW475 (h_2)	MW191 (h_1) to MW471 (h_2)	MW471 (h_1) to MW475 (h_2)	MW475 (h_1) to Ohio River (h_2)
		Δl (ft)	10,845	7,596	3,522	4,150
Sep 24, 2013	287.25	h_1 (ft)	324.23	324.23	323.12	317.24
		h_2 (ft)	317.24	323.12	317.24	287.25
		Δh/Δl (ft/ft)	*0.0006*	*0.0001*	*0.0017*	*0.0072*
Sep 29-Oct 1, 2014	295.25	h_1 (ft)	323.62	323.62	322.77	317.39
		h_2 (ft)	317.39	322.77	317.39	295.25
		Δh/Δl (ft/ft)	*0.0006*	*0.0001*	*0.0015*	*0.0053*
Sep 1-2, 2015	293.84	h_1 (ft)	326.04	326.04	325.30	319.71
		h_2 (ft)	319.71	325.30	319.71	293.84
		Δh/Δl (ft/ft)	*0.0006*	*0.0001*	*0.0016*	*0.0062*
Aug 22-24, 2016	299.56	h_1 (ft)	326.33	326.33	325.07	319.50
		h_2 (ft)	319.50	325.07	319.50	299.56
		Δh/Δl (ft/ft)	*0.0006*	*0.0002*	*0.0016*	*0.0048*
Aug 28, 2017	296.42	h_1 (ft)	325.66	325.66	324.28	318.62
		h_2 (ft)	318.62	324.28	318.62	296.42
		Δh/Δl (ft/ft)	*0.0006*	*0.0002*	*0.0016*	*0.0053*
Aug 20-21, 2018	297.88	h_1 (ft)	326.47	326.47	323.83	317.88
		h_2 (ft)	317.88	323.83	317.88	297.88
		Δh/Δl (ft/ft)	*0.0008*	*0.0003*	*0.0017*	*0.0048*
Operation of the Olmsted Dam on September 6, 2018						
Oct 10-11, 2018	305.63	h_1 (ft)	325.19	325.19[c]	323.04	318.60
		h_2 (ft)	318.60	323.04	318.60	305.63
		Δh/Δl (ft/ft)	*0.0006*	*0.0003*	*0.0013*	*0.0031*
Nov 7, 2018	313.76	h_1 (ft)	324.19	324.19[c]	322.13	318.24
		h_2 (ft)	318.24	322.13	318.24	313.76
		Δh/Δl (ft/ft)	*0.0005*	*0.0003*	*0.0011*	*0.0011*
Dec 5, 2018	316.35	h_1 (ft)	324.40	324.40[c]	326.18	319.61
		h_2 (ft)	319.61	326.18	319.61	316.35
		Δh/Δl (ft/ft)	*0.0004*	*-0.0002*[b]	*0.0019*	*0.0008*

Table 7. Hydraulic Gradients Along Transect A (Continued)

Date	Ohio River Elevation North of the PGDP[a]	Transect A				
		Gradient Parameter	Sitewide	South	North	North to Ohio River
			MW191 (h_1) to MW475 (h_2)	MW191 (h_1) to MW471 (h_2)	MW471 (h_1) to MW475 (h_2)	MW475 (h_1) to Ohio River (h_2)
		Δl (ft)	10,845	7,596	3,522	4,150
Jan 9, 2019	325.42	h_1 (ft)	325.69	325.69[c]	328.07	323.65
		h_2 (ft)	323.65	328.07	323.65	325.42
		Δh/Δl (ft/ft)	*0.0002*	*-0.0003*[b]	*0.0013*	*-0.0004*[b]
Feb 13, 2019	326.67	h_1 (ft)	328.14	328.14[c]	330.77	325.74
		h_2 (ft)	325.74	330.77	325.74	326.67
		Δh/Δl (ft/ft)	*0.0002*	*-0.0003*[b]	*0.0014*	*-0.0002*[b]
Mar 13, 2019	329.89	h_1 (ft)	331.92	331.92[c]	332.98	331.86
		h_2 (ft)	331.86	332.98	331.86	329.89
		Δh/Δl (ft/ft)	*0.00001*	*-0.0001*[b]	*0.0003*	*0.0005*
Apr 2, 2019	316.70	h_1 (ft)	332.98	332.98[c]	332.18	326.18
		h_2 (ft)	326.18	332.18	326.18	316.70
		Δh/Δl (ft/ft)	*0.0006*	*0.0001*	*0.0017*	*0.0023*
May 8, 2019	322.80	h_1 (ft)	333.28	333.28[c]	332.14	327.69
		h_2 (ft)	327.69	332.14	327.69	322.80
		Δh/Δl (ft/ft)	*0.0005*	*0.0001*	*0.0013*	*0.0012*
Jun 5, 2019	318.65	h_1 (ft)	333.22	333.22[c]	331.43	325.27
		h_2 (ft)	325.27	331.43	325.27	318.65
		Δh/Δl (ft/ft)	*0.0007*	*0.0002*	*0.0017*	*0.0016*
Jul 3, 2019	322.53	h_1 (ft)	333.08	333.08[c]	331.75	327.49
		h_2 (ft)	327.49	331.75	327.49	322.53
		Δh/Δl (ft/ft)	*0.0005*	*0.0002*	*0.0012*	*0.0012*
Aug 12-15, 2019	301.11	h_1 (ft)	331.37	331.37	328.64	321.56
		h_2 (ft)	321.56	328.64	321.56	301.11
		Δh/Δl (ft/ft)	*0.0009*	*0.0004*	*0.0020*	*0.0049*
Sep 4, 2019	301.19	h_1 (ft)	329.76	329.76[c]	327.33	320.58
		h_2 (ft)	320.58	327.33	320.58	301.19
		Δh/Δl (ft/ft)	*0.0008*	*0.0003*	*0.0019*	*0.0047*
Oct 10, 2019	301.25	h_1 (ft)	325.19	325.19[c]	326.24	318.87
		h_2 (ft)	318.87	326.24	318.87	301.25
		Δh/Δl (ft/ft)	*0.0006*	*-0.0001*[b]	*0.0021*	*0.0042*
Nov 7, 2019	306.72	h_1 (ft)	324.19	324.19[c]	325.33	318.51
		h_2 (ft)	318.51	325.33	318.51	306.72
		Δh/Δl (ft/ft)	*0.0005*	*-0.0002*[b]	*0.0019*	*0.0028*
Dec 16-18, 2019	310.26	h_1 (ft)	326.05	326.05	324.34	319.49
		h_2 (ft)	319.49	324.34	319.49	310.26
		Δh/Δl (ft/ft)	*0.0006*	*0.0002*	*0.0014*	*0.0022*
Aug 24-26, 2020	301.48	h_1 (ft)	328.04	328.04	325.78	319.48
		h_2 (ft)	319.48	325.78	319.48	301.48
		Δh/Δl (ft/ft)	*0.0008*	*0.0003*	*0.0018*	*0.0043*
Nov 11-12, 2020	300.99	h_1 (ft)	325.90	325.90	324.02	318.51
		h_2 (ft)	318.51	324.02	318.51	300.99
		Δh/Δl (ft/ft)	*0.0007*	*0.0002*	*0.0016*	*0.0042*
Feb 23-24, 2021	304.43	h_1 (ft)	326.26	326.26	324.74	319.19
		h_2 (ft)	319.19	324.74	319.19	304.43
		Δh/Δl (ft/ft)	*0.0007*	*0.0002*	*0.0016*	*0.0036*
May 24-27, 2021	299.58	h_1 (ft)	329.64	329.64	327.64	320.92
		h_2 (ft)	320.92	327.64	320.92	299.58
		Δh/Δl (ft/ft)	*0.0008*	*0.0003*	*0.0019*	*0.0051*
Aug 23-25, 2021	301.93	h_1 (ft)	327.45	327.45	325.38	319.20
		h_2 (ft)	319.20	325.38	319.20	301.93
		Δh/Δl (ft/ft)	*0.0008*	*0.0003*	*0.0018*	*0.0042*
Nov 15-18, 2021	300.70	h_1 (ft)	325.04	325.04	322.92	317.62
		h_2 (ft)	317.62	322.92	317.62	300.70
		Δh/Δl (ft/ft)	*0.0007*	*0.0003*	*0.0015*	*0.0041*

Table 7. Hydraulic Gradients Along Transect A (Continued)

Date	Ohio River Elevation North of the PGDP	Gradient Parameter	Transect A			
			Sitewide	South	North	North to Ohio River
			MW191 (h_1) to MW475 (h_2)	MW191 (h_1) to MW471 (h_2)	MW471 (h_1) to MW475 (h_2)	MW475 (h_1) to Ohio River (h_2)
		Δl (ft)	10,845	7,596	3,522	4,150
Feb 21-23, 2022	318.06	h_1 (ft)	326.07	326.07	324.75	321.70
		h_2 (ft)	321.70	324.75	321.70	318.06
		$\Delta h/\Delta l$ (ft/ft)	*0.0004*	*0.0002*	*0.0009*	*0.0009*
Mean Hydraulic Gradient (ft/ft)			**0.00059**	**0.0001**	**0.0015**	**0.0032**
Pre-Dam Mean Hydraulic Gradient (ft/ft)—Dry Months			**0.00065**	**0.0002**	**0.0016**	**0.0056**
Post-Dam Mean Hydraulic Gradient (ft/ft)—Dry Months			**0.0008**	**0.0003**	**0.0019**	**0.0045**
Post-Dam Mean Hydraulic Gradient (ft/ft)			**0.00057**	**0.0001**	**0.0015**	**0.0026**

Notes:
ft = feet
ft/ft = feet per foot
h1, h2 = groundwater elevation (head) at identified MWs
Δh = change in groundwater elevation between identified MWs
Δl = distance between identified MWs
Δh/Δl = hydraulic gradient

[a] Ohio River elevation calculated as the average elevations measured at the Paducah and Olmsted stations.

[b] Negative values in hydraulic gradient due to higher surface water elevation in Ohio River than the northern MWs indicating groundwater recharge from the river to the RGA.

[c] Groundwater elevation for the MW is not available; therefore, groundwater elevation data from the nearest MW along similar equipotential surface was used.

Table 8. Hydraulic Gradients Along Transect B

Date	Ohio River Elevation North of the PGDP	Gradient Parameter	Transect B			
			Sitewide	South	North	North to Ohio River
			MW145 (h_1) to MW473 (h_2)	MW145 (h_1) to MW483 (h_2)	MW483 (h_1) to MW475 (h_2)	MW475 (h_1) to Ohio River (h_2)
		Δl (ft)	11,852	5,945	6,060	4,300
Sep 24, 2013	287.25	h_1 (ft)	324.73	324.73[c]	323.76	317.16
		h_2 (ft)	317.16	323.76	317.16	287.25
		$\Delta h/\Delta l$ (ft/ft)	*0.0006*	*0.0002*	*0.0011*	*0.0069*
Sep 29-Oct 1, 2014	295.25	h_1 (ft)	325.01	325.01	323.64	317.16
		h_2 (ft)	317.16	323.64	317.16	295.25
		$\Delta h/\Delta l$ (ft/ft)	*0.0007*	*0.0002*	*0.0011*	*0.0051*
Sep 1-2, 2015	293.84	h_1 (ft)	327.32	327.32	325.62	319.37
		h_2 (ft)	319.37	325.62	319.37	293.84
		$\Delta h/\Delta l$ (ft/ft)	*0.0007*	*0.0003*	*0.0010*	*0.0059*
Aug 22-24, 2016	299.56	h_1 (ft)	327.17	327.17	325.38	319.10
		h_2 (ft)	319.10	325.38	319.10	299.56
		$\Delta h/\Delta l$ (ft/ft)	*0.0007*	*0.0003*	*0.0010*	*0.0045*
Aug 28, 2017	296.42	h_1 (ft)	326.81	326.81	324.79	318.27
		h_2 (ft)	318.27	324.79	318.27	296.42
		$\Delta h/\Delta l$ (ft/ft)	*0.0007*	*0.0003*	*0.0011*	*0.0051*
Aug 20-21, 2018	297.88	h_1 (ft)	326.73	326.73	324.90	317.73
		h_2 (ft)	317.73	324.90	317.73	297.88
		$\Delta h/\Delta l$ (ft/ft)	*0.0008*	*0.0003*	*0.0012*	*0.0046*

Table 8. Hydraulic Gradients Along Transect B (Continued)

Date	**Ohio River Elevation North of the PGDP**[a]	**Transect B**				
		Gradient Parameter	**Site-wide**	**South**	**North**	**North to Ohio River**
			MW145 (h_1) to MW473 (h_2)	**MW145 (h_1) to MW483 (h_2)**	**MW483 (h_1) to MW473 (h_2)**	**MW473 (h_1) to Ohio River (h_2)**
		Δl (ft)	11,852	5,945	6,060	4,300
Operation of the Olmsted Dam on September 6, 2018						
Oct 10-11, 2018	305.63	h_1 (ft)	325.19	325.19[c]	--	318.57
		h_2 (ft)	318.57	--	318.57	305.63
		Δh/Δl (ft/ft)	*0.0006*	--	--	*0.0030*
Nov 7, 2018	313.76	h_1 (ft)	324.19	324.19[c]	323.07	318.15
		h_2 (ft)	318.15	323.07	318.15	313.76
		Δh/Δl (ft/ft)	*0.0005*	*0.0002*	*0.0008*	*0.0010*
Dec 5, 2018	316.35	h_1 (ft)	324.40	324.40[c]	323.58	319.71
		h_2 (ft)	319.71	323.58	319.71	316.35
		Δh/Δl (ft/ft)	*0.0004*	*0.0001*	*0.0006*	*0.0008*
Jan 9, 2019	325.42	h_1 (ft)	325.69	325.69[c]	325.36	323.19
		h_2 (ft)	323.19	325.36	323.19	325.42
		Δh/Δl (ft/ft)	*0.0002*	*0.0001*	*0.0004*	*-0.0005*[b]
Feb 13, 2019	326.67	h_1 (ft)	328.14	328.14[c]	328.08	325.53
		h_2 (ft)	325.53	328.08	325.53	326.67
		Δh/Δl (ft/ft)	*0.0002*	*0.0000*	*0.0004*	*-0.0003*[b]
Mar 13, 2019	329.89	h_1 (ft)	331.92	331.92[c]	332.87	331.61
		h_2 (ft)	331.61	332.87	331.61	329.89
		Δh/Δl (ft/ft)	*0.0000*	*-0.0002*[b]	*0.0002*	*0.0004*
Apr 2, 2019	316.70	h_1 (ft)	332.98	332.98[c]	332.58	326.07
		h_2 (ft)	326.07	332.58	326.07	316.70
		Δh/Δl (ft/ft)	*0.0006*	*0.0001*	*0.0011*	*0.0022*
May 8, 2019	322.80	h_1 (ft)	333.28	333.28[c]	332.58	327.51
		h_2 (ft)	327.51	332.58	327.51	322.80
		Δh/Δl (ft/ft)	*0.0005*	*0.0001*	*0.0008*	*0.0011*
Jun 5, 2019	318.65	h_1 (ft)	333.22	333.22[c]	332.10	325.08
		h_2 (ft)	325.08	332.10	325.08	318.65
		Δh/Δl (ft/ft)	*0.0007*	*0.0002*	*0.0012*	*0.0015*
Jul 3, 2019	322.53	h_1 (ft)	333.08	333.08[c]	332.27	327.26
		h_2 (ft)	327.26	332.27	327.26	322.53
		Δh/Δl (ft/ft)	*0.0005*	*0.0001*	*0.0008*	*0.0011*
Aug 12-15, 2019	301.11	h_1 (ft)	331.56	331.56	329.52	321.31
		h_2 (ft)	321.31	329.52	321.31	301.11
		Δh/Δl (ft/ft)	*0.0009*	*0.0003*	*0.0014*	*0.0047*
Sep 4, 2019	301.19	h_1 (ft)	329.76	329.76[c]	328.15	320.36
		h_2 (ft)	320.36	328.15	320.36	301.19
		Δh/Δl (ft/ft)	*0.0008*	*0.0003*	*0.0013*	*0.0045*
Oct 10, 2019	301.25	h_1 (ft)	325.19	325.19[c]	--	318.71
		h_2 (ft)	318.71	--	318.71	301.25
		Δh/Δl (ft/ft)	*0.0005*	--	--	*0.0041*
Nov 7, 2019	306.72	h_1 (ft)	324.19	324.19[c]	323.10	318.28
		h_2 (ft)	318.28	323.10	318.28	306.72
		Δh/Δl (ft/ft)	*0.0005*	*0.0002*	*0.0008*	*0.0026*

Table 8. Hydraulic Gradients Along Transect B (Continued)

Date	Ohio River Elevation North of the PGDP^a	Gradient Parameter	Transect B			
			Site-wide	South	North	North to Ohio River
			MW145 (h_1) to MW473 (h_2)	MW145 (h_1) to MW483 (h_2)	MW483 (h_1) to MW473 (h_2)	MW473 (h_1) to Ohio River (h_2)
		Δl (ft)	11,852	5,945	6,060	4,300
Dec 16-18, 2019	310.26	h_1 (ft)	326.02	326.02	324.54	319.21
		h_2 (ft)	319.21	324.54	319.21	310.26
		Δh/Δl (ft/ft)	*0.0006*	*0.0002*	*0.0009*	*0.0021*
Aug 24-26, 2020	301.48	h_1 (ft)	328.29	328.29	326.50	319.14
		h_2 (ft)	319.14	326.50	319.14	301.48
		Δh/Δl (ft/ft)	*0.0008*	*0.0003*	*0.0012*	*0.0041*
Nov 11-12, 2020	300.99	h_1 (ft)	326.00	326.00	324.63	318.15
		h_2 (ft)	318.15	324.63	318.15	300.99
		Δh/Δl (ft/ft)	*0.0007*	*0.0002*	*0.0011*	*0.0040*
Feb 23-24, 2021	304.43	h_1 (ft)	326.03	326.03	325.13	318.86
		h_2 (ft)	318.86	325.13	318.86	304.43
		Δh/Δl (ft/ft)	*0.0006*	*0.0002*	*0.0010*	*0.0034*
May 24-27, 2021	299.58	h_1 (ft)	329.40	329.40	328.40	322.51
		h_2 (ft)	322.51	328.40	322.51	299.58
		Δh/Δl (ft/ft)	*0.0006*	*0.0002*	*0.0010*	*0.0053*
Aug 23-25, 2021	301.93	h_1 (ft)	327.49	327.49	326.09	318.96
		h_2 (ft)	318.96	326.09	318.96	301.93
		Δh/Δl (ft/ft)	*0.0007*	*0.0002*	*0.0012*	*0.0040*
Nov 15-18, 2021	300.70	h_1 (ft)	325.25	325.25	323.57	317.34
		h_2 (ft)	317.34	323.57	317.34	300.70
		Δh/Δl (ft/ft)	*0.0007*	*0.0003*	*0.0010*	*0.0039*
Feb 21-23, 2022	318.06	h_1 (ft)	326.14	326.14	324.95	320.59
		h_2 (ft)	320.59	324.95	320.59	318.06
		Δh/Δl (ft/ft)	*0.0005*	*0.0002*	*0.0007*	*0.0006*
Mean Hydraulic Gradient (ft/ft)			**0.00057**	**0.0002**	**0.0009**	**0.0031**
Pre-Dam Mean Hydraulic Gradient (ft/ft)			**0.00069**	**0.0003**	**0.0011**	**0.0054**
Post-Dam Mean Hydraulic Gradient (ft/ft)—Dry Months			**0.0008**	**0.0003**	**0.0013**	**0.0043**
Post-Dam Mean Hydraulic Gradient (ft/ft)			**0.00054**	**0.0002**	**0.0009**	**0.0024**

Notes:

h1, h2 = groundwater elevation (head) at identified MWs

Δh = change in groundwater elevation between identified MWs

Δl = distance between identified MWs

Δh/Δl = hydraulic gradient

[a] Ohio River elevation calculated as the average elevations measured at the Paducah and Olmsted stations.

