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REPORT ON

2024 ANNUAL GROUNDWATER MONITORING REPORT FOR RETROFIT BOTTOM ASH POND (RBAP) CARDINAL POWER PLANT FACILITY BRILLIANT, OHIO

by
Haley & Aldrich, Inc.
Cleveland, Ohio

for
Cardinal Operating Company
Brilliant, Ohio

File No. 210218
January 2025

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1. Annual Groundwater Monitoring Report Summary

Haley & Aldrich, Inc. has prepared this 2024 Annual Groundwater Monitoring Report (Report) for the Retrofit Bottom Ash Pond (RBAP), an existing coal combustion residual (CCR) unit at the Cardinal Power Plant Facility in Brilliant, Ohio. This Report was prepared to comply with the United States Environmental Protection Agency (EPA) Hazardous and Solid Waste Management System; Disposal of CCR from Electric Utilities, Title 40 Code of Federal Regulations (CFR) Part 257, Subpart D dated 17 April 2015 (Rule), specifically subsection § 257.90(e)(1) through (6).

This Report summarizes groundwater monitoring activities conducted pursuant to the CCR Rule from 1 January 2024 through 31 December 2024.

In accordance with § 257.90(e)(6), an overview of the current status of groundwater monitoring and corrective action programs for the CCR unit is provided below:

- At the start of the current annual reporting period (1 January 2024), the RBAP was operating under the detection monitoring program.

At the end of the current annual reporting period (31 December 2024), the RBAP was operating under the detection monitoring program.

Statistically significant increases (SSI) above background levels were identified during the October 2023 sampling event for the following Appendix III constituents:

  - boron: MW-BAP-3, MW-BAP-1002, and MW-BAP-1003
  - calcium: MW-BAP-1002 and MW-BAP-1003
  - chloride: MW-BAP-3, MW-BAP-1002, and MW-BAP-1003
  - sulfate: MW-BAP-3 and MW-BAP-1002
  - total dissolved solids: MW-BAP-3, MW-BAP-1001 and MW-BAP-1003
  - pH: MW-BAP-3

SSIs above background levels were identified during the April 2024 sampling event for the following Appendix III constituents:

  - boron: MW-BAP-1002, MW-BAP-1003, and MW-BAP-3
  - calcium: MW-BAP-1002 and MW-BAP-1003
  - chloride: MW-BAP-1002, MW-BAP-1003, and MW-BAP-3
  - sulfate: MW-BAP-1002, MW-BAP-1003, and MW-BAP-3
  - total dissolved solids: MW-BAP-1002 and MW-BAP-1003

- Statistical analysis of the October 2024 Monitoring Event is ongoing and will be presented in the 2025 Annual Report.
- In accordance with § 257.94(e)(2) of the CCR Rule, an Alternate Source Demonstration (ASD) concluded that the SSIs are attributable to sources other than the RBAP, and the RBAP can remain in detection monitoring.
- There were no statistically significant levels (SSLs) of Appendix IV constituents detected at the RBAP.

- No groundwater corrective measures monitoring activities were required to be completed in the annual reporting period in accordance with § 257.98(a)(1).

2. 40 CFR §257.90 Applicability

To report on the activities conducted during the prior calendar year and document progress complying with the CCR Rule, the specific requirements listed in § 257.90(e)(1) through (5) are provided in the next section in bold/italic type followed by a short narrative stating how that specific requirement was met.

2.1 40 CFR § 257.90(a) AND (c)

All CCR landfills, CCR surface impoundments, and lateral expansions of CCR units are subject to the groundwater monitoring and corrective action requirements under § 257.90 through § 257.98.

Once a groundwater monitoring system and groundwater monitoring program has been established at the CCR unit as required by this subpart, the owner or operator must conduct groundwater monitoring and, if necessary, corrective action through the active life and post-closure care period of the CCR unit.

The RBAP is a CCR surface impoundment. The groundwater system for the RBAP was established in March 2022. This document satisfies the requirement under § 257.90(e) which requires the CCR Unit Owner/Operator to prepare an Annual Groundwater Monitoring and Corrective Action Report.

2.2 40 CFR § 257.90(e) SUMMARY

Annual groundwater monitoring and corrective action report. For existing CCR landfills and existing CCR surface impoundments, no later than January 31, 2018, and annually thereafter, the owner or operator must prepare an annual groundwater monitoring and corrective action report. For the preceding calendar year, the annual report must document the status of the groundwater monitoring and corrective action program for the CCR unit, summarize key actions completed, describe any problems encountered, discuss actions to resolve the problems, and project key activities for the upcoming year. For purposes of this section, the owner or operator has prepared the annual report when the report is placed in the facility's operating record as required by § 257.105(h)(1).

This Report documents the activities completed in 2024 for the RBAP as required by the subject regulations. Groundwater sampling and analysis were conducted per the requirements of § 257.93, and the status of the groundwater monitoring program, set forth in § 257.95, is provided in this Report.

2.2.1 Status of the Groundwater Monitoring Program

SSIs of Appendix III constituents were identified at the RBAP during the first semiannual monitoring event. In accordance with § 257.94(e)(2) of the CCR Rule, an ASD concluded that the SSIs are attributable to sources other than the RBAP, and the RBAP can remain in detection monitoring.

2.2.2 Key Actions Completed

In 2024, two groundwater monitoring events were completed. The first semiannual groundwater monitoring event was completed in April and the second semiannual groundwater monitoring event was conducted in October, with a resample in December.

- Potentiometric monitoring was conducted during the semiannual sampling events, as detailed in Section 2.3.5.
- Two semiannual statistical evaluations were completed in 2024. These evaluations were conducted for the October 2023 and April 2024 semiannual sampling events. The statistical evaluation of the October 2024 semiannual sampling event is ongoing and will be presented in the 2025 Annual Report.
- An ASD was completed in May 2024 to address SSIs detected during the October 2023 semiannual sampling event (Appendix A).
- An Addendum to the ASD completed for the October 2023 semiannual sampling event (dated May 2024) was completed in December 2024 (Appendix B).
- An ASD was completed in November 2024 to address SSIs detected during the April 2024 semiannual sampling event (Appendix C).
- A groundwater monitoring network update and certification was completed in October 2024 to include an additional upgradient well.

2.2.3 Problems Encountered

During the October 2024 sampling event, inconsistent pH readings were discovered in the data collected in the field. As such, a re-sample event was conducted as allowed under the RBAP statistical analysis plan. The sampling equipment was determined to be responsible for the inconsistent data.

2.2.4 Actions to Resolve Problems

Future sampling events will confirm that field sampling parameters are within the expected ranges for accurate sample collection.

2.2.5 Project Key Activities for Upcoming Year

Key activities to be completed in 2025 include the following:

- Prepare the 2024 annual report; place it in the record as required by § 257.105(h)(1), notify the state [§ 257.106(d)]; and post to website [§ 257.107(d)].
- Prepare the semiannual statistical report for the second semiannual event of 2024.
- Conduct semiannual groundwater monitoring and reporting as required by § 257.95.
- Conduct semiannual statistical analyses in accordance with the RBAP Statistical Analysis Plan.
- Update background values for the groundwater monitoring network.

2.3 40 CFR § 257.90(e) – INFORMATION

At a minimum, the annual groundwater monitoring and corrective action report must contain the following information, to the extent available:

2.3.1 40 CFR § 257.90(e)(1)

A map, aerial image, or diagram showing the CCR unit and all background (or upgradient) and downgradient monitoring wells, to include the well identification numbers, that are part of the groundwater monitoring program for the CCR unit;

As required by § 257.90(e)(1), a map showing the location of the RBAP and associated upgradient and downgradient monitoring wells is presented as Figure 1.

2.3.2 40 CFR § 257.90(e)(2)

Identification of any monitoring wells that were installed or decommissioned during the preceding year, along with a narrative description of why those actions were taken;

A groundwater monitoring network update and certification was completed in October 2024. An existing well, MW-BAP-5, was added to the network as a background well to supplement the network's lone background well, MW-BAP-1001.

2.3.3 40 CFR § 257.90(e)(3)

In addition to all the monitoring data obtained under § 257.90 through § 257.98, a summary including the number of groundwater samples that were collected for analysis for each background and downgradient well, the dates the samples were collected, and whether the sample was required by the detection monitoring or assessment monitoring programs;

In accordance with § 257.95(b) and § 257.95(d)(1), two independent samples from each background and downgradient monitoring well were collected and analyzed. A summary table including the sample names, dates of sample collection, reason for sample collection (detection or assessment), and monitoring data obtained for the groundwater monitoring program for the RBAP is presented in Table 1. A summary of the analytical results is presented in Table 2.

2.3.4 40 CFR § 257.90(e)(4)

A narrative discussion of any transition between monitoring programs (e.g., the date and circumstances for transitioning from detection monitoring to assessment monitoring in addition to identifying the constituent(s) detected at a statistically significant increase over background levels); and

The RBAP remained in detection monitoring throughout 2024.

2.3.5 40 CFR § 257.90(e)(5)

Other information required to be included in the annual report as specified in § 257.90 through § 257.98.

Other information specified in § 257.90 through § 257.98 is discussed in preceding sections.

As specified in § 257.93(c), the groundwater flow rates and directions are provided as Figures 2 and 3, and Tables 3 and 4 for each sampling event.

TABLES

TABLE 1
SUMMARY OF 2024 SAMPLES COLLECTED
RBAP
CARDINAL POWER PLANT FACILITY
BRILLIANT, OHIO

Location Name	Type of Well	Sample Date	Constituents Analyzed	Purpose	Sample Type
MW-BAP-3	Downgradient	04/17/2024	Appendix III	Detection Monitoring	Primary
MW-BAP-3	Downgradient	10/21/2024	Appendix III	Detection Monitoring	Primary
MW-BAP-3	Downgradient	12/05/2024	Appendix III	Detection Monitoring	Primary
MW-BAP-5	Background	10/21/2024	Appendix III	Detection Monitoring	Primary
MW-BAP-1001	Background	04/17/2024	Appendix III	Detection Monitoring	Primary
MW-BAP-1001	Background	10/21/2024	Appendix III	Detection Monitoring	Primary
MW-BAP-1002	Downgradient	04/17/2024	Appendix III	Detection Monitoring	Primary
MW-BAP-1002	Downgradient	04/17/2024	Appendix III	Detection Monitoring	Duplicate
MW-BAP-1002	Downgradient	10/21/2024	Appendix III	Detection Monitoring	Primary
MW-BAP-1002	Downgradient	12/05/2024	Appendix III	Detection Monitoring	Primary
MW-BAP-1003	Downgradient	04/17/2024	Appendix III	Detection Monitoring	Primary
MW-BAP-1003	Downgradient	10/21/2024	Appendix III	Detection Monitoring	Primary
MW-BAP-1003	Downgradient	10/21/2024	Appendix III	Detection Monitoring	Duplicate
MW-BAP-1003	Downgradient	12/05/2024	Appendix III	Detection Monitoring	Primary

TABLE 2
SUMMARY OF 2024 ANALYTICAL RESULTS
RBAP
CARDINAL POWER PLANT FACILITY
BRILLIANT, OHIO

Location Name	MW-BAP-3	MW-BAP-3	MW-BAP-3	MW-BAP-5	MW-BAP-1001	MW-BAP-1001	MW-BAP-1002	MW-BAP-1002
Sample Name	MW-BAP-3 rBAP-04172024	MW-BAP-3-10212024	MW-BAP-3-12052024	MW-BAP-5-10212024	MW-BAP-1001-04172024	MW-BAP-1001-10212024	MW-BAP-1002-04172024	MW-BAP-1002_DUP-04172024
Sample Date	04/17/2024	10/21/2024	12/05/2024	10/21/2024	04/17/2024	10/21/2024	04/17/2024	04/17/2024
Sample Type	Primary	Primary	Primary	Primary	Primary	Primary	Primary	Duplicate
Well Type	Downgradient	Downgradient	Downgradient	Background	Background	Background	Downgradient	Downgradient
APPENDIX III CONSTITUENTS (mg/L)								
Boron, Total	**2.12**	**1.9**	**1.98**	**0.116**	**0.0334**	**0.036**	**2.35**	**2.36**
Calcium, Total	**81.5**	**78.5**	-	**187**	**83.9**	**74.7**	**91.6**	**93.5**
Chloride	**33.5**	**67.7**	**65.7**	**15.1**	**6.3**	**10.9**	**59.6**	**59.3**
Fluoride	**0.13**	**0.17**	-	**0.069**	**0.16**	**0.19**	**0.17**	**0.18**
Sulfate	**110**	**156**	-	**387**	**36.3**	**48.8**	**144**	**145**
Total Dissolved Solids (TDS)	**374**	**442**	-	**870**	**296**	**290**	**474**	**469**
pH, Field (pH units)	**6.85**	**6.5**	**6.95**	**6.72**	**7.71**	**7.2**	**7.13**	-

< = Not detected at reporting limit
Bold = detected
- = Not Analyzed

TABLE 2
SUMMARY OF 2024 ANALYTICAL RESULTS
RBAP
CARDINAL POWER PLANT FACILITY
BRILLIANT, OHIO

Location Name	MW-BAP-1002	MW-BAP-1002	MW-BAP-1003	MW-BAP-1003	MW-BAP-1003	MW-BAP-1003
Sample Name	MW-BAP-1002-10212024	MW-BAP-1002-12052024	MW-BAP-1003-04172024	MW-BAP-1003-10212024	MW-BAP-1003A-10212024	MW-BAP-1003-12052024
Sample Date	10/21/2024	12/05/2024	04/17/2024	10/21/2024	10/21/2024	12/05/2024
Sample Type	Primary	Primary	Primary	Primary	Duplicate	Primary
Well Type	Downgradient	Downgradient	Downgradient	Downgradient	Downgradient	Downgradient
APPENDIX III CONSTITUENTS (mg/L)						
Boron, Total	**2.96**	**2.55**	**0.798**	**0.838**	**0.803**	**0.82**
Calcium, Total	**96.6**	-	**101**	**99.5**	**102**	-
Chloride	**67.1**	**62.2**	**59.8**	**61.2**	**62.1**	**61.7**
Fluoride	**0.19**	-	**0.12**	**0.14**	**0.14**	-
Sulfate	**85.3**	-	**59.2**	**62**	**62.1**	-
Total Dissolved Solids (TDS)	**461**	-	**431**	**468**	**463**	-
pH, Field (pH units)	**6.36**	**7.3**	**7.23**	**6.54**	-	**7.24**

< = Not detected at reporting limit
Bold = detected
- = Not Analyzed

TABLE 3
GROUNDWATER FLOW CALCULATIONS
RBAP
CARDINAL POWER PLANT
BRILLIANT, OHIO

Program	Groundwater Zone	Well	Hydraulic Location	Depth to Water (ft)	Potentiometric Elevation (ft)	Gradient[1] (ft/ft)	Hydraulic Conductivity[2] (cm/sec)			Effective Porosity	Groundwater Velocity (ft/day)			Well Diameter[3] (in)	Residence Time in Well[4] (days)		
							Low	Representative	High		Low	Representative	High		Low	Representative	High
RBAP	RBAP	MW-BAP-1001	Upgradient	27.06	646.17	0.0004	0.0002	0.05	0.3	0.36	0.0006	**0.15**	0.88	8	0.76	**4.57**	1143
RBAP	RBAP	MW-BAP-1002	Downgradient	26.87	645.97	0.0003	0.0002	0.05	0.3	0.36	0.0004	**0.10**	0.62	8	1.07	**6.41**	1603
RBAP	RBAP	MW-BAP-1003	Downgradient	26.7	645.93	0.0003	0.0002	0.05	0.3	0.36	0.0005	**0.11**	0.68	8	0.98	**5.85**	1463
RBAP	RBAP	MW-BAP-3	Downgradient	27.17	645.88	0.0004	0.0002	0.05	0.3	0.36	0.0006	**0.14**	0.86	8	0.78	**4.66**	1166

Notes:

Measurements and calculations represent conditions on 9 April 2024.

1 Hydraulic gradient was calculated from a potentiometric surface using Arcmap software tools.

2 Low and high conductivity values are from the 2022 Groundwater Monitoring Network Evaluation, with a representative value chosen within this range that is consistent with previous velocity calculations.

3 Well diameter represents the diameter of the borehole (sandpack).

4 Residence time is an estimation of how long it would take groundwater to travel a distance equivalent to the well diameter at the calculated velocity.

TABLE 3
GROUNDWATER FLOW CALCULATIONS
RBAP
CARDINAL POWER PLANT
BRILLIANT, OHIO

Program	Groundwater Zone	Well	Hydraulic Location	Depth to Water (ft)	Potentiometric Elevation (ft)	Gradient[1] (ft/ft)	Hydraulic Conductivity[2] (cm/sec)			Effective Porosity	Groundwater Velocity (ft/day)			Well Diameter[3] (in)	Residence Time in Well[4] (days)		
							Low	Representative	High		Low	Representative	High		Low	Representative	High
RBAP	RBAP	MW-BAP-1001	Upgradient	28.54	644.81	0.0002	0.0002	0.05	0.3	0.36	0.0003	**0.07**	0.39	8	1.71	**10.24**	2561
RBAP	RBAP	MW-BAP-1002	Downgradient	28.17	644.73	0.0001	0.0002	0.05	0.3	0.36	0.0002	**0.06**	0.35	8	1.91	**11.43**	2858
RBAP	RBAP	MW-BAP-1003	Downgradient	28.03	644.65	0.0001	0.0002	0.05	0.3	0.36	0.0002	**0.05**	0.30	8	2.24	**13.41**	3353
RBAP	RBAP	MW-BAP-3	Downgradient	28.47	644.66	0.0003	0.0002	0.05	0.3	0.36	0.0005	**0.13**	0.76	8	0.87	**5.25**	1312
RBAP	RBAP	MW-BAP-5	Upgradient	27.51	644.67	0.0003	0.0002	0.05	0.3	0.36	0.0005	**0.11**	0.69	9	1.09	**6.52**	1631

Notes:

Measurements and calculations represent conditions on 14 October 2024.

1 Hydraulic gradient was calculated from a potentiometric surface from the most recent representative conditions.

2 Low and high conductivity values are from the 2022 Groundwater Monitoring Network Evaluation, with a representative value chosen within this range that is consistent with previous velocity calculations.

3 Well diameter represents the diameter of the borehole (sandpack).

4 Residence time is an estimation of how long it would take groundwater to travel a distance equivalent to the well diameter at the calculated velocity.

FIGURES

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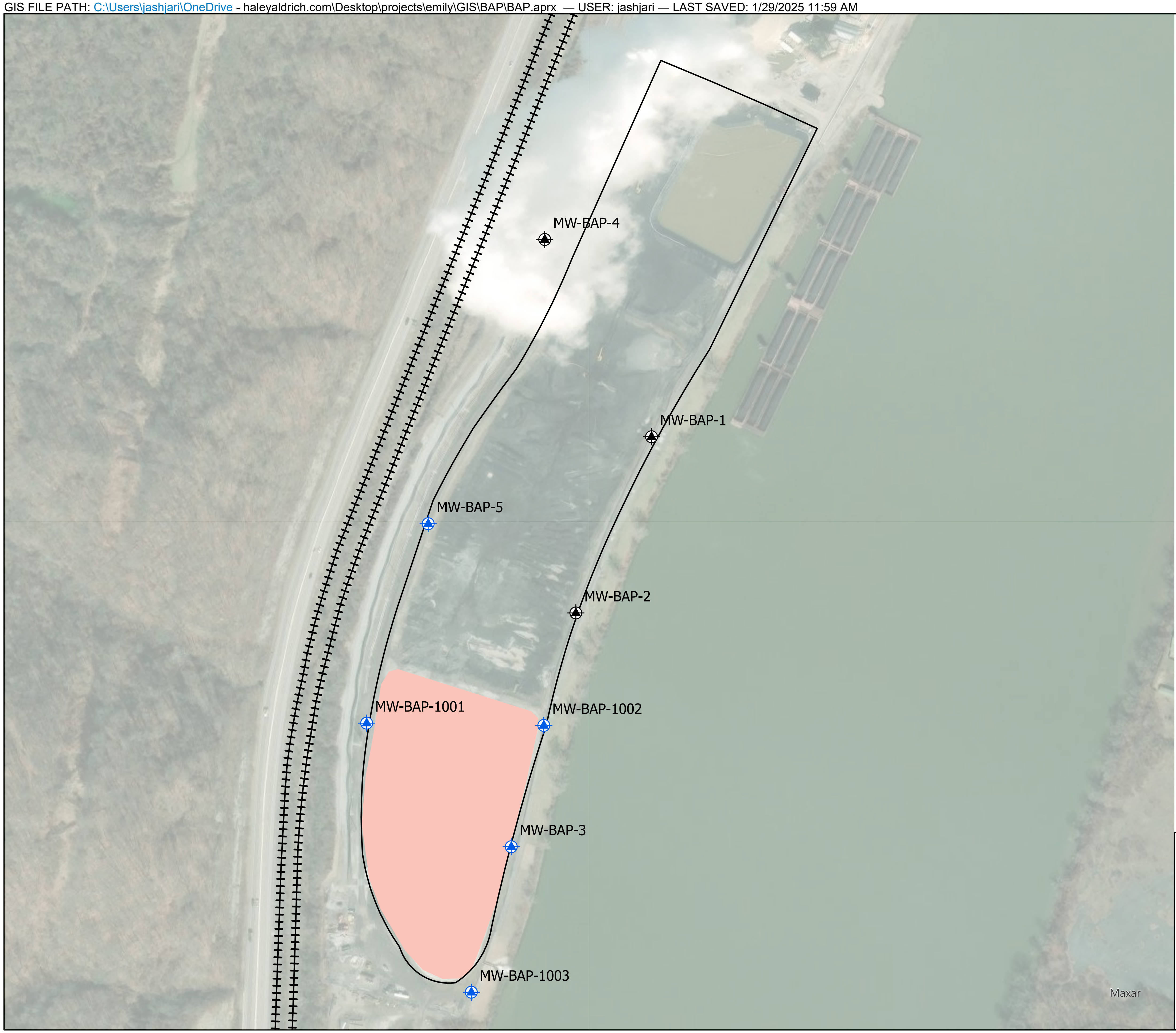

Legend

- BAP MONITORING WELL
- RBAP MONITORING WELL
- RAILROAD
- HISTORIC BOTTOM ASH POND (BAP)
- RETROFITTED BOTTOM ASH POND (RBAP)

NOTES:

1.ALL LOCATIONS AND DIMENSIONS ARE APPROXIMATE

2. DEFFINITIONS
FT=FOOT
NGVD29=NATIONAL GEODETIC VERTICAL DATUM 1929

3. ELEVATIONS IN FEET ABOVE MEAN SEA LEVEL (FT MSL)

4. AERIAL IMAGERY SOURCE NEARMAP 14 MAY 2023

5. MW-BAP-5 WAS ADDED TO THE RBAP MONITORING WELL NETWORK IN OCTOBER 2024.

N

0 230 460
SCALE IN FEET

HALEY ALDRICH

RETROFIT BOTTOM ASH POND (RBAP)
CARDINAL POWER PLANT FACILITY
BRILLIANT, OHIO

CCR UNIT AND MONITORING WELLS

JANUARY 2025

FIGURE 1

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LEGEND

- RBAP MONITORING WELL WITH **GROUNDWATER ELEVATION** IN FEET
- BAP MONITORING WELL WITH **GROUNDWATER ELEVATION** IN FEET
- GROUNDWATER ELEVATION CONTOUR, 0.05-FT INTERVAL (NGVD29)
- RAILROAD
- RETROFITTED BOTTOM ASH POND (RBAP)
- HISTORIC BOTTOM ASH POND (BAP)

NOTES

1. ALL LOCATIONS AND DIMENSIONS ARE APPROXIMATE.
2. DEFINITIONS:
   FT = FOOT
   NGVD29 = NATIONAL GEODETIC VERITCAL DATUM 1929
3. GROUNDWATER ELEVATIONS MEASURED 9 APRIL 2024.
4. ELEVATIONS IN FEET ABOVE MEAN SEA LEVEL (FT MSL).
5. AERIAL IMAGERY SOURCE: NEARMAP, 14 MAY 2023

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CARDINAL POWER PLANT FACILITY
BRILLIANT, OHIO

POTENTIOMETRIC SURFACE
RBAP UPPERMOST AQUIFER
APRIL 2024

AUGUST 2024

FIGURE 2

LEGEND

- BAP MONITORING WELL WITH **GROUNDWATER ELEVATION** IN FEET
- RBAP MONITORING WELL WITH **GROUNDWATER ELEVATION** IN FEET
- GROUNDWATER ELEVATION CONTOUR, 0.05-FT INTERVAL (NGVD29)
- RAILROAD
- RETROFITTED BOTTOM ASH POND (RBAP)
- HISTORIC BOTTOM ASH POND (BAP)

NOTES

1. ALL LOCATIONS AND DIMENSIONS ARE APPROXIMATE.
2. DEFINITIONS:
   FT = FOOT
   NGVD29 = NATIONAL GEODETIC VERITCAL DATUM 1929
3. GROUNDWATER ELEVATIONS MEASURED 2 DECEMBER 2024.
4. ELEVATIONS IN FEET ABOVE MEAN SEA LEVEL (FT MSL).
5. AERIAL IMAGERY SOURCE: NEARMAP, 14 MAY 2023

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CARDINAL PLANT
BRILLIANT, OHIO

POTENTIOMETRIC SURFACE
RBAP UPPERMOST AQUIFER
DECEMBER 2024

JANUARY 2025

FIGURE 3

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APPENDIX A
ASD for the October 2023 Monitoring Event

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REPORT ON

ALTERNATE SOURCE DEMONSTRATION FOR THE RETROFIT BOTTOM ASH POND CARDINAL OPERATING COMPANY – CARDINAL POWER PLANT 306 COUNTY ROAD 7E BRILLIANT, OHIO

by
Haley & Aldrich, Inc.
Cleveland, Ohio

for
Cardinal Operating Company
Brilliant, Ohio

File No. 210218
May 2024

Executive Summary

Haley & Aldrich, Inc. prepared this Alternate Source Demonstration (ASD) for the Cardinal Operating Company to determine if there is an alternate source of Appendix III constituents at the Cardinal Power Plant (Site) Retrofitted Bottom Ash Pond (RBAP) located in Brilliant, Ohio. The RBAP is a coal combustion residuals unit at the Site. The evaluation presented herein is in response to statistically significant increases (SSIs) of Appendix III constituents identified during the second semiannual groundwater sampling event held in October 2023. Detection monitoring results indicated boron, calcium, chloride and sulfate concentrations in monitoring wells were identified as having SSIs above background concentrations. These constituents have been consistently elevated since before the operation of the RBAP. Statistical analysis of these constituents' concentrations compared to individual well baseline conditions do not indicate increases have occurred during the RBAP operational period. Thus, demonstrating there has not been a release from the RBAP.

The historical bottom ash pond complex (BAC), which is undergoing closure, and the impacts of regional historical coal mining, have contributed to the elevated concentrations of constituent in monitoring wells that were identified to have SSI above background. The RBAP will remain in detection monitoring since an alternate source for the SSIs above background concentrations was identified.

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1. Introduction

1.1 INTRODUCTION AND PURPOSE

To maintain compliance with the United States Environmental Protection Agency's (USEPA) Code of Federal Regulations (CFR) regarding disposal of coal combustion residuals (CCR) in landfills and surface impoundments (40 CFR § 257.90 through 257.98, "CCR Rule") the second semiannual groundwater sampling event was conducted in October 2023 at the Retrofitted Bottom Ash Pond (RBAP), a CCR unit operated by the Cardinal Power Plant in Brilliant Ohio (Site). The RBAP was recently developed as a replacement storage facility of the historical Bottom Ash Pond Complex (BAC) used at the Site. Statistical evaluations, performed by Cox-Colvin & Associated (Cox-Colvin) as part of the detection monitoring program, identified statistically significant increases (SSI) of some Appendix III constituents over background concentrations in accordance with 40 CFR § 257.93(f).

The CCR Rule provides a process under 40 CFR Section § 257.94(e)(2) for the owner/operator of a regulated CCR unit to demonstrate that an SSI above background concentrations of Appendix III constituents during the detection monitoring program is from an alternate source via an alternate source demonstration (ASD). The purpose of this report is to document that alternate sources are responsible for the SSIs of constituents above background identified during RBAP detection monitoring in October 2023.

1.2 SITE DESCRIPTION

The Site is located in Jefferson County approximately one mile south of Brilliant, Ohio and is operated by the Cardinal Operating Company (Cardinal). The three coal-powered units that make up the generating station are located immediately west of the Ohio River with Units 1 and 2 in operation since 1967 and Unit 3 in operation since 1977. This study focuses on the RBAP located south of the generating station and immediately west of the Ohio River as seen in Figure 1. The surface area of the RBAP is approximately 7 acres and has a storage capacity of approximately 74 acre-feet. The RBAP is designed to operate as the only CCR pond for management of bottom ash sluicing discharge from the generating station. Dewatered bottom ash is dredged from the pond and disposed in the Landfill, north of the generating station.

1.3 SITE GEOLOGY AND HYDROGEOLOGY

1.3.1 Geologic Setting

The geologic setting in the vicinity of the RBAP can be described as sedimentary bedrock overlain by unconsolidated deposits associated with the Ohio River Valley. Cross-sections prepared by Cox-Colvin are presented in Appendix A that show the geologic units below the RBAP. As depicted in the cross-sections, three distinct lithologies are present consisting of the following:

- Fill Material – a product of previous earth work in the area for the construction of the former Bottom Ash Pond. Fill materials are approximately 10 to 20 feet thick.
- Alluvium – consisting of silt, clay, and sand deposited by the Ohio River approximately 10 to 20 feet thick.
- Glacial Outwash – alluvial deposits of sand and gravel that are between 5 to 50 feet thick.

Bedrock is closer to the surface along the western portion of the RBAP and deepens toward the Ohio River to the east. Consequently, the glacial outwash that is the primary aquifer below the RBAP pinches out to the west as the bedrock comes closer to the surface and thickens to the east below the Ohio River.

1.3.2 Hydrogeologic Setting

Groundwater flows from the west of the RBAP to the east and ultimately flows into the Ohio River under non-flood conditions. Groundwater elevations observed in MW-BAP-1001 depict this interaction as well as the interaction between bedrock and unconsolidated material as groundwater flows to the Ohio River to the east. Groundwater flows through the Glacial Outwash aquifer below the RBAP to the east/southeast where the groundwater/surface water interface occurs to the Ohio River. The groundwater potentiometric surface map for the October 2023 semi-annual sampling event is presented in Appendix B. Through the 17 groundwater gauging events, presented separately in previously submitted Annual Reports, flow remains consistently toward the Ohio River to the east/southeast with the exception of one gauging event (October 17, 2022) where groundwater flow direction changed due to elevated river levels during flood conditions.

The Glacial Outwash material consists of highly conductive sand and gravel that has a strong connection to the nearby Ohio River. Hydraulic conductivities for wells along the east of the RBAP are approximately 2.9×10^{-1} centimeters per second as presented in the January 3, 2022 *Groundwater Monitoring System for Retrofitted Bottom Ash Pond (BAP)* prepared by Cox-Colvin. The high level of connection is evident by the very shallow gradients observed across the RBAP area. Water levels vary less than 0.3 feet from MW-BAP-1001 (upgradient west of the RBAP) to MW-BAP-3 (downgradient east of the RBAP).

1.4 GROUNDWATER MONITORING SYSTEM

The RBAP groundwater monitoring system report was prepared by Cox-Colvin and certified on January 3, 2022 (Cox-Colvin, 2022a). Groundwater monitoring activities were implemented to comply with the requirements of 40 CFR § 257.90 through 257.98. The monitoring system consists of four wells. Upgradient well, MW-BAP-1001, is used to monitor background conditions. The three downgradient monitoring wells (MW-BAP-1002, MW-BAP-1003, and MW-BAP-3) are used for compliance monitoring of downgradient water quality from the RBAP. Monitoring well MW-BAP-3 was installed in 2015 and is also used as part of the Bottom Ash Pond CCR unit monitoring network. All other monitoring wells that are part of the network were installed in 2021. A series of wells that are part of the BAC monitoring network are utilized for groundwater level measurements and interpreting groundwater flow conditions in the RBAP. These wells are MW-BAP-1, MW-BAP-2, MW-BAP-3, and MW-BAP-4. Figure 2 shows the groundwater monitoring system together with the layout of the RBAP.

1.5 FALL 2023 DETECTION MONITORING STATISTICALLY SIGNIFICANT INCREASES

Water samples were collected in October 2023 from the RBAP monitoring well network for detection monitoring. Appendix III constituents for each sample were compared to previously established interwell Upper Prediction Limits (UPLs) and Lower Prediction Limits (LPLs; Cox-Colvin, 2024a). Results indicate SSIs above background concentrations for the following constituents and well pairings:

- Boron: MW-BAP-3, MW-BAP-1002, MW-BAP-1003
- Calcium: MW-BAP-1002, MW-BAP-1003

- Chloride: MW-BAP-3, MW-BAP-1002
- Sulfate: MW-BAP-3, MW-BAP-1002
- Total Dissolved Solids (TDS): MW-BAP-3, MW-BAP-1002, MW-BAP-1003

These SSIs were identified using statistical methodologies outlined in the RBAP statistical analysis plan (Geosyntec, 2020) and in accordance with 40 CFR § 257.93.

1.6 CCR RULE REQUIREMENTS

If the owner or operator of the CCR unit determines there are SSIs of Appendix III constituents, then 40 CFR § 257.94 (e) states:

> *The owner or operator may demonstrate that a source other than the CCR unit caused the statistically significant increase over background levels for a constituent or that the statistically significant increase resulted from error in sampling, analysis, statistical evaluation, or natural variation in groundwater quality. The owner or operator must complete the written demonstration within 90 days of detecting a statistically significant increase over background levels to include obtaining a certification from a qualified professional engineer or approval from the Participating State Director or approval from EPA where EPA is the permitting authority verifying the accuracy of the information in the report. If a successful demonstration is completed within the 90-day period, the owner or operator of the CCR unit may continue with a detection monitoring program under this section. If a successful demonstration is not completed within the 90-day period, the owner or operator of the CCR unit must initiate an assessment monitoring program as required under § 257.95. The owner or operator must also include the demonstration in the annual groundwater monitoring and corrective action report required by § 257.90(e), in addition to the certification by a qualified professional engineer or approval from the Participating State Director or approval from EPA where EPA is the permitting authority.*

1.7 CONSTRUCTION AND OPERATIONAL HISTORY

The BAC was originally constructed in the 1960s and further modified in 1974 and 2008. The BAC was historically used by Cardinal to manage sluiced bottom ash and other non-CCR Low Volume Waste (LVW) streams including stormwater runoff. The BAC consisted of two impoundments: the bottom ash pond (North Pond) and the recirculating pond (South Pond). Due to a pipe network connecting these two ponds they were monitored as a single unit referred to as the Bottom Ash Pond (BAP) CCR unit. Both ponds in the BAC were previously unlined.

In 2021 Cardinal elected to divide the BAC into two separate ponds to segregate and properly manage two waste streams: CCR waste and non CCR-LVW. Beginning in August 2021, waste streams were no longer distributed to the South Pond, excavation of the historical ash deposits were completed, and the South Pond was relined (Buckeye Power Inc., 2021). On March 27, 2022, all retrofit activities were completed in accordance with the written retrofit plan (Sargent & Lundy, 2020a) and the requirements of 40 CFR § 257.102(k) (Sargent & Lundy, 2022). The liner systems consist of three components: 1) a graded and compacted native soil base in compliance with the CCR Rule permeability requirement 2) a geosynthetic clay layer overlying the native compacted soil and 3) a 60-mil textured high-density polyethylene (HDPE) geomembrane topping the clay. The liner is protected with additional geotextiles and natural gravel to protect the HDPE geomembrane during bottom ash removal (Cox-Colvin, 2023). The name was changed to Retrofit Bottom Ash Pond (RBAP) when the retrofit was completed of the south recirculating pond.

The northern portion of the BAC is currently undergoing a retrofit with a National pollutant Discharge Elimination System liner to receive non-CCR Low Volume Waste (Cox-Colvin, 2022a). The North Pond ceased receiving waste stream on March 24, 2023, and the retrofit is ongoing (Cox-Colvin, 2023). The associated closure activities should eliminate the potential of constituents from the BAP to result in future exceedances of the groundwater protection standard (GWPS). Closure of the BAP includes removal of all CCR materials and mitigating all areas affected by releases in accordance with 40 CFR § 257.102 (Sargent & Lundy, 2020b). These activities will be complete when all the CCR material is removed from the BAP.

1.8 HISTORICAL GROUNDWATER MONITORING

1.8.1 Bottom Ash Pond

Groundwater monitoring of the BAP utilized five monitoring wells: two upgradient monitoring wells (MW-BAP-4 and MW-BAP-5) to characterize background conditions and three downgradient monitoring wells (MW-BAP-1, MW-BAP-2, MW-BAP-3) used for compliance monitoring. Baseline conditions were established in these wells and semiannual monitoring has continued to evaluate if CCR materials are impacting water quality. Results of this monitoring have shown SSIs above background levels downgradient of the BAP for Appendix III parameters including boron, chloride, sulfate, pH, fluoride, and TDS (Cox-Colvin, 2022b). However, assessment monitoring and statistical analysis have demonstrated constituent concentrations did not reach statistically significant levels in excess of BAP GWPS that would require further action. The BAP was in assessment monitoring prior to operation of the RBAP groundwater monitoring system.

1.8.2 Retrofitted Bottom Ash Pond

Groundwater monitoring of the RBAP has identified SSIs above background concentrations since detection monitoring began in November 2022. Constituents that have had SSIs above background include boron, calcium, chloride, pH, sulfate, and TDS (Cox-Colvin, 2024b). The most recent ASD attributed these increases to the historical BAC and regional historical coal mining impacts (Cox-Colvin, 2023). Accordingly, the RBAP has remained in detection monitoring and has not entered into assessment monitoring.

2. Background Determinations

Background conditions used in statistical analysis to determine SSI of Appendix III constituents were established using background water quality data collected between June 21, 2021 and May 2, 2022 from the upgradient well (MW-BAP-1001). The UPLs were calculated for Appendix III constituents based on a one-of- two sampling plan with seven constituents analyzed semiannually in three downgradient compliance wells. In addition, an LPL was calculated for pH (Cox-Colvin, 2022c).

As required in 40 CFR § 257.91(a)(1) the groundwater monitoring network must yield groundwater samples from the uppermost aquifer that accurately represent the quality of background groundwater. While the UPLs calculated from the upgradient well (MW-BAP-1001) reflect upgradient conditions, these conditions are not representative of baseline (background) conditions of all wells in the RBAP monitoring well network and result in SSIs of some Appendix III constituents that are not attributed to release from the RBAP. Interwell comparison of baseline conditions suggests a high degree of variance between monitoring wells in the well network prior to operation of the RBAP. Variation in monitoring well baseline conditions between the upgradient well and downgradient compliance monitoring wells is attributed to natural variation associated with historical impacts from the BAP and upgradient regional mining activity, which are discussed in the following sections.

2.1 COMPARISON OF BASELINE CONDITIONS

2.1.1 Visual Evaluation and Comparison to Upper Prediction Limits

Baseline conditions in each monitoring well in the RBAP monitoring network were compared for constituents that had an SSI above background using water samples collected between June 21, 2021 and March 27, 2022. March 27, 2022 is the date of completion of retrofit activities for the RBAP and is different from the sample set used for background concentration determination for detection monitoring which included data collected between March 27, 2022 and May 2, 2022. Summary statistics of baseline constituent concentrations for each well are presented in Table 1. Baseline constituent concentrations and variation between monitoring wells were visually evaluated using box and whisker plots illustrated in Figure 3. In these plots the UPLs that are used to determine SSIs above background concentrations for the RBAP are plotted for each constituent to allow for comparison to baseline concentrations. These plots demonstrate there is a high degree of variability in baseline constituent concentrations that were found to have an SSI above background in the October 2023 sampling event. In addition, these box and whisker plots demonstrate that every constituent well pairing that was identified to have an SSI over background in the October 2023 sampling event had concentrations well above the UPL prior to operation of the RBAP.

2.1.2 Statistical Comparison of Baseline Conditions

To evaluate the differences between baseline concentrations datasets between monitoring wells in the RBAP monitoring network, a series of Levene tests and Welch’s ANOVA tests were performed on each constituent. Results of these statistical analyses are presented in Table II. There is a statistically significant variance between the monitoring well datasets for boron and sulfate. Based on the Welch’s ANOVA test, there are significant differences between the monitoring well baseline datasets for every constituent evaluated.

2.2 INTERWELL AND INTRAWELL STATISTICAL EVALUATION

Background concentrations for compliance monitoring can be established using interwell and intrawell approaches. The USEPA unified statistical guidance (USEPA, 2009) recommends the use of intrawell statistical tests that compare historical background data to recent data at a single well to avoid spurious SSIs at sites with a high degree of spatial variation in constituent concentrations.

3. Sampling, Analysis and Statistical Evaluation Errors

In accordance with 40 CFR § 257.94(e) a demonstration that sampling, analysis and statistical analysis error resulted in SSIs of constituents above background then a transition to assessment monitoring is not required. No errors in sampling, laboratory analysis or statistical evaluations have been identified that would contribute to the SSI of constituents above background (Cox-Colvin, 2024).

4. RBAP Source Evaluation

The implementation of a CCR-compliant liner system makes release of constituents from the RBAP into the underlying aquifer highly unlikely. As described in Section 2, there has historically been a high degree of variability in Appendix III constituent concentrations in the RBAP monitoring network and the constituents with SSIs above background were above UPL prior to completion of the RBAP. While the presence of these elevated constituent concentrations prior to RBAP operation demonstrate an alternate source is contributing to the SSI it is important to determine if a release from the RBAP has occurred and affecting water quality. An evaluation was conducted to determine if RBAP operation is contributing to the SSI using control charts, which is a statistical approach that allows comparison of constituents to baseline conditions. This method and results of these analyses are discussed in Section 4.1.

