Intended for
Illinois Power Resources Generating, LLC

Date
April 19, 2022

Project No.
1940101010-010

GROUNDWATER MODELING REPORT

ASH POND

EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

GROUNDWATER MODELING REPORT
EDWARDS POWER PLANT ASH POND

Project Name	**Edwards Power Plant Ash Pond**
Project No.	**1940101010-010**
Recipient	**Illinois Power Resources Generating, LLC**
Document Type	**Groundwater Modeling Report**
Revision	**FINAL DRAFT**
Date	**April 19, 2022**

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ACRONYMS AND ABBREVIATIONS

§	Section
35 I.A.C.	Title 35 of the Illinois Administrative Code
40 C.F.R.	Title 40 of the Code of Federal Regulations
BCU	bedrock confining unit
bgs	below ground surface
CBR	closure by removal
CCR	coal combustion residuals
CIP	closure in place
cm/s	centimeters per second
CSM	conceptual site model
EPP	Edwards Power Plant
Federal CCR Rule	40 C.F.R. § 257 Subpart D
ft/day	feet/foot per day
ft^2/d	feet squared per day
GHB	general head boundary conditions
GMP	Groundwater Monitoring Plan
GMR	Groundwater Modeling Report
Golder	Golder Associates USA Inc.
GWPS	Groundwater Protection Standard
HCR	Hydrogeologic Site Characterization Report
HELP	Hydrologic Evaluation of Landfill Performance
ID	identification
IEPA	Illinois Environmental Protection Agency
in	inches
in/yr	inches per year
IPRG	Illinois Power Resources Generating, LLC
ISWS	Illinois State Water Survey
Kd	distribution coefficient
K_D	linear partition coefficients
K_F	Freundlich partition coefficients
K_L	Langmuir partition coefficients
Kh/Kv	vertical anisotropy
L/kg	liters per kilogram
mg/L	milligrams per liter
MGD	million gallons per day
mL/g	milliliters per gram
NAVD88	North American Vertical Datum of 1988
NGVD29	National Geodetic Vertical Datum of 1929
NID	National Inventory of Dams
No.	number
NPDES	National Pollutant Discharge Elimination System
NRT	Natural Resource Technology, Inc.

NRT/OBG	Natural Resource Technology Inc., an OBG Company
p	probability
Part 845	35 I.A.C. § 845: Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments
PMP	Potential Migration Pathway
R2	correlation coefficient
Ramboll	Ramboll Americas Engineering Solutions, Inc.
SI	surface impoundment
SSR	sum of squared residuals
S_y	specific yield
SW	surface water
TDS	total dissolved solids
TVD	total-variation-diminishing
UA	uppermost aquifer
UCF	Upper Cahokia Formation
US	United States
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
Wittman	Wittman Hydro Planning Associates, Inc.

EXECUTIVE SUMMARY

Ramboll Americas Engineering Solutions, Inc. (Ramboll) has prepared this Groundwater Modeling Report (GMR) on behalf of the Edwards Power Plant (EPP), operated by Illinois Power Resources Generating, LLC (IPRG), in accordance with requirements of Title 35 of the Illinois Administrative Code (35 I.A.C.) Section (§) 845: Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments (Part 845) (Illinois Environmental Protection Agency [IEPA], April 15, 2021). This document presents the results of predictive groundwater modeling simulations for proposed closure scenarios for the Ash Pond. The Ash Pond (Vistra identification [ID] number [No.] 301, IEPA ID No. W1438050005-01, and National Inventory of Dams [NID] No. IL50710) is the only coal combustion residuals (CCR) unit present on the EPP property.

The EPP is located in Bartonville, Illinois (**Figure 1-1**). The EPP property is situated in an agricultural/industrial area. The EPP is bound by a salt processing facility to the north, a fertilizer processing plant and the Illinois River to the east, agricultural fields to the south, and railroad tracks, former Orchard Mines, and Highway 24 to the west (**Figure 1-2**).

A detailed summary of site conditions was provided in the Hydrogeologic Site Characterization Report (HCR; Ramboll, 2021a). Four distinct water-bearing units have been identified in the vicinity of the Ash Pond based on stratigraphic relationships and common hydrogeologic characteristics. The units are described as follows from the surface downward:

- **CCR:** Saturated CCR consisting primarily of fly ash within the Ash Pond. CCR is present at thicknesses up to 46.5 feet and at elevations as low as 413.9 feet North American Vertical Datum of 1988 (NAVD88) in the central and northern portion of the Ash Pond.
- **Upper Cahokia Formation (UCF)/Potential Migration Pathway (PMP):** Low permeability clays and silts of the UCF are present at the surface. This unit is considered a PMP at elevations similar to the base of the Ash Pond, and in places where thin discontinuous sand lenses occur within the UCF adjacent to the Ash Pond.
- **Uppermost Aquifer (UA):** Thin (generally less than 4 feet), moderate permeability sand, silty sand, and clayey gravel material within the Lower Cahokia Formation, bedrock, and/or weathered shale bedrock, where present. In locations where higher permeability materials and coarser grained material are absent, the UA is interpreted as the interface between the Lower Cahokia Formation and shale bedrock.
- **Bedrock Confining Unit (BCU):** Thick, very low permeability shales and siltstones of the Carbondale and Modesto Formations. This unit was encountered at elevations ranging from approximately 400 to 422 feet NAVD88 with higher bedrock elevations occurring beneath the northern portion of the Ash Pond.

In general, the UCF consists of low permeability clays and silts, with limited occurrences of thin discontinuous sand lenses. Occasional sand lenses within the UCF, and clay intervals downgradient at elevations similar to the base of ash in the Ash Pond were identified as PMPs. In several locations, generally near the southern and western portions of the unit, coarser grained materials are present at the base of the Lower Cahokia Formation and/or the top of the bedrock is weathered resulting in relatively higher hydraulic conductivities. Because the interface is laterally continuous, and has relatively higher conductivity, the unlithified/lithified contact was designated as the UA.

The underlying bedrock is interpreted as the lower confining unit and has hydraulic conductivities generally an order of magnitude less than those measured in the UA. Groundwater occurs within both the unlithified materials and bedrock and consistently flows east to west in the UA. Offsite groundwater in the Sankoty Aquifer flows to the north and south towards identified Peoria and Pekin pumping centers, respectively. Groundwater in the Sankoty Aquifer may be hydraulically connected to the UA (*i.e.,* unlithified/ lithified contact) identified onsite.

A review and summary of data collected from 2015 through 2021 for parameters with groundwater protection standards (GWPS) listed in 35 I.A.C. § 845.600 is provided in the HCR (Ramboll, 2021a). Concentration results presented in the HCR and summarized in the History of Potential Exceedances (Ramboll, 2021b) are considered potential exceedances because the methodology used to determine them is proposed in the Statistical Analysis Plan (Appendix A to the Groundwater Monitoring Plant [GMP], Ramboll 2021c), which has not been reviewed or approved by IEPA at the time of submittal of the Part 845 operating permit application. The following constituents with potential exceedances of the GWPS listed in 35 I.A.C. § 845.600 were identified: barium, boron, chloride, lithium, sulfate, and total dissolved solids (TDS) (Ramboll, 2021b).

A Technical Memorandum (**Appendix A**) was prepared by Golder Associates USA Inc. (Golder, 2022a), *Evaluation of Potential GWPS Exceedances, Edwards Ash Pond [CCR Unit 301], Edwards Power Plant, Peoria County, Illinois*, to further evaluate potential GWPS exceedances. The results of the evaluation demonstrated that the potential GWPS exceedances of lithium in well AP05D and AP07D, chloride in well AP07D, and barium in well AW-15C are not related to the Ash Pond based on multiple lines of evidence presented in the Technical Memorandum. Statistically significant correlations between boron concentrations and concentrations of sulfate and TDS identified as potential exceedances of the GWPS indicate boron is an acceptable surrogate for these parameters in the groundwater model. Concentrations of these parameters are expected to change along with model predicted boron concentrations.

It was assumed that boron would not significantly sorb or chemically react with aquifer solids (distribution coefficient [Kd] was set to 0 milliliters per gram [mL/g]) which is a conservative estimate for predicting contaminant transport times in the model. Boron, sulfate, and TDS transport is likely to be affected by both chemical and physical attenuation mechanisms (*i.e.,* adsorption and/or precipitation reactions as well as dilution and dispersion).

Data collected from previous field investigations, as well as the 2021 field investigations, were used to develop a groundwater model for the Ash Pond. The MODFLOW and MT3DMS models were then used to evaluate two closure scenarios, including CCR consolidation and closure in place (CIP), and closure by removal (CBR) scenarios, using information provided in the Draft CCR Final Closure Plan (IngenAE, 2022):

- Scenario 1: CIP (CCR removal from the northwest areas of the Ash Pond, consolidation to the northeast, central and southern areas of the Ash Pond, and construction of a cover system over the remaining CCR)
- Scenario 2: CBR (CCR removal from the Ash Pond)

Prior to the simulation of these scenarios, a dewatering simulation was included for the removal of free liquids from the Ash Pond prior to the implementation of the two scenarios.

Differences exist in the timeframes to reach the GWPS for most monitoring wells between CIP and CBR. For instance, wells with observations above the standard GWPS for boron (2 milligrams per liter [mg/L]) from November 2015 to August 2021 (AP07S, AW-05, AW-15S, AW-18, AW-19, AW-20, AW-21) are predicted to reach the GWPS in 198 years after CIP implementation, and 104 years after CBR implementation. Shorter timeframes were predicted to reach the GWPS for wells located on the northern edge of the Ash Pond where observed boron concentrations were the highest (AW-21 and AP07S). AW-21 and AP07S, which had the highest concentrations in the UA and UCF, respectively, were predicted to decline below the GWPS at 121 and 32 years, respectively, after CIP implementation, and at 88 and 15 years, respectively, after CBR implementation. However, as a result of the south-southwest trending plume of residual boron concentrations above the standard GWPS for boron (2 mg/L) released prior to closure, which remains for a long period of time following implementation of both scenarios, all monitoring wells are not predicted to reach the GWPS until after 767 years and 748 years following implementation of CIP and CBR, respectively.

The observed timeframes to reach the GWPS for both the CIP and CBR prediction scenarios were on the order of hundreds of years from present. These predicted timeframes to meet the GWPS are less reliable than timeframes that are closer temporally to the data used for calibration (between 2015 and 2021). From a modeling perspective, the 19-year difference between CIP and CBR to reach the GWPS at all monitoring wells surrounding the ash pond is negligible. In other words, both scenarios are predicted to reach the GWPS after approximately 750 years, and the simulated 19-year difference between these two scenarios is not significant. Further, the boron plumes for both CIP and CBR remain in close proximity to the Ash Pond while they recede, indicating they are equally protective.

Results of groundwater fate and transport modeling conservatively estimate that groundwater will attain the GWPS for all constituents identified as potential exceedances of the GWPS in approximately 750 years following closure implementation for both CIP and CBR. The long timeframes observed are a result of the generally low permeability materials adjacent to and underlying the Ash Pond, and generally low groundwater flow velocities observed within the water-bearing units of the site, which results in reduced transport and slow physical attenuation (dilution and dispersion). The predicted maximum extent of the plume above the standard GWPS for boron (2 mg/L) stays in close proximity to the ash pond as it recedes.

1. INTRODUCTION

1.1 Overview

In accordance with requirements of Part 845 (IEPA, 2021), Ramboll has prepared this GMR on behalf of EPP, operated by IPRG. This report will apply specifically to the CCR unit referred to as the Ash Pond (**Figure 1-1**). The Ash Pond is a 91-acre unlined CCR surface impoundment (SI) used to manage CCR and non-CCR waste streams prior to discharge in accordance with the plant's National Pollutant Discharge Elimination System (NPDES) permit (IL0001970) at the EPP. This GMR presents and evaluates the results of predictive groundwater modeling simulations for two proposed closure scenarios, including CCR consolidation and CIP, and CBR scenarios summarized below:

- Scenario 1: CIP (CCR removal from the northwest areas of the Ash Pond, consolidation to the northeast, central and southern areas of the Ash Pond, and construction of a cover system over the remaining CCR)
- Scenario 2: CBR (CCR removal from the Ash Pond)

1.2 Site Location and Background

The EPP is located in Peoria County between Mapleton and Bartonville in Section 11, Township 7 North, Range 7 East (**Figure 1-1**). The EPP is located near the Illinois River adjacent to a levee and has one CCR SI, the Ash Pond.

The EPP is situated in a predominantly agricultural area with industrial parcels bordering the property. Historically several coal mines were operated at depths of 100 to 160 feet below ground surface (bgs) in the vicinity of the EPP. The EPP property is bordered by a salt processing facility to the north, railroad right-of-way and former Orchard Mines to the west, the Illinois River and fertilizer production facility to the east, and agricultural land to the south (**Figure 1-2**).

The Ash Pond was investigated in 2013 (Natural Resource Technology, Inc. [NRT], 2013) and exceedances of Class I Groundwater Standards were reported for pH, chloride, iron, manganese, TDS, and sulfate. Additional wells were installed in 2015 to comply with Title 40 of the Code of Federal Regulations (40 C.F.R) § 257 Subpart D (Federal CCR Rule), and again in 2021 to collect additional data to meet the requirements of 35 I.A.C. § 845.620.

1.3 Site History and Unit Description

The EPP began power generation in 1960 and the original Ash Pond embankments were placed into service at that time. In 2004, modifications to the rail loop surrounding the Ash Pond increased the elevations of the embankments and reduced the footprint of the active impoundment (AECOM, 2016a). CCR material remains between the rail loop and the berm at the south end of the Ash Pond. High power transmission lines bisect the Ash Pond and two sub-basins, referred to as the North and South Ponds, were established. The sub-basins are hydraulically connected and CCR placement is continuous throughout the Ash Pond.

The Ash Pond has a surface area of approximately 91 acres with berms up to 27 feet higher than the surrounding land surface. This pond currently discharges to the Illinois River through Outfall 001 included in the facility NPDES permit, IL0001970. The primary treatment method for the pond water is settlement via reduced velocity whereby solids settle out in various flow channels and in the main South Pond. The permitted total average daily flow is 5.24 million gallons per day (MGD) (Foth, 2017).

2. SITE GEOLOGY AND HYDROGEOLOGY

Ash Pond hydrogeologic and groundwater quality data presented in the HCR (Ramboll, 2021a) was used to establish a conceptual site model (CSM) for this GMR, and is summarized below. The EPP and embankments surrounding the Ash Pond are located at an elevation of approximately 460 feet NAVD88 (**Figure 2-1**). Topographic maps drawn prior to construction indicate the areas of the Ash Pond were generally between 435 and 440 feet National Geodetic Vertical Datum (NGVD29), except for a historic drainage feature or former river channel located in the western portion of the Ash Pond, which has an elevation of approximately 430 feet NGVD29 (Appendix A of the HCR). The areas surrounding the EPP are generally at an elevation of around 435 to 440 feet NVGD29. West of the Ash Pond (across Highway 24), the elevation increases to approximately 600 feet NGVD29 (**Figure 1-1**), where bedrock outcrops are present near the surface at the edge of the former historic Illinois River valley.

There are three principal types of unlithified materials above the bedrock in the vicinity of the Ash Pond, these include the following in descending order: Fill, predominantly coal ash (fly ash, bottom ash, and slag) within the Ash Pond, and materials within constructed berms and railroad embankments, are present around the Ash Pond; UCF (fine-grained deposits of the Cahokia Formation ranging in thickness at the Ash Pond from 5 to 40 feet); and Lower Cahokia Formation (course-grained deposits of the Cahokia Formation consisting of sands and gravels ranging in thickness at the Ash Pond from 1 to 4 feet). Depth to bedrock at the Ash Pond ranges from approximately 20 feet in the north to 58 feet in the southwest.

Four distinct water-bearing units have been identified in the vicinity of the Ash Pond based on stratigraphic relationships and common hydrogeologic characteristics. The units are described as follows from the surface downward:

- **CCR:** Saturated CCR consisting primarily of fly ash within the Ash Pond. CCR is present at thicknesses up to 46.5 feet and at elevations as low as 413.9 feet NAVD88 in the central and northern portion of the Ash Pond**.**
- **UCF/ PMP:** Low permeability clays and silts of the UCF are present at the surface. This unit is considered a PMP at elevations similar to the base of the Ash Pond, and in places where thin discontinuous sand lenses occur within the UCF adjacent to the Ash Pond.
- **UA:** Thin (generally less than 4 feet), moderate permeability sand, silty sand, and clayey gravel material within the Lower Cahokia Formation, bedrock, and/or weathered shale bedrock, where present. In locations where higher permeability materials and coarser grained material are absent, the UA is interpreted as the interface between the Lower Cahokia Formation and shale bedrock.
- **BCU:** Thick, very low permeability shales and siltstones of the Carbondale and Modesto Formations. This unit was encountered at elevations ranging from approximately 400 to 422 feet NAVD88 with higher bedrock elevations occurring beneath the northern portion of the Ash Pond.

In general, the UCF consists of low permeability clays and silts, with limited occurrences of thin discontinuous sand lenses. Occasional sand lenses within the UCF, and clay intervals downgradient at elevations similar to the base of ash in the Ash Pond were identified as PMPs. In several locations, generally near the southern and western portions of the Ash Pond, coarser grained materials are present at the base of the Lower Cahokia Formation and/or the top of the bedrock is weathered resulting in relatively higher hydraulic conductivities. Because the interface is laterally continuous, and has relatively higher conductivity, the unlithified/lithified contact was designated as the UA.

The underlying bedrock is interpreted as the lower confining unit and has hydraulic conductivities generally an order of magnitude less than those measured in the UA. Groundwater occurs within both the unlithified materials and bedrock and consistently flows east to west in the UA (**Figure 2-2** and **Figure 2-3**). In the northernmost portion of the Ash Pond there is a minor northwest and northern component of flow in both the UA and PMP. In the southern portion of the Ash Pond, groundwater flow has a southerly component of flow towards what is interpreted as a former channel of the Illinois River. Groundwater elevations vary seasonally, generally less than 5 feet, while across the site they range between approximately 430 and 450 feet, although flow directions are generally consistent. Additional groundwater contour maps are located in Appendix E of the HCR (Ramboll, 2021a).

Groundwater elevations in PMP wells range from approximately 455 feet NAVD88 (APW-02) to 430 feet NAVD88 (AW-15S) with flow generally from the east to the south and northwest (**Figure 2-2** and **Figure 2-3**), similar to that observed in the UA. Groundwater elevations measured at APW02 are similar to CCR piezometers and the location of the well (within the berm of the unit) may be affected by water elevations in the active Ash Pond. Given the elevations of groundwater detected in these unconfined wells and the lowest elevation of ash (414 feet NAVD88), portions of the Ash Pond are likely in contact with groundwater. Comparison of elevations in bedrock wells shows flow directions may be consistent with shallower flow systems.

Groundwater velocities in the UA determined in the center portion of the Ash Pond (between AW-08 and AW-06) ranged from approximately 1.7×10^{-4} to 4.0×10^{-4} feet per day (ft/day) in 2021 with an average of 2.5×10^{-4} ft/day. Groundwater velocities determined in the southern portion of the Ash Pond between AW-10 and AW-15 were consistent with an average of 0.26 ft/day. The higher velocities observed in the southern portion of the Ash Pond are a result of coarse-grained materials present there.

The results of a recent review of available offsite groundwater level and flow direction data completed after submittal of the HCR (Ramboll, 2021a) and presented herein supports the CSM presented in the HCR (summarized above) and further describes offsite hydrogeologic conditions. The existing CSM has been refined in this GMR to incorporate additional offsite hydrogeologic information as follows:

- The unlithified/lithified contact designated as the UA onsite may be hydraulically connected to the sands of the Sankoty Aquifer identified offsite and utilized for potable supply in Peoria, East Peoria, and Pekin.
- The thick sand and gravels along the Illinois River from Hennepin to Peoria form what has been commonly referred to as the Sankoty Aquifer. The Sankoty sand and gravels are hydrologically connected to the Illinois River and are a productive aquifer in the Middle Illinois water supply planning (Illinois State Water Survey [ISWS], 2016). At the EPP, the thick sands and gravels of the Sankoty Aquifer are absent. Fine-grained quaternary deposits of the Cahokia Formation are present from ground surface to the top of bedrock. The UA at the EPP represents the most permeable material present above bedrock. Alluvial deposits belonging to either the Cahokia or the Sankoty are present in a north-south orientation along the Illinois

River at the EPP and are not expected to occur in the areas west of United States (US) Highway 24 where the bedrock elevation increases above ground surface at the EPP. US Highway 24 runs along the base of the bluff and areas west of US Highway 24 are coincident with areas where the aquifer is not present as illustrated in Figure 5 of Burch and Kelly, 1993 (**Appendix B**).

- Offsite groundwater in the Sankoty Aquifer flows to the north and south towards identified Peoria and Pekin pumping centers, respectively, as illustrated in Figure 5 and Figure 6 of Burch and Kelly, 1993 (**Appendix B**). As reported by Burch and Kelly (1993), "*Smaller flow domains are sometimes formed by pumpage at municipal well fields, which reverse the ground-water flow direction and frequently capture induced recharge from the river and the ground-water ordinarily moving toward it*."
- A review of pumping data for Peoria (ISWS, 2018) indicates that between 1990 and 2010 potable groundwater supply usage increased approximately three percent, while East Peoria and Pekin estimates (Wittman Hydro Planning Associates, Inc. [Wittman], 2008) indicate an increase of 30 and 60 percent, respectively, between 1990 and 2005. Based on these references and IEPA databases (IEPA, 2022) Peoria and Pekin pumping centers identified in the 1993 ISWS Peoria-Pekin Regional Ground-Water Quality Assessment report (Burch and Kelly, 1993) remain active. The increase in reported usage in conjunction with historic records and reports (Burch and Kelley, 1993) indicate high-capacity wells located in Peoria and Pekin continue to influence groundwater flow directions towards their respective pumping centers.

Prior to 2015, there were four monitoring wells (APW-01 through APW-04) located around the Ash Pond for monitoring groundwater. In 2015 and 2017, additional wells and piezometers were installed within and around the Ash Pond to meet requirements of 40 C.F.R. § 257. In 2021, additional wells were installed to provide information to meet the requirements of Part 845. A summary of monitoring well locations and construction details are included in **Table 2-1** and depicted on **Figure 2-4**. Boring logs, monitoring well and piezometer construction forms are provided in Appendix C of the HCR (Ramboll, 2021a).

3. GROUNDWATER QUALITY

Per 35 I.A.C. § 620.210, groundwater within the UA at the Ash Pond meets the definition of a Class I – Potable Resource Groundwater based on the following criteria:

- Groundwater in the UA extends 10 feet or more below the land surface.
- Hydraulic conductivity exceeds the 1 x 10^{-4} centimeters per second (cm/s) criterion (Table 3-3 of the HCR; Ramboll, 2021a).

Field hydraulic conductivity tests performed on the unlithified geologic materials that include moderate permeability sand, silty sand, and clayey gravel units which includes the Lower Cahokia Formation and the bedrock interface) and lithified materials (shales and siltstones of the Carbondale and Modesto Formations) at the EPP had geometric mean hydraulic conductivities exceeding 1 x 10^{-4} cm/s. Based on this information groundwater is classified as Class I – Potable Resource Groundwater.

A review and summary of data collected from 2015 through 2021 for parameters with GWPSs listed in 35 I.A.C. § 845.600 is provided in the HCR (Ramboll, 2021a). Concentration results presented in the HCR were compared directly to 35 I.A.C. § 845.600 GWPSs to determine potential exceedances. The results are considered potential exceedances because the results were compared directly to the standard and did not include an evaluation of background groundwater quality or utilize the statistical methodologies proposed in the groundwater monitoring plan (GMP; Ramboll, 2021c) attached to the operating permit application.

Groundwater concentrations from 2015 to 2021 are summarized in the History of Potential Exceedances (Ramboll, 2021b) (attached to the operating permit application) and are considered potential exceedances because the methodology used to determine them is proposed in the Statistical Analysis Plan (Appendix A to the GMP, Ramboll 2021c), which has not been reviewed or approved by IEPA at the time of submittal of the Part 845 operating permit application.

The History of Potential Exceedances attached to the operating permit application summarizes all potential groundwater exceedances following the proposed Statistical Analysis Plan. The following potential exceedances were identified:

- Barium – determined at well AW-15C
- Boron – determined at wells AP07S, AW-05, AW-15S, AW-19, AW-20, and AW-21
- Chloride – determined at wells AP07D
- Lithium – determined at wells AP05D and AP07D
- Sulfate – determined at well AW-15S
- TDS – determined at wells AP07S and AW-15S

A Technical Memorandum (**Attachment A**) was prepared by Golder (2022), *Evaluation of Potential GWPS Exceedances, Edwards Ash Pond [CCR Unit 301], Edwards Power Plant, Peoria County, Illinois*, to further evaluate potential GWPS exceedances. The results of the evaluation demonstrated that the potential GWPS exceedances of lithium in well AP05D and AP07D, chloride in well AP07D and barium in well AW-15C are not related to the Ash Pond based on several lines of evidence presented in the Technical Memorandum. Since potential GWPS exceedances for lithium, chloride, and barium are not related to the Ash Pond, these parameters will not be discussed further in this GMR.

4. GROUNDWATER MODEL

4.1 Overview

Data collected from previous field investigations, as well as the 2021 field investigations, were used to develop a groundwater model for the Ash Pond. The MODFLOW and MT3DMS models were then used to evaluate two closure scenarios, including CCR consolidation and CIP using information provided in the Draft CCR Final Closure Plan (IngenAE, 2022), and CBR scenarios. The results of the CIP and CBR closure scenarios are summarized and evaluated in this GMR. Associated model files are included as **Appendix C.**

4.2 Conceptual Site Model

The HCR (Ramboll, 2021a) is the foundation document for the site setting and CSM that describes groundwater flow at the Site, which was refined to incorporate additional offsite hydrogeologic information summarized in Section 2 of this GMR. The Ash Pond overlies the recharge area for the underlying geologic media (*i.e.*, low permeability clays and silts of the UCF; and moderate permeability sand, silty sand, and clayey gravel material within the Lower Cahokia Formation, bedrock, and/or weathered shale bedrock, where present [UA]). Groundwater enters the model domain vertically via recharge. Groundwater may also enter or exit the model through the stormwater drainage ditches and ponds identified immediately west and north of the Ash Pond, or the Illinois River located east of the Ash Pond. Groundwater occurs within both the unlithified materials and bedrock and consistently flows east to west in the UA. In the northernmost portion of the Ash Pond, there is a minor northwest and northern component of flow in both the UA and PMP. In the southern portion of the Ash Pond groundwater flow has a southerly component of flow towards what is interpreted as a former channel of the Illinois River. Offsite groundwater in the Sankoty Aquifer flows to the north and south towards identified Peoria and Pekin pumping centers, respectively.

Boron was selected for transport modeling. Boron is commonly used as an indicator parameter for contaminant transport modeling for CCR because: (i) it is commonly present in coal ash leachate; (ii) it is mobile and typically not very reactive but conservative (*i.e.*, low rates of sorption or degradation) in groundwater; and (iii) it is less likely than other constituents to be present in background groundwater from natural or other anthropogenic sources. The only significant source of boron is the Ash Pond. The Ash Pond is constructed over low permeability clays and silts of the UCF. Mass (boron) is added to groundwater via vertical recharge through CCR, and horizontal groundwater flow through CCR where it is in contact with the water table. Mass flows with groundwater (onsite and offsite groundwater flow directions described above). The primary transport pathway is the UA, as indicated by groundwater observations. The UCF is also a PMP at elevations similar to the base of the Ash Pond, and in places where thin discontinuous sand lenses occur within the UCF adjacent to the Ash Pond.

4.3 Model Approach

Comparisons of observed sulfate and TDS concentrations to boron (**Figure A** and **Figure B**, respectively, below) indicate statistically significant correlations between these parameters at UCF and UA wells. Observed concentrations were transformed into Log10 concentrations for evaluation. The correlation coefficient (R2) and p values (indicator of statistical significance) are also provided on **Figure A** and **Figure B**. Higher R2 values (*i.e.*, closer to 1) indicate stronger correlation between parameters. A correlation is considered statistically significant when the probability (p) value is lower than 0.05. Both correlations have p values less than the target of 0.05, indicating correlations are statistically significant. The correlations are strongest between sulfate and boron. The statistically significant correlations associated with boron concentrations indicate boron is an acceptable surrogate for sulfate and TDS in the groundwater model, and concentrations of these parameters are expected to change along with model predicted boron concentrations.

Figure A. Boron Correlation with Sulfate in UCF and UA Wells

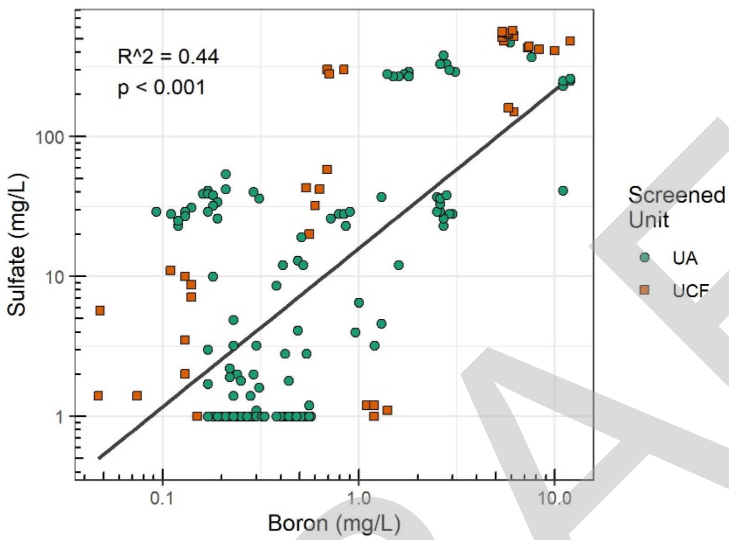
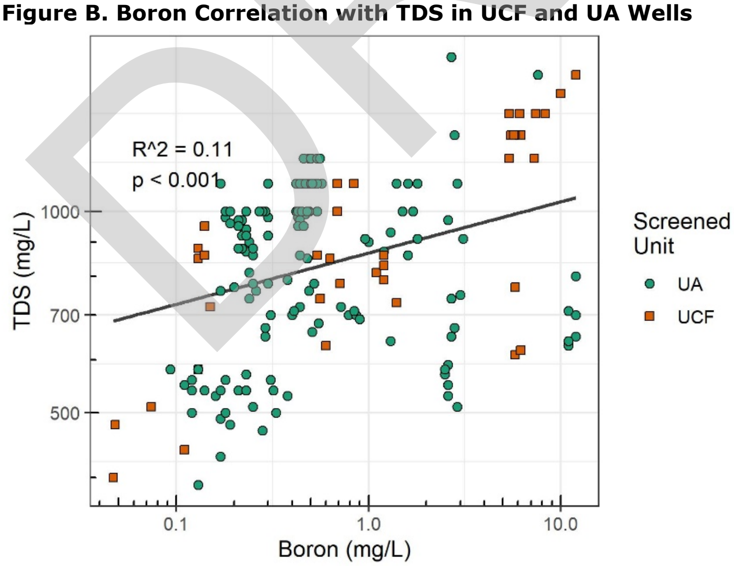


Figure B. Boron Correlation with TDS in UCF and UA Wells



A three-dimensional groundwater flow and transport model was calibrated to represent the conceptual flow system described above. Initial modeling was performed for a 62-year period to represent boron concentrations for site conditions in 2022, 62 years following construction of the Ash Pond in 1960. The model was calibrated to match groundwater elevation and concentration observed at each monitoring well. Prediction simulations were then performed to evaluate the effects of CIP and CBR closure scenarios for the Ash Pond on groundwater quality for a period of 1,000 years following initial corrective action measures, which include dewatering of the Ash Pond (1-year period), consolidation of CCR and cover system construction or removal of CCR. The calibration and prediction model timelines are illustrated in **Figure 4-1**.

Three model codes were used to simulate groundwater flow and contaminant transport:

- Groundwater flow was modeled in three dimensions using MODFLOW 2005
- Contaminant transport was modeled in three dimensions using MT3DMS
- Percolation (recharge) after consolidation of CCR and cover system construction was modeled using the results of the Hydrologic Evaluation of Landfill Performance (HELP) model.

5. MODEL SETUP AND CALIBRATION

5.1 Model Descriptions

For the construction and calibration of the numerical groundwater flow model for the site, Ramboll selected the model code MODFLOW, a publicly available groundwater flow simulation program developed by the United States Geological Survey (USGS) (McDonald and Harbaugh, 1988). MODFLOW is thoroughly documented, widely used by consultants, government agencies and researchers, and is consistently accepted in regulatory and litigation proceedings. MODFLOW uses a finite difference approximation to solve a three-dimensional head distribution in a transient, multi-layer, heterogeneous, anisotropic, variable-gradient, variable-thickness, confined or unconfined flow system—given user-supplied inputs of hydraulic conductivity, aquifer/layer thickness, recharge, wells, and boundary conditions. The program also calculates water balance at wells, rivers, and drains.

Major assumptions of the MODFLOW code are: (i) groundwater flow is governed by Darcy's law; (ii) the formation behaves as a continuous porous medium; (iii) flow is not affected by chemical, temperature, or density gradients; and (iv) hydraulic properties are constant within a grid cell. Other assumptions concerning the finite difference equation can be found in McDonald and Harbaugh (1988). MODFLOW 2005 was used for these simulations with Groundwater Vistas 7 software for model pre- and post- processing tasks (Environmental Simulations, Inc., 2017).

MT3DMS (Zheng and Wang, 1998) is an update of MT3D. It calculates concentration distribution for a single dissolved solute as a function of time and space. Concentration is distributed over a three-dimensional, non-uniform, transient flow field. Solute mass may be input at discrete points (wells, drains, river nodes, constant head cells), or distributed evenly or unevenly over the land surface (recharge).

MT3DMS accounts for advection, dispersion, diffusion, first-order decay, and sorption. Sorption can be calculated using linear, Freundlich, or Langmuir isotherms. First-order decay terms may be differentiated for the adsorbed and dissolved phases.

The program uses the standard finite difference method, the particle-tracking-based Eulerian-Lagrangian methods, and the higher-order finite-volume total-variation-diminishing (TVD) method for the solution schemes. The finite difference solution has numerical dispersion for low-dispersivity transport scenarios but conserves good mass balance. The particle-tracking method avoids numerical dispersion but was not accurate in conserving mass. The TVD solution is not subject to significant numerical distribution and adequately conserves mass, but is numerically intensive, particularly for long-term models such as developed for the Ash Pond. The finite difference solution was used for this simulation.

Major assumptions of MT3DMS are: (i) changes in the concentration field do not affect the flow field; (ii) changes in the concentration of one solute do not affect the concentration of another solute; (iii) chemical and hydraulic properties are constant within a grid cell; and (iv) sorption is instantaneous and fully reversible, while decay is not reversible.

The HELP model was developed by the United States Environmental Protection Agency (USEPA). HELP is a one-dimensional hydrologic model of water movement across, into, through, and out of a landfill or soil column based on precipitation, evapotranspiration, runoff, and the geometry and hydrogeologic properties of a layered soil and waste profile. For this modeling, results of the HELP model, HELP Version 4.0 (Tolaymat and Krause, 2020), were used to estimate the hydraulic conditions beneath removal and consolidation areas.

5.2 Flow and Transport Model Setup

The modeled area was approximately 15,975 feet (478 rows) by 9,500 feet (334 columns) with the Ash Pond located in the west-central portion of the model. The eastern edge of the model is bounded by the Illinois River. The north, west, and south edges of the model were selected to maintain sufficient distance from the Ash Pond to reduce boundary interference with model calculations, while not extending too far past the extent of available calibration data. The northwest edge of the model is defined by the edge of the former historic Illinois River valley, where the elevation increases to approximately 600 feet NGVD29, and bedrock outcrops or is present near the surface (across Highway 24). The model grid and boundary conditions are displayed in **Figure 5-1 through Figure 5-6**.