[b] Negative values in hydraulic gradient due to higher surface water elevation in Ohio River than the northern MWs indicating groundwater recharge from the river to the RGA.

[c] Groundwater elevation for the MW is not available. Therefore, groundwater elevation data from the nearest MW along similar equipotential surface was used.

Table 9. Hydraulic Gradients Along Transect C

Date	Ohio River elevation north of the PGDP^a	Gradient Parameter	Transect C			
			Site-wide	South	North	North to Ohio River
			MW426 (h_1) to MW445 (h_2)	MW426 (h_1) to MW202 (h_2)	MW202 (h_1) to MW445 (h_2)	MW445 (h_1) to Ohio River (h_2)
		Δl (ft)	13,289	8,468	4,937	6,500
Sep 24, 2013	287.25	h_1 (ft)	325.60	325.60	323.02	318.25
		h_2 (ft)	318.25	323.02	318.25	287.25
		Δh/Δl (ft/ft)	*0.0006*	*0.0003*	*0.0010*	*0.0048*
Sep 29-Oct 1, 2014	295.25	h_1 (ft)	325.58	325.58	322.58	317.41
		h_2 (ft)	317.41	322.58	317.41	295.25
		Δh/Δl (ft/ft)	*0.0006*	*0.0004*	*0.0010*	*0.0034*

Table 9. Hydraulic Gradients Along Transect C (Continued)

Date	Ohio River elevation north of the PGDP[a]	Transect C				
		Gradient Parameter	Site-wide	South	North	North to Ohio River
			MW426 (h1) to MW445 (h2)	MW426 (h1) to MW202 (h2)	MW202 (h1) to MW445 (h2)	MW445 (h1)
Sep 1-2, 2015	293.84	h_1 (ft)	328.16	328.16	325.30	319.14
		h_2 (ft)	319.14	325.30	319.14	293.84
		$\Delta h/\Delta l$ (ft/ft)	*0.0007*	*0.0003*	*0.0012*	*0.0039*
Aug 22-24, 2016	299.56	h_1 (ft)	327.49	327.49	324.91	319.08
		h_2 (ft)	319.08	324.91	319.08	299.56
		$\Delta h/\Delta l$ (ft/ft)	*0.0006*	*0.0003*	*0.0012*	*0.0030*
Aug 28, 2017	296.42	h_1 (ft)	327.27	327.27	324.32	318.40
		h_2 (ft)	318.40	324.32	318.40	296.42
		$\Delta h/\Delta l$ (ft/ft)	*0.0007*	*0.0003*	*0.0012*	*0.0034*
Aug 20-21, 2018	297.88	h_1 (ft)	327.31	327.31	324.36	319.16
		h_2 (ft)	319.16	324.36	319.16	297.88
		$\Delta h/\Delta l$ (ft/ft)	*0.0006*	*0.0003*	*0.0011*	*0.0033*
Operation of the Olmsted Dam on September 6, 2018						
Oct 10-11, 2018	305.63	h_1 (ft)	325.67	325.67	--	--
		h_2 (ft)	--	--	--	305.63
		$\Delta h/\Delta l$ (ft/ft)	--	--	--	--
Nov 7, 2018	313.76	h_1 (ft)	324.77	324.77	--	--
		h_2 (ft)	--	--	--	313.76
		$\Delta h/\Delta l$ (ft/ft)	--	--	--	--
Dec 5, 2018	316.35	h_1 (ft)	324.76	324.76	--	--
		h_2 (ft)	--	--	--	316.35
		$\Delta h/\Delta l$ (ft/ft)	--	--	--	--
Jan 9, 2019	325.42	h_1 (ft)	325.95	325.95	--	--
		h_2 (ft)	--	--	--	325.42
		$\Delta h/\Delta l$ (ft/ft)	--	--	--	--
Feb 13, 2019	326.67	h_1 (ft)	328.31	328.31	--	--
		h_2 (ft)	--	--	--	326.67
		$\Delta h/\Delta l$ (ft/ft)	--	--	--	--
Mar 13, 2019	329.89	h_1 (ft)	332.21	332.21	--	--
		h_2 (ft)	--	--	--	329.89
		$\Delta h/\Delta l$ (ft/ft)	--	--	--	--
Apr 2, 2019	316.70	h_1 (ft)	333.06	333.06	--	--
		h_2 (ft)	--	--	--	316.70
		$\Delta h/\Delta l$ (ft/ft)	--	--	--	--
May 8, 2019	322.80	h_1 (ft)	333.47	333.47	--	--
		h_2 (ft)	--	--	--	322.80
		$\Delta h/\Delta l$ (ft/ft)	--	--	--	--
Jun 5, 2019	318.65	h_1 (ft)	333.09	333.09	--	--
		h_2 (ft)	--	--	--	318.65
		$\Delta h/\Delta l$ (ft/ft)	--	--	--	--
Jul 3, 2019	322.53	h_1 (ft)	332.77	332.77	--	--
		h_2 (ft)	--	--	--	322.53
		$\Delta h/\Delta l$ (ft/ft)	--	--	--	--
Aug 12-15, 2019	301.11	h_1 (ft)	331.18	331.18	328.04	323.68
		h_2 (ft)	323.68	328.04	323.68	301.11
		$\Delta h/\Delta l$ (ft/ft)	*0.0006*	*0.0004*	*0.0009*	*0.0034*
Sep 4, 2019	301.19	h_1 (ft)	329.92	329.92	--	--
		h_2 (ft)	--	--	--	301.19
		$\Delta h/\Delta l$ (ft/ft)	--	--	--	--
Oct 10, 2019	301.25	h_1 (ft)	325.59	325.59	--	--
		h_2 (ft)	--	--	--	301.25
		$\Delta h/\Delta l$ (ft/ft)	--	--	--	--

Table 9. Hydraulic Gradients Along Transect C (Continued)

Date	Ohio River elevation north of the PGDP[a]	Gradient Parameter	Transect C			
			Site-wide	South	North	North to Ohio River
			MW426 (h_1) to MW445 (h_2)	MW426 (h_1) to MW202 (h_2)	MW202 (h_1) to MW445 (h_2)	MW445 (h_1) to Ohio River (h_2)
		Δl (ft)	13,289	8,468	4,937	6,500
Nov 7, 2019	306.72	h_1 (ft)	324.69	324.69	--	--
		h_2 (ft)	--	--	--	306.72
		$\Delta h/\Delta l$ (ft/ft)	--	--	--	--
Dec 16-18, 2019	310.26	h_1 (ft)	325.97	325.97	--	319.86
		h_2 (ft)	319.86	--	319.86	310.26
		$\Delta h/\Delta l$ (ft/ft)	*0.0005*	--	--	*0.0015*
Aug 24-26, 2020	301.48	h_1 (ft)	328.19	328.19	325.17	319.70
		h_2 (ft)	319.70	325.17	319.70	301.48
		$\Delta h/\Delta l$ (ft/ft)	*0.0006*	*0.0004*	*0.0011*	*0.0028*
Nov 11-12, 2020	300.99	h_1 (ft)	325.74	325.74	323.33	319.11
		h_2 (ft)	319.11	323.33	319.11	300.99
		$\Delta h/\Delta l$ (ft/ft)	*0.0005*	*0.0003*	*0.0009*	*0.0028*
Feb 23-24, 2021	304.43	h_1 (ft)	326.09	326.09	324.35	319.65
		h_2 (ft)	319.65	324.35	319.65	304.43
		$\Delta h/\Delta l$ (ft/ft)	*0.0005*	*0.0002*	*0.0010*	*0.0023*
May 24-27, 2021	299.58	h_1 (ft)	329.66	329.66	327.60	321.17
		h_2 (ft)	321.17	327.60	321.17	299.58
		$\Delta h/\Delta l$ (ft/ft)	*0.0006*	*0.0002*	*0.0013*	*0.0033*
Aug 23-25, 2021	301.93	h_1 (ft)	327.48	327.48	324.57	319.46
		h_2 (ft)	319.46	324.57	319.46	301.93
		$\Delta h/\Delta l$ (ft/ft)	*0.0006*	*0.0003*	*0.0010*	*0.0027*
Nov 15-18, 2021	300.70	h_1 (ft)	325.02	325.02	322.39	318.20
		h_2 (ft)	318.20	322.39	318.20	300.70
		$\Delta h/\Delta l$ (ft/ft)	*0.0005*	*0.0003*	*0.0008*	*0.0027*
Feb 21-23, 2022	318.06	h_1 (ft)	326.24	326.24	324.75	320.54
		h_2 (ft)	320.54	324.75	320.54	318.06
		$\Delta h/\Delta l$ (ft/ft)	*0.0004*	*0.0002*	*0.0009*	*0.0004*
Mean Hydraulic Gradient (ft/ft)			**0.00057**	**0.0003**	**0.0010**	**0.0029**
Pre-Dam Mean Hydraulic Gradient (ft/ft)			**0.00063**	**0.0003**	**0.0011**	**0.0036**
Post-Dam Mean Hydraulic Gradient (ft/ft)—Dry Months			**0.0006**	**0.0004**	**0.0010**	**0.0030**
Post-Dam Mean Hydraulic Gradient (ft/ft)			**0.00054**	**0.0003**	**0.0010**	**0.0024**

Notes:
h1, h2 = groundwater elevation (head) at identified MW
Δh = change in groundwater elevation between identified MWs
Δl = distance between identified MWs
Δh/Δl = hydraulic gradient
[a] Ohio River elevation calculated as the average elevations measured at the Paducah and Olmsted stations.
[b] Negative values in hydraulic gradient due to higher surface water elevation in Ohio River than the northern MWs indicating groundwater recharge from the river to the RGA.
[c] Groundwater elevation for the MW is not available. Therefore, groundwater elevation data from the nearest MW along similar equipotential surface was used.

4.3.2.1 Transect A

The groundwater elevations in MWs along Transect A and the distance of the MWs from the Ohio River are indicated in Figure 18. Overall, lower groundwater elevations near the Ohio River and rising groundwater elevations further south from the river indicate groundwater flow from the south to the north. When the Ohio River water elevation was above the MW nearest to the river along Transect A (i.e., MW475), the groundwater flow direction reversed toward the south (away from the Ohio River) and into the RGA (shown with dashed line in Figure 18). Groundwater elevations in MWs along Transect A pre- and post-operation of the dam are provided in Figures 19 and 20, respectively.

When the Ohio River elevation is below the groundwater elevation in the RGA, the hydraulic gradients in the RGA increased toward the Ohio River. For example, the distance (*Δl*) between MW150 and MW410 is similar to the distance between MW411 and MW475 (Figures 18, 19, and 20). As observed in the graph, the hydraulic gradient between MW411 and MW475 is steeper than the hydraulic gradient between MW150 and MW410. Moore and Clausen also documented the increase in hydraulic gradients toward the Ohio River and flow reversal from the river to the RGA aquifer to the northernmost part of the RGA (Moore and Clausen 1997).

When the elevation of the Ohio River increases, hydraulic gradients between MWs declines. With the rising river water elevations, the groundwater elevations also increased in MWs; however, the changes in groundwater elevation are a function of distance from the river. MWs closer to the river (e.g., MW475) increased by as much as 14 ft whereas MWs further from the river (e.g., MW150) increased by approximately 9 ft.

Based on Ohio River elevation downgradient of the Paducah Site (calculated as the mean river elevations of the Olmsted and Paducah stations), the Ohio River elevation was higher than the potentiometric surface of the RGA during the January 2019 and February 2019 synoptic events (shown with dashed line in Figure 20). During these monitoring periods, the Ohio River water flows into the RGA. Since the flow reversal is short and usually limited in extent to the northern part of the aquifer (approximately 6,000 ft from the river), no change in groundwater flow direction was observed in MWs at PGDP. Increased Ohio River elevation that reached to levels above the groundwater elevation had an effect on the migration of impacted groundwater due to the decline in the hydraulic gradient during high river flow condition which resulted in lower groundwater flow velocity and subsequently the downgradient migration of impacted groundwater from PGDP.

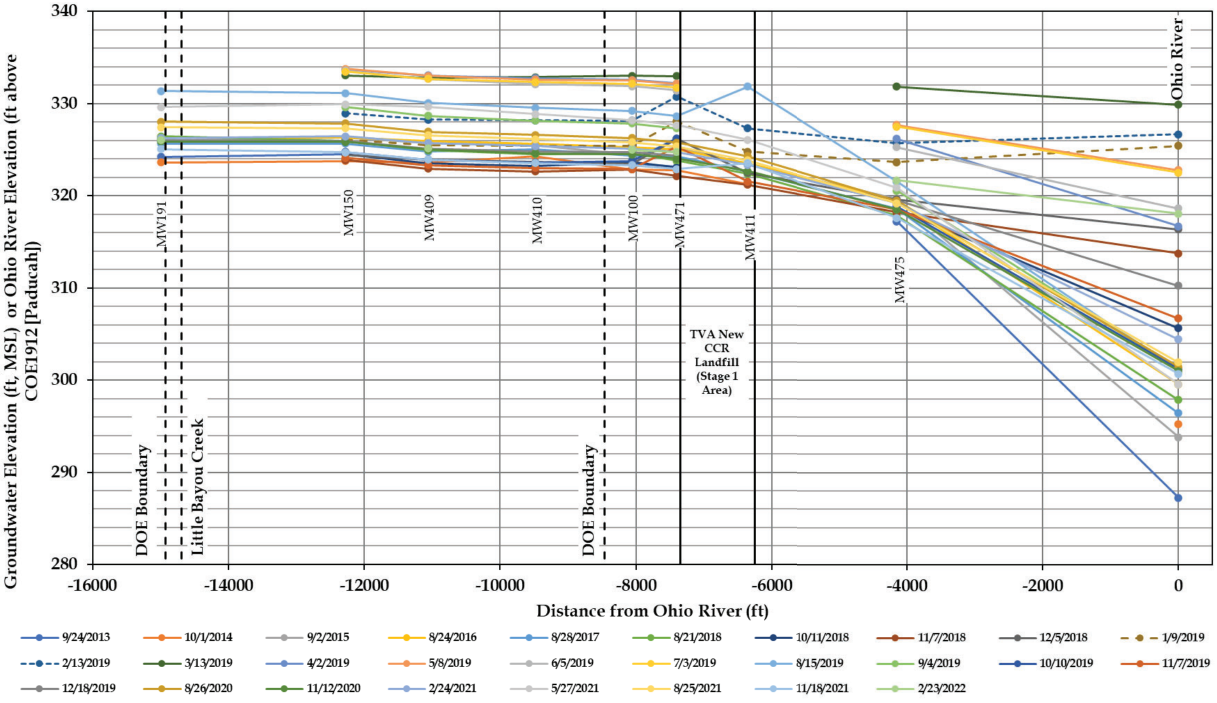

Figure 18. Groundwater and Ohio River Elevation Along Transect A

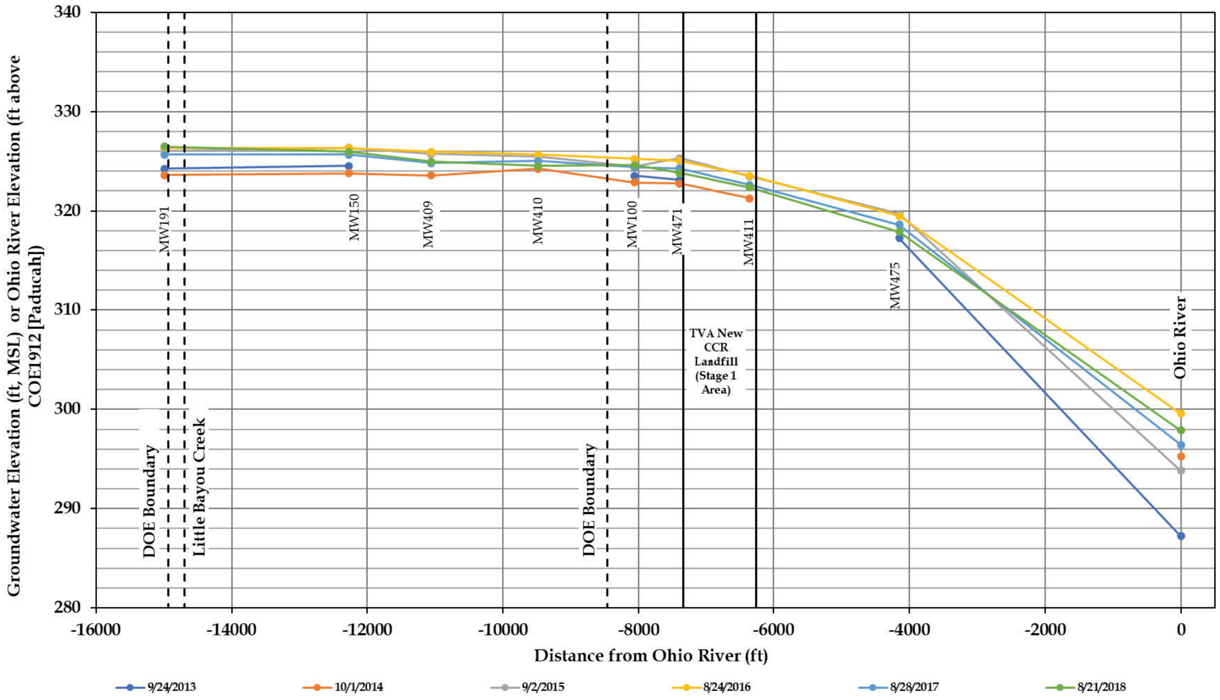

Figure 19. Groundwater and Ohio River Elevation Along Transect A—Pre-operation of the Olmsted Dam