4.1 SHEWHART-CUSUM CONTROL CHARTS

Use of control charts are a valid statistical method to evaluate CCR groundwater monitoring data in accordance with 40 CFR § 257. 93(f)(4). The specific control chart recommended in the USEPA Unified Guidance is the Shewhart-CUSUM control chart (USEPA, 2009). This control chart effectively combines the two separate evaluation procedures; the Shewhart portion produces a control limit, which is similar to the upper prediction limit where compliance measurements are individually compared, and the cumulative sum (CUSUM) portion which sequentially analyzes each new measurement with prior compliance data. Together the Shewhart and CUSUM results are used to assess the similarity of compliance data to background during detection monitoring.

In all statistical analyses provided herein the monitored constituents that were below detection are reported at one half of the reporting limit and only the parent samples were used when duplicate samples were collected. Based on the high degree of variation in the baseline datasets between monitoring wells, an intrawell approach was taken to determine baseline conditions for the compliance monitoring wells. The baseline dataset consists of monitoring well data from June 2021 until implementation of the RBAP on March 7, 2022. These data were used to determine a non-standardized control limit (h_c) which effectively serves as both the decision internal value (h) and the Shewhart Control Limit as the USEPA Unified Guidance recommends only one standardized control limit be utilized (USEPA, 2009). In these calculations, h was set to 5 and k was set to 1, as referenced in the Unified Guidance. Visual inspection of the data does not suggest seasonality and as a result the data were not adjusted for seasonality.

There are two scenarios in which the control chart can be out-of-control: 1) the trace of non-standardized constituent concentrations exceeds h_c based on the Shewhart component of the analysis, and 2) the CUSUM become too large and exceed the h_c based on the CUSUM portion of the analysis. A control chart that is categorized as out-of-control due to the first scenario is attributed to a rapid increased in constituent concentrations in the most recent sampling event. A control chart that is categorized as out-of-control due to the second scenario may also be due to a sudden rise in constituent concentrations and/or a gradual increase in concentration over time. If the non-standardized constituent concentrations do not exceed h_c but the CUSUM does exceed h_c then the out-of-control result is attributed to a trend of gradual increases. Thus, control charts can be used to assess both sudden or gradual contamination at a compliance point.

The use of Shewhart-CUSUM control charts is an effective method to determine if constituents of interest have increased during groundwater monitoring compared to baseline conditions prior to establishing the RBAP. Increases in constituent concentrations over baseline would be expected if the RBAP was the source of Appendix III constituents in the monitoring well network.

4.2 STATISITCAL EVALUATION RESULTS

Groundwater samples collected between June 21, 2021 and March 27, 2022 were used as baseline data. Shewhart-CUSUM control charts require baseline data to be normally distributed (i.e., parametric). Shapiro-Wilk statistical tests were conducted on all baseline constituent datasets to determine if the data are normally distributed and appropriate for Shewhart-CUSUM control charts. The results of these evaluations are tabulated in Table III. All datasets were found to be normally distributed except for MW-BAP-3 chloride data. Groundwater samples collected between March 27, 2023 and October 18, 2023 were used as detection monitoring in the Shewhart-CUSUM control charts. Shewhart-CUSUM control charts were developed using Python for every constituent well pair that was found to have SSIs above background in the October 2023 sampling event, and are included in Appendix C. Because the chloride baseline data at MW-BAP-3 is non-parametric, the upper prediction limit was conservatively set at the maximum concentration observed in the baseline data. No well-constituent pairs were identified to be out-of-control when compared to intrawell baseline conditions and demonstrate that the RBAP is not a source responsible for the SSIs above background identified.

5. Other Potential Sources

The historical BAC is attributed to elevated concentrations of boron, sulfate, chloride, and TDS in the RBAP detection monitoring wells. The RBAP was constructed in the southern portion of the historical BAC. As discussed, elevated concentrations of Appendix III constituents have been present since the RBAP monitoring network was created. Assessment monitoring of the historical BAC was initiated in August 2018 as a result of detection monitoring constituents having SSIs over background concentrations. Within the BAP, SSIs of Appendix III constituents have been identified for: boron, chloride, sulfate and TDS (Cox-Colvin, 2022b). This provides strong evidence that historical use of the BAC is attributed to the SSIs over background observed for boron, chloride, sulfate and TDS in the RBAP. Use of the northern portion of the BAP for CCR material ceased in March 2023 and this area is undergoing closure, which will result in the removal of all CCR materials. In the interim, operations and CCR material in the BAP may continue to affect water quality.

Upgradient of the historical BAC and the RBAP is a network of historical coal mine operations as seen in Figure 4 that was developed by Cox-Colvin. Weathering of mine waste results in the generation of acid rock drainage which is characterized by low pH, high sulfate concentration and high TDS. As these low pH waters interact with soils and enter the aquifer, they are neutralized with a principal reaction responsible for neutralization being the dissolution of carbonate minerals. The dissolution of limestone, a carbonate mineral, results in the release of calcium and elevated concentrations in aquifer groundwater. Acid rock drainage is expected to affect the entire shallow aquifer throughout the region.

6. Conclusion

In October 2023 detection monitoring of the RBAP identified SSIs above background concentrations for boron, calcium, chloride, sulfate, and TDS. The monitoring wells identified as having had SSIs above background concentrations used in this assessment have consistently had elevated concentrations of these constituents prior to operation of the RBAP which demonstrates an alternate source is responsible. The historical BAC and historical mining impacts are attributed to the elevated concentrations of these constituents. Statistical evaluations comparing intrawell baseline conditions prior to the RBAP operation to detection monitoring results do not indicate a release from the RBAP.

7. Professional Engineer Certification

Pursuant to 40 CFR § 257.94(e)(2), Haley & Aldrich, Inc., on behalf of the Cardinal Operating Company, conducted an alternate source demonstration to substantiate that a source other than the Retrofitted Bottom Ash Pond caused the statistically significant increase (SSI) over background identified during detection monitoring. I certify that this report and all attachments were prepared by me or under my direct supervision. I am a professional engineer who is registered in the Commonwealth of Kentucky.

This certification and the underlying data support the conclusion that a source other than the Retrofitted Bottom Ash Pond is the cause of the SSIs over background levels for Appendix III constituents identified during detection monitoring of this unit.

The information contained herein is, to the best of my knowledge, true, accurate, and complete.

Steven F. Putrich, P.E.
State of Ohio Professional Engineer
Registration Number 67329

May 16, 2024

References

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https://haleyaldrich.sharepoint.com/sites/CardinalOperatingCompany/Shared Documents/0210218.Cardinal Plant CCR GW/Project Work/rBAP/2024- ASD/2024-0516_Cardinal_RBAP ASD_F.docx

TABLES

TABLE I
CONSTITUENT BASELINE SUMMARY STATISTICS
ALTERNATIVE SOURCE DEMONSTRATION
CARDINAL POWER PLANT
BRILLIANT, OHIO

	Well ID	MW-BAP-1001	MW-BAP-1002	MW-BAP-1003	MW-BAP-3
Boron, Total (mg/L)	count	8	8	8	8
	mean	0.04	2.74	0.92	2.09
	Standard Deviation	0.00	0.35	0.08	0.21
	Minimum	0.03	2.29	0.84	1.84
	1st Quartile	0.04	2.38	0.88	1.95
	Median	0.04	2.85	0.90	2.08
	3rd Quartile	0.04	2.99	0.96	2.19
	Maximum	0.05	3.15	1.05	2.48
Calcium, Total (mg/L)	count	8	8	8	8
	mean	86.01	102.08	104.50	75.48
	Standard Deviation	1.69	3.05	3.12	3.70
	Minimum	83.20	96.60	101.00	69.80
	1st Quartile	85.13	100.75	102.50	73.43
	Median	86.50	102.00	104.00	75.30
	3rd Quartile	86.93	104.25	106.00	76.85
	Maximum	88.10	106.00	109.00	80.70
Chloride (mg/L)	count	8	8	8	8
	mean	6.71	71.54	72.01	75.35
	Standard Deviation	0.49	5.02	5.44	12.64
	Minimum	5.80	65.00	66.20	66.00
	1st Quartile	6.48	68.63	69.05	68.80
	Median	6.85	71.00	71.60	70.95
	3rd Quartile	6.90	73.63	73.18	74.53
	Maximum	7.50	81.30	83.60	104.00
Sulfate (mg/L)	count	8	8	8	8
	mean	42.24	139.26	30.59	189.88
	Standard Deviation	7.00	50.39	4.25	34.75
	Minimum	27.50	85.30	25.30	153.00
	1st Quartile	40.65	98.70	27.90	169.75
	Median	43.05	125.00	28.70	181.50
	3rd Quartile	44.83	186.00	34.08	196.50
	Maximum	50.40	210.00	37.50	262.00
Total Dissolved Solids (mg/L)	count	8	8	8	8
	mean	359.88	526.50	489.75	459.63
	Standard Deviation	9.78	20.92	13.05	21.33
	Minimum	343.00	493.00	473.00	420.00
	1st Quartile	354.75	515.00	482.25	454.00
	Median	363.50	525.50	485.00	464.00
	3rd Quartile	366.75	544.00	498.50	467.00
	Maximum	369.00	552.00	512.00	493.00

TABLE II

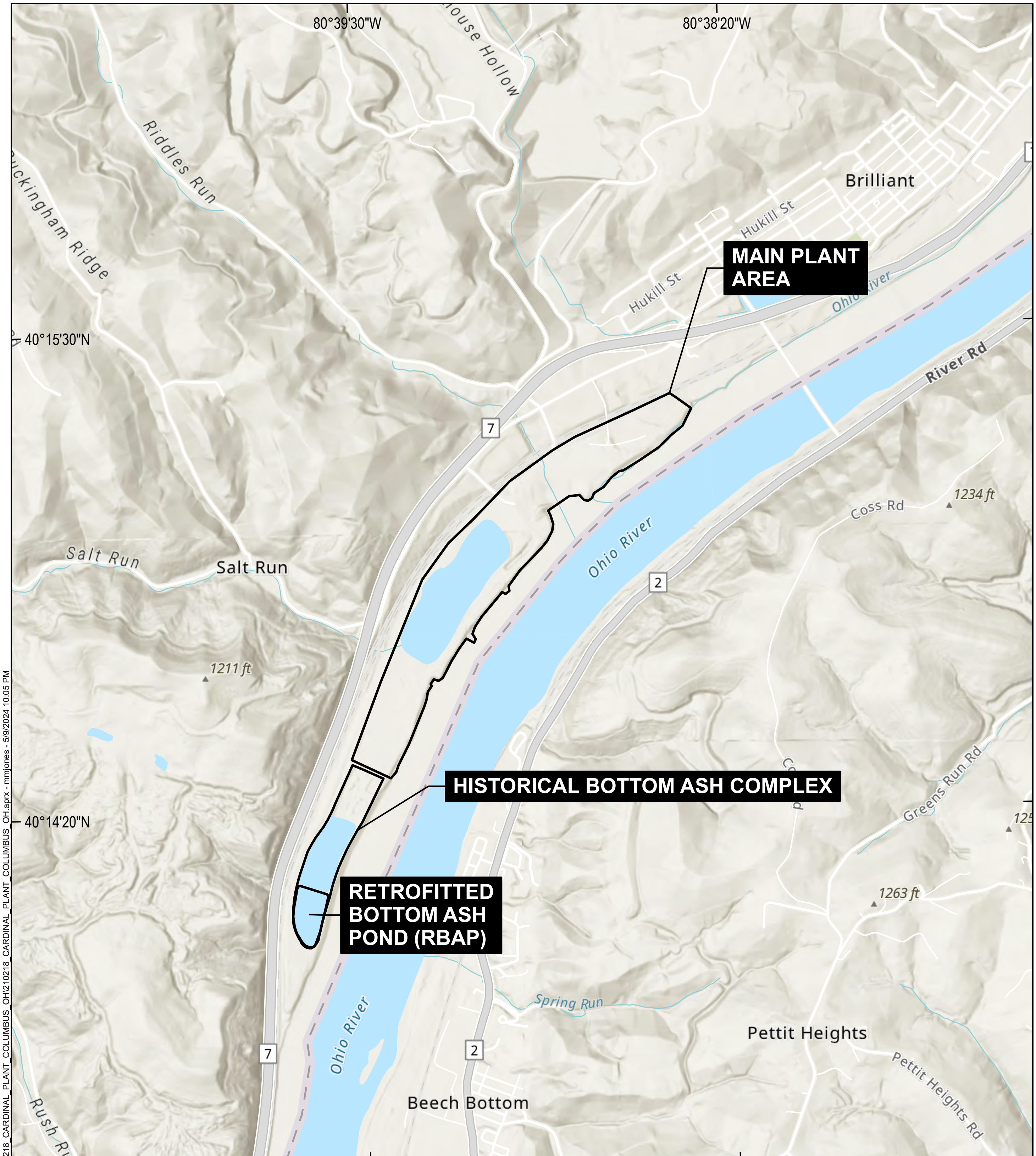
CONSTITUENT BASELINE STATISTICAL COMPARISON
ALTERNATIVE SOURCE DEMONSTRATION
CARDINAL POWER PLANT
BRILLIANT, OHIO

Constituent	Levene Test Statistic	Levene p-value	Statistically Significant Variance Levene Test (p<0.05)	Welch's ANOVA F-value	Welch's ANOVA p-value	Statistically Significant Differences Welch's ANOVA (p<0.05)
Boron, Total	6.922	0.001	Yes	653.31	2.78E-13	Yes
Calcium, Total	0.843	0.482	No	142.02	4.18E-11	Yes
Chloride	1.595	0.213	No	799.87	6.58E-14	Yes
Sulfate	5.794	0.003	Yes	63.67	3.16E-08	Yes
Total Dissolved Solids	0.964	0.423	No	232.93	1.03E-12	Yes

TABLE III
CONSTITUENT BASELINE SHAPIRO-WILK RESULTS
ALTERNATIVE SOURCE DEMONSTRATION
CARDINAL POWER PLANT
BRILLIANT, OHIO

	Well ID	Shapiro-Wilk Statistic	p-value	Shapiro-Wilk Test (p<0.05)
Boron, Total	MW-BAP-1001	0.922	0.448	Normally Distributed
	MW-BAP-1002	0.867	0.139	Normally Distributed
	MW-BAP-1003	0.856	0.108	Normally Distributed
	MW-BAP-3	0.945	0.659	Normally Distributed
Calcium, Total	MW-BAP-1001	0.928	0.499	Normally Distributed
	MW-BAP-1002	0.960	0.812	Normally Distributed
	MW-BAP-1003	0.877	0.175	Normally Distributed
	MW-BAP-3	0.917	0.404	Normally Distributed
Chloride	MW-BAP-1001	0.933	0.541	Normally Distributed
	MW-BAP-1002	0.925	0.473	Normally Distributed
	MW-BAP-1003	0.862	0.125	Normally Distributed
	MW-BAP-3	0.720	0.004	Not Normally Distributed
Sulfate	MW-BAP-1001	0.857	0.112	Normally Distributed
	MW-BAP-1002	0.877	0.178	Normally Distributed
	MW-BAP-1003	0.899	0.286	Normally Distributed
	MW-BAP-3	0.881	0.191	Normally Distributed
Total Dissolved Solids	MW-BAP-1001	0.870	0.150	Normally Distributed
	MW-BAP-1002	0.951	0.724	Normally Distributed
	MW-BAP-1003	0.938	0.595	Normally Distributed
	MW-BAP-3	0.934	0.550	Normally Distributed

FIGURES



MAP SOURCE: ESRI
SITE COORDINATES: 40°14'55"N, 80°39'05"W

HALEY ALDRICH

CARDINAL PLANT
BRILLIANT, OHIO

PROJECT LOCUS

APPROXIMATE SCALE: 1 IN = 2000 FT
MAY 2024

FIGURE 1

GIS: \\haleyaldrich\share\CF\Projects\0210218\GIS\210218_CARDINAL_PLANT_COLUMBUS_OH210218_CARDINAL_PLANT_COLUMBUS_OH.aprx - mmjones - 5/9/2024 10:05 PM

LEGEND

- MONITORING WELL
- HISTORICAL BOTTOM ASH COMPLEX
- MAIN PLANT AREA
- RETROFITTED BOTTOM ASH POND (RBAP)

NOTES

1. ALL LOCATIONS AND DIMENSIONS ARE APPROXIMATE.
2. MW-BAP-1001 IS THE UPGRADIENT MONITORING WELL FOR THE RBAP AND REPRESENTS BACKGROUND CONDITIONS FOR THE RBAP.
3. MW-BAP-1002, MW-BAP-3, AND MW-BAP-1003 ARE DOWNGRADIENT MONITORING WELLS FOR THE RBAP.
4. MW-BAP-4 AND MW-BAP-5 ARE UPGRADIENT MONITORING WELLS FOR THE BAP AND REPRESENTS BACKGROUND CONDITIONS FOR THE BAP CCR UNIT.
5. MW-BAP-1, MW-BAP-2, AND MW-BAP-3 ARE DOWNGRADIENT MONITORING WELLS FOR THE BAP CCR UNIT.
6. CCR = COAL COMBUSTION RESIDUAL
7. AERIAL IMAGERY SOURCE: NEARMAP, 14 MAY 2023

N

0 350 700
SCALE IN FEET

HALEY ALDRICH

CARDINAL PLANT
BRILLIANT, OHIO

MONITORING WELL NETWORK OF BOTTOM ASH POND AND RETROFITTED BOTTOM ASH POND CCR UNITS

MAY 2024

FIGURE 2

GIS FILE PATH: \\haleyaldrich\share\CF\Projects\0210218\GIS\210218_CARDINAL_PLANT_COLUMBUS_OH\210218_CARDINAL_PLANT_COLUMBUS_OH.aprx - USER: mmjones - LAST SAVED: 5/7/2024 9:09 PM

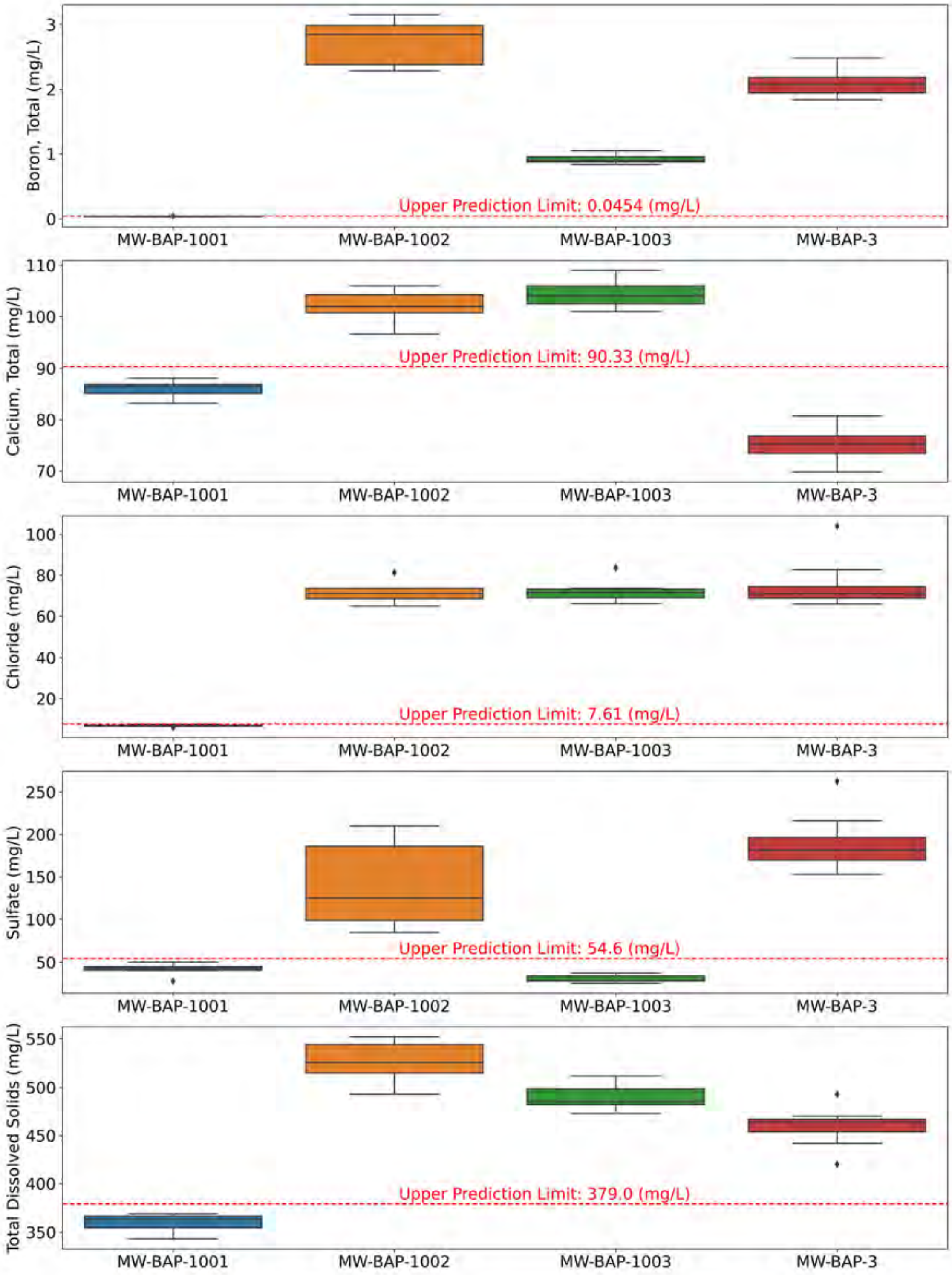
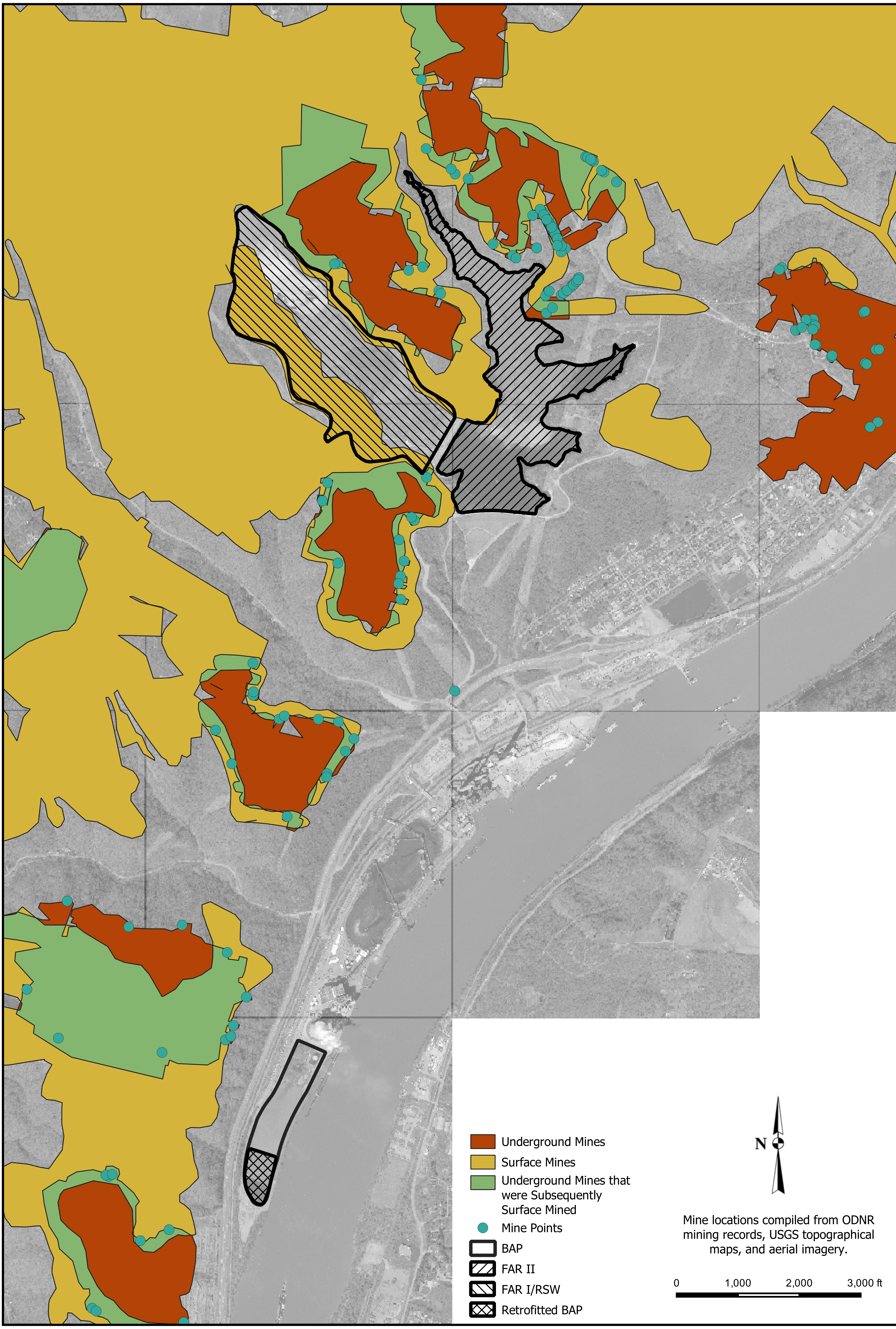


Figure 3
Baseline Box and Whiskers Plots

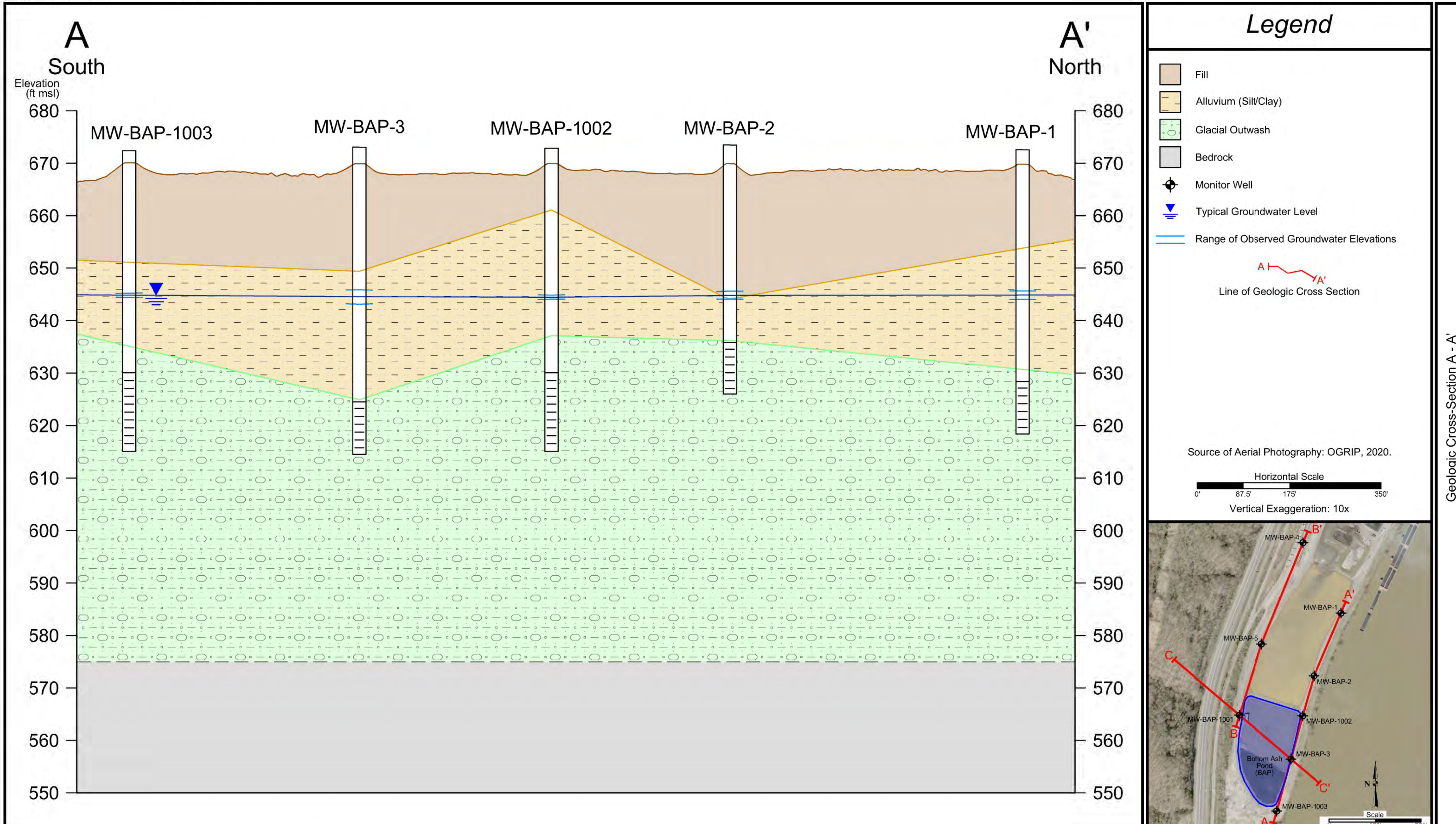


Cox-Colvin & ASSOCIATES, INC. ENVIRONMENTAL SERVICES

Regional Mining Activity
Buckeye Power, Cardinal Generating Plant
Brilliant, Ohio

Figure 4

APPENDIX A
Geologic Cross Sections



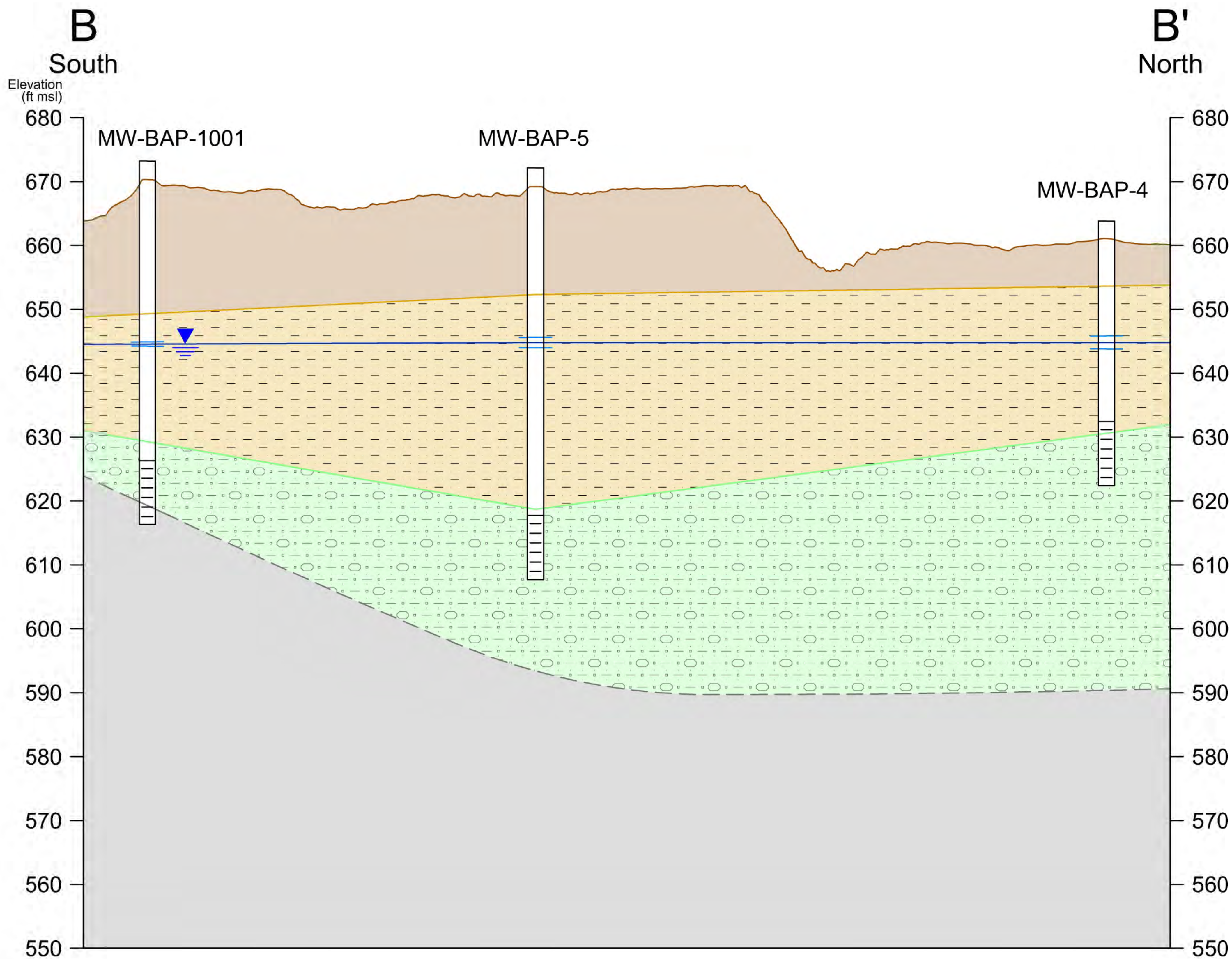
Cox-Colvin & ASSOCIATES, INC. ENVIRONMENTAL SERVICES

Geologic Cross-Section A - A',
Cardinal Power Plant BAP,
Brilliant, Ohio

Figure

3-1A

DWG NAME: Cross Section DATE: 10/20/2021



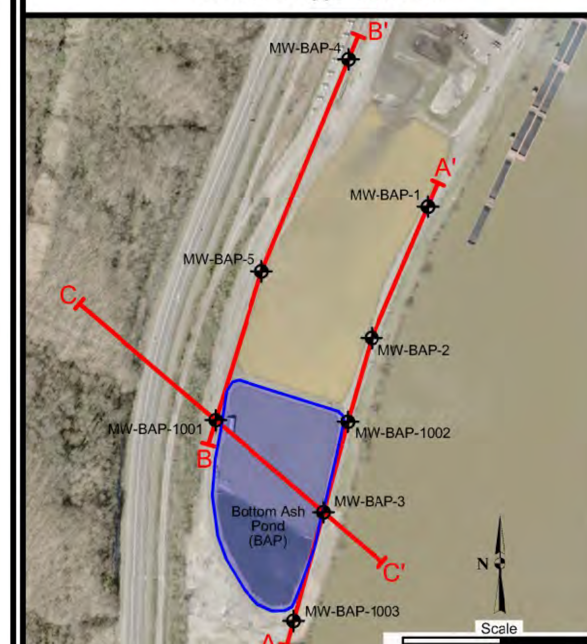
Legend

- Fill
- Alluvium (Silt/Clay)
- Glacial Outwash
- Bedrock
- Monitor Well
- Typical Groundwater Level
- Range of Observed Groundwater Elevations
- Line of Geologic Cross Section

Source of Aerial Photography: OGRIP, 2020.

Horizontal Scale: 0' 87.5' 175' 350'

Vertical Exaggeration: 10x



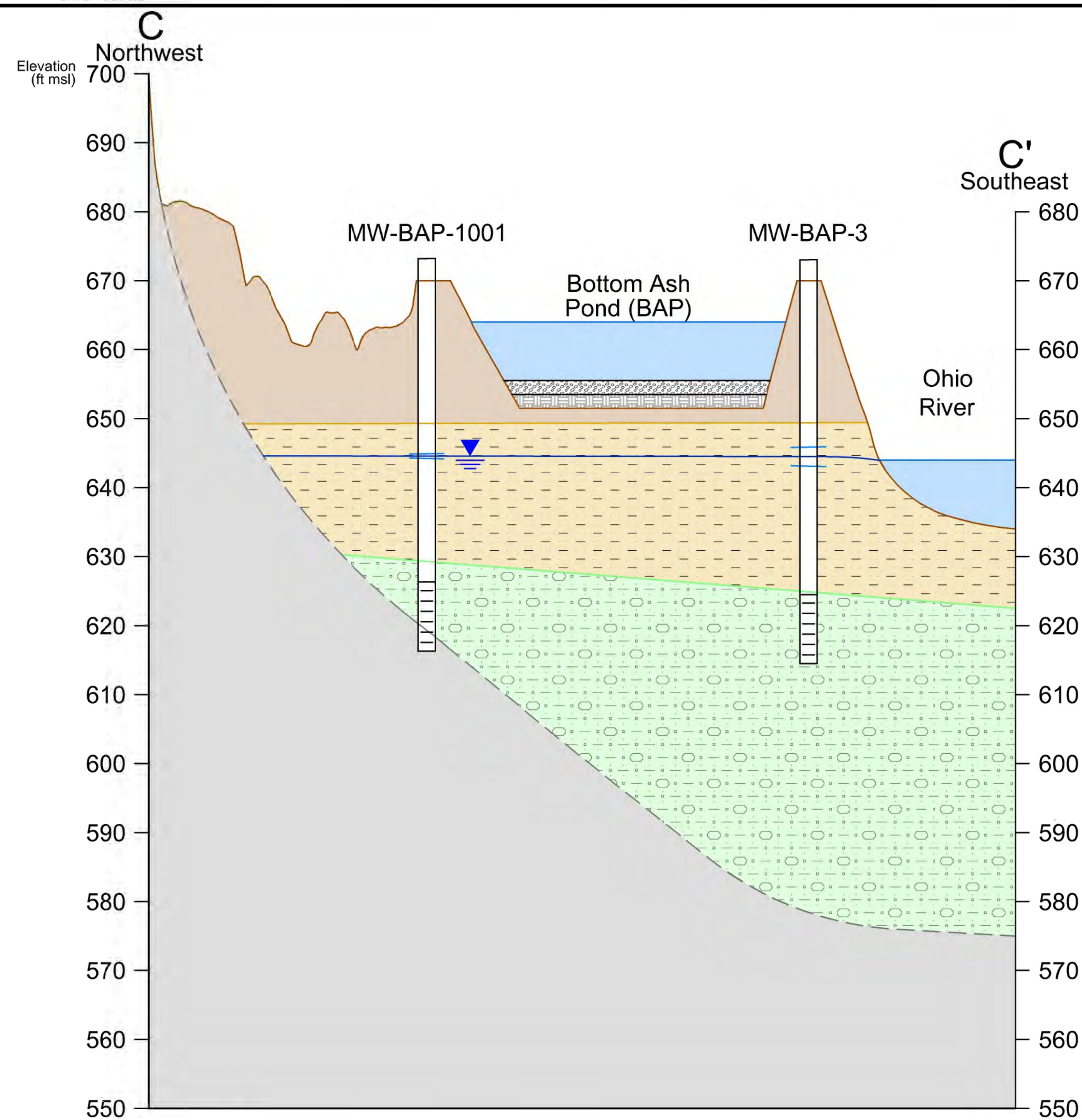
Geologic Cross-Section B - B'

Cox-Colvin & Associates, Inc. Environmental Services

Geologic Cross-Section B - B',
Cardinal Power Plant BAP,
Brilliant, Ohio

Figure 3-1B

DWG NAME: Cross Section DATE:



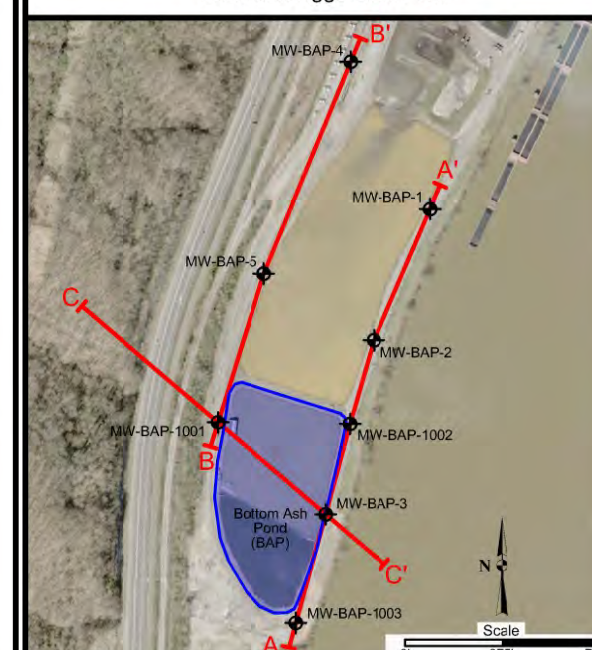
Legend

- Fill
- Alluvium (Silt/Clay)
- Glacial Outwash
- Bedrock
- Monitor Well
- Typical Groundwater Level
- Range of Observed Groundwater Elevations
- C — C' Line of Geologic Cross Section

Source of Aerial Photography: OGRIP, 2020.

Horizontal Scale: 0' 90' 180' 330'

Vertical Exaggeration: 10x



Geologic Cross-Section C - C'

Cox-Colvin & Associates, Inc. Environmental Services

Geologic Cross-Section C - C',
Cardinal Power Plant BAP,
Brilliant, Ohio

Figure 3-1C

APPENDIX B
Potentiometric Surface Map

DWG NAME: Water Levels 2023 DATE PRINTED: 1/22/2024 K:\CCA\PROJECTS\Buckeye_Power\Cardinal\Drawings

Legend

RBAP Monitor Well

Non-RBAP Monitor Well

644.76 Approximate Groundwater Elevation Contour

644.75 Groundwater Elevation on October 9, 2023

Retrofitted Bottom Ash Pond (RBAP)

Source of Aerial Photograph: Ohio Statewide Imagery Program, 2020.