Evaluation of monitoring well data for the Ash Pond has not identified statistically significant seasonal trends in groundwater quality which could affect model applicability for prediction of boron transport. The MODFLOW model was calibrated to mean groundwater elevation collected from November 2015 to August 2021 presented in **Table 2-2**. MT3DMS was run on the calibrated flow model and model-simulated concentrations were calibrated to the range of observed boron concentration values at the monitoring wells from November 2015 to August 2021 presented in **Table 2-2**. Multiple iterations of MODFLOW and MT3DMS calibration were performed to achieve an acceptable match to observed flow and transport data. For the Ash Pond, the calibrated flow and transport models were used in predictive modeling to evaluate the CIP and CBR closure scenarios by removing saturated ash cells and using HELP modeled recharge values to simulate changes proposed in the closure scenarios.

5.2.1 Grid and Boundary Conditions

A five-layer, 478 x 334 node grid was established with 25-foot grid spacing in the vicinity of the Ash Pond and EPP property. The grid increases gradually to a maximum 225-foot row spacing and 112.5-foot column spacing near the edges of the model (**Figure 5-1**). Boundary conditions are illustrated in **Figure 5-2 through Figure 5-6**. The northwest and eastern edges of the model are no-flow (Neumann) boundaries in all layers of the model with the exceptions of the eastern edge in Layer 3, where a river (Mixed) boundary was placed to simulate the mean flow conditions of the Illinois River, and the north and southeast edges in layer 4, where a general head (Dirichlet) boundary (denoted as general head boundary conditions [GHB] on the figure) was placed to simulate the influence of pumping centers located in Peoria and Pekin on groundwater flow direction. The bottom of the model was also a no-flow (Neumann) boundary. The top of the model was a time-dependent specified flux (Neumann) boundary, with specified flux rates equal to the recharge rate. A specified mass flux (Cauchy condition) boundary was used to simulate downward percolation of solute mass from the Ash Pond. This boundary condition assigns a specified concentration to recharge water entering the node, and the resulting concentration in the node is a function of the relative rate and concentration of recharge water (water percolating from the impoundment) compared to the rate and concentration of other water entering the node.

5.2.2 Flow Model Input Values and Sensitivity

Flow model input values and sensitivity analyses results are presented in **Table 5-1** and described below.

The modeled well location layers and flow model calibration targets (*i.e.*, mean groundwater elevations from November 2015 to August 2021 and target well locations) are summarized in **Table 2-2**. Anomalous groundwater elevations (*e.g.,* groundwater elevations that do not represent static groundwater conditions or groundwater elevations measured in error) monitored between November 2015 and August 2021 were removed from the mean groundwater calculations used as flow calibration targets at wells AP05D, AP07D, APW-02, APW-03, AW-08, and AW-14. Wells APW-02, AW-18, AW-19, AW-20, AW-21, AW-22, and P002 are hydraulically connected to multiple hydrostratigraphic units (*i.e.,* modeled layers) and/or screened across multiple hydrostratigraphic units (*i.e.,* modeled layers). In the flow calibration model, flow calibration targets for wells APW-02, AW-18, AW-19, AW-20, AW-21, AW-22, and P002 were placed in model layers that exhibited heads more representative of the groundwater observations in these wells.

Sensitivity analysis was conducted by changing input values and observing changes in the sum of squared residuals (SSR). Horizontal conductivity, vertical conductivity, and river and general head conductance terms were all varied between one-tenth and ten times calibrated values. Recharge terms were varied between one-half and two times calibrated values. River stage for river reach 1 and general head boundary head terms were varied between 98.5 and 101.5 percent of calibrated values. River stage for river reaches 2 through 4 were varied between 99.5 and 100.5 percent of calibrated values. When the calibrated model was tested, SSR was 374.3. Sensitivity test results were categorized into negligible, low, moderate, moderately high, and high sensitivity based on the change in SSR as summarized in the notes in **Table 5-1**.

5.2.2.1 Model Layers

The bottom elevation of the BCU in layer 5 was flat lying and assumed to be an elevation of 200 feet NAVD88. All available boring log data included in the HCR (Ramboll, 2021a) was used to develop surfaces utilizing Surfer® software for each of the four distinct water-bearing units described in **Section 2**. The modeled UCF was split into three modeled layers, where model layer 1 represented the upper clay of the UCF, model layer 2 represented a transmissive zone within the UCF (this unit is considered a PMP at elevations similar to the base of the Ash Pond, and in places where thin discontinuous sand lenses occur within the UCF adjacent to the Ash Pond), and model layer 3 represented the lower clay of the UCF. Model layer 4 represented the UA onsite, as well as the hydraulically connected sands of the Sankoty Aquifer identified offsite. Model layer 5 represented the BCU. The approximate base of ash surface in the Ash Pond was developed from information presented in the HCR (Ramboll, 2021a) and confirmed with IngenAE. The CCR was modeled in layers 1 and 2 within the limits of the Ash Pond, where the base of layer 2 within the limits of the Ash Pond was consistent with the base of ash surface. The resulting surfaces were imported as layers into the model to represent the distribution and change in thickness of each water-bearing unit across the model domain.

5.2.2.2 Hydraulic Conductivity

Hydraulic conductivity values and sensitivity results are summarized in **Table 5-1**. When available, these values were derived from field or laboratory measured values reported in the

Geotechnical Data Report (AECOM, 2016b), Hydrogeologic Monitoring Plan (Natural Resource Technology, an OBG Company [NRT/OBG], 2017), Technical Memorandum: Ash Pond – Underlying Clay and Depth of CCR Evaluation (Haley & Aldrich, Inc., 2018), and Hydrogeologic Site Characterization Report (Ramboll, 2021a), to be representative of site-specific conditions. The sources of the hydraulic conductivity values are summarized in **Table 5-1**. Conductivity zones that did not have representative site data (*i.e.,* zones 7 and 9, representing the cells above the river cells and the Sankoty Aquifer, respectively) were determined through model calibration. No horizontal anisotropy was assumed. Vertical anisotropy (presented as Kh/Kv in **Table 5-1**) was applied to conductivity zones to simulate preferential flow in the horizontal direction in these materials. Permeability tests discussed in the Geotechnical Data Report (AECOM, 2016b), 2017 Hydrogeologic Monitoring Plan (NRT/OBG, 2017), Technical Memorandum: Ash Pond – Underlying Clay and Depth of CCR Evaluation (Haley & Aldrich, Inc., 2018), and 2021 Hydrogeologic Characterization Report (Ramboll, 2021a) indicate vertical conductivity values that are lower than horizontal conductivity values.

The spatial distribution of the hydraulic conductivity zones (**Figure 5-7 through Figure 5-11**) in each layer simulates the distribution of hydrostratigraphic units as reported in the HCR (Ramboll, 2021a). All hydraulic conductivity zones were laterally continuous within the model with the exception of the Fill Unit (CCR) hydraulic conductivity zone (zone 6), the Weathered Shale (UA) hydraulic conductivity zone (zone 4), and the Sankoty Aquifer hydraulic conductivity (zone 9). The limits of the ash fill were determined from data presented in the HCR (Ramboll, 2021a) and confirmed with IngenAE. The ash fill extent was propagated through all related ash fill property zones and boundary conditions (*i.e.*, recharge, storage, effective porosity, and constant concentration cells). The extent of the Weathered Shale (UA) hydraulic conductivity zone and Sankoty Aquifer hydraulic conductivity zone offsite in model layer 4 was determined through a review of available offsite water well boring logs and through calibration. Conductivity zone 7 was also placed above river cells representing the Illinois River to improve communication between the river and the groundwater in layers above the layer in which the river was placed.

The model was highly sensitive to changes in horizontal conductivity in zones 2 (Transmissive Zone [UCF/PMP]), 4 (Weathered Shale [UA]), 6 (Fill Unit [CCR]), and 9 (Sankoty Aquifer - Sands), where the model was moderately sensitive to horizontal conductivity in the remaining hydrostratigraphic units and low in zone 1 (Upper Clay [UCF]). The model was highly sensitive to changes in vertical conductivity in zone 1 (Upper Clay [UCF]) and zone 3 (Lower Clay [UCF]), while the model exhibited a negligible to moderate sensitivity in the remaining zones.

5.2.2.3 Recharge

Recharge rates were determined through calibration of the model to the groundwater elevation and groundwater quality data collected from November 2015 to August 2021 (**Table 5-1**). The spatial distribution of recharge zones were based on the location and type of material present at land surface (**Figure 5-12**). Six different zones were created to simulate recharge in the model area. One zone (zone 1) was used to simulate ambient recharge over the upper clay of the UCF outside the limits of the Ash Pond. The recharge occurring through the ash fill placed in the Ash Pond was split into five different values, where recharge was varied based upon the historical use of each ash fill area (AECOM, 2016a) and the response of flow calibration target heads. Zones 2, 3, 4, 5, and 7 represent recharge in the Ash Pond area. The greatest recharge in the model was simulated in an area on the northeast edge of the pond where the fill materials are sluiced into the Ash Pond (zone 7) and the greatest heads were observed. The remaining ash fill areas (recharge zones) are listed in order of greatest to least simulated recharge along with their historical use based on the history of construction (AECOM, 2016a): central area (zone 2, Fly Ash Pond), northwest area (zone 4, Process Water Pond), south area (zone 5, Clarification Pond), and south of railroad area (zone 3, Inactive Area). The area south of the railroad (zone 3) was simulated to have recharge values near ambient recharge as a result of the 2004 modifications to the rail loop surrounding the Ash Pond which increased the elevations of the embankments and reduced the footprint of the active impoundment (AECOM, 2016a).

The model had a high sensitivity to changes in recharge in zones 1 (Upper Clay [UCF]), 2 (Fill Unit – CCR [Central, Fly Ash Pond]), and 7 (Fill Unit - CCR [Northeast, Sluice Area]). The model had negligible to moderate sensitivity to changes in recharge in the remaining zones, with the exception of zone 4 (Fill Unit – CCR [Northwest, Process Water Pond), where sensitivity was moderately high.

5.2.2.4 Storage and Specific Yield

The calibration model did not use these terms because it was run at steady state. For the transport model, which was run in transient, no field data defining these terms were available so published values were used consistent with Fetter (1988). Specific yield (S_Y) was set to equal effective porosity values described in **Section 5.2.3.3**. The spatial distribution of the storage and specific yield zones were consistent with those of the hydraulic conductivity zones. The sensitivity of these parameters was tested by evaluating their effect on the transport model as described in **Section 5.2.3.4**.

5.2.2.5 River Parameters

The Illinois River was simulated using head-dependent flux nodes in modeled river reach 1 that required inputs for river stage, width, bed thickness, and bed hydraulic conductivity (**Table 5-1**). River width, bed thickness, and bed hydraulic conductivity parameters were used to calculate a conductance term for the boundary node. This conductance term was determined by adjusting hydraulic conductivity during model calibration, while bed thickness was set at 1 foot and river width was set at 750 feet. Final hydraulic conductivity value was set at 1 ft/day. The length of the modeled river extends from the northernmost extent of the model domain to the southernmost extent of the model domain using river reach 1. The modeled river stage in the calibration model was based on available Illinois River stage data at Peoria, Illinois (United States Army Corps of Engineers [USACE] 404208089335201 Illinois River at Peoria, Illinois [Corps]), Edwards Power Plant (Plant Gaging Station), and Kingston, Illinois (USGS 05568500 Illinois River at Kingston Mines, Illinois) gaging stations. The river boundary was placed in layer 3 corresponding with simulated river elevation (**Figure 5-4**).

A median slope was calculated from available data at upstream Peoria, Illinois gaging station (USACE 404208089335201 Illinois River at Peoria, Illinois [Corps]) and downstream Kingston, Illinois gaging station (USGS 05568500 Illinois River at Kingston Mines, Illinois). The mean river stage was then calculated based upon available gage data (hourly data from October 2007 to January 2022) of the Illinois River from Kingston, Illinois (USGS 05568500 Illinois River at Kingston Mines, Illinois) gaging station. The calculated median slope along with the mean river stage at Kingston, Illinois was used to interpolate the mean river stage throughout the model domain. The interpolated mean value near the EPP was confirmed to be within the range of observations at EPP gaging station.

The drainage ditch, bordering the western edge of the Ash Pond and continuing south to the Illinois River, was simulated using head dependent flux nodes in modeled river reach 2 (**Table 5-1**). The conductance term was determined by adjusting hydraulic conductivity during model calibration, while bed thickness was set at 1 foot and river width was set at 20 feet. Final hydraulic conductivity value was set at 0.00001 ft/day to reflect the low vertical hydraulic conductivity of the underlying UCF material. The drainage ditch stage was based on the mean drainage ditch water surface elevation from survey data collected by IngenAE in February 2022. The drainage ditch modeled river reach 2 was placed in layer 1. A second drainage feature, the drainage swale (reach 3) to the north of the Ash Pond had similar input parameters, however the river width was set to 25 and simulated river stage had a slightly lower elevation based on survey data collected by IngenAE in February 2022. A third drainage feature, the drainage pond (reach 4) to the northeast of the Ash Pond had similar input parameters; however, the river stage had a slightly higher elevation based on survey data collected by IngenAE in February 2022. River reaches 3 through 4 were also placed in layer 1.

The model had negligible to low sensitivity to changes in river stage, with the exception of reach 1 (Illinois River), where the sensitivity was moderate. The model had negligible to low sensitivity to changes in river conductance, with the exception of reach 2 (Drainage Ditch West of Ash Pond), where the sensitivity was moderate.

5.2.2.6 General Head Boundary Parameters

GHB were used along the north edge of the model as well as along the southeast edge of the model in layer 4 (**Figure 5-5**). The GHB at the northern limit of the model (reach 1) was used to simulate groundwater flow leaving the model domain in the Sankoty Aquifer due to the influence of pumping centers in Peoria. GHB elevation, conductance, and distance were established during calibration (**Table 5-1**). GHB cell width was set at 150 feet, distance to the GHB head was set at 1 foot, and average saturated thickness of the cell was set at 100 feet. Final hydraulic conductivity value was set at 100 ft/day to be similar in magnitude to the horizontal conductivity of the permeable sands. The GHB at the southeastern limit of the model (reach 1) was used to simulate groundwater flow leaving the model domain in the Sankoty Aquifer due to the influence of pumping centers in Pekin. GHB elevation, conductance, and distance were established during calibration (**Table 5-1**). GHB cell width was set at 750 feet, distance to the GHB head was set at 1 foot, and average saturated thickness of the cell was set at 39 feet. Final hydraulic conductivity value was set at 100 ft/day to be similar in magnitude to the horizontal hydraulic conductivity of the permeable sands. The GHB at the north edge of the model (reach 1) and the southeast edge of the model (reach 1) were placed in layer 4 with a constant elevation of 426 feet NAVD88. The sensitivity to changes in specified head was high for reach 1. The flow calibration model had a negligible sensitivity to changes in conductance.

5.2.3 Transport Model Input Values and Sensitivity

MT3DMS input values are listed in **Table 5-2** and described below. Sensitivity of the transport model is summarized in **Table 5-3**.

Groundwater transport was calibrated to groundwater boron concentration ranges at each well as measured from the monitoring wells between November 2015 and August 2021. The transport model calibration targets are summarized in **Table 2-2**.

Sensitivity analysis was conducted by changing input values and observing percent change in boron concentration at each well from the calibrated model boron concentration. Effective porosity was varied by decreasing and increasing calibrated model values by 0.05. Storage values were multiplied and divided by a factor of 10, and specific yield by a factor of 2. High specific yield sensitivity was not analyzed for zone 8 (UCF above River Boundary Conditions) since the calibration value was already near upper limits of acceptable values for specific yield (0.5).

5.2.3.1 Initial Concentrations

No initial concentrations were placed in the calibration model. The flow model was run as transient and concentration was added to the model through recharge and constant concentration cells starting at the same time as flow simulation. Modeling was performed for two stress periods, where the first stress period (stress period 1) started at the time of Ash Pond construction (1960) and ended in 2004 (44-year stress period) when modifications to the rail loop surrounding the Ash Pond increased the elevations of the embankments and reduced the footprint of the active impoundment (AECOM, 2016a). The second stress period (stress period 2) started in 2005 following the Ash Pond modifications and included reduced recharge in the ash fill area south of the railroad (recharge zone 3) to simulate the reduced activity in this area of the pond. The second stress period ended in 2022 (18-year stress period). The transport model timeline is illustrated in **Figure 4-1**.

5.2.3.2 Source Concentrations

Five concentration sources in the form of vertical percolation (recharge) through CCR were simulated in fill unit layer 1 for calibration (**Table 5-2**) (in order of greatest to least simulated recharge): (i) percolation through CCR in the northeast edge of the pond where the fill materials are sluiced into the Ash Pond (zone 7, Sluice Area), (ii) percolation through CCR in the central area (zone 2, Fly Ash Pond), (iii) percolation through CCR in the northwest area (zone 4, Process Water Pond), (iv) percolation through CCR in the south area (zone 5, Clarification Pond), and (v) percolation through CCR south of railroad (zone 3, Inactive Area)(**Figure 5-12**). All five sources were simulated by assigning concentration to the recharge input. The CCR sources were also simulated with constant concentration cells placed in fill unit layer 1 and layer 2 (**Figure 5-2** and **Figure 5-3**) to simulate saturated ash conditions. From the model perspective, this means that when the simulated water level is above the base of these cells, water that passes through the cell will take on the assigned concentration. All source concentrations were calibrated in the transport model to the boron concentration data collected from November 2015 to August 2021. The source concentrations applied to the recharge zones and saturated ash cells immediately below the recharge zones have the same concentration values.

Because these are the sources of concentration in the model, the model will be highly sensitive to changes in the input values. For that reason, sensitivity testing was not completed for the source values.

5.2.3.3 Effective Porosity

Effective porosity for each modeled hydrostratigraphic unit were derived from an average between estimated values of 0.20 for silt material, 0.267 for gravel, 0.07 for clay, and 0.28 for sand from Morris and Johnson (1967) and Heath (1983) and presented in **Table 5-2**.

The model had a negligible to moderately high sensitivity to decreases in porosity values, with the exception of four monitoring locations where sensitivity was high (*i.e.,* APW-01, APW-04, AW-05, and AW-12) and not including monitoring locations where the calibration concentration was less than 0.1 mg/L (*i.e.*, AP05S, AP05D, AP07D, AW-06, AW-08, and AW-15C) (**Table 5-3**). The model had a negligible to moderate sensitivity to increases in porosity values, not including monitoring locations where the calibration concentration was less than 0.1 mg/L (*i.e.*, AP05S, AP05D, AP07D, APW-01, APW-04, AW-06, AW-08, AW-12, and AW-15C) (**Table 5-3**).

5.2.3.4 Storage and Specific Yield Sensitivity

The transport model had a negligible to low sensitivity to changes in storage and specific yield, with the exception of sensitivity at monitoring wells AP05S, AP05D, APW-01, APW-04, and AW-12, where sensitivity was moderate to moderately high; however, boron concentration in both the calibrated model and sensitivity models were negligible (<0.1 mg/L) at these wells (**Table 5-3**).

5.2.3.5 Dispersivity

Physical attenuation (dilution and dispersion) of contaminants is simulated in MT3DMS. Dispersion in porous media refers to the spreading of contaminants over a greater region than would be predicted solely from the average groundwater velocity vectors (Anderson, 1979; Anderson, 1984). Dispersion is caused by both mechanical dispersion, a result of deviations of actual velocity at a microscale from the average groundwater velocity, and molecular diffusion driven by concentration gradients. Molecular diffusion is generally secondary and negligible compared to the effects of mechanical dispersion and only becomes important when groundwater velocity is very low. The sum of mechanical dispersion and molecular diffusion is termed hydrodynamic dispersion, or simply dispersion (Zheng and Wang, 1998).

Dispersivity values were applied to the entire model domain and determined during calibration. Longitudinal dispersivity was set at 3 feet. The transverse and vertical dispersivity were set at 1/10 and 1/100 of longitudinal dispersivity. These input values were determined during model calibration. With travel distances of less than 100 feet for groundwater from the source to the majority of the monitoring points, the model is not expected to be sensitive to dispersivity inputs and the sensitivity of the model to dispersivity was not tested.

5.2.3.6 Retardation

It was assumed that boron would not significantly sorb or chemically react with aquifer solids (distribution coefficient [Kd] was set to 0 mL/g) which is a conservative estimate for estimating contaminant transport times. Boron, sulfate, and TDS transport is likely to be affected by both chemical and physical attenuation mechanisms (*i.e.*, adsorption and/or precipitation reactions as well as dilution and dispersion). Batch adsorption testing was conducted to generate site specific partition coefficient results for boron and sulfate (Golder, 2022b, **Appendix D**) for locations AW-15S and AW-19. Results of the testing are summarized below:

- Boron: Calculated linear partition coefficient (K_D) values were 1.50 and -0.19 liters per kilogram (L/kg), respectively. Langmuir partition coefficient (K_L) values were 3.8×10^4 and -2×10^5 L/kg, respectively. Freundlich partition coefficients (K_F) values were 82 and 215 L/kg, respectively. In Strenge and Peterson (1989), partition coefficients for boron range from 0.19 to 1.3 L/kg, depending on pH conditions and the amount of sorbent present.
- Sulfate: Calculated K_D values were 0.47 and -1.0 L/kg, respectively. K_L values were 778 and -2,950 L/kg, respectively. The K_F values for AW-15S and AW-19 were 63 and 1.2 L/kg,

respectively. In Strenge and Peterson (1989), partition coefficients for sulfate are 0.0 L/kg, regardless of pH conditions and the amount of sorbent present.

The results from site samples have a high degree of variation and little correlation with the literature values provided for comparison. The potential exceedances identified in groundwater (boron, sulfate, and TDS) are affected by natural attenuation processes in multiple ways and to varying degrees. Further assessment of these processes and how they may be applied as a potential groundwater remedy will be completed as part of future remedy selection evaluations, as necessary. For the purposes of this GMR, and as mentioned at the beginning of this section, no retardation was applied to boron transport in the model (*i.e.,* Kd was set to 0).

5.3 Flow and Transport Model Assumptions and Limitations

Simplifying assumptions were made while developing this model:

- Leading up to 2022, the groundwater flow system can be simulated as steady state.
- Natural recharge is constant over the long term.
- Fluctuations in river stage do not affect groundwater flow and transport over the long term.
- Hydraulic conductivity is consistent within hydrostratigraphic units
- The approximate base of ash surface in the Ash Pond was developed from information presented in the HCR (Ramboll, 2021a) and confirmed with IngenAE. Observed concentrations in groundwater exhibit no long-term trend.
- Source concentrations are assumed to remain constant over time. Only recharge rate was modified in 2004 to simulate modifications to Ash Pond operation south of the railroad (recharge zone 3).
- Boron is not adsorbed and does not decay, and mixing and dispersion are the only attenuation mechanisms.

The model is limited by the data used for calibration, which adequately define the local groundwater flow system and the source and extent of the plume. Since data used for calibration are near the Ash Pond, model predictions of transport distant spatially and temporally from the calibrated conditions at the CCR units will not be as reliable as predictions closer to the CCR units and concentrations observed between 2015 and 2021.

5.4 Calibration Flow and Transport Model Results

Results of the MODFLOW/MT3DMS modeling are presented below. Electronic copies of the model files are attached to this report (**Appendix C**).

Observed and simulated heads are presented in **Figure 5-13 through Figure 5-17**. The mass balance error for the flow model was -0.19 percent and the ratio of the residual standard deviation to the range was 11.6 percent; the mass balance error for the flow model was within the target for the criteria of 1 percent and the ratio of the residual standard deviation to the range was near target for the criteria of 10 percent. Another flow model calibration goal is that residuals are evenly distributed such that there is no bias affecting modeled flow. The observed heads are plotted versus the simulated heads in **Figure 5-18**. The near-linear relationship between observed and simulated values indicates that the model adequately represents the calibration dataset. The residual mean was -1.81 feet; in general the simulated values were evenly distributed above and below the observed values. This is also illustrated in the observed versus residuals plot at the bottom of **Figure 5-19**; however, some simulated values were overpredicted in the areas north of the Ash Pond or in model layer 2 immediately adjacent to the Ash Pond (transmissive zone within the UCF) where observed heads in the UCF (flow calibration targets) were significantly lower than observed heads (flow calibration targets) in the adjacent Ash Pond. These residuals plot in the lower left quadrant of **Figure 5-19**.

The range of observed boron concentrations between November 2015 and August 2021 for transport calibration locations are summarized in **Table 2-2**. The goals of the transport model calibration were to have predicted concentrations fall within the range of observed concentrations, and/or have predicted concentrations above and below the GWPS for boron (2 mg/L) match observed concentrations above or below the standard at each well. One or both of these goals were achieved at all but three of the transport calibration location wells, including AW-17, AW-22, and P002, where concentrations were overpredicted (**Figure 5-20**). Deviations from the observed ranges are discussed below.

- P002 is identified as a PMP well in the HCR (Ramboll, 2021a). P002 was modeled in layer 3 which represents the lower clay beneath the Ash Pond rather than layer 2, which represents the transmissive zone of the UCF (PMP) in the model. Since layer 2 was modeled as ash fill at the location of P002, the well was placed in layer 3 of the model immediately beneath the ash fill. The ash fill above the modeled location of P002 had the highest model source concentrations, which contribute to the over-predicted concentrations of boron at P002.
- In general, the model over-predicts boron concentrations to the north of the Ash Pond (AW-19, AW-20, AW-22, and P002) in wells adjacent to wells AP07S and AW021 where the highest boron concentrations were observed. The proximity of P002 and AW-22 to the highest boron concentration targets contributed to the over-predicted boron concentrations at these wells. Similarly, the over-prediction of boron concentration at AW-17 is associated with the proximity of AW-17 to AW-18 where observed boron concentrations are elevated.

The remaining calibration locations had predicted concentrations that fall within the range of observed concentrations and/or have predicted concentrations above and below the GWPS for boron (2 mg/L) matching observed concentrations above or below the standard at each well. In other words, there was a very good match between predicted and observed boron concentrations relative to wells with concentrations above and below the GWPS. UA well AW-21, located north of the Ash Pond, where the highest boron concentrations were observed, was also calibrated near the mean concentration of the observed values from November 2015 to August 2021. Similarly, PMP well AP07S located north of the Ash Pond, where the highest concentrations in the UCF were observed, was calibrated just below the maximum of the observed range from November 2015 to August 2021. The calibration result for wells AW-21 and AP07S indicate the transport calibration model was able to simulate the highest observed concentrations in both the UA and transmissive zone of the UCF (PMP), respectively. The remaining wells with observations above the standard GWPS for boron (2 mg/L) from November 2015 to August 2021 had calibrated concentrations above the GWPS (AW-05, AW-15S, AW-18, AW-19, AW-20). The distribution of boron concentrations in the calibrated model are presented on **Figure 5-21 through Figure 5-25**.

6. SIMULATION OF CLOSURE SCENARIO

6.1 Overview and Prediction Model Development

Prediction simulations were performed to evaluate the effects of closure (source control) measures (CCR consolidation and CIP and CBR scenarios) for the Ash Pond on groundwater quality following initial corrective action measures, which includes removal of free liquids from the Ash Pond (**Figure 4-1**). As discussed in **Section 5.2.3.5**, physical attenuation (dilution and dispersion) of contaminants in groundwater is simulated in MT3DMS, which captures the physical process of natural attenuation as part of corrective actions for both closure scenarios simulated. No retardation was applied to boron transport in the model (*i.e.,* Kd was set to 0) as discussed in **Section 5.2.3.6**. The following methods were used to develop the prediction models and simulate the CIP and CBR closure scenarios:

- Define ash fill material removal and consolidation areas based on designs provided in the Draft CCR Final Closure Plan (IngenAE, 2022).
- Apply a constant head to the Ash Pond for the dewatering period (approximately 1 year) to remove free liquids within the Ash Pond and simulate heads near ambient conditions.
- Remove source concentrations within the removal areas (source concentrations associated with recharge zones and saturated ash cells [constant concentration cells]).
- Apply drains (drain input parameters approximated designs provided in the Draft CCR Final Closure Plan [IngenAE, 2022]) to simulate storm water management within removal areas following closure.
- Apply hydraulic conductivity, recharge (HELP calculated percolation rates were developed based on soil backfill materials and final grading designs provided in the Draft CCR Final Closure Plan [IngenAE, 2022]), storage, and specific yield property zones to simulate soil backfill materials placed in the Ash Pond removal areas.
- Apply reduced recharge in the consolidation and closure in place areas to simulate the effects of the cover system on transport (HELP calculated percolation rates were developed based on cover system construction materials and designs provided in the Draft CCR Final Closure Plan [IngenAE, 2022]).

HELP modeling input and output values are summarized in **Table 6-1** and described in detail below. Prediction simulations were performed to evaluate changes in boron concentrations from two closure scenarios, including consolidation and CIP, and CBR scenarios. The following simplifying assumptions were made during the simulations:

- In the two closure scenarios, HELP-calculated average annual percolation rates were developed from a 30-year HELP model run. This 30-year HELP-calculated percolation rate remained constant over duration of the closure scenario prediction model runs following closure.
- Changes in recharge resulting from dewatering, ash fill removal, consolidation, construction of the cover system, and soil backfill placement and final grading (recharge rates are based on HELP-calculated average annual percolation rates) have an instantaneous effect on recharge and percolation through surface materials.

- Boron source concentrations were assumed to remain constant as a function of time following the end of the calibration simulation. Boron concentration in the ash fill removal areas was assumed to be 0 mg/L following construction to simulate removal of ash that is the source of boron.
- The start of each closure prediction simulation was initiated at the end of the calibration model period from 1960 to 2022. Two models were included for each closure prediction simulation, where the first model simulated the removal of free liquids period (1 year) and the second model simulated the final closure conditions (1,000 years). The prediction modeling timeline for each scenario is illustrated in **Figure 4-1**.
- The geocomposite drainage layer and geomembrane liner placed over the ash consolidation area were assumed to have good field placement and assumed to have the same slope as the final grade of the overlying cover materials based on the design drawings provided in the Draft CCR Final Closure Plan (IngenAE, 2022).
- Ash fill removal areas were assumed to be graded following placement of soil backfill based on the design drawings provided in the Draft CCR Final Closure Plan (IngenAE, 2022).
- All saturated ash (constant concentration cells) within removal areas in the transport calibration model were removed instantaneously in all prediction models following ash fill removal/final soil backfill grading. Local fill materials assumed to be sourced from surrounding UCF materials replaced ash fill in areas of removal.
- Local fill materials applied to the prediction models have similar hydraulic properties as the UCF materials used in the transport calibration models.

6.2 HELP Model Setup and Results

HELP (Version 4.0; Tolaymat and Krause, 2020) was used to estimate percolation through the Ash Pond areas for two ash fill closure scenarios and three area types, including CBR removal areas, CIP removal areas, and CIP consolidation and cover system areas. HELP input and output files are included electronically and attached to this report (**Appendix C**).

HELP input data and results are provided in **Table 6-1**. All scenarios were modeled for a period of 30 years. Climatic inputs were synthetically generated using default equations developed for Peoria, Illinois (the closest weather station included in the HELP database). Precipitation, temperature, and solar radiation was simulated based on the latitude of the Ash Pond. Thickness and type of the geosynthetic drainage layer, geomembrane liner, soil backfill, and soil runoff input parameters were developed for the ash fill removal and consolidation scenarios using data provided the Draft CCR Final Closure Plan (IngenAE, 2022).

HELP model results (**Table 6-1**) indicated 5.09 inches of percolation per year for the Ash Pond CBR removal areas, 4.03 inches of percolation per year for the Ash Pond CIP removal areas, and 0.0002 inches of percolation per year for the Ash Pond consolidation and cover system areas. The differences in HELP model runs for each area included the following parameters: evaporation zone thickness (limited by unsaturated soil backfill thickness in the Ash Pond), area, soil backfill thickness, and soil runoff slope length; all other HELP model input parameters were the same for each simulated area.

6.3 Simulation of Closure Scenarios

The calibrated model was used to evaluate the effectiveness of the two closure scenarios by defining ash fill material removal and consolidation area, reducing head to simulate a dewatering period (approximately 1 year), removing source concentrations within the removal areas, applying drains to simulate storm water management within removal areas following closure, applying hydraulic conductivity, recharge, storage, and specific yield property zones to simulate soil backfill materials placed in the Ash Pond removal areas, and applying reduced recharge in the consolidation and closure in place areas to simulate the effects of the cover system on transport.

Each prediction scenario was initiated at the end of the calibration model and consisted of two models where the first model simulated the dewatering period (1 year) and the second model simulated the final closure conditions (**Figure 4-1**). The prediction model input values are summarized in **Table 6-2** and illustrated in **Figure 6-1 through Figure 6-6**.

In general, long predicted timeframes to reach the GWPS were observed for most wells in both CIP and CBR prediction scenarios. The long timeframes observed are a result of the generally low permeability materials adjacent to and underlying the Ash Pond, and generally low groundwater flow velocities observed within the water-bearing units of the site, which results in reduced transport and slow physical attenuation (dilution and dispersion). The observed timeframes to reach the GWPS for some wells in both the CIP and CBR prediction scenarios were on the order of hundreds of years from present. These predicted timeframes to meet the GWPS are less reliable than timeframes that are closer temporally to the data used for calibration (between 2015 and 2021). The two closure scenarios are discussed in this report based on predicted changes in boron concentrations as described below.

6.3.1 Closure Scenario 1 (CIP) Predicted Boron Concentrations

The design for Scenario 1: CIP includes an initial 1-year dewatering period to remove free liquids followed by CCR removal from the northwest areas of the Ash Pond, consolidation to the northeast, central and southern areas of the Ash Pond, and construction of a cover system over the remaining CCR (**Figure 4-1**).

Predicted concentrations start to decline at all monitoring wells with observations above the GWPS for boron (2 mg/L) (AP07S, AW-05, AW-15S, AW-18, AW-19, AW-20, AW-21) once closure actions are initiated within the prediction model. These declines occur as the northwest area of ash fill is removed and saturated ash cells (constant concentration cells) are reduced in the area of the highest modeled source concentrations. Following removal of ash fill in the northwest area, boron concentrations are no longer entering the model domain from recharge or from saturated ash cells (constant concentration cells). Dewatering also reduces the head within the Ash Pond. These low heads are maintained following completion of closure by the drain cells that simulate storm water management designs within the removal area to the northwest, and by the greatly reduced infiltration rates (recharge) that result from placement of the cover system over the consolidated ash fill. As a result of the reduced heads and recharge, downward percolation of solute mass from the Ash Pond is reduced, which decreases the boron concentration entering the model domain. The reduced recharge resulting from placement of the cover system also reduces the number of active saturated ash cells (constant concentration cells) contributing boron to the model domain. All monitoring wells with observations above the GWPS for boron (2 mg/L) are predicted to be below the GWPS 198 years after CIP implementation (model year 260 as illustrated in

Figure 6-7). AW-19 takes the longest of these wells to be reduced below the GWPS, but like AW-20, this well is over-predicted in the calibration model. AW-21 and AP07S, which had the highest concentrations in the UA and UCF, respectively, and were among the wells with the best-fit model calibrations for boron concentration, were predicted to decline below the GWPS at 121 and 32 years, respectively, after CIP implementation (model years 183 and 94, respectively, as illustrated in **Figure 6-7**).

With the exception of wells AW-09 and AW-16, located along the southwestern side of the Ash Pond, all other modeled boron concentrations are predicted to decrease below the GWPS 382 years after CIP implementation (model year 444 as illustrated in **Figure 6-7**). The maximum extent of the plume above the standard GWPS for boron (2 mg/L) at this time is illustrated in **Figure 6-8,** where boron exceedances have retreated within the footprint of the former Ash Pond except along the southwestern edge of the pond. Along the southwestern edge of the pond, including wells AW-09 and AW-16, the model indicates concentrations will increase for a period of time following implementation of corrective measures before decreases are predicted.