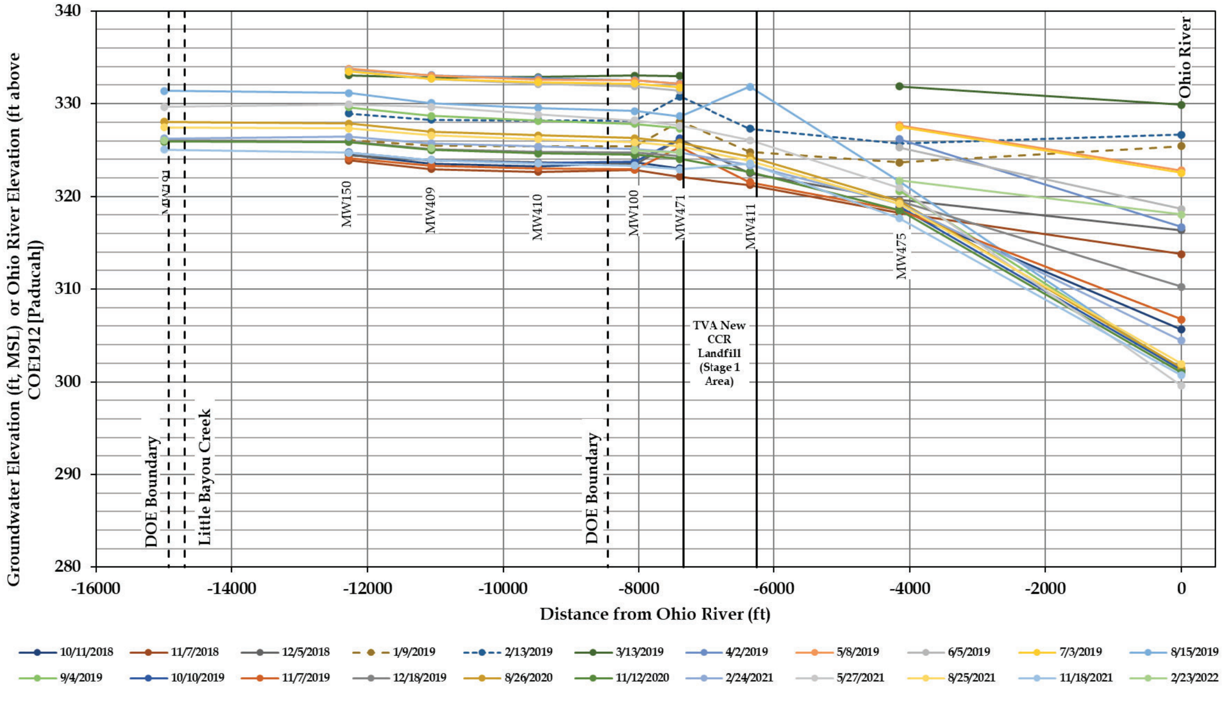

Figure 20. Groundwater and Ohio River Elevation Along Transect A—Post-operation of the Olmsted Dam

The hydraulic gradients calculated along Transect A between 2013 and 2022 during different seasons are shown in Table 7. Consistent with available historical potentiometric surface maps (Appendix B), the calculated hydraulic gradients indicated increasing hydraulic gradients northward toward the Ohio River.

The mean hydraulic gradient which was calculated using MWs near PGDP (e.g., 0.0001 ft/ft between wells MW191 and MW471 located south of Transect A) was lower than the hydraulic gradient which was calculated using wells MW471 and MW475 located north of Transect A (0.0015 ft/ft) or the sitewide hydraulic gradient along the transect (0.006 ft/ft). Similarly, the hydraulic gradient calculated between the north MWs located along the transect of MW475 and the Ohio River (0.0032 ft/ft), was higher than the gradients calculated along Transect A.

Comparing the hydraulic gradient between the north MW (MW475) and the Ohio River elevation at different seasons, the hydraulic gradient declined as the Ohio River elevation increased. For example, a hydraulic gradient of 0.0022 ft/ft was calculated when the river elevation was 310.02 ft in December 2019. When the river elevation reached 326.67 ft in February 2019, a hydraulic gradient of -0.0004 ft/ft was calculated indicating flow reversal and river water flows into the northernmost of the aquifer. Figure 21 is a graph of calculated sitewide hydraulic gradients and river elevations for Transects A, B, and C. The graph shows a decline in the hydraulic gradients with an increase in river elevation.

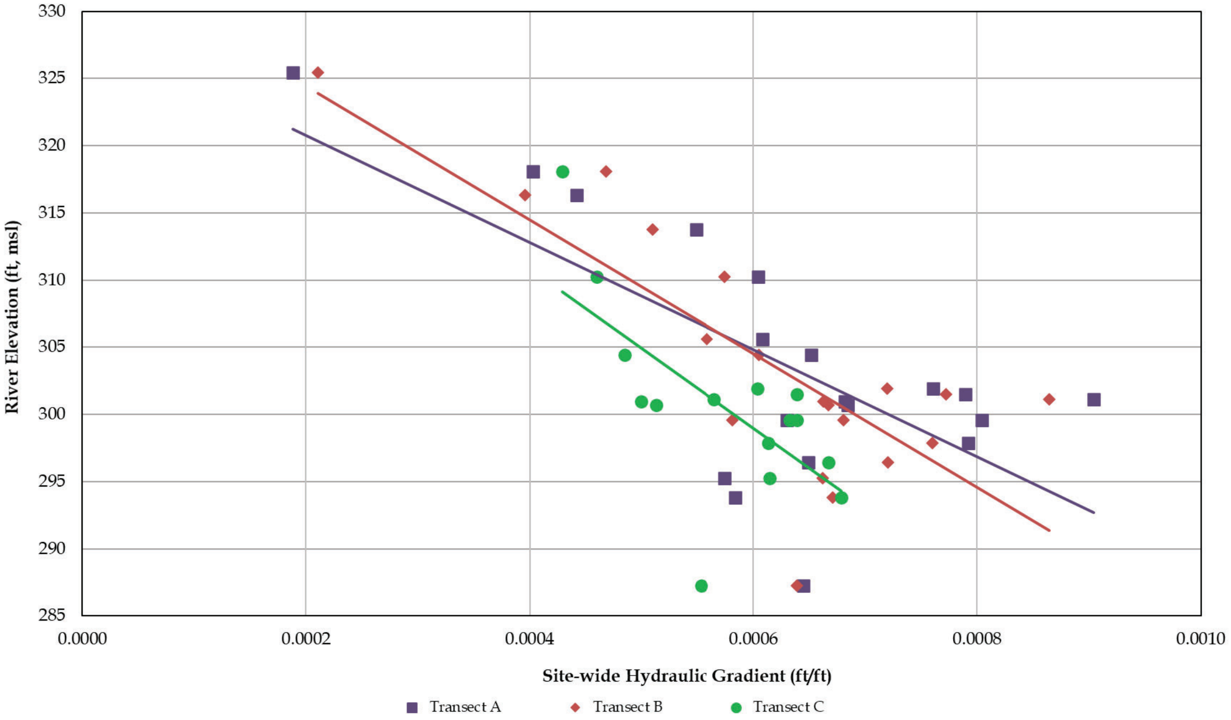

Figure 21. Calculated Sitewide Hydraulic Gradients and River Elevation for Transects A, B, and C

Groundwater elevation graphs along Transect A pre- and post-operation of the Olmsted Dam, respectively, are shown in Figures 19 and 20. Because the pre-operation of Olmsted Dam data were collected during historically drier months of the year and when the Ohio River water elevations were typically low, groundwater flow directions during the measurements were to the north toward the Ohio River; however, hydraulic gradients were relatively lower post-operation of the dam with occasional groundwater flow reversals observed.

In summary, hydraulic gradients across Transect A changed both spatially and seasonally. Hydraulic gradients decline with distance from the Ohio River. The hydraulic gradients also vary seasonally with relatively lower gradients when the river elevation rises. Due to higher Ohio River elevations following operation of the Olmsted Dam, the mean hydraulic gradients between the north MW (MW475) and the

Ohio River were lower compared to the mean hydraulic gradients pre-operation of the Olmsted Dam. Increasing river elevations and lower hydraulic gradients will result in the reduction of groundwater flow velocity and reduction in the migration of the impacted groundwater from PGDP. Flow reversal occurred during high river flow conditions, but lasted for short periods.

4.3.2.2 Transect B

Groundwater elevations in MWs along Transect B are shown in Figure 22. Groundwater elevations in MWs along Transect B pre- and post-operation of the dam are provided in Figures 23 and 24, respectively. Ohio River water elevation is generally lower than the groundwater elevations further south at PGDP indicating groundwater flow direction from the north; however, during the January 2019 and February 2019 synoptic water level measurements, the Ohio River water elevation was higher than MW473 and MW463, located north of the DOE boundary. During these measurement periods, the groundwater flow direction was from the Ohio River to the RGA; however, the extent of the groundwater flow reversal was limited to a distance of approximately 7,500 ft from the river.

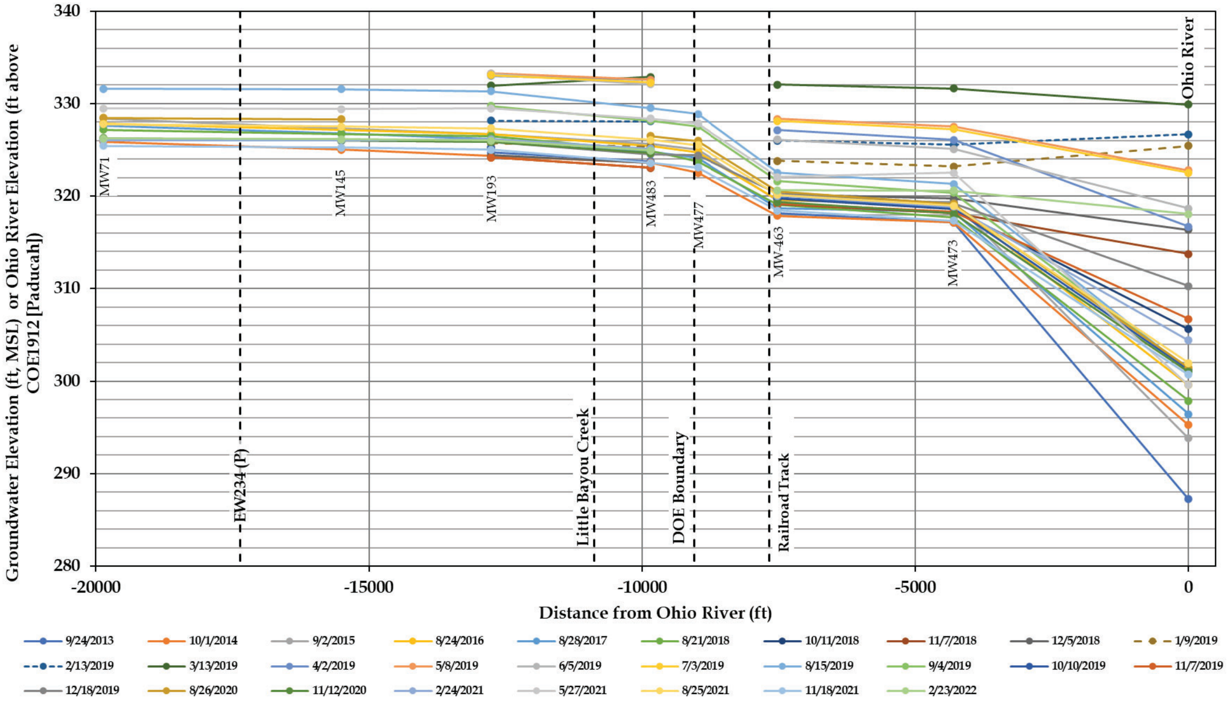

Figure 22. Groundwater and Ohio River Elevation Along Transect B

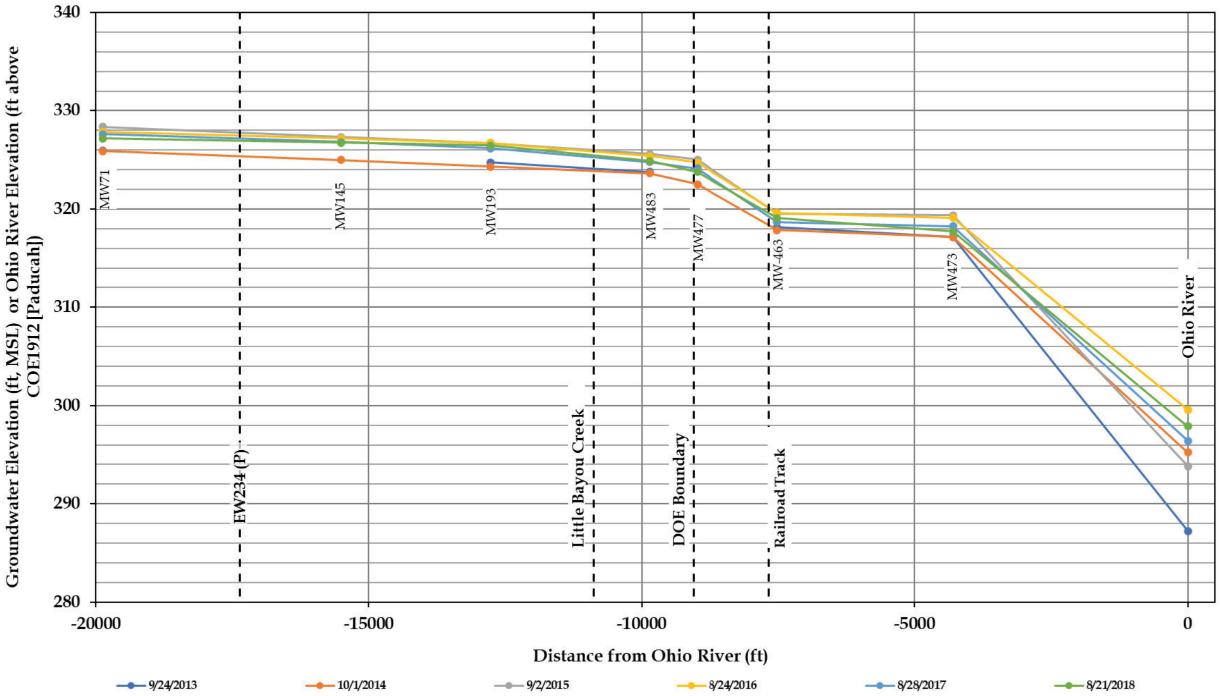

Figure 23. Groundwater and Ohio River Elevation Along Transect B—Pre-operation of the Olmsted Dam

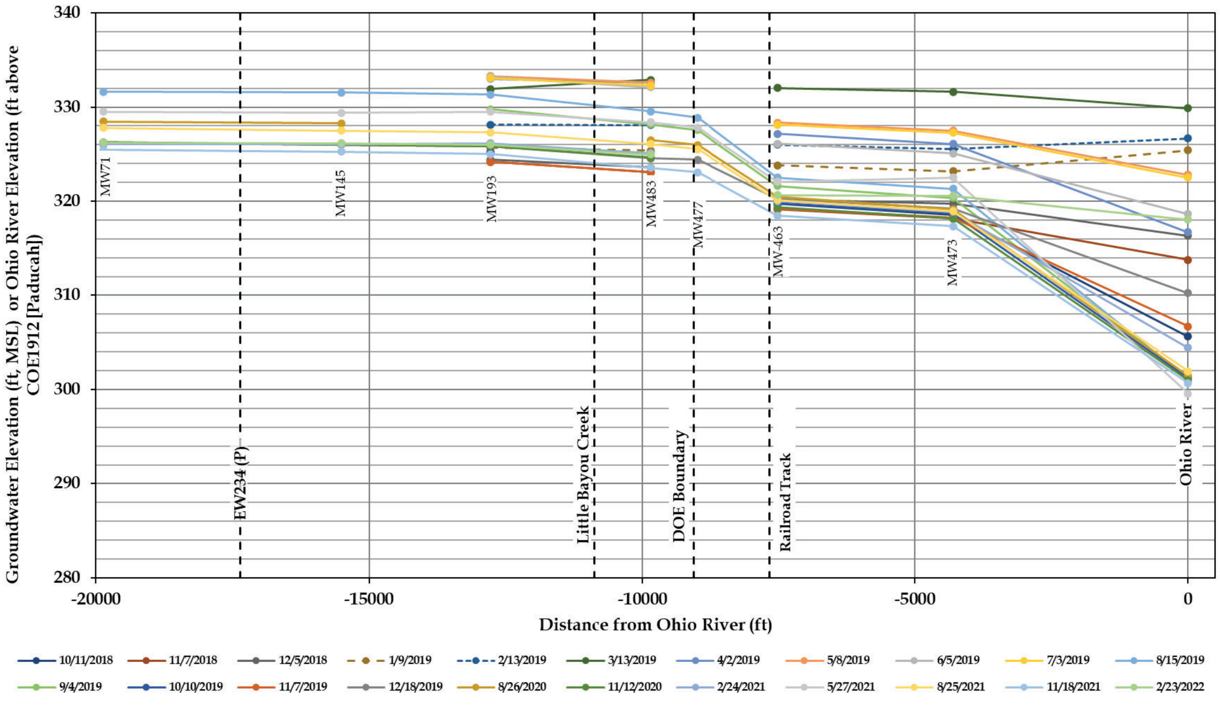

Figure 24. Groundwater and Ohio River Elevation Along Transect B—Post-operation of the Olmsted Dam

When the Ohio River elevation is lower than the groundwater elevation in the RGA, the hydraulic gradients along Transect B increase toward the river, with the steepest gradient observed between the Ohio River and

MW473. The hydraulic gradients between MW473 and MW463 are consistently flat compared to the gradients to the north and south of these two MWs.