N

Scale

0' 150' 300' 600'

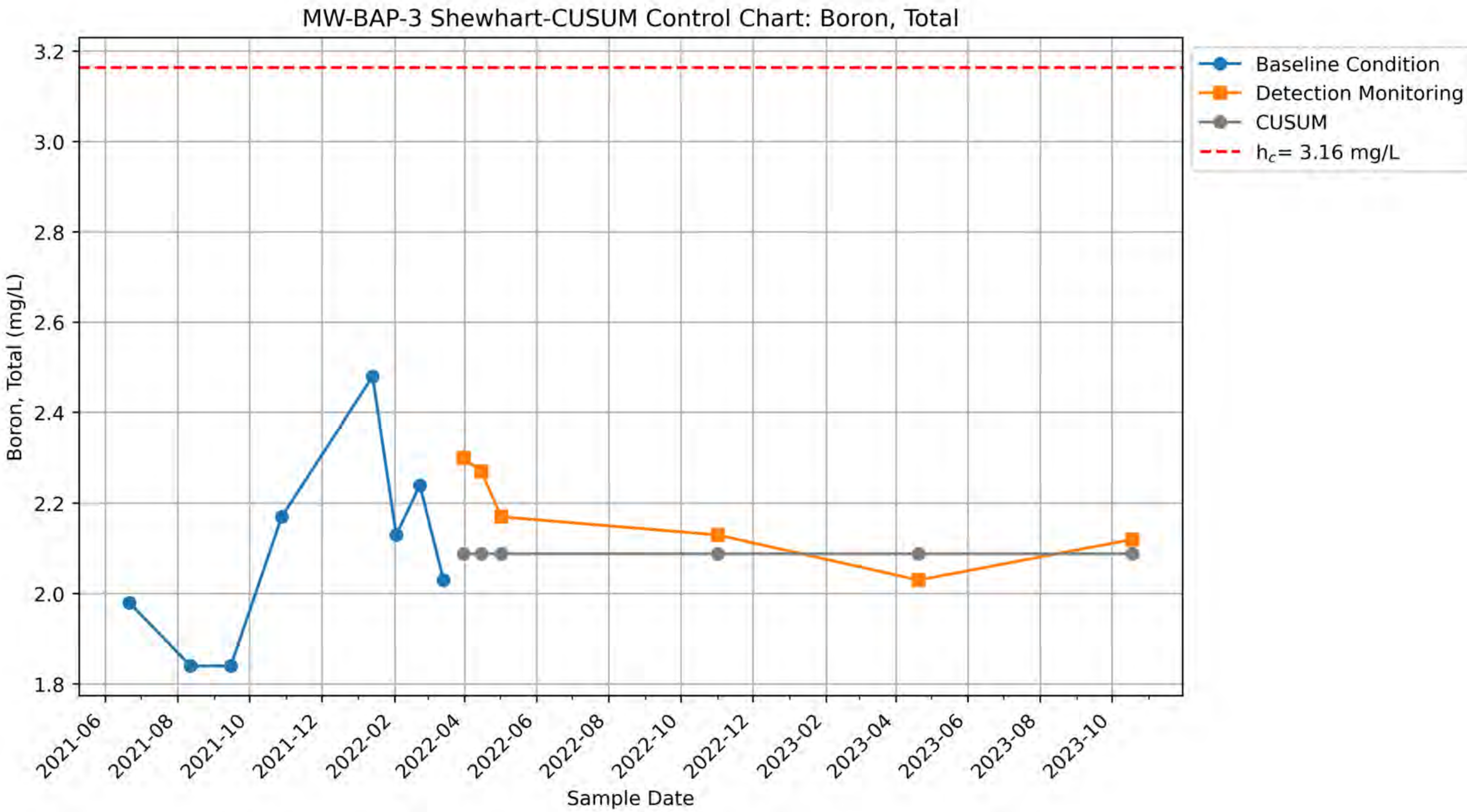
Cox-Colvin
& ASSOCIATES, INC.
ENVIRONMENTAL SERVICES

Figure

4-2

Potentiometric Surface Map - Uppermost Aquifer - October 9, 2023, Retrofitted Bottom Ash Pond (RBAP), Cardinal Plant, Brilliant, Ohio

APPENDIX C
Control Charts



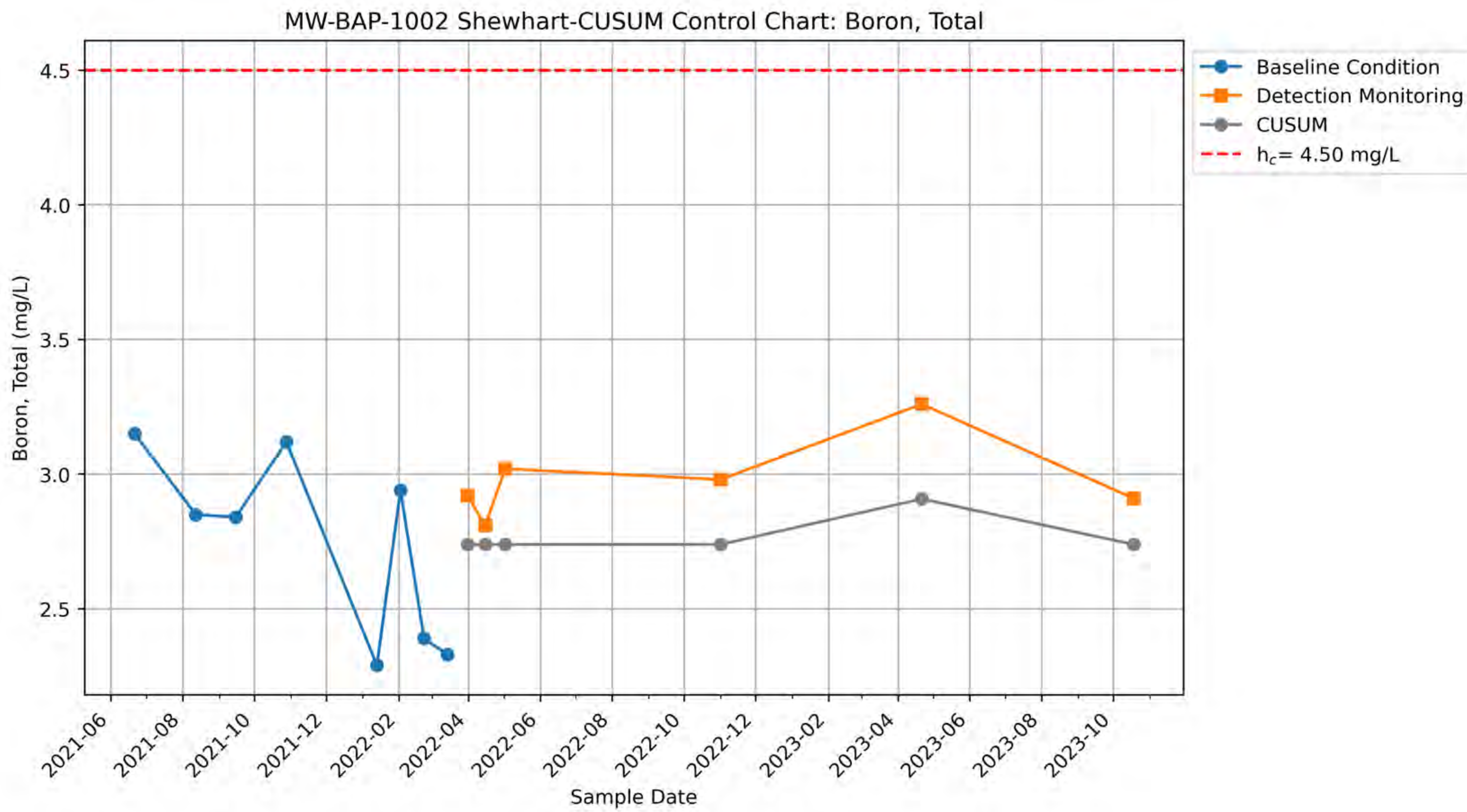
HALEY ALDRICH

Cardinal Power Plant
Retrofitted Bottom Ash Pond Alternate Source Demonstration
Brilliant, Ohio

Shewhart-CUSUM Control Chart
MW-BAP-3
Boron, Total

May 2024

FIGURE 1



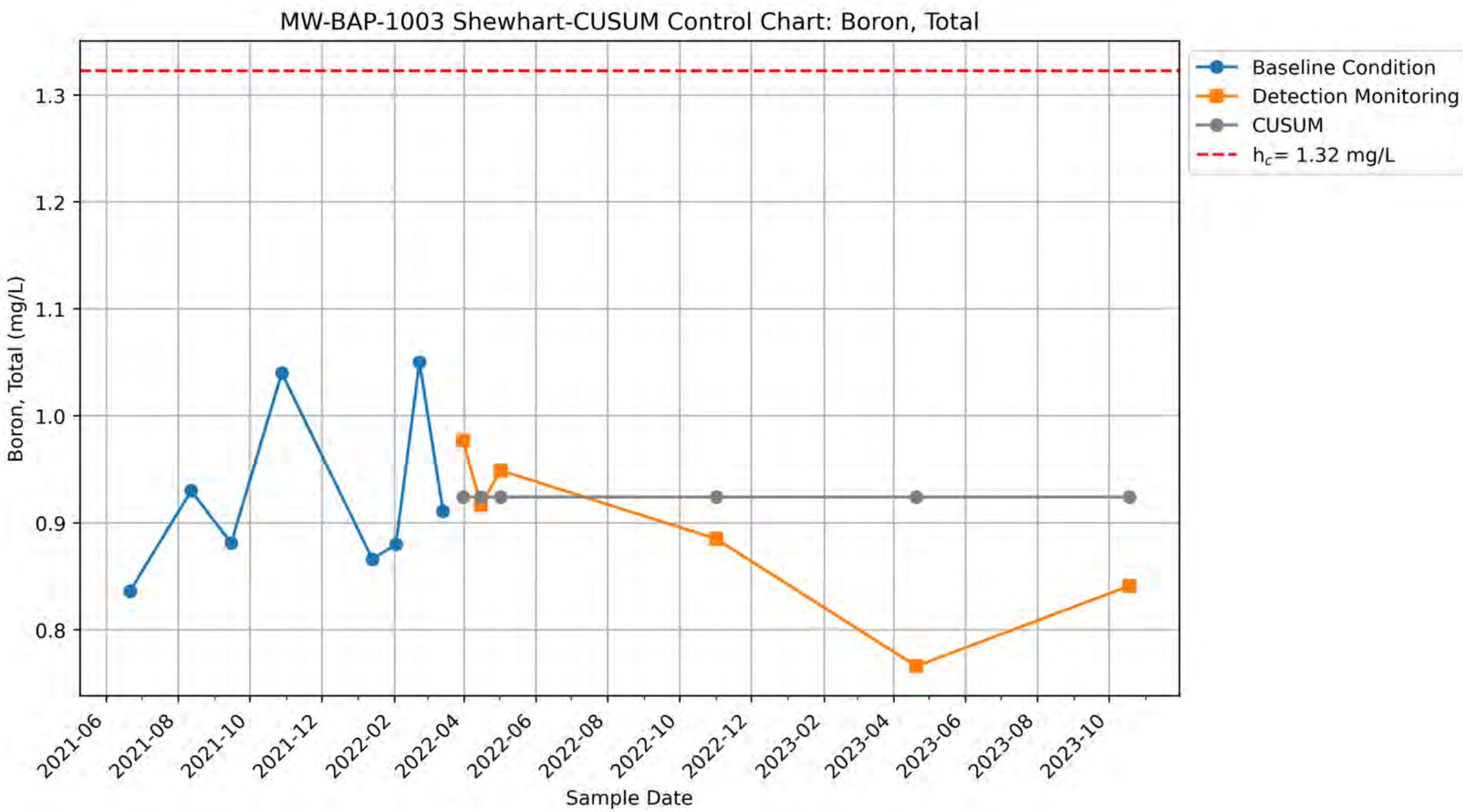
HALEY ALDRICH

Cardinal Power Plant
Retrofitted Bottom Ash Pond Alternate Source Demonstration
Brilliant, Ohio

Shewhart-CUSUM Control Chart
MW-BAP-1002
Boron, Total

May 2024

FIGURE 2



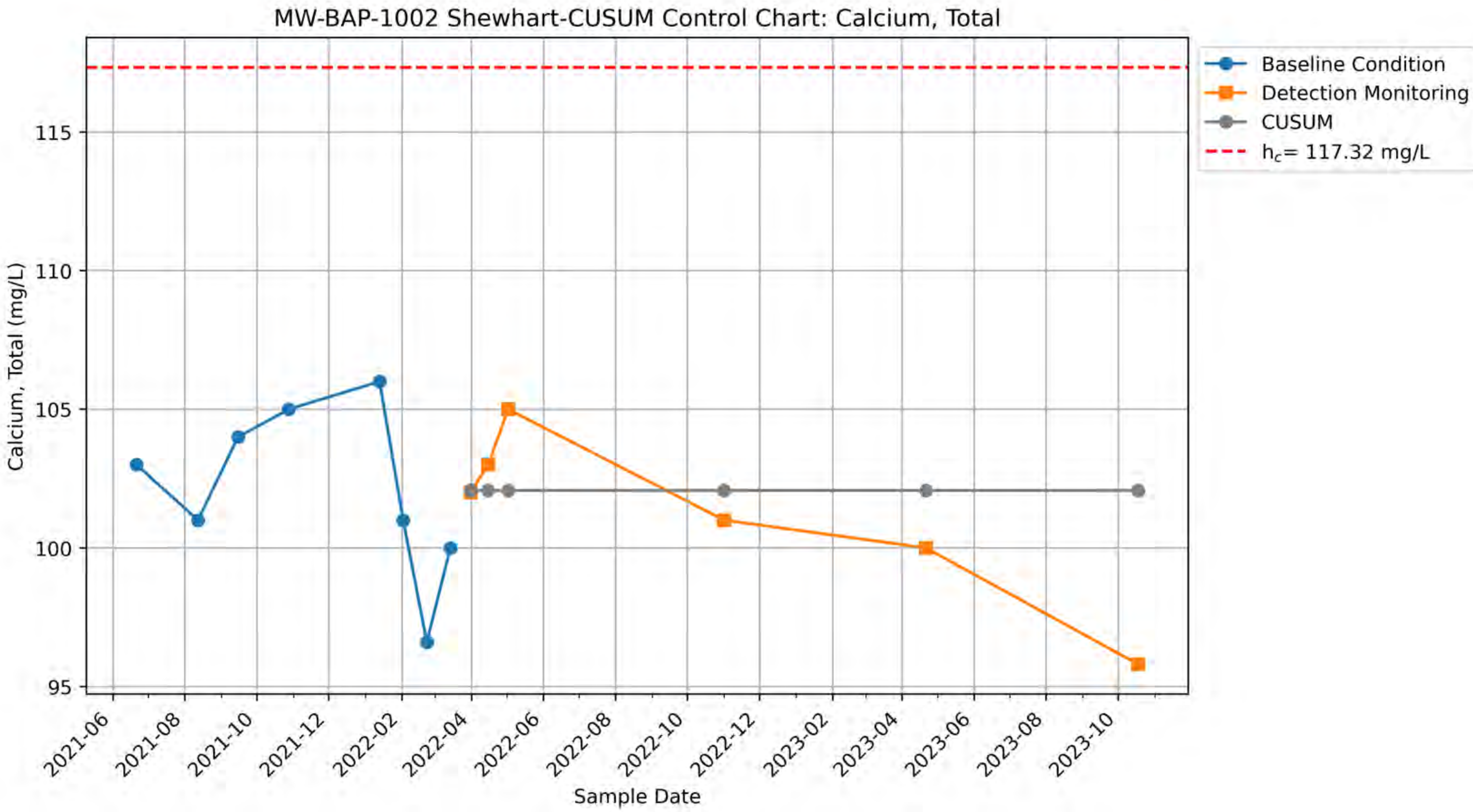
HALEY ALDRICH

Cardinal Power Plant
Retrofitted Bottom Ash Pond Alternate Source Demonstration
Brilliant, Ohio

Shewhart-CUSUM Control Chart
MW-BAP-1003
Boron, Total

May 2024

FIGURE 3



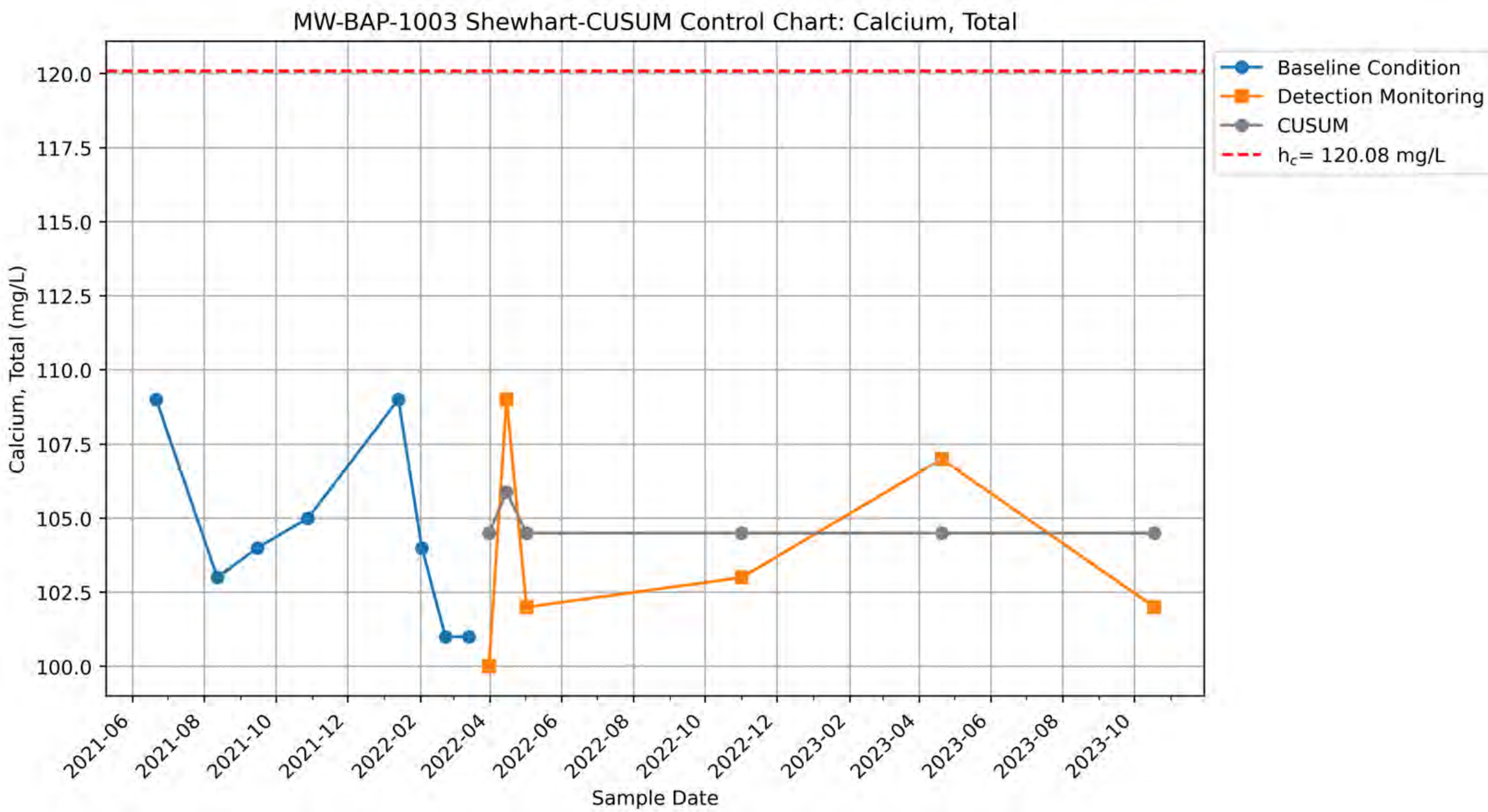
HALEY ALDRICH

Cardinal Power Plant
Retrofitted Bottom Ash Pond Alternate Source Demonstration
Brilliant, Ohio

Shewhart-CUSUM Control Chart
MW-BAP-1002
Calcium, Total

May 2024

FIGURE 4



https://haleyaldrich.sharepoint.com/sites/CardinalOperatingCompany/Shared Documents/ 0210218.Cardinal Plant CCR GW/Project Work/ BAP/ 2024-ASD/ Appendix C

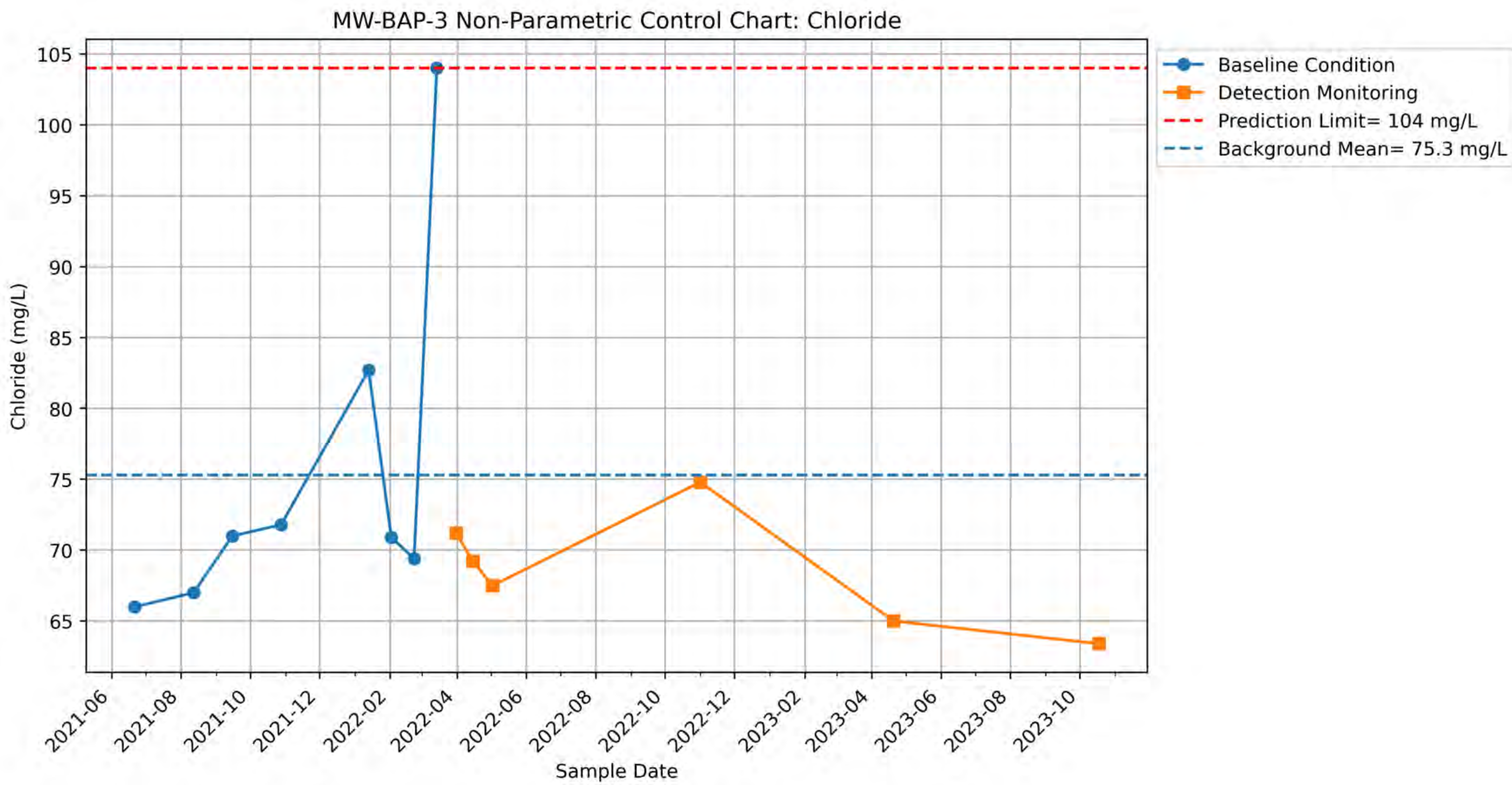
HALEY ALDRICH

Cardinal Power Plant
Retrofitted Bottom Ash Pond Alternate Source Demonstration
Brilliant, Ohio

Shewhart-CUSUM Control Chart
MW-BAP-1003
Calcium, Total

May 2024

FIGURE 5



https://haleyaldrich.sharepoint.com/sites/CardinalOperatingCompany/Shared Documents/ 0210218.Cardinal Plant CCR GW/Project Work/ BAP/ 2024-ASD/ Appendix C

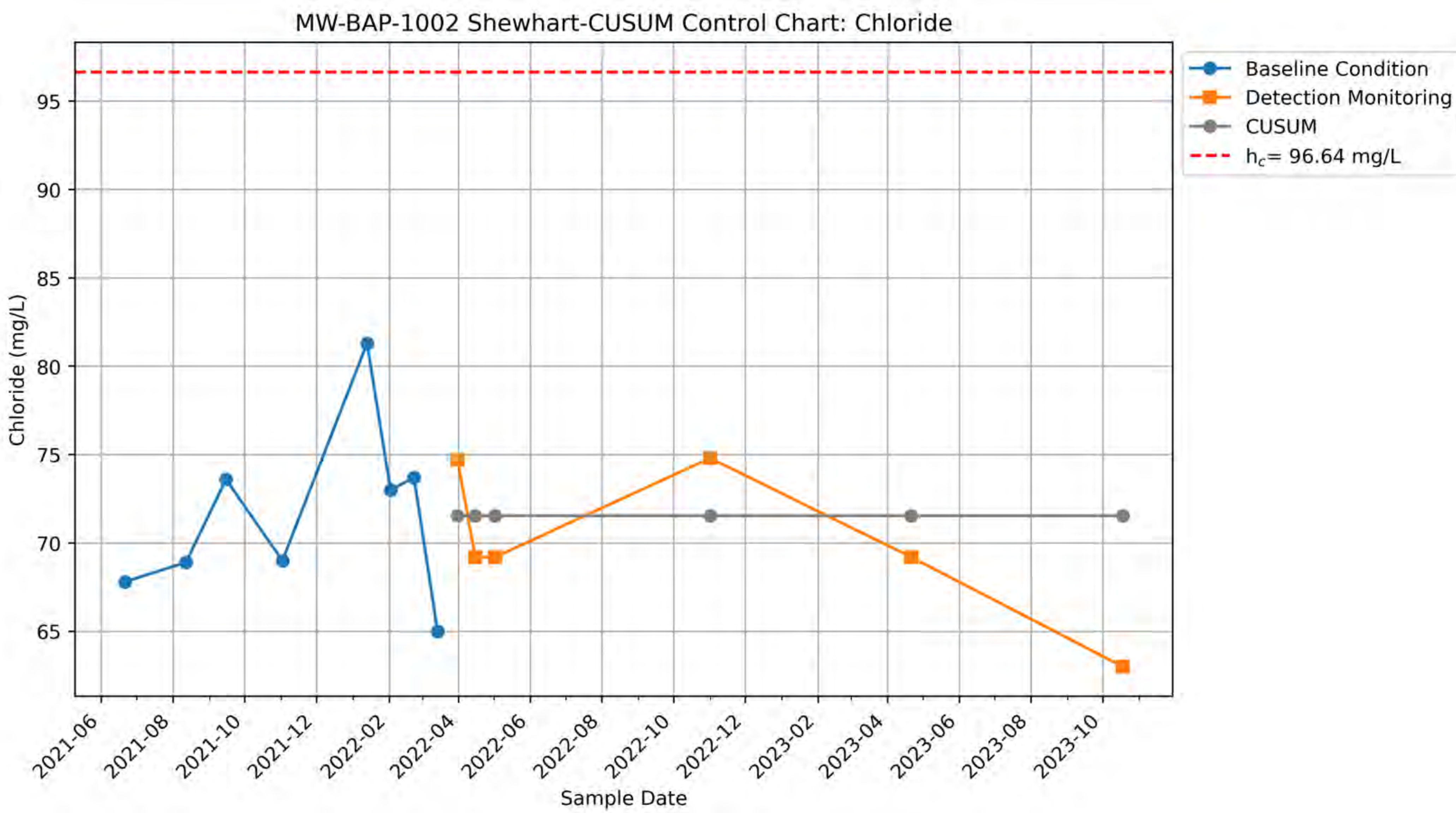
HALEY ALDRICH

Cardinal Power Plant
Retrofitted Bottom Ash Pond Alternate Source Demonstration
Brilliant, Ohio

Non-Parametric Control Chart
MW-BAP-3
Chloride

May 2024

FIGURE 6



https://haleyaldrich.sharepoint.com/sites/CardinalOperatingCompany/Shared Documents/ 0210218.Cardinal Plant CCR GW/Project Work/ BAP/ 2024-ASD/ Appendix C

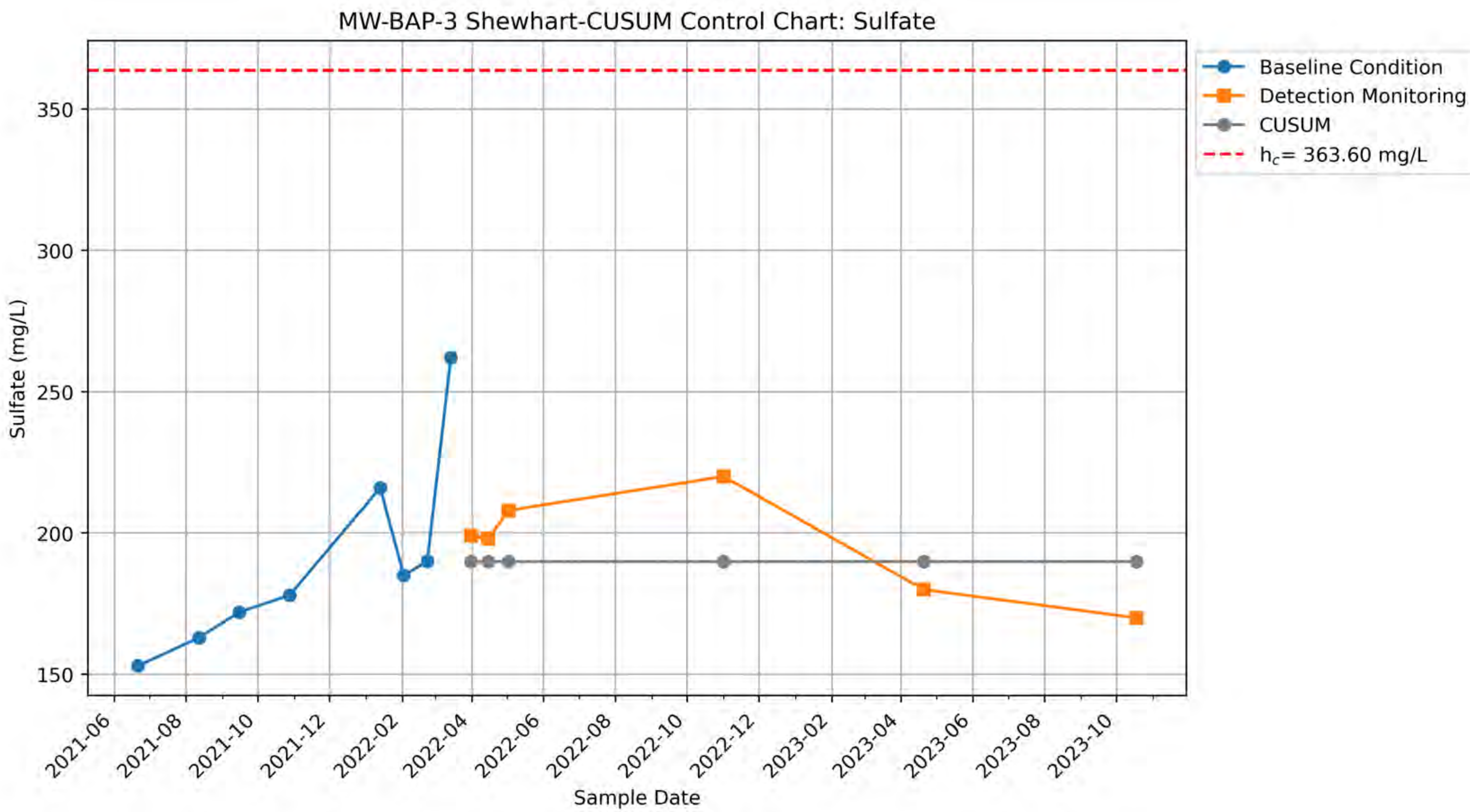
HALEY ALDRICH

Cardinal Power Plant
Retrofitted Bottom Ash Pond Alternate Source Demonstration
Brilliant, Ohio

Shewhart-CUSUM Control Chart
MW-BAP-1002
Chloride

May 2024

FIGURE 7



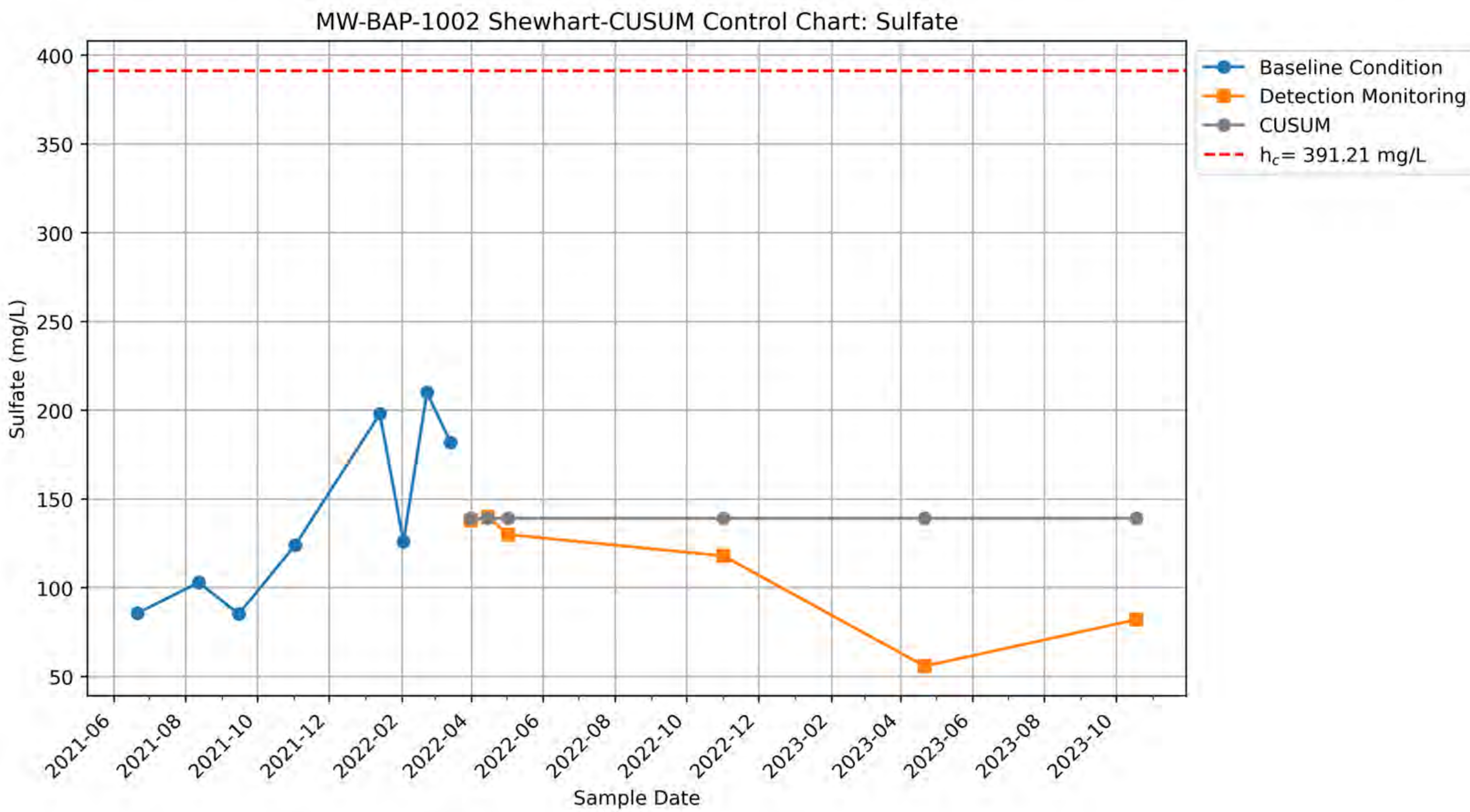
HALEY ALDRICH

Cardinal Power Plant
Retrofitted Bottom Ash Pond Alternate Source Demonstration
Brilliant, Ohio

Shewhart-CUSUM Control Chart
MW-BAP-3
Sulfate

May 2024

FIGURE 8



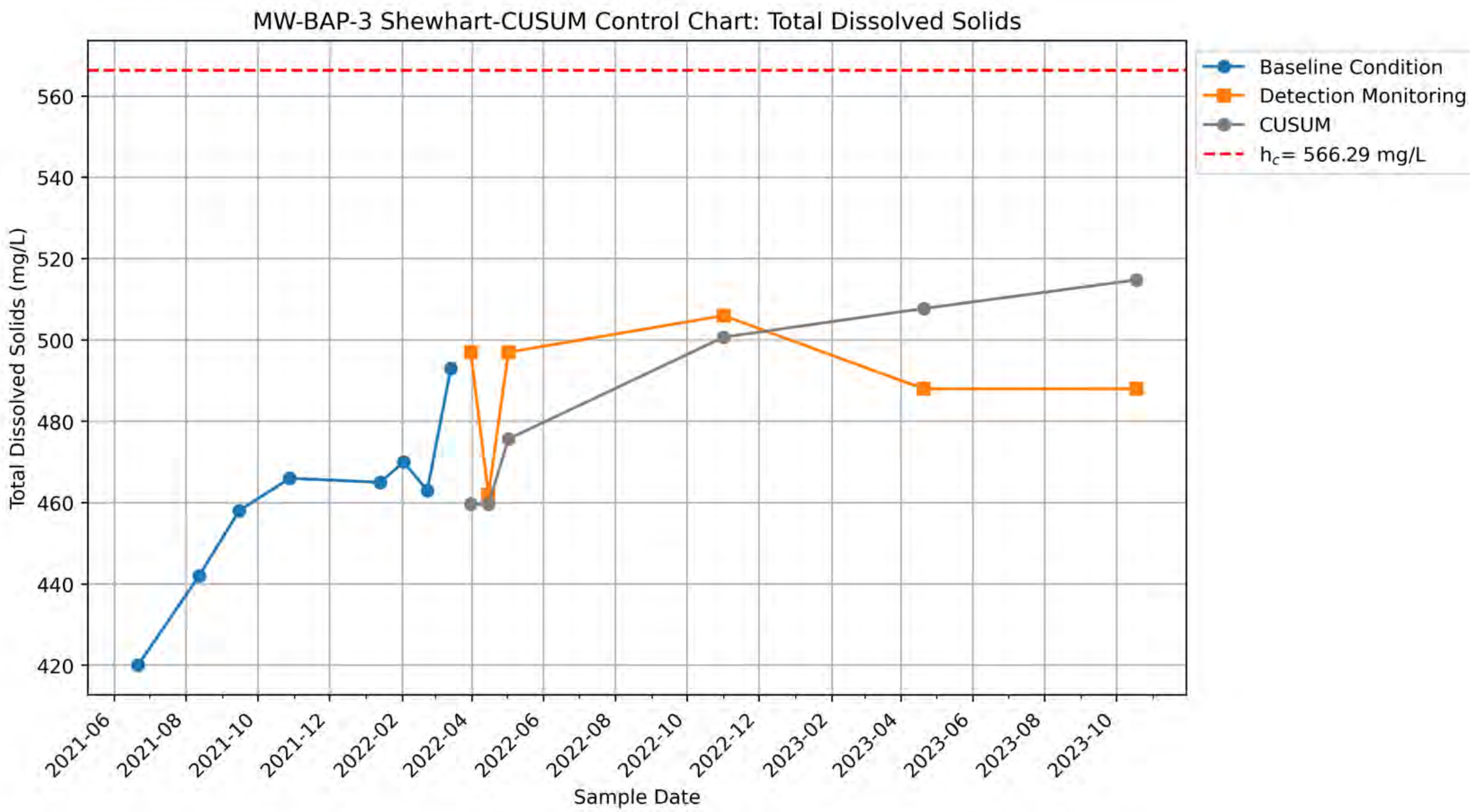
HALEY ALDRICH

Cardinal Power Plant
Retrofitted Bottom Ash Pond Alternate Source Demonstration
Brilliant, Ohio

Shewhart-CUSUM Control Chart
MW-BAP-1002
Sulfate

May 2024

FIGURE 9



https://haleyaldrich.sharepoint.com/sites/CardinalOperatingCompany/Shared Documents/ 0210218.Cardinal Plant CCR GW/Project Work/ BAP/ 2024-ASD/ Appendix C

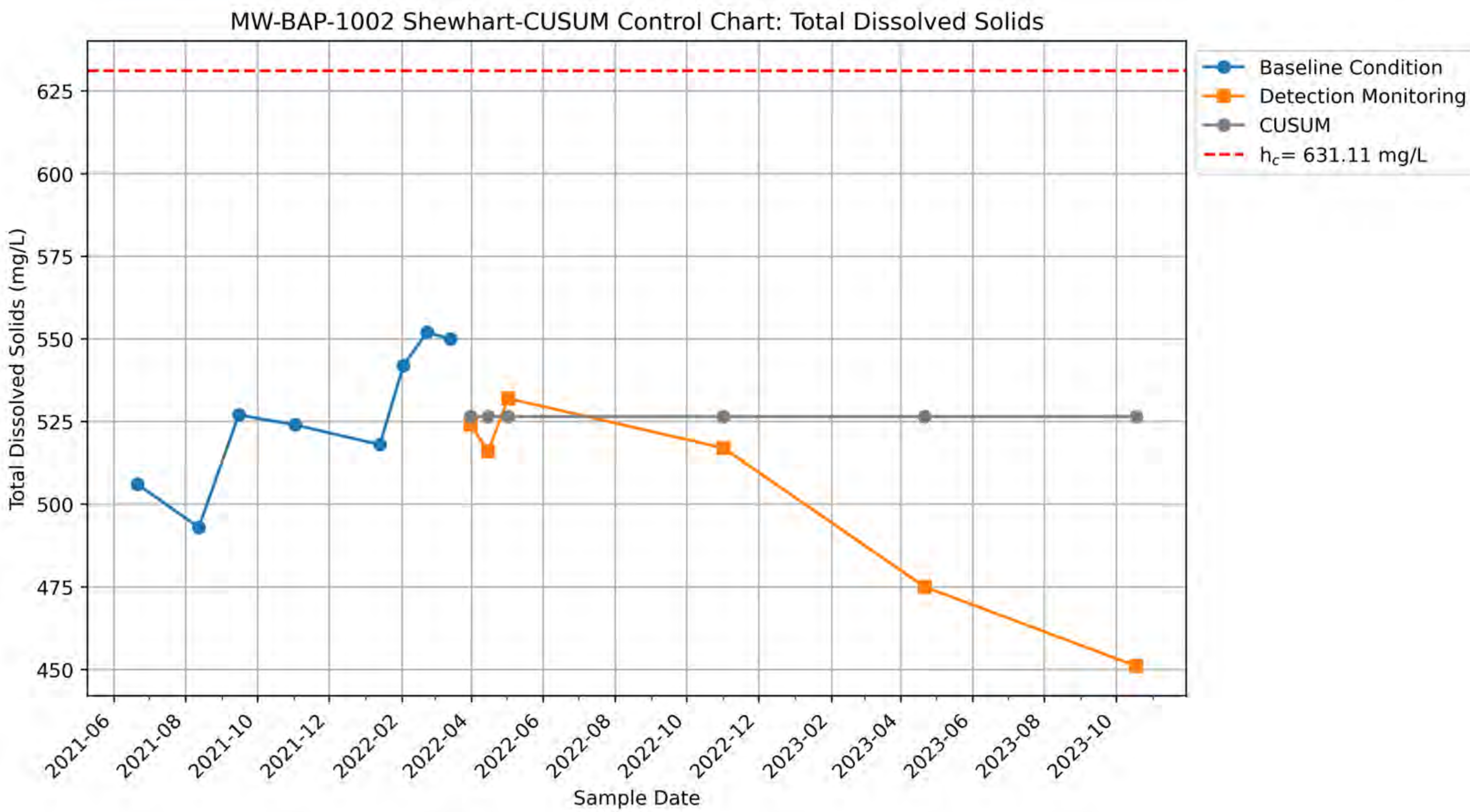
HALEY ALDRICH

Cardinal Power Plant
Retrofitted Bottom Ash Pond Alternate Source Demonstration
Brilliant, Ohio