The predicted increase and delayed reduction in concentration at wells AW-09 and AW-16 is a result of the wells being located along the flow path of the residual boron concentrations released into native geologic materials prior to closure. The prediction model indicates that as the plume recedes over time a south-southwest trending plume of historic boron concentrations above the standard GWPS for boron (2 mg/L) slowly moves along this flowpath as physical attenuation takes place, eventually reducing concentrations at these wells to concentrations below the standard GWPS 767 years after implementation of closure (model year 829 as illustrated in **Figure 6-7**). The maximum extent of the plume at this time (model year 829) is illustrated in **Figure 6-9**. As illustrated in **Figure 6-8** and **Figure 6-9** the maximum extent of the plume at 382 (model year 444) and 767 (model year 829) years after CIP implementation remains in close proximity to the Ash Pond as the plume recedes and concentrations at monitoring wells AW-09 and AW-16 decrease (**Figure 6-7**).

6.3.2 Closure Scenario 2 (CBR) Predicted Boron Concentrations

The design for Scenario 2: CBR includes an initial 1-year dewatering period followed by CCR removal from the Ash Pond (**Figure 4-1**).

Like CIP, predicted concentrations for CBR start to decline at all monitoring wells with observations above the standard GWPS for boron (2 mg/L) (AP07S, AW-05, AW-15S, AW-18, AW-19, AW-20, AW-21) once the closure actions are initiated within the prediction model. In CBR, these declines occur as the ash fill is removed from the Ash Pond and saturated ash cells (constant concentration cells) are removed. Following removal of ash fill, boron concentrations are no longer entering the model domain from recharge or from saturated ash cells (constant concentration cells); all source concentrations are removed. Dewatering through removal of free liquids also reduces the head within the Ash Pond. These low heads are maintained following completion of closure by the drain cells that simulate storm water management designs within the Ash Pond. As a result of the reduced heads, downward percolation of existing solute mass from the Ash Pond is reduced. All monitoring wells with observations above the standard GWPS for boron (2 mg/L) are predicted to be below the GWPS 104 years after closure implementation (model year 166 as illustrated in **Figure 6-10**). Similar to CIP, AW-19 takes the longest of these wells to be reduced below the GWPS. AW-21 and AP07S, which had the highest concentrations in the UA and UCF, respectively, and were among the wells with the best-fit model calibrations for boron concentration, were predicted to decline below the GWPS at 88 and 15 years, respectively, after CBR implementation (model years 150 and 77, respectively, as illustrated in **Figure 6-10**).

With the exception of wells AW-09 and AW-16, boron concentrations are predicted to decrease below the GWPS 201 years after CBR implementation (model year 263 as illustrated in **Figure 6-10**). The maximum extent of the plume at this time is illustrated in **Figure 6-11** where boron exceedances have retreated within the footprint of the former Ash Pond except along a limited portion of the southwestern edge of the pond. Like CIP, at wells AW-09 and AW-16 the model indicates concentrations will increase for a period of time following implementation of closure before decreases are predicted.

Also, like CIP, the predicted increase and delayed reduction in concentration at wells AW-09 and AW-16 is a result of the wells being located along the flow path of the residual boron concentrations released into native geologic materials prior to closure. The prediction model indicates that as the plume recedes over time a south-southwest trending plume of historic boron concentrations above the standard GWPS for boron (2 mg/L) slowly moves along this flowpath as physical attenuation takes place, eventually reducing concentrations at these wells to concentrations below the GWPS 748 years after implementation of closure (model year 810 as illustrated in **Figure 6-10**). The maximum extent of the plume at this time is illustrated in **Figure 6-12**. As illustrated in **Figure 6-11** and **Figure 6-12** the maximum extent of the plume at 201 (model year 263) and 748 (model year 810) years after CBR implementation, remains in close proximity to the Ash Pond as the plume recedes and concentrations at monitoring wells AW-09 and AW-16 decrease (**Figure 6-10**).

7. CONCLUSIONS

This GMR has been prepared to evaluate how proposed CIP and CBR closure scenarios will achieve compliance with the applicable groundwater standards at the EPP. Data collected from sampling events between November 2015 and August 2021 was used to develop a groundwater model for the EPP Ash Pond and surrounding area. The MODFLOW and MT3DMS models were then used to evaluate CIP using information provided in the Draft CCR Final Closure Plan (IngenAE, 2022), and CBR closure scenarios:

- Scenario 1: CIP (CCR removal from the northwest areas of the Ash Pond, consolidation to the northeast, central and southern areas of the Ash Pond, and construction of a cover system over the remaining CCR)
- Scenario 2: CBR (CCR removal from the Ash Pond)

Differences exist in the timeframes to reach the GWPS for most monitoring wells between CIP and CBR. For instance, wells with observations above the standard GWPS for boron (2 mg/L) from November 2015 to August 2021 (AP07S, AW-05, AW-15S, AW-18, AW-19, AW-20, AW-21) are predicted to reach the GWPS in 198 years after CIP implementation, and 104 years after CBR implementation. Shorter timeframes were predicted to reach the GWPS for wells located on the northern edge of the Ash Pond where observed boron concentrations were the highest (AW-21 and AP07S). AW-21 and AP07S, which had the highest concentrations in the UA and UCF, respectively, were predicted to decline below the GWPS at 121 and 32 years, respectively, after CIP implementation, and at 88 and 15 years, respectively, after CBR implementation. However, as a result of the south-southwest trending plume of residual boron concentrations above the GWPS for boron (2 mg/L) released to native geologic materials prior to closure, which remains for a long period of time following implementation of both scenarios, all monitoring wells are not predicted to reach the GWPS until after 767 years and 748 years following implementation of CIP and CBR, respectively.

The observed timeframes to reach the GWPS for both the CIP and CBR prediction scenarios were on the order of hundreds of years from present; these predicted timeframes to meet the GWPS are less reliable than timeframes that are closer temporally to the data used for calibration (between 2015 and 2021). From a modeling perspective, the 19-year difference between CIP and CBR to reach the GWPS is negligible. In other words, both scenarios are predicted to reach the GWPS after approximately 750 years, and the simulated 19-year difference between these two scenarios is not significant. Further, the boron plumes for both CIP and CBR remain in close proximity to the Ash Pond while they recede, indicating they are equally protective.

Statistically significant correlations between boron concentrations and concentrations of sulfate and TDS identified as potential exceedances of the GWPS indicate boron is an acceptable surrogate for these parameters in the groundwater model. Concentrations of these parameters are expected to change along with model predicted boron concentrations.

Results of groundwater fate and transport modeling conservatively estimate that groundwater will attain the GWPS for all constituents identified as potential exceedances of the GWPS in approximately 750 years following closure implementation for both CIP and CBR. The long timeframes observed are a result of the generally low permeability materials adjacent to and underlying the Ash Pond, and generally low groundwater flow velocities observed within the water-bearing units of the site, which results in reduced transport and slow physical attenuation (dilution and dispersion). The predicted maximum extent of the plume above the standard GWPS for boron (2 mg/L) stays in close proximity to the ash pond as it recedes.

8. REFERENCES

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TABLES

TABLE 2-1. MONITORING WELL LOCATIONS AND CONSTRUCTION DETAILS
GROUNDWATER MODELING REPORT
EDWARDS POWER PLANT
ASH POND
BARTONVILLE, ILLINOIS

Well Number	HSU	Date Constructed	Top of PVC Elevation (ft)	Measuring Point Elevation (ft)	Measuring Point Description	Ground Elevation (ft)	Screen Top Depth (ft BGS)	Screen Bottom Depth (ft BGS)	Screen Top Elevation (ft)	Screen Bottom Elevation (ft)	Well Depth (ft bgs)	Bottom of Boring Elevation (ft)	Screen Length (ft)	Screen Diameter (inches)	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)
AP05S	UA	11/29/2016	443.53	443.53	Top of PVC	441.13	32.87	37.64	408.26	403.49	38.06	403.10	4.8	2	40.598807	-89.66191
AP05D	BCU	12/05/2016	443.45	443.45	Top of PVC	441.23	47.09	56.69	394.14	384.54	57.17	382.90	9.6	2	40.598796	-89.661901
AP06	UCF	11/30/2016	442.17	442.17	Top of PVC	439.53	19.93	24.72	419.60	414.81	25.00	414.50	4.8	2	40.601038	-89.662759
AP07S	UCF	12/02/2016	461.08	461.08	Top of PVC	458.31	29.95	34.74	428.36	423.57	35.00	423.30	4.8	2	40.59793	-89.666919
AP07D	BCU	12/08/2016	460.89	460.89	Top of PVC	458.42	55.01	64.59	403.41	393.83	65.00	393.40	9.6	2	40.597941	-89.666926
AP08	CCR	12/06/2016	460.60	460.60	Top of PVC	458.10	9.99	19.58	448.11	438.52	19.98	438.10	9.6	2	40.594578	-89.668728
AP09	CCR	12/07/2016	460.22	460.22	Top of PVC	457.24	9.79	19.39	447.45	437.85	19.80	437.40	9.6	2	40.59149	-89.666303
APW-01	UCF	07/27/2010	441.07	441.07	Top of PVC	437.83	7.60	18.00	430.23	419.83	18.00	419.30	10.4	2	40.600127	-89.66512
APW-02	UCF	07/20/2010	464.92	464.92	Top of PVC	461.72	39.60	50.00	422.12	411.72	50.00	411.70	10.4	2	40.594228	-89.665642
APW-03	UCF	07/19/2010	444.37	444.37	Top of PVC	441.22	19.60	30.00	421.62	411.22	30.00	411.20	10.4	2	40.591259	-89.663843
APW-04	UCF	07/27/2010	439.66	439.66	Top of PVC	437.19	9.60	20.00	427.59	417.19	20.00	417.20	10.4	2	40.587909	-89.663726
AW-01	PMP	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
AW-05	UA	07/22/2015	--	443.37	Top of Disk	440.55	15.87	20.47	424.68	420.08	21.10	419.50	4.6	2	40.598645	-89.666407
AW-06	UA	08/03/2015	--	461.57	Top of Disk	459.19	36.60	41.09	422.59	418.10	41.69	416.90	4.5	2	40.594237	-89.670051
AW-08	UA	07/21/2015	--	462.54	Top of Disk	460.66	47.55	57.19	413.11	403.47	57.70	403.00	9.6	2	40.593964	-89.661996
AW-09	UA	08/03/2015	--	461.45	Top of Disk	458.32	47.14	51.62	411.18	406.70	52.23	406.10	4.5	2	40.590422	-89.668777
AW-10	UA	07/23/2015	--	439.93	Top of Disk	437.64	27.62	32.23	410.02	405.41	32.74	404.90	4.6	2	40.590733	-89.663826
AW-11	UA	07/28/2015	--	439.87	Top of Disk	437.16	24.21	28.81	412.95	408.35	29.31	407.20	4.6	2	40.587261	-89.663781
AW-12	UA	01/07/2021	443.80	443.80	Top of PVC	441.16	26.00	31.00	415.16	410.16	31.00	406.20	5	2	40.591071	-89.661333
AW-13	UA	01/09/2021	441.26	441.26	Top of PVC	438.67	25.00	30.00	413.67	408.67	30.00	408.70	5	2	40.588378	-89.663714
AW-14	UA	01/08/2021	439.40	439.40	Top of PVC	436.83	24.00	29.00	412.83	407.83	29.00	401.80	5	2	40.58729	-89.665621
AW-15	UA	01/08/2021	441.51	441.51	Top of PVC	438.95	33.00	38.00	405.95	400.95	38.00	399.00	5	2	40.587964	-89.666822
AW-15C	BCU	01/08/2021	440.02	440.02	Top of PVC	437.62	43.00	48.00	394.62	389.62	48.00	337.60	5	2	40.588	-89.666882

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AW-15S	UCF	01/08/2021	440.71	440.71	Top of PVC	437.92	8.00	18.00	429.92	419.92	18.00	417.90	10	2	40.587955	-89.666841
AW-16	UA	01/08/2021	461.79	461.79	Top of PVC	459.45	55.00	60.00	404.45	399.45	60.00	396.50	5	2	40.589457	-89.667799
AW-17	UA	01/08/2021	462.10	462.10	Top of PVC	459.69	51.00	56.00	408.69	403.69	56.00	402.70	5	2	40.591698	-89.669404
AW-18	UA	01/09/2021	462.65	462.65	Top of PVC	460.28	46.00	51.00	414.28	409.28	51.00	405.30	5	2	40.593044	-89.669822
AW-19	UA	01/09/2021	460.74	460.74	Top of PVC	458.53	35.00	40.00	423.53	418.53	40.00	415.50	5	2	40.595434	-89.66972
AW-20	UA	01/10/2021	461.48	461.48	Top of PVC	459.08	36.50	41.50	422.58	417.58	41.50	416.10	5	2	40.596469	-89.66891
AW-21	UA	01/10/2021	460.61	460.61	Top of PVC	458.28	32.00	37.00	426.28	421.28	37.00	420.30	5	2	40.597294	-89.667734
AW-22	UA	01/08/2021	463.19	463.19	Top of PVC	460.30	44.00	49.00	416.30	411.30	49.00	410.30	5	2	40.596836	-89.666783
P002	UCF	--	460.39	460.39	Top of PVC	458.70	30.60	35.60	--	--	35.90	--	5	2	40.596235	-89.669084
XPW01A	CCR	01/09/2021	464.16	464.16	Top of PVC	460.99	33.00	43.00	427.99	417.99	43.00	418.00	10	2	40.596306	-89.667345
XPW02	CCR	01/09/2021	473.79	473.79	Top of PVC	471.16	36.00	46.00	435.16	425.16	46.00	424.20	10	2	40.594351	-89.668312
XPW03	CCR	01/10/2021	466.04	466.04	Top of PVC	462.62	27.00	37.00	435.62	425.62	37.00	422.60	10	2	40.591416	-89.666188
SG-01	SW	--	--	--	--	--	--	--	--	--	--	--	--	--	40.596075	-89.661625

Notes:
All elevation data are presented relative to the North American Vertical Datum 1988 (NAVD88), GEOID 12A
-- = data not available
BCU = bedrock confining unit
bgs = below ground surface
CCR = coal combustion residuals
ft = foot or feet
HSU = Hydrostratigraphic Unit
PMP = potential migration pathway
PVC = polyvinyl chloride
SW = surface water
UA = uppermost aquifer
UCF = Upper Cahokia Formation
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TABLE 2-2. FLOW AND TRANSPORT MODEL CALIBRATION TARGETS

GROUNDWATER MODELING REPORT

EDWARDS POWER PLANT

ASH POND

BARTONVILLE, IL

Well ID	Monitored Hydrogeologic Unit	Modeled Well Location (Layer Number)	Modeled Target Location (Layer Number)	Flow Model Target Groundwater Elevation Mean Value November 2015 to August 2021 (feet NAVD88)	Transport Model Target Boron Concentrations November 2015 to August 2021 (mg/L)		
					Minimum	Mean	Maximum
AP05S	UA	4	4	438.14	0.2	0.3	0.4
AP05D	BCU	5	5	439.88 [1]	1.0	1.3	1.7
AP06	UCF	3	3	437.72	No Target		
AP07S	UCF	2	2	436.45	5.8	7.9	12.0
AP07D	BCU	5	5	437.92 [1]	1.2	1.4	1.8
AP08	CCR	1	1	452.28	3.0	7.5	12.0
AP09	CCR	1	1	451.93	3.1	4.2	5.3
APW-01	UCF	3	3	435.62	0.7	0.7	0.8
APW-02	UCF	3	1	454.95 [2]	0.0	0.1	0.1
APW-03	UCF	3	3	436.52 [2]	0.1	0.1	0.2
APW-04	UCF	2	2	432.65	0.5	0.6	0.7
AW-05	UA	4	4	434.93	1.4	2.9	7.6
AW-06	UA	5	5	434.49	0.1	0.2	0.3
AW-08	UA	4	4	440.60 [2]	0.1	0.1	0.2
AW-09	UA	4	4	435.68	0.2	0.5	1.3
AW-10	UA	4	4	438.89	0.4	0.5	0.6
AW-11	UA	4	4	433.79	0.2	0.2	0.3
AW-12	UA	4	4	436.56	0.2	0.2	0.3
AW-13	UA	4	4	435.69	0.3	0.3	0.3
AW-14	UA	4	4	432.85 [3]	0.2	0.2	0.2
AW-15	UA	4	4	433.66	0.3	0.4	0.6
AW-15C	BCU	5	5	433.38	0.6	0.7	0.8
AW-15S	UCF	2	2	430.93	5.4	5.7	6.2
AW-16	UA	4	4	437.68	0.5	0.5	0.6
AW-17	UA	4	4	437.31	0.4	0.4	0.5
AW-18	UA	4	5	435.15	0.4	1.5	3.0
AW-19	UA	4	3	447.39	2.5	2.7	2.9
AW-20	UA	4	3	445.03	2.1	2.2	2.3
AW-21	UA	4	3	443.70	11.0	11.5	12.0

TABLE 2-2. FLOW AND TRANSPORT MODEL CALIBRATION TARGETS

GROUNDWATER MODELING REPORT

EDWARDS POWER PLANT

ASH POND

BARTONVILLE, IL

Well ID	Monitored Hydrogeologic Unit	Modeled Well Location (Layer Number)	Modeled Target Location (Layer Number)	Flow Model Target Groundwater Elevation Mean Value November 2015 to August 2021 (feet NAVD88)	Transport Model Target Boron Concentrations November 2015 to August 2021 (mg/L)		
					Minimum	Mean	Maximum
AW-22	UA	3	1	451.58	0.2	0.3	0.4
P002	UCF	3	2	448.39	1.1	1.2	1.4
XPW01A	CCR	2	2	452.57	15	16.7	19
XPW02	CCR	2	2	453.29	13	14.5	16
XPW03	CCR	2	2	450.75	4.9	5.5	7

[O: EGP4/5/22, C: JJW 4/5/22; JRK 4/11/22]

Notes:

[1] Target groundwater elevations presented are from data collected between February 2020 and February 2021. Groundwater elevations collected prior to and after these dates were recovering between sampling events and do not represent static groundwater conditions in each well.

[2] Target groundwater elevations exclude February 11th, 2021 event due to groundwater elevations recovering between sampling events.

[3] Target groundwater elevations exclude June 15th, 2021 event due to gauging error.

ID = identification

mg/L = milligrams per liter

NAVD88 = North American Vertical Datum of 1988

Hydrogeologic Unit:

BCU = bedrock confining unit

CCR = coal combustion residuals

PMP = primary migration pathway

UA = uppermost aquifer

UCF = upper cahokia formation

TABLE 5-1. FLOW MODEL INPUT AND SENSITIVITY ANALYSIS RESULTS

GROUNDWATER MODELING REPORT
EDWARDS POWER PLANT
ASH POND
BARTONVILLE, ILLINOIS

Zone	Hydrostratigraphic Unit	Materials	ft/d	cm/s	Kh/Kv	Value Source	Sensitivity[1]
Horizontal Hydraulic Conductivity			**Calibration Model**			**Calibration Model**	
1	Upper Clay (UCF)	clay and silt	0.002	7.06E-07	NA	Calibrated	low
2	Transmissive Zone (UCF [PMP])	clay and silt at elevations similar to base of ash, thin discontinuous sand lenses	2	7.06E-04	NA	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	high
3	Lower Clay (UCF)	clay and silt	0.011	3.88E-06	NA	Calibrated	moderate
4	Weathered Shale (UA)	weathered shale, sand, silty sand, clayey gravel, bedrock contact with overlying materials	3	1.06E-03	NA	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	high
5	Competent Shale (BCU)	shale	0.01	3.53E-06	NA	Geomean of Field Test Results (Ramboll, 2021a)	moderate
6	Fill Unit (CCR)	CCR	0.1	3.53E-05	NA	Calibrated	high
7	UCF above River Boundary Conditions	NA	200	7.06E-02	NA	Calibrated - Conductivity Value to Allow Groundwater Flow from UCF to River Boundary Conditions	moderate
9	Sankoty Aquifer - Sands	sand	42	1.48E-02	NA	Calibrated	high
Vertical Hydraulic Conductivity			**Calibration Model**			**Calibration Model**	
1	Upper Clay (UCF)	clay and silt	0.0002	7.06E-08	10	Geomean of Laboratory Test Results (Ramboll, 2021a)	high
2	Transmissive Zone (UCF [PMP])	clay and silt at elevations similar to base of ash, thin discontinuous sand lenses	0.2	7.06E-05	10	Calibrated	low
3	Lower Clay (UCF)	clay and silt	0.00011	3.88E-08	100	Geomean of Laboratory Test Results (Ramboll, 2021a; Haley & Aldrich, Inc., 2018)	high
4	Weathered Shale (UA)	weathered shale, sand, silty sand, clayey gravel, bedrock contact with overlying materials	0.3	1.06E-04	10	Calibrated	negligible
5	Competent Shale (BCU)	shale	0.0001	3.53E-08	100	Calibrated	moderate
6	Fill Unit (CCR)	CCR	0.006	2.12E-06	17	Calibrated - Within Range Laboratory Test Results (Ramboll, 2021a)	moderate
7	UCF above River Boundary Conditions	NA	200	7.06E-02	1	Calibrated - Conductivity Value to Allow Groundwater Flow from UCF to River Boundary Conditions	negligible
9	Sankoty Aquifer - Sands	sand	42	1.48E-02	1	Calibrated	negligible
Zone	**Hydrostratigraphic Unit**	**Materials**	**ft/d**	**in/yr**	**Kh/Kv**	**Value Source**	**Sensitivity[1]**
Recharge			**Calibration Model**			**Calibration Model**	
1	Upper Clay (UCF)	clay and silt	1.00E-05	0.044	NA	Calibrated	high
2	Fill Unit - CCR (Central, Fly Ash Pond)	CCR	2.20E-04	0.96	NA	Calibrated	high
3	Fill Unit - CCR (South of Railroad, Inactive Area)	CCR	1.00E-05	0.044	NA	Calibrated	negligible
4	Fill Unit - CCR (Northwest, Process Water Pond)	CCR	1.50E-04	0.66	NA	Calibrated	moderately high
5	Fill Unit - CCR (South, Clarification Pond)	CCR	5.00E-05	0.22	NA	Calibrated	moderate
7	Fill Unit - CCR (Northeast, Sluice Area)	CCR	9.00E-04	3.94	NA	Calibrated	high
Storage							
1	Upper Clay (UCF)	clay and silt	*Not used in steady-state calibration model*				
2	Transmissive Zone (UCF [PMP])	clay and silt at elevations similar to base of ash, thin discontinuous sand lenses					
3	Lower Clay (UCF)	clay and silt					
4	Weathered Shale (UA)	weathered shale, sand, silty sand, clayey gravel, bedrock contact with overlying materials					
5	Competent Shale (BCU)	shale					
6	Fill Unit (CCR)	CCR					
7	Sankoty Aquifer - Sands	sand					
8	UCF above River Boundary Conditions	NA					

RAMBOLL

TABLE 5-1. FLOW MODEL INPUT AND SENSITIVITY ANALYSIS RESULTS
GROUNDWATER MODELING REPORT
EDWARDS POWER PLANT
ASH POND
BARTONVILLE, ILLINOIS

River Parameters

	Relative Location	River Width (feet)	Average Length of River (feet)	Bed Thickness (feet)	Hydraulic Conductivity (ft/d)	Stage (feet)	Average River Conductance (ft^2/d)
Reach 1	Illinois River	750	24.5	1	1	438.44 - 438.24	1.84E+04
Sensitivity[1]	NA	- - -	- - -	- - -	- - -	moderate	negligible
Reach 2	Drainage Ditch West of Ash Pond	20	25	1	0.00001	432	5.00E-03
Sensitivity[1]	NA	- - -	- - -	- - -	- - -	low	moderate
Reach 3	Drainage Swale North of Ash Pond	25	25	1	0.00001	430.07	6.25E-03
Sensitivity[1]	NA	- - -	- - -	- - -	- - -	negligible	low
Reach 4	Drainage Pond Northeast of Ash Pond	25	25	1	0.00001	433.24	6.25E-03
Sensitivity[1]	NA	- - -	- - -	- - -	- - -	low	low
Value Source	NA	Calibrated	Calibrated	Calibrated	Calibrated	Calibrated - Mean Illinois River Stage at Edwards Power Plant Interpolated from Stage Data Provided at Peoria, Illinois (USCE 404208089335201), Edwards Power Plant (Plant Gaging Station), and Kingston, Illinois (USGS 05568500) Gaging Stations; Drainage Feature Stage (Reach 2 - 4) Based on Survey Data Collected by IngenAE in February 2022	Calibrated

General Head Parameters

	Relative Location	Width of General Head Boundary Cell (feet)	Distance to General Head Boundary Head (feet)	Average Saturated Thickness of Cell (feet)	Hydraulic Conductivity (ft/d)	Head (feet)	Average General Head Boundary Conductance (ft^2/d)
Reach 1	North Edge of Model (Peoria Pumping Center) and Southeast Edge of Model (Pekin Pumping Center)	150 (North Edge of Model); 750 (Southeast Edge of Model)	1	100 (North Edge of Model); 39 (Southeast Edge of Model)	100	426	1.50E+06 (North Edge of Model); 2.92E+06 (Southeast Edge of Model)
Sensitivity[1]	NA	- - -	- - -	- - -	- - -	high	negligible
Value Source	NA	Calibrated	Calibrated	Calibrated	Calibrated	Calibrated - Location of General Head Boundaries Based on Data Availabile in Burch and Kelly (1993)	Calibrated

[O: JJW 4/14/22; C: JRK 4/14/22]

Notes:
[1] Sensitivity Explanation:
Negligible - SSR changed by less than 1%
Low - SSR change between 1% and 10%
Moderate - SSR change between 10% and 50%
Moderately High - SSR change between 50% and 100%
High - SSR change greater than 100%
SSR = sum of squared residuals
- - - = not tested
CCR = coal combustion residuals
cm/s = centimeters per second
ft/d = feet per day
ft^2/day = feet squared per day
in/yr = inches per year
Kh/Kv = anisotropy ratio
NA = not applicable

Hydrogeologic Unit:
BCU = bedrock confining unit
CCR = coal combustion residuals
PMP = primary migration pathway
UA = uppermost aquifer
UCF = upper cahokia formation

References:
Burch, S. L. and D. J. Kelly., 1993. Peoria-Pekin Regional Ground-Water Quality Assessment. Illinois State Water Survey (ISWS), Champaign, Research Report 124.
Haley & Aldrich, Inc., 2018. Technical Memorandum: Ash Pond – Underlying Clay and Depth of CCR Evaluation, Edwards Station, Bartonville, Illinois, February 12, 2018.
Ramboll Americas Engineering Solutions, Inc. (Ramboll), 2021a. Hydrogeologic Site Characterization Report. Edwards Ash Pond. Edwards Power Plant. Bartonville, Illinois.

TABLE 5-2. TRANSPORT MODEL INPUT VALUES (CALIBRATION)
GROUNDWATER MODELING REPORT
EDWARDS POWER PLANT
ASH POND
BARTONVILLE, ILLINOIS

Zone	Hydrostratigraphic Unit	Materials	Calibration Model						
			Stress Period 1 Dates: 1960-2004 Recharge (ft/d)	Stress Period 2 Dates: 2005-2022 Recharge (ft/d)	Boron Concentration (mg/L)			Value Source	Sensitivity
Initial Concentration									
Entire Domain	NA	NA	NA	NA	0			NA	- - -
Source Concentration (recharge)									
2	Fill Unit - CCR (Central, Fly Ash Pond)	CCR	2.20E-04	2.20E-04	3			calibrated	- - -
3	Fill Unit - CCR (South of Railroad, Inactive Area)	CCR	1.00E-05	1.00E-05	3			calibrated	- - -
4	Fill Unit - CCR (Northwest, Process Water Pond)	CCR	1.50E-04	1.50E-04	13			calibrated	- - -
5	Fill Unit - CCR (South, Clarification Pond)	CCR	5.00E-05	5.00E-05	3			calibrated	- - -
7	Fill Unit - CCR (Northeast, Sluice Area)	CCR	9.00E-04	9.00E-04	0.5			calibrated	- - -
Source Concentration (constant concentration cells)									
Reach 2	Fill Unit - CCR (Central, Fly Ash Pond)	CCR	NA	NA	3			calibrated	- - -
Reach 3	Fill Unit - CCR (South of Railroad, Inactive Area)	CCR	NA	NA	3			calibrated	- - -
Reach 4	Fill Unit - CCR (Northwest, Process Water Pond)	CCR	NA	NA	13			calibrated	- - -
Reach 5	Fill Unit - CCR (South, Clarification Pond)	CCR	NA	NA	3			calibrated	- - -
Reach 7	Fill Unit - CCR (Northeast, Sluice Area)	CCR	NA	NA	0.5			calibrated	- - -
Storage, Specific Yield and Effective Porosity									
Zone	**Hydrostratigraphic Unit**	**Materials**	NA	NA	**Storage**	**Specific Yield**	**Effective Porosity**	**Value Source**	**Sensitivity**
1	Upper Clay (UCF)	clay and silt	NA	NA	0.003	0.135	0.135	Storage Estimated from Literature (Fetter, 1988); Specific Yield Set Equal to Effective Porosity; Effective Porosity Esitmated from Literature (Morris and Johnson, 1967; Heath, 1983)	see Table 5-3
2	Transmissive Zone (UCF [PMP])	clay and silt at elevations similar to base of ash, thin discontinuous sand lenses	NA	NA	0.003	0.183	0.183	Storage Estimated from Literature (Fetter, 1988); Specific Yield Set Equal to Effective Porosity; Effective Porosity Esitmated from Literature (Morris and Johnson, 1967; Heath, 1983)	see Table 5-3
3	Lower Clay (UCF)	clay and silt	NA	NA	0.003	0.07	0.07	Storage Estimated from Literature (Fetter, 1988); Specific Yield Set Equal to Effective Porosity; Effective Porosity Esitmated from Literature (Morris and Johnson, 1967; Heath, 1983)	see Table 5-3
4	Weathered Shale (UA)	weathered shale, sand, silty sand, clayey gravel, bedrock contact with overlying materials	NA	NA	0.003	0.204	0.204	Storage Estimated from Literature (Fetter, 1988); Specific Yield Set Equal to Effective Porosity; Effective Porosity Esitmated from Literature (Morris and Johnson, 1967; Heath, 1983)	see Table 5-3
5	Competent Shale (BCU)	shale	NA	NA	0.003	0.1	0.1	Storage Estimated from Literature (Fetter, 1988); Specific Yield Set Equal to Effective Porosity; Effective Porosity Esitmated from Literature (Morris and Johnson, 1967; Heath, 1983)	see Table 5-3
6	Fill Unit (CCR)	CCR	NA	NA	0.003	0.2	0.2	Storage Estimated from Literature (Fetter, 1988); Specific Yield Set Equal to Effective Porosity; Effective Porosity Esitmated from Literature (Morris and Johnson, 1967; Heath, 1983)	see Table 5-3
7	Sankoty Aquifer - Sands	sand	NA	NA	0.003	0.274	0.274	Storage Estimated from Literature (Fetter, 1988); Specific Yield Set Equal to Effective Porosity; Effective Porosity Esitmated from Literature (Morris and Johnson, 1967; Heath, 1983)	see Table 5-3
8	UCF above River Boundary Conditions	NA	NA	NA	0.003	0.5	0.5	Storage Estimated from Literature (Fetter, 1988); Specific Yield Set Equal to Effective Porosity; Effective Porosity Esitmated from Literature (Morris and Johnson, 1967; Heath, 1983)	see Table 5-3
Dispersivity									
Applicable Region	**Hydrostratigraphic Unit**	**Materials**	NA	NA	**Longitudinal (feet)**	**Transverse (feet)**	**Vertical (feet)**	**Value Source**	**Sensitivity**
Entire Domain	NA	NA	NA	NA	3	0.3	0.03	calibrated	- - -

[O: JJW 4/11/22; EGP 4/11/22]

Notes:
[1] The concentrations from the end of the calibrated transport model were imported as initial concentrations for the prediction model runs.
- - - = not tested
ft/d = feet per day
mg/L = milligrams per liter
NA = not applicable

Hydrogeologic Unit:
BCU = bedrock confining unit
CCR = coal combustion residuals
PMP = primary migration pathway
UA = uppermost aquifer
UCF = upper cahokia formation

References:
Fetter, C.W., 1988, Applied Hydrogeology, Merrill Publishing Company, Columbus, Ohio.
Morris, D.A and A.I. Johnson, 1967. Summary of hydrologic and physical properties of rock and soil materials
as analyzed by the Hydrologic Laboratory of the U.S. Geological Survey. U.S. Geological Survey Water-Supply Paper 1839-D, 42p.
Heath, R.C., 1983. Basic ground-water hydrology, U.S. Geological Survey Water-Supply Paper 2220, 86p.