When the Ohio River water elevation increased, the groundwater elevations in MWs also increased; however, the changes in groundwater elevation are a function of distance from the Ohio River. MWs closer to the river (e.g., MW473) showed an increase of as much as 16 ft whereas MWs further from the river (e.g., MW193) showed an increase of approximately 7 ft. In MWs at PGDP (e.g., MW71), the groundwater level showed an increase of approximately 5 ft.

The hydraulic gradients calculated along sections of Transect B during different synoptic events are shown in Table 8. Like Transect A, hydraulic gradients are generally lower near PGDP and increase near the Ohio River. The hydraulic gradients calculated using MWs at PGDP (i.e., wells located south along Transect B) are lower than the hydraulic gradients calculated using MWs north of PGDP along the transect. Similarly, the highest hydraulic gradients were calculated between the north MWs (MW473/MW474) and the Ohio River water elevation.

A comparison of hydraulic gradients between the north MWs (MW473/MW474) and the Ohio River elevations at different seasons indicated that hydraulic gradients declined as the Ohio River elevation increased. For example, a hydraulic gradient of 0.0021 ft/ft was calculated when the river elevation was 310.26 ft in December 2019. When the river elevation rose to 326.67 ft in February 2019, the hydraulic gradient reversed (-0.0003 ft/ft) which indicated that the river was recharging the RGA.

Groundwater elevation graphs along Transect B pre- and post-operation of the Olmsted Dam, respectively, are shown in Figures 23 and 24. Because the pre-operation Olmsted Dam data were collected during historically drier months of the year and when the Ohio River water elevations were typically low, groundwater flow directions were to the north with relatively steep hydraulic gradients. Contrastingly, hydraulic gradients were generally lower post-operation of the dam with the occasional reversal of groundwater flow direction near the Ohio River.

In summary, both synoptic groundwater and river elevation data along Transect B indicated spatial and seasonal changes in the hydraulic gradients. Hydraulic gradients declined with distance from the Ohio River. The hydraulic gradients also varied seasonally with lower gradients when the Ohio River elevation rose. Groundwater flow reversals occurred during high river flow conditions but lasted for shorter periods.

4.3.2.3 Transect C

Similar to Transects A and B, the groundwater elevations for Transect C decline toward the Ohio River which indicates groundwater flow direction from PGDP to the Ohio River (Figure 25). Hydraulic gradients generally increase toward the river; however, when the Ohio River water elevations rose, the hydraulic gradient in the RGA near the river showed a significant decline. Due to missing groundwater elevation data from MWs near the river (e.g., MW445 during high river elevation in January 2019 through March 2019), a reversal in groundwater flow direction similar to Transects A and B was not observed along Transect C.

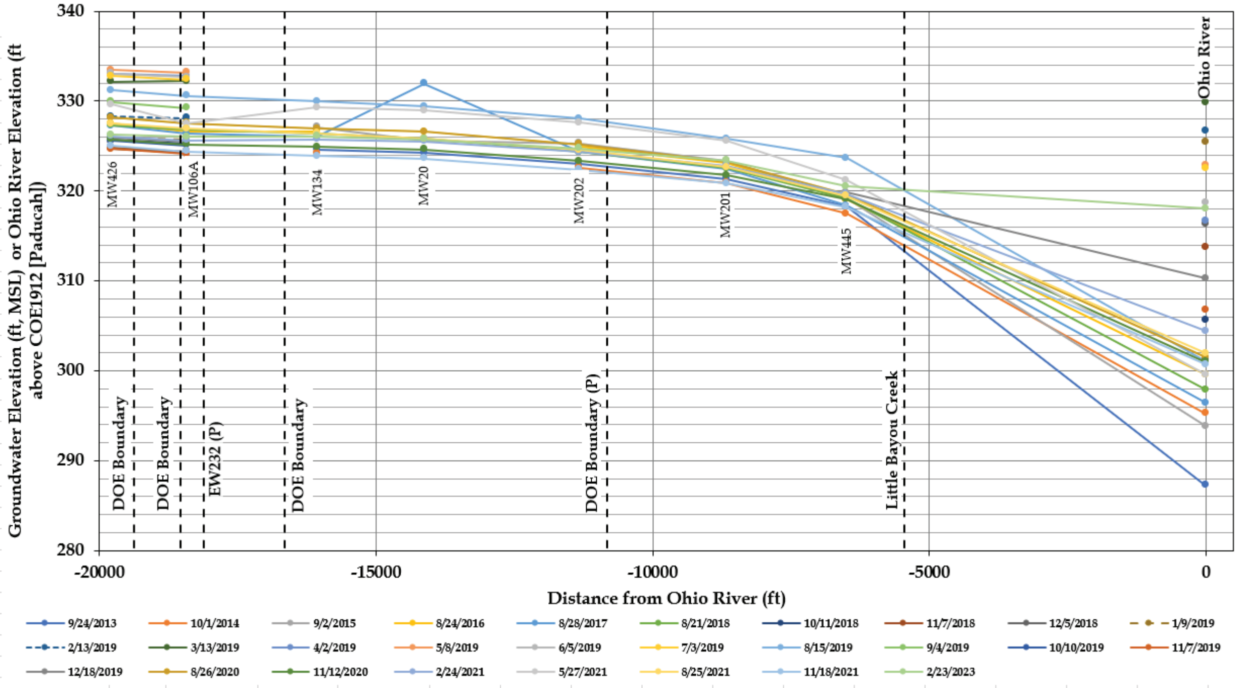

Figure 25. Groundwater and Ohio River Elevation Along Transect C

Hydraulic gradients were calculated along sections of Transect C during different seasons (Table 9). Similar to Transects A and B, the calculated hydraulic gradients were lower near PGDP and increased with distance from the Ohio River.

A comparison of hydraulic gradients between the north MW (MW445) and the river elevations at different seasons indicated that hydraulic gradients declined as the Ohio River elevation increased. For example, a hydraulic gradient of 0.0015 ft/ft was calculated when the river elevation was 310.26 ft in December 2019; with a rise in river elevation to 318.06 ft in February 2022, the hydraulic gradient declined to 0.0004 ft/ft.

In summary, spatial and seasonal changes in hydraulic gradients were noted across Transect C. In general, hydraulic gradients along Transect C were slightly lower than the gradients along Transects A and B, which is consistent with historical potentiometric surface maps. Hydraulic gradients were steeper closer to the Ohio River. The hydraulic gradients also varied seasonally with declining gradients when the Ohio River elevation rose.

Groundwater elevation data before the Olmsted Dam operation date of September 6, 2018, were collected in August or September, when the river water elevations were relatively lower (Figures 4 through 9). After operation of the dam, groundwater elevation data were collected during both low and high river flow conditions. To compare hydraulic gradients from the same season, data collected during the months of August and September, after operation of the dam began, were selected for further analysis. Hydraulic gradients calculated between the groundwater elevations in north MWs and the Ohio River elevations were used for comparison because the groundwater closer to the river showed greater fluctuation as demonstrated in prior discussions. Comparisons of the mean hydraulic gradient values calculated from six synoptic gauging events conducted before Olmsted Dam operation and the mean hydraulic gradient values from four events post-operation of Olmsted Dam are shown in Table 7 through Table 9. The tables denote lower hydraulic gradients after the dam operation. Statistical comparison of the hydraulic gradient data collected during the months of August and September was performed using analysis of variance. The comparison indicated statistically significant differences in the hydraulic gradient (Appendix A). The lower hydraulic gradients after the dam operation are attributed to increases in Ohio River water elevations. Low hydraulic gradients imply lower groundwater flow velocities, which consequently result in slower migration of the impacted groundwater in addition to other reasons (e.g., groundwater extraction, treatment, natural attenuation).

4.3.2.4 Transect D through Transect G

Transects D through G were drawn along MWs with comparable equipotential surfaces as presented on available historical potentiometric surface maps (Appendix B). Synoptic groundwater elevation data and Ohio River elevation data are shown in Figure 26 and Table 10. Overall, comparable groundwater elevations along these transects indicated consistent rates of groundwater fluctuations in the east-west direction during high and low river flow conditions. Groundwater elevations generally mimic river water elevations. Increased river water elevations in 2019 were expressed with rising groundwater elevations in MWs along these transects. During the high river elevations, when the river water elevations were at the level of the groundwater elevations of MWs along Transect D (approximately 320 ft amsl), hydraulic gradient between the transects decreased (i.e., the spacing between the transects declined significantly). When the river elevation declined quickly between July 2019 and August 2019, there was lag time for the declining hydraulic gradients among the transects.

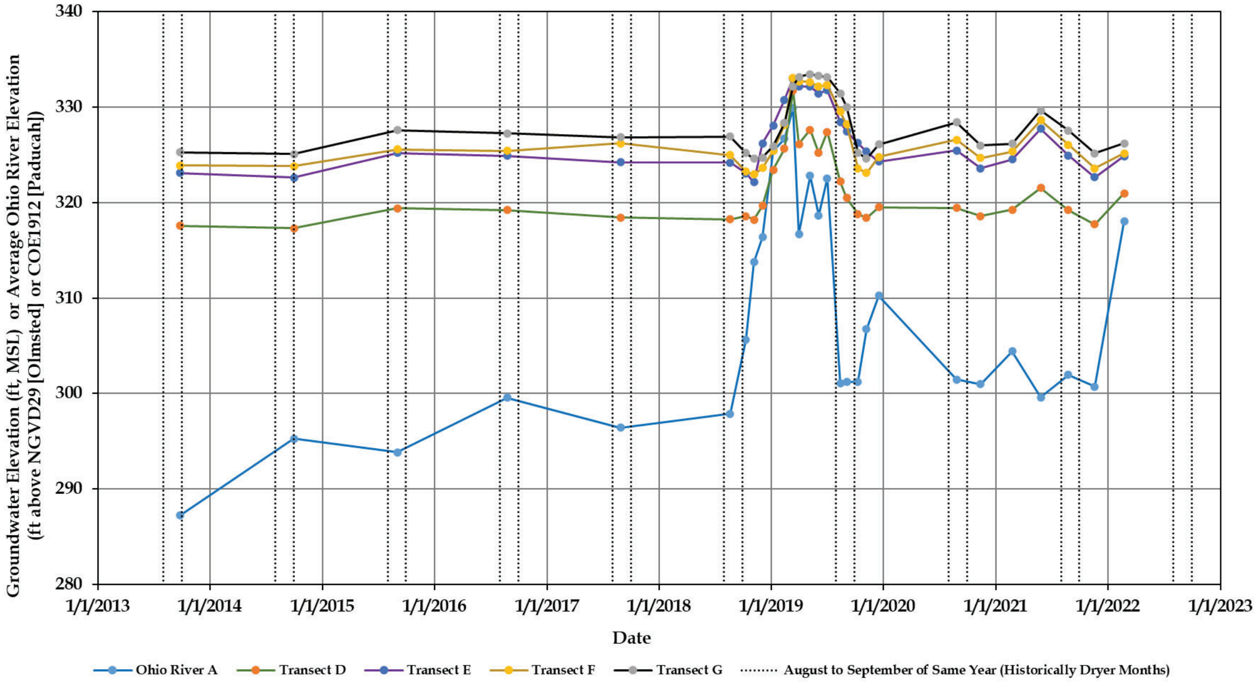

Figure 26. Comparison of Average Groundwater Elevation Along Transects D through G, shown in Table 10 with Ohio River Elevation

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Table 10. Groundwater and Ohio River Elevation Along Transects D through G

Date	Transect D				Transect E						Transect F					
	MW445	MW473	MW475	Average Groundwater Elevation Along Transect	MW199	MW202	MW491	MW477	MW471	Average Groundwater Elevation Along Transect	MW20	MW483	MW485	MW488	MW410	Average Groundwater Elevation Along Transect
Sep 24, 2013	318.25	317.16	317.24	317.55	323.15	323.02	323.03		323.12	323.08	324.25	323.76	323.69	323.76	--	323.87
Sep 29-Oct 1, 2014	317.46	317.16		317.31	322.59	322.58	322.61	322.54	322.77	322.62	--	323.64	323.80	323.48	324.25	323.79
Sep 1-2, 2015	319.14	319.37	319.71	319.41	325.52	325.30	324.79	325.04	325.30	325.19	325.65	325.62	325.51	325.58	325.48	325.57
Aug 22-24, 2016	319.08	319.10	319.50	319.23	325.29	324.91	324.38	324.75	325.07	324.88	--	325.38	325.29	325.36	325.67	325.43
Aug 28, 2017	318.40	318.27	318.62	318.43	324.46	324.32	323.85	324.12	324.28	324.21	331.95	324.79	324.60	324.64	325.01	326.20
Aug 20-21, 2018	319.16	317.73	317.88	318.25	324.56	324.36	324.33	323.76	323.83	324.17	325.78	324.90	324.81	324.81	324.52	324.96
Oct 10-11, 2018	--	318.57	318.60	318.58	--	--	--	--	323.04	323.04	--	--	--	--	323.23	323.23
Nov 7, 2018	--	318.15	318.24	318.19	--	--	--	--	322.13	322.13	--	323.07	323.02	322.98	322.64	322.93
Dec 5, 2018	--	319.71	319.61	319.66	--	--	--	--	326.18	326.18	--	323.58	323.60	323.60	323.67	323.61
Jan 9, 2019	--	323.19	323.65	323.42	--	--	--	--	328.07	328.07	--	325.36	325.40	325.42	325.40	325.39
Feb 13, 2019	--	325.53	325.74	325.63	--	--	--	--	330.77	330.77	--	328.08	328.13	328.18	328.19	328.14
Mar 13, 2019	--	331.61	331.86	331.74	--	--	--	--	332.98	332.98	--	332.87	333.62	332.88	332.88	333.06
Apr 2, 2019	--	326.07	326.18	326.12	--	--	--	--	332.18	332.18	--	332.58	332.64	332.74	332.76	332.68
May 8, 2019	--	327.51	327.69	327.60	--	--	--	--	332.14	332.14	--	332.58	332.64	332.66	332.60	332.62
Jun 5, 2019	--	325.08	325.27	325.18	--	--	--	--	331.43	331.43	--	332.10	332.13	332.18	332.13	332.13
Jul 3, 2019	--	327.26	327.49	327.38	--	--	--	--	331.75	331.75	--	332.27	332.32	332.34	332.32	332.32
Aug 12-15, 2019	323.68	321.31	321.56	322.18	328.52	328.04	328.07	328.86	328.64	328.43	329.43	329.52	329.54	329.61	329.55	329.53
Sep 4, 2019	--	320.36	320.58	320.47	--	--	--	327.55	327.33	327.44	--	328.15	328.16	328.19	328.15	328.16
Oct 10, 2019	--	318.71	318.87	318.79	--	--	--	--	326.24	326.24	--	--	--	--	323.59	323.59
Nov 7, 2019	--	318.28	318.51	318.40	--	--	--	--	325.33	325.33	--	323.10	323.14	323.08	323.02	323.09
Dec 16-18, 2019	319.86	319.21	319.49	319.52	324.38	--	323.96	324.42	324.34	324.28	--	324.54	324.91	324.85	324.84	324.79
Aug 24-26, 2020	319.70	319.14	319.48	319.44	325.36	325.17	324.97	325.95	325.78	325.45	326.60	326.50	326.51	326.57	326.59	326.55
Nov 11-12, 2020	319.11	318.15	318.51	318.59	323.53	323.33	323.47	--	324.02	323.59	324.61	324.63	324.67	324.71	324.62	324.65
Feb 23-24, 2021	319.65	318.86	319.19	319.23	324.80	324.35	324.16	--	324.74	324.51	325.52	325.13	325.31	325.36	325.38	325.34
May 24-27, 2021	321.17	322.51	320.92	321.53	328.15	327.60	327.38	327.84	327.64	327.72	328.97	328.40	328.42	328.40	328.85	328.61
Aug 23-25, 2021	319.46	318.96	319.20	319.20	324.80	324.57	324.45	325.51	325.38	324.94	325.80	326.09	326.02	326.11	326.16	326.04
Nov 15-18, 2021	318.20	317.34	317.62	317.72	322.45	322.39	322.37	323.07	322.92	322.64	323.61	323.57	323.57	323.57	323.55	323.57
Feb 21-23, 2022	320.54	320.59	321.70	320.95	325.44	324.75	324.50	--	324.75	324.86	325.75	324.95	324.97	324.95	--	325.16

Table 10. Groundwater and Ohio River Elevation Along Transects D through G (Continued)