Shewhart-CUSUM Control Chart
MW-BAP-3
Total Dissolved Solids (TDS)

May 2024

FIGURE 10



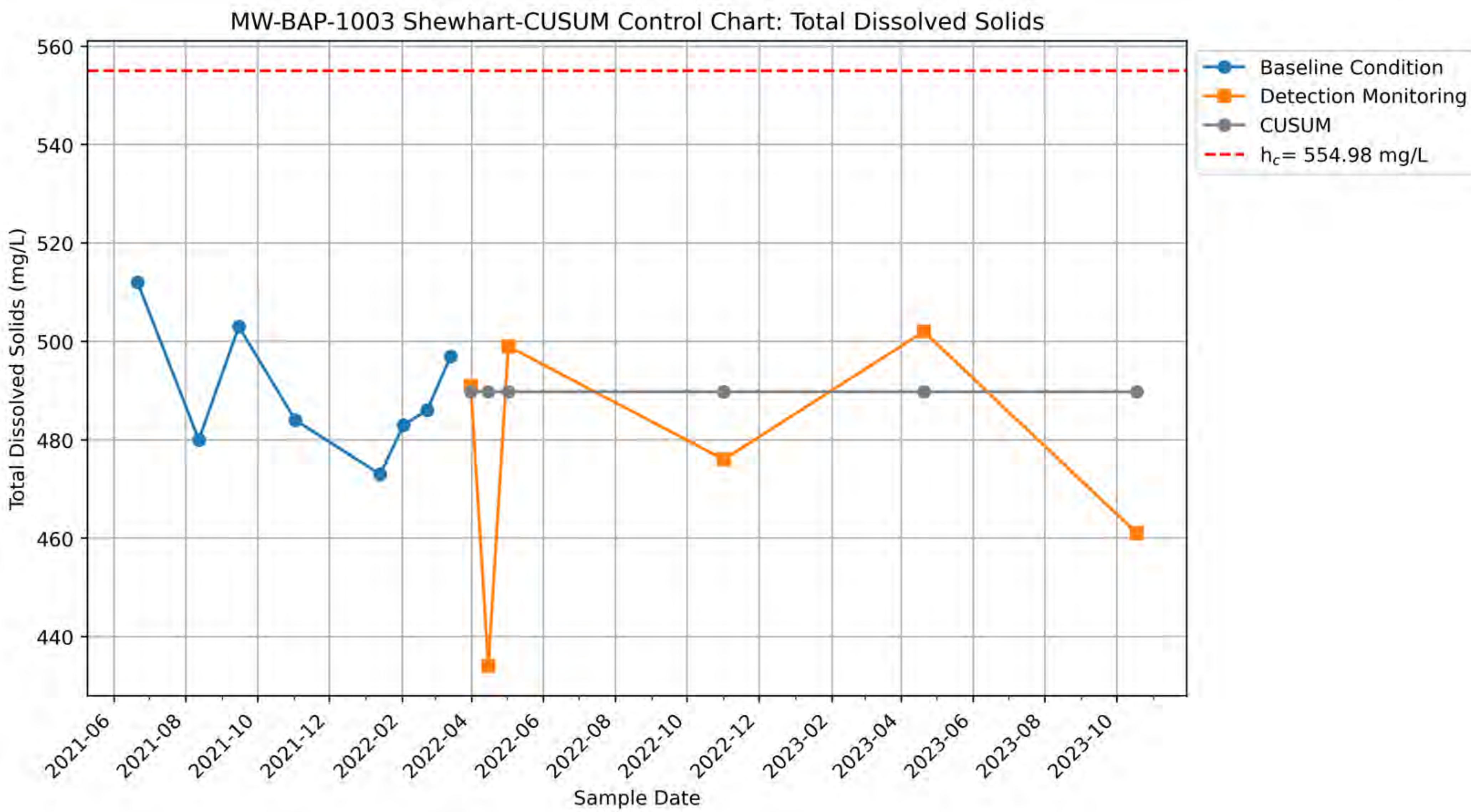
Cardinal Power Plant
Retrofitted Bottom Ash Pond Alternate Source Demonstration
Brilliant, Ohio

Shewhart-CUSUM Control Chart
MW-BAP-1002
Total Dissolved Solids (TDS)

May 2024

FIGURE 11

https://haleyaldrich.sharepoint.com/sites/CardinalOperatingCompany/Shared Documents/ 0210218.Cardinal Plant CCR GW/Project Work/ BAP/ 2024-ASD/ Appendix C



HALEY ALDRICH

Cardinal Power Plant
Retrofitted Bottom Ash Pond Alternate Source Demonstration
Brilliant, Ohio

Shewhart-CUSUM Control Chart
MW-BAP-1003
Total Dissolved Solids (TDS)

May 2024

FIGURE 12

APPENDIX B
Addendum to the October 2023 Monitoring Event ASD

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ADDENDUM TO THE FALL 2023 ALTERNATE SOURCE DEMONSTRATION FOR THE RETROFITTED BOTTOM ASH POND
CARDINAL POWER PLANT
BRILLIANT, OHIO

by
Haley & Aldrich, Inc.
Cleveland, Ohio

for
Cardinal Operating Company
Brilliant, Ohio

File No. 210218
December 2024

HALEY & ALDRICH, INC.
6500 Rockside Road
Suite 200
Cleveland, OH 44131
216.739.0555

19 December 2024
File No. 0210218

Cardinal Operating Company
306 County Road 7E
Brilliant, Ohio 43913

Attention: Nicholas Kasper

Subject: Addendum to the Fall 2023 Alternate Source Demonstration
for the Retrofitted Bottom Ash Pond
Cardinal Power Plant
Brilliant, Ohio

To maintain compliance with the United States Environmental Protection Agency's (USEPA's) 40 Code of Federal Regulations (CFR) §§257.90 through 257.98 ("CCR Rule"), semiannual groundwater sampling is conducted at the Retrofitted Bottom Ash Pond (RBAP), a coal combustion residual (CCR) unit operated by the Cardinal Power Plant in Brilliant, Ohio (Site). The CCR Rule provides a process under 40 CFR Section §257.94(e)(2) for the owner/operator of a regulated CCR unit to demonstrate that a statistically significant increase (SSI) above background concentrations of Appendix III constituents during the detection monitoring program is from an alternate source via an Alternate Source Demonstration (ASD).

As part of the semiannual groundwater sampling and statistical analyses of Appendix III constituents conducted in October 2023 and as detailed below, Cox-Colvin & Associates, Inc. (Cox-Colvin) identified SSIs above established background concentrations for some constituents. Haley & Aldrich, Inc. (Haley & Aldrich) completed an ASD for these constituents in May 2024 (Haley & Aldrich, 2024). Haley & Aldrich has identified two additional SSIs from the fall 2023 RBAP sampling event that were not previously reported. The objective of this addendum is to document the additional SSIs from the fall 2023 groundwater sampling event and provide further analysis to demonstrate alternative sources are responsible for these additional SSIs.

Fall 2023 Detection Monitoring Statistically Significant Increases

Groundwater samples were collected in October 2023 from the RBAP monitoring well network for detection monitoring. Cox-Colvin compared fall 2023 sampling event data to previously established interwell Upper Prediction Limits (UPLs) and Lower Prediction Limits (LPLs; Cox Colvin, 2024) and identified and reported SSIs for the following well constituent pairs:

- Boron: MW-BAP-3, MW-BAP-1002, and MW-BAP-1003

- Calcium: MW-BAP-1002 and MW-BAP-1003
- Chloride: MW-BAP-3 and MW-BAP-1002
- Sulfate: MW-BAP-3 and MW-BAP-1002
- Total Dissolved Solids: MW-BAP-3, MW-BAP-1002, and MW-BAP-1003

Haley & Aldrich identified two additional SSI well constituent pairs from the fall 2023 sampling event that were previously not identified in the 2023 fall semiannual RBAP Statistical Analysis Summary (Cox-Colvin, 2024) or addressed in the associated ASD (Haley & Aldrich, 2024). These SSIs were identified using statistical methodologies outlined in the RBAP Statistical Analysis Plan (Geosyntec, 2020) and in accordance with 40 CFR §257.90. The additional SSIs are:

- Chloride: MW-BAP-1003
- pH (low): MW-BAP-3

Alternate Source Demonstration

The following sections address the additional well-constituent pairings that were found to have SSIs during the fall 2023 Sampling event. This analysis supplements previous results and interpretations provided in the fall 2023 ASD for the RBAP (Haley & Aldrich, 2024).

COMPARISON OF BASELINE CONDITIONS AND SHEWHART-CUSUM CONTROL CHARTS

As described in the fall 2023 RBAP ASD, background conditions used to establish the UPL and LPL are from one upgradient monitoring well (MW-BAP-1001). There is a high degree of variability in constituent concentrations in the baseline dataset (21 June 2021 to 14 March 2022) for the monitoring well network prior to construction and operation of the RBAP in March 2023. Baseline constituent concentrations and variations in baseline conditions were visually evaluated using boxplots of chloride in MW-BAP-1003 and pH in MW-BAP-3 to the background monitoring well (MW-BAP-1001), illustrated in Figure 1. In these plots, the UPLs that are used to determine SSIs above background concentrations for the RBAP are plotted for each constituent to allow for comparison to the baseline concentrations in each monitoring well. Baseline chloride concentrations in MW-BAP-1003 are above the 7.61 milligrams per liter (mg/L) UPL, and over seven out of eight of the pH baseline measurements from MW-BAP-3 are below the 6.7 standard units (S.U.) LPL. These boxplots indicate that an alternate source, present prior to the creation of the RBAP, is responsible for the SSIs in MW-BAP-1003 and MW-BAP-3.

As discussed in the original ASD, the use of Shewhart-CUSUM control charts (control charts) is an effective intrawell method to determine if constituents of interest have increased (or decreased for pH) during groundwater monitoring when compared to baseline conditions prior to establishing the RBAP in monitoring wells that have highly variable conditions across a site from natural or previous impacts. Control charts are an effective method of monitoring both sudden and gradual changes to constituent concentrations. An increase in chloride concentration or a decrease in pH that results in a control chart being out-of-control may indicate a release from the RBAP has occurred. Baseline conditions from each well constituent pairing collected between 21 June 2021 and 14 March 2022 were used to develop background conditions in each monitoring well, and non-standardized control limits (h_c) were used to compare compliance monitoring data.

The use of Shewhart-CUSUM control charts requires that the baseline data be normally distributed. Baseline data summary statistics are provided in Table 1. Shapiro-Wilk statistical tests conducted on both baseline datasets indicate both datasets are normally distributed, and the results of these tests are tabulated in Table 1. Measurements collected between 31 March 2022 and 18 October 2023 were used as detection monitoring results. These detection monitoring results and associated CUSUMs were compared to the control limits (h_c) established from the baseline conditions. Additional details on the use of Shewhart-CUSUM control charts and the associated parameters used to establish the control charts are provided in the fall 2023 ASD (Haley & Aldrich, 2024). Figure 2 and Figure 3 are control charts for chloride in MW-BAP-1003 and pH in MW-BAP-3, respectively. Both constituents are in control and do not indicate that a release from the RBAP has occurred.

Table 1. Baseline Concentration Statistical Results

Constituent	Chloride	pH
Monitoring Well ID	**MW-BAP-1003**	**MW-BAP-3**
Count	8	8
Mean (mg/L)	72.01	6.55
Standard deviation (mg/L)	5.44	0.17
Minimum (mg/L)	66.2	6.25
25% Quartile	69.05	6.5
Median (mg/L)	71.6	6.56
75% Quartile (mg/L)	73.18	6.68
Maximum (mg/L)	83.6	6.75
Shapiro-Wilk Statistic	0.862	0.928
p value	0.125	0.501
Shapiro-Wilk Test ($p < 0.05$)	Normally Distributed	Normally Distributed

ALTERNATE SOURCES

As discussed in the original ASD, the elevated concentrations of chloride in MW-BAP-1003 are attributed to the ongoing closure of the bottom ash pond (BAP) to the north of the RBAP and impacts from the historical bottom ash complex that encompassed the area of the current RBAP. There have been SSIs identified with the BAP monitoring network for chloride (Cox-Colvin, 2022). In addition to impacts from bottom ash, there is a history of coal mining in the area surrounding the RBAP. Impacts from acid mine drainage emanating from mine adits and waste rock is thought to have impacted pH within the shallow aquifer. This is evident in monitoring data from MW-BAP-5, which is upgradient of the RBAP, collected between 28 June 2016 to 18 October 2023, where the mean measured pH is 6.63 S.U., the standard deviation is 0.25 S.U., and the minimum is 6.06 S.U. Measured pH values in MW-BAP-3 fall within the natural variability of measurements observed in MW-BAP-5. As demonstrated, there is no indication that the RBAP is responsible for the additional SSIs observed in the fall 2023 sampling event.

Professional Engineer Certification

Pursuant to 40 CFR §257.94(e)(2), Haley & Aldrich, Inc., on behalf of the Cardinal Operating Company, conducted an Alternate Source Demonstration to substantiate that a source other than the Retrofitted Bottom Ash Pond caused the statistically significant increase over background identified during detection monitoring. I certify that this report and all attachments were prepared by me or under my direct supervision. I am a professional engineer who is registered in the State of Ohio.

This certification and the underlying data support the conclusion that a source other than the Retrofitted Bottom Ash Pond is the cause of the SSIs over background levels for Appendix III constituents identified during detection monitoring of this unit.

The information contained herein is, to the best of my knowledge, true, accurate, and complete.

Steven F. Putrich, P.E.
State of Ohio Professional Engineer
Registration Number 67329

19 December 2024

Enclosures:
- References
- Figure 1 – Box Plots: Baseline Conditions (21 June 2021 - 14 March 2022)
- Figure 2 – MW-BAP-1003 Shewhart-CUSUM Control Chart: Chloride
- Figure 3 – MW-BAP-3 Shewhart-CUSUM Control Chart: pH

References

1. Cox-Colvin & Associates, Inc., 2022. 2021 Annual Groundwater Monitoring Report for Bottom Ash Pond (BAP) Cardinal Operating Company - Cardinal Plant 306 Country Road 7E Brilliant Ohio. 27 January.

2. Cox-Colvin & Associates, Inc., 2024. Cardinal Power Plant Facility Retrofitted BAP Statistical Analysis Summary - 2023 Second Semiannual Event. Technical Memorandum. 18 February.

3. Geosyntec, 2020. Statistical Analysis Plan Cardinal Power Plant Brilliant Ohio. August.

4. Haley & Aldrich, Inc., 2024. Alternate Source Demonstration for the Retrofit Bottom Ash Pond Cardinal Operating Company - Cardinal Power Plant. File No. 210218. May.

FIGURES

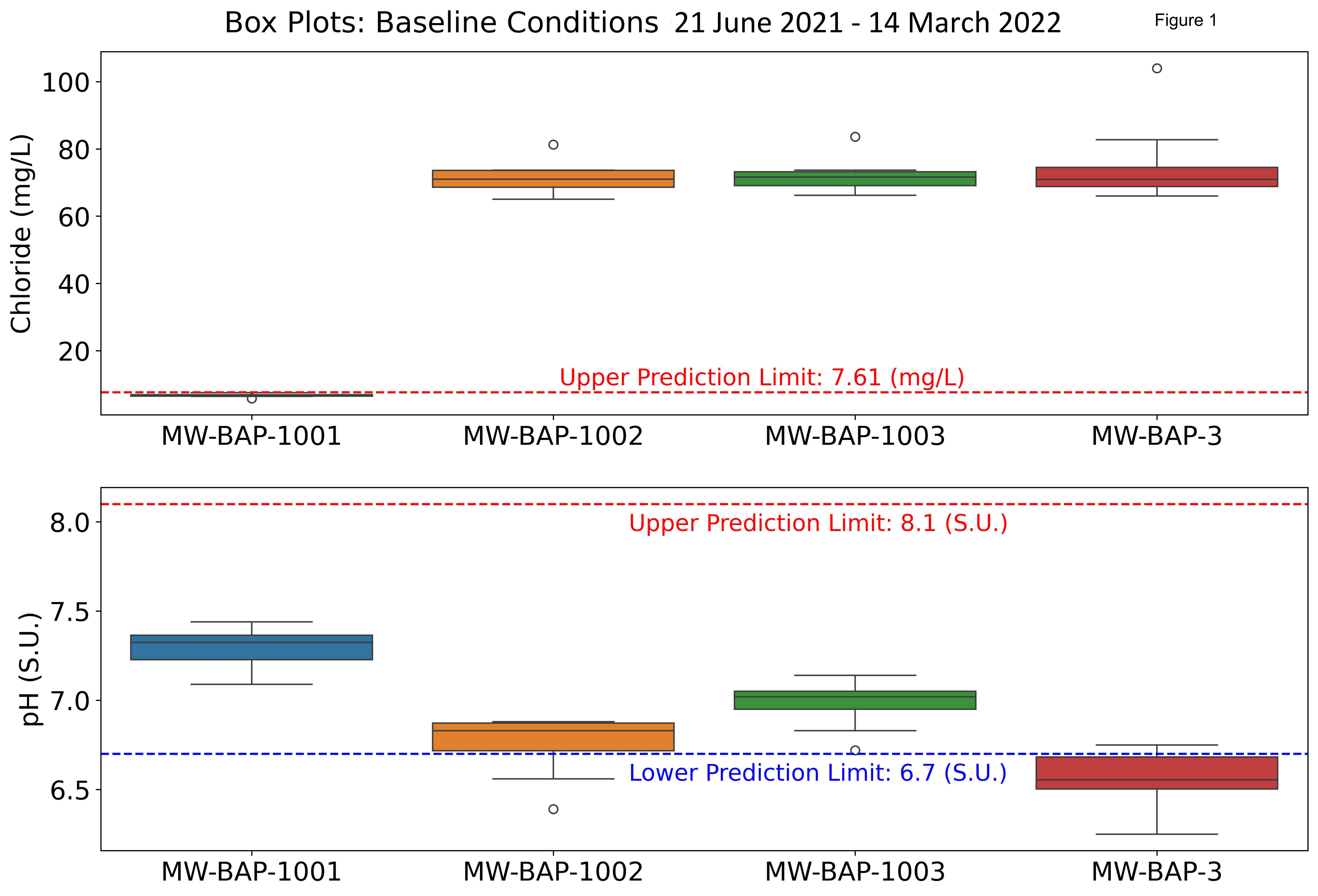
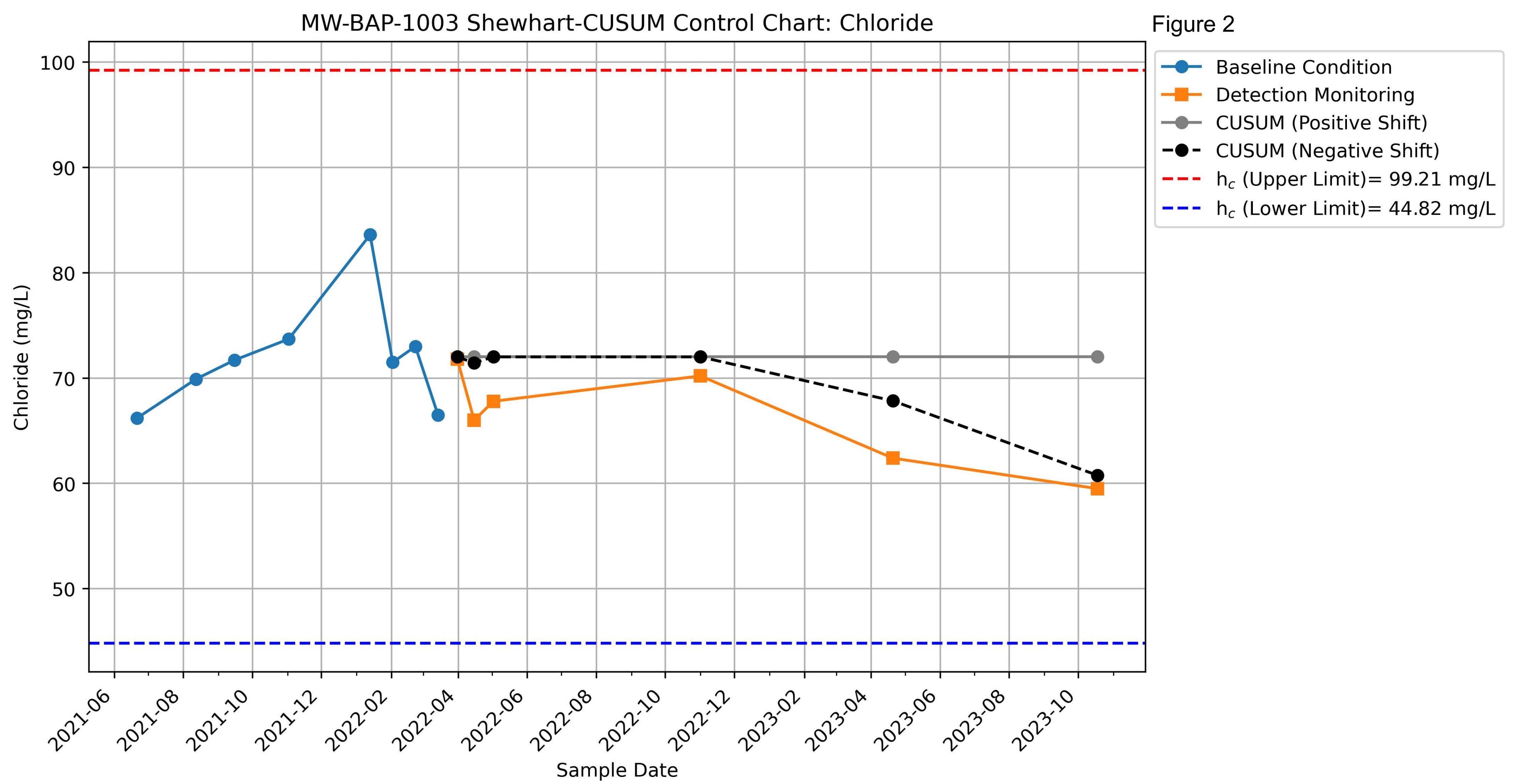
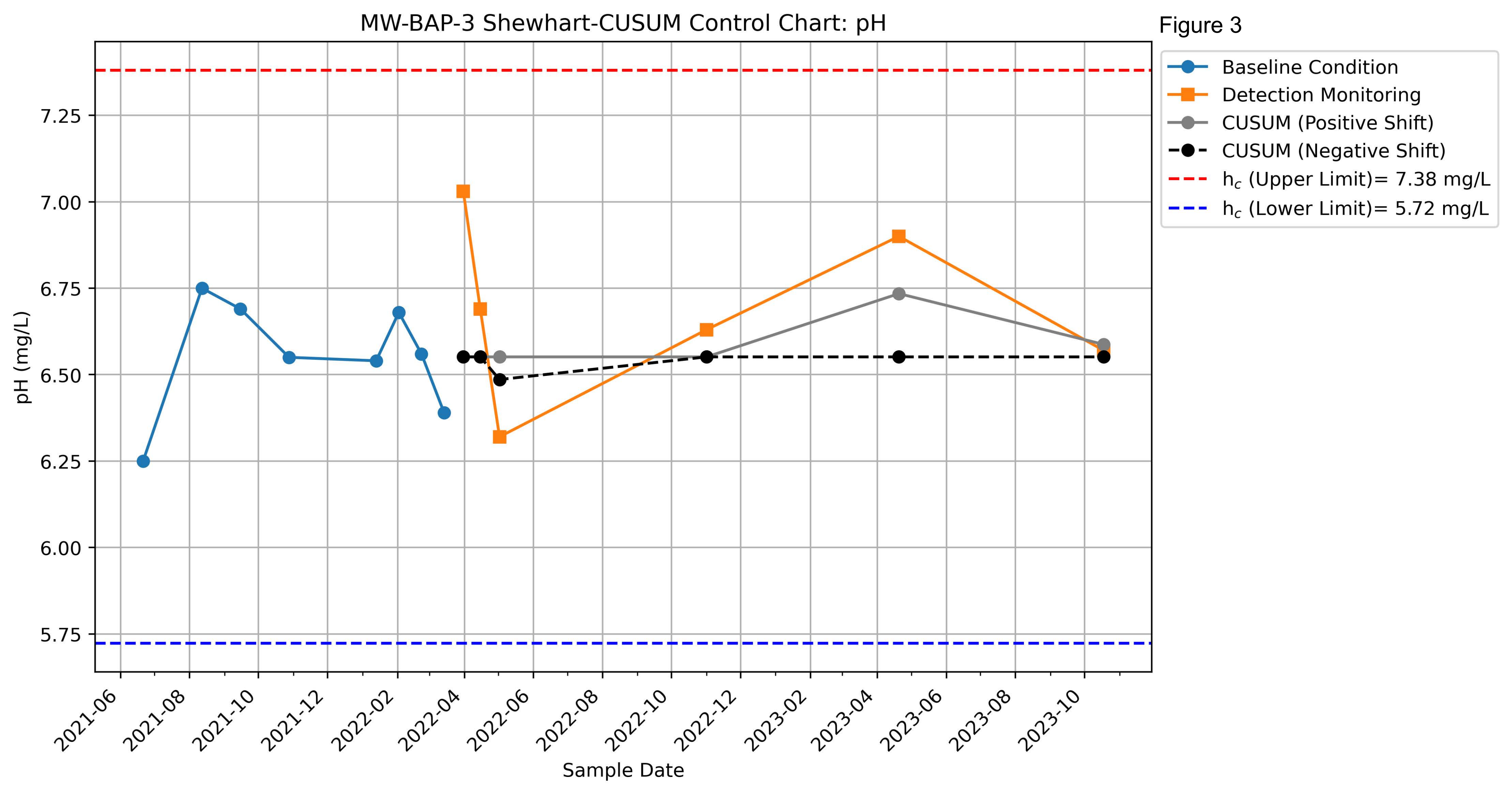

Box Plots: Baseline Conditions 21 June 2021 - 14 March 2022
Figure 1
Chloride (mg/L)
100
80
60
40
20
Upper Prediction Limit: 7.61 (mg/L)
MW-BAP-1001
MW-BAP-1002
MW-BAP-1003
MW-BAP-3
pH (S.U.)
8.0
7.5
7.0
6.5
Upper Prediction Limit: 8.1 (S.U.)
Lower Prediction Limit: 6.7 (S.U.)
MW-BAP-1001
MW-BAP-1002
MW-BAP-1003
MW-BAP-3

Figure 2



MW-BAP-1003 Shewhart-CUSUM Control Chart: Chloride
Chloride (mg/L)
100
90
80
70
60
50
2021-06
2021-08
2021-10
2021-12
2022-02
2022-04
2022-06
2022-08
2022-10
2022-12
2023-02
2023-04
2023-06
2023-08
2023-10
Sample Date
Baseline Condition
Detection Monitoring
CUSUM (Positive Shift)
CUSUM (Negative Shift)
h$_c$ (Upper Limit)= 99.21 mg/L
h$_c$ (Lower Limit)= 44.82 mg/L


MW-BAP-3 Shewhart-CUSUM Control Chart: pH
Figure 3
Baseline Condition
Detection Monitoring
CUSUM (Positive Shift)
CUSUM (Negative Shift)
h_c (Upper Limit)= 7.38 mg/L
h_c (Lower Limit)= 5.72 mg/L
pH (mg/L)
Sample Date
7.25
7.00
6.75
6.50
6.25
6.00
5.75
2021-06
2021-08
2021-10
2021-12
2022-02
2022-04
2022-06
2022-08
2022-10
2022-12
2023-02
2023-04
2023-06
2023-08
2023-10

APPENDIX C
ASD for the April 2024 Monitoring Event

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REPORT ON

ALTERNATE SOURCE DEMONSTRATION
FOR THE RETROFIT BOTTOM ASH POND
CARDINAL OPERATING COMPANY – CARDINAL POWER PLANT
306 COUNTY ROAD 7E
BRILLIANT, OHIO

by
Haley & Aldrich, Inc.
Cleveland, Ohio

for
Cardinal Operating Company
Brilliant, Ohio

File No. 210218
November 2024

Executive Summary

Haley & Aldrich, Inc. prepared this Alternate Source Demonstration (ASD) for the Cardinal Operating Company to determine if there is an alternate source of Appendix III constituents at the Cardinal Power Plant (Site) Retrofitted Bottom Ash Pond (RBAP) located in Brilliant, Ohio. The RBAP is a coal combustion residuals unit at the Site. The evaluation presented herein is in response to statistically significant increases (SSIs) of Appendix III constituents identified during the first semiannual groundwater sampling event held in April 2024. Detection monitoring results indicated boron, calcium, chloride, and sulfate concentrations in monitoring wells were identified as having SSIs above background concentrations. These constituents have been consistently elevated since before the operation of the RBAP. Statistical analysis of these constituents' concentrations compared to individual well baseline conditions do not indicate increases have occurred during the RBAP operational period. Thus, this demonstrates that there has not been a release from the RBAP.

The ongoing closure of the historical bottom ash pond complex (BAC) and natural variability in the groundwater have contributed to the elevated concentrations of constituents in monitoring wells that were identified to have SSIs above background. Interwell comparison of baseline conditions suggests a high degree of variance among monitoring wells in the well network prior to operation of the RBAP. Intrawell well evaluations demonstrate that, with the exception of sulfate in one monitoring well, the concentrations identified as SSIs are not different than the concentrations at those locations prior to the operation of the RBAP. Therefore, those SSIs are associated with the variability of groundwater conditions from sources prior to the operation of the RBAP. In addition, the observed natural variability of groundwater is greater than what is represented by the one monitoring well used in the interwell evaluation. Additional evaluation of natural occurring concentrations of sulfate in background groundwater, as well as concentrations observed in the adjacent Ohio River, demonstrates that the sulfate concentration at MW-BAP-1003 is well within the range of natural variability and concentrations; therefore, it does not represent a SSI over background. The RBAP will remain in detection monitoring since SSIs can be attributed to an alternate source.

Table of Contents

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1. Introduction

1.1 INTRODUCTION AND PURPOSE

To maintain compliance with the United States Environmental Protection Agency's (USEPA's) Code of Federal Regulations (CFR) regarding disposal of coal combustion residuals (CCRs) in landfills and surface impoundments (40 CFR §§257.90 through 257.98, "CCR Rule"), the first semiannual groundwater sampling event was conducted in April 2024 at the Retrofitted Bottom Ash Pond (RBAP), a CCR unit operated by the Cardinal Power Plant in Brilliant, Ohio (Site). The RBAP was recently developed as a replacement storage facility of the historical Bottom Ash Pond Complex (BAC) used at the Site. Statistical evaluations, performed by Cox-Colvin & Associates, Inc. (Cox-Colvin) and Haley & Aldrich, Inc. (Haley & Aldrich) as part of the ongoing detection monitoring program, identified statistically significant increases (SSI) of some Appendix III constituents over background concentrations in accordance with 40 CFR §257.93(f).

The CCR Rule provides a process under 40 CFR Section §257.94(e)(2) for the owner/operator of a regulated CCR unit to demonstrate that a SSI above background concentrations of Appendix III constituents during the detection monitoring program is from an alternate source via an Alternate Source Demonstration (ASD). The purpose of this report is to document that natural variability in the groundwater and alternate sources are responsible for the SSIs of constituents above background identified during RBAP detection monitoring in April 2024.

1.2 SITE DESCRIPTION

The Site is located in Jefferson County, approximately 1 mile south of Brilliant, Ohio and is operated by the Cardinal Operating Company (Cardinal). The three coal-powered units that make up the generating station are located immediately west of the Ohio River, with Units 1 and 2 in operation since 1967 and Unit 3 in operation since 1977. This study focuses on the RBAP located south of the generating station and immediately west of the Ohio River, as shown on Figure 1. The surface area of the RBAP is approximately 7 acres, and it has a storage capacity of approximately 74 acre-feet. The RBAP is designed to operate as the only CCR pond for management of bottom ash sluicing discharge from the generating station. Dewatered bottom ash is dredged from the pond and disposed of in the Landfill, north of the generating station.

1.3 SITE GEOLOGY AND HYDROGEOLOGY

1.3.1 Geologic Setting

The geologic setting in the vicinity of the RBAP can be described as sedimentary bedrock overlain by unconsolidated deposits associated with the Ohio River Valley. Cross-sections prepared by Cox-Colvin are presented in Appendix A that show the geologic units below the RBAP. As depicted in the cross-sections, three distinct lithologies are present consisting of the following:

- Fill Material – a product of previous earth work in the area for the construction of the former Bottom Ash Pond. Fill materials are approximately 10 to 20 feet thick.
- Alluvium – consisting of silt, clay, and sand deposited by the Ohio River approximately 10 to 20 feet thick.

- Glacial Outwash – alluvial deposits of sand and gravel that are between 5 to 50 feet thick.

Bedrock is closer to the surface along the western portion of the RBAP and deepens toward the Ohio River to the east. Consequently, the glacial outwash that is the primary aquifer below the RBAP pinches out to the west, as the bedrock comes closer to the surface and thickens to the east below the Ohio River.

1.3.2 Hydrogeologic Setting

Groundwater flows from the west of the RBAP to the east and ultimately flows into the Ohio River under non-flood conditions. The aquifer near the RBAP exhibits a strong connection with the river. Groundwater elevations observed in MW-BAP-1001 depict this interaction, as well as the interaction between bedrock and unconsolidated material as groundwater flows to the Ohio River to the east. Groundwater flows through the Glacial Outwash aquifer below the RBAP to the east-southeast where the groundwater/surface water interface occurs to the Ohio River. The groundwater potentiometric surface map for the April 2024 semiannual sampling event is presented as Figure 2. Through the groundwater gauging events, presented separately in previously submitted Annual Reports, flow remains consistently toward the Ohio River to the east-southeast, with the exception of one gauging event (17 October 2022), where the groundwater flow direction changed due to elevated river levels during flood conditions.

The Glacial Outwash material consists of highly conductive sand and gravel that has a strong connection to the nearby Ohio River. Hydraulic conductivities for wells along the east of the RBAP are approximately 2.9×10^{-1} centimeters per second, as presented in the 3 January 2022 *Groundwater Monitoring System for Retrofitted Bottom Ash Pond (BAP)* prepared by Cox-Colvin. The high level of connection is evident by the very shallow gradients observed across the RBAP area. Water levels vary less than 0.3 feet from MW-BAP-1001 (upgradient west of the RBAP) to MW-BAP-3 (downgradient east of the RBAP).

1.4 GROUNDWATER MONITORING SYSTEM

The *Groundwater Monitoring System for Retrofitted Bottom Ash Pond (BAP)* was prepared by Cox-Colvin and certified on 3 January 2022 (Cox-Colvin, 2022a). Groundwater monitoring activities were implemented to comply with the requirements of 40 CFR §§257.90 through 257.98. The monitoring system consists of four wells. Upgradient well, MW-BAP-1001, is used to monitor background conditions. The three downgradient monitoring wells (MW-BAP-1002, MW-BAP-1003, and MW-BAP-3) are used for compliance monitoring of downgradient water quality from the RBAP. Monitoring well MW-BAP-3 was installed in 2015 and is also used as part of the Bottom Ash Pond CCR unit monitoring network. All other monitoring wells that are part of the network were installed in 2021. A series of wells that are part of the BAC monitoring network are utilized for groundwater level measurements and interpreting groundwater flow conditions in the RBAP. These wells are MW-BAP-1, MW-BAP-2, MW-BAP-3, and MW-BAP-4. Figure 3 shows the groundwater monitoring system, together with the layout of the RBAP.

1.5 SPRING 2024 DETECTION MONITORING STATISTICALLY SIGNIFICANT INCREASES

Water samples were collected in April 2024 from the RBAP monitoring well network for detection monitoring. Appendix III constituents for each sample were compared to previously established interwell Upper Prediction Limits (UPLs) and Lower Prediction Limits (LPLs; Cox-Colvin, 2024b). Results indicate SSIs above background concentrations for the following constituents and well pairings:

- boron: MW-BAP-1002, MW-BAP-1003, and MW-BAP-3
- calcium: MW-BAP-1002 and MW-BAP-1003
- chloride: MW-BAP-1002, MW-BAP-1003, and MW-BAP-3
- sulfate: MW-BAP-1002, MW-BAP-1003, and MW-BAP-3
- total dissolved solids (TDS): MW-BAP-1002 and MW-BAP-1003

These SSIs were identified using statistical methodologies outlined in the RBAP Statistical Analysis Plan (Geosyntec, 2020) and are in accordance with 40 CFR §257.93.

1.6 CCR RULE REQUIREMENTS

If the owner or operator of the CCR unit determines there are SSIs of Appendix III constituents, then 40 CFR §257.94 (e) states:

> *"The owner or operator may demonstrate that a source other than the CCR unit caused the statistically significant increase over background levels for a constituent or that the statistically significant increase resulted from error in sampling, analysis, statistical evaluation, or natural variation in groundwater quality. The owner or operator must complete the written demonstration within 90 days of detecting a statistically significant increase over background levels to include obtaining a certification from a qualified professional engineer or approval from the Participating State Director or approval from EPA where EPA is the permitting authority verifying the accuracy of the information in the report. If a successful demonstration is completed within the 90-day period, the owner or operator of the CCR unit may continue with a detection monitoring program under this section. If a successful demonstration is not completed within the 90-day period, the owner or operator of the CCR unit must initiate an assessment monitoring program as required under § 257.95. The owner or operator must also include the demonstration in the annual groundwater monitoring and corrective action report required by § 257.90(e), in addition to the certification by a qualified professional engineer or approval from the Participating State Director or approval from EPA where EPA is the permitting authority."*

1.7 CONSTRUCTION AND OPERATIONAL HISTORY

The BAC was originally constructed in the 1960s and was further modified in 1974 and 2008. The BAC was historically used by Cardinal to manage sluiced bottom ash and other non-CCR low-volume waste (LVW) streams, including stormwater runoff. The BAC consisted of two impoundments, the bottom ash pond (North Pond) and the recirculating pond (South Pond). Due to a pipe network connecting these two ponds, they were monitored as a single unit that is referred to as the Bottom Ash Pond (BAP) CCR unit. Both ponds in the BAC were previously unlined.

In 2021, Cardinal elected to divide the BAC into two separate ponds to segregate and properly manage two waste streams, CCR waste and non CCR-LVW. Beginning in August 2021, waste streams were no longer distributed to the South Pond, excavation of the historical ash deposits was completed, and the

South Pond was relined (Buckeye Power Inc., 2021). On 27 March 2022, all retrofit activities were completed in accordance with the written retrofit plan (Sargent & Lundy, 2020a) and the requirements of 40 CFR § 257.102(k) (Sargent & Lundy, 2022). The liner systems consist of three components: 1) a graded and compacted native soil base in compliance with the CCR Rule permeability requirement; 2) a geosynthetic clay layer overlying the native compacted soil; and 3) a 60-mil textured high-density polyethylene (HDPE) geomembrane topping the clay. The liner is protected with additional geotextiles and natural gravel to protect the HDPE geomembrane during bottom ash removal (Cox-Colvin, 2023). The name was changed to Retrofit Bottom Ash Pond (RBAP) when the retrofit of the South Pond was completed.

During the spring 2024 sampling event, closure by removal was ongoing for the northern portion of the historical BAC.

1.8 HISTORICAL GROUNDWATER MONITORING

1.8.1 Bottom Ash Pond

Groundwater monitoring of the BAP utilized five monitoring wells, including two upgradient monitoring wells (MW-BAP-4 and MW-BAP-5) to characterize background conditions and three downgradient monitoring wells (MW-BAP-1, MW-BAP-2, and MW-BAP-3) used for compliance monitoring. Baseline conditions were established in these wells and semiannual monitoring has continued to evaluate if CCR materials are impacting water quality. Results of this monitoring have shown SSIs above background levels downgradient of the BAP for Appendix III parameters, including boron, chloride, sulfate, pH, fluoride, and TDS (Cox-Colvin, 2022b). However, assessment monitoring and statistical analysis have demonstrated constituent concentrations did not reach statistically significant levels in excess of BAP Groundwater Protection Standards (GWPS) that would require further action. The BAP was in assessment monitoring prior to operation of the RBAP groundwater monitoring system.

1.8.2 Retrofitted Bottom Ash Pond

Groundwater monitoring of the RBAP has identified SSIs above background concentrations since detection monitoring began in November 2022. Constituents that have had SSIs above background include boron, calcium, chloride, pH, sulfate, and TDS (Cox-Colvin, 2024a). The most recent ASD, conducted for the sampling event in October 2023, attributed these increases to the historical BAC and regional historical coal mining impacts (Haley & Aldrich, 2024). Accordingly, the RBAP has remained in detection monitoring and has not entered into assessment monitoring.