TABLE 5-3. TRANSPORT MODEL INPUT VALUES (SENSITIVITY)

GROUNDWATER MODELING REPORT
EDWARDS POWER PLANT
ASH POND
BARTONVILLE, ILLINOIS

Well ID	Calibration Concentration (mg/L)	Storage and Specific Yield				Effective Porosity			
		File Name		File Name		File Name		File Name	
		EDW_Conc_339_s_sy_low.gwv		EDW_Conc_339_s_sy_high.gwv		EDW_Conc_339_Por_low.gwv		EDW_Conc_339_Por_high.gwv	
		Concentration (mg/L)	Sensitivity [1]	Concentration (mg/L)	Sensitivity [1]	Concentration (mg/L)	Sensitivity [1]	Concentration (mg/L)	Sensitivity [1]
AP05S	0.0	0.0	moderate	0.0	moderate	0.0	high	0.0	moderately high
AP05D	0.0	0.0	moderately high	0.0	moderately high	0.0	high	0.0	moderately high
AP07S	11.6	11.5	negligible	11.5	negligible	11.8	low	11.3	low
AP07D	0.0	0.0	low	0.0	low	0.1	high	0.0	moderately high
AP08	3.0	3.0	negligible	3.0	negligible	3.0	negligible	3.0	negligible
AP09	3.0	3.0	negligible	3.0	negligible	3.0	negligible	3.0	negligible
APW-01	0.0	0.0	moderate	0.0	moderate	0.4	high	0.0	moderately high
APW-02	0.8	0.8	low	0.8	low	1.4	moderately high	0.5	moderate
APW-03	1.3	1.3	low	1.3	low	2.1	moderately high	0.9	moderate
APW-04	0.1	0.1	low	0.1	moderate	0.3	high	0.0	moderately high
AW-05	2.3	2.4	low	2.3	low	7.5	high	0.6	moderately high
AW-06	0.0	0.0	low	0.0	low	0.0	high	0.0	moderately high
AW-08	0.0	0.0	low	0.0	low	0.0	high	0.0	moderately high
AW-09	1.3	1.3	negligible	1.3	negligible	2.3	moderately high	0.7	moderate
AW-10	1.1	1.1	negligible	1.1	negligible	1.9	moderately high	0.7	moderate
AW-11	1.6	1.6	negligible	1.6	negligible	2.0	moderate	1.3	moderate
AW-12	0.0	0.0	moderate	0.0	moderate	0.1	high	0.0	moderately high
AW-13	1.6	1.6	low	1.6	low	2.1	moderate	1.3	moderate
AW-14	1.9	1.9	negligible	1.9	low	2.3	moderate	1.7	moderate
AW-15	1.5	1.5	low	1.6	low	2.1	moderate	1.2	moderate
AW-15C	0.0	0.0	negligible	0.0	low	0.0	high	0.0	moderately high
AW-15S	2.4	2.4	negligible	2.5	negligible	2.6	low	2.2	low
AW-16	1.2	1.2	negligible	1.2	negligible	2.0	moderately high	0.7	moderate
AW-17	2.2	2.2	negligible	2.2	negligible	2.9	moderate	1.6	moderate
AW-18	2.8	2.8	negligible	2.8	negligible	3.3	moderate	2.3	moderate
AW-19	7.3	7.3	negligible	7.3	negligible	9.5	moderate	5.4	moderate
AW-20	5.3	5.5	low	5.5	low	9.4	moderately high	3.2	moderate
AW-21	11.4	11.4	negligible	11.4	negligible	12.4	low	10.2	moderate
AW-22	3.3	3.3	negligible	3.3	negligible	3.6	moderate	2.5	moderate
P002	11.4	11.4	negligible	11.4	negligible	12.3	low	10.4	low
XPW01A	13.0	13.0	negligible	13.0	negligible	13.0	negligible	13.0	negligible
XPW02	3.0	3.0	negligible	3.0	negligible	3.0	negligible	3.0	negligible
XPW03	3.0	3.0	negligible	3.0	negligible	3.0	negligible	3.0	negligible
		S*0.1 Sy*0.5		S*10 Sy*2[2]		Porosity-0.05		Porosity+0.05	

[O: JJW 4/14/22; C: JRK 4/14/22]

TABLE 5-3. TRANSPORT MODEL INPUT VALUES (SENSITIVITY)

GROUNDWATER MODELING REPORT

EDWARDS POWER PLANT

ASH POND

BARTONVILLE, ILLINOIS

Notes:

[1] Sensitivity Explanation:

Negligible = concentration changed by less than 1%

Low = concentration change between 1% and 10%

Moderate = concentration change between 10% and 50%

Moderately High = concentration change between 50% and 100%

High = concentration change greater than 100%

[2] High specific yield sensitivity not analyzed for zone 8 (UCF above River Boundary Conditions) since the calibration value was already near upper limits of acceptable values for specific yield

ID = identification

mg/L = milligrams per liter

S = storativity

Sy = specific yield

TABLE 6-1. HELP MODEL INPUT AND OUTPUT VALUES
GROUNDWATER MODELING REPORT
EDWARDS POWER PLANT
ASH POND
BARTONVILLE, ILLINOIS

Closure Scenario - Area Description	CBR - Removal Area	CIP - Removal Area	CIP - Consolidation and Cover System Area	Notes
Input Parameter				
Climate-General				
City	Bartonville, IL	Bartonville, IL	Bartonville, IL	Nearby city to the Site within HELP database
Latitude	40.60	40.60	40.60	Site latitude
Evaporative Zone Depth	18	18	18	Estimated based on geographic location (Illinois) and uppermost soil type (Tolaymat, T. and Krause, M, 2020)
Maximum Leaf Area Index	4.5	4.5	4.5	Maximum for geographic location (Illinois) (Tolaymat, T. and Krause, M, 2020)
Growing Season Period, Average Wind Speed, and Quarterly Relative Humidity	Peoria, IL	Peoria, IL	Peoria, IL	Nearby city to the Edwards Ash Pond within HELP database
Number of Years for Synthetic Data Generation	30	30	30	
Temperature, Evapotranspiration, and Precipitation	Precipitation, temperature, and solar radiation was simulated based on HELP V4 weather simulation for: Lat/Long: 40.60/-89.66	Precipitation, temperature, and solar radiation was simulated based on HELP V4 weather simulation for: Lat/Long: 40.60/-89.66	Precipitation, temperature, and solar radiation was simulated based on HELP V4 weather simulation for: Lat/Long: 40.60/-89.66	
Soils-General				
% where runoff possible	100	100	100	
Area (acres)	91	22	69	CBR - Removal Area based on HCR (Ramboll, 2021a); CIP - Consolidation and Cover System Area based on construction drawing for Edwards Ash Pond; CIP -Removal Area equals the difference
Specify Initial Moisture Content	No	No	No	
Surface Water/Snow	Model Calculated	Model Calculated	Model Calculated	
Soils-Layers				
1	Unsaturated Backfill Material (HELP Final Cover Soil [topmost layer])	Unsaturated Backfill Material (HELP Final Cover Soil [topmost layer])	Vegetative Soil Layer (HELP Final Cover Soil [topmost layer])	Layers details for CBR and CIP areas based on grading plans, construction drawings, and cover system design for Edwards Ash Pond
2	--	--	Protective Soil Layer (HELP Vertical Percolation Layer)	
3	--	--	Geocomposite Drainage Layer (HELP Geosynthetic Drainage Net)	
4	--	--	Geomembrane Liner	
5	--	--	Unsaturated CCR Material (HELP Waste)	
Soil Parameters--Layer 1, Unsaturated Backfill Material (HELP Final Cover Soil [topmost layer]) or Vegetative Soil Layer (HELP Final Cover Soil [topmost layer])				
Type	1	1	1	Vertical Percolation Layer (Cover Soil)
Thickness (in)	12	72	6	For CBR and CIP removal areas, layer 1 thickness is the average thickness of unsaturated backfill material placed after removal
Texture	12	12	23	defaults used
Description	Silty Clay Loam	Silty Clay Loam	Silty Loam (Moderate)	
Saturated Hydraulic Conductivity (cm/s)	4.20E-05	4.20E-05	9.00E-06	defaults used
Soil Parameters--Layer 2, Protective Soil Layer (HELP Vertical Percolation Layer)				
Type	--	--	1	Vertical Percolation Layer
Thickness (in)	--	--	18	design thickness
Texture	--	--	10	defaults used
Description	--	--	Sandy Clay Loam	
Saturated Hydraulic Conductivity (cm/s)	--	--	1.20E -4	defaults used

TABLE 6-1. HELP MODEL INPUT AND OUTPUT VALUES
GROUNDWATER MODELING REPORT
EDWARDS POWER PLANT
ASH POND
BARTONVILLE, ILLINOIS

Closure Scenario - Area Description	CBR - Removal Area	CIP - Removal Area	CIP - Consolidation and Cover System Area	Notes
Soil Parameters--Layer 3, Geocomposite Drainage Layer(HELP Geosynthetic Drainage Net)				
Type	--	--	2	Lateral Drainage Layer
Thickness (in)	--	--	0.2	design thickness
Texture	--	--	20	defaults used
Description	--	--	Geosynthetic Drainage Net	
Saturated Hydraulic Conductivity (cm/s)	--	--	1.00E+01	defaults used
Soil Parameters--Layer 4, Geomembrane Liner				
Type	--	--	4	Flexible Membrane Liner
Thickness (in)	--	--	0.04	design thickness
Texture	--	--	36	defaults used
Description	--	--	Geomembrane	
Saturated Hydraulic Conductivity (cm/s)			4.00E -13	defaults used
Soil Parameters--Layer 5, Unsaturated CCR Material (HELP Waste)				
Type	--	--	1	Vertical Percolation Layer (Waste)
Thickness (in)	--	--	408	Estimated unsaturated CCR thickness within CIP Consolidation and Cover System Area
Texture	--	--	30	Custom layer, adjusted for site specific hydraulic conductivity
Description	--	--	High-Density Electric Plant Coal Fly Ash	
Saturated Hydraulic Conductivity (cm/s)	--	--	2.08E-06	calibrated flow model vertical hydraulic conductivity for CCR
Soils--Runoff				
Runoff Curve Number	86.1	86.1	89.3	HELP-computed curve number
Slope	0.25%	0.25%	1.27%	Estimated average from construction design drawings for Edwards Ash Pond
Length (ft)	1300	1300	1190	estimated maximum flow path
Texture	12	12	23	uppermost layer texture
Vegetation	fair	fair	fair	fair indicating fair stand of grass on surface of soil backfill
Execution Parameters				
Years	30	30	30	
Report Daily	No	No	No	
Report Monthly	No	No	No	
Report Annual	Yes	Yes	Yes	
Output Parameter				
Percolation Rate (in/yr)	**5.09**	**4.03**	**0.0002**	

O: EGP 4/5/2022 C: JJW 4/5/2022

Notes:
% = percent
cm/s = centimeters per second
ft = feet
HELP = Hydrologic Evaluation of Landfill Performance
IL = Illinois
in = inches
in/yr = inches per year
Lat = latitude
Long = longitude
CBR = Closure By Removal
CIP = Closure In Place
HCR = Hydrogeologic Characterization Report

References:
Tolaymat, T. and Krause, M, 2020. *Hydrologic Evaluation of Landfill Performance: HELP 4.0 User Manual*. United States Environmental Protection Agency, Washington, DC, EPA/600/B 20/219.
Ramboll Americas Engineering Solutions, Inc. (Ramboll), 2021a. Hydrogeologic Site Characterization Report. Edwards Ash Pond. Edwards Power Plant. Bartonville, Illinois.

TABLE 6-2. PREDICTION MODEL INPUT VALUES
GROUNDWATER MODELING REPORT
EDWARDS POWER PLANT
ASH POND
BARTONVILLE, ILLINOIS

Scenario 1: CIP (CCR removal from the northwest areas of the Ash Pond, consolidation to the northeast, central and southern areas of the Ash Pond, and construction of a cover system over the remaining CCR)

Prediction Model	Construction Period (years)	Hydrostratigraphic Unit	Recharge Zone	Boron Recharge Concentration (mg/L)	Recharge (ft/day)	Recharge (in/yr)	Constant Head (feet)	Constant Concentration (mg/L)
Dewatering	1	Fill Unit - CCR Consolidation and Cover System (Central, Fly Ash Pond)	2	3	4.44E-08	0.0002	434	3
Dewatering	1	Fill Unit - CCR Consolidation and Cover System (South of Railroad, Inactive Area)	3	3	4.44E-08	0.0002	434	3
Dewatering	1	Fill Unit - CCR Consolidation and Cover System (Northwest, Process Water Pond)	4	13	4.44E-08	0.0002	434	13
Dewatering	1	Fill Unit - CCR Consolidation and Cover System (South, Clarification Pond)	5	3	4.44E-08	0.0002	434	3
Dewatering	1	Fill Unit - CCR Consolidation and Cover System (Northeast, Sluice Area)	7	0.5	4.44E-08	0.0002	434	0.5
Dewatering	1	Fill Unit - CCR Removal (Northwest, Process Water Pond and Fly Ash Pond)	10	0	9.19E-04	4.03	434	0
CIP	1000	Fill Unit - CCR Consolidation and Cover System (Central, Fly Ash Pond)	2	3	4.44E-08	0.0002	--	3
CIP	1000	Fill Unit - CCR Consolidation and Cover System (South of Railroad, Inactive Area)	3	3	4.44E-08	0.0002	--	3
CIP	1000	Fill Unit - CCR Consolidation and Cover System (Northwest, Process Water Pond)	4	13	4.44E-08	0.0002	--	13
CIP	1000	Fill Unit - CCR Consolidation and Cover System (South, Clarification Pond)	5	3	4.44E-08	0.0002	--	3
CIP	1000	Fill Unit - CCR Consolidation and Cover System (Northeast, Sluice Area)	7	0.5	4.44E-08	0.0002	--	0.5
CIP	1000	Fill Unit - CCR Removal (Northwest, Process Water Pond and Fly Ash Pond)	10	0	9.19E-04	4.03	--	--
Prediction Model	**Construction Period (years)**	**Hydrostratigraphic Unit**	**Hydraulic Conductivity Zone**	**Horizontal Hydraulic Conductivity (ft/d)**	**Horizontal Hydraulic Conductivity (cm/s)**	**Vertical Hydraulic Conductivity (ft/d)**		**Vertical Hydraulic Conductivity (cm/s)**
Dewatering	1	Fill Unit (CCR)	6	0.1	3.53E-05	0.006		2.12E-06
Dewatering	1	Fill Unit (Soil Backfill)	10	1.19	4.20E-04	0.119		4.20E-05
CIP	1000	Fill Unit (CCR)	6	0.1	3.53E-05	0.006		2.12E-06
CIP	1000	Fill Unit (Soil Backfill)	10	1.19	4.20E-04	0.119		4.20E-05
Prediction Model	**Construction Period (years)**	**Hydrostratigraphic Unit**	**Storage, Specific Yield and Effective Porosity Zone**		**Storage**	**Specific Yield**		**Effective Porosity**
Dewatering	1	Fill Unit (CCR)	6		0.003	0.2		0.2
Dewatering	1	Fill Unit (Soil Backfill)	10		0.003	0.16		0.16
CIP	1000	Fill Unit (CCR)	6		0.003	0.2		0.2
CIP	1000	Fill Unit (Soil Backfill)	10		0.003	0.16		0.16
Prediction Model	**Construction Period (years)**	**Drain Width (feet)**	**Length of Drain Cell (feet)**	**Drain Bed Thickness (feet)**	**Hydraulic Conductivity (ft/d)**	**Stage of Drain (feet)**		**Drain Conductance (ft^2/d)**
Dewatering	1	Fill Unit (Soil Backfill)	--	--	--	--		--
CIP	1000	Fill Unit (Soil Backfill)	25	1	50	433		3.13E+04

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TABLE 6-2. PREDICTION MODEL INPUT VALUES
GROUNDWATER MODELING REPORT
EDWARDS POWER PLANT
ASH POND
BARTONVILLE, ILLINOIS

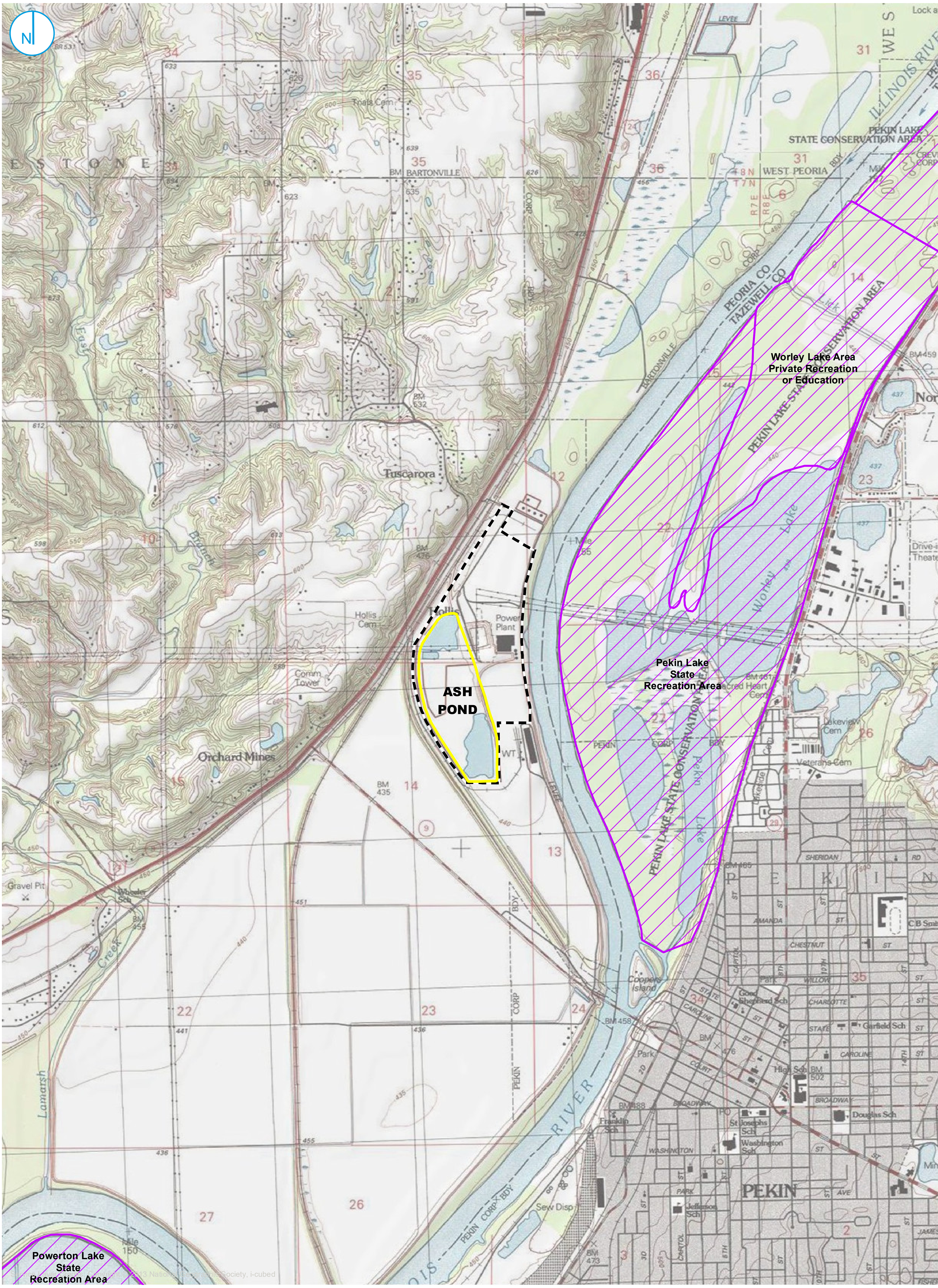
Scenario 2: CBR (CCR removal from the Ash Pond)

Prediction Model	Construction Period (years)	Hydrostratigraphic Unit	Recharge Zone	Boron Recharge Concentration (mg/L)	Recharge (ft/day)	Recharge (in/yr)	Constant Head (feet)	Constant Concentration (mg/L)
Dewatering	1	Fill Unit - CCR Removal (Central, Fly Ash Pond)	2	0	1.16E-03	5.08	434	0
Dewatering	1	Fill Unit - CCR Removal (South of Railroad, Inactive Area)	3	0	1.16E-03	5.08	434	0
Dewatering	1	Fill Unit - CCR Removal (Northwest, Process Water Pond)	4	0	1.16E-03	5.08	434	0
Dewatering	1	Fill Unit - CCR Removal (South, Clarification Pond)	5	0	1.16E-03	5.08	434	0
Dewatering	1	Fill Unit - CCR Removal (Northeast, Sluice Area)	7	0	1.16E-03	5.08	434	0
CBR	1000	Fill Unit - CCR Removal (Central, Fly Ash Pond)	2	0	1.16E-03	5.08	--	--
CBR	1000	Fill Unit - CCR Removal (South of Railroad, Inactive Area)	3	0	1.16E-03	5.08	--	--
CBR	1000	Fill Unit - CCR Removal (Northwest, Process Water Pond)	4	0	1.16E-03	5.08	--	--
CBR	1000	Fill Unit - CCR Removal (South, Clarification Pond)	5	0	1.16E-03	5.08	--	--
CBR	1000	Fill Unit - CCR Removal (Northeast, Sluice Area)	7	0	1.16E-03	5.08	--	--
Prediction Model	**Construction Period (years)**	**Hydrostratigraphic Unit**	**Hydraulic Conductivity Zone**	**Horizontal Hydraulic Conductivity (ft/d)**	**Horizontal Hydraulic Conductivity (cm/s)**	**Vertical Hydraulic Conductivity (ft/d)**		**Vertical Hydraulic Conductivity (cm/s)**
Dewatering	1	Fill Unit (CCR)	--	--	--	--		--
Dewatering	1	Fill Unit (Soil Backfill)	6	1.19	4.20E-04	0.119		4.20E-05
CBR	1000	Fill Unit (CCR)	--	--	--	--		--
CBR	1000	Fill Unit (Soil Backfill)	6	1.19	4.20E-04	0.119		4.20E-05
Prediction Model	**Construction Period (years)**	**Hydrostratigraphic Unit**	**Storage, Specific Yield and Effective Porosity Zone**		**Storage**	**Specific Yield**		**Effective Porosity**
Dewatering	1	Fill Unit (CCR)	--		--	--		--
Dewatering	1	Fill Unit (Soil Backfill)	6		0.003	0.16		0.16
CBR	1000	Fill Unit (CCR)	--		--	--		--
CBR	1000	Fill Unit (Soil Backfill)	6		0.003	0.16		0.16
Prediction Model	**Construction Period (years)**	**Drain Width (feet)**	**Length of Drain Cell (feet)**	**Drain Bed Thickness (feet)**	**Hydraulic Conductivity (ft/d)**	**Stage of Drain (feet)**		**Drain Conductance (ft^2/d)**
Dewatering	1	Fill Unit (Soil Backfill)	--	--	--	--		--
CBR	1000	Fill Unit (Soil Backfill)	25	1	50	433		3.13E+04

[O: JJW 4/11/22; C: EGP 4/12/22]

Notes:
-- = boundary condition or property zone not included in prediction model
CBR = Closure By Removal
CCR = coal combustion residuals
CIP = Closure In Place
ft^2/day = feet squared per day
ft/day = feet per day
in/yr = inches per year
mg/L = milligrams per liter
cm/s = centimeters per second

FIGURES



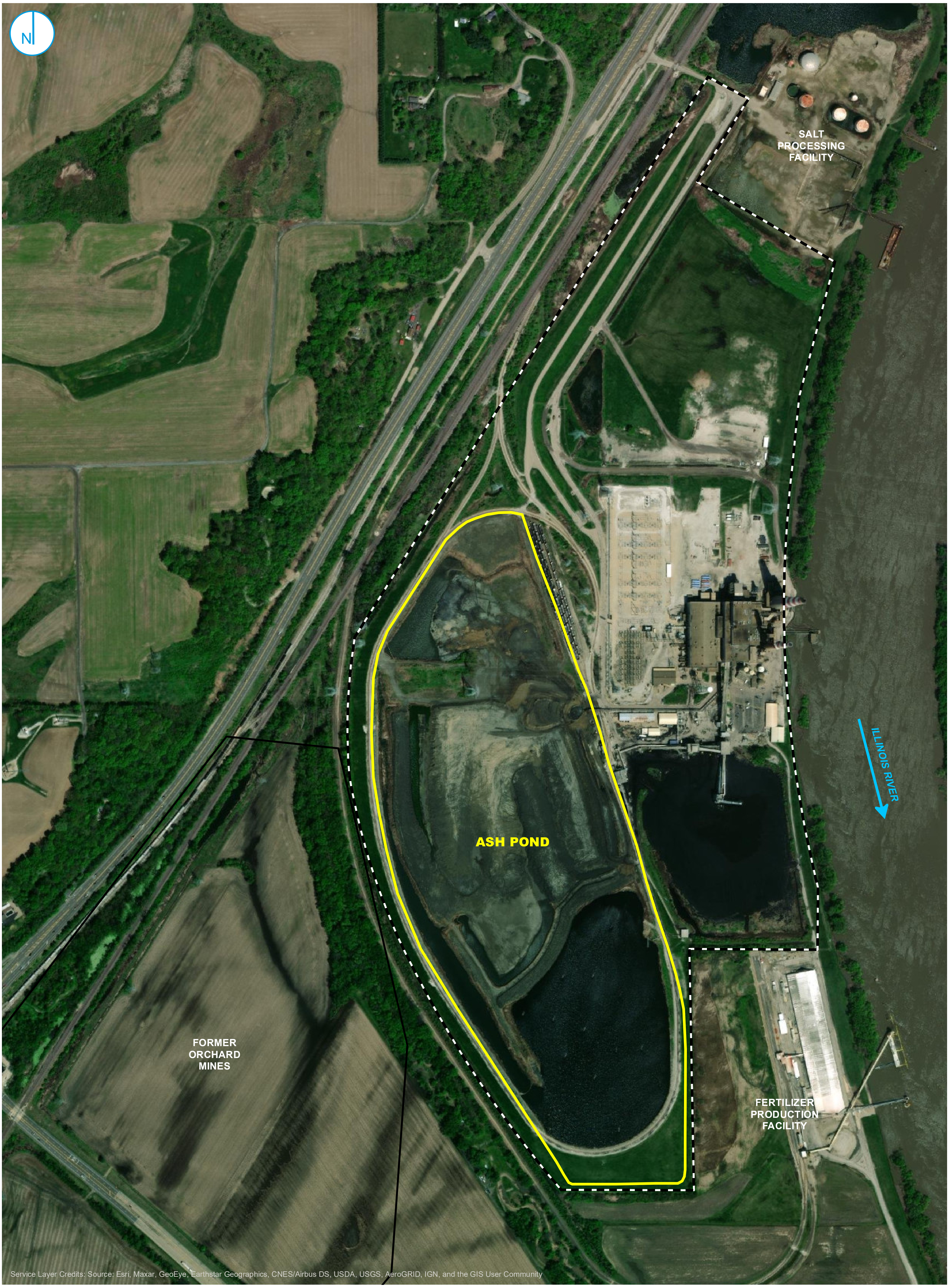
PART 845 REGULATED UNIT (SUBJECT UNIT)
PROPERTY BOUNDARY
PROTECTED AREA

SITE LOCATION MAP

FIGURE 1-1

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.



PART 845 REGULATED UNIT (SUBJECT UNIT)
FORMER ORCHARD MINES AREA
PROPERTY BOUNDARY

0 250 500 Feet

DRAFT

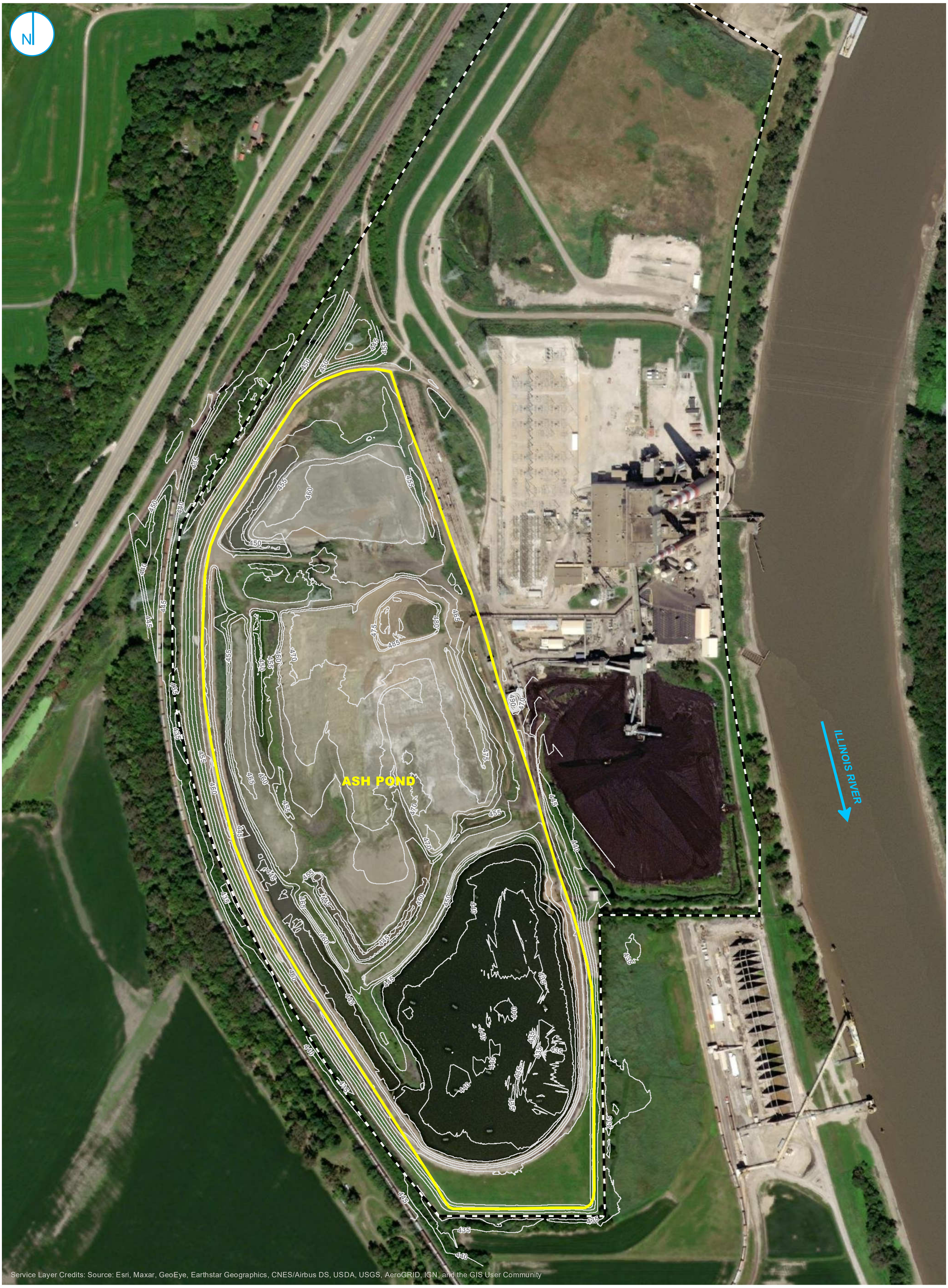
SITE MAP

FIGURE 1-2

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

RAMBOLL



5FT TOPOGRAPHIC CONTOUR
PART 845 REGULATED UNIT (SUBJECT UNIT)
PROPERTY BOUNDARY

Note:
Elevation contours shown in feet, North American Vertical Datum of 1988 (NAVD88)

0 200 400 Feet

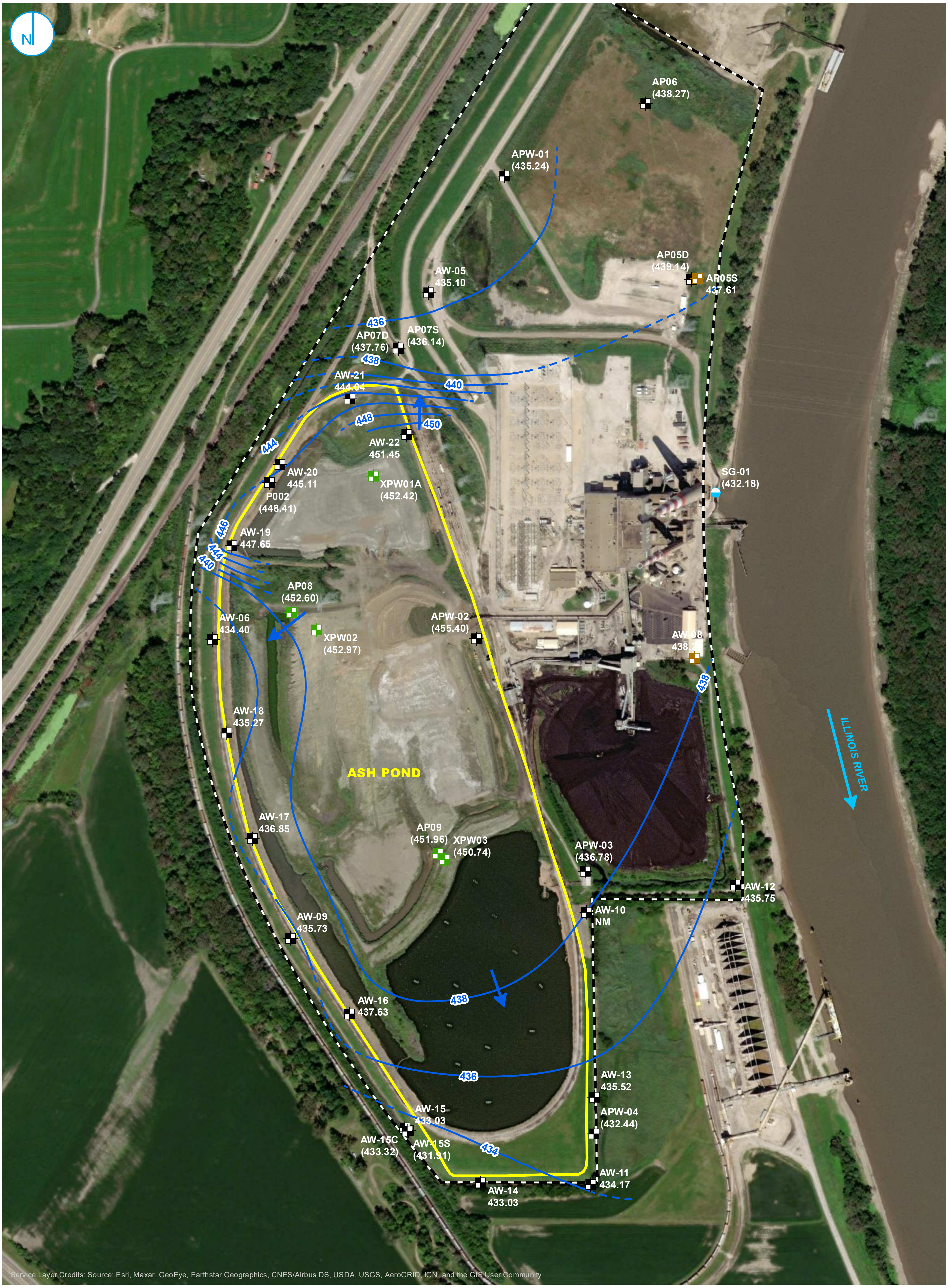
DRAFT

SITE TOPOGRAPHIC MAP

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

FIGURE 2-1

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.



BACKGROUND WELL
MONITORING WELL
PORE WATER WELL
STAFF GAGE, RIVER
PART 845 REGULATED UNIT (SUBJECT UNIT)
PROPERTY BOUNDARY

GROUNDWATER ELEVATION CONTOUR (2-FT CONTOUR INTERVAL, NAVD88)
INFERRED GROUNDWATER ELEVATION CONTOUR
GROUNDWATER FLOW DIRECTION

0 212.5 425 Feet

NOTES
1. PARENTHESIS INDICATES WELL NOT USED FOR CONTOURING
2. ELEVATION CONTOURS SHOWN IN FEET, NORTH AMERICAN VERTICAL DATUM OF 1988

DRAFT

UPPERMOST AQUIFER POTENTIOMETRIC SURFACE MAP FEBRUARY 9, 2021

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

FIGURE 2-2

RAMBOLL AMERICAS ENGINEERING SOLUTIONS, INC.