Date	Transect G								Average Ohio River Elevation	Ohio River Paducah	Ohio River Olmsted
	MW426	MW354	MW329	MW71	MW145	MW191	MW150	Average Groundwater Elevation Along Transect			
Sep 24, 2013	325.60	325.60	325.74	325.91		324.23	324.53	325.27	287.25		
Sep 29-Oct 1, 2014	325.56	325.72	325.80	325.89	325.01	323.62	323.79	325.05	295.25		287.25
Sep 1-2, 2015	328.16	328.32	328.42	328.38	327.32	326.04	326.34	327.57	293.84	302.06	288.44
Aug 22-24, 2016	327.49	327.65	327.72	327.87	327.17	326.33	326.34	327.22	299.56	301.71	285.97
Aug 28, 2017	327.27	327.42	327.50	327.60	326.81	325.66	325.65	326.84	296.42	301.97	297.16
Aug 20-21, 2018	327.31	327.17	327.43	327.17	326.73	326.47	325.96	326.89	297.88	301.65	291.19
Oct 10-11, 2018	325.67	325.63	324.87	--	--	--	324.53	325.17	305.63	302.63	293.13
Nov 7, 2018	324.77	324.74	324.91	--	--	--	323.88	324.57	313.76	307.30	303.97
Dec 5, 2018	324.76	324.77	324.80	--	--	--	324.45	324.69	316.35	316.19	311.33
Jan 9, 2019	325.95	325.83	325.81	--	--	--	326.06	325.91	325.42	319.21	313.49
Feb 13, 2019	328.31	328.07	328.04	--	--	--	328.94	328.34	326.67	328.75	322.09
Mar 13, 2019	332.21	331.81	331.65	--	--	--	333.05	332.18	329.89	330.23	323.11
Apr 2, 2019	333.06	332.90	332.88	--	--	--	333.70	333.14	316.70	333.41	326.36
May 8, 2019	333.47	333.38	333.22	--	--	--	333.77	333.46	322.80	317.86	315.54
Jun 5, 2019	333.09	333.15	333.25	--	--	--	333.60	333.27	318.65	323.90	321.71
Jul 3, 2019	332.77	333.14	333.12	--	--	--	333.48	333.13	322.53	319.36	317.94
Aug 12-15, 2019	331.18	331.45	331.67	331.60	331.56	331.37	331.14	331.42	301.11	323.69	321.37
Sep 4, 2019	329.92	330.16	330.36	--	--	--	329.63	330.02	301.19	301.94	300.28
Oct 10, 2019	325.59	325.68	324.81	--	--	--	324.75	325.21	301.25	301.82	300.57
Nov 7, 2019	324.69	324.68	324.85	--	--	--	324.12	324.59	306.72	301.80	300.70
Dec 16-18, 2019	325.97	326.11	326.23	326.24	326.02	326.05	325.93	326.08	310.26	307.86	305.58
Aug 24-26, 2020	328.19	328.35	329.57	328.45	328.29	328.04	327.85	328.39	301.48	313.15	307.36
Nov 11-12, 2020	325.74	325.92	326.13	326.27	326.00	325.90	325.87	325.98	300.99	302.14	300.82
Feb 23-24, 2021	326.09	326.10	326.20	326.05	326.03	326.26	326.45	326.17	304.43	302.09	299.89
May 24-27, 2021	329.66	329.64	329.69	329.49	329.40	329.64	329.91	329.63	299.58	308.05	300.80
Aug 23-25, 2021	327.48	327.59	327.64	327.79	327.49	327.45	327.33	327.54	301.93	300.49	298.67
Nov 15-18, 2021	325.02	325.18	325.40	325.44	325.25	325.04	324.73	325.15	300.70	304.84	299.03
Feb 21-23, 2022	326.24	326.18	326.35	326.24	326.14	326.07	--	326.20	318.06	301.70	299.71

5. CONCLUSION

Synoptic groundwater elevation data and Ohio River elevation data collected pre- and post-operation of the Olmsted Dam met the evaluation DQOs and are adequate to evaluate the impact of the operations of the Olmsted Dam on groundwater flow at the Paducah Site. Operation of the Olmsted Dam increased the minimum elevation of the Ohio River at the Olmsted Station to approximately 295 ft to 300 ft amsl. Synoptic water level measurements and Ohio River elevation data collected for several years indicated spatial and seasonal changes of groundwater flow at the Paducah Site. Spatial changes were observed with relatively steeper hydraulic gradients near the Ohio River than at PGDP. Seasonal changes were observed when hydraulic gradients changed in response to the elevations of the Ohio River. Evaluation of groundwater data indicated that there are no uncertainties that would be anticipated to impact the conclusions of this evaluation.

Steady groundwater elevations were apparent when the Ohio River elevations were low. During these low river flow periods, groundwater flow direction was consistently to the north toward the Ohio River. Hydraulic gradients were steeper toward the river and groundwater flow was from the RGA to the Ohio River. The groundwater level fluctuations generally mimic the river water fluctuations with the magnitude of the fluctuations showing a decline with an increase in distance from the river.

As the Ohio River elevation increased to the level of the RGA potentiometric surface, a decline in hydraulic gradient was observed in the vicinity of the river. Groundwater elevations in MWs near the river increased by as much as 7 ft while groundwater elevations in MWs at PGDP increased by 4 ft. When the river elevation is higher than the RGA potentiometric surface, a reversal in flow direction from the Ohio River to the RGA was observed as evidenced by negative hydraulic gradients that were calculated during the period of January 2019 to February 2019. The extent of the groundwater flow reversal was limited to a distance of approximately 6,000 ft to 7,500 ft from the river, whereas PGDP is situated approximately 12,000 ft from the river.

The increase in Ohio River water elevation post-operation of the Olmsted Dam resulted in lower hydraulic gradients that were calculated between an equipotential surface in the northern part of the RGA and the river elevation. The mean hydraulic gradient of 0.005 ft/ft pre-operation of the dam declined to a mean gradient of 0.004 ft/ft post-operation. Lower hydraulic gradients after the operation of the dam imply lower groundwater flow velocities, which could potentially contribute to slower migration of the impacted groundwater from PGDP.

The two main findings of this evaluation are: (1) seasonal variation of groundwater flow occurs in the RGA with relatively lower gradients when the river elevation rises; and (2) although no changes in groundwater flow direction are observed due to operations of the Olmsted Dam, an increase in river water elevation after operation of the Olmsted Dam showed a decline in hydraulic gradient between the river and MWs located north of PGDP. These observations are consistent with prior studies that indicated a decline in hydraulic gradients and short-term flow of river water into the northernmost part of the RGA. A decline in hydraulic gradient associated with increased river elevation contributes to lower groundwater flow velocity. Based on the findings of this evaluation, the use of the pre- and post-operation Olmsted Dam datasets are available (and appropriate) for groundwater model calibration; however, predictive modeling should be limited to Olmsted Dam post-operation conditions.

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APPENDIX A

STATISTICAL ANALYSIS RESULTS

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Parametric Prediction Interval Analysis

Parameter: Precipitation

Original Data (Not Transformed)

USEPA Formula 95% Comparison
Number of comparisons = 1
Future Samples (k) = 1 = lesser of 5 or number of comparions
Recent Dates = 1
Background Samples = 8
Background mean = 54.1887 Std Dev = 6.10485
95% confidence t = 1.89458 at 7 degrees of freedom
Actual confidence level is 1.0 - (0.05/1) = 95 %

2019 Cumulative Precipitation

Date	Samples	Mean	Interval	Significant
12/31/2019	1	70.27	[0, 66.4565]	TRUE

Parametric Analysis of Variance

Parameter: Hydraulic Gradient

Original Data (Not Transformed)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares	F
Between Data	4.88103e-006	1	4.88103e-006	4.29388
Error (within Data)	3.0692e-005	27	1.13674e-006	
Totals	3.5573e-005	28		

4.29388 exceeds 4.21001 indicating a significant difference in group comparisons

Individual Data Comparisons

29 total observations - 2 Groups = 27 degrees of freedom
5% Invidual Comparison Rate
Bonferroni t = 1.70329 at 1, 27 degrees of freedom

Data	Mean	Dif from Pre-Olmsted	Std. Error	Critical Value
Post-Olmstead Dar	0.00402668	-0.000845516	0.00040	0.000695001

Date	Conc.	Residual
8/12/2019	0.00492759	0.000900911
8/12/2019	0.00469779	0.000671112
8/12/2019	0.00347258	-0.000554094
9/4/2019	0.0046717	0.00064502
9/4/2019	0.00445757	0.000430891
8/24/2020	0.00433735	0.00031067
8/24/2020	0.00410698	8.02977e-005
8/24/2020	0.00280308	-0.0012236
8/23/2021	0.00416145	0.000134767
8/23/2021	0.00396046	-6.62143e-005
8/23/2021	0.00269692	-0.00132976

APPENDIX B

HISTORICAL POTENTIOMETRIC SURFACE MAPS

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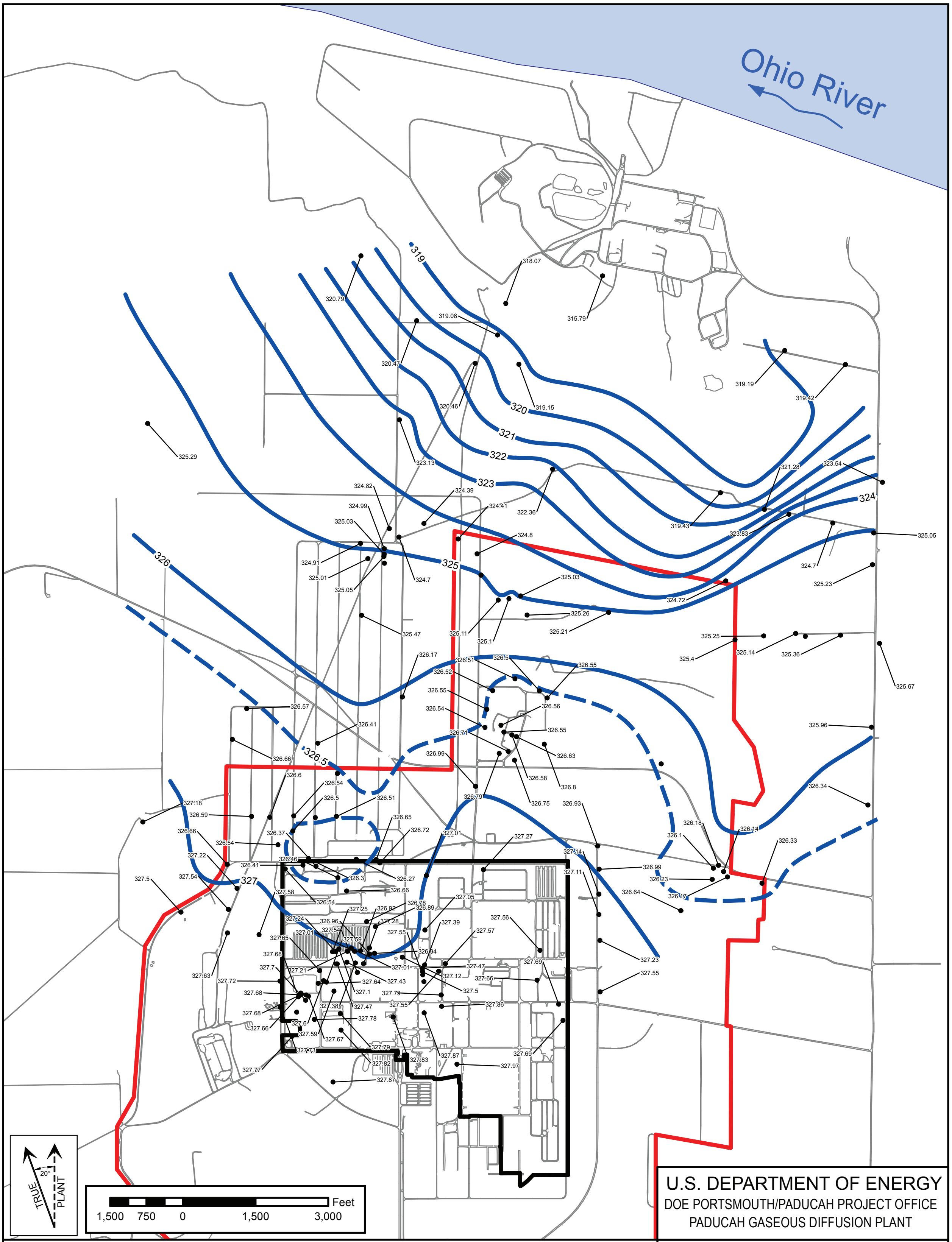

Figure 10. Regional Gravel Aquifer Potentiometric Map (August 2016)

G:\GIS\ARCVIEWS\PROJECTS\PLUMES\2016 Plumes\WaterLevelBasemap.mxd 3/13/2017

Figure B.1. Regional Gravel Aquifer Potentiometric Surface Map (August 2016)

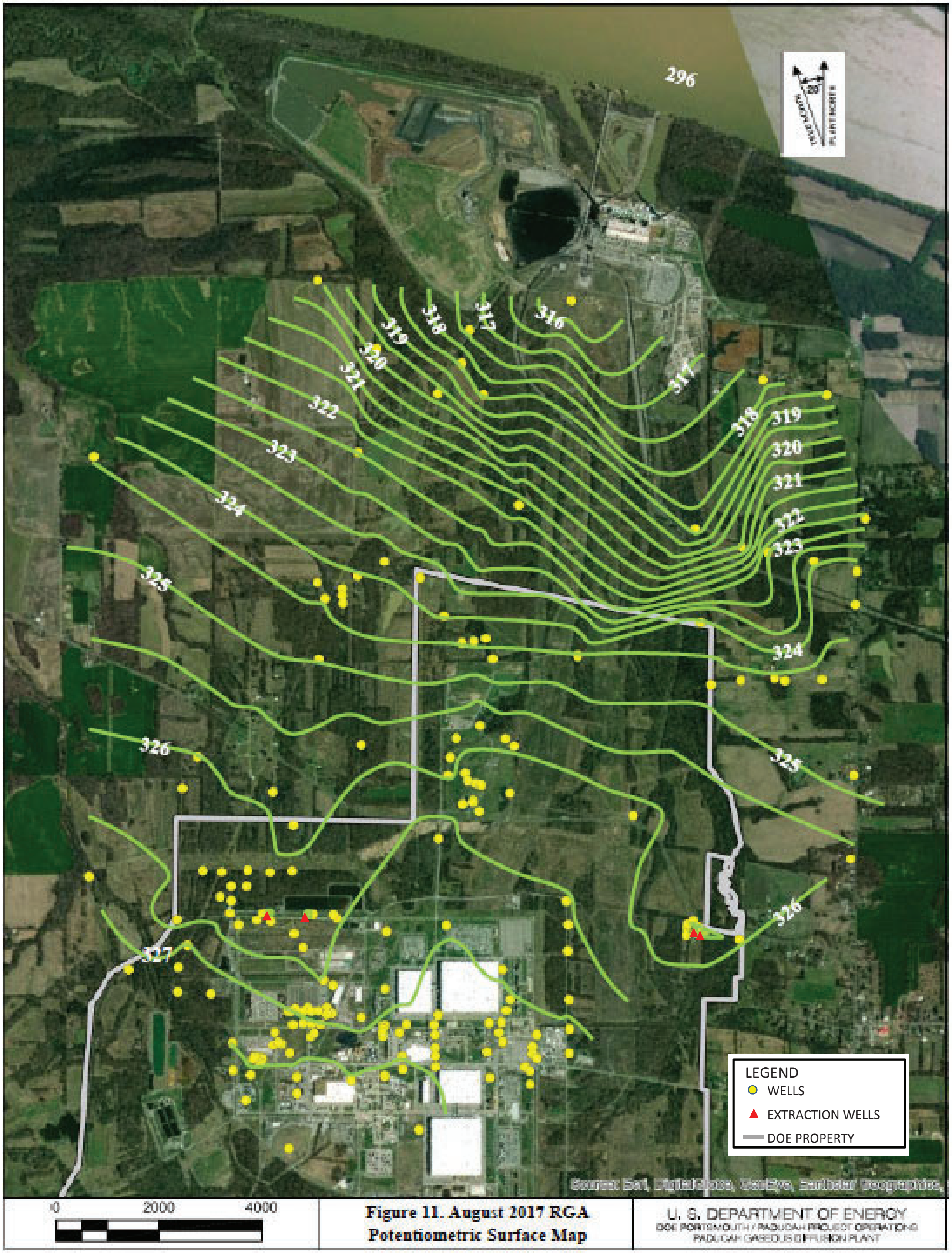

Figure B.2. Regional Gravel Aquifer Potentiometric Surface Map (August 2017)

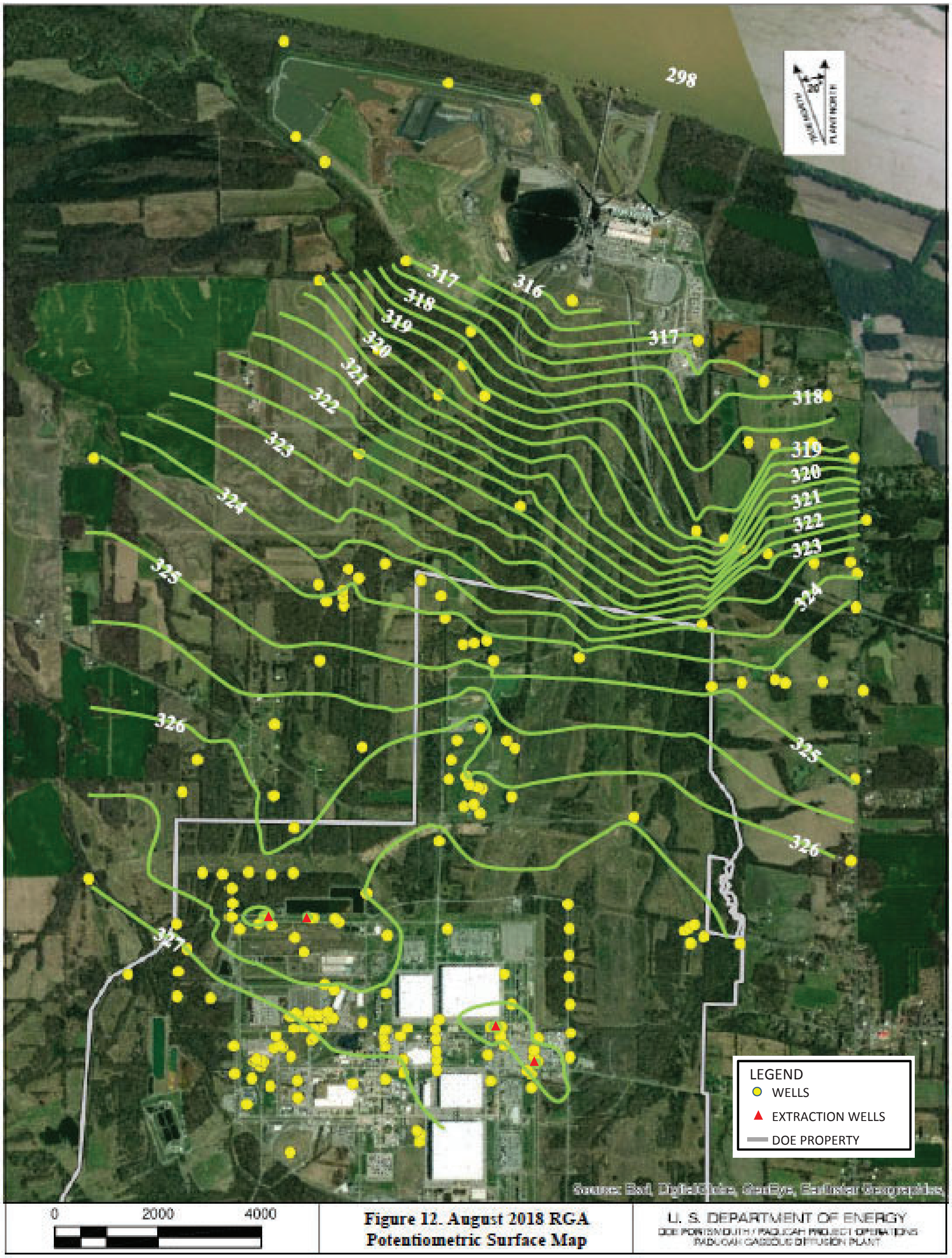

Figure B.3. Regional Gravel Aquifer Potentiometric Surface Map (August 2018)