2. Background Determinations

Background conditions used in statistical analysis to determine SSIs of Appendix III constituents were established using background water quality data collected between 21 June 2021 and 2 May 2022 from the upgradient well (MW-BAP-1001). The UPLs were calculated for Appendix III constituents based on a one-of-two sampling plan, with seven constituents analyzed semiannually in three downgradient compliance wells. In addition, a LPL was calculated for pH (Cox-Colvin, 2022c).

As required in 40 CFR §257.91(a)(1), the groundwater monitoring network must yield groundwater samples from the uppermost aquifer that accurately represent the quality of background groundwater. While the UPLs calculated from the upgradient well (MW-BAP-1001) reflect upgradient conditions, these conditions are not representative of baseline (background) conditions of all wells in the RBAP monitoring well network and result in SSIs of some Appendix III constituents that are not attributed to a release from the RBAP. Interwell comparison of baseline conditions suggests a high degree of variance among monitoring wells in the well network prior to operation of the RBAP. Variation in monitoring well baseline conditions between the upgradient well and downgradient compliance monitoring wells is attributed to natural variation associated and historical impacts from the BAP, which are discussed in the following sections.

2.1 COMPARISON OF BASELINE CONDITIONS

2.1.1 Visual Evaluation and Comparison to Upper Prediction Limits

Baseline conditions in each monitoring well in the RBAP monitoring network were compared for constituents that had a SSI above background using water samples collected between 21 June 2021 and 27 March 2022. The date of completion of retrofit activities for the RBAP (27 March 2022) is different from the sample set used for the background concentration determination for detection monitoring, which included data collected between 27 March and 2 May 2022. Summary statistics of baseline constituent concentrations for each well are presented in Table I. Baseline constituent concentrations and variation among monitoring wells were visually evaluated using box and whisker plots as illustrated in Figure 4. In these plots, the UPLs that are used to determine SSIs above background concentrations for the RBAP are plotted for each constituent to allow for comparison to baseline concentrations. These plots demonstrate there is a high degree of variability in baseline constituent concentrations that were found to have a SSI above background during the April 2024 sampling event. In addition, these box and whisker plots demonstrate that every constituent well pairing that was identified to have a SSI over background in the April 2024 sampling event had concentrations well above the UPL prior to operation of the RBAP.

2.1.2 Statistical Comparison of Baseline Conditions

To evaluate the differences between baseline concentrations datasets among monitoring wells in the RBAP monitoring network, a series of Levene tests and Welch's ANOVA tests were performed on each constituent. Results of these statistical analyses are presented in Table II. There is a statistically significant variance between the monitoring well datasets for boron and sulfate. Based on the Welch's ANOVA test, there are significant differences between the monitoring well baseline datasets for every constituent evaluated.

2.2 INTERWELL AND INTRAWELL STATISTICAL EVALUATION

Background concentrations for compliance monitoring can be established using interwell and intrawell approaches. The USEPA Unified Guidance (USEPA, 2009) recommends the use of intrawell statistical tests that compare historical background data to recent data at a single well to avoid spurious SSIs at sites with a high degree of spatial variation in constituent concentrations.

3. Sampling, Analysis, and Statistical Evaluation Errors

In accordance with 40 CFR §257.94(e) a demonstration that sampling, analysis, and statistical analysis error resulted in SSIs of constituents above background resulting in a transition to assessment monitoring is not required. No errors in sampling, laboratory analysis, or statistical evaluations have been identified that would contribute to the SSIs of constituents (Haley & Aldrich, 2024).

4. RBAP Source Evaluation

The implementation of a CCR-compliant liner system makes release of constituents from the RBAP into the underlying aquifer highly unlikely. As described in Section 2, there has historically been a high degree of variability in Appendix III constituent concentrations in the RBAP monitoring network, and the constituents with SSIs above background were above UPLs prior to completion of the RBAP. While the presence of these elevated constituent concentrations prior to RBAP's operation demonstrate an alternate source is contributing to the SSI, it is important to determine if a release from the RBAP has occurred and is affecting water quality. An evaluation was conducted to determine if RBAP's operation is contributing to the SSI using control charts, which is a statistical approach that allows comparison of constituents to baseline conditions. This method and results of these analyses are discussed in Section 4.1.

4.1 SHEWHART-CUSUM CONTROL CHARTS

The use of control charts is a valid statistical method to evaluate CCR groundwater monitoring data in accordance with 40 CFR §257. 93(f)(4). The specific control chart recommended in the USEPA Unified Guidance is the Shewhart-CUSUM control chart (USEPA, 2009). This control chart effectively combines the two separate evaluation procedures; the Shewhart portion produces a control limit, which is similar to the UPL where compliance measurements are individually compared, and the cumulative sum (CUSUM) portion sequentially analyzes each new measurement with prior compliance data. Together the Shewhart and CUSUM results are used to assess the similarity of compliance data to background during detection monitoring.

In all statistical analyses provided herein, the monitored constituents that were below detection are reported at one-half of the reporting limit, and only the parent samples were used when duplicate samples were collected. Based on the high degree of variation in the baseline datasets among monitoring wells, an intrawell approach was taken to determine baseline conditions for the compliance monitoring wells. The baseline dataset consists of monitoring well data from June 2021 until implementation of the RBAP on 7 March 2022. These data were used to determine a non-standardized control limit (h_c) that effectively serves as both the decision internal value (h) and the Shewhart Control Limit, as the USEPA Unified Guidance recommends only one standardized control limit be utilized (USEPA, 2009). In these calculations, h was set to 5 and k was set to 1, as referenced in the Unified Guidance. Visual inspection of the data does not suggest seasonality, and as a result, the data were not adjusted for seasonality.

There are two scenarios in which the control chart can be out-of-control: 1) the trace of non-standardized constituent concentrations exceeds h_c based on the Shewhart component of the analysis; and 2) the CUSUM becomes too large and exceeds the h_c based on the CUSUM portion of the analysis. A control chart that is categorized as out-of-control due to the first scenario is attributed to a rapid increased in constituent concentrations in the most recent sampling event. A control chart that is categorized as out-of-control due to the second scenario may also be due to a sudden rise in constituent concentrations and/or a gradual increase in concentrations over time. If the non-standardized constituent concentrations do not exceed the h_c but the CUSUM does the exceed h_c, then the out-of-control result is attributed to a trend of gradual increases. Thus, control charts can be used to assess both sudden or gradual contamination at a compliance point.

The use of Shewhart-CUSUM control charts is an effective method to determine if constituents of interest have increased during groundwater monitoring compared to baseline conditions prior to establishing the RBAP. Increases in constituent concentrations over baseline would be expected if the RBAP was the source of Appendix III constituents in the monitoring well network.

4.2 STATISTICAL EVALUATION RESULTS

Groundwater samples collected between 21 June 2021 and 27 March 2022 were used as baseline data. Shewhart-CUSUM control charts require baseline data to be normally distributed (i.e., parametric). Shapiro-Wilk statistical tests were conducted on all baseline constituent datasets to determine if the data are normally distributed and appropriate for Shewhart-CUSUM control charts. The results of these evaluations are tabulated in Table III. All datasets were found to be normally distributed, except for the MW-BAP-3 chloride data. Groundwater samples collected between 27 March and 18 October 2023 were used for detection monitoring in the Shewhart-CUSUM control charts. Shewhart-CUSUM control charts were developed for every constituent well pair that was found to have SSIs above background during the April 2024 sampling event and are included in Appendix C. Because the chloride baseline data at MW-BAP-3 is non-parametric, the upper prediction limit was conservatively set at the maximum concentration observed in the baseline data. The well-constituent pair of sulfate at MW-BAP-1003 was identified to be out-of-control when compared to intrawell baseline conditions. Further analysis for this well-constituent pairing is discussed below. All other well-constituent pairings were identified as out-of-control when compared to intrawell baseline conditions, which demonstrates that the RBAP is not a source responsible for the SSIs above background identified in those wells.

5. Other Potential Sources

The ongoing closure of the historical BAC is attributed to elevated concentrations of boron, sulfate (for monitoring wells MW-BAP-1002 and MW-BAP-3), chloride, and TDS in the RBAP detection monitoring wells. The RBAP was constructed in the southern portion of the historical BAC. As discussed, elevated concentrations of Appendix III constituents have been present since the RBAP monitoring network was created. Assessment monitoring of the historical BAC was initiated in August 2018 as a result of detection monitoring constituents having SSIs over background concentrations. Within the BAP, SSIs of Appendix III constituents have been identified for boron, chloride, sulfate, and TDS (Cox-Colvin, 2022b). This provides strong evidence that the historical use of the BAC is attributed to the SSIs over background observed for boron, chloride, sulfate, and TDS in the RBAP. Use of the northern portion of the BAP for CCR material ceased in March 2023, and closure by removal was ongoing during the April 2024 sampling event. Impacts from historical CCR material in the historical BAC may continue to affect water quality.

A potential example of the above are sulfate concentrations in MW-BAP-1003. As noted above, sulfate in MW-BAP-1003 is not within its Shewhart-CUSUM control chart. In addition, the water quality in upgradient monitoring well MW-BAP-1001 may not be the best indicator of water quality in MW-BAP-1003. As shown on the potentiometric maps (Appendix B), MW-BAP-1001 is not hydraulically upgradient of MW-BAP-1003. Flow arrows have been added to previously published potentiometric maps to highlight groundwater flow direction.

To understand the upgradient water quality in the RBAP and determine a more representative background value for the RBAP, it is valuable to consider using more than one monitoring well to understand the natural variability in upgradient groundwater quality. This is particularly important noting the spatial variability observed in groundwater conditions prior the construction of the RBAP. Specifically, using MW-BAP-1001 and MW-BAP-5 as a pooled dataset, is appropriate and provides a better understanding of natural variability within the water quality upgradient of the RBAP.

As shown in the sulfate box and whisker plots (Figure 5), the natural variability is clearly exhibited in the pooled dataset, which includes MW-BAP-1001 and MW-BAP-5. The sulfate in the groundwater in MW-BAP-1003 sits at the low end of the range of these wells in the area.

As supporting evidence of the above, the Ohio River Valley Water Sanitation Commission (ORSANCO) conducts bimonthly monitoring of water quality parameters. The New Cumberland sampling location (Ohio River mile 54.4) is the most representative of water quality proximal to the Ohio River at the Cardinal Plant. From the bimonthly samples collected from 2010 to 2023, the mean value of the sulfate results is 65 milligrams per liter (mg/L). This sulfate value is similar to the value observed at MW-BAP-1003, supporting the fact that the MW-BAP-1003 sulfate concentration falls within the natural variability of sulfate in groundwater at the RBAP.

Considering all of these observations, the sulfate in MW-BAP-1003 is not indicative of a release from the RBAP, rather that the concentration of sulfate at MW-BAP-1003 is within the natural variability and range of concentrations that are exhibited within in upgradient groundwater and adjacent surface water.

6. Conclusion

In April 2024 detection monitoring of the RBAP identified SSIs for boron, calcium, chloride, sulfate, and TDS. The monitoring wells identified as having had SSIs used in this assessment have consistently had elevated concentrations of these constituents prior to operation of the RBAP, which demonstrates an alternate source is responsible. Natural variability in the groundwater and the ongoing closure of the historical BAC are attributed to the elevated concentrations of these constituents. Statistical evaluations comparing intrawell baseline conditions prior to the RBAP operation to detection monitoring results do not indicate a release from the RBAP. Variation in monitoring well baseline conditions between the upgradient well and downgradient compliance monitoring wells is attributed to natural variation for sulfate in MW-BAP-1003. The RBAP will remain in detection monitoring.

7. Professional Engineer Certification

Pursuant to 40 CFR §257.94(e)(2), Haley & Aldrich, Inc., on behalf of the Cardinal Operating Company, conducted an Alternate Source Demonstration to substantiate that natural variability and a source other than the Retrofitted Bottom Ash Pond caused the statistically significant increases (SSIs) identified during detection monitoring. I certify that this report and all attachments were prepared by me or under my direct supervision. I am a professional engineer who is registered in the State of Ohio.

This certification and the underlying data support the conclusion that natural variability, as well as a source other than the Retrofitted Bottom Ash Pond, is the cause of the SSIs for Appendix III constituents identified during detection monitoring of this unit.

The information contained herein is, to the best of my knowledge, true, accurate, and complete.

Steven F. Putrich, P.E.
State of Ohio Professional Engineer
Registration Number 67329

November 15, 2024

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TABLES

TABLE I
CONSTITUENT BASELINE SUMMARY STATISTICS
ALTERNATIVE SOURCE DEMONSTRATION
CARDINAL POWER PLANT
BRILLIANT, OHIO

	Well ID	MW-BAP-1001	MW-BAP-1002	MW-BAP-1003	MW-BAP-3
Boron, Total (mg/L)	Count	8	8	8	8
	Mean (mg/L)	0.04	2.74	0.92	2.09
	Standard Deviation (mg/L)	0.00	0.35	0.08	0.21
	Minimum (mg/L)	0.03	2.29	0.84	1.84
	1st Quartile (mg/L)	0.04	2.38	0.88	1.95
	Median (mg/L)	0.04	2.85	0.90	2.08
	3rd Quartile (mg/L)	0.04	2.99	0.96	2.19
	Maximum (mg/L)	0.05	3.15	1.05	2.48
Calcium, Total	Count	8	8	8	8
	Mean (mg/L)	86.01	102.08	104.50	75.48
	Standard Deviation (mg/L)	1.69	3.05	3.12	3.70
	Minimum (mg/L)	83.20	96.60	101.00	69.80
	1st Quartile (mg/L)	85.13	100.75	102.50	73.43
	Median (mg/L)	86.50	102.00	104.00	75.30
	3rd Quartile (mg/L)	86.93	104.25	106.00	76.85
	Maximum (mg/L)	88.10	106.00	109.00	80.70
Chloride (mg/L)	Count	8	8	8	8
	Mean (mg/L)	6.71	71.54	72.01	75.35
	Standard Deviation (mg/L)	0.49	5.02	5.44	12.64
	Minimum (mg/L)	5.80	65.00	66.20	66.00
	1st Quartile (mg/L)	6.48	68.63	69.05	68.80
	Median (mg/L)	6.85	71.00	71.60	70.95
	3rd Quartile (mg/L)	6.90	73.63	73.18	74.53
	Maximum (mg/L)	7.50	81.30	83.60	104.00
Sulfate (mg/L)	Count	8	8	8	8
	Mean (mg/L)	42.24	139.26	30.59	189.88
	Standard Deviation (mg/L)	7.00	50.39	4.25	34.75
	Minimum (mg/L)	27.50	85.30	25.30	153.00
	1st Quartile (mg/L)	40.65	98.70	27.90	169.75
	Median (mg/L)	43.05	125.00	28.70	181.50
	3rd Quartile (mg/L)	44.83	186.00	34.08	196.50
	Maximum (mg/L)	50.40	210.00	37.50	262.00
Total Dissolved Solids (mg/L)	Count	8	8	8	8
	Mean (mg/L)	359.88	526.50	489.75	459.63
	Standard Deviation (mg/L)	9.78	20.92	13.05	21.33
	Minimum (mg/L)	343.00	493.00	473.00	420.00
	1st Quartile (mg/L)	354.75	515.00	482.25	454.00
	Median (mg/L)	363.50	525.50	485.00	464.00
	3rd Quartile (mg/L)	366.75	544.00	498.50	467.00
	Maximum (mg/L)	369.00	552.00	512.00	493.00

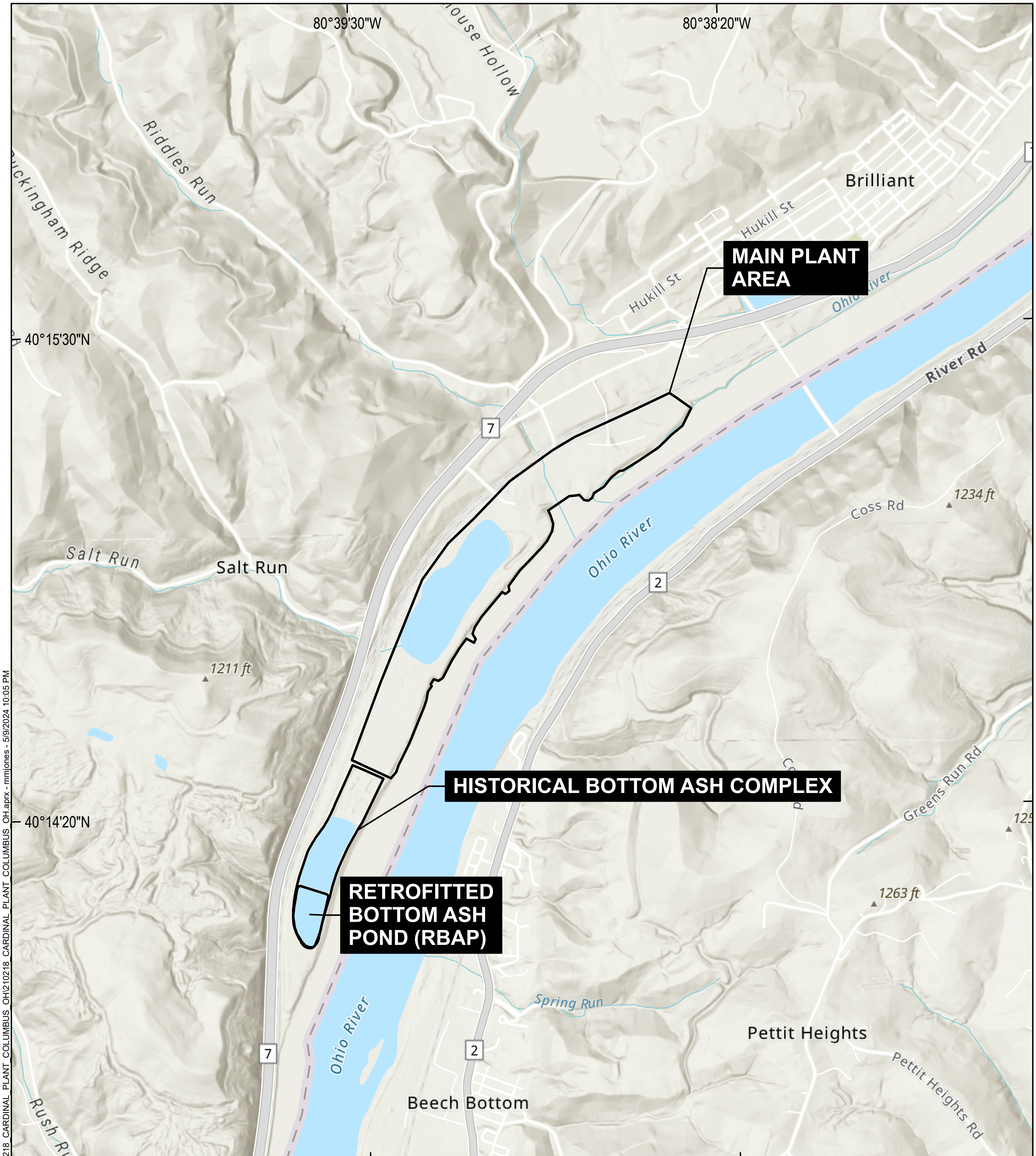
TABLE II
CONSTITUENT BASELINE STATISTICAL COMPARISON
ALTERNATIVE SOURCE DEMONSTRATION
CARDINAL POWER PLANT
BRILLIANT, OHIO

Constituent	Levene Test Statistic	Levene p-value	Statistically Significant Variance Levene Test (p<0.05)	Welch's ANOVA F-value	Welch's ANOVA p-value	Statistically Significant Differences Welch's ANOVA (p<0.05)
Boron, Total	6.922	0.001	Yes	653.31	2.78E-13	Yes
Calcium, Total	0.843	0.482	No	142.02	4.18E-11	Yes
Chloride	1.595	0.213	No	799.87	6.58E-14	Yes
Sulfate	5.794	0.003	Yes	63.67	3.16E-08	Yes
Total Dissolved Solids	0.964	0.423	No	232.93	1.03E-12	Yes

TABLE III
CONSTITUENT BASELINE SHAPIRO-WILK RESULTS
ALTERNATIVE SOURCE DEMONSTRATION
CARDINAL POWER PLANT
BRILLIANT, OHIO

	Well ID	Shapiro-Wilk Statistic	p-value	Shapiro-Wilk Test (p<0.05)
Boron, Total	MW-BAP-1001	0.922	0.448	Normally Distributed
	MW-BAP-1002	0.867	0.139	Normally Distributed
	MW-BAP-1003	0.856	0.108	Normally Distributed
	MW-BAP-3	0.945	0.659	Normally Distributed
Calcium, Total	MW-BAP-1001	0.928	0.499	Normally Distributed
	MW-BAP-1002	0.960	0.812	Normally Distributed
	MW-BAP-1003	0.877	0.175	Normally Distributed
	MW-BAP-3	0.917	0.404	Normally Distributed
Chloride	MW-BAP-1001	0.933	0.541	Normally Distributed
	MW-BAP-1002	0.925	0.473	Normally Distributed
	MW-BAP-1003	0.862	0.125	Normally Distributed
	MW-BAP-3	0.720	0.004	Not Normally Distributed
Sulfate	MW-BAP-1001	0.857	0.112	Normally Distributed
	MW-BAP-1002	0.877	0.178	Normally Distributed
	MW-BAP-1003	0.899	0.286	Normally Distributed
	MW-BAP-3	0.881	0.191	Normally Distributed
Total Dissolved Solids	MW-BAP-1001	0.870	0.150	Normally Distributed
	MW-BAP-1002	0.951	0.724	Normally Distributed
	MW-BAP-1003	0.938	0.595	Normally Distributed
	MW-BAP-3	0.934	0.550	Normally Distributed

FIGURES



MAP SOURCE: ESRI
SITE COORDINATES: 40°14'55"N, 80°39'05"W

HALEY ALDRICH

CARDINAL PLANT
BRILLIANT, OHIO

PROJECT LOCUS

APPROXIMATE SCALE: 1 IN = 2000 FT
MAY 2024

FIGURE 1

GIS: \\haleyaldrich\share\CF\Projects\0210218\GIS\210218_CARDINAL_PLANT_COLUMBUS_OH\210218_CARDINAL_PLANT_COLUMBUS_OH.aprx - mmjones - 5/9/2024 10:05 PM

LEGEND

- RBAP MONITORING WELL WITH **GROUNDWATER ELEVATION** IN FEET
- BAP MONITORING WELL WITH **GROUNDWATER ELEVATION** IN FEET
- GROUNDWATER ELEVATION CONTOUR, 0.05-FT INTERVAL (NGVD29)
- RAILROAD
- RETROFITTED BOTTOM ASH POND (RBAP)
- HISTORIC BOTTOM ASH POND (BAP)

NOTES

1. ALL LOCATIONS AND DIMENSIONS ARE APPROXIMATE.
2. DEFINITIONS:
   FT = FOOT
   NGVD29 = NATIONAL GEODETIC VERITCAL DATUM 1929
3. GROUNDWATER ELEVATIONS MEASURED 9 APRIL 2024.
4. ELEVATIONS IN FEET ABOVE MEAN SEA LEVEL (FT MSL).
5. AERIAL IMAGERY SOURCE: NEARMAP, 14 MAY 2023

N

0 150 300
SCALE IN FEET

HALEY ALDRICH

CARDINAL POWER PLANT
BRILLIANT, OHIO

POTENTIOMETRIC SURFACE RBAP
UPPERMOST AQUIFER
9 APRIL 2024

AUGUST 2024

FIGURE 2

GIS FILE PATH: \\haleyaldrich.com\share\CF\Projects\0210218\GIS\210218_CARDINAL_PLANT_COLUMBUS_OH210218_CARDINAL_PLANT_COLUMBUS_OH.aprx - USER: mtoner - LAST SAVED: 8/1/2024 3:40 PM

LEGEND

- MONITORING WELL
- HISTORICAL BOTTOM ASH COMPLEX
- MAIN PLANT AREA
- RETROFITTED BOTTOM ASH POND (RBAP)

NOTES

1. ALL LOCATIONS AND DIMENSIONS ARE APPROXIMATE.
2. MW-BAP-1001 IS THE UPGRADIENT MONITORING WELL FOR THE RBAP AND REPRESENTS BACKGROUND CONDITIONS FOR THE RBAP.
3. MW-BAP-1002, MW-BAP-3, AND MW-BAP-1003 ARE DOWNGRADIENT MONITORING WELLS FOR THE RBAP.
4. MW-BAP-4 AND MW-BAP-5 ARE UPGRADIENT MONITORING WELLS FOR THE BAP AND REPRESENTS BACKGROUND CONDITIONS FOR THE BAP CCR UNIT.
5. MW-BAP-1, MW-BAP-2, AND MW-BAP-3 ARE DOWNGRADIENT MONITORING WELLS FOR THE BAP CCR UNIT.
6. CCR = COAL COMBUSTION RESIDUAL
7. AERIAL IMAGERY SOURCE: NEARMAP, 14 MAY 2023

N

0 350 700
SCALE IN FEET

HALEY ALDRICH

CARDINAL PLANT
BRILLIANT, OHIO

MONITORING WELL NETWORK OF BOTTOM ASH POND AND RETROFITTED BOTTOM ASH POND CCR UNITS

MAY 2024

FIGURE 3

GIS FILE PATH: \\haleyaldrich\share\CF\Projects\0210218\GIS\210218_CARDINAL_PLANT_COLUMBUS_OH\210218_CARDINAL_PLANT_COLUMBUS_OH.aprx - USER: mmjones - LAST SAVED: 5/7/2024 9:09 PM

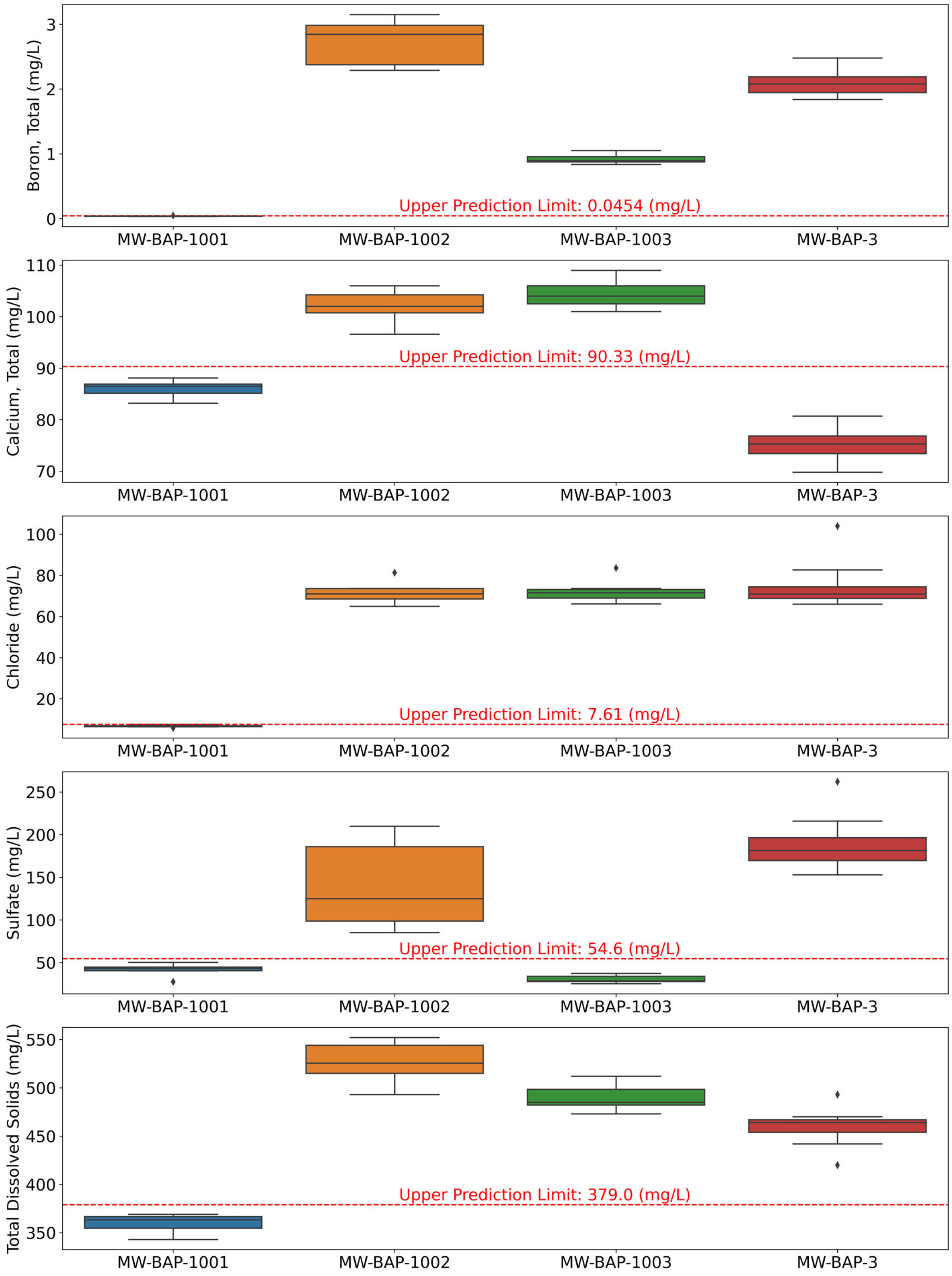
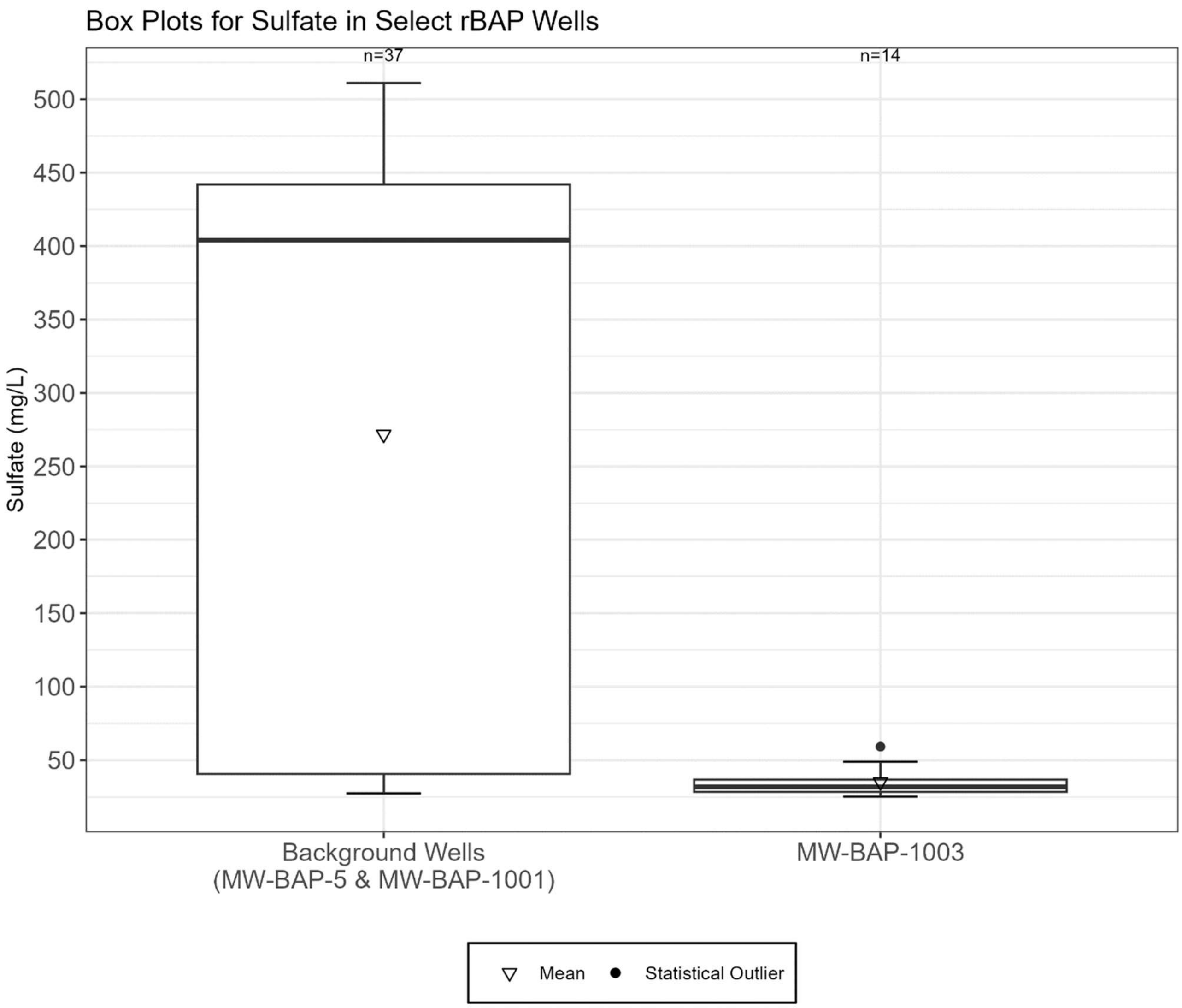


Figure 4
Baseline Box and Whiskers Plots

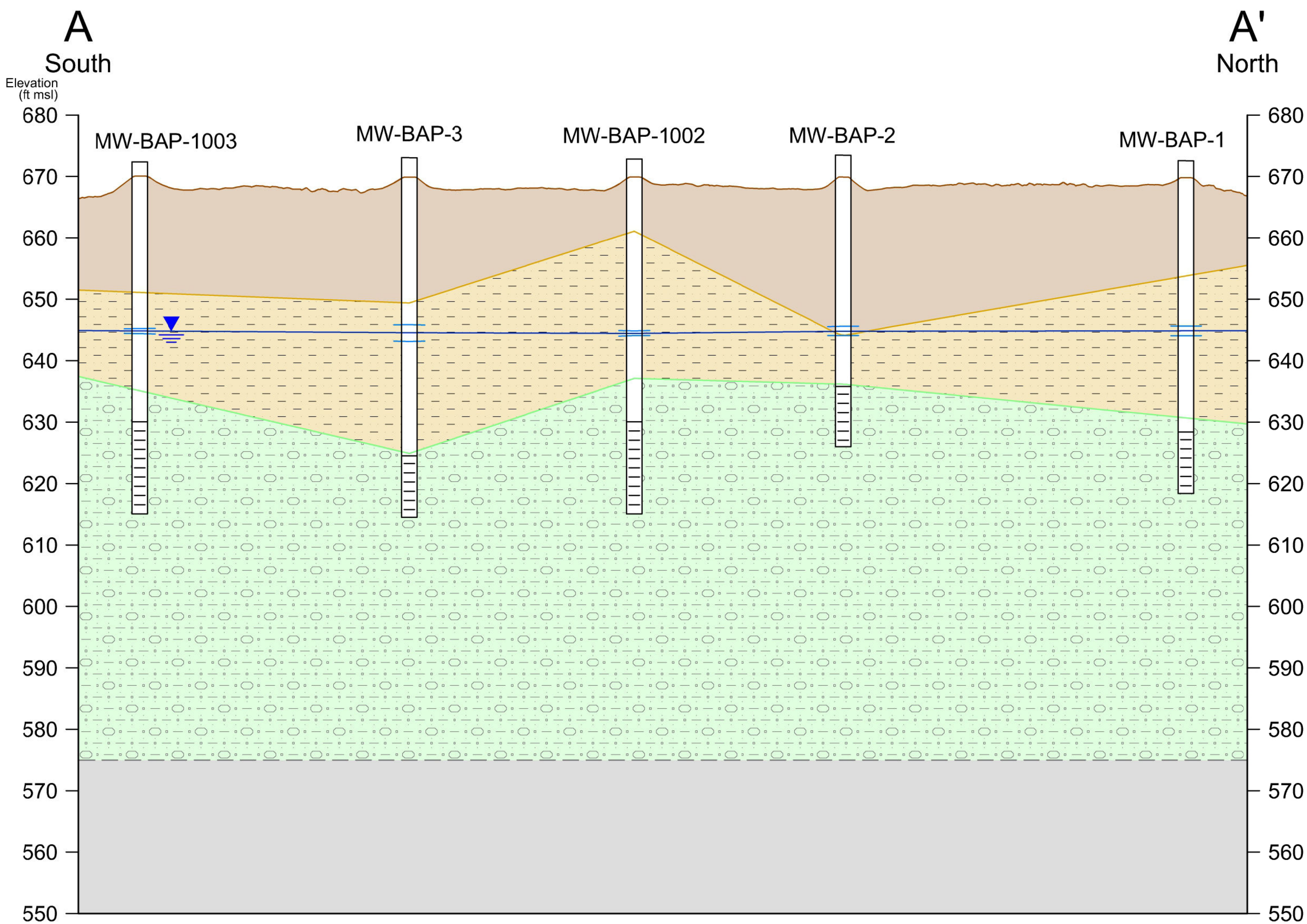
FIGURE 5
SULFATE BOX PLOTS
ALTERNATIVE SOURCE DEMONSTRATION
CARDINAL POWER PLANT
BRILLIANT, OHIO



Notes: Plotted datasets include samples collected between June 2016 and April 2024

APPENDIX A
Geologic Cross-Sections

DWG NAME: Cross Section DATE: 10/20/2021



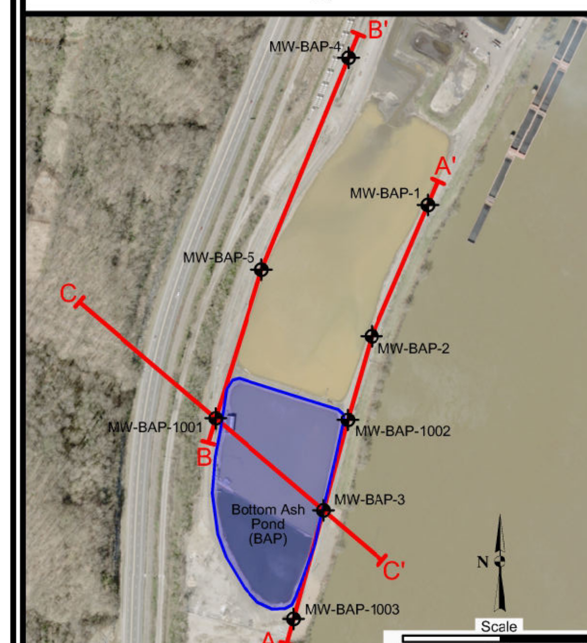
Legend

- Fill
- Alluvium (Silt/Clay)
- Glacial Outwash
- Bedrock
- Monitor Well
- Typical Groundwater Level
- Range of Observed Groundwater Elevations
- Line of Geologic Cross Section

Source of Aerial Photography: OGRIP, 2020.

Horizontal Scale: 0' 87.5' 175' 350'

Vertical Exaggeration: 10x

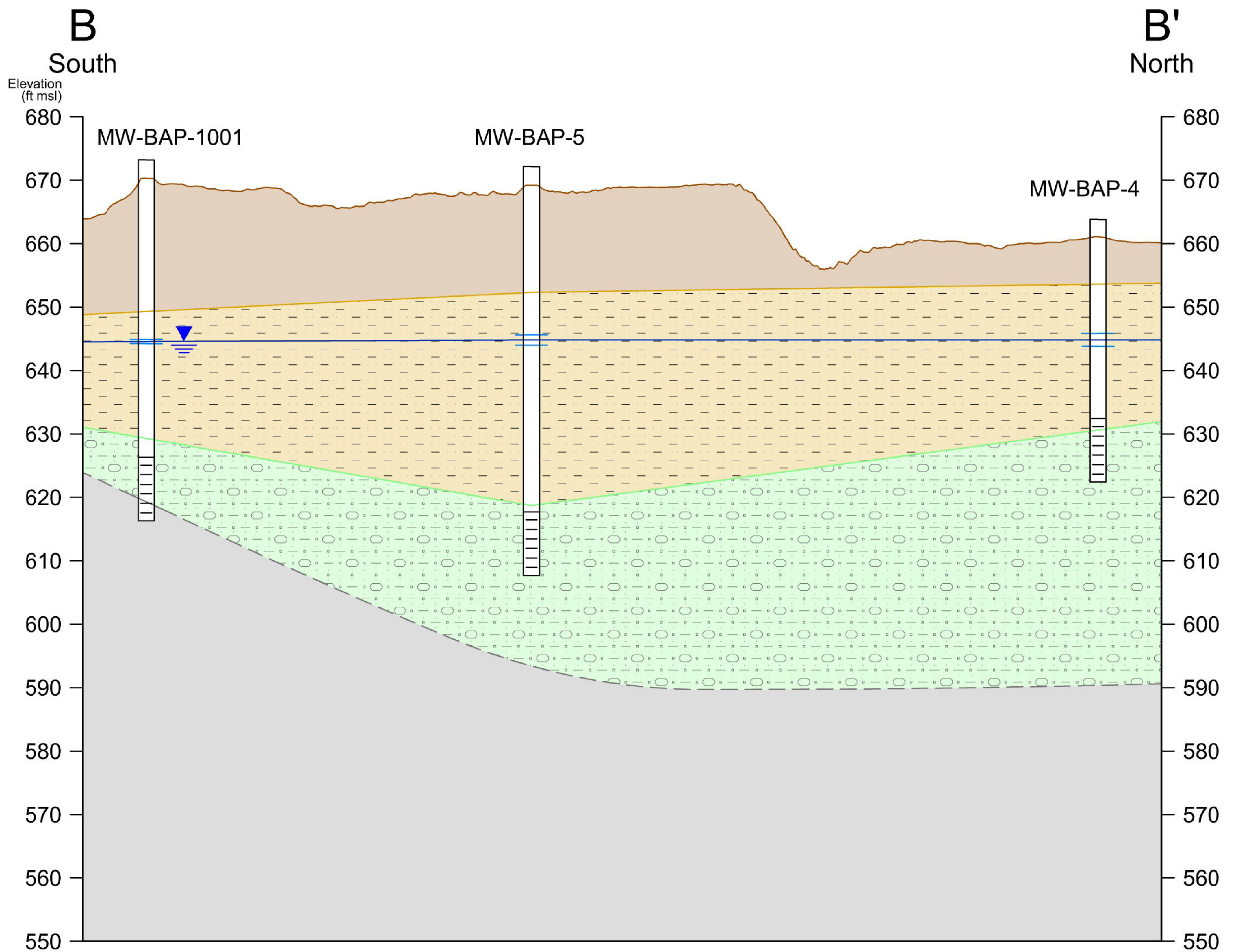


Geologic Cross-Section A - A'

Cox-Colvin & Associates, Inc. Environmental Services

Geologic Cross-Section A - A',
Cardinal Power Plant BAP,
Brilliant, Ohio

Figure 3-1A



Legend

Fill

Alluvium (Silt/Clay)

Glacial Outwash

Bedrock

Monitor Well

Typical Groundwater Level

Range of Observed Groundwater Elevations

B B'

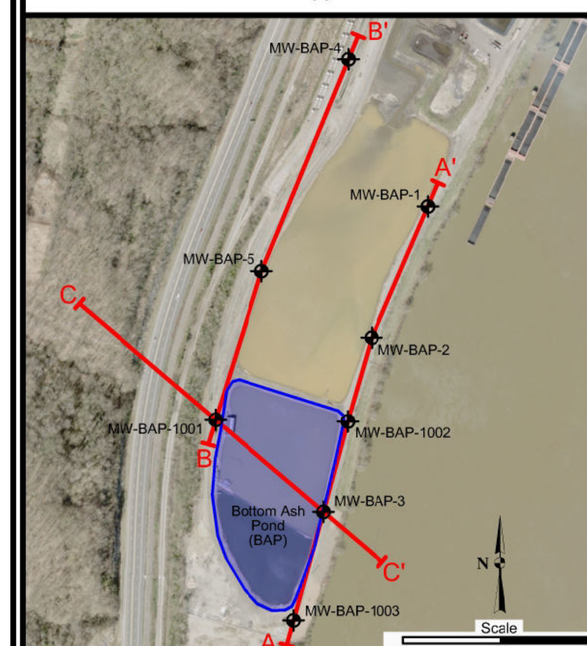
Line of Geologic Cross Section

Source of Aerial Photography: OGRIP, 2020.