RAMBOLL

BACKGROUND WELL
MONITORING WELL
PORE WATER WELL
STAFF GAGE, RIVER
PART 845 REGULATED UNIT (SUBJECT UNIT)
PROPERTY BOUNDARY

GROUNDWATER ELEVATION CONTOUR (2-FT CONTOUR INTERVAL, NAVD88)
INFERRED GROUNDWATER ELEVATION CONTOUR
GROUNDWATER FLOW DIRECTION

0 212.5 425 Feet

NOTES
1. PARENTHESIS INDICATES WELL NOT USED FOR CONTOURING
2. ELEVATION CONTOURS SHOWN IN FEET, NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD88)

UPPERMOST AQUIFER POTENTIOMETRIC SURFACE MAP MARCH 22, 2021

FIGURE 2-3

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

RAMBOLL AMERICAS ENGINEERING SOLUTIONS, INC.
RAMBOLL

MONITORING WELL
PORE WATER WELL
STAFF GAGE, RIVER
PART 845 REGULATED UNIT (SUBJECT UNIT)
PROPERTY BOUNDARY

0 200 400 Feet

MONITORING WELL LOCATION MAP

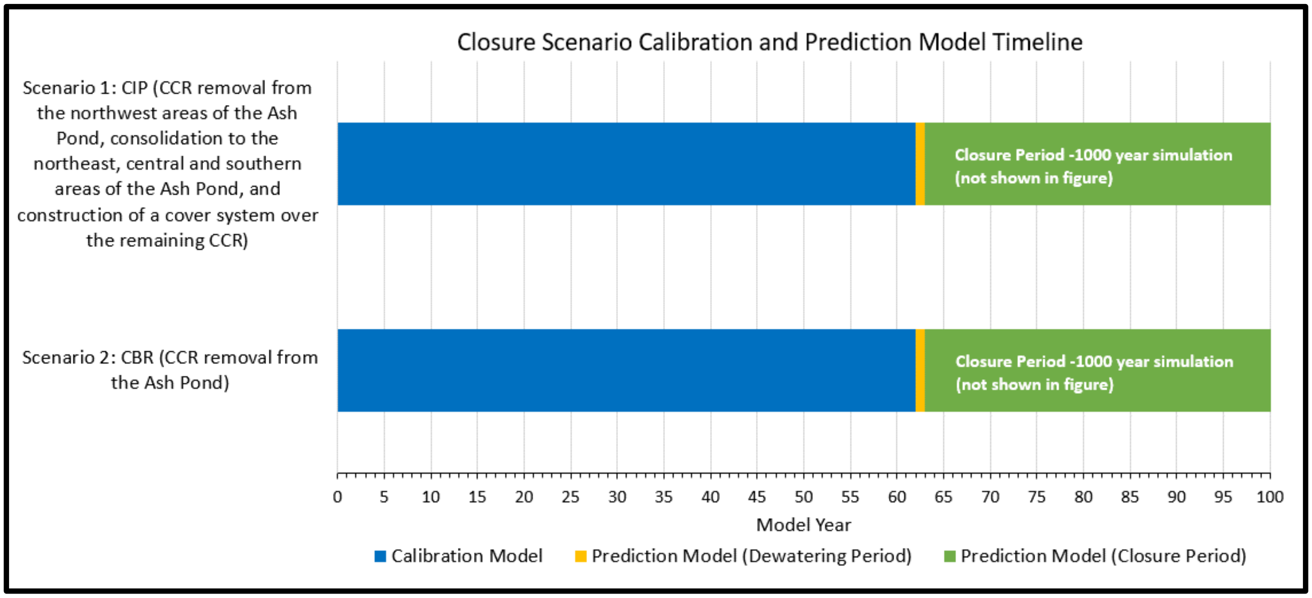
FIGURE 2-4

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

RAMBOLL

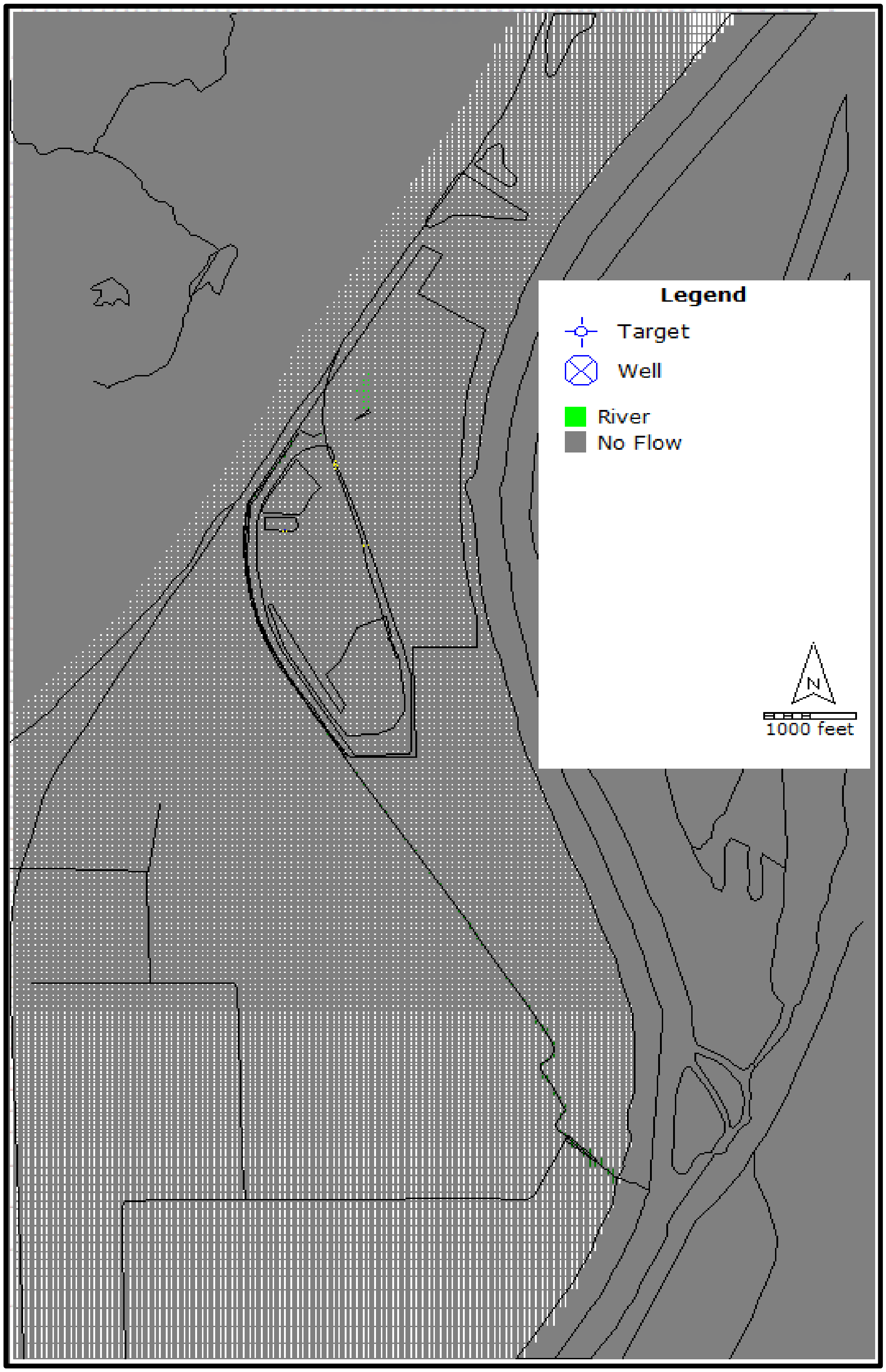
FIGURE 4-1



CLOSURE SCENARIO CALIBRATION AND PREDICTION MODEL TIMELINE

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

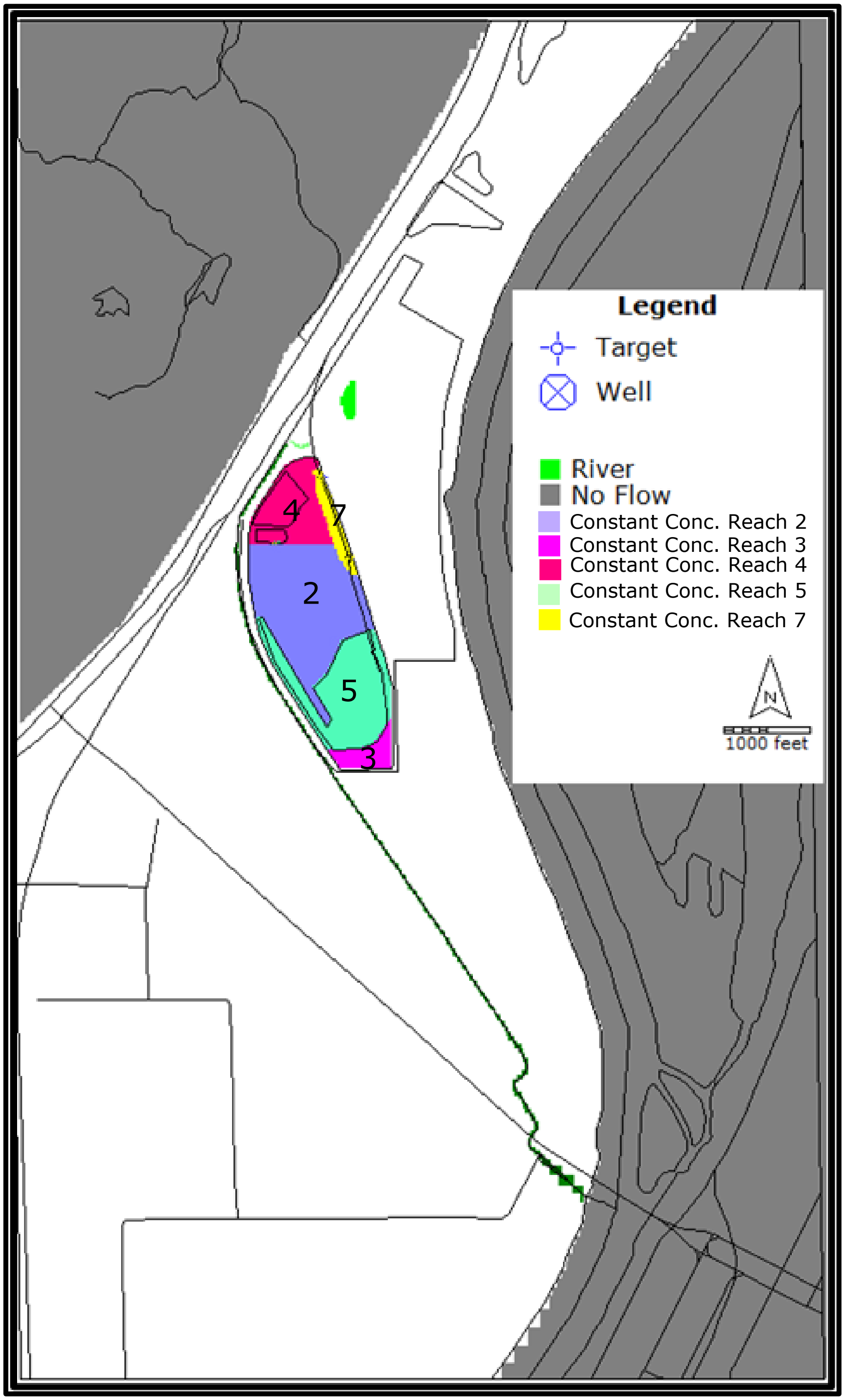
RAMBOLL



MODEL GRID FOR LAYERS 1 THROUGH 5

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

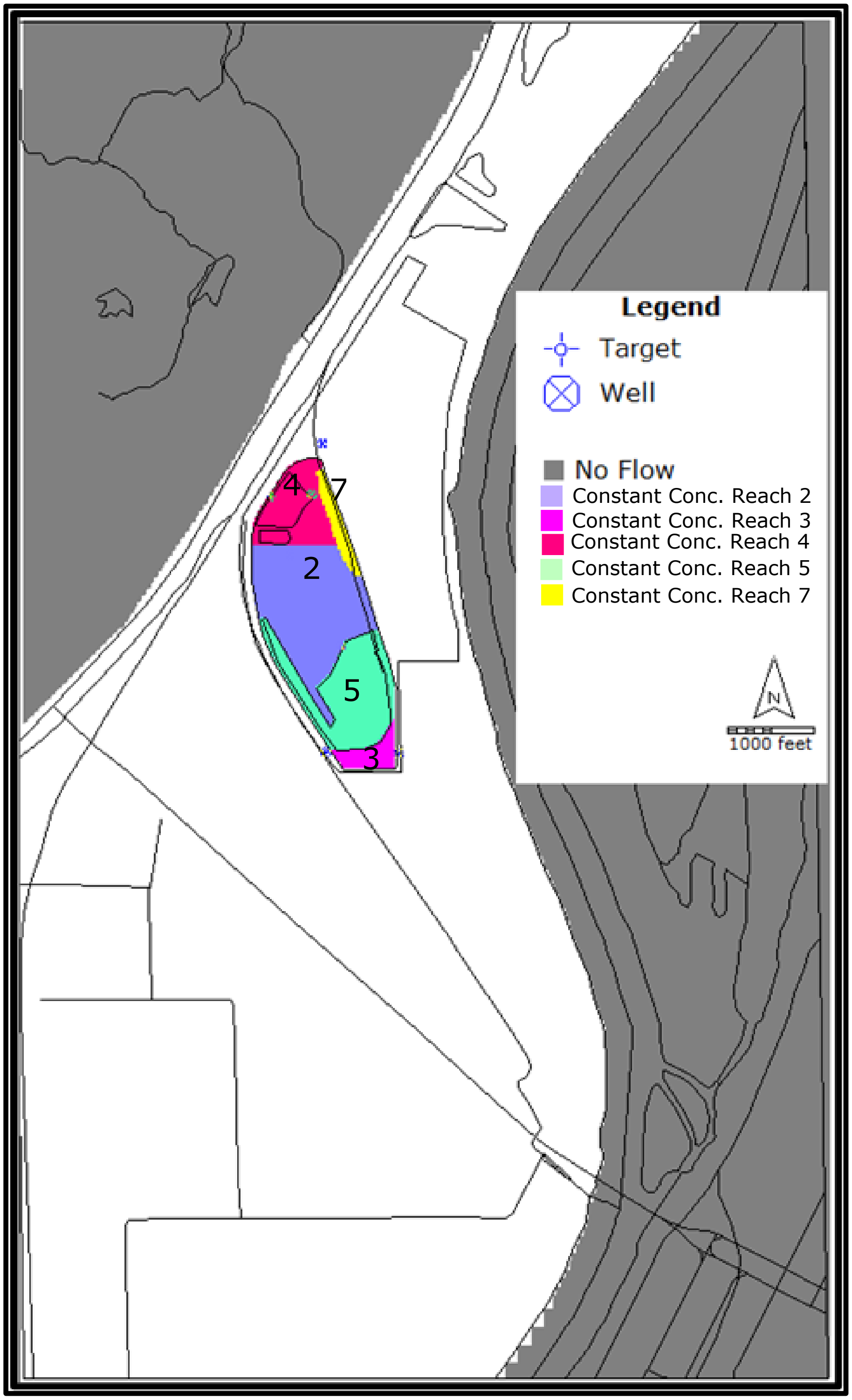
RAMBOLL



BOUNDARY CONDITIONS FOR LAYER 1

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

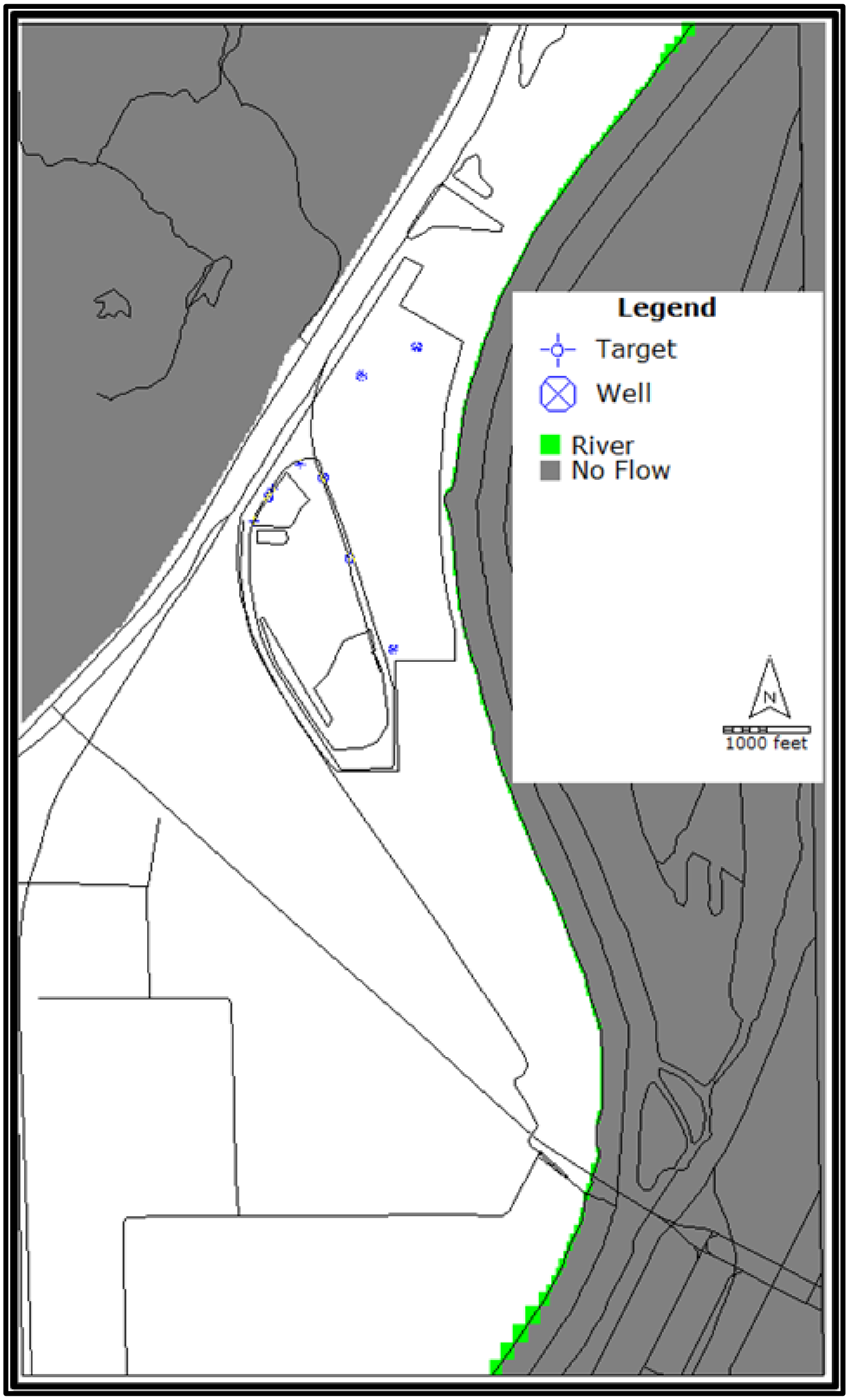
RAMBOLL



BOUNDARY CONDITIONS FOR LAYER 2

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

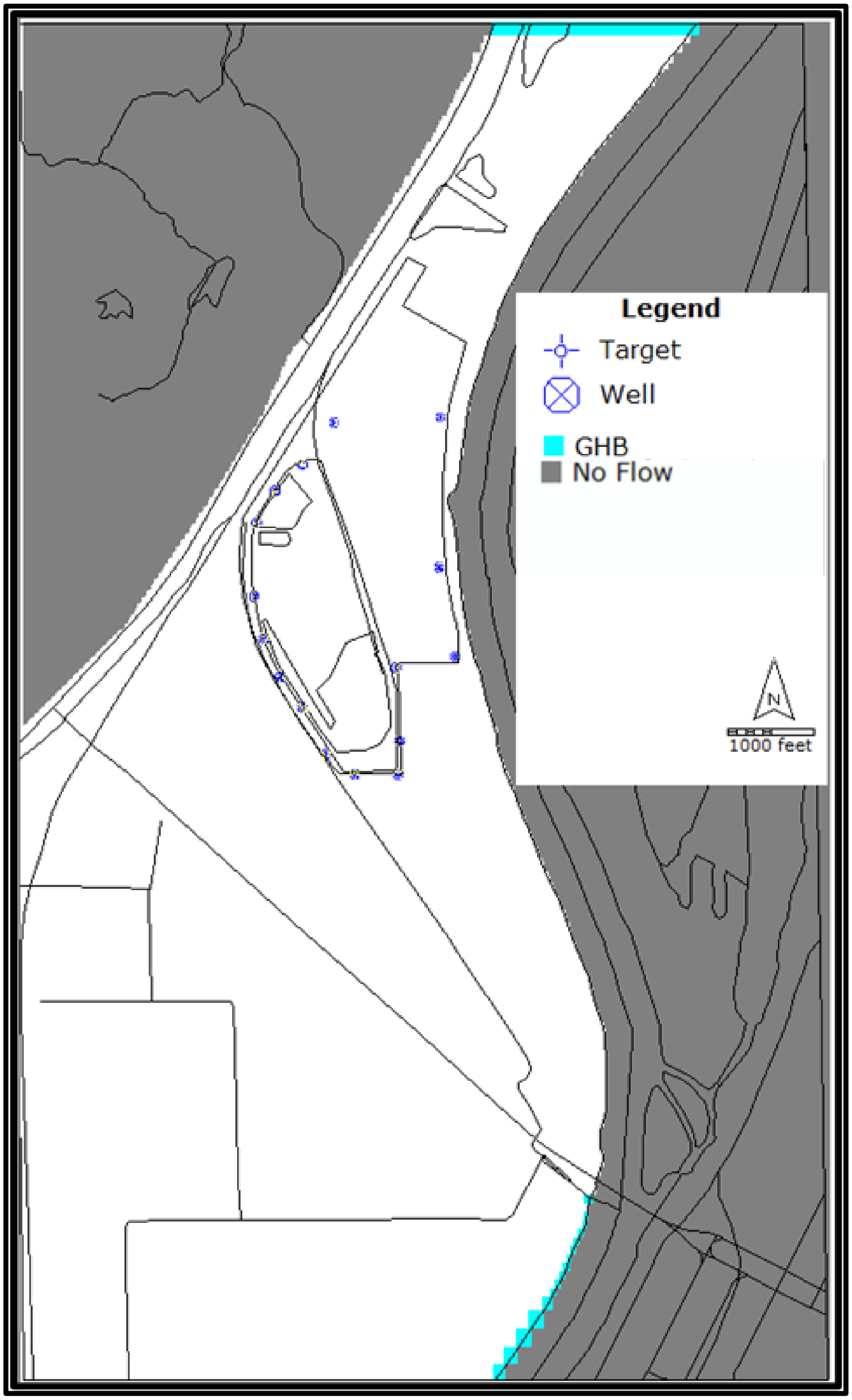
RAMBOLL



BOUNDARY CONDITIONS FOR LAYER 3

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

RAMBOLL

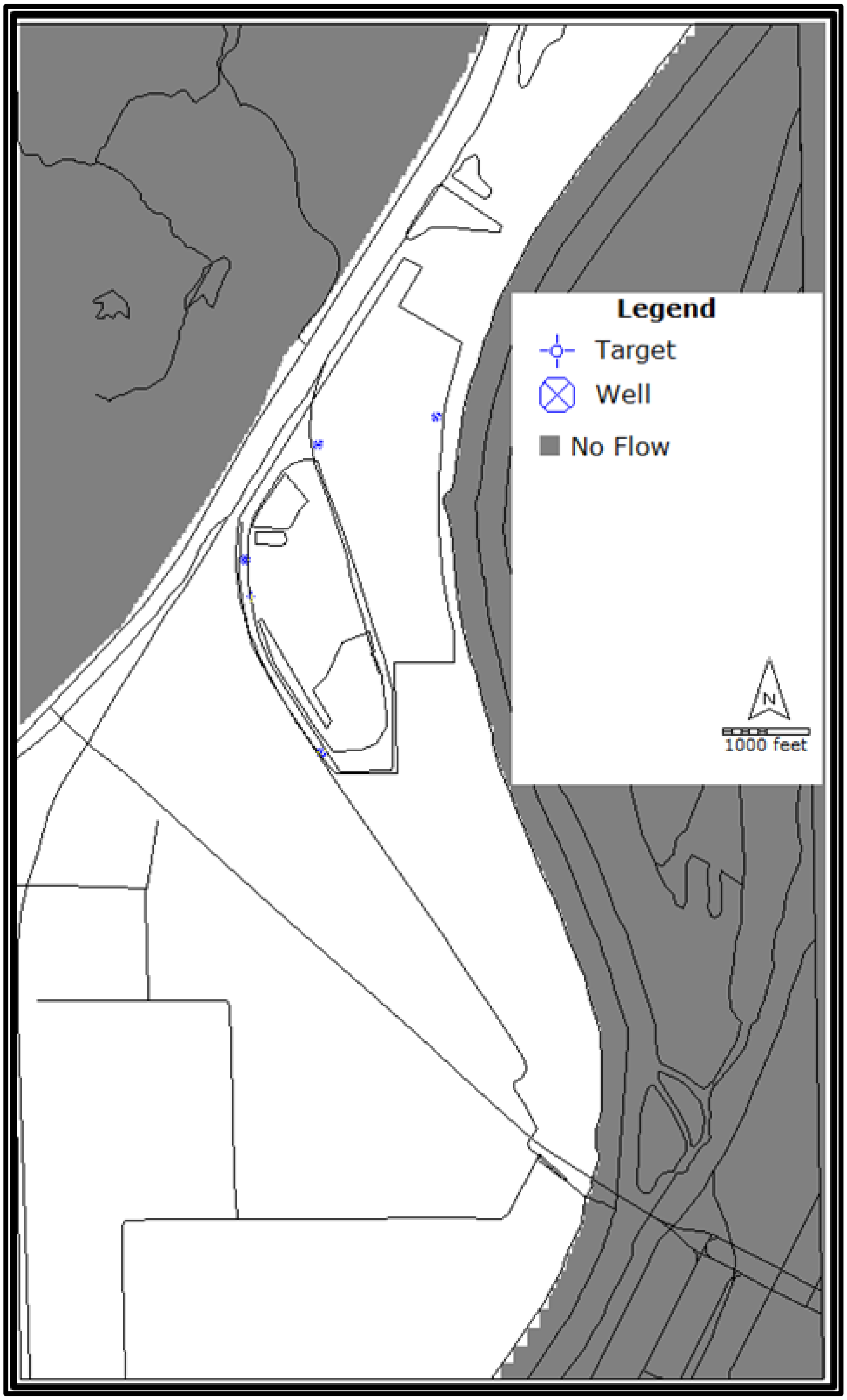


BOUNDARY CONDITIONS FOR LAYER 4

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

RAMBOLL

FIGURE 5-6

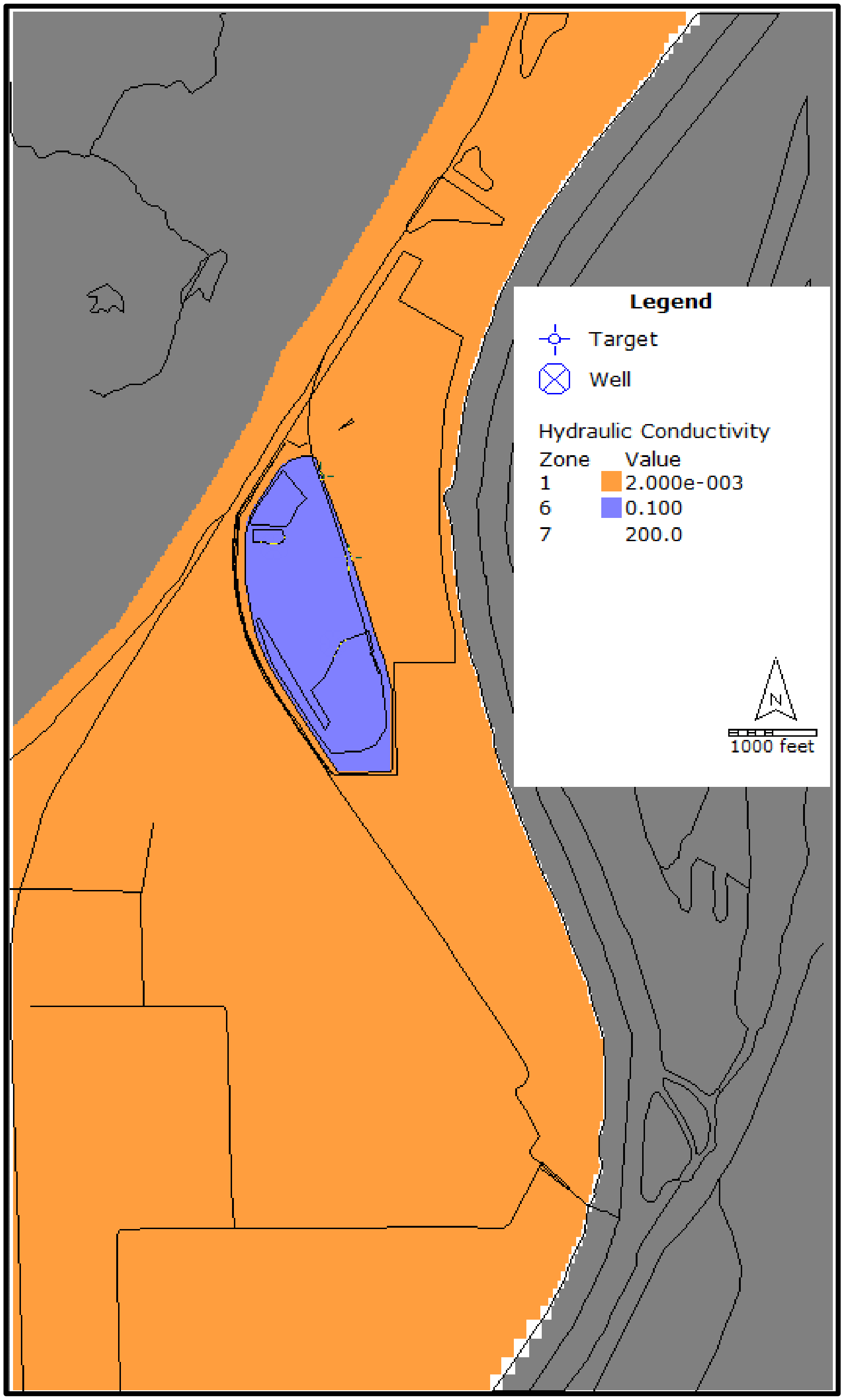


BOUNDARY CONDITIONS FOR LAYER 5

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

RAMBOLL

FIGURE 5-7

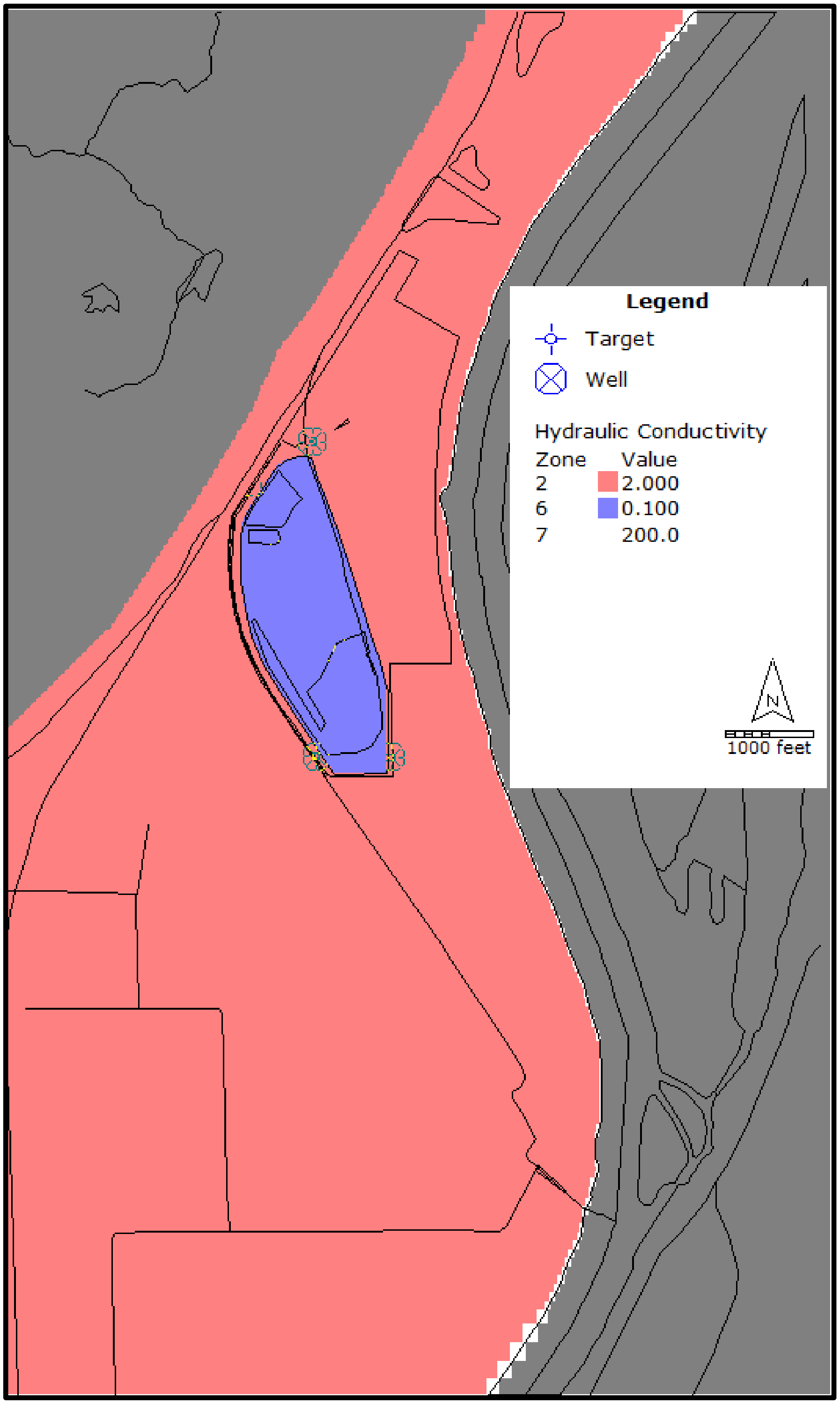


DISTRIBUTION OF HYDRAULIC CONDUCTIVITY ZONE (FEET/DAY) FOR LAYER 1

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

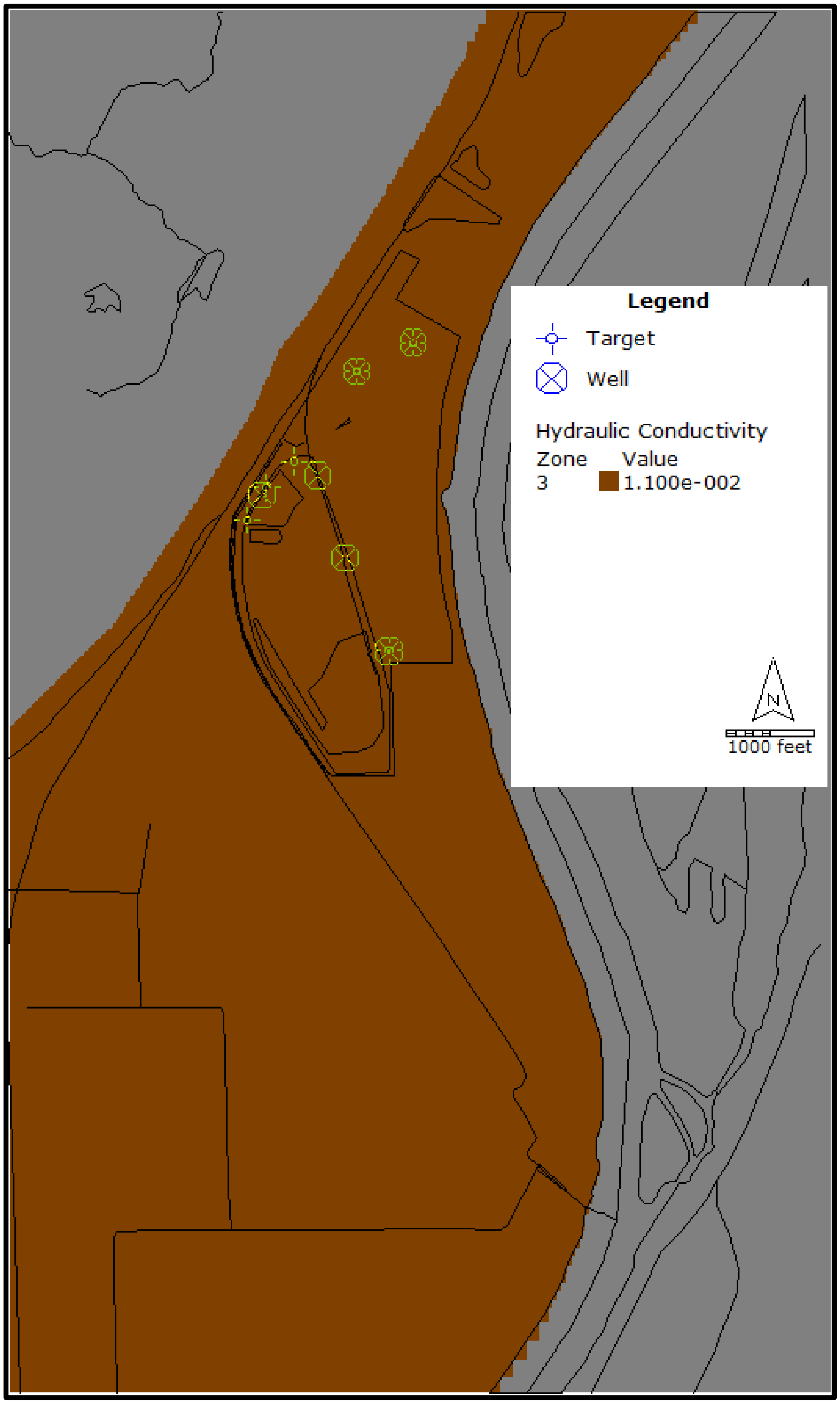
RAMBOLL

FIGURE 5-8



DISTRIBUTION OF HYDRAULIC CONDUCTIVITY ZONE (FEET/DAY) FOR LAYER 2

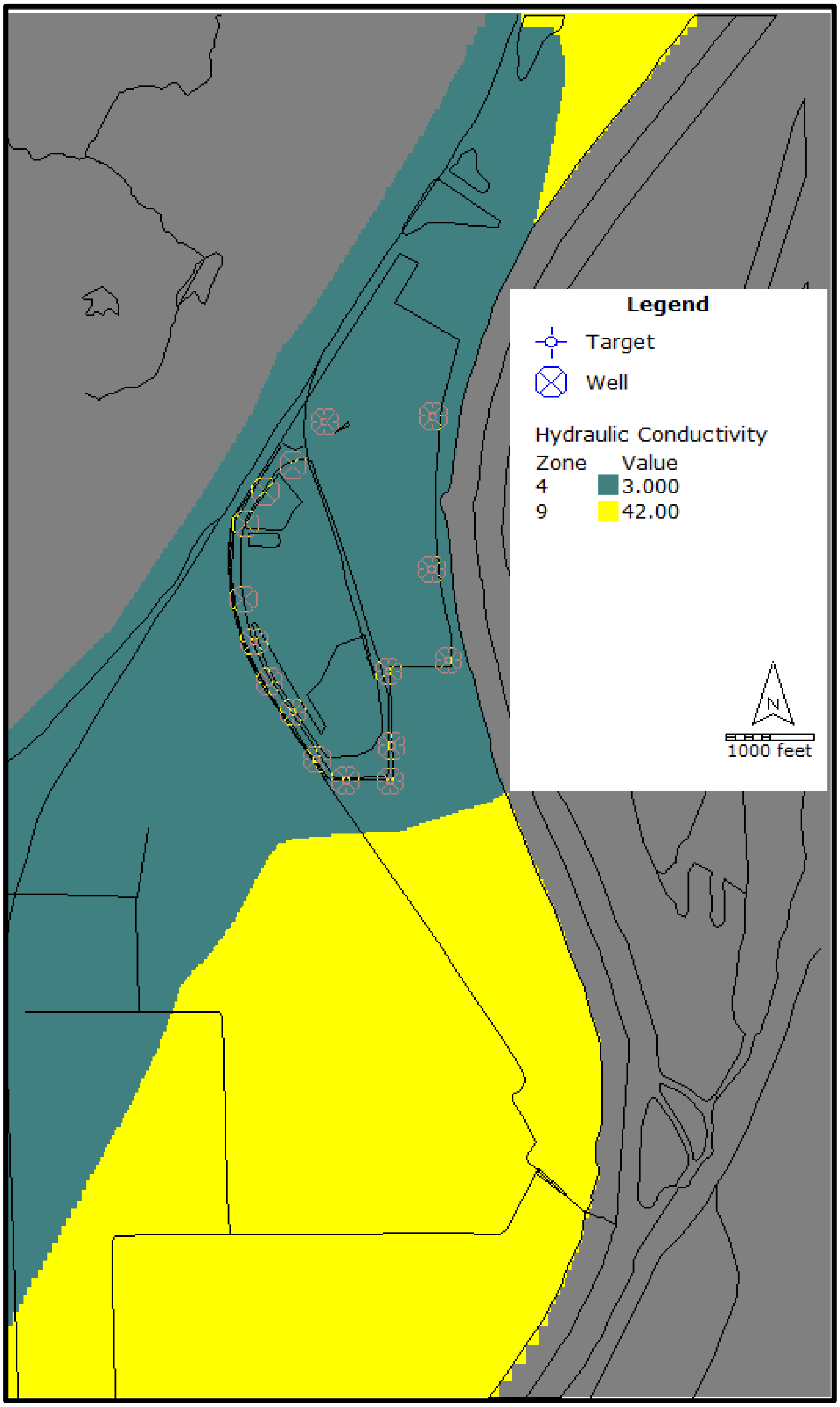
GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS