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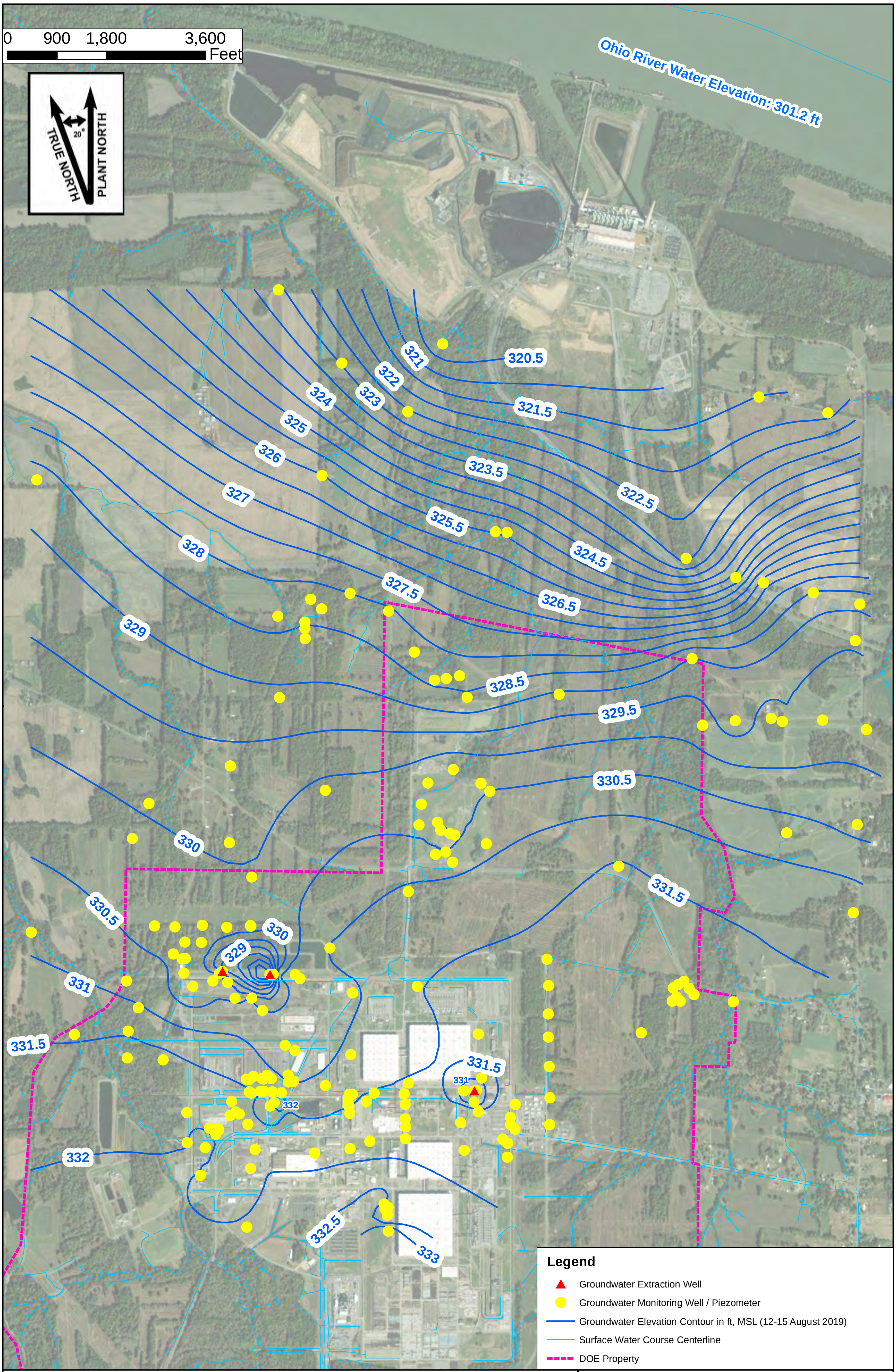

MAP SOURCE INFORMATION

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Map Layer Location: Geosyntec\\knoxville-01\data\PROJECTS\Paducah_FRNP\2020 Plume Maps\Potentiometric Surface Maps\Figure 11 August 2019 Potentiometric Surface Map.mxd
Image Source: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Shapefiles for DOE Boundary and Surface Water Course Centerline were obtained from Pegasis (https://pegasis.pad.pppo.gov/), downloaded on 3/16/2021
Groundwater elevation was based on the August 12-15, 2019 measurements. Ohio River elevation was estimated as the average
of elevations measured by the USGS at Paducah Station USGS 0361100 and Olmsted, IL Station (USGS 03612600) between August 12-15, 2019.

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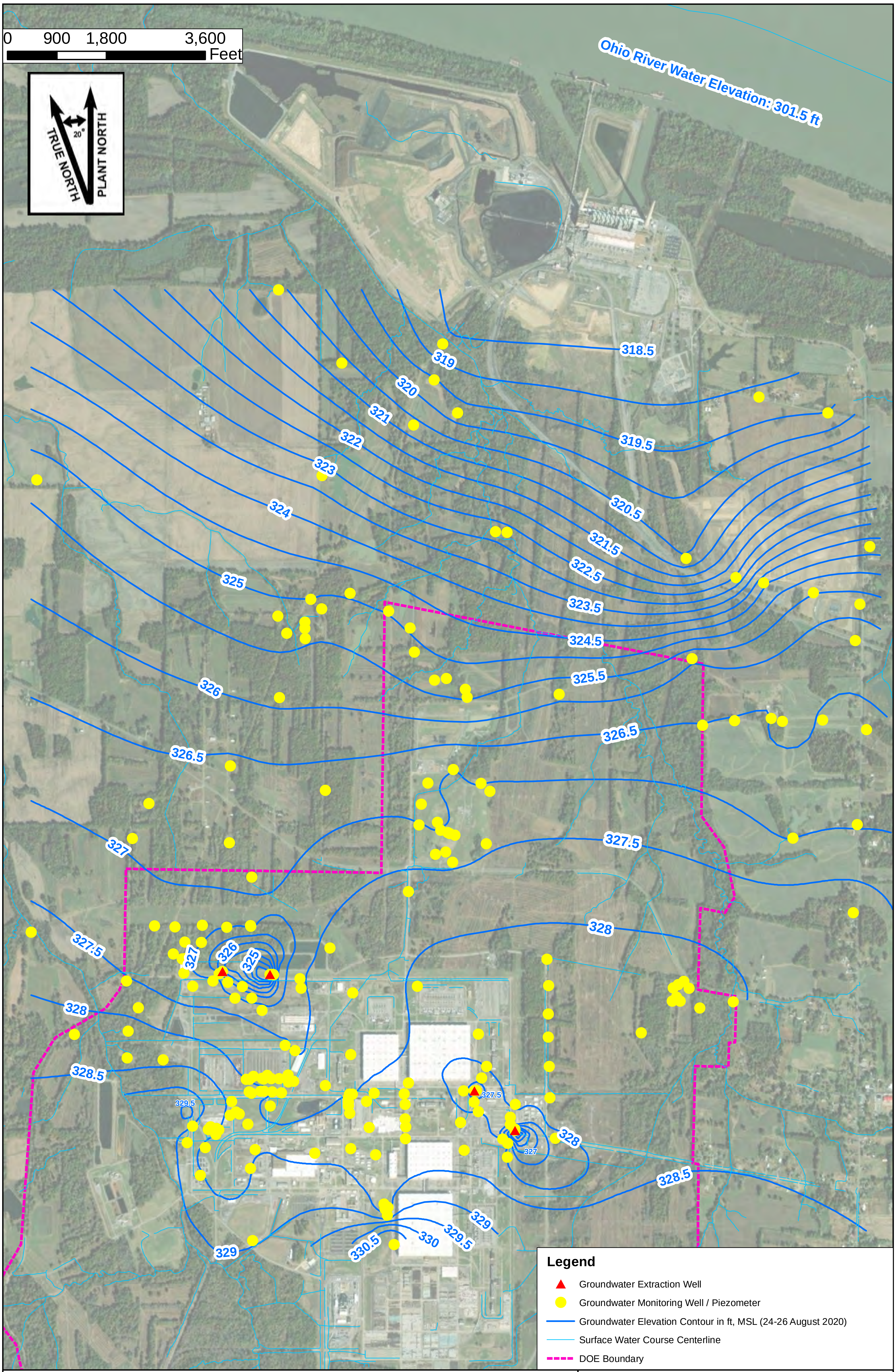
Figure B.4. Regional Gravel Aquifer Potentiometric Surface Map (August 2019)



MAP SOURCE INFORMATION

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Map Layer Location: Geosyntec\\knoxville-01\data\PROJECTS\Paducah_FRNP\2020 Plume Maps\Potentiometric Surface Maps\Figure 12 August 2020 Potentiometric Surface Map.mxd
Image Source: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Shapefiles for DOE Boundary and Surface Water Course Centerline were obtained from Pegasis (https://pegasis.pad.pppo.gov/), Downloaded on 3/16/2021.
Groundwater elevation was based on the August 24-26, 2020 measurements. Ohio River elevation was estimated as the average
of elevations measured by the USGS at Paducah Station USGS 0361100 and Olmsted, IL Station (USGS 03612600)
between August 24-26, 2020.

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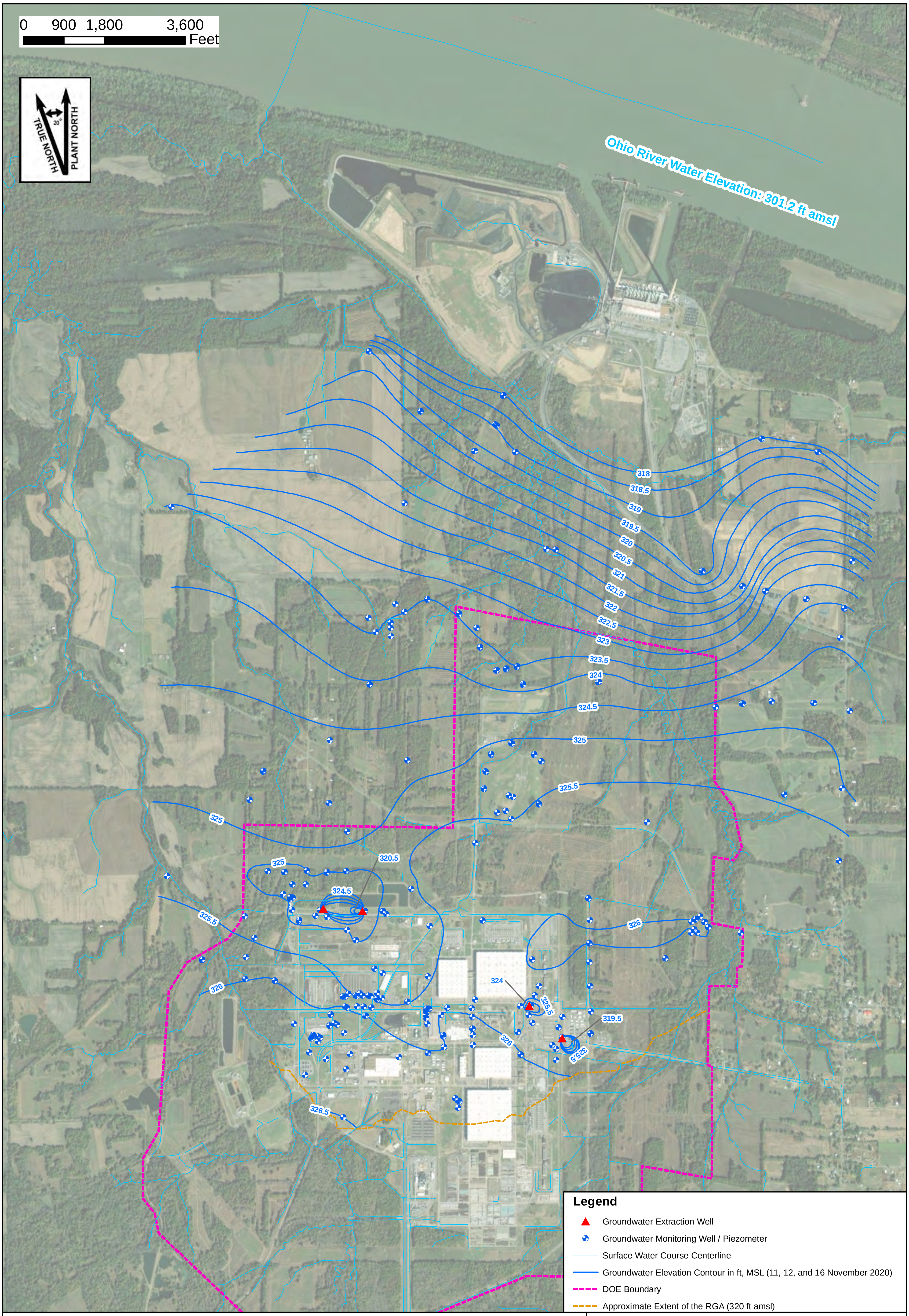
Figure B.5 Regional Gravel Aquifer Potentiometric Surface Map (August 2020)



MAP SOURCE INFORMATION

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Image Source: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Shapefile for Surface Water Course Centerline was obtained from Pegasis (https://pegasis.pad.pppo.gov/), downloaded on 12/1/2021.
DOE Property Boundary provided by FRNP 2/4/2021.
Northing and easting of wells obtained from Pegasis, downloaded on 10/5/2021.
Groundwater elevation was based on the August 12-15, 2019 measurements. Ohio River elevation was estimated as the average
of elevations measured by the USGS at Paducah Station USGS 0361100 and Olmsted, IL Station (USGS 03612600) between November 11-24, 2020.

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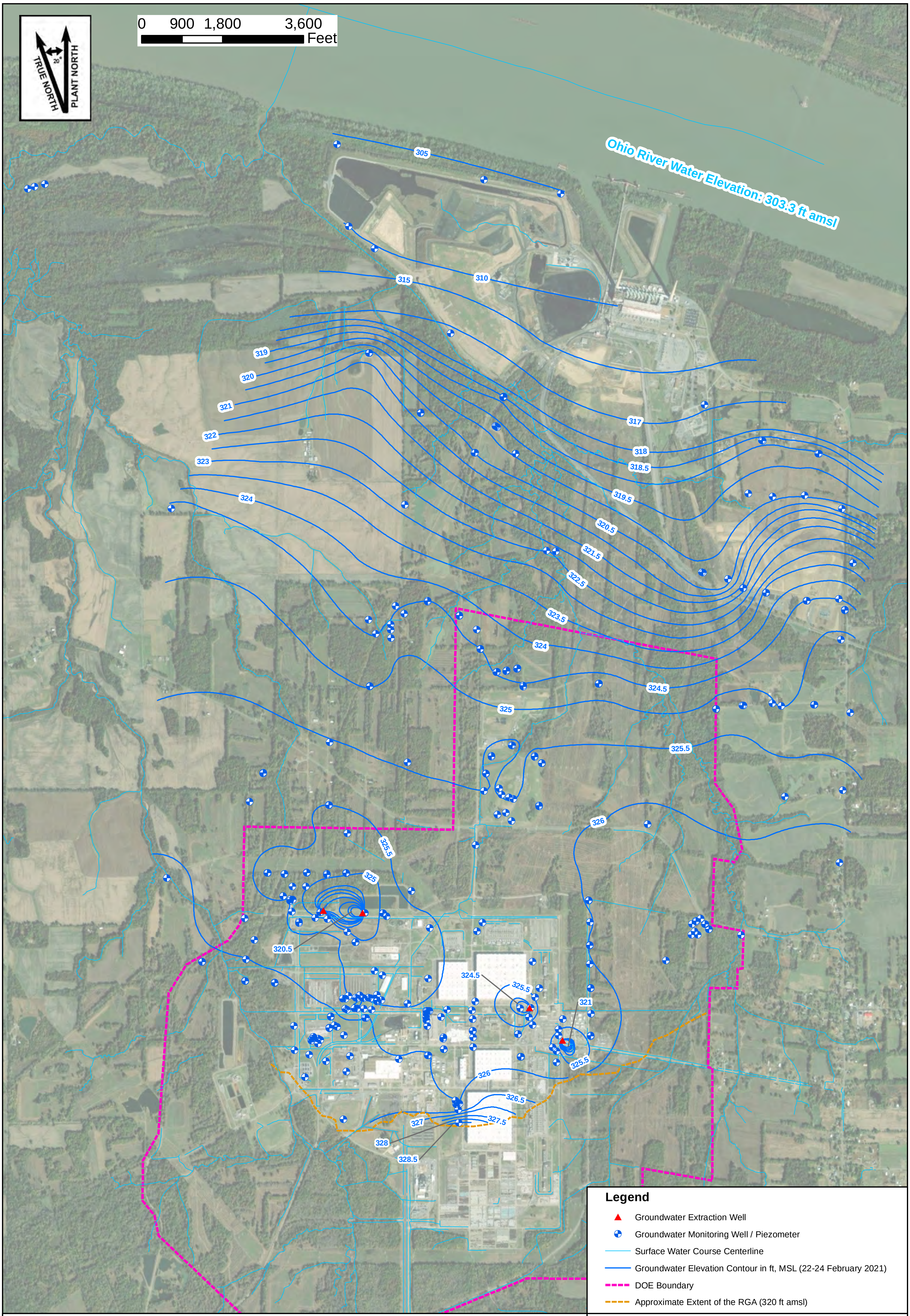
Figure B.6. Regional Gravel Aquifer Potentiometric Surface Map (November 2020)



MAP SOURCE INFORMATION

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Image Source: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Shapefile for Surface Water Course Centerline was obtained from Pegasis (https://pegasis.pad.pppo.gov/), Downloaded on 12/1/2021.
DOE Property Boundary provided by FRNP 2/4/2021.
Northing and easting of wells obtained from Pegasis, downloaded on 10/5/2021. Northing and easting of SHF and TVAGW series wells obtained from OREIS on 10/15/2021.
Groundwater elevation was based on the February 22-24, 2021 measurements. Ohio River elevation was estimated as the average
of elevations measured by the USGS at Paducah Station USGS 0361100 and Olmsted, IL Station (USGS 03612600) between February 22-24, 2021.