Horizontal Scale

0' 87.5' 175' 350'

Vertical Exaggeration: 10x



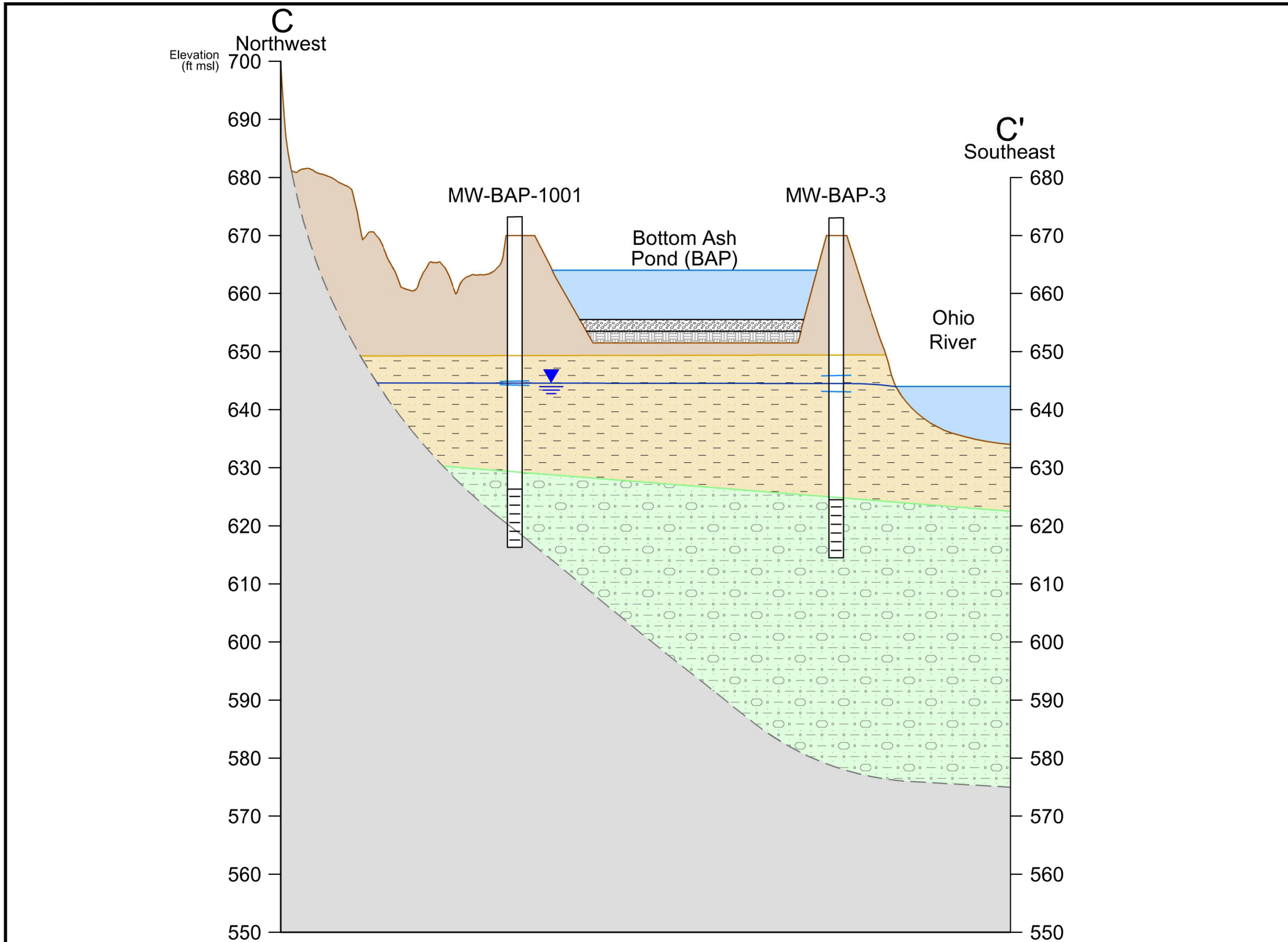
Geologic Cross-Section B - B'

Cox-Colvin & ASSOCIATES, INC. ENVIRONMENTAL SERVICES

Geologic Cross-Section B - B',
Cardinal Power Plant BAP,
Brilliant, Ohio

Figure

3-1B



Legend

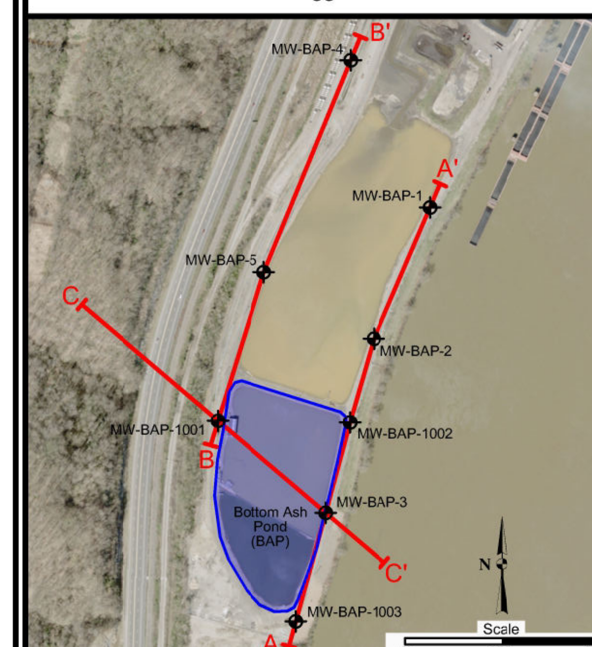
- Fill
- Alluvium (Silt/Clay)
- Glacial Outwash
- Bedrock
- Monitor Well
- Typical Groundwater Level
- Range of Observed Groundwater Elevations
- C — C' Line of Geologic Cross Section

Source of Aerial Photography: OGRIP, 2020.

Horizontal Scale

0' 90' 180' 330'

Vertical Exaggeration: 10x



Geologic Cross-Section C - C'

Cox-Colvin & Associates, Inc. Environmental Services

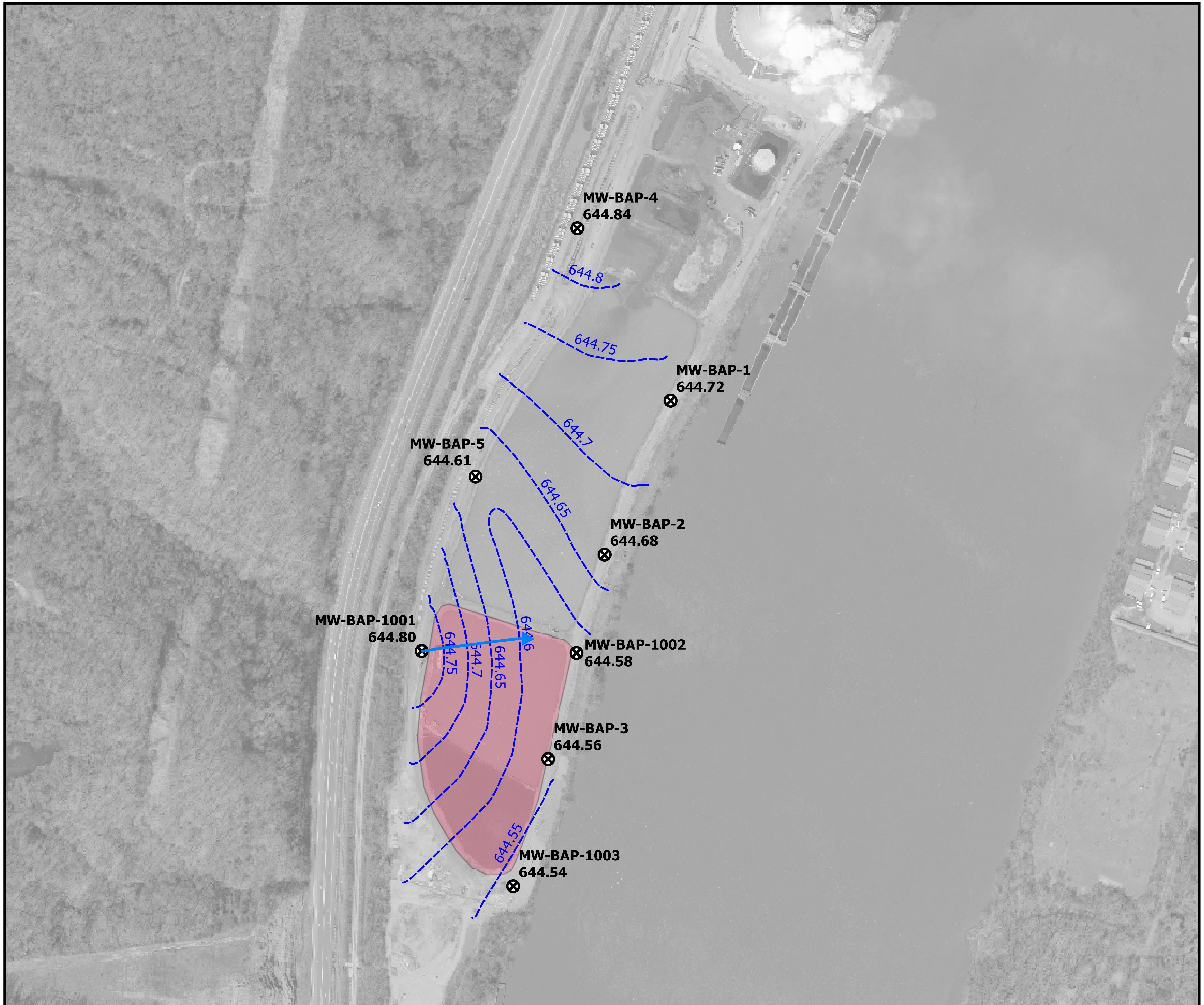
Geologic Cross-Section C - C',
Cardinal Power Plant BAP,
Brilliant, Ohio

Figure

3-1C

APPENDIX B
Potentiometric Surface Maps

K:\CCA\PROJECTS\Buckeye_Power\Cardinal\Drawings\GIS\Cardinal_QGIS_Scratch.qgz : 2022-01-03 12:04



Legend

- Retrofitted BAP
- Approximate Groundwater Elevation Contour
- Monitor Well and Groundwater Elevation
- Estimated Groundwater Flow Direction

N

0 200 400 600 800 1,000 ft

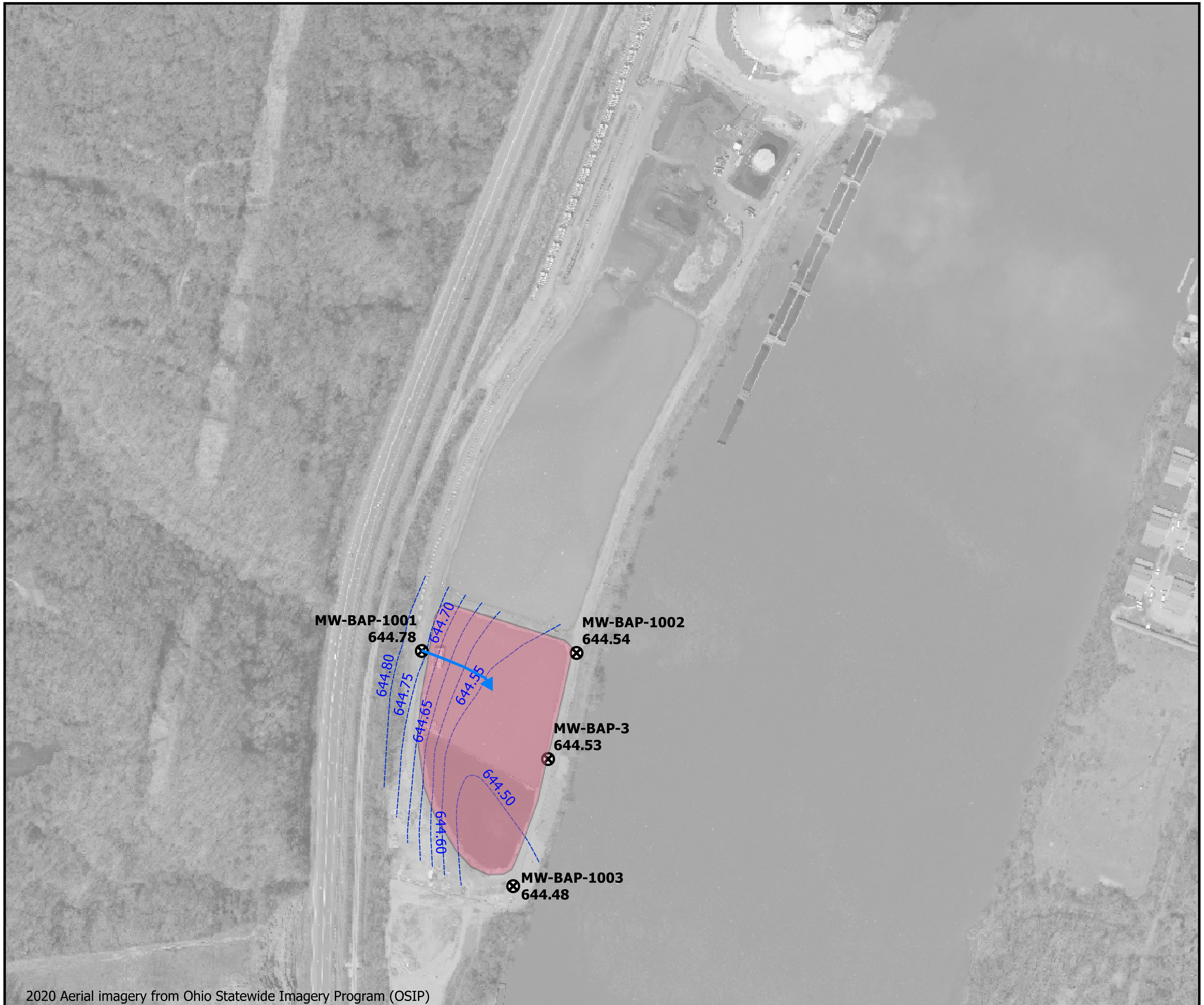
Cox-Colvin & Associates, Inc.
Environmental Services

Figure

3-2A

Potentiometric Surface Map - Uppermost Aquifer
Bottom Ash Pond - April 5, 2021
Buckeye Power, Cardinal Generating Plant
Brilliant, Ohio

K:\CCA\PROJECTS\Buckeye_Power\Cardinal\Drawings\GIS\Cardinal_Potentiometric.qgz : 2023-01-27 16:54



Legend

- Retrofitted Bottom Ash Pond (RBAP)
- RBAP Monitoring Well and Groundwater Elevation
- Approximate Groundwater Elevation Contour
- Estimated Groundwater Flow Direction

N

0 200 400 600 800 1,000 ft

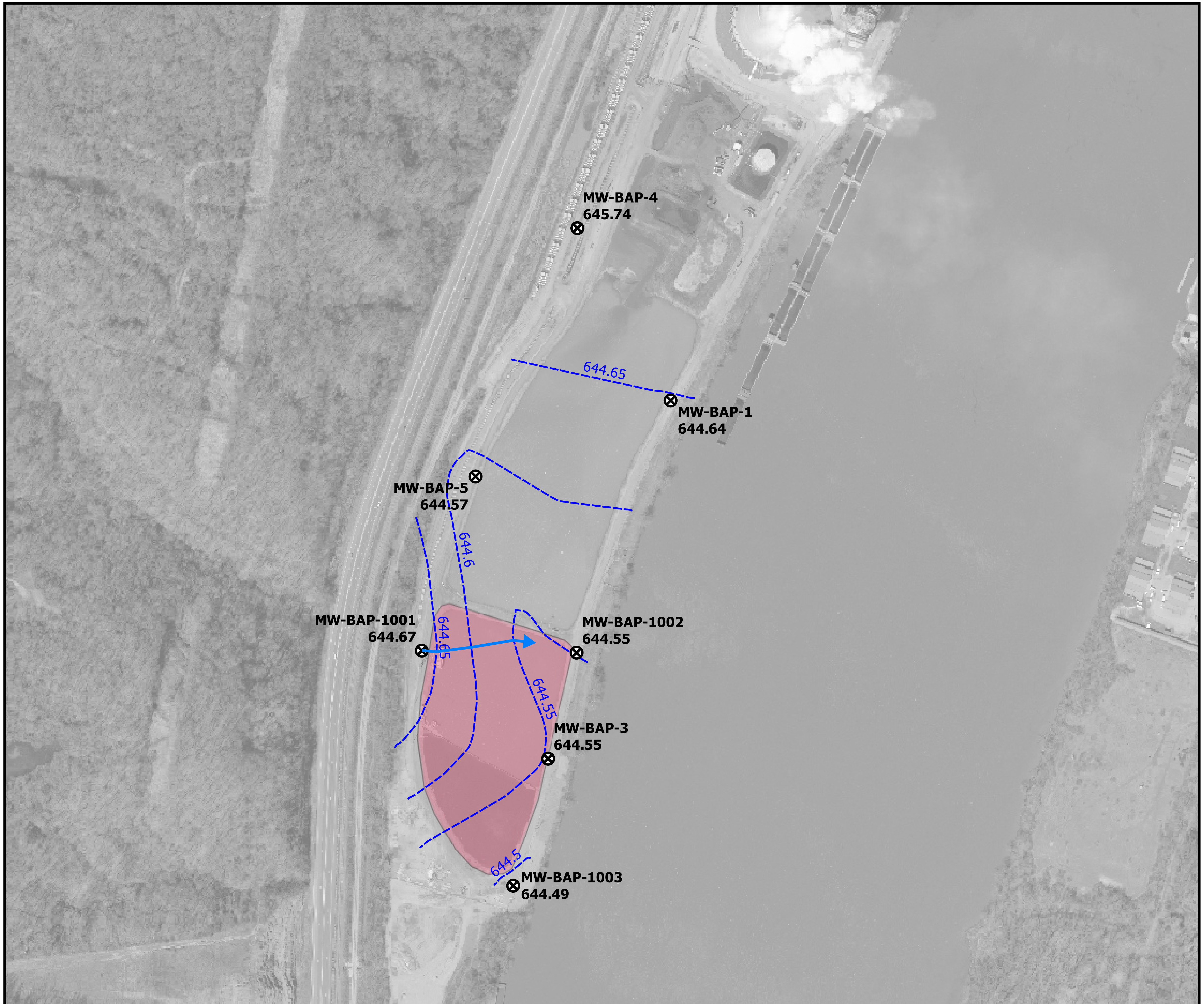
Cox-Colvin & ASSOCIATES, INC. ENVIRONMENTAL SERVICES

Figure

4-1

Potentiometric Surface Map - Uppermost Aquifer
Retrofitted Bottom Ash Pond - June 21, 2021
Cardinal Plant
Brilliant, Ohio

K:\CCA\PROJECTS\Buckeye_Power\Cardinal\Drawings\GIS\Cardinal_QGIS_Scratch.qgz : 2022-01-03 12:04



Legend

Retrofitted BAP
Approximate Groundwater Elevation Contour
Monitor Well and Groundwater Elevation
Estimated Groundwater Flow Direction

N

0 200 400 600 800 1,000 ft

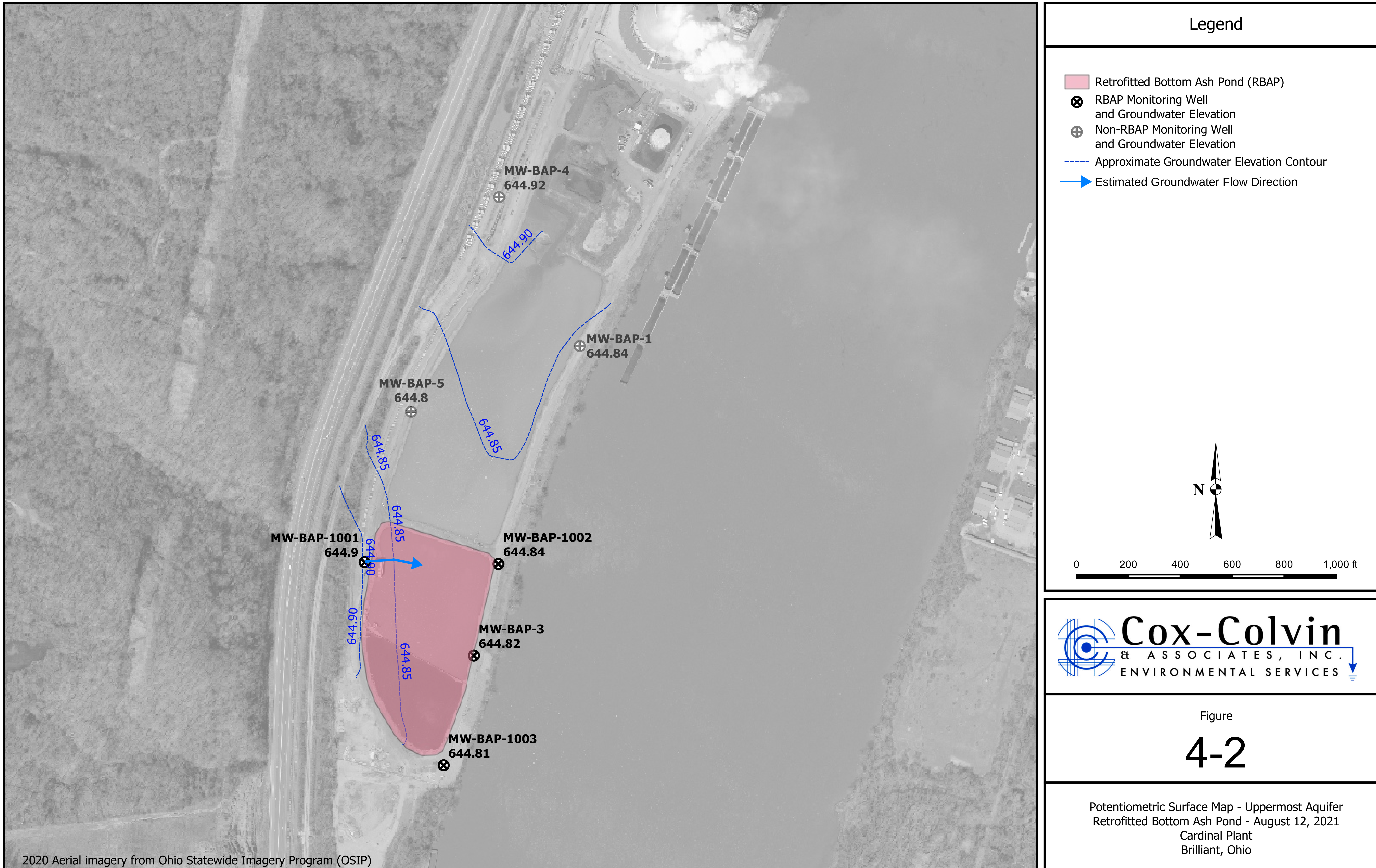
Cox-Colvin
& ASSOCIATES, INC.
ENVIRONMENTAL SERVICES

Figure

3-2B

Potentiometric Surface Map - Uppermost Aquifer
Bottom Ash Pond - July 29, 2021
Buckeye Power, Cardinal Generating Plant
Brilliant, Ohio

K:\CCA\PROJECTS\Buckeye_Power\Cardinal\Drawings\GIS\Cardinal_Potentiometric.qgz : 2023-01-27 16:55



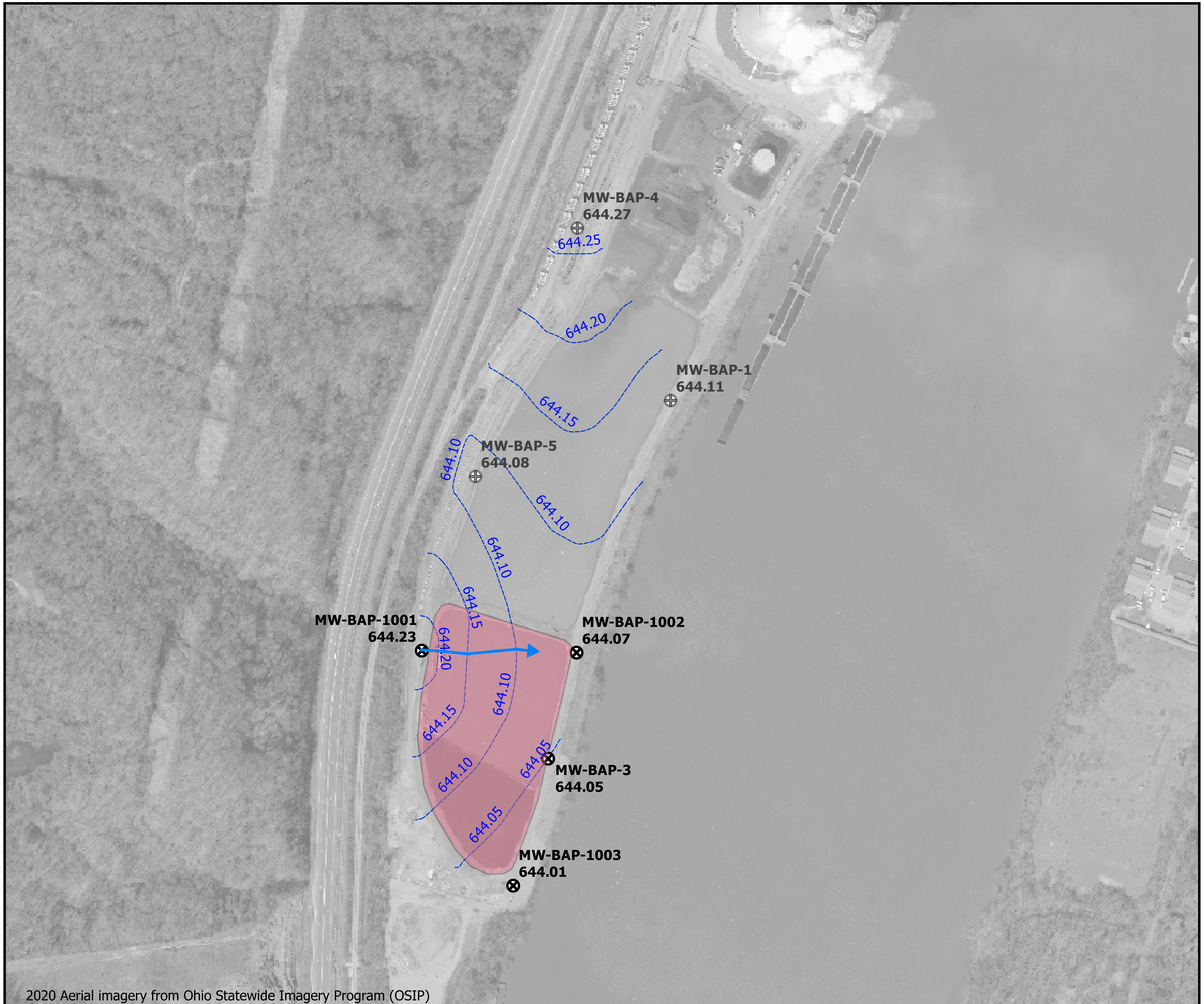
Cox-Colvin & ASSOCIATES, INC.
ENVIRONMENTAL SERVICES

Figure

4-2

Potentiometric Surface Map - Uppermost Aquifer
Retrofitted Bottom Ash Pond - August 12, 2021
Cardinal Plant
Brilliant, Ohio

K:\CCA\PROJECTS\Buckeye_Power\Cardinal\Drawings\GIS\Cardinal_Potentiometric.qgz : 2023-01-27 16:55



Legend

- Retrofitted Bottom Ash Pond (RBAP)
- RBAP Monitoring Well and Groundwater Elevation
- Non-RBAP Monitoring Well and Groundwater Elevation
- Approximate Groundwater Elevation Contour
- Estimated Groundwater Flow Direction

N

0 200 400 600 800 1,000 ft

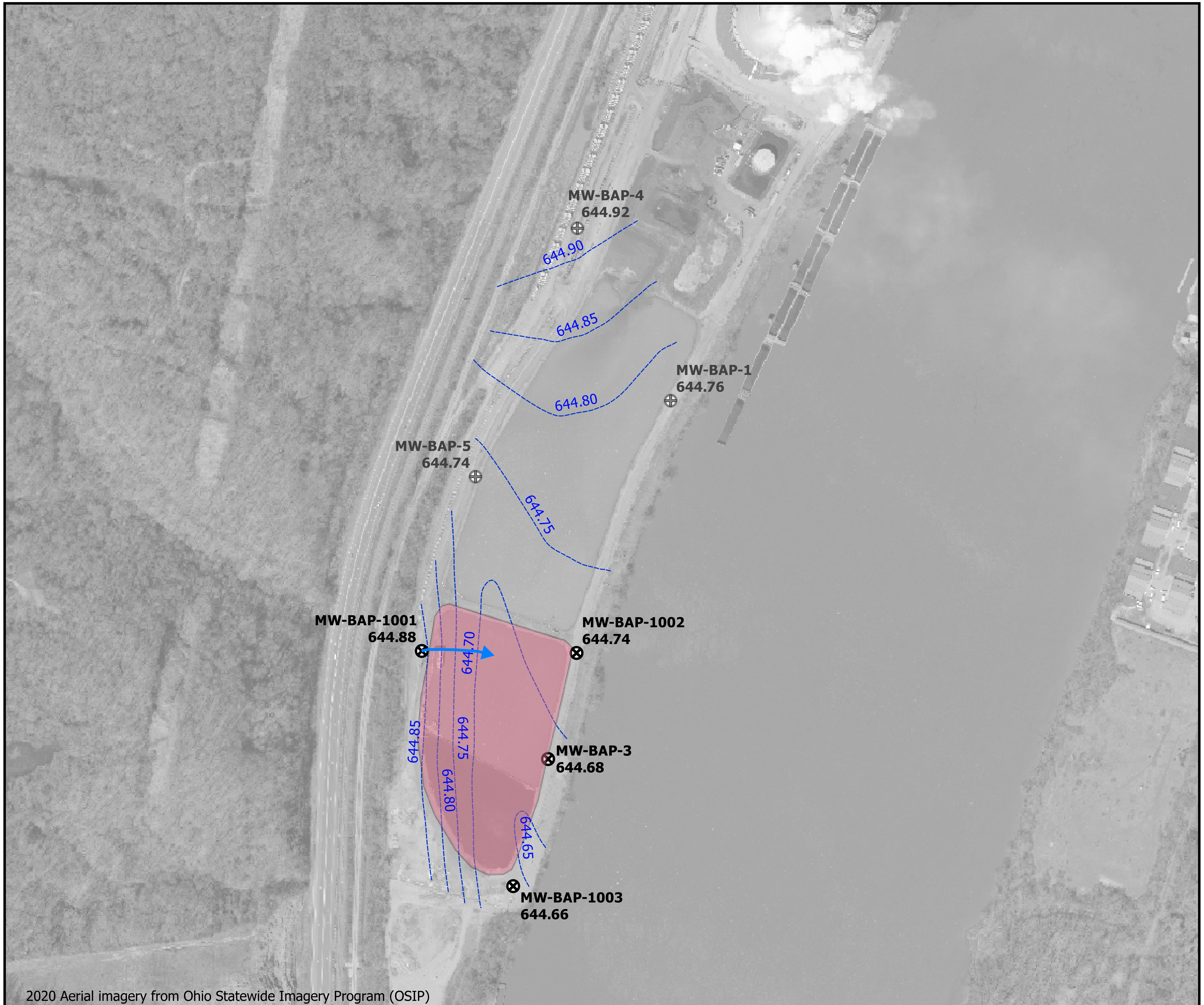
Cox-Colvin & ASSOCIATES, INC. ENVIRONMENTAL SERVICES

Figure

4-3

Potentiometric Surface Map - Uppermost Aquifer
Retrofitted Bottom Ash Pond - September 15, 2021
Cardinal Plant
Brilliant, Ohio

K:\CCA\PROJECTS\Buckeye_Power\Cardinal\Drawings\GIS\Cardinal_Potentiometric.qgz : 2023-01-27 16:56



Legend

- Retrofitted Bottom Ash Pond (RBAP)
- RBAP Monitoring Well and Groundwater Elevation
- Non-RBAP Monitoring Well and Groundwater Elevation
- Approximate Groundwater Elevation Contour
- Estimated Groundwater Flow Direction

N

0 200 400 600 800 1,000 ft

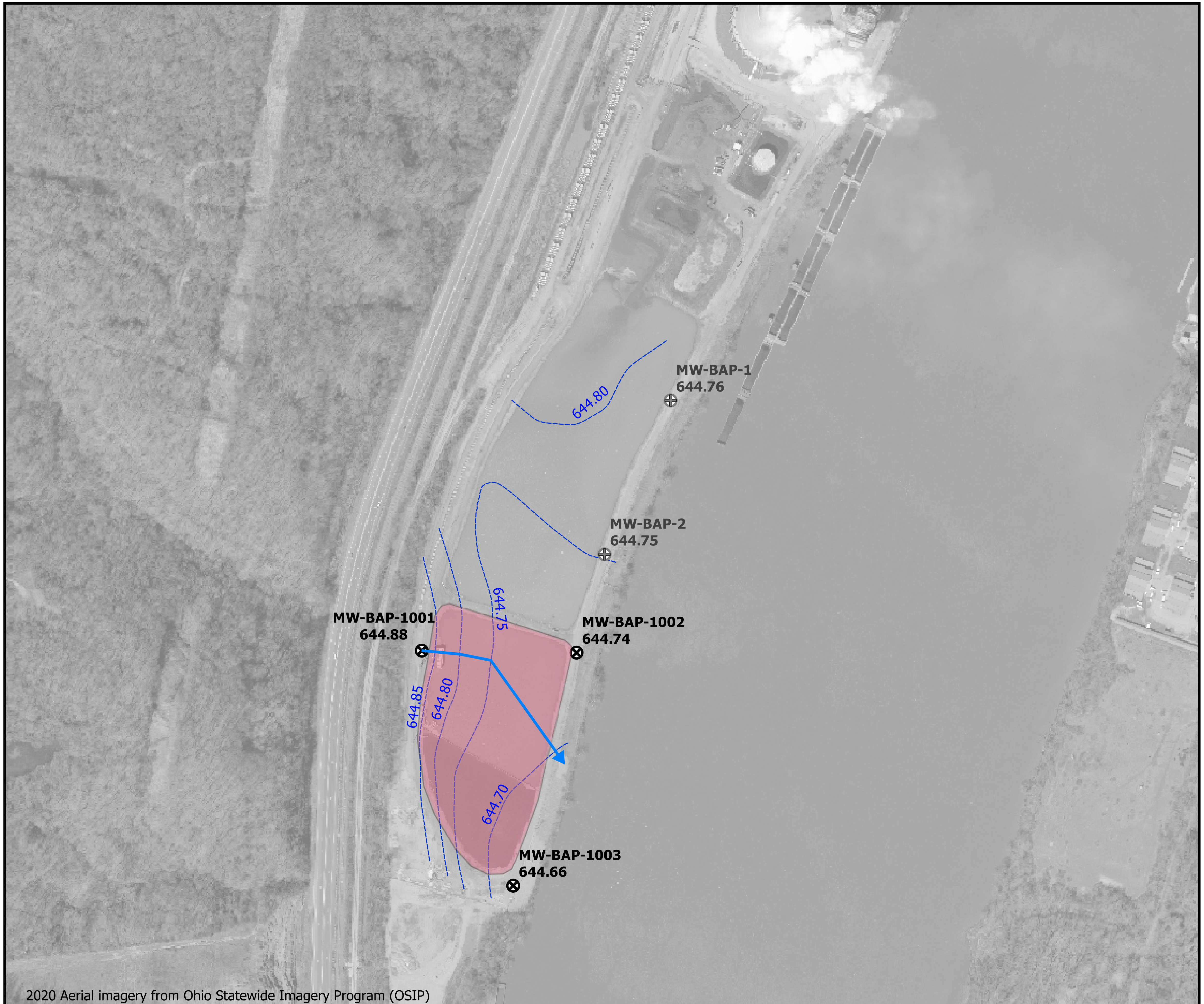
Cox-Colvin & Associates, Inc.
Environmental Services

Figure

4-4

Potentiometric Surface Map - Uppermost Aquifer
Retrofitted Bottom Ash Pond - October 28, 2021
Cardinal Plant
Brilliant, Ohio

K:\CCA\PROJECTS\Buckeye_Power\Cardinal\Drawings\GIS\Cardinal_Potentiometric.qgz : 2023-01-27 16:56



Legend

- Retrofitted Bottom Ash Pond (RBAP)
- RBAP Monitoring Well and Groundwater Elevation
- Non-RBAP Monitoring Well and Groundwater Elevation
- Approximate Groundwater Elevation Contour
- Estimated Groundwater Flow Direction

N

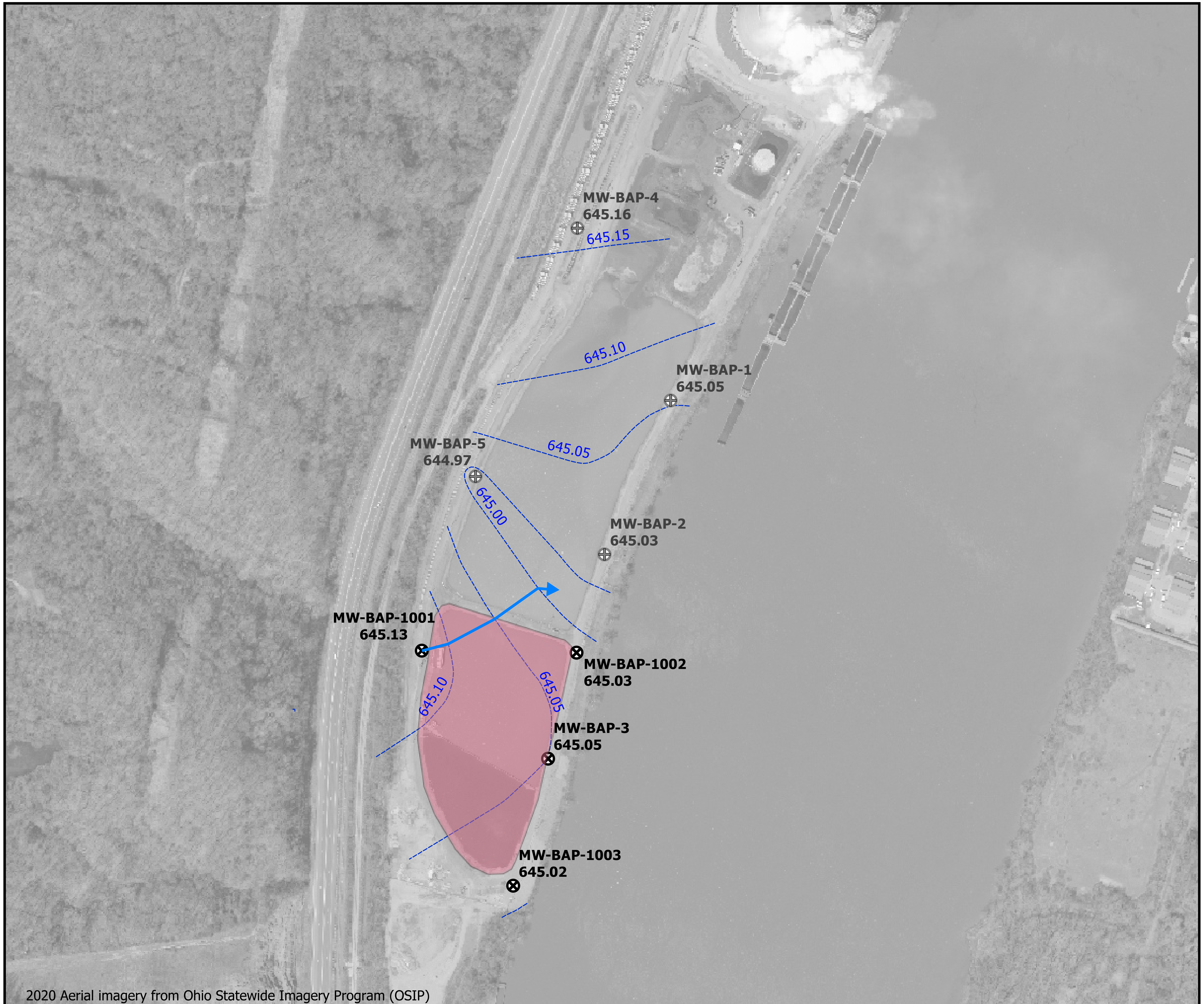
0 200 400 600 800 1,000 ft

Cox-Colvin & ASSOCIATES, INC. ENVIRONMENTAL SERVICES

Figure

4-5

Potentiometric Surface Map - Uppermost Aquifer
Retrofitted Bottom Ash Pond - November 2, 2021
Cardinal Plant
Brilliant, Ohio