DISTRIBUTION OF HYDRAULIC CONDUCTIVITY ZONE (FEET/DAY) FOR LAYER 3

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

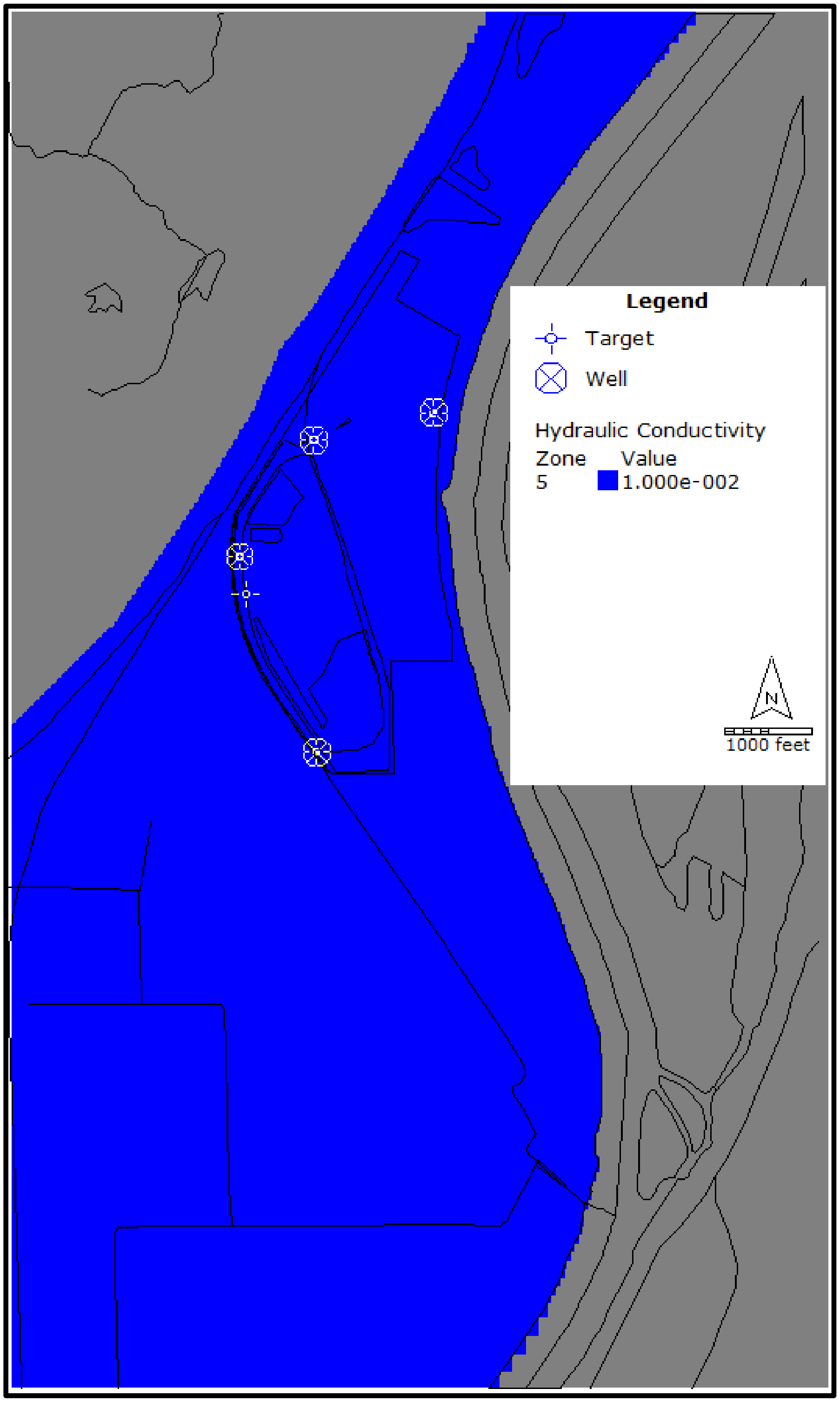
RAMBOLL



DISTRIBUTION OF HYDRAULIC CONDUCTIVITY ZONE (FEET/DAY) FOR LAYER 4

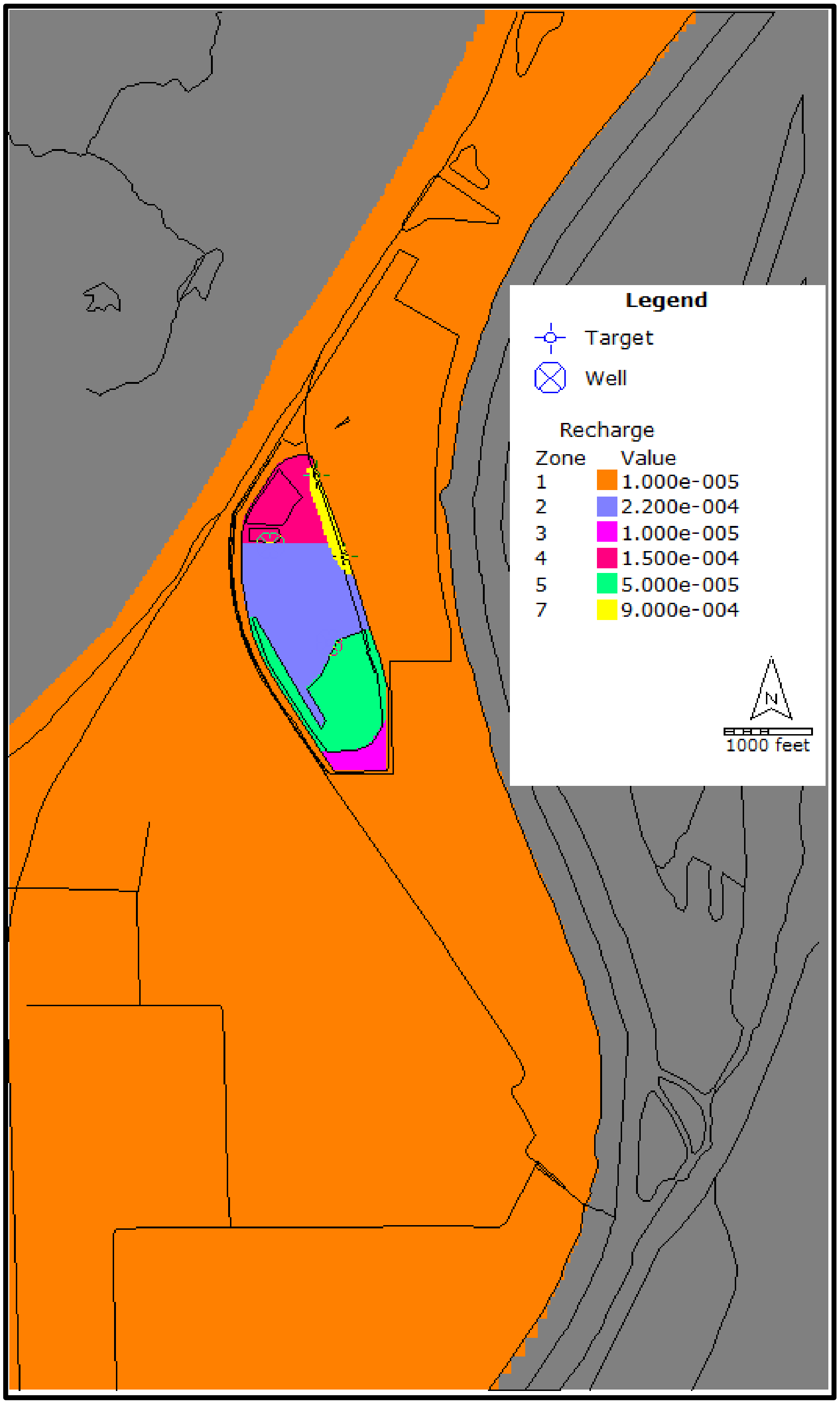
GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

RAMBOLL



DISTRIBUTION OF HYDRAULIC CONDUCTIVITY ZONE (FEET/DAY) FOR LAYER 5

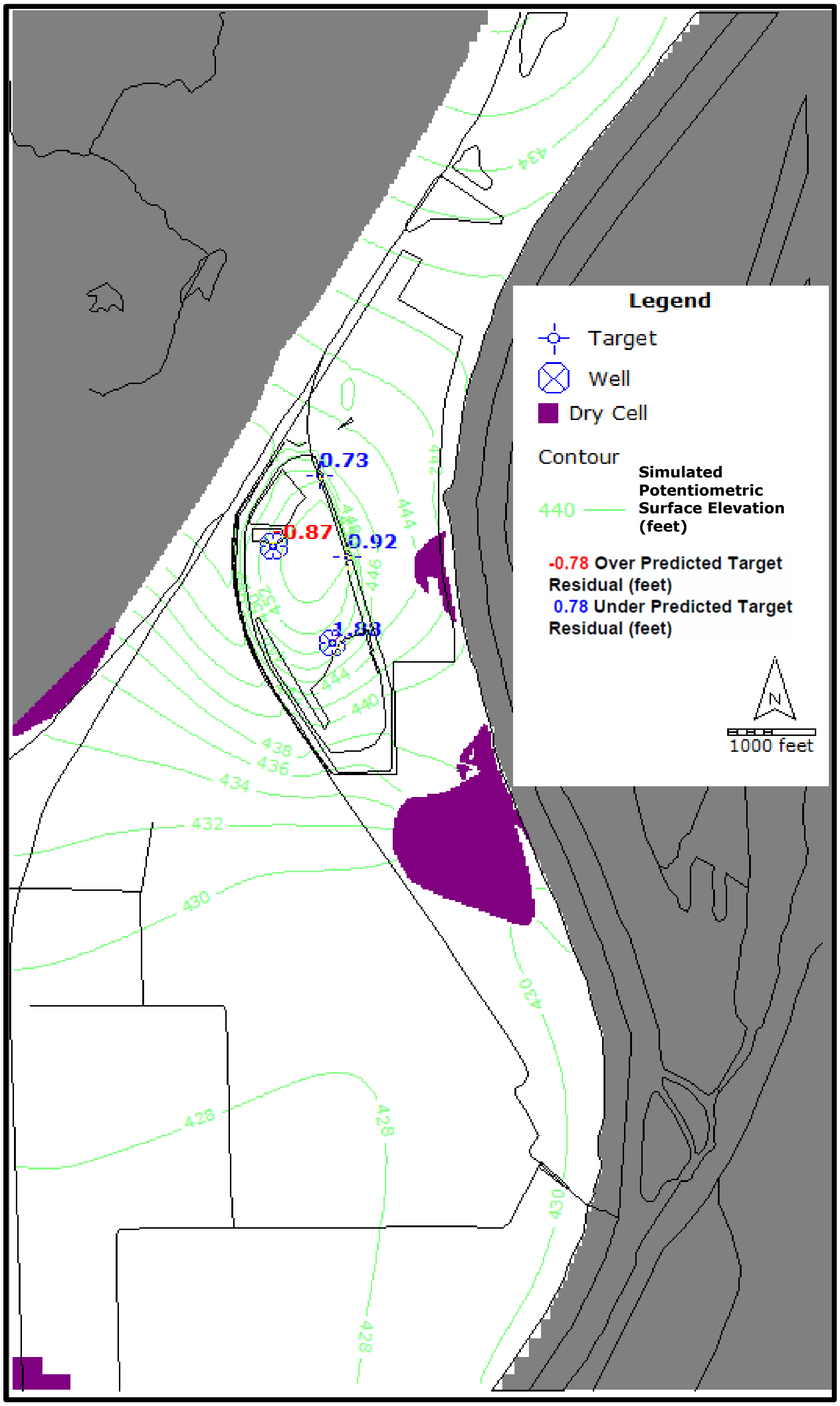
GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS



DISTRIBUTION OF RECHARGE ZONES (FEET/DAY)

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

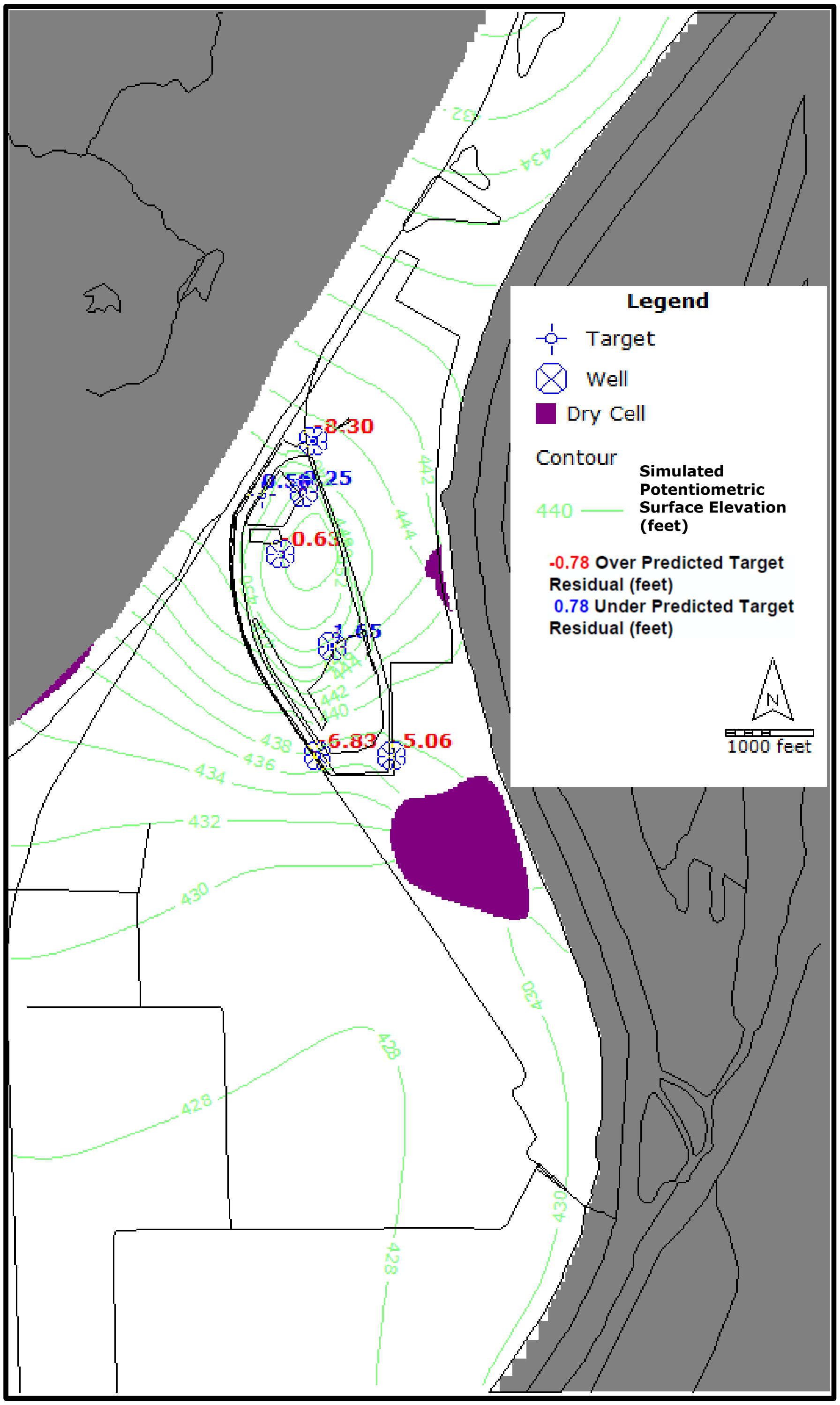
RAMBOLL



OBSERVED VERSUS SIMULATED GROUNDWATER ELEVATIONS FOR LAYER 1

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

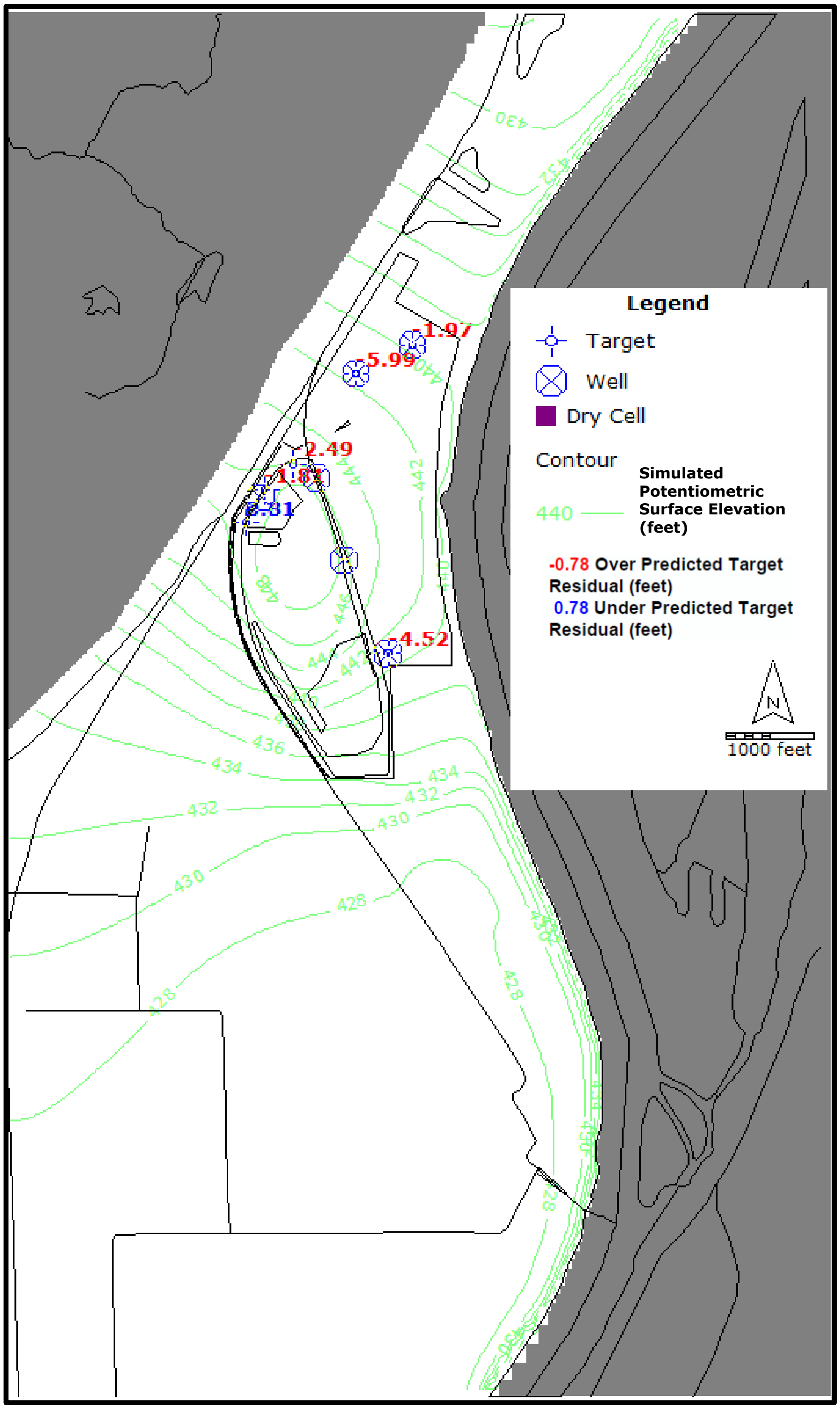
RAMBOLL



OBSERVED VERSUS SIMULATED GROUNDWATER ELEVATIONS FOR LAYER 2

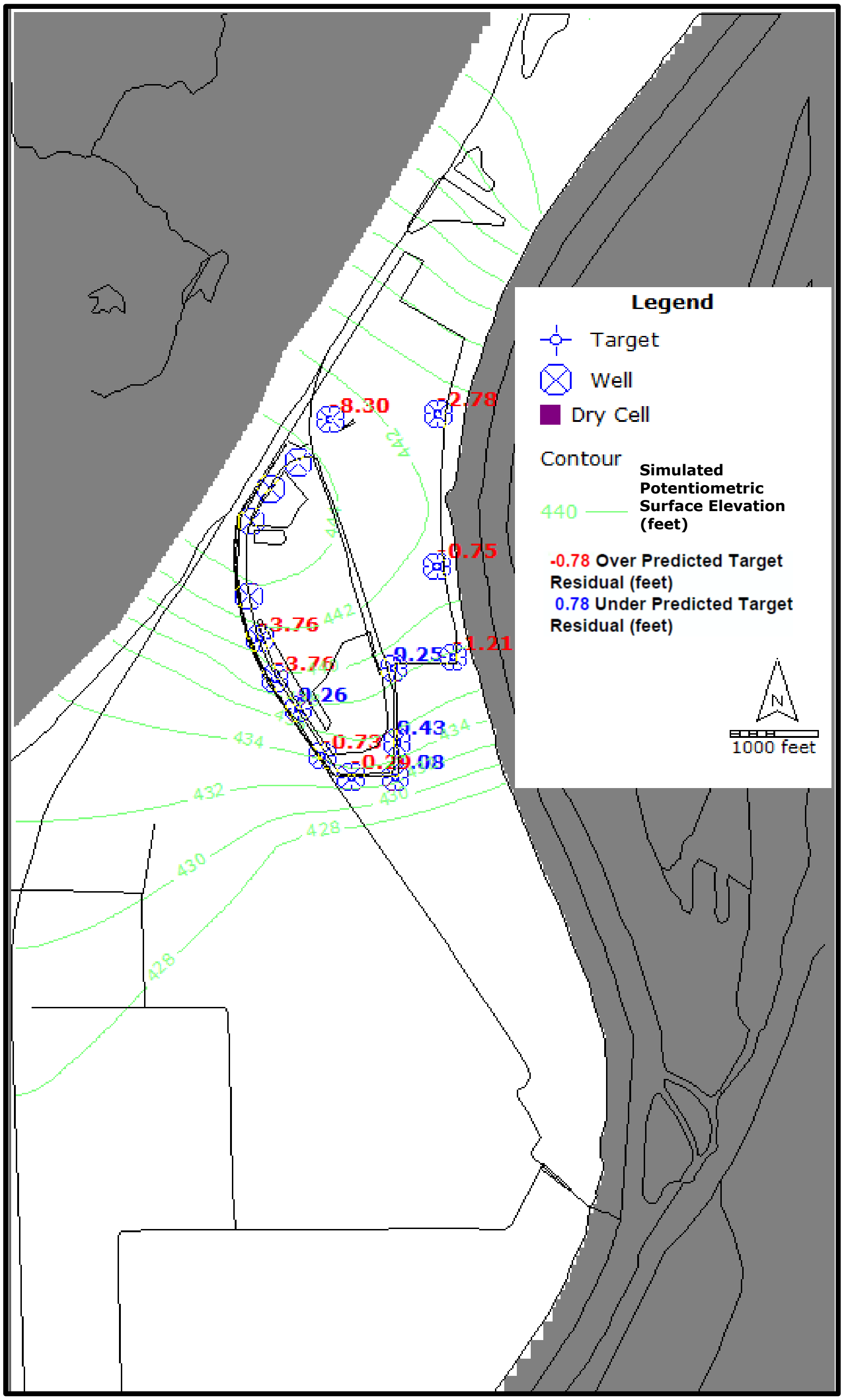
GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

RAMBOLL



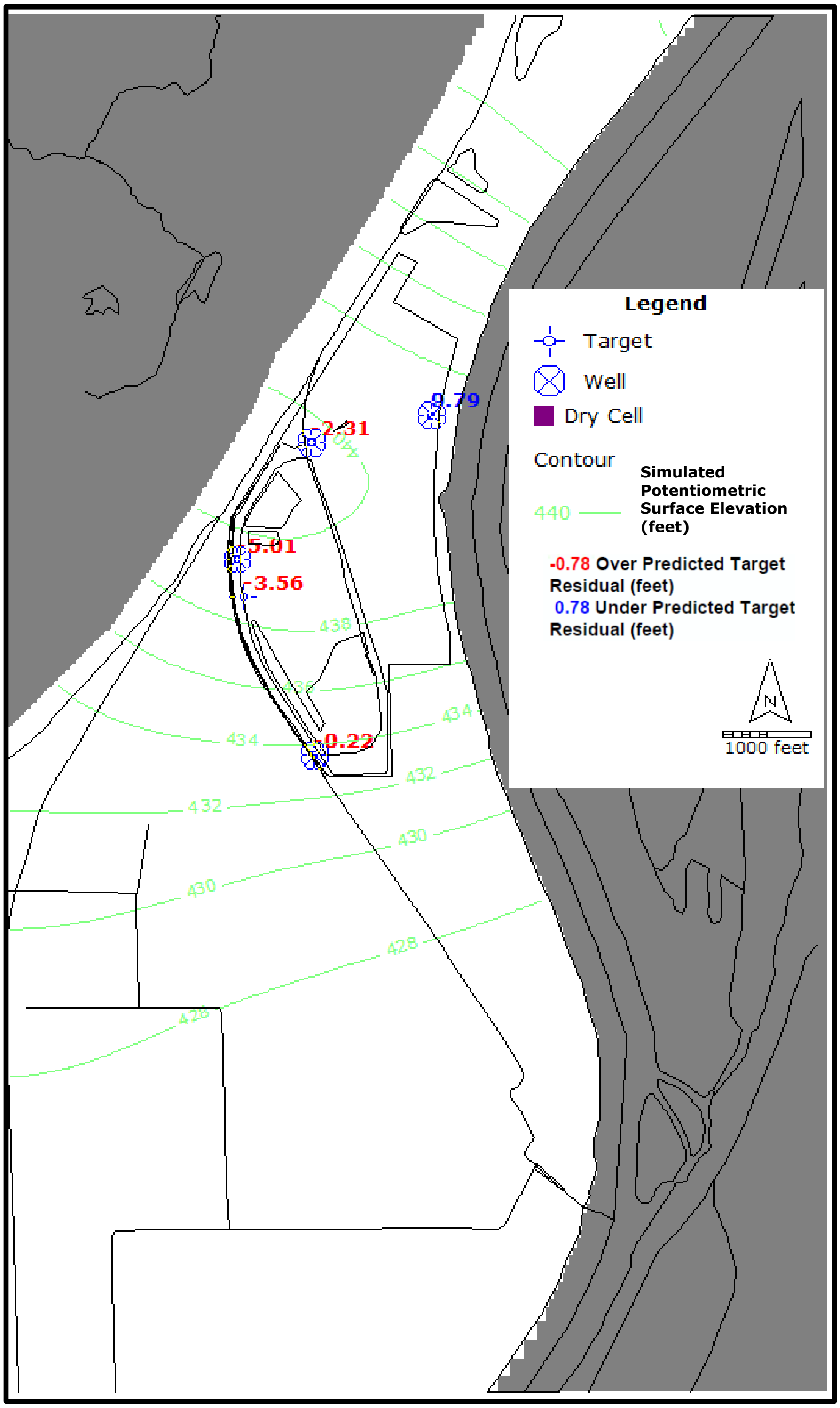
OBSERVED VERSUS SIMULATED GROUNDWATER ELEVATIONS FOR LAYER 3

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS



OBSERVED VERSUS SIMULATED GROUNDWATER ELEVATIONS FOR LAYER 4

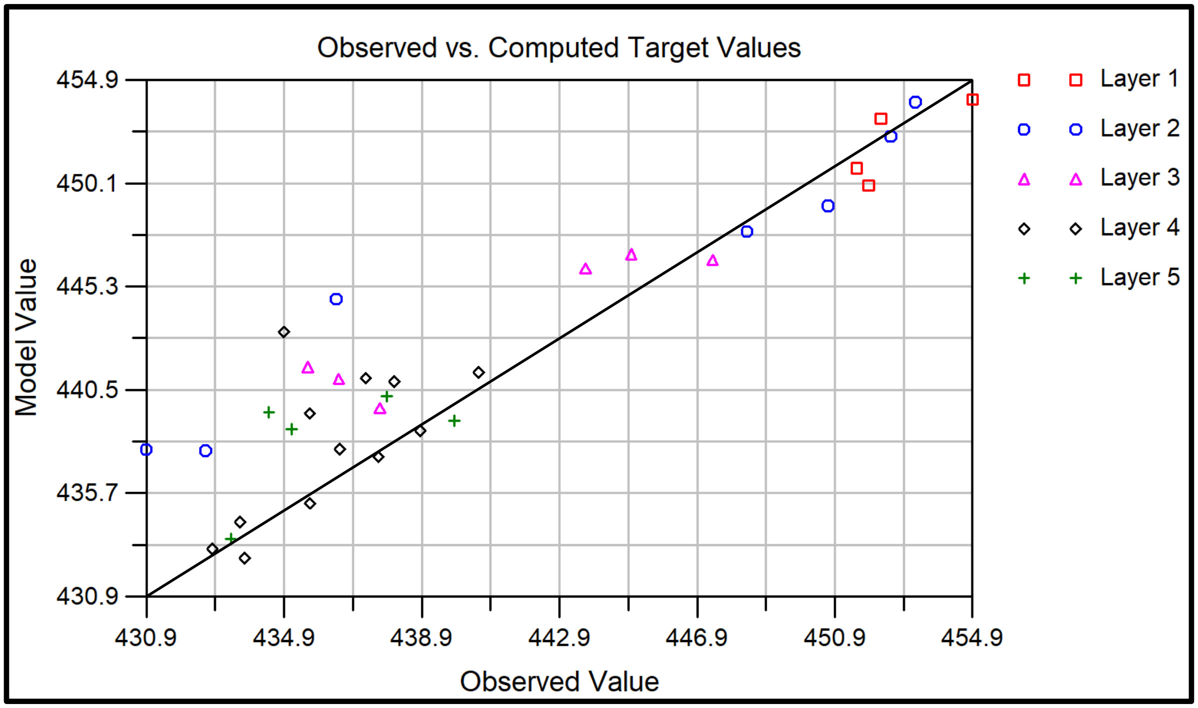
GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS



OBSERVED VERSUS SIMULATED GROUNDWATER ELEVATIONS FOR LAYER 5

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

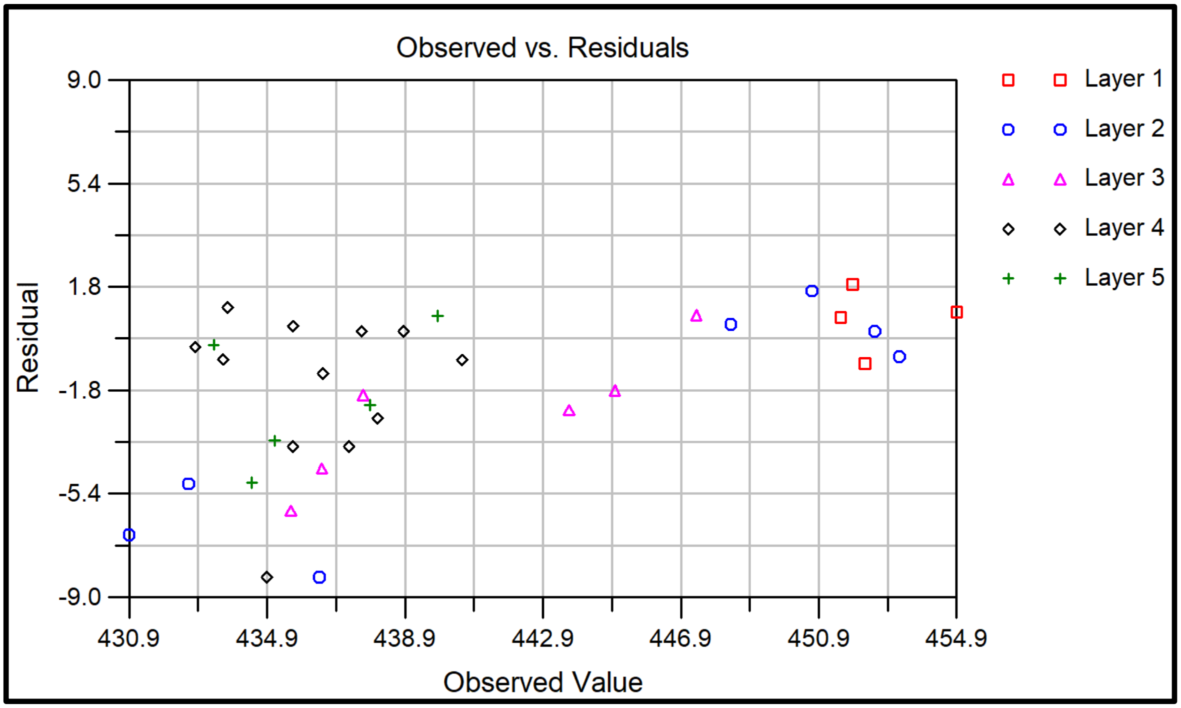
RAMBOLL



STEADY STATE MODFLOW CALIBRATION RESULTS – OBSERVED VERSUS SIMULATED (FT)