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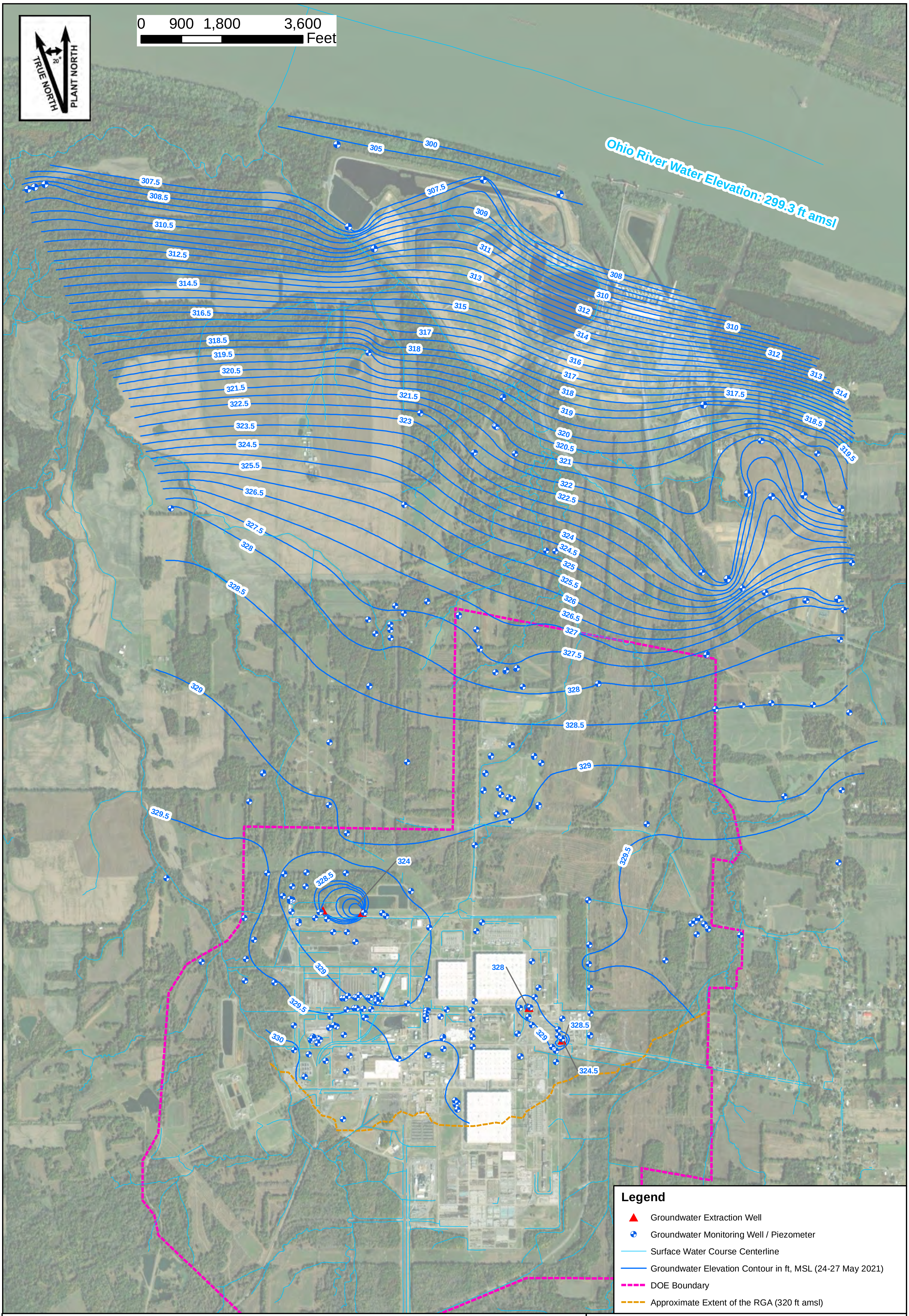
Figure B.7. Regional Gravel Aquifer Potentiometric Surface Map (February 2021)



Legend

▲	Groundwater Extraction Well
●	Groundwater Monitoring Well / Piezometer
—	Surface Water Course Centerline
—	Groundwater Elevation Contour in ft, MSL (24-27 May 2021)
- - -	DOE Boundary
- - -	Approximate Extent of the RGA (320 ft amsl)

MAP SOURCE INFORMATION

Map Generation Date and Location - 8/8/2022 Geosyntec\\fedprojects-01\paducah$\Knoxville\GW Strategy\GIS\MXDs\2020-2021 Potentiometric Surface Maps
Map Layer Location: Geosyntec\\fedprojects-01\paducah$\Knoxville\GW Strategy\GIS\MXDs\2020-2021 Potentiometric Surface Maps\May 2021 Potentiometric Surface Map.mxd
Image Source: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Shapefile for Surface Water Course Centerline was obtained from Pegasis (https://pegasis.pad.pppo.gov/), Downloaded on 12/1/2021.
DOE Property Boundary provided by FRNP 2/4/2021.
Northing and easting of wells obtained from Pegasis, downloaded on 10/5/2021. Northing and easting of SHF and TVAGW series wells obtained from OREIS on 10/15/2021.
Groundwater elevation was based on the May 24-27, 2021 measurements. Ohio River elevation was estimated as the average
of elevations measured by the USGS at Paducah Station USGS 0361100 and Olmsted, IL Station (USGS 03612600) between May 24-27, 2021.

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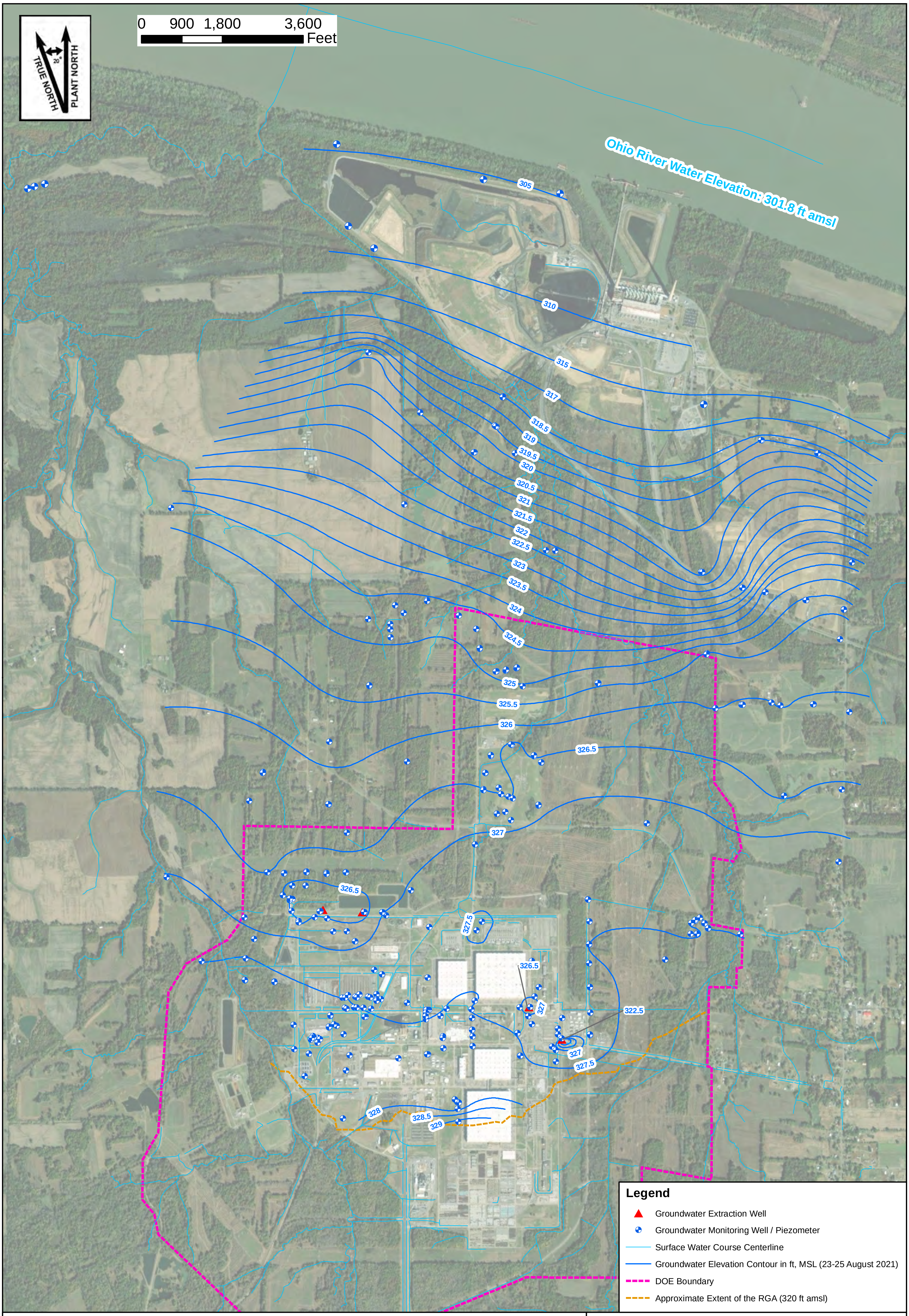
Figure B.8. Regional Gravel Aquifer Potentiometric Surface Map (May 2021)



MAP SOURCE INFORMATION

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Image Source: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Shapefile for Surface Water Course Centerline was obtained from Pegasis (https://pegasis.pad.pppo.gov/), downloaded on 12/1/2021.
DOE Property Boundary provided by FRNP 2/4/2021.
Northing and easting of wells obtained from Pegasis, downloaded on 10/5/2021. Northing and easting of SHF and TVAGW series wells obtained from OREIS on 10/15/2021.
Ohio River elevation was estimated as the average of elevations measured by the USGS at Paducah Station USGS 0361100 and Olmsted, IL Station (USGS 03612600) between August 23-25, 2021.

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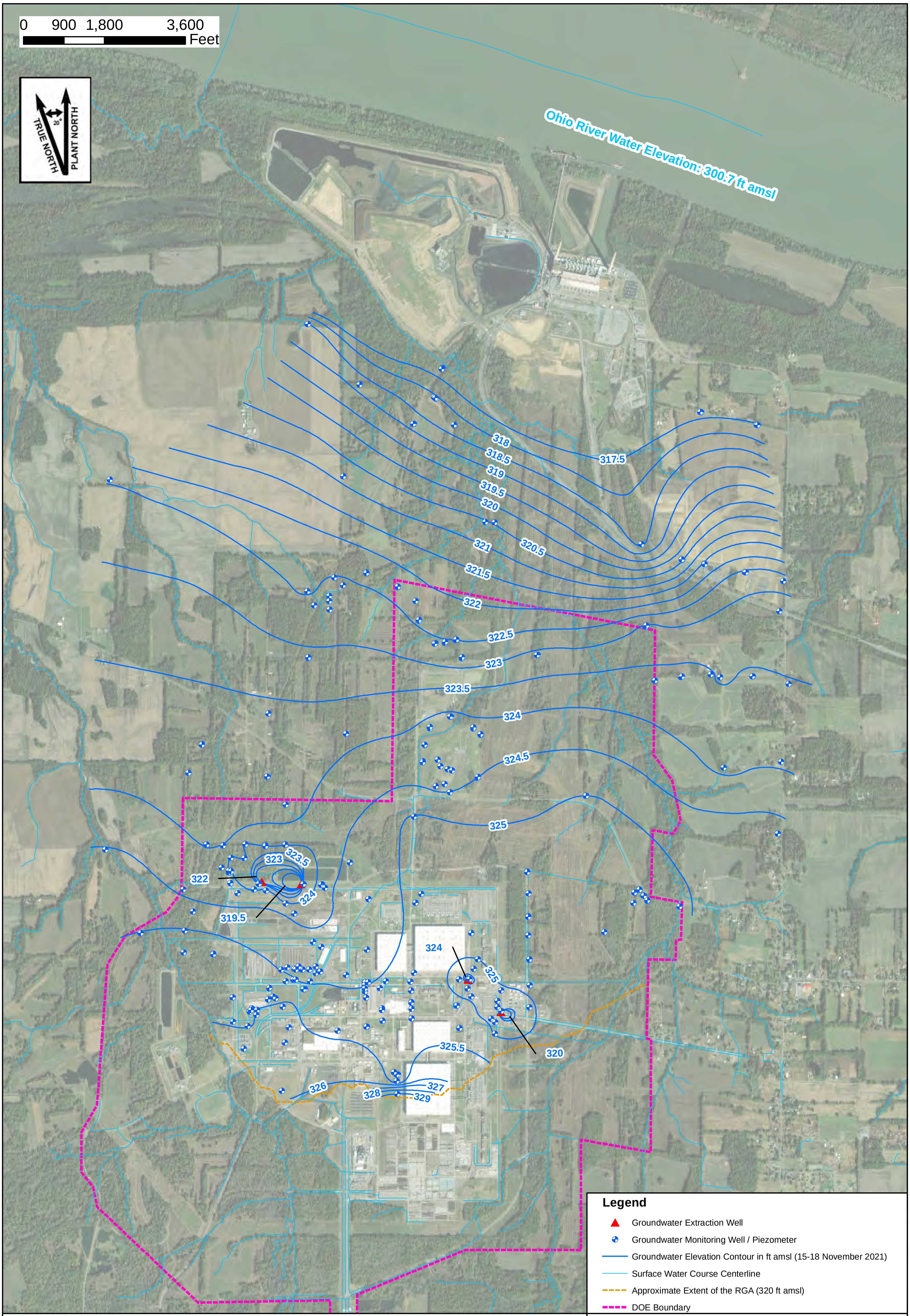
Figure B.9. Regional Gravel Aquifer Potentiometric Surface Map (August 2021)



MAP SOURCE INFORMATION

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Map Layer Location: Geosyntec\\fedprojects-01\paducah$\Knoxville\GW Strategy\GIS\MXDs\2020-2021 Potentiometric Surface Maps\November 2021 Potentiometric Surface Map.mxd
Image Source: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Shapefile for Surface Water Course Centerline was obtained from Pegasis (https://pegasis.pad.pppo.gov/), downloaded on 12/1/2021.
DOE Property Boundary provided by FRNP 2/4/2021.
Northing and easting of wells obtained from Pegasis, downloaded on 12/7/2021.
Groundwater elevation was based on the November 15-18, 2021 measurements. Ohio River elevation was estimated as the average
of elevations measured by the USGS at Paducah Station USGS 0361100 and Olmsted, IL Station (USGS 03612600) between November 15-18, 2021.
amsl = above mean sea level

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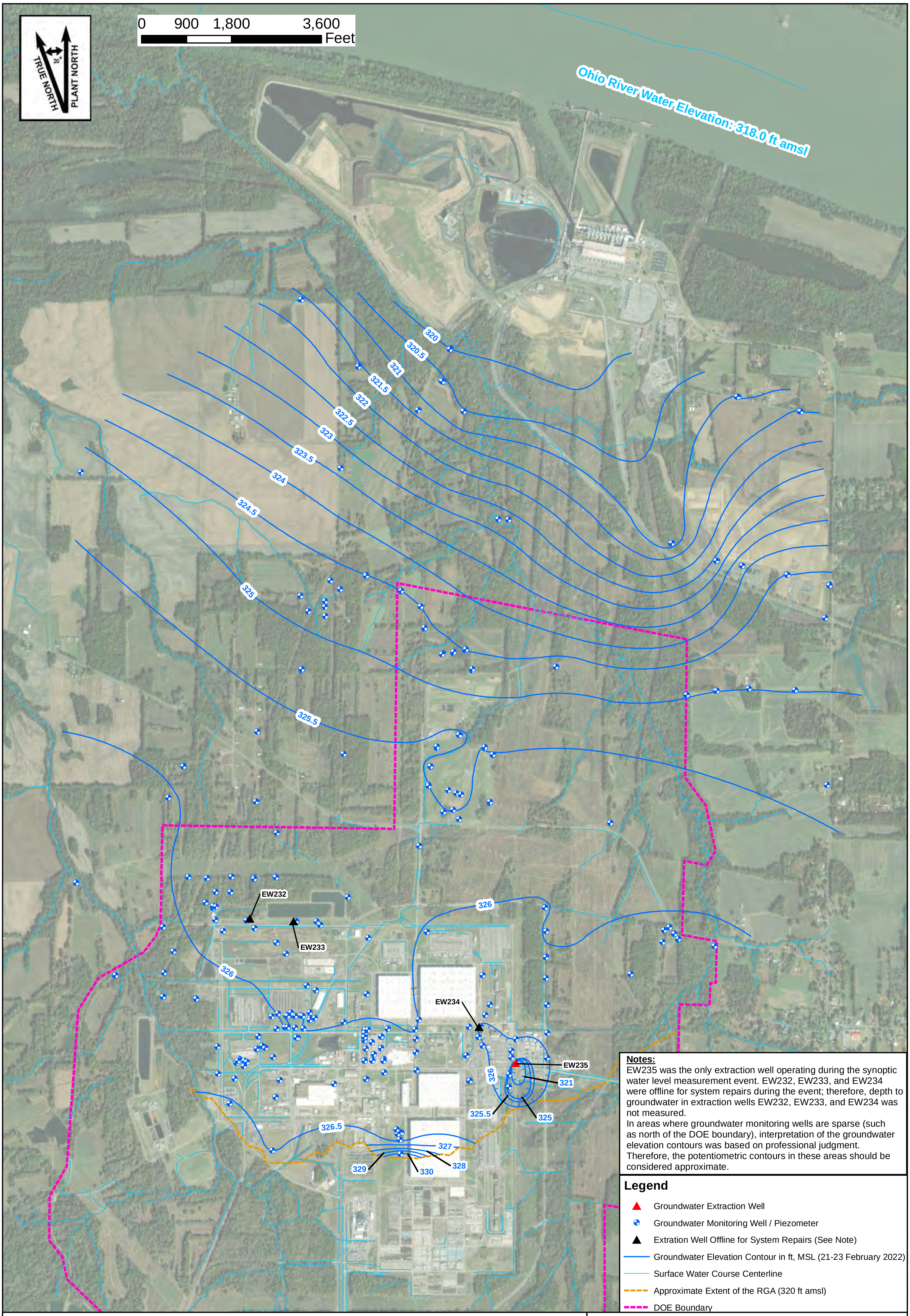
Figure B.10. Regional Gravel Aquifer Potentiometric Surface Map (November 2021)



Notes:
EW235 was the only extraction well operating during the synoptic water level measurement event. EW232, EW233, and EW234 were offline for system repairs during the event; therefore, depth to groundwater in extraction wells EW232, EW233, and EW234 was not measured.
In areas where groundwater monitoring wells are sparse (such as north of the DOE boundary), interpretation of the groundwater elevation contours was based on professional judgment. Therefore, the potentiometric contours in these areas should be considered approximate.