Legend

- Retrofitted Bottom Ash Pond (RBAP)
- RBAP Monitoring Well and Groundwater Elevation
- Non-RBAP Monitoring Well and Groundwater Elevation
- Approximate Groundwater Elevation Contour
- Estimated Groundwater Flow Direction

N

0 200 400 600 800 1,000 ft

Cox-Colvin & ASSOCIATES, INC. ENVIRONMENTAL SERVICES

Figure

4-6

Potentiometric Surface Map - Uppermost Aquifer
Retrofitted Bottom Ash Pond - January 13, 2022
Cardinal Plant
Brilliant, Ohio

K:\CCA\PROJECTS\Buckeye_Power\Cardinal\Drawings\GIS\Cardinal_Potentiometric.qgz : 2023-01-27 16:57

Legend

- Retrofitted Bottom Ash Pond (RBAP)
- RBAP Monitoring Well and Groundwater Elevation
- Approximate Groundwater Elevation Contour
- Estimated Groundwater Flow Direction

N

0 200 400 600 800 1,000 ft

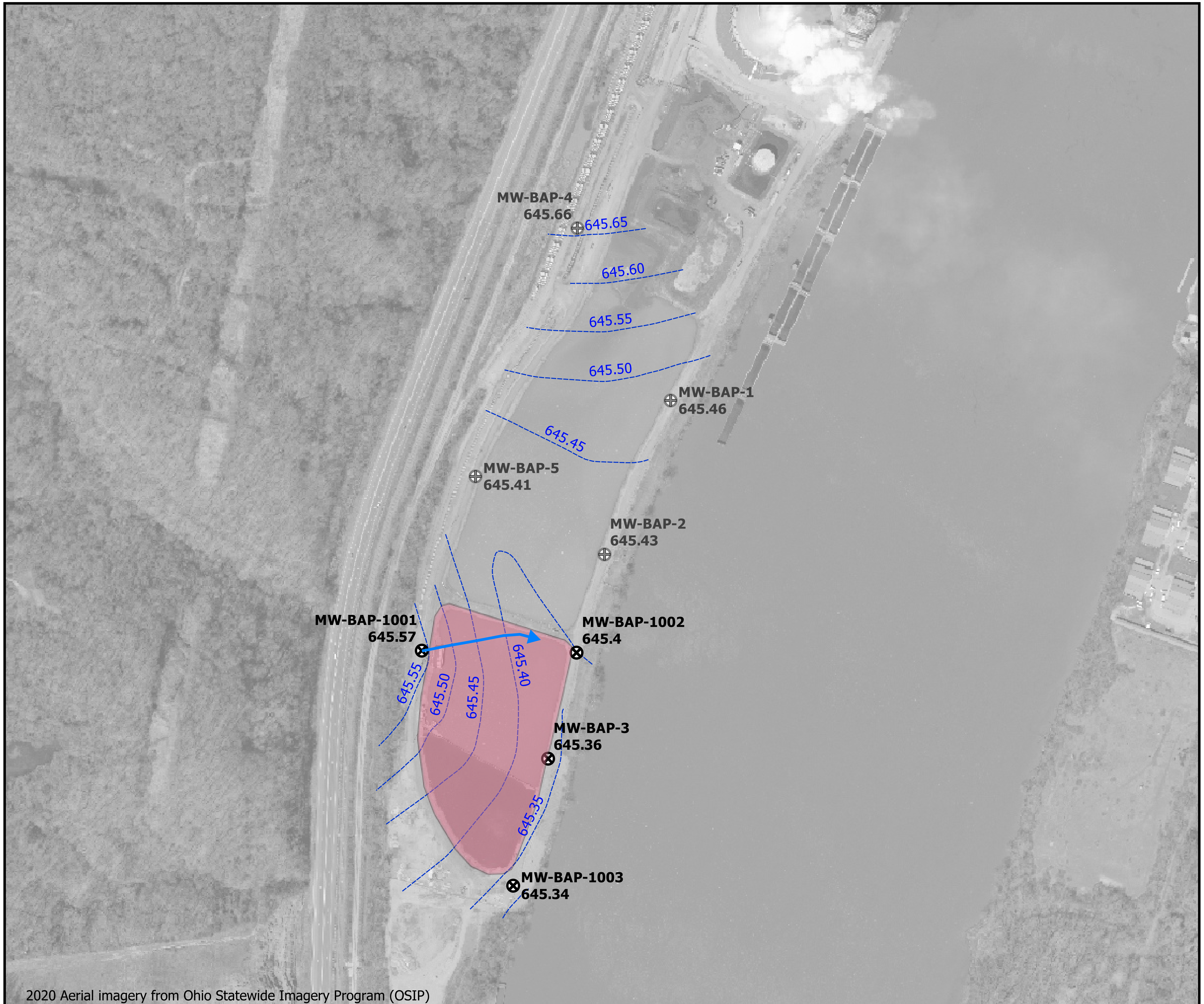
Cox-Colvin & ASSOCIATES, INC. ENVIRONMENTAL SERVICES

Figure

4-7

Potentiometric Surface Map - Uppermost Aquifer
Retrofitted Bottom Ash Pond - February 2, 2022
Cardinal Plant
Brilliant, Ohio

K:\CCA\PROJECTS\Buckeye_Power\Cardinal\Drawings\GIS\Cardinal_Potentiometric.qgz : 2023-01-27 16:58



Legend

- Retrofitted Bottom Ash Pond (RBAP)
- RBAP Monitoring Well and Groundwater Elevation
- Non-RBAP Monitoring Well and Groundwater Elevation
- Approximate Groundwater Elevation Contour
- Estimated Groundwater Flow Direction

N

0 200 400 600 800 1,000 ft

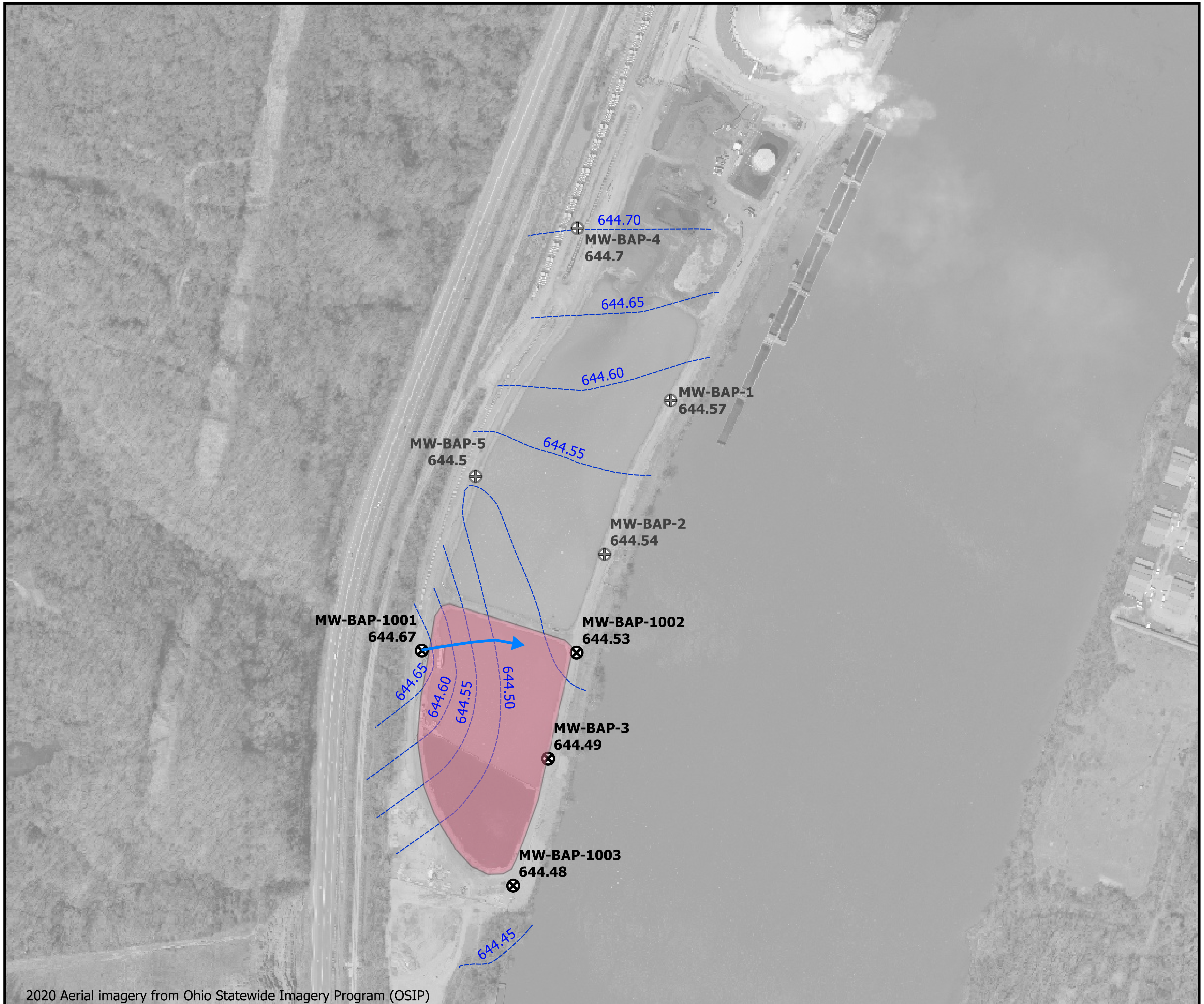
Cox-Colvin & ASSOCIATES, INC.
ENVIRONMENTAL SERVICES

Figure

4-8

Potentiometric Surface Map - Uppermost Aquifer
Retrofitted Bottom Ash Pond - February 22, 2022
Cardinal Plant
Brilliant, Ohio

K:\CCA\PROJECTS\Buckeye_Power\Cardinal\Drawings\GIS\Cardinal_Potentiometric.qgz : 2023-01-27 16:58



Legend

- Retrofitted Bottom Ash Pond (RBAP)
- RBAP Monitoring Well and Groundwater Elevation
- Non-RBAP Monitoring Well and Groundwater Elevation
- Approximate Groundwater Elevation Contour
- Estimated Groundwater Flow Direction

N

0 200 400 600 800 1,000 ft

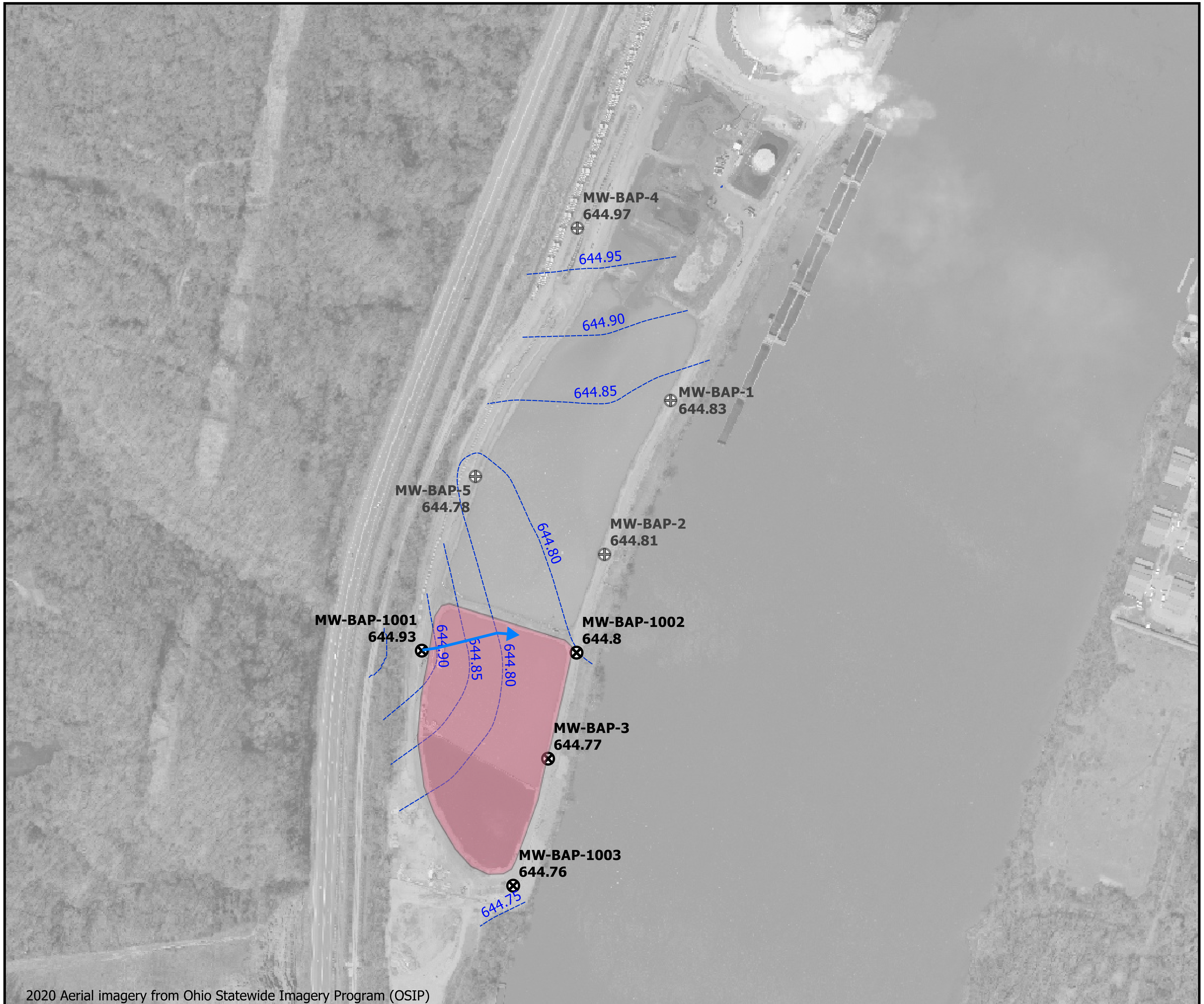
Cox-Colvin & Associates, Inc.
Environmental Services

Figure

4-9

Potentiometric Surface Map - Uppermost Aquifer
Retrofitted Bottom Ash Pond - March 14, 2022
Cardinal Plant
Brilliant, Ohio

K:\CCA\PROJECTS\Buckeye_Power\Cardinal\Drawings\GIS\Cardinal_Potentiometric.qgz : 2023-01-27 16:59



Legend

- Retrofitted Bottom Ash Pond (RBAP)
- RBAP Monitoring Well and Groundwater Elevation
- Non-RBAP Monitoring Well and Groundwater Elevation
- Approximate Groundwater Elevation Contour
- Estimated Groundwater Flow Direction

N

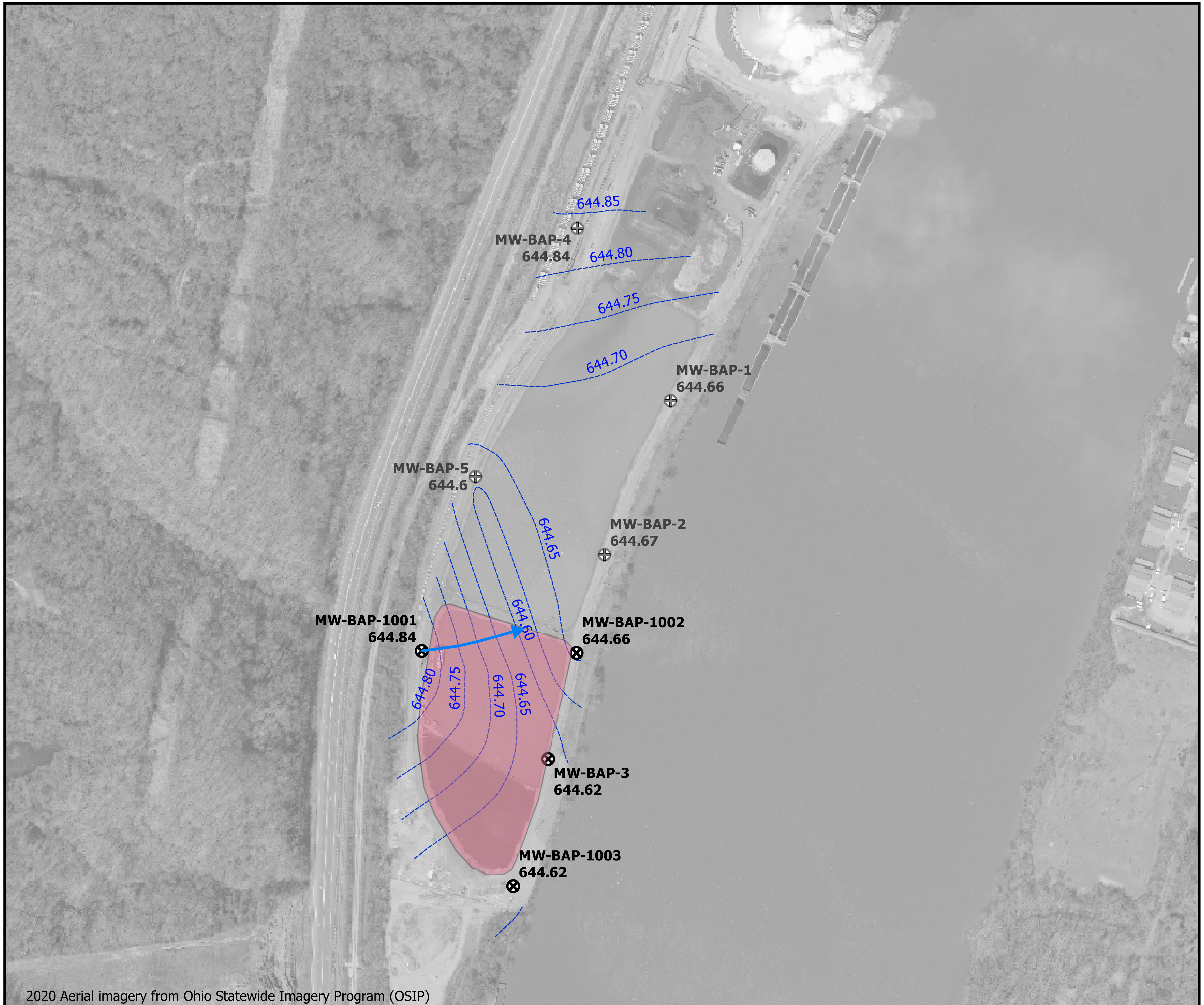
0 200 400 600 800 1,000 ft

Cox-Colvin & ASSOCIATES, INC. ENVIRONMENTAL SERVICES

Figure

4-10

Potentiometric Surface Map - Uppermost Aquifer
Retrofitted Bottom Ash Pond - March 31, 2022
Cardinal Plant
Brilliant, Ohio



Legend

- Retrofitted Bottom Ash Pond (RBAP)
- RBAP Monitoring Well and Groundwater Elevation
- Non-RBAP Monitoring Well and Groundwater Elevation
- Approximate Groundwater Elevation Contour
- Estimated Groundwater Flow Direction

N

0 200 400 600 800 1,000 ft

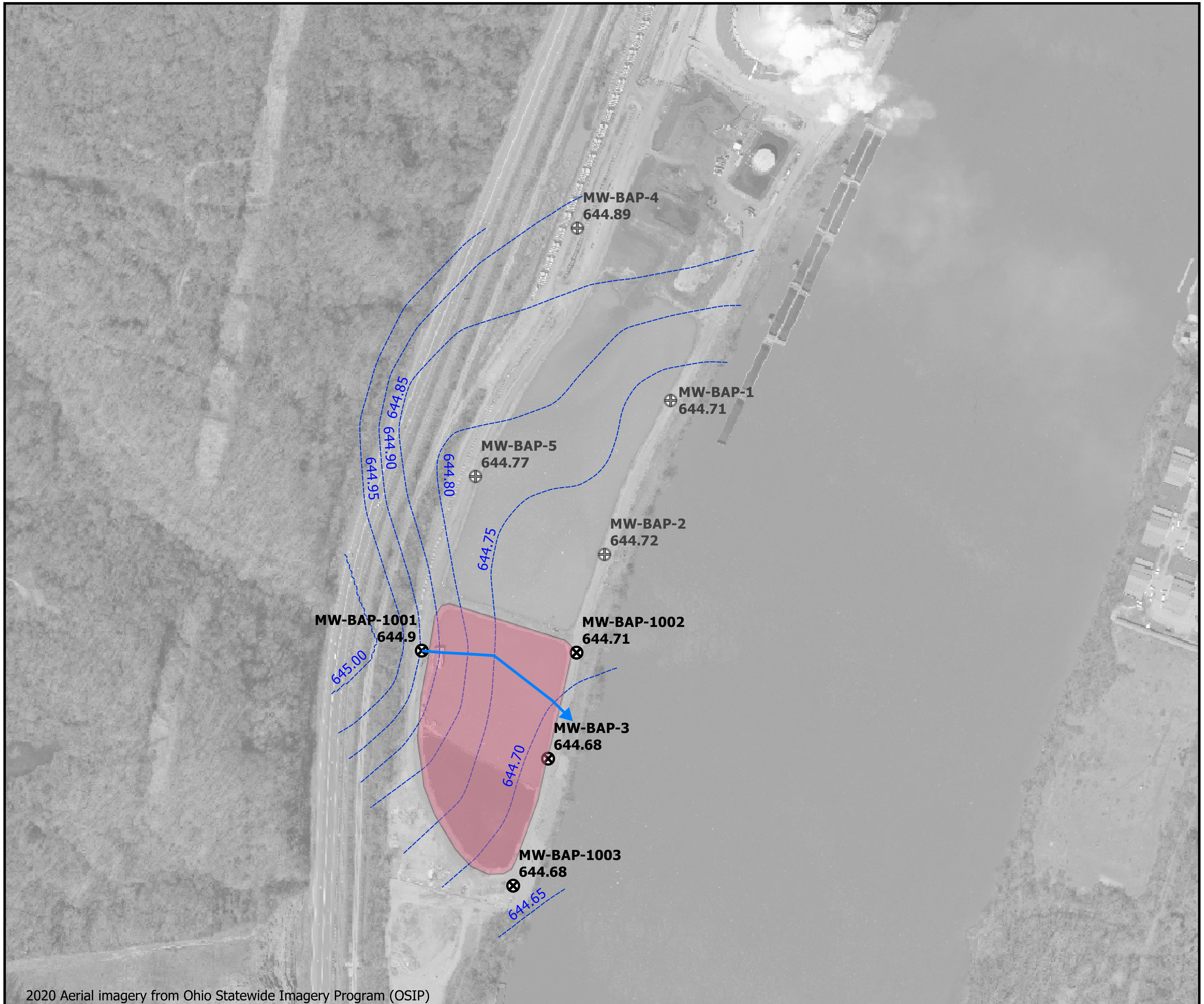
Cox-Colvin & Associates, Inc.
Environmental Services

Figure

4-11

Potentiometric Surface Map - Uppermost Aquifer
Retrofitted Bottom Ash Pond - April 15, 2022
Cardinal Plant
Brilliant, Ohio

K:\CCA\PROJECTS\Buckeye_Power\Cardinal\Drawings\GIS\Cardinal_Potentiometric.qgz : 2023-01-27 17:00



Legend

- Retrofitted Bottom Ash Pond (RBAP)
- RBAP Monitoring Well and Groundwater Elevation
- Non-RBAP Monitoring Well and Groundwater Elevation
- Approximate Groundwater Elevation Contour
- Estimated Groundwater Flow Direction

N

0 200 400 600 800 1,000 ft

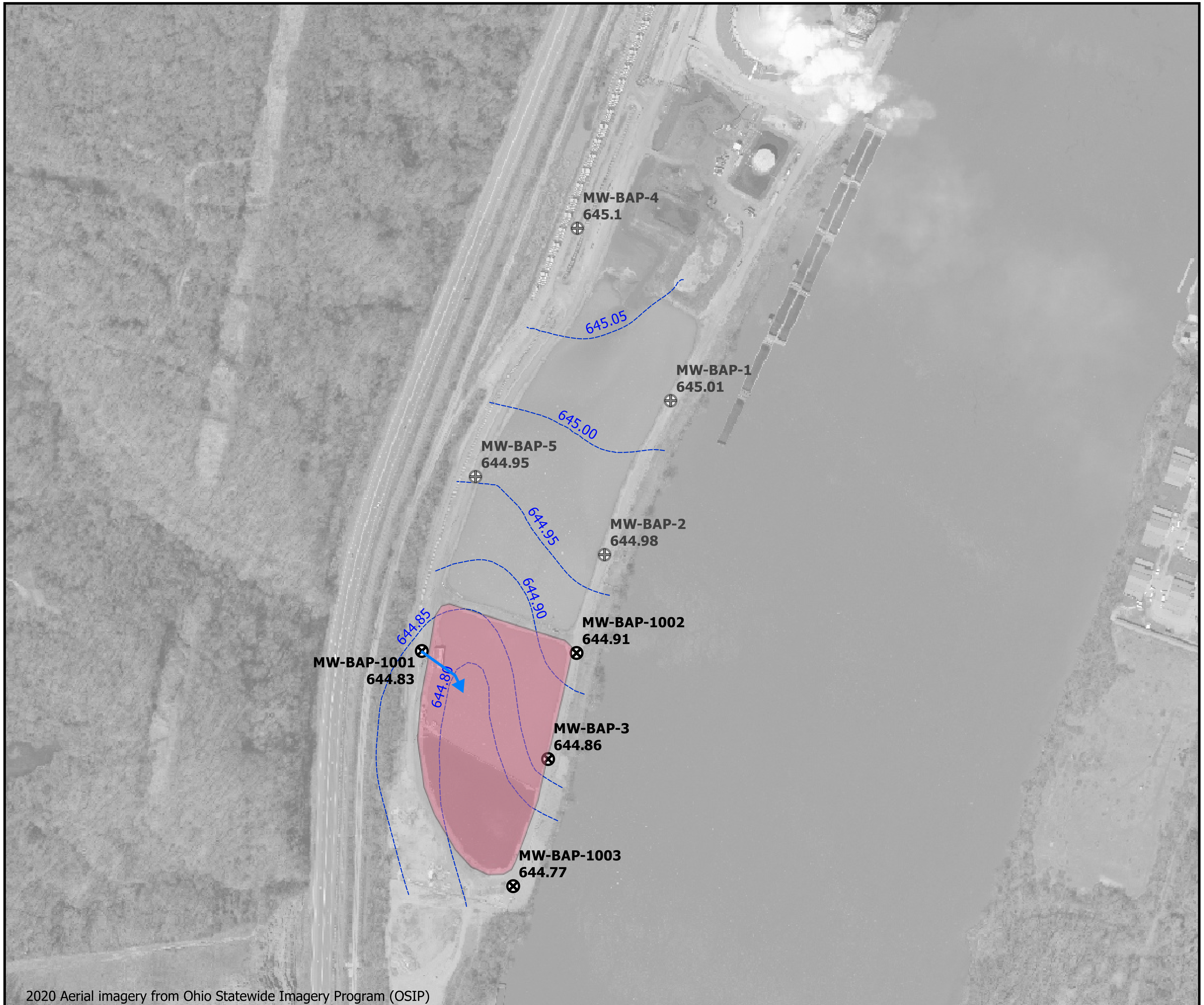
Cox-Colvin & ASSOCIATES, INC. ENVIRONMENTAL SERVICES

Figure

4-12

Potentiometric Surface Map - Uppermost Aquifer
Retrofitted Bottom Ash Pond - May 2, 2022
Cardinal Plant
Brilliant, Ohio

K:\CCA\PROJECTS\Buckeye_Power\Cardinal\Drawings\GIS\Cardinal_Potentiometric.qgz : 2023-01-30 11:33



Legend

- Retrofitted Bottom Ash Pond (RBAP)
- RBAP Monitoring Well and Groundwater Elevation
- Non-RBAP Monitoring Well and Groundwater Elevation
- Approximate Groundwater Elevation Contour
- Estimated Groundwater Flow Direction

N

0 200 400 600 800 1,000 ft

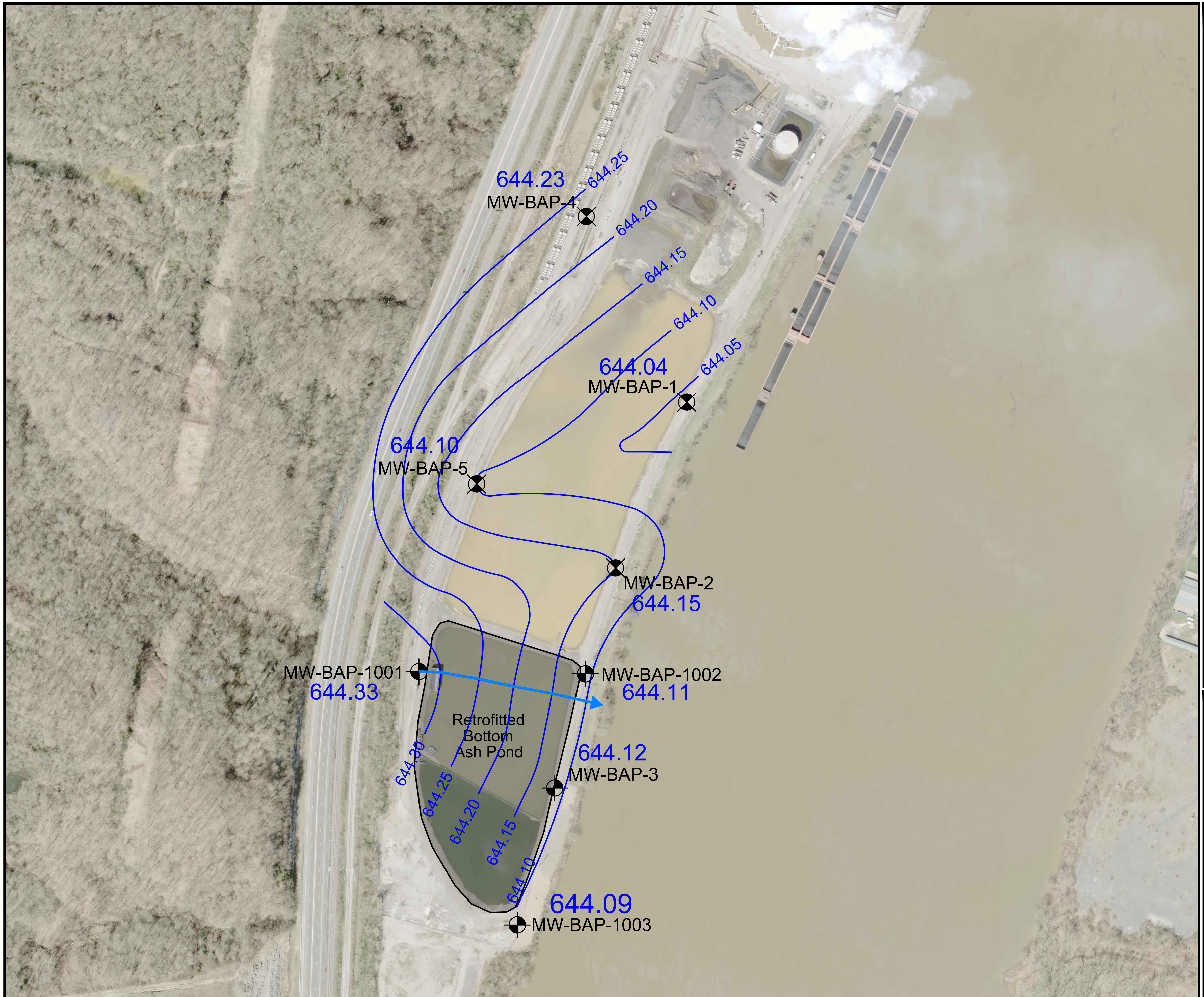
Cox-Colvin & ASSOCIATES, INC. ENVIRONMENTAL SERVICES

Figure

4-13

Potentiometric Surface Map - Uppermost Aquifer
Retrofitted Bottom Ash Pond - October 17, 2022
Cardinal Plant
Brilliant, Ohio

DWG NAME: Water Levels 2023 DATE PRINTED: 1/22/2024 K:\CCA\PROJECTS\Buckeye_Power\Cardinal\Drawings



Legend

- RBAP Monitor Well
- Non-RBAP Monitor Well
- 644.05 Approximate Groundwater Elevation Contour
- 644.04 Groundwater Elevation on April 10, 2023
- Retrofitted Bottom Ash Pond (RBAP)
- Estimated Groundwater Flow Direction

Source of Aerial Photograph: Ohio Statewide Imagery Program, 2020.

N

Scale

0' 150' 300' 600'

Cox-Colvin & ASSOCIATES, INC. ENVIRONMENTAL SERVICES

Figure

4-1

Potentiometric Surface Map - Uppermost Aquifer - April 10, 2023, Retrofitted Bottom Ash Pond (RBAP), Cardinal Plant, Brilliant, Ohio

DWG NAME: Water Levels 2023 DATE PRINTED: 1/22/2024 K:\CCA\PROJECTS\Buckeye_Power\Cardinal\Drawings

Legend

RBAP Monitor Well

Non-RBAP Monitor Well

644.76 Approximate Groundwater Elevation Contour

644.75 Groundwater Elevation on October 9, 2023

Retrofitted Bottom Ash Pond (RBAP)

Estimated Groundwater Flow Direction

Source of Aerial Photograph: Ohio Statewide Imagery Program, 2020.

N

Scale

0' 150' 300' 600'

Cox-Colvin & ASSOCIATES, INC. ENVIRONMENTAL SERVICES

Figure

4-2

Potentiometric Surface Map - Uppermost Aquifer - October 9, 2023, Retrofitted Bottom Ash Pond (RBAP), Cardinal Plant, Brilliant, Ohio

LEGEND

- RBAP MONITORING WELL WITH **GROUNDWATER ELEVATION** IN FEET
- BAP MONITORING WELL WITH **GROUNDWATER ELEVATION** IN FEET
- GROUNDWATER ELEVATION CONTOUR, 0.05-FT INTERVAL (NGVD29)
- RAILROAD
- RETROFITTED BOTTOM ASH POND (RBAP)
- HISTORIC BOTTOM ASH POND (BAP)
- ESTIMATED GROUNDWATER FLOW DIRECTION

NOTES

1. ALL LOCATIONS AND DIMENSIONS ARE APPROXIMATE.
2. DEFINITIONS:
   FT = FOOT
   NGVD29 = NATIONAL GEODETIC VERITCAL DATUM 1929
3. GROUNDWATER ELEVATIONS MEASURED 9 APRIL 2024.
4. ELEVATIONS IN FEET ABOVE MEAN SEA LEVEL (FT MSL).
5. AERIAL IMAGERY SOURCE: NEARMAP, 14 MAY 2023

HALEY ALDRICH

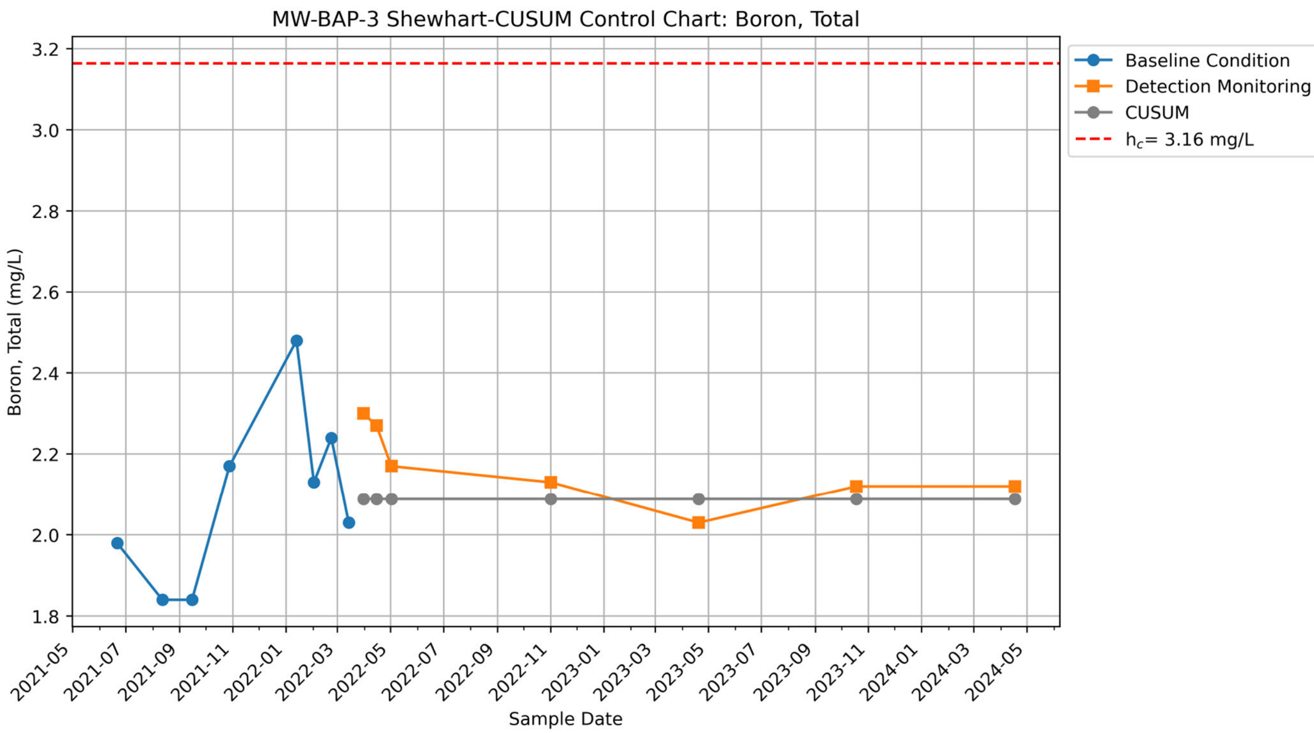
CARDINAL POWER PLANT
BRILLIANT, OHIO

POTENTIOMETRIC SURFACE RBAP
UPPERMOST AQUIFER
9 APRIL 2024

AUGUST 2024

FIGURE 2

APPENDIX C
Control Charts



MW-BAP-3 Shewhart-CUSUM Control Chart: Boron, Total
Baseline Condition
Detection Monitoring
CUSUM
h_c= 3.16 mg/L
Boron, Total (mg/L)
Sample Date
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
2021-05
2021-07
2021-09
2021-11
2022-01
2022-03
2022-05
2022-07
2022-09
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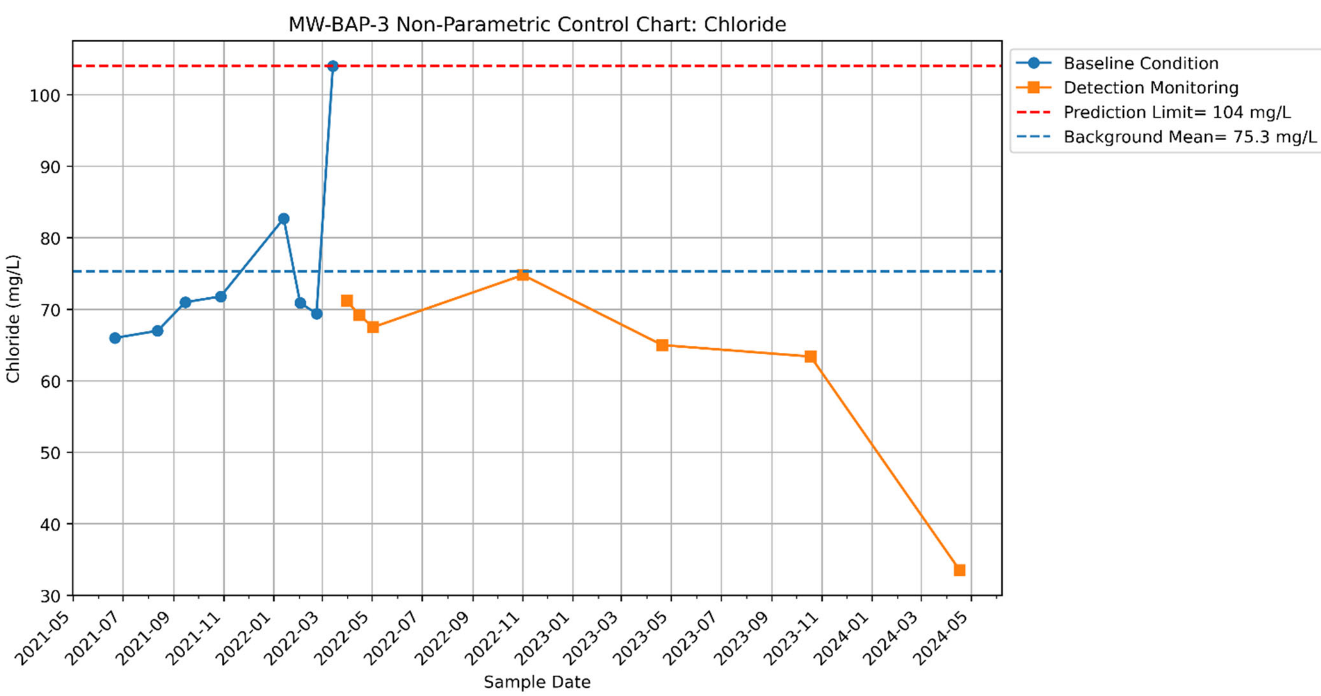
2024-03
2024-05