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

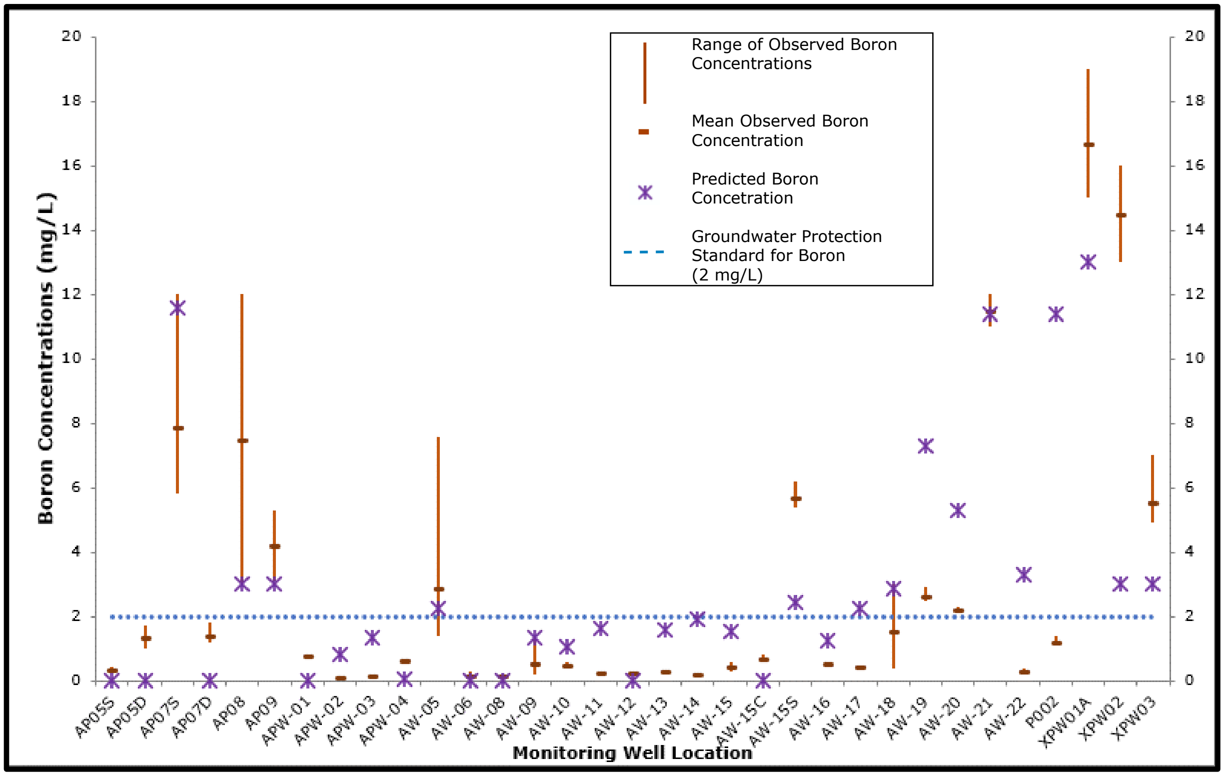
RAMBOLL



STEADY STATE MODFLOW CALIBRATION RESULTS – OBSERVED VERSUS RESIDUALS (FT)

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

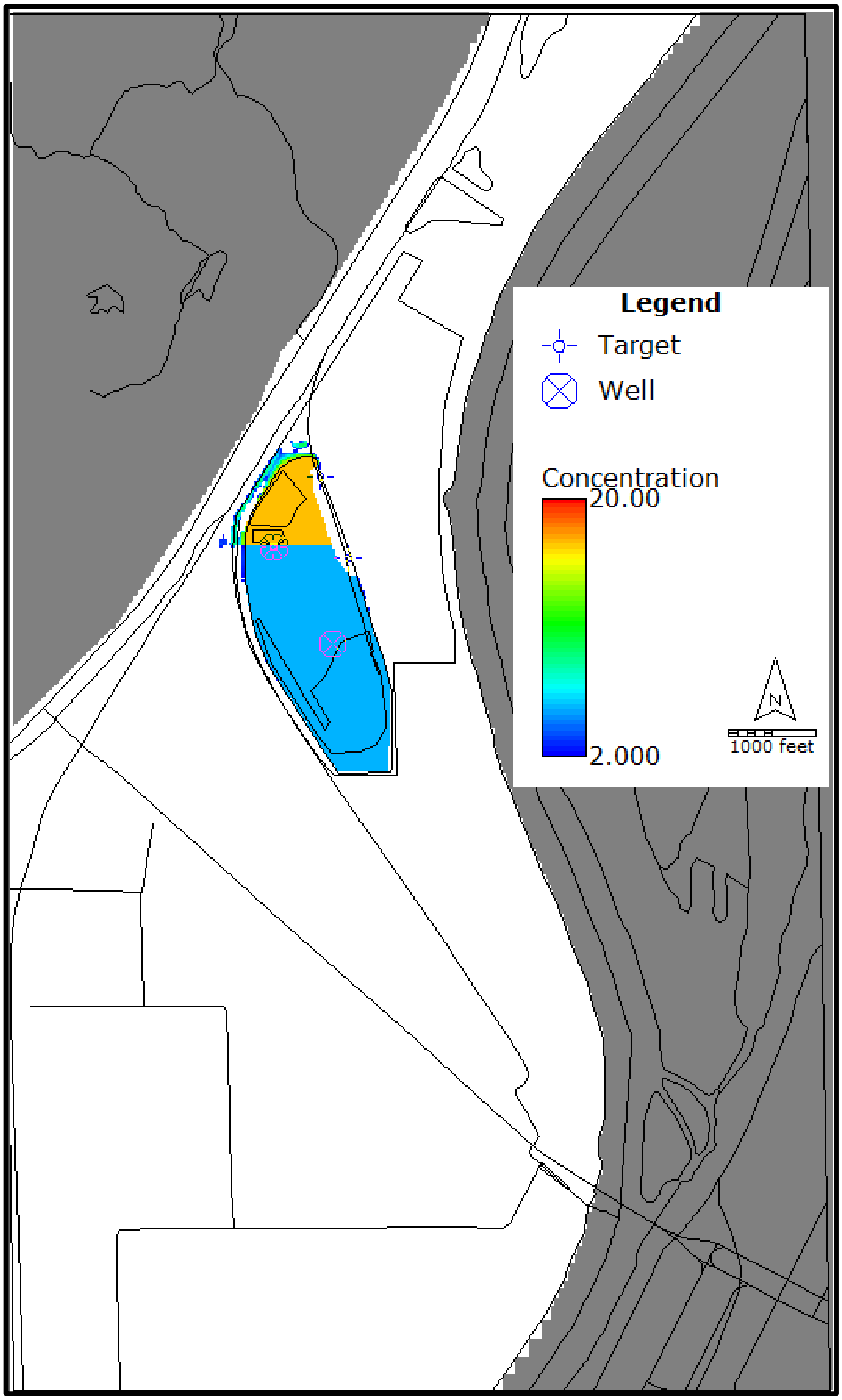
RAMBOLL



OBSERVED AND SIMULATED BORON CONCENTRATIONS (mg/L)

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

RAMBOLL

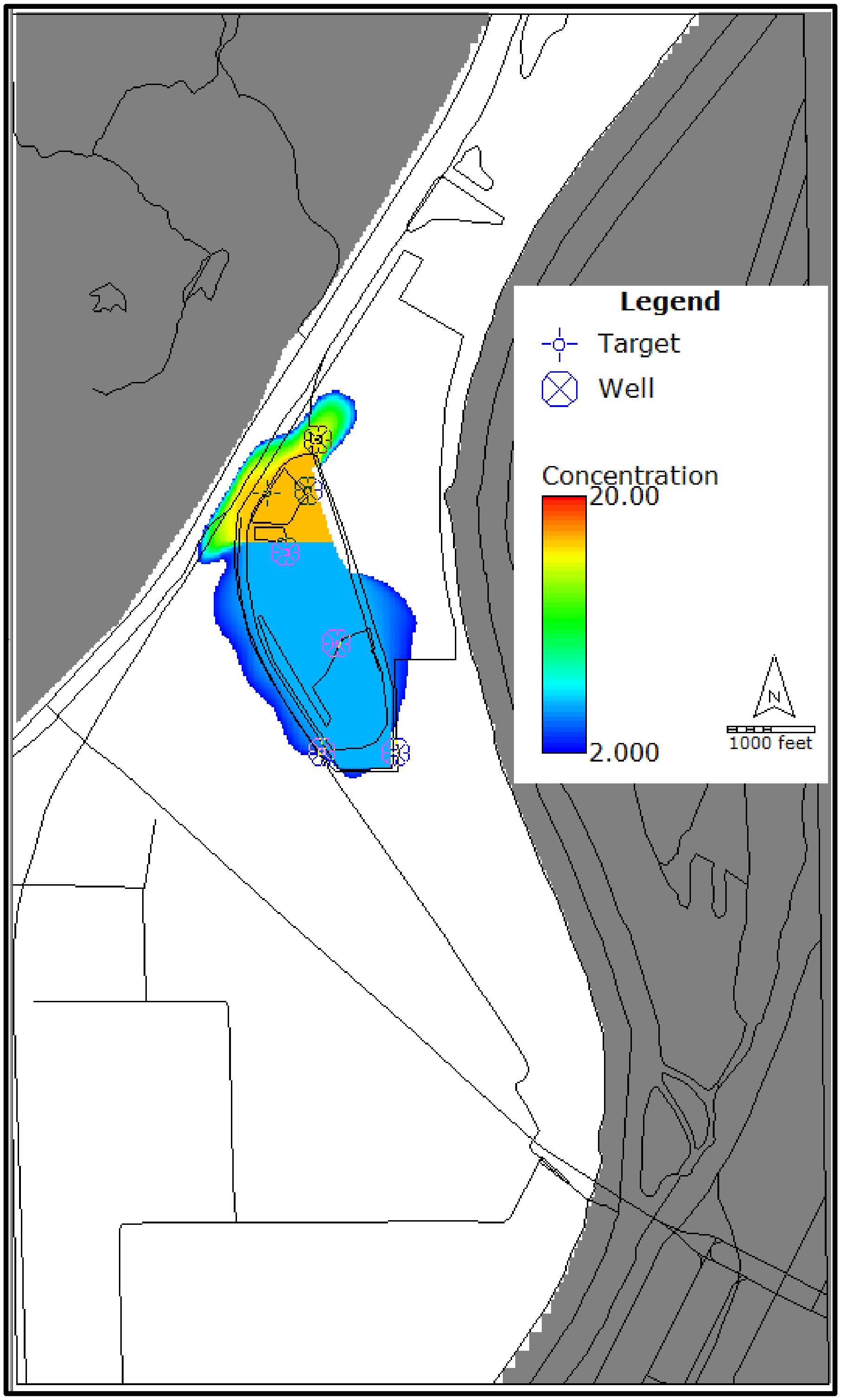


LAYER 1 DISTRIBUTION OF BORON CONCENTRATIONS (mg/L) IN THE CALIBRATED MODEL (UCF)

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

RAMBOLL

FIGURE 5-22

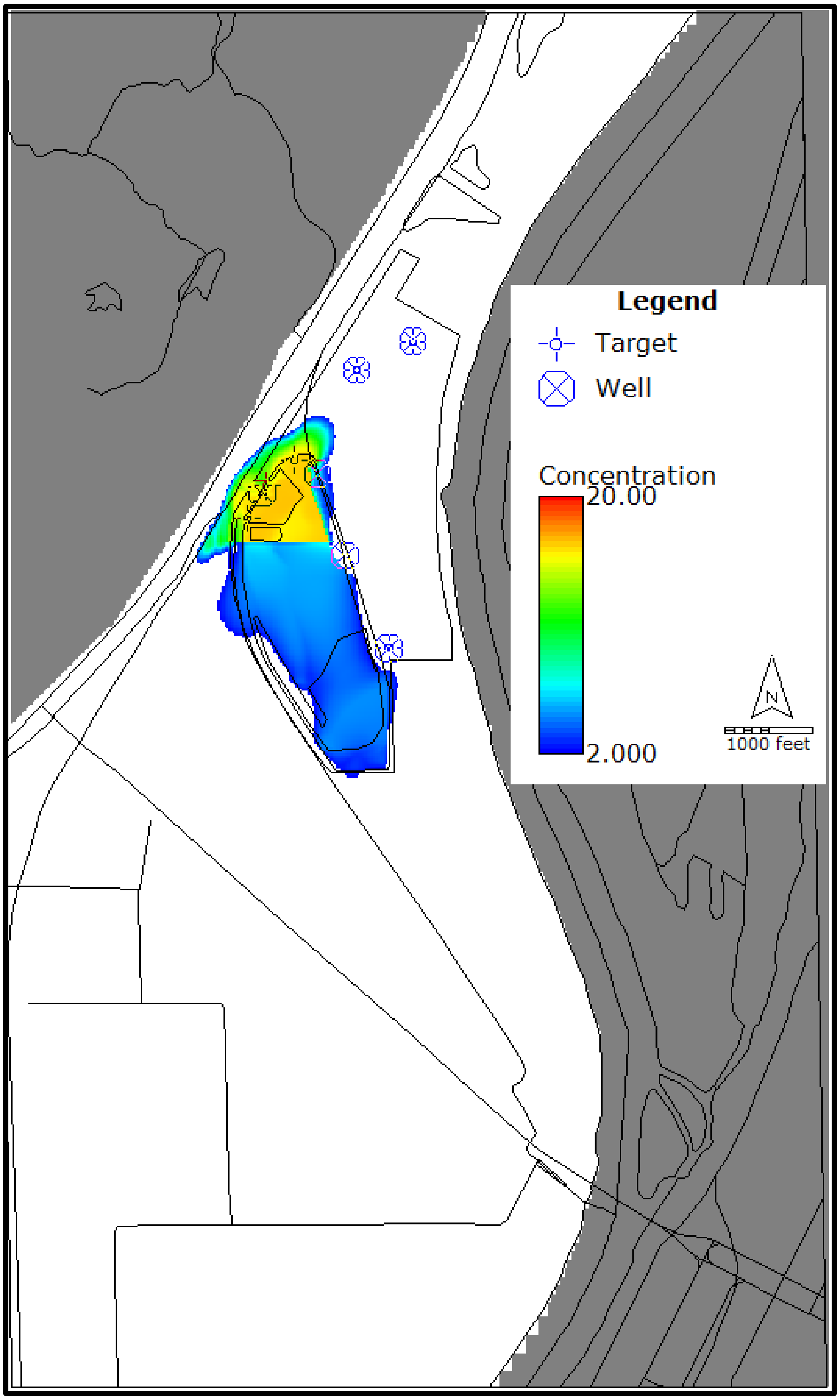


LAYER 2 DISTRIBUTION OF BORON CONCENTRATIONS (mg/L) IN THE CALIBRATED MODEL (UCF [PMP])

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

RAMBOLL

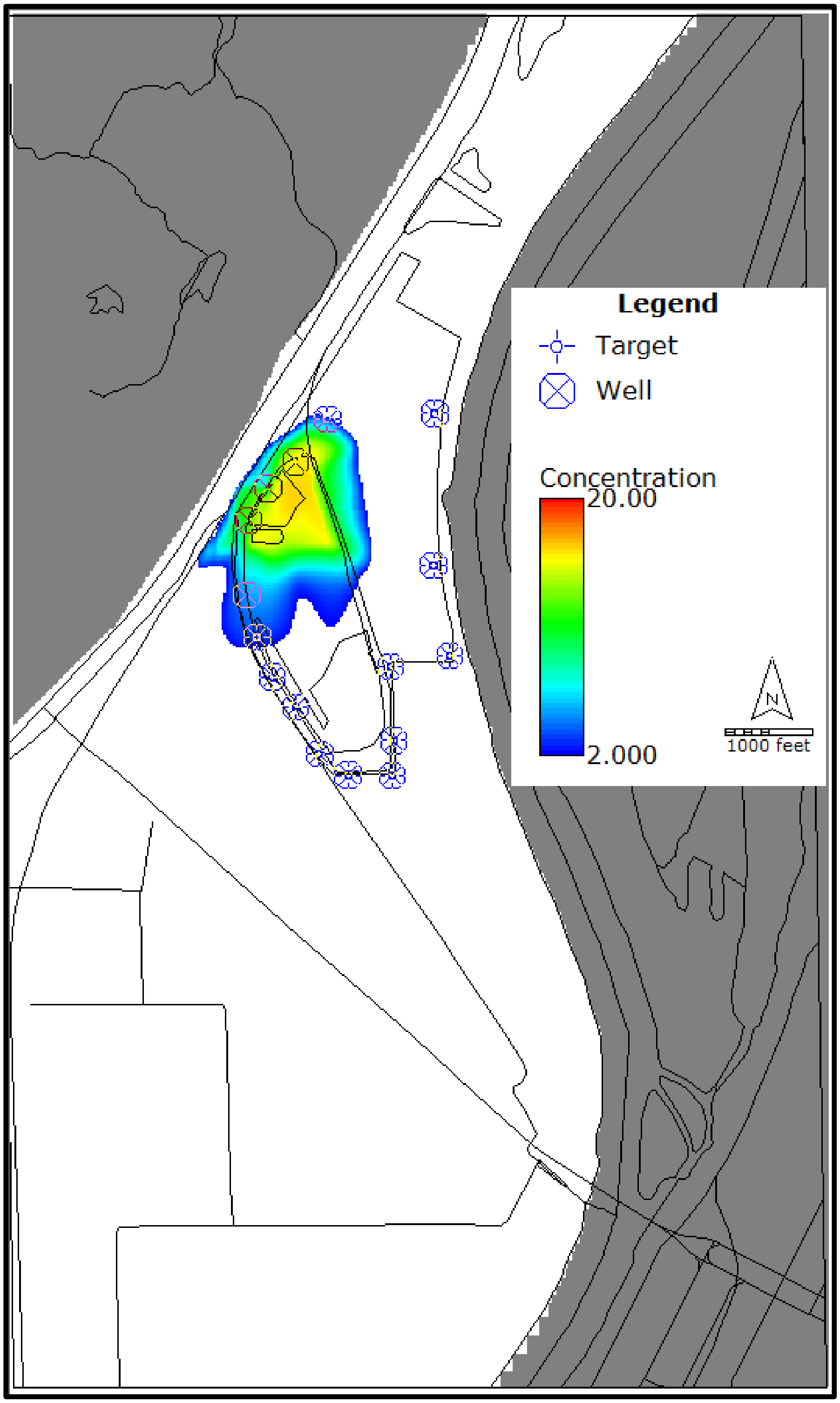
FIGURE 5-23



LAYER 3 DISTRIBUTION OF BORON CONCENTRATIONS (mg/L) IN THE CALIBRATED MODEL (UCF)

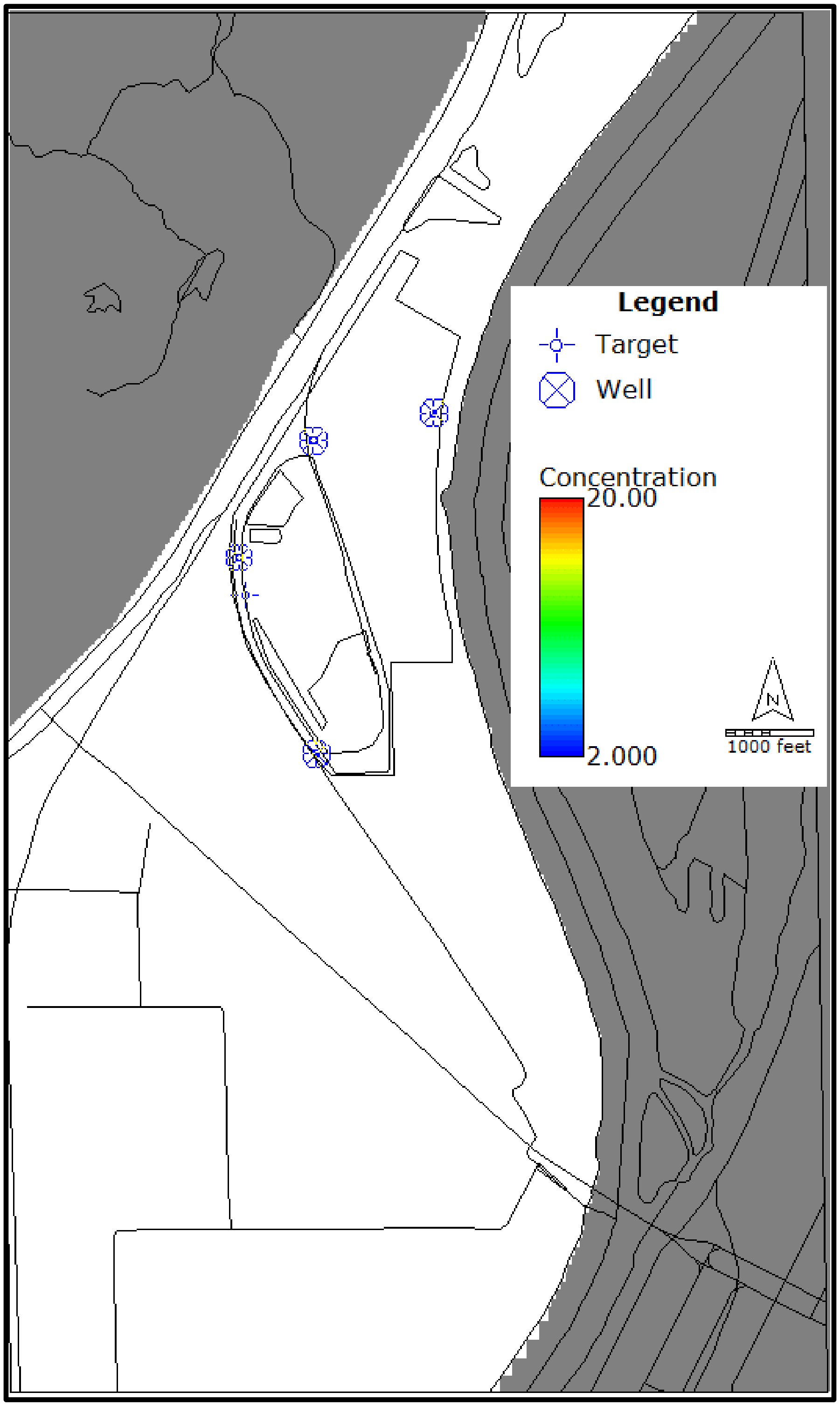
GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

RAMBOLL



LAYER 4 DISTRIBUTION OF BORON CONCENTRATIONS (mg/L) IN THE CALIBRATED MODEL (UA)

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

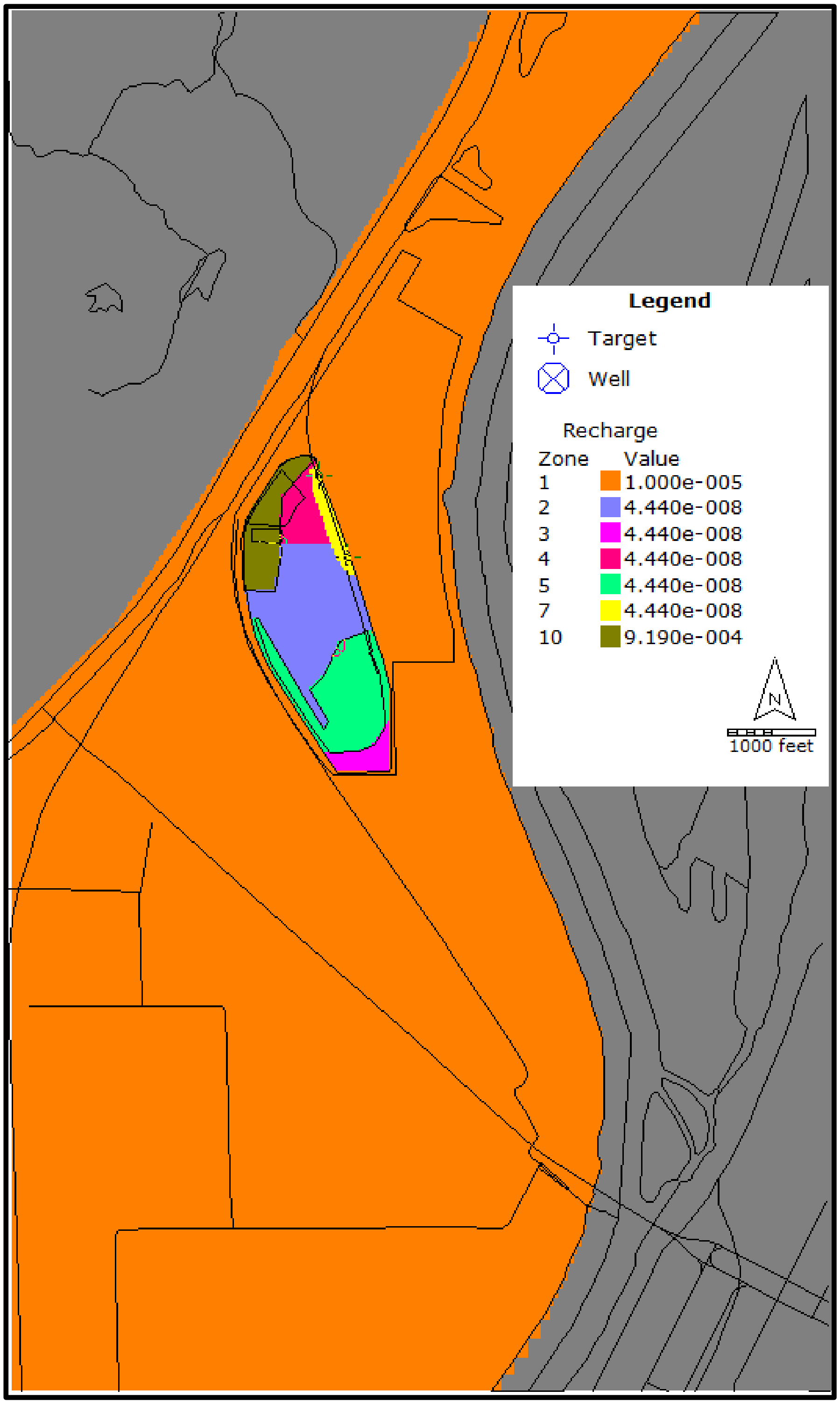


LAYER 5 DISTRIBUTION OF BORON CONCENTRATIONS (mg/L) IN THE CALIBRATED MODEL (BCU)

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

RAMBOLL

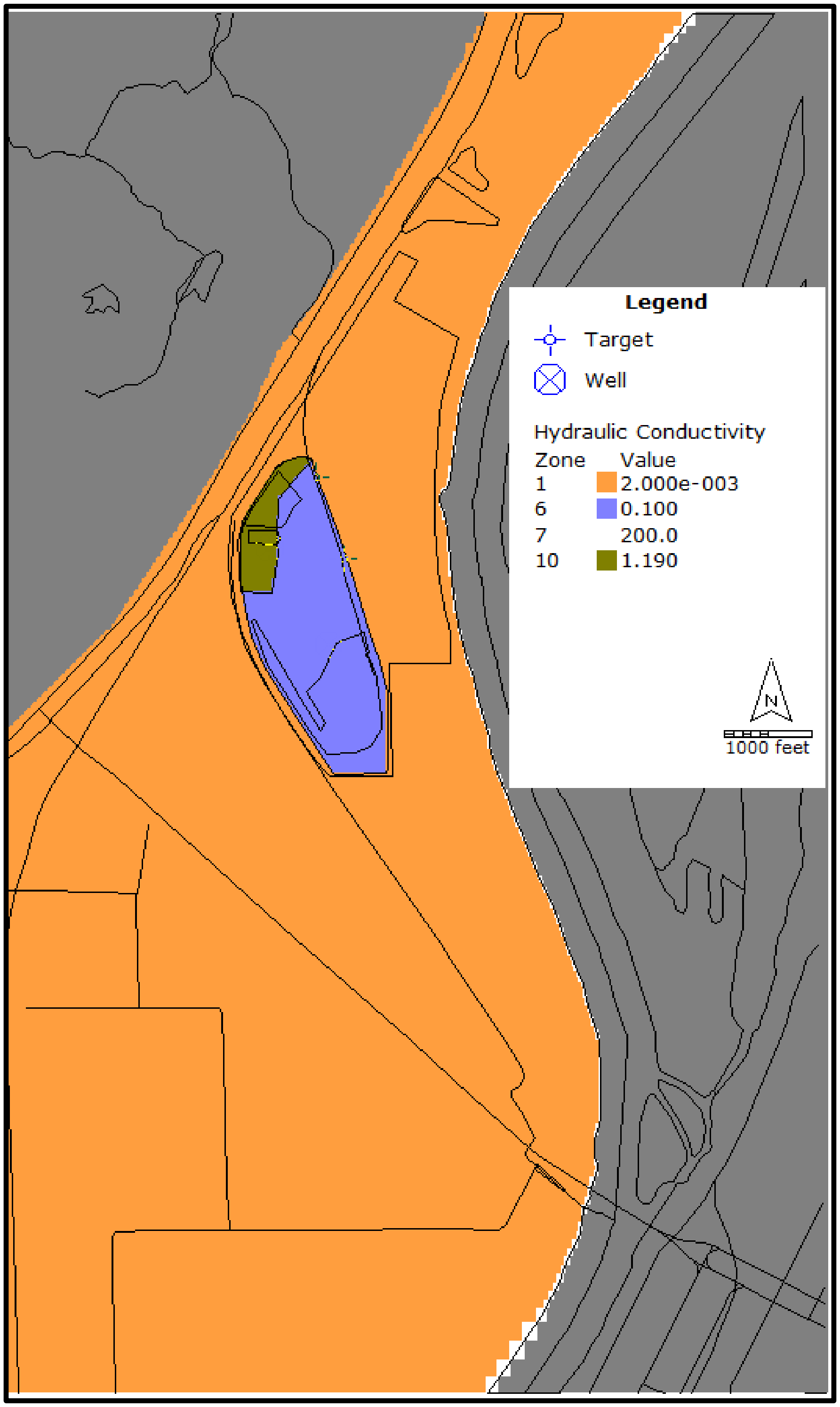
FIGURE 6-1



DISTRIBUTION OF RECHARGE ZONES (FEET/DAY) FOR CLOSURE IN PLACE

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

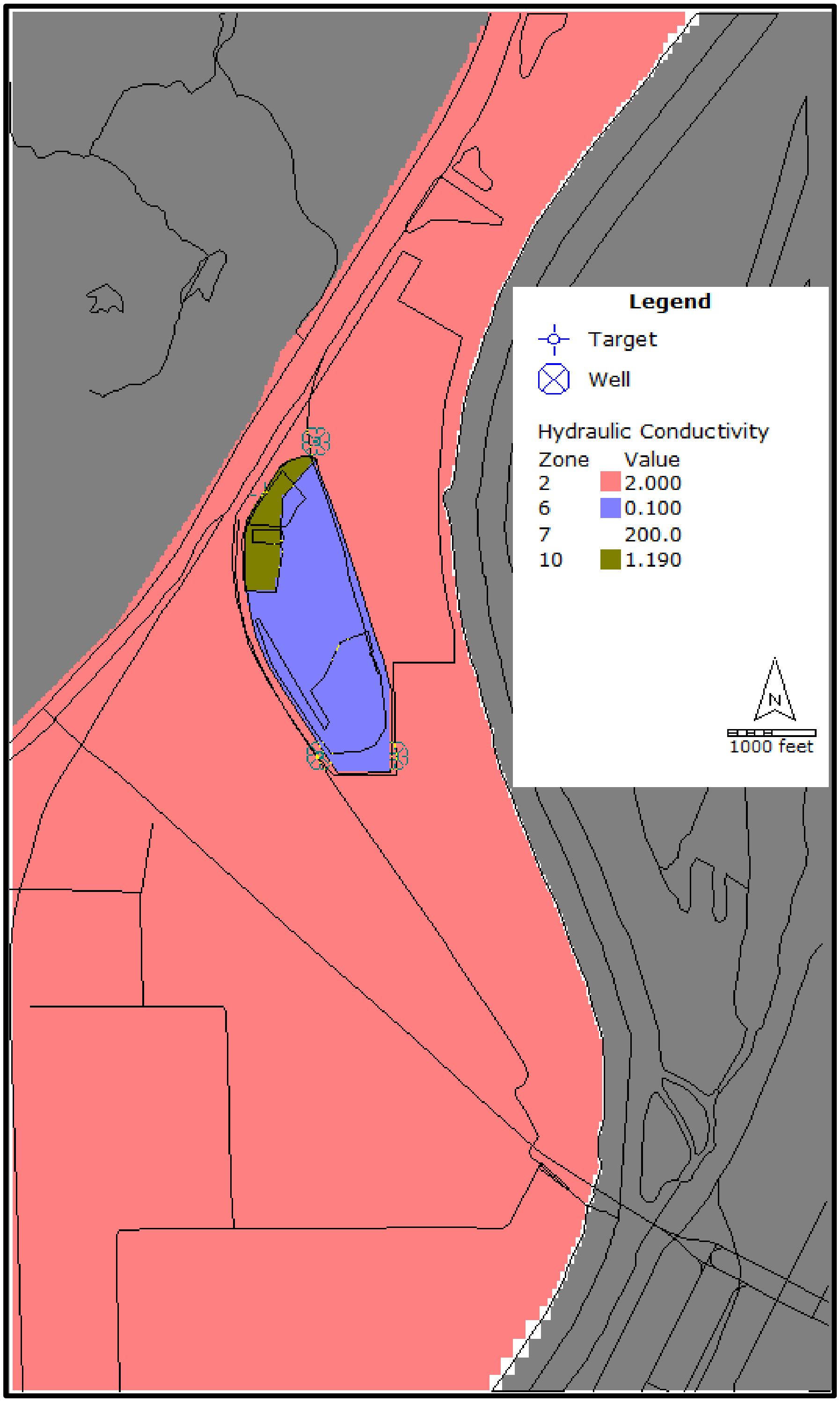
RAMBOLL



DISTRIBUTION OF HYDRAULIC CONDUCTIVITY ZONES (FEET/DAY) FOR LAYER 1 FOR CLOSURE IN PLACE

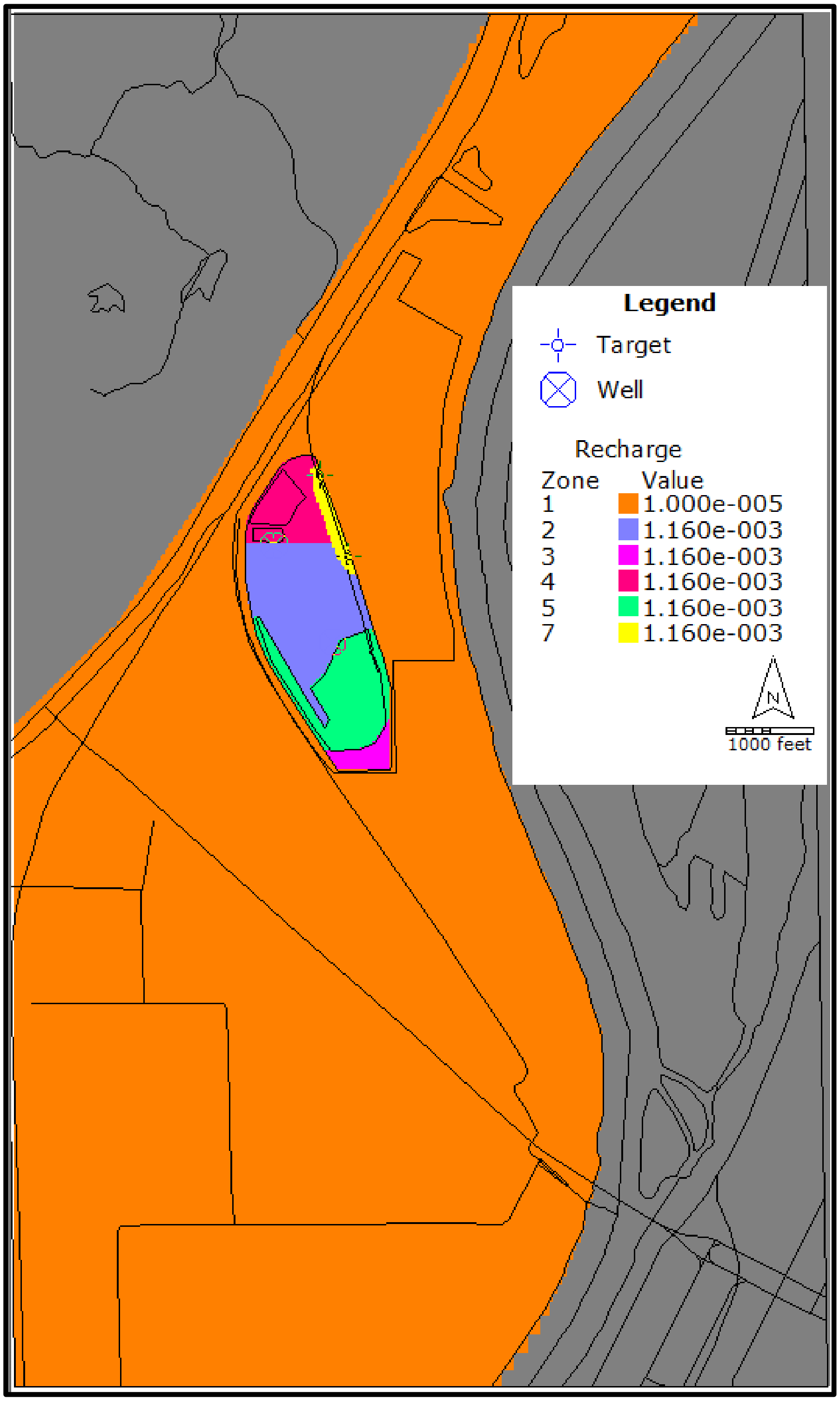
GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

RAMBOLL



DISTRIBUTION OF HYDRAULIC CONDUCTIVITY ZONES (FEET/DAY) FOR LAYER 2 FOR CLOSURE IN PLACE

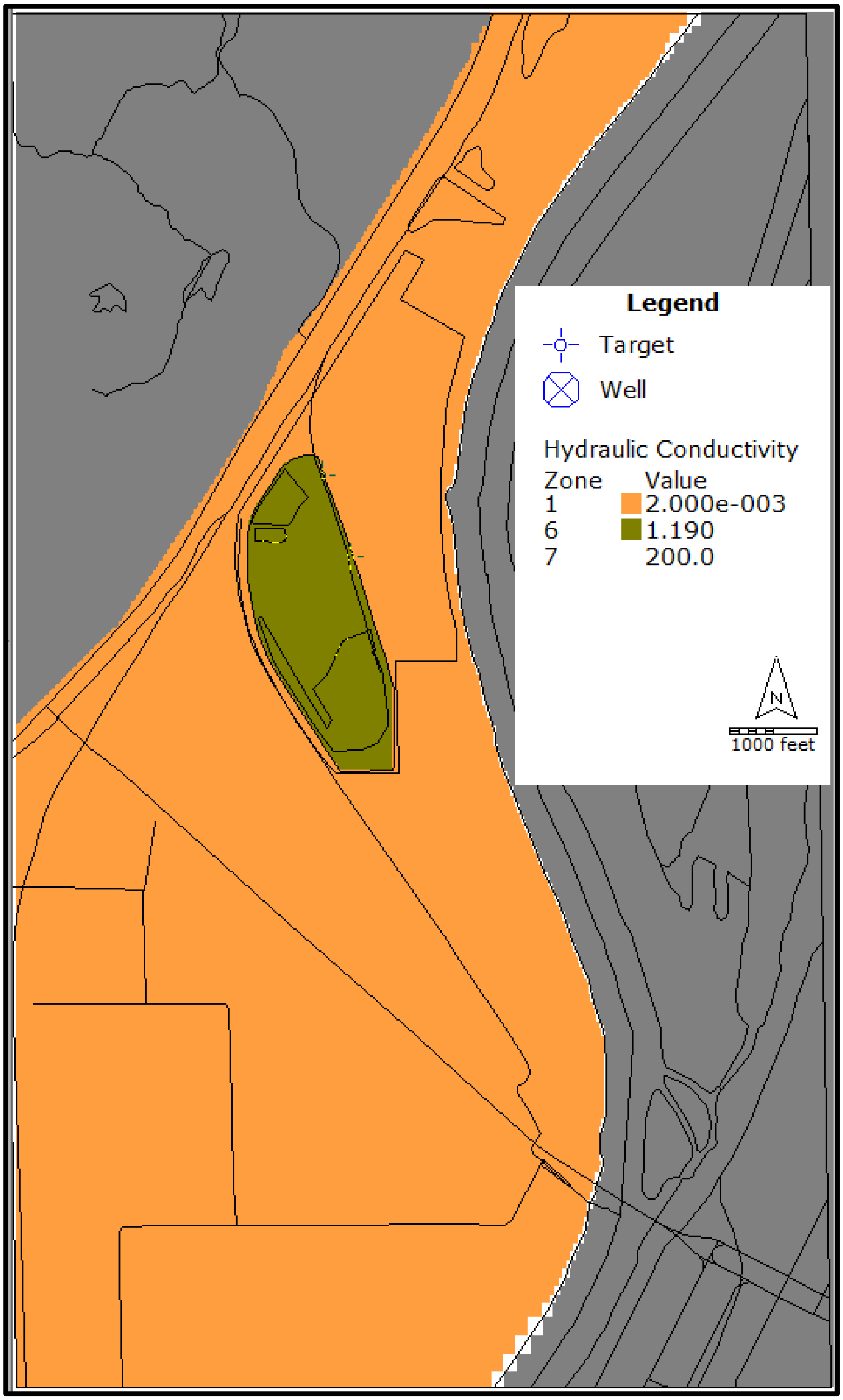
GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS



DISTRIBUTION OF RECHARGE ZONES (FEET/DAY) FOR CLOSURE BY REMOVAL

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

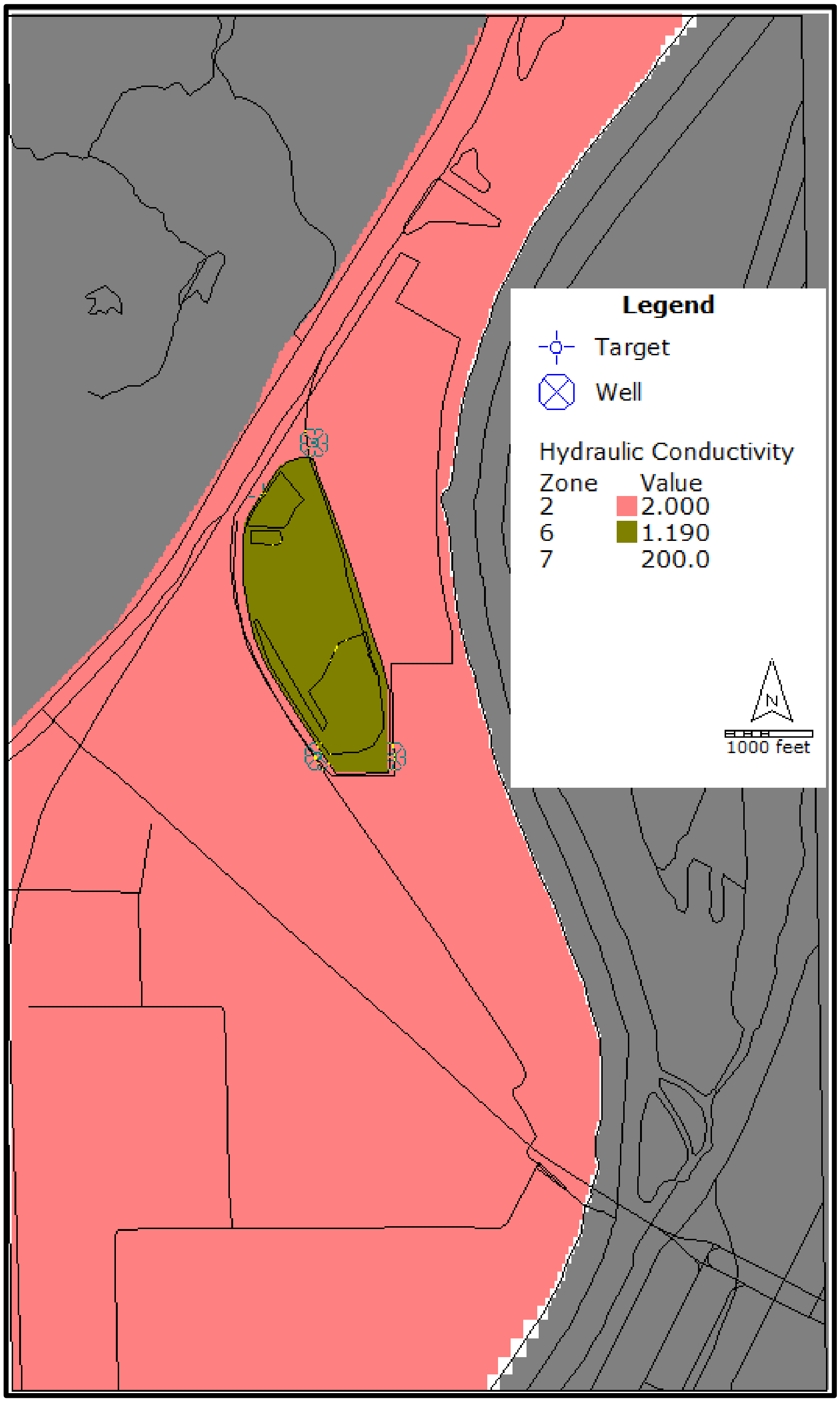
RAMBOLL



DISTRIBUTION OF HYDRAULIC CONDUCTIVITY ZONES (FEET/DAY) FOR LAYER 1 FOR CLOSURE BY REMOVAL

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

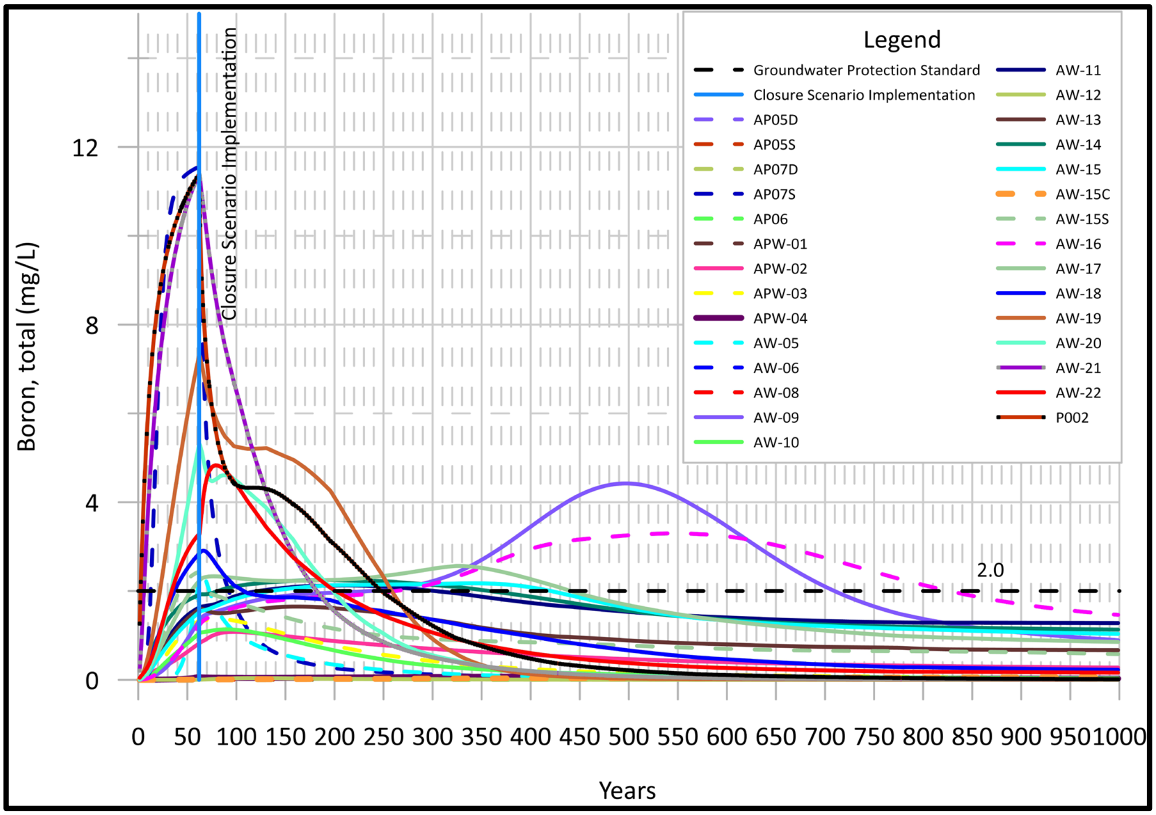
RAMBOLL



DISTRIBUTION OF HYDRAULIC CONDUCTIVITY ZONES (FEET/DAY) FOR LAYER 2 FOR CLOSURE BY REMOVAL

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

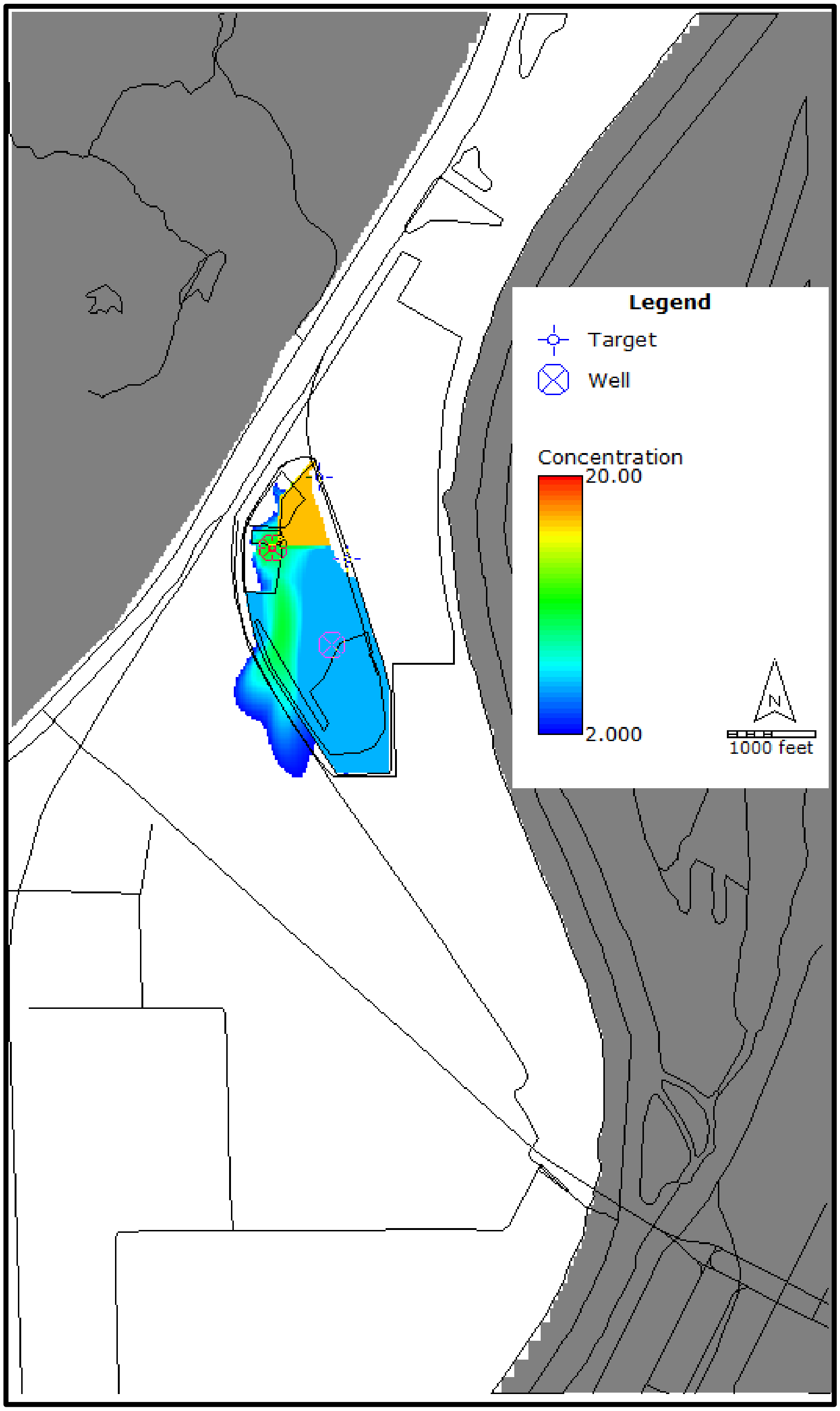
RAMBOLL



CIP – MODEL PREDICTED BORON CONCENTRATION

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

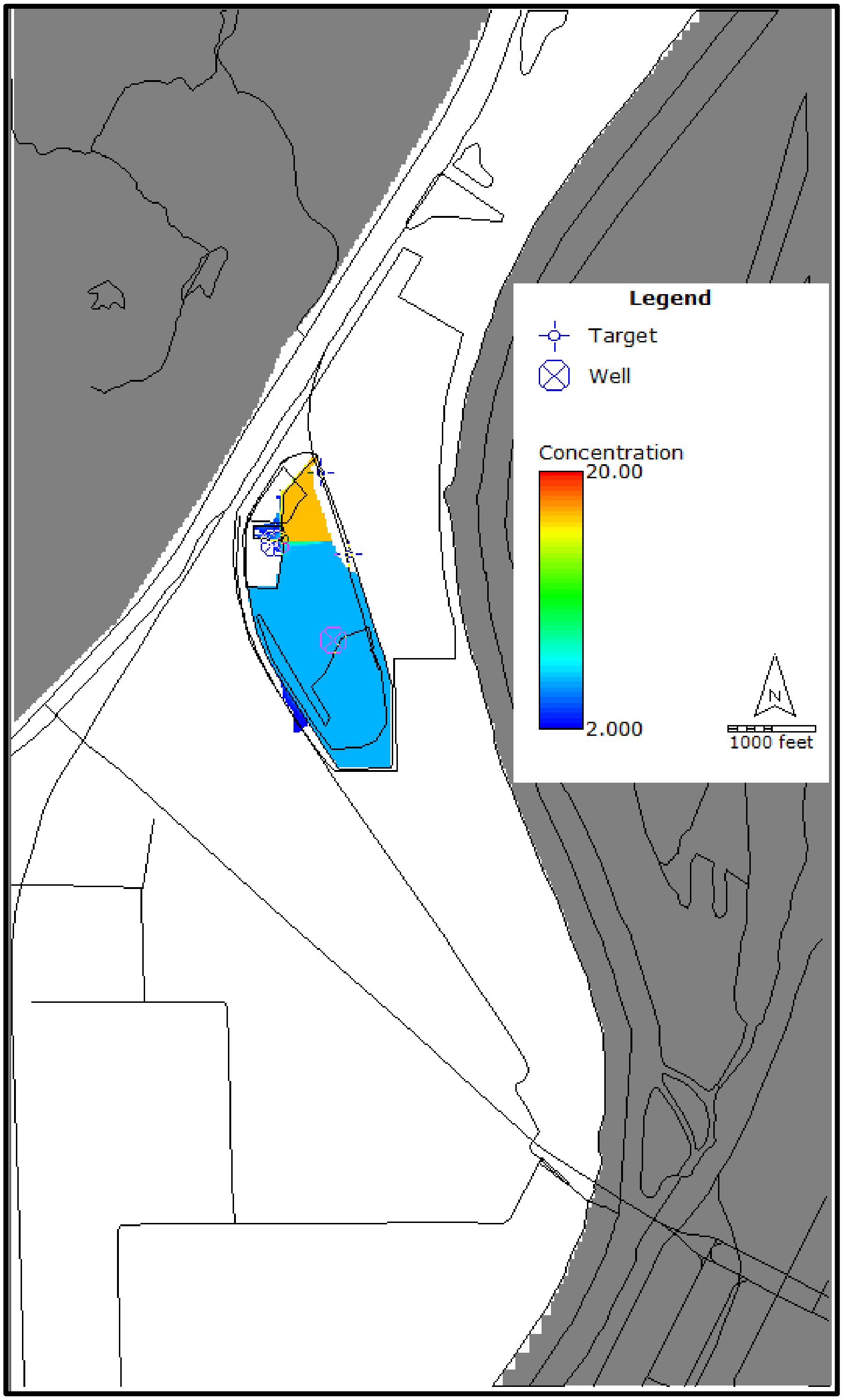
RAMBOLL



CIP – (SCENARIO 1) – MODEL PREDICTED MAXIMUM BORON PLUME IN ALL LAYERS
APPROXIMATELY 382 YEARS AFTER IMPLEMENTATION

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

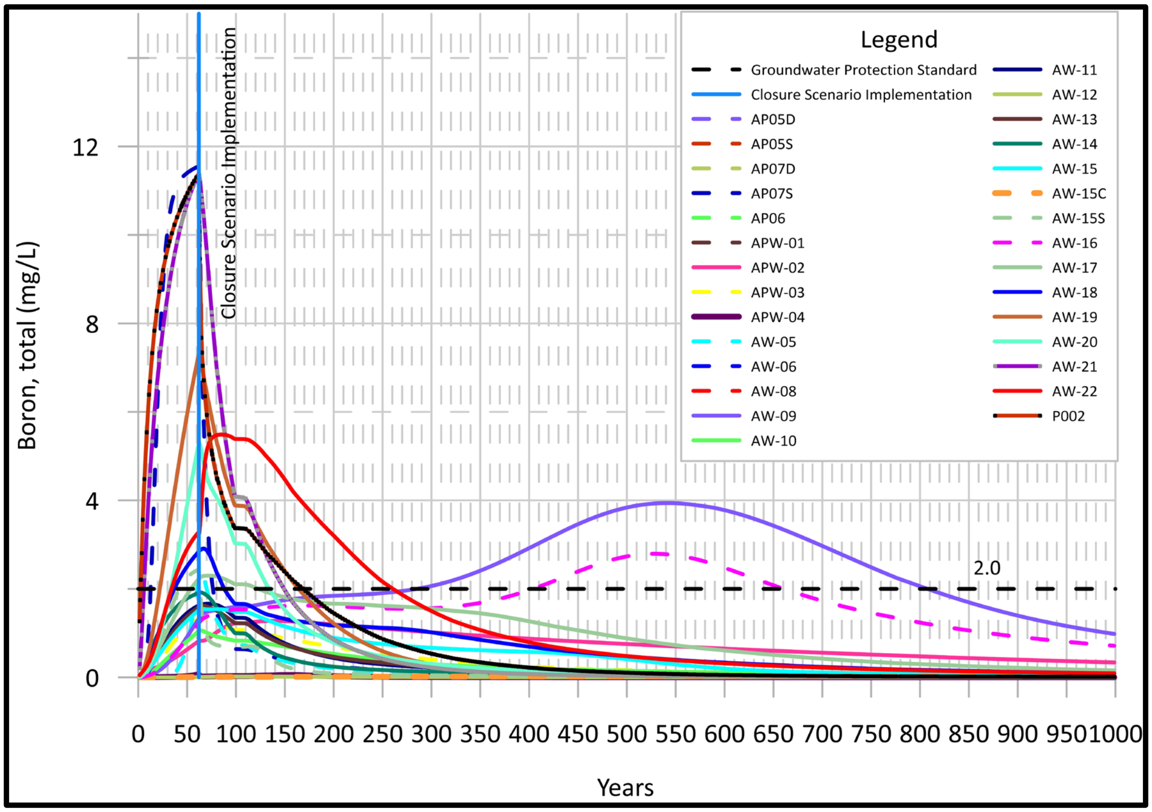
RAMBOLL



CIP – (SCENARIO 1) – MODEL PREDICTED MAXIMUM BORON PLUME IN ALL LAYERS
APPROXIMATELY 767 YEARS AFTER IMPLEMENTATION

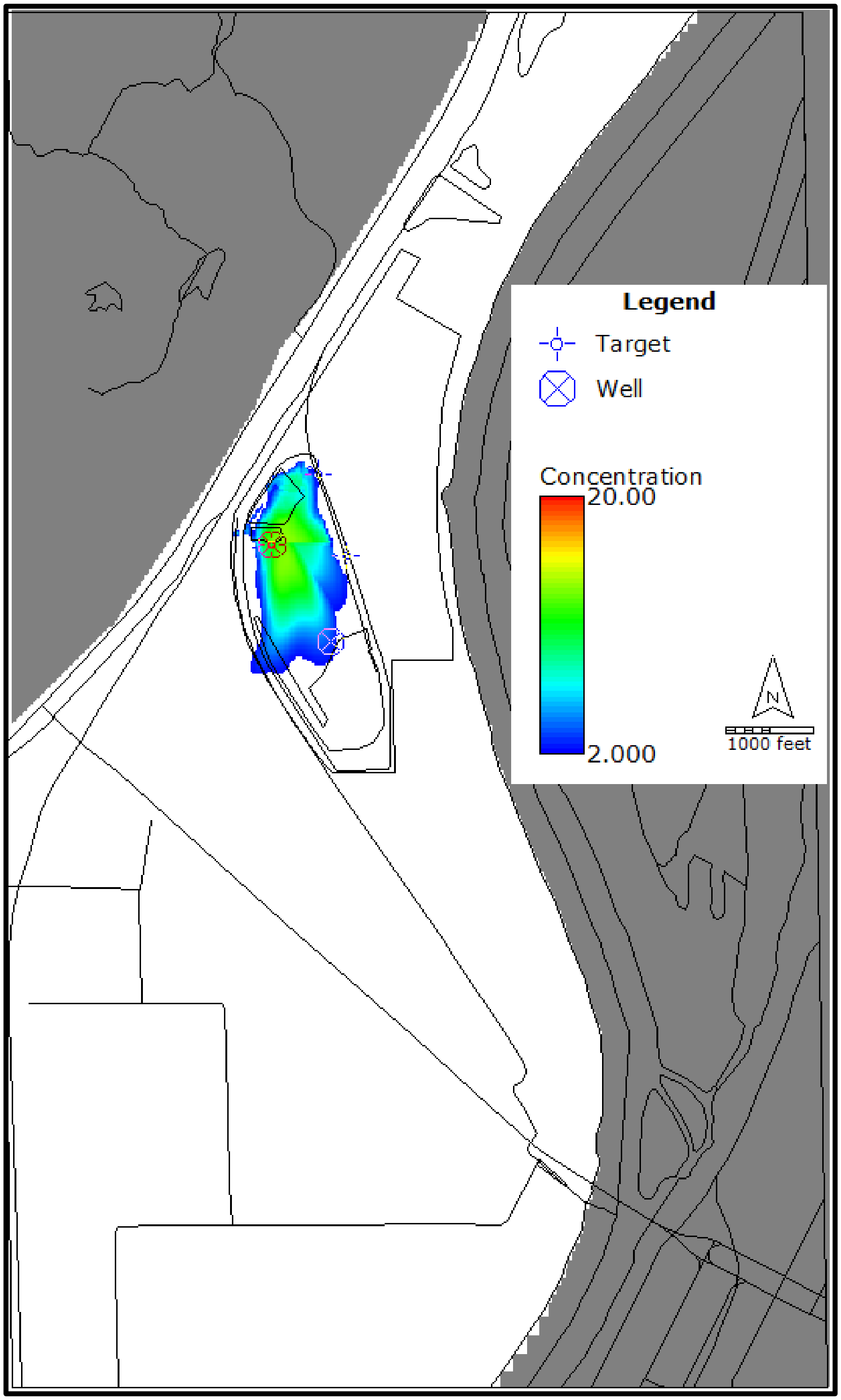
GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

RAMBOLL



CBR – MODEL PREDICTED BORON CONCENTRATION

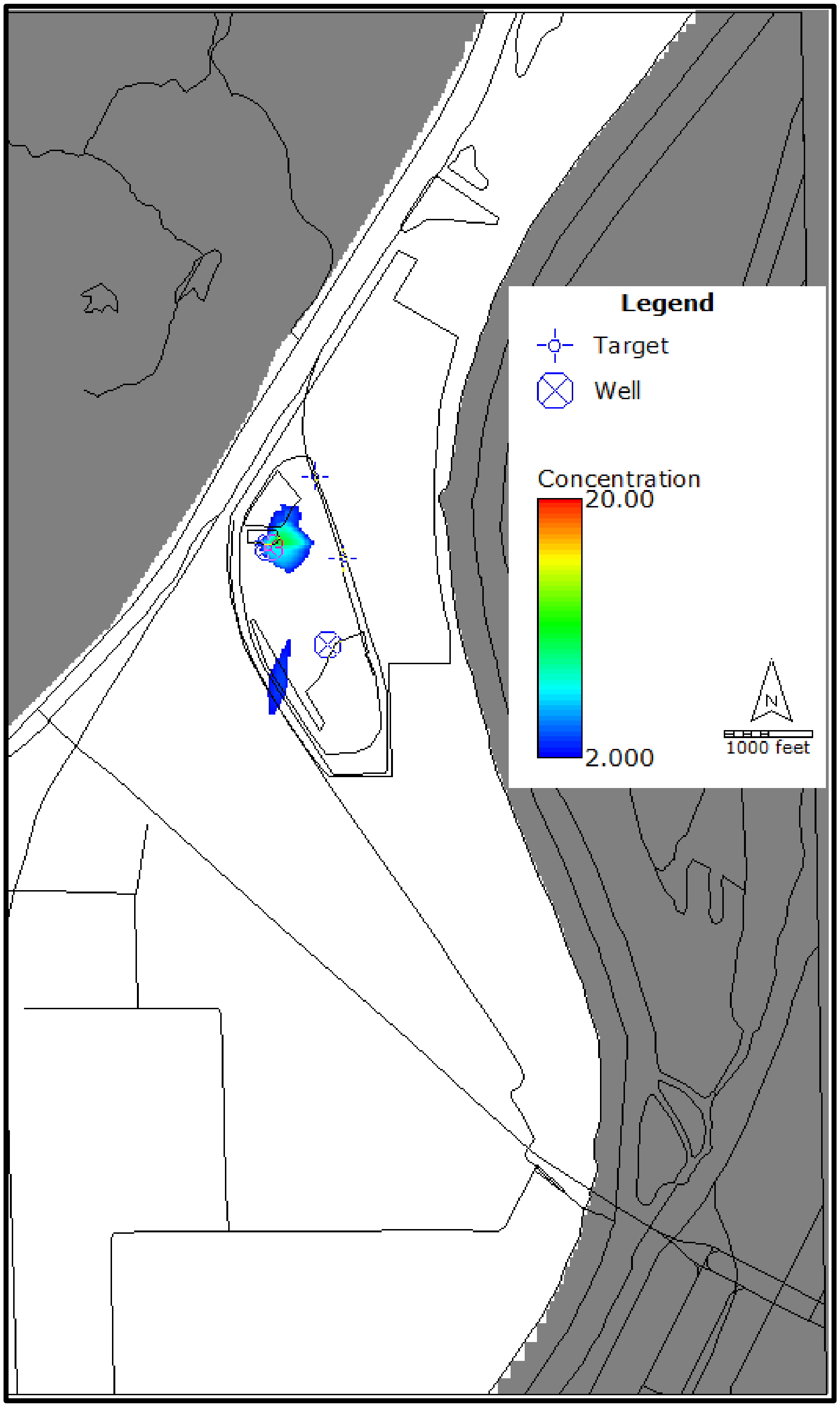
GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS



CBR – (SCENARIO 2) – MODEL PREDICTED MAXIMUM BORON PLUME IN ALL LAYERS
APPROXIMATELY 201 YEARS AFTER IMPLEMENTATION

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

RAMBOLL



CBR – (SCENARIO 2) – MODEL PREDICTED MAXIMUM BORON PLUME IN ALL LAYERS
APPROXIMATELY 748 YEARS AFTER IMPLEMENTATION

GROUNDWATER MODELING REPORT
ASH POND
EDWARDS POWER PLANT
BARTONVILLE, ILLINOIS

RAMBOLL

APPENDIX A
EVALUATION OF POTENTIAL GWPS EXCEEDANCES
(GOLDER ASSOCIATES USA INC., 2022)

TECHNICAL MEMORANDUM

DATE April 14, 2022 **Project No.** 21454831

TO David Mitchell, Stu Cravens, Vic Modeer
Illinois Power Resources Generating, LLC.

CC Brian Hennings - Ramboll

FROM Roberta Russell, Jeffrey Ingram, Pat Behling **EMAIL jeffrey.ingram@wsp.com**

EVALUATION OF POTENTIAL GWPS EXCEEDANCES, EDWARDS ASH POND (CCR UNIT 301), EDWARDS POWER PLANT, PEORIA COUNTY, ILLINOIS

1.0 INTRODUCTION

Illinois Power Resource Generating, LLC (IPRG) currently operates the Edwards Power Plant (EPP) located in Peoria County, Illinois. The Edwards Ash Pond (EAP), Illinois Environmental Protection Agency (IEPA ID No. W1438050005 - 01) is a 91-acre unlined surface impoundment used to manage coal combustion residuals (CCRs) at the EPP. The EAP is regulated under Part 845 *"Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments"* (State CCR Rule or Part 845) which was promulgated by the Illinois Pollution Control Board (IPCB) on April 21, 2021.

IPRG is currently preparing a Construction Permit application for the EAP as required under Section 845.220 which requires groundwater modeling be completed for the known potential exceedances of groundwater protection standards (GWPS) as outlined in the Operating Permit application (Burns and McDonnell 2021). In October 2021, Ramboll Americas Engineering Solutions, Inc. (Ramboll) identified potential GWPS exceedances for lithium, chloride and barium in certain monitoring wells in the vicinity of the EAP (Ramboll 2021b). This Technical Memorandum was developed to further evaluate these potential GWPS exceedances.

1.1 Site Setting, Geology, and Hydrogeology

The EPP is located in Peoria County between Mapleton and Bartonville in Section 11, Township 7 North, Range 7 East, on the floodplain of the Illinois River adjacent to a levee. The EPP has one CCR surface impoundment, the Ash Pond, covering approximately 91 surface acres.

The EPP is situated in a predominantly agricultural area with industrial parcels bordering the property. Historically, several coal mines were operated at depths of 100 to 160 feet below ground surface (bgs) in the vicinity of the EPP. The EPP property is bordered by a salt processing facility to the north, railroad right-of-way and former Orchard Mines to the west, the Illinois River and a fertilizer production facility to the east, and agricultural land to the south.

Four hydrogeologic units are present at the EPP. They are described as follows in the Hydrogeologic Site Characterization Report (Ramboll 2021c), in downward order:

- **CCR:** Saturated CCR consisting primarily of fly ash within the Ash Pond. CCR is present at thicknesses up to 46.5 feet and at elevations as low as 413.9 feet North American Vertical Datum of 1988 (NAVD88) in the central and northern portion of the Ash Pond**.**
- **Upper Cahokia Formation