MAP SOURCE INFORMATION

Map Generation Date and Location - 3/18/2022 Geosyntec\\fedprojects-01\paducah$\Knoxville\GW Strategy\GIS\MXDs\2021-2022 Potentiometric Surface Maps
Map Layer Location: Geosyntec\\fedprojects-01\paducah$\Knoxville\GW Strategy\GIS\MXDs\2021-2022 Potentiometric Surface Maps\February 2022 Potentiometric Surface Map.mxd
Image Source: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Shapefile for Surface Water Course Centerline was obtained from Pegasis (https://pegasis.pad.pppo.gov/), downloaded on 12/1/2021.
DOE Property Boundary provided by FRNP 2/4/2021.
Northing and easting of wells obtained from Pegasis, downloaded on 12/7/2021.
Groundwater elevation was based on the February 21-23, 2022 measurements. Ohio River elevation was estimated as the average
of elevations measured by the USGS at Paducah Station USGS 0361100 and Olmsted, IL Station (USGS 03612600) between February 21-23, 2022.
amsl = above mean sea level

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Figure B.11. Regional Gravel Aquifer Potentiometric Surface Map (February 2022)

APPENDIX H

DEGRADATION OF TRICHLOROETHENE AT THE PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY, FRNP-RPT-0282

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FRNP-RPT-0282

Degradation of Trichloroethene at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

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This document is approved for public release per review by:

JACKIE THOMPSON (Affiliate)
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FRNP Classification Support

Date

Degradation of Trichloroethene at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

Date Issued—April 2023

U.S. DEPARTMENT OF ENERGY
Office of Environmental Management

Prepared by
FOUR RIVERS NUCLEAR PARTNERSHIP, LLC,
managing the
Deactivation and Remediation Project at the
Paducah Gaseous Diffusion Plant
under Contract DE-EM0004895

CONTENTS

ACRONYMS

DNAPL	dense nonaqueous-phase liquid
DOE	U.S. Department of Energy
EAP	enzyme activity probe
ORP	oxidation-reduction potential
OU	operable unit
PGDP	Paducah Gaseous Diffusion Plant
RGA	Regional Gravel Aquifer
RI	remedial investigation
SWMU	solid waste management unit
UCRS	Upper Continental Recharge System

1. INTRODUCTION

The objective of this white paper is to summarize documented information on the degradation of dissolved phase trichloroethene (TCE) at the Paducah Gaseous Diffusion Plant (PGDP) within the Regional Gravel Aquifer (RGA) and the Upper Continental Recharge System (UCRS). Because information related to TCE degradation will continue to be collected during environmental remediation projects at PGDP, the information presented in this paper must be evaluated to ensure it is consistent with current information before it is used for decision making.

Groundwater beneath PGDP is contaminated by the chlorinated solvent TCE. TCE was released as a result of historical, routine PGDP industrial activities and spills. TCE is present in subsurface soils and groundwater as both a dense nonaqueous-phase liquid (DNAPL) and a dissolved contaminant. The introduction of TCE to shallow subsurface soils and the underlying sands and gravels of the RGA resulted in the evolution of three groundwater contaminant plumes (the Northeast Plume, the Northwest Plume, and the Southwest plume). Groundwater contamination associated with the Northeast and Northwest Plumes is sourced primarily from DNAPL located in the RGA and UCRS at the C-400 Cleaning Building. These plumes are impacted along their on-site flowpaths by additional sources of contamination, which include burial grounds and closed disposal areas around PGDP. The Southwest Plume groundwater contamination is thought to originate from Solid Waste Management Unit (SWMU) 4 (C-747 Contaminated Burial Ground) and SWMU 91 (UF_6 Cylinder Drop Test Pit) (areas of *in situ* treatment of TCE-contaminated soils using the LASAGNA^{TM} technology), both of which are in the vicinity of the C-720 Maintenance & Storage Building area [e.g., SWMU 211-A (C-720 TCE Spill Site Northeast), SWMU 211-B (C-720 TCE Spill Site Southeast), and SWMU 1 (C-747-C Oil Landfarm)]. Another possible source of contamination is from the migration of TCE from the C-400 area. Bacteria capable of aerobically biodegrading TCE are present in the Northwest Plume at PGDP. The number and distribution of bacteria appear sufficient to contribute to the biodegradation of TCE in RGA groundwater. The organic carbon in this oligotrophic, "nutrient limited" system is low. The microbial community appears to be stable and sustainable; that is, the control and plume well data are similar (DOE 2008). As presented in this white paper, analytical data collected during recent investigations from the three groundwater contaminant plumes and the soils from the UCRS indicate that anaerobic and aerobic cometabolic degradation of the TCE is occurring. Recent investigations include the following:

- *PGDP Trichloroethene Biodegradation Investigation Summary Report Regional Gravel Aquifer & Northwest Plume* (KRCEE 2008)

- *Remedial Investigation/Feasibility Study Report for the C-400 Complex Operable Unit at the Paducah Gaseous Diffusion Plant* (DOE 2022)

- *Addendum to the Final Characterization Report for Solid Waste Management Units 211-A and 211-B Volatile Organic Compound Sources for the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant* (DOE 2016)

The historical RGA groundwater sampling analytical data taken into consideration in this white paper includes both upgradient source areas at the C-400 Cleaning Building and the C-720 Maintenance & Storage Building, as well as downgradient areas in the dissolved phase portion of the plume(s). Additionally, historical soils data from the UCRS are taken into consideration regarding molecular biological studies associated with natural attenuation processes.

2. BACKGROUND

PGDP is located in the Jackson Purchase region of western Kentucky, approximately 10 miles west of Paducah, Kentucky, and 4 miles south of the Ohio River. The uppermost aquifer underlying the majority of PGDP is the RGA. The RGA pinches out to the south, southeast, and southwest along the buried slope of the Porters Creek Clay Terrace, which is overlain by the Terrace Gravel flow system, and also pinches out to the north and then terminates at the Ohio River. The UCRS overlies the RGA and thins to the north; however, the UCRS is not a pathway for off-site contaminant migration. The RGA is the main conduit for groundwater flow to the north, where groundwater discharges to the Ohio River, and also is the main pathway for off-site contaminant plume migration. The McNairy Formation underlies the RGA and also flows to the north but is not a significant pathway for contaminant migration when compared to the RGA.

Three groundwater plumes (southwest, northwest, and northeast) exist in the RGA. The Northwest and the Northeast Plumes have both followed the groundwater flow north from the C-400 Complex Operable Unit (OU) to locations off of U.S. Department of Energy (DOE) property. The Southwest Plume remains within the DOE property boundary.

The magnitude and extent of the groundwater plumes are generally known. TCE DNAPL and dissolved phase contamination exists in the soils and groundwater of the UCRS and the groundwater plumes within the RGA (DOE 2001, DOE 2022).

3. DISCUSSION

The first evaluation of TCE biodegradation and RGA geochemistry is documented in *Evaluation of the Natural Attenuation Processes for Trichloroethylene and Technetium-99* [Tc-99] *in the Northwest Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (Clausen et al. 1997). The report concluded that degradation was occurring and that it was consistent with—though relatively slow in comparison to—literature values for reductive dechlorination. Assumptions for TCE degradation factors from this evaluation were included in groundwater modeling through 2005, when some recommendations for additional field sampling events, specifically those that would evaluate the potential for aerobic degradation, were developed (KRCEE 2006). Subsequent investigators and field-scale efforts have also confirmed TCE degradation by measuring against the comparatively nonreactive cocontaminant Tc-99 as TCE and Tc-99 migrate through PGDP's groundwater system (DOE 2008).

A study was conducted in 2007 regarding the identification and evaluation of biological degradation processes that actively influence TCE fate and transport in the RGA (DOE 2008, KRCEE 2008). These activities centered on a portion of the Northwest Plume and included sampling locations along the plume axis from upgradient source areas at the C-400 Complex to downgradient areas in the dissolved phase portion of the plume. Using the *Scenarios Evaluation Tool for Chlorinated Solvent MNA* (*A Research Study of the Monitored Natural Attenuation/Enhanced Attenuation for Chlorinated Solvents Technology Alternative Project)*, WSRC-STI-2006-00096 (DOE 2007), along with information obtained from the U.S. Environmental Protection Agency's technical guidance document, *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water* (EPA 1998), the study concluded that microbial degradation was occurring in PGDP's aerobic groundwater environment.[1] This conclusion is evident based on the following information.

- First-order rate constant calculations demonstrated that TCE is preferentially degraded along Northwest Plume flowpaths relative to the tracer chloride.[2]
- Genetic profiling, enzyme activity probes (EAP), and related control studies indicated the following:
  - — The appropriate genetic material is present in the RGA for the production of enzymes responsible for the destruction of TCE;
  - — The enzymes are present and actively being produced in the RGA; and
  - — The microbial populations evaluated through the EAPs and genetic profiling are representative of the aquifer and not biofouling populations of individual wells.
- Based on evaluations of the stable carbon isotopes data, aerobic degradation of TCE is occurring.
- Study area and sitewide RGA geochemical evaluations indicated that dissolved oxygen, pH, and oxidation-reduction potential (ORP) sources are sufficient to support populations of aerobic bacteria capable of TCE biodegradation.[3]

The estimated degradation rates for PGDP of 9.4 to 26.7 years are based on previous studies and a comparison of plume scale TCE transport to Tc-99 (which comparatively acts as a tracer) (DOE 2008, KRCEE 2008), and are consistent with the published literature for aerobic cometabolism in large aerobic plumes (i.e., half-life in the range of 9 to 25 years) (ITRC 2017). The number and distribution of bacteria in the Northwest Plume appear sufficient to contribute to the biodegradation of TCE in RGA groundwater. The organic carbon in this oligotrophic, "nutrient limited" system is low. The microbial community appears to be stable and sustainable; that is, the control and plume well data are similar (DOE 2008).

The 2007 Northwest Plume evaluation also recommended the following actions to better understand TCE degradation rates and support remedial decisions involving bioremediation approaches.

- Through a project team data quality objective process, consider the development of a comprehensive sampling and analysis plan to expand the characterization of microbial degradation across the extent of the three plumes to include the following:
  - — Expand the well selection criteria to accommodate all three plumes, including spatial characterization of the upper, middle, and lower RGA, as permissible.
  - — Evaluate the temporal and spatial inputs to and distribution of dissolved oxygen, pH, and temperature.

---

[1] Groundwater samples at the site have been analyzed for the presence of *Dehalococcoides mccartyi* (*Dhc*) (DOE 2013). *Dhc* was not measured at a concentration greater than the reporting limits; the absence of detectable *Dhc* suggested that reductive dechlorination is not occurring at a high rate under sampled groundwater conditions. No specific anaerobic testing for TCE degradation rates has been performed at PGDP.

[2] The study also evaluated Tc-99 degradation rates.

[3] Aerobic conditions are not ubiquitous to the RGA; ORP conditions and the presence of anaerobic degradation products, including *cis*-1,2-dichloroethene (DCE) indicate that anaerobic conditions exist locally in on-site and near-site areas of the RGA (DOE 2007, KRCEE 2008). Anaerobic degradation byproducts are also produced in the UCRS and migrate to the RGA.

- Identify and document the individual species in RGA groundwater microbial populations responsible for TCE degradation.

- Sample RGA groundwater to characterize the following parameters:
  - Specific isotope analyses for stable carbon and stable hydrogen isotopes;
    - Collect sufficient temporal data at enough locations to satisfy statistical requirements of the student t-test.
  - Dissolved inorganic carbon, dissolved oxygen, temperature, pH, ferric and ferrous iron, sulfate, fatty acids, *Dhc*, and ethenogenes as indicators of degradation processes;
  - ORP with temperature as an indicator of ORP conditions that support aerobic or anaerobic degradation processes;
  - Specific conductivity to augment characterization of the RGA at sub-plume scales;
  - Ammonium (NH_4+) as an indicator of anoxic conditions and as a substrate for organic compound degradation;
  - TCE degradation products, *cis*-1,2-DCE, *trans*-1,1-DCE, and vinyl chloride (via molar concentrations) as indicators of anoxic conditions in the RGA and UCRS; and
  - Copper and copper-based compounds, as well as other substances to be determined from process and industrial operations, that may have biocidal effects on microorganisms in the RGA and UCRS.

- Evaluate what groundwater geochemical data exists and compare against recommendations and complete data gaps.

- Evaluate the potential impacts of past, ongoing, and planned PGDP remedial activities on existing biogeochemical conditions in the RGA.

- Upon collection of the data described within these recommendations, it is recommended that an updated kinetic rate study be performed to develop a site-specific degradation rate constant.

- With the site-specific degradation rate, evaluate enhancement opportunities to either the RGA environment and/or the biogeochemical processes, and assess the need for bench scale and pilot studies if enhancements are to be pursued as part of a dissolved phase plume remediation option.

- Evaluate the cost and schedule of investing the time and effort to develop data quality objectives, a sampling and analysis plan, and a work plan against site conditions to determine if degradation rates of TCE in the soil are needed for various projects.

- Using the geotechnical and geochemical data collected as part of the C-400 Complex OU remedial investigation (RI), develop degradation rates of TCE in the UCRS subsurface soil.

This white paper provides the first steps in the development of degradation rates. Relevant data from the C-400 Complex OU RI and subsequent remedial activities will be incorporated into this paper as they are made available and as appropriate.

Unlike the studies performed in the RGA, breakdown compounds identified in the sample data for PGDP soils indicated some level of degradation may be occurring (DOE 2016, DOE 2022). These breakdown compounds include *cis*-1,2-DCE, *trans*-1,2-DCE, and vinyl chloride (DOE 2016, DOE 2022); however, testing of the SWMU 211-A subsurface did not identify the presence of *Dhc* (DOE 2013, DOE 2016, DOE 2022).

Thermal treatment has been performed at PGDP in the southwest portion of the C-400 Complex OU. Thermal treatment may induce enhanced chlorinated ethene biodegradation where the appropriate bacteria for complete biodegradation are present or when combined with enhanced *in situ* bioremediation. In terms of temperature range on the rate of dechlorination, studies have shown that *Dhc* can effectively dechlorinate chlorinated ethenes when temperatures are increased to 35°C; however, degradation substantially decreases when temperatures are greater than 43°C (Marcet et al. 2018; Friis et al. 2005; Friis et al. 2006). Thermal treatment has been shown to desorb chlorinated volatile organic compounds and dissolve total organic carbon from the subsurface matrix. Additionally, thermal remediation generally decreases the dissolved oxygen concentration in groundwater and can also change and/or decrease ORP. Each of these changes may have an impact on the rate of bioremediation of TCE. Warmer conditions should make all species of dechlorinators more active; however, if the appropriate bacteria to reduce *cis*-1,2-DCE to vinyl chloride or vinyl chloride to ethene are not present, *cis*-1,2-DCE or vinyl chloride may accumulate in warmer groundwater.

With the presence of breakdown compounds, *cis*-1,2-DCE and *trans*-1,2-DCE, degradation may be occurring; however, further verification processes are needed to determine potential degradation rates (Maymó-Gatell, Anguish, and Zinder 1999; Chaudhry and Chapalamadugu 1991). Because thermal treatment has been performed at PGDP in the southwest portion of the C-400 Complex OU, future evaluations in these areas should assess whether the thermal treatment has influenced TCE degradation rates.

4. SUMMARY

The 2007 Northwest Plume evaluation found that the estimated TCE degradation rates for PGDP, based on comparison of plume scale TCE transport to a tracer (Tc-99), are consistent with the published literature for aerobic cometabolism in large aerobic plumes and are on the order of 9 to 25 years half-life.

The analyses further demonstrated the presence of appropriate genetic material to produce the enzymes capable of TCE cometabolism, the presence of active enzymes being produced by microbes in Northwest Plume core and control well groundwater samples, and the number of microbes in Northwest Plume sample populations that express the enzymes are capable of TCE cometabolism. Data indicating isotopic carbon enrichment provides an additional line of evidence of aerobic microbial activity.

Although data exists for the Northwest Plume, the potential impacts of past, ongoing, and planned PGDP remedial activities should consider the impacts of current biogeochemical conditions in the RGA in each of the three plumes.

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