MW-BAP-3 Non-Parametric Control Chart: Chloride
Baseline Condition
Detection Monitoring
Prediction Limit= 104 mg/L
Background Mean= 75.3 mg/L
Chloride (mg/L)
Sample Date
30
40
50
60
70
80
90
100
2021-05
2021-07
2021-09
2021-11
2022-01
2022-03
2022-05
2022-07
2022-09
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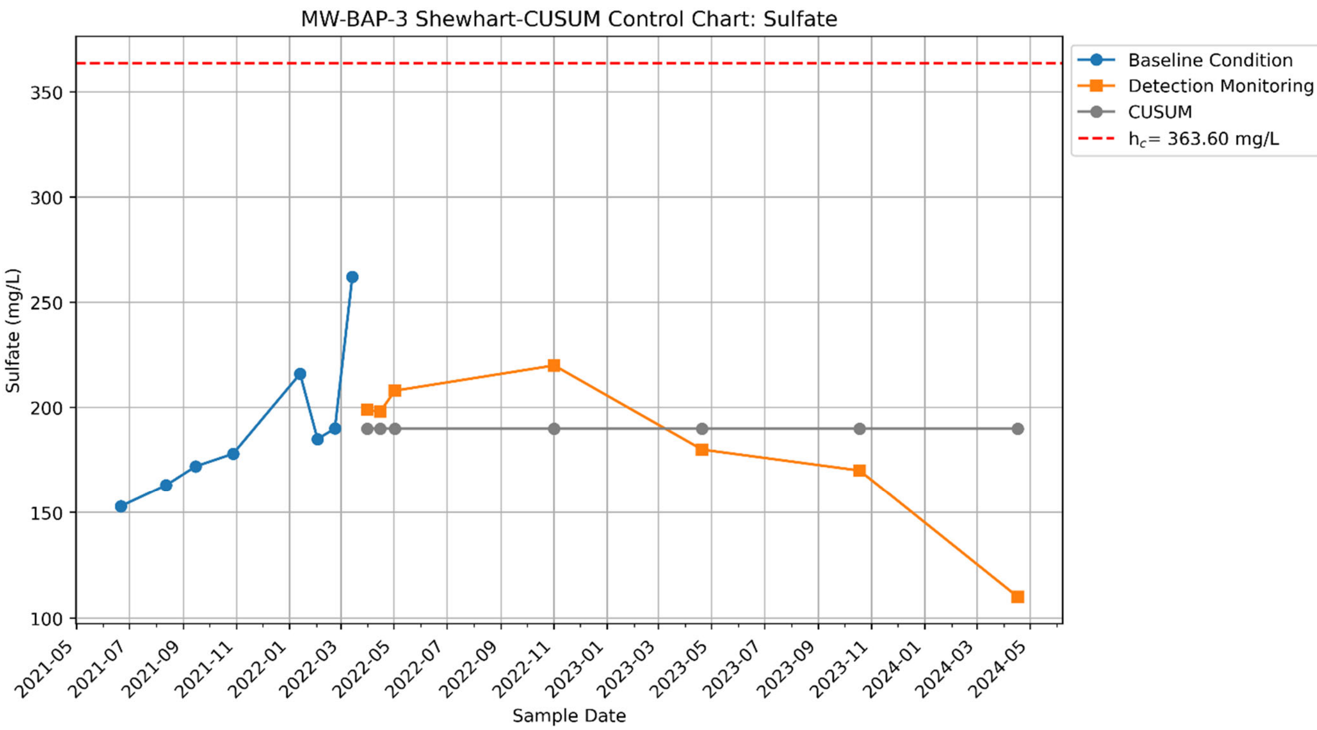
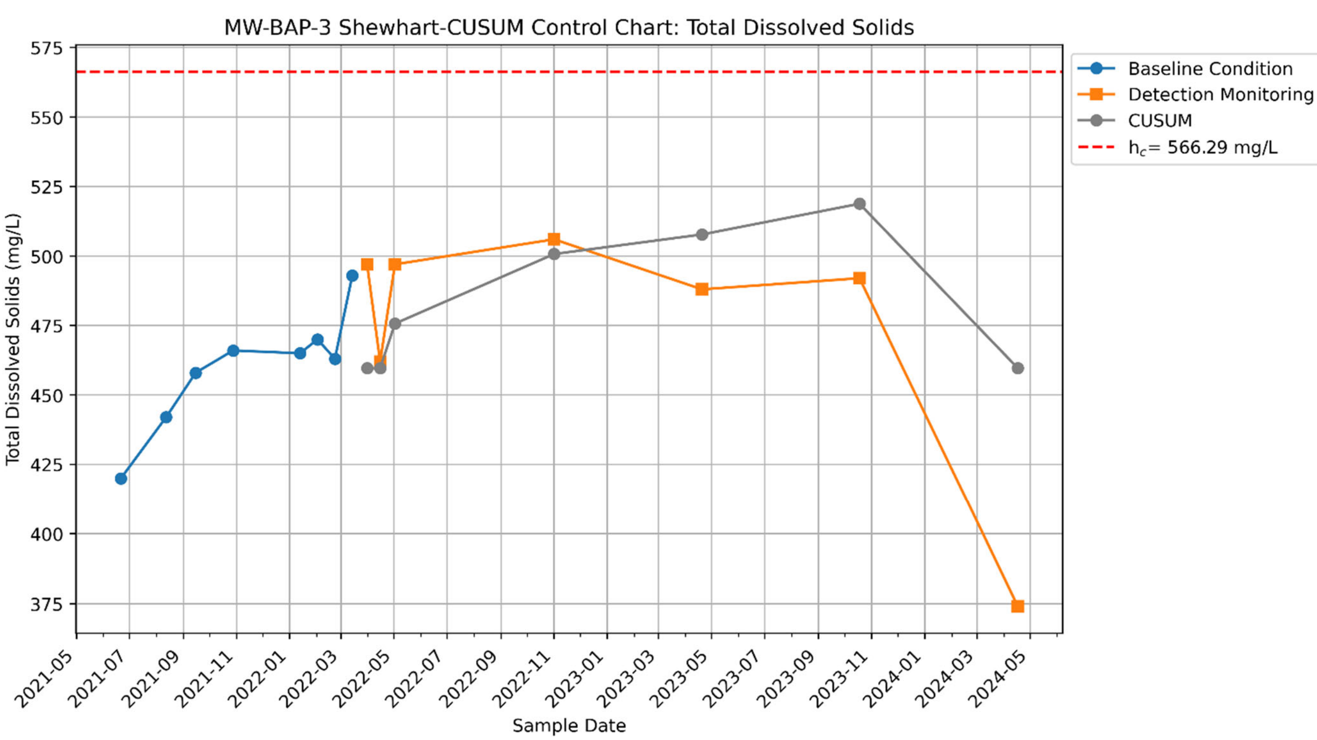
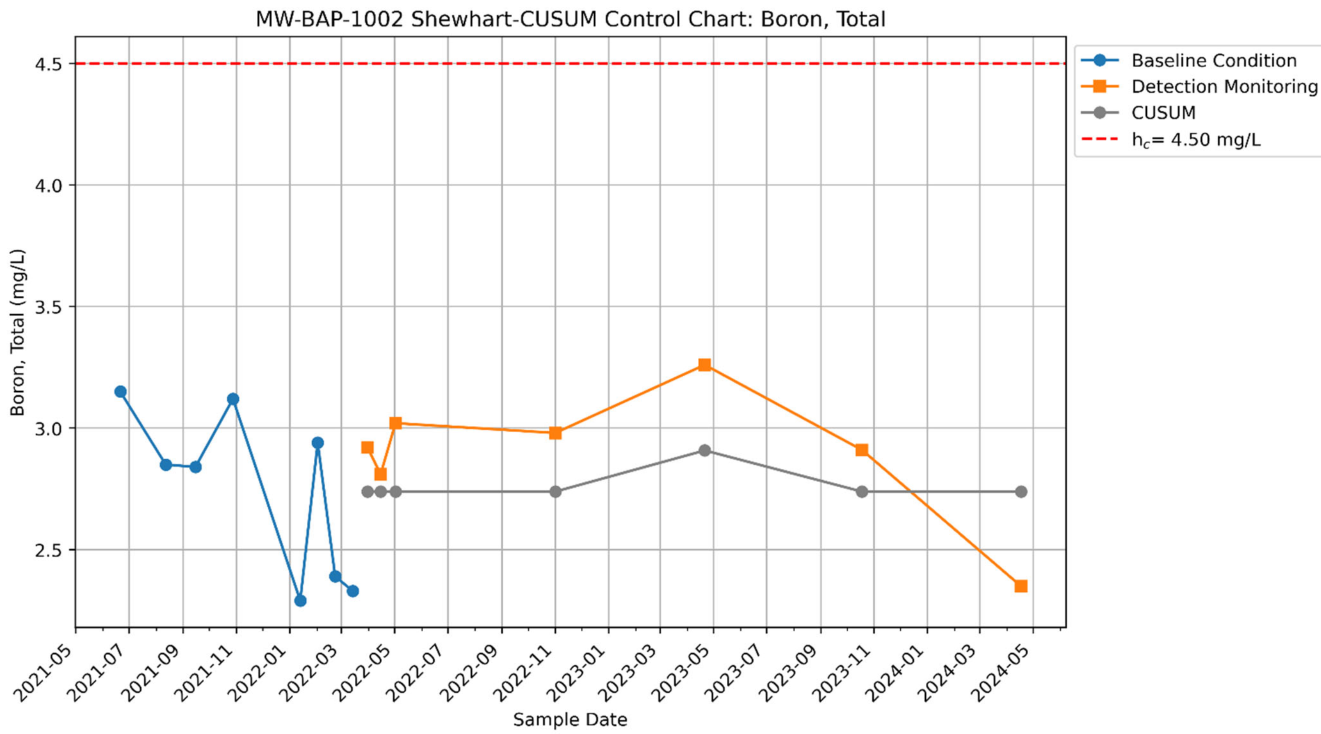
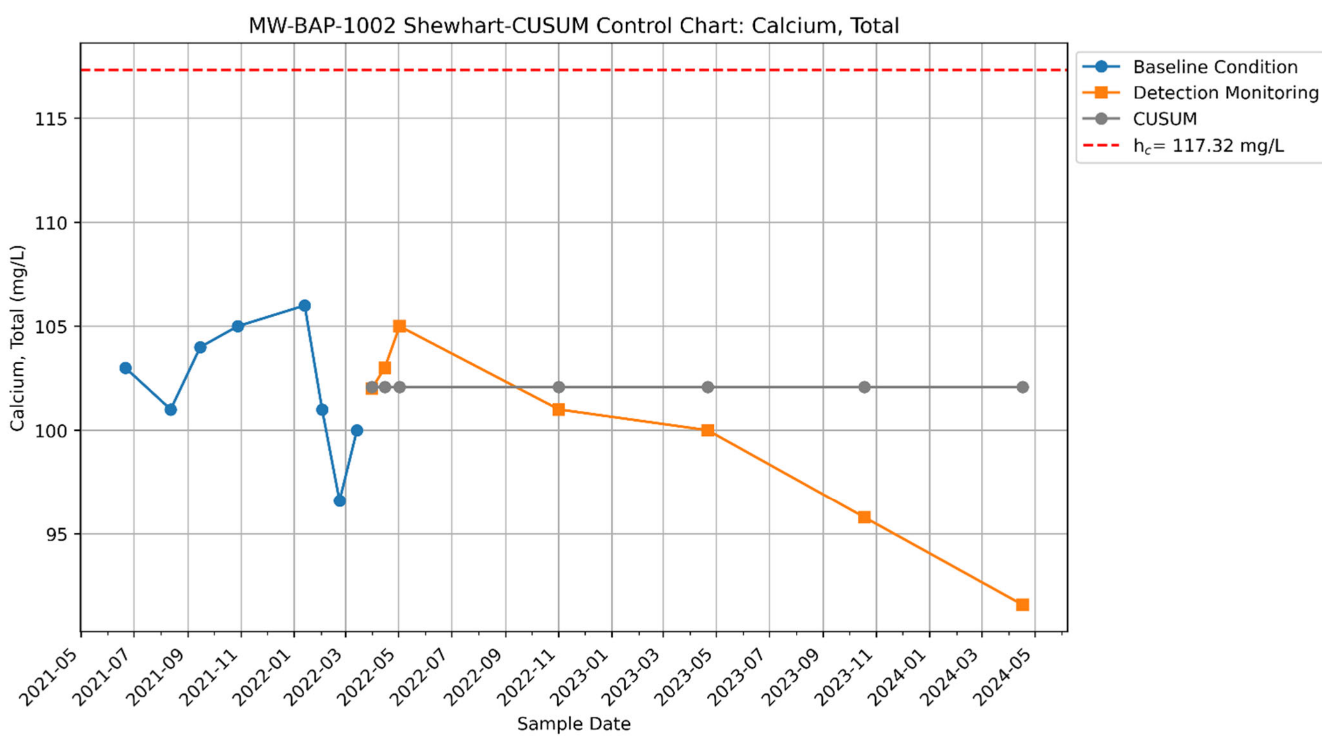
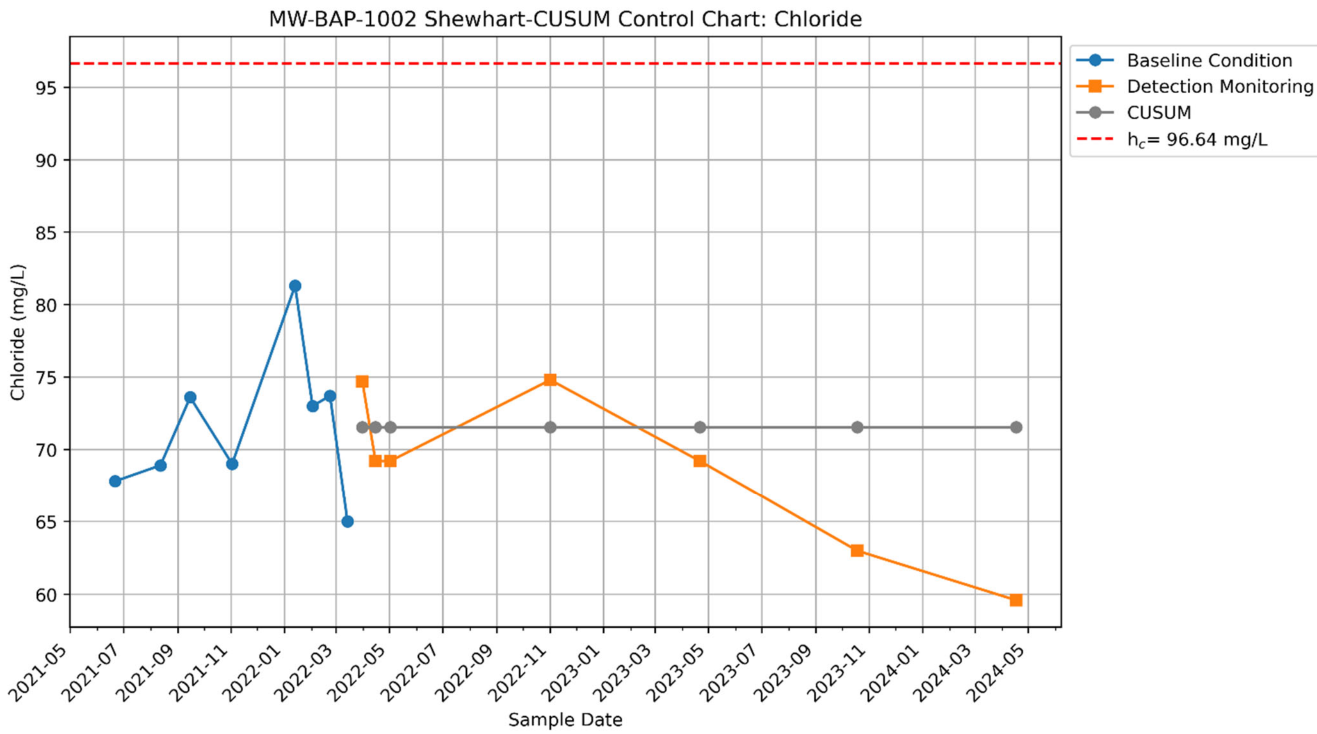
2024-03
2024-05


MW-BAP-3 Shewhart-CUSUM Control Chart: Sulfate
Sulfate (mg/L)
Sample Date
Baseline Condition
Detection Monitoring
CUSUM
h_c= 363.60 mg/L
100
150
200
250
300
350
2021-05
2021-07
2021-09
2021-11
2022-01
2022-03
2022-05
2022-07
2022-09
2022-11
2023-01
2023-03
2023-05
2023-07
2023-09
2023-11
2024-01
2024-03
2024-05


MW-BAP-3 Shewhart-CUSUM Control Chart: Total Dissolved Solids
Total Dissolved Solids (mg/L)
Sample Date
Baseline Condition
Detection Monitoring
CUSUM
h_c= 566.29 mg/L
375
400
425
450
475
500
525
550
575
2021-05
2021-07
2021-09
2021-11
2022-01
2022-03
2022-05
2022-07
2022-09
2022-11
2023-01
2023-03
2023-05
2023-07
2023-09
2023-11
2024-01
2024-03
2024-05


MW-BAP-1002 Shewhart-CUSUM Control Chart: Boron, Total
Baseline Condition
Detection Monitoring
CUSUM
h_c= 4.50 mg/L
Boron, Total (mg/L)
4.5
4.0
3.5
3.0
2.5
2021-05
2021-07
2021-09
2021-11
2022-01
2022-03
2022-05
2022-07
2022-09
2022-11
2023-01
2023-03
2023-05
2023-07
2023-09
2023-11
2024-01
2024-03
2024-05
Sample Date


MW-BAP-1002 Shewhart-CUSUM Control Chart: Calcium, Total
Baseline Condition
Detection Monitoring
CUSUM
h_c= 117.32 mg/L
Calcium, Total (mg/L)
115
110
105
100
95
2021-05
2021-07
2021-09
2021-11
2022-01
2022-03
2022-05
2022-07
2022-09
2022-11
2023-01
2023-03
2023-05
2023-07
2023-09
2023-11
2024-01
2024-03
2024-05
Sample Date


MW-BAP-1002 Shewhart-CUSUM Control Chart: Chloride
Baseline Condition
Detection Monitoring
CUSUM
h_c= 96.64 mg/L
Chloride (mg/L)
Sample Date
95
90
85
80
75
70
65
60
2021-05
2021-07
2021-09
2021-11
2022-01
2022-03
2022-05
2022-07
2022-09
2022-11
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2023-05
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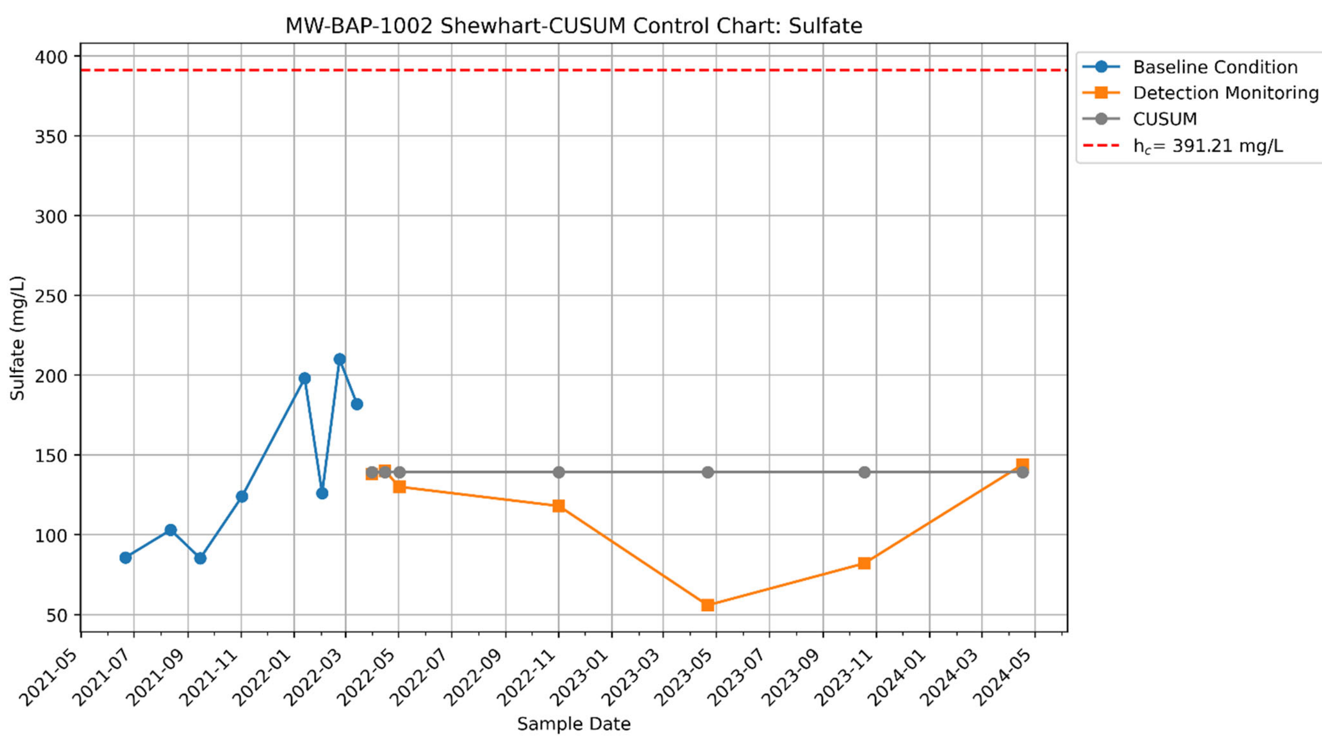
2023-11
2024-01
2024-03
2024-05


MW-BAP-1002 Shewhart-CUSUM Control Chart: Sulfate
Baseline Condition
Detection Monitoring
CUSUM
h_c= 391.21 mg/L
Sulfate (mg/L)
Sample Date
400
350
300
250
200
150
100
50
2021-05
2021-07
2021-09
2021-11
2022-01
2022-03
2022-05
2022-07
2022-09
2022-11
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2023-03
2023-05
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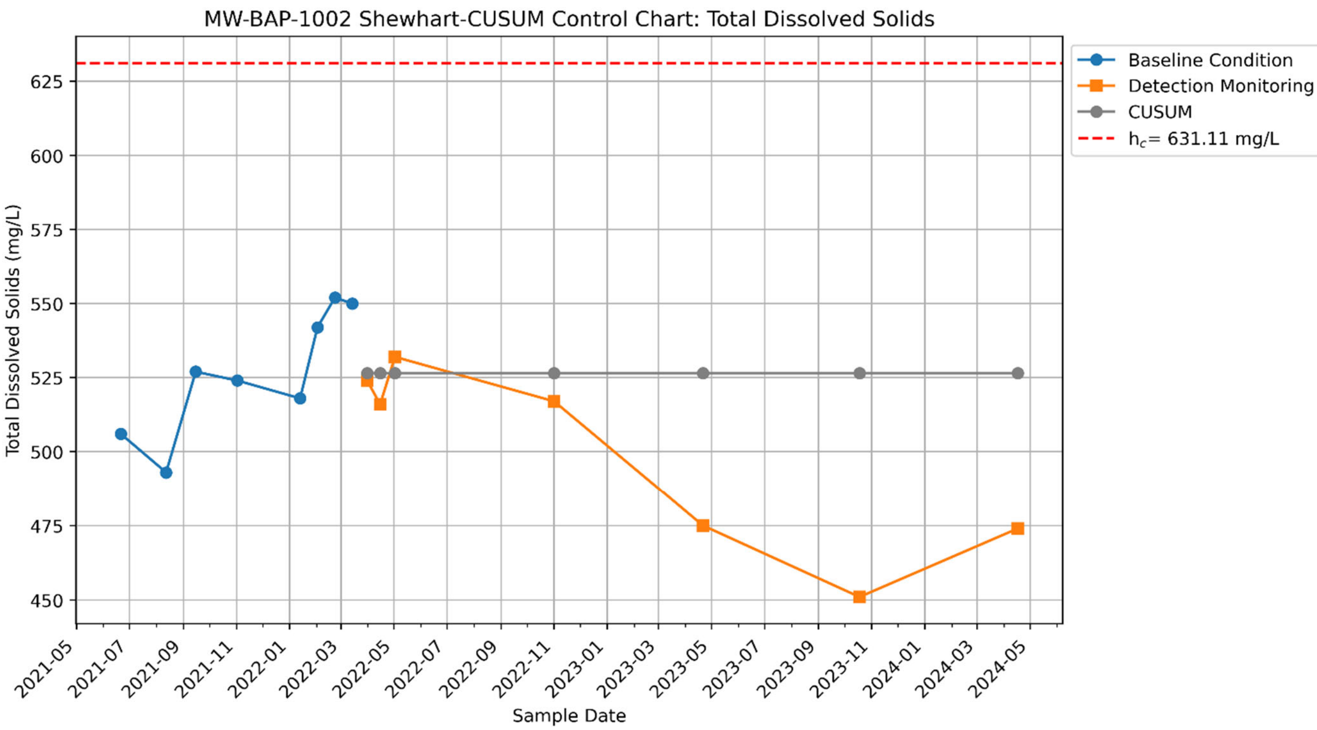
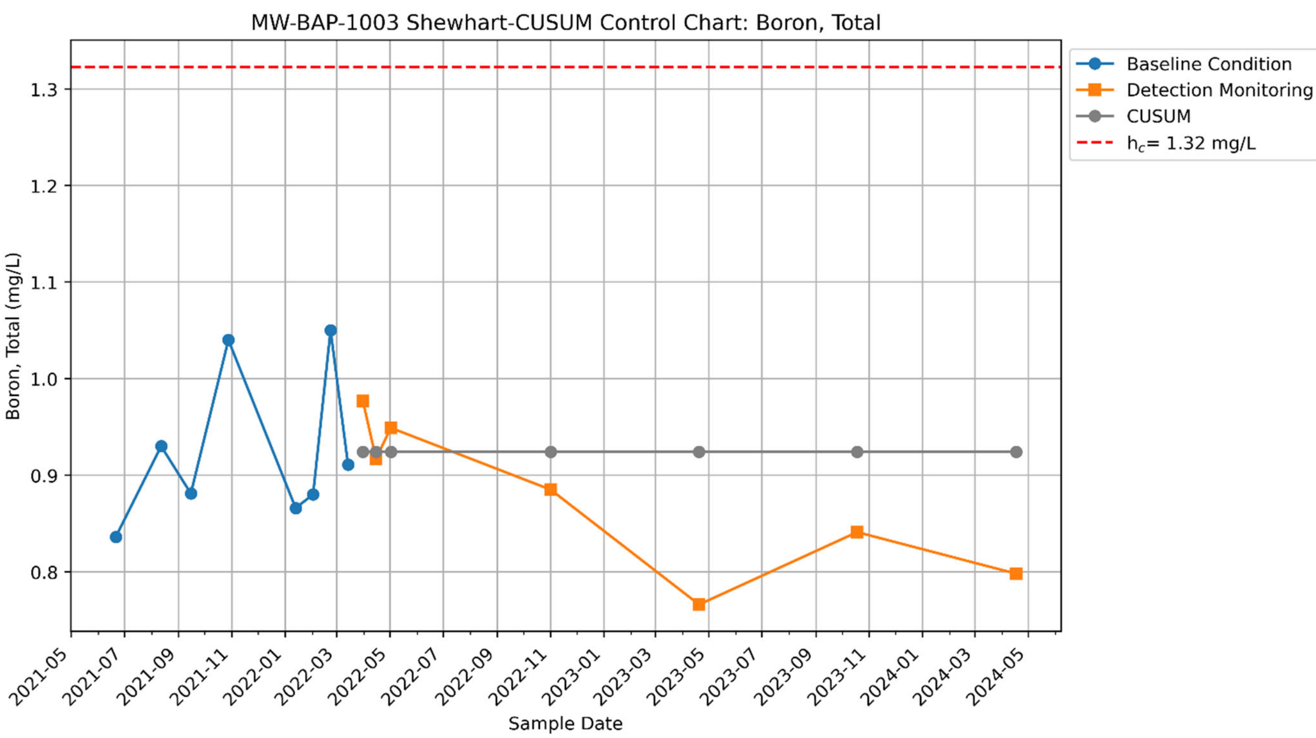
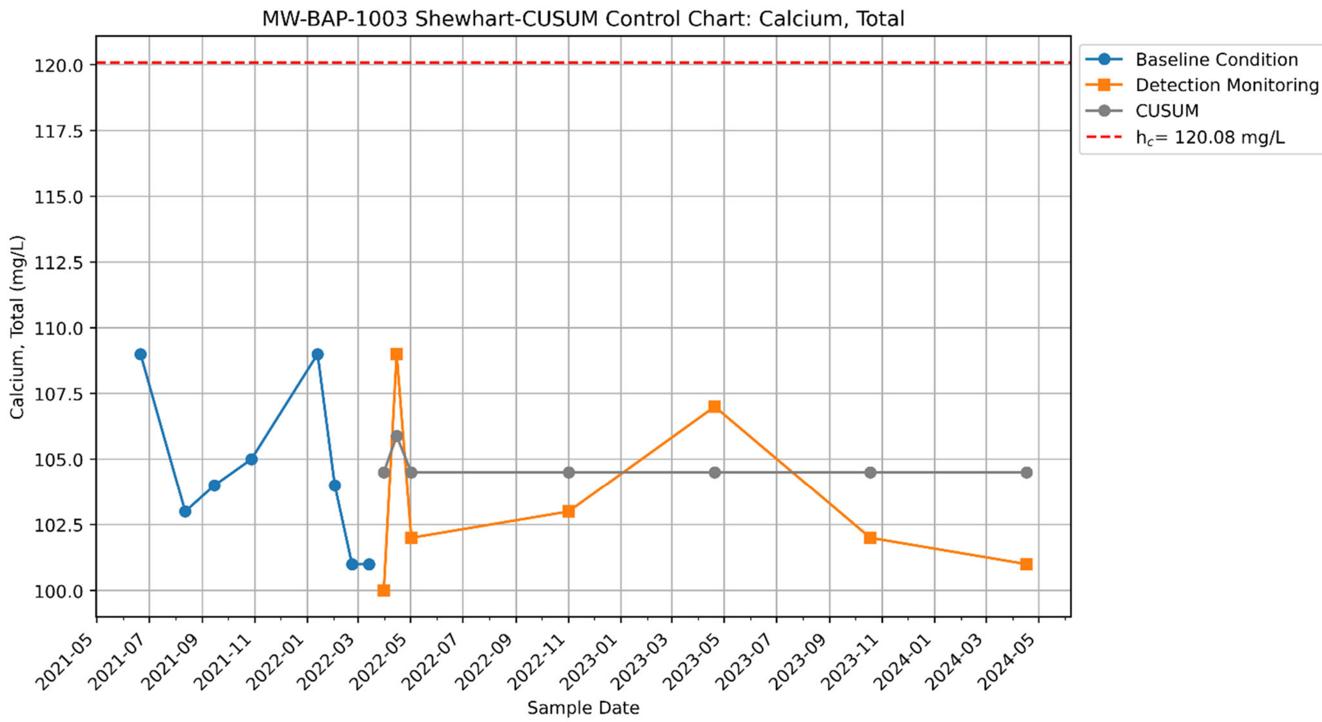
2023-11
2024-01
2024-03
2024-05

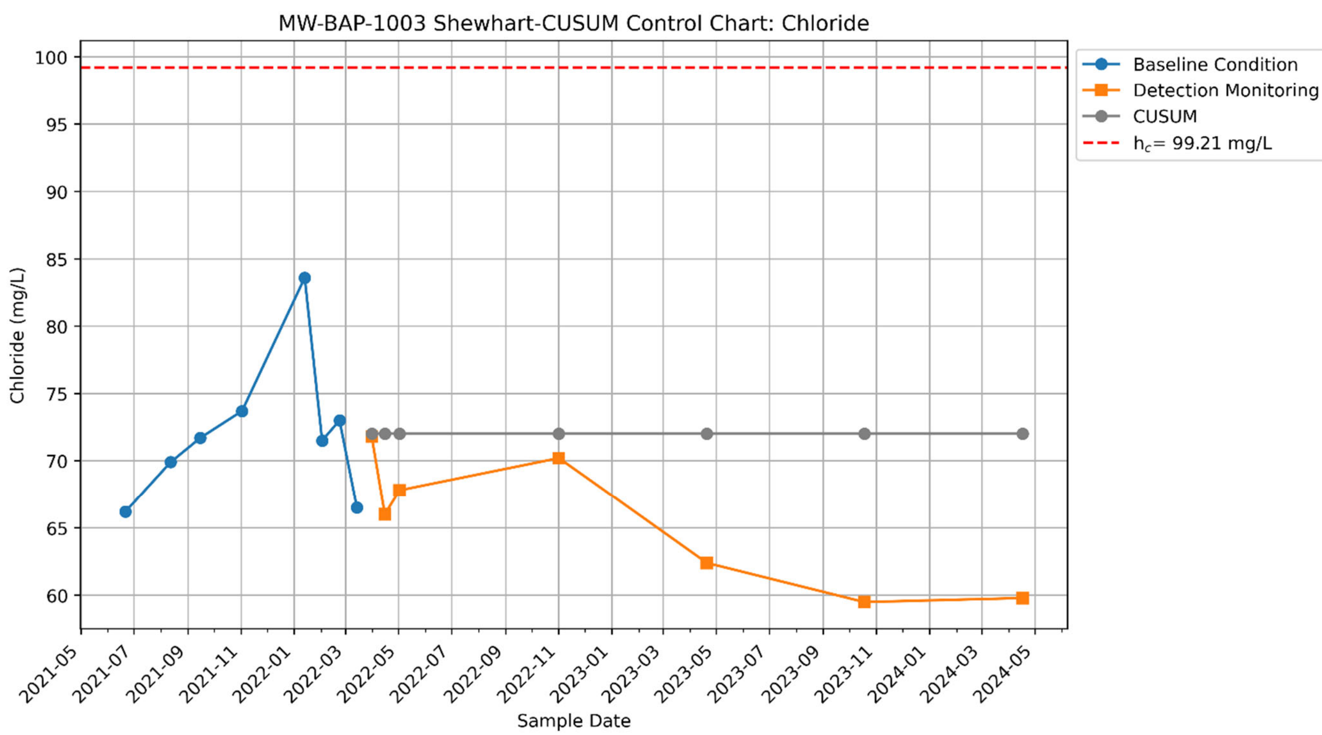


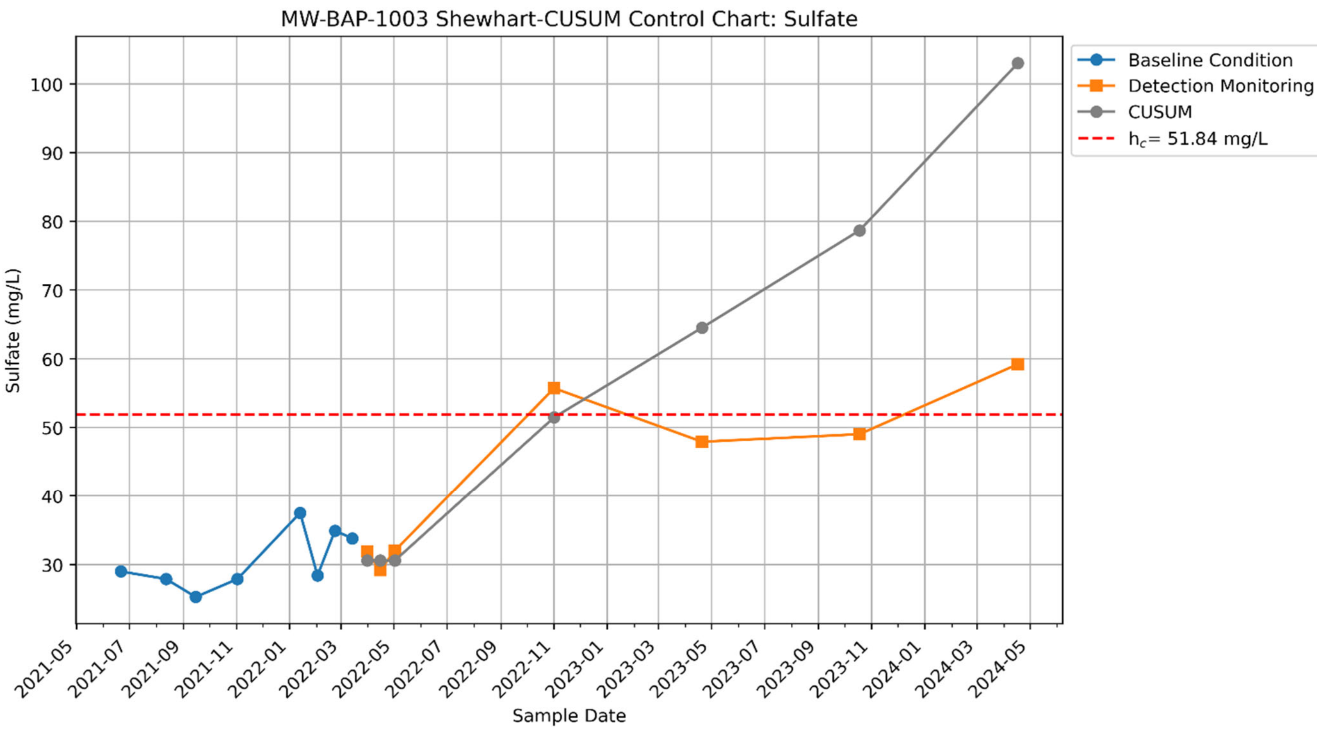
MW-BAP-1002 Shewhart-CUSUM Control Chart: Total Dissolved Solids
Baseline Condition
Detection Monitoring
CUSUM
h_c= 631.11 mg/L
Total Dissolved Solids (mg/L)
Sample Date

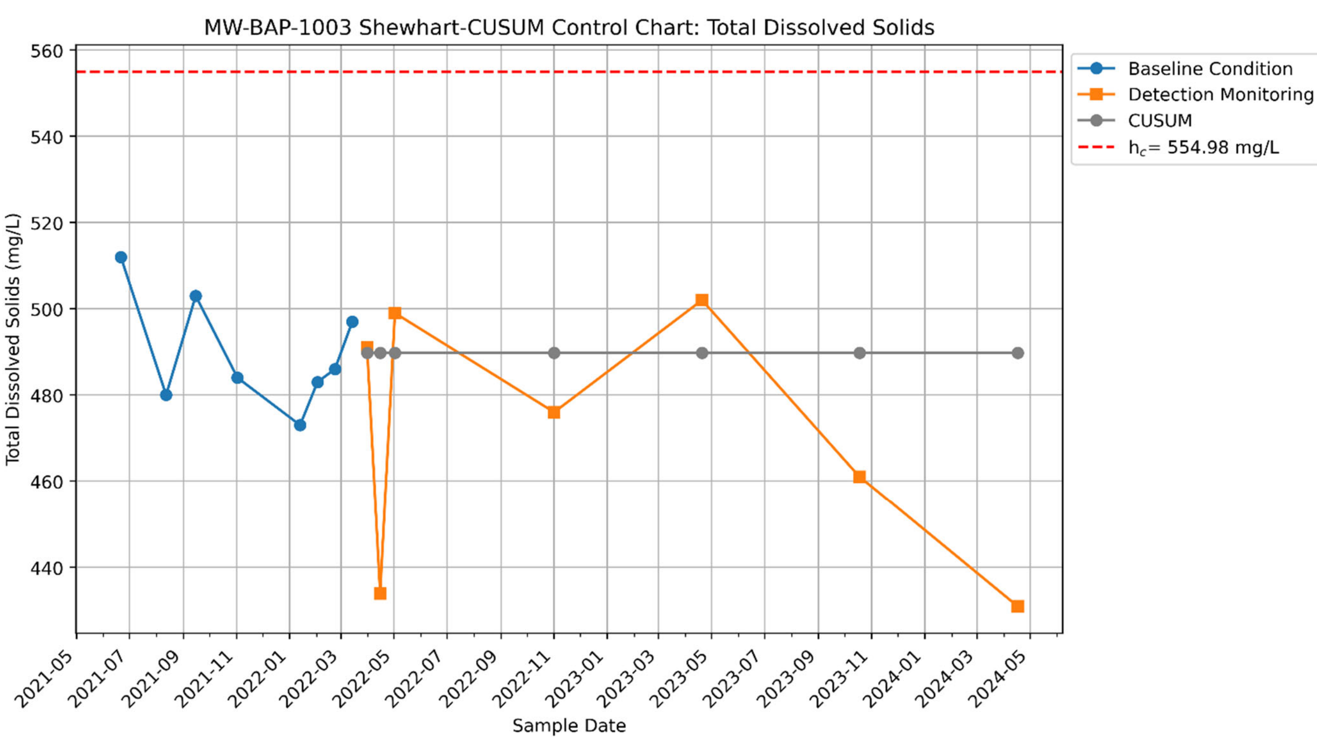


MW-BAP-1003 Shewhart-CUSUM Control Chart: Boron, Total
Baseline Condition
Detection Monitoring
CUSUM
h_c= 1.32 mg/L
Boron, Total (mg/L)
Sample Date


MW-BAP-1003 Shewhart-CUSUM Control Chart: Calcium, Total
Baseline Condition
Detection Monitoring
CUSUM
h_c= 120.08 mg/L
Calcium, Total (mg/L)
120.0
117.5
115.0
112.5
110.0
107.5
105.0
102.5
100.0
2021-05
2021-07
2021-09
2021-11
2022-01
2022-03
2022-05
2022-07
2022-09
2022-11
2023-01
2023-03
2023-05
2023-07
2023-09
2023-11
2024-01
2024-03
2024-05
Sample Date


MW-BAP-1003 Shewhart-CUSUM Control Chart: Chloride
Baseline Condition
Detection Monitoring
CUSUM
h_c= 99.21 mg/L
Chloride (mg/L)
100
95
90
85
80
75
70
65
60
2021-05
2021-07
2021-09
2021-11
2022-01
2022-03
2022-05
2022-07
2022-09
2022-11
2023-01
2023-03
2023-05
2023-07
2023-09
2023-11
2024-01
2024-03
2024-05
Sample Date


MW-BAP-1003 Shewhart-CUSUM Control Chart: Sulfate
Baseline Condition
Detection Monitoring
CUSUM
h_c= 51.84 mg/L
Sulfate (mg/L)
Sample Date


MW-BAP-1003 Shewhart-CUSUM Control Chart: Total Dissolved Solids
Baseline Condition
Detection Monitoring
CUSUM
h_c= 554.98 mg/L
Total Dissolved Solids (mg/L)
Sample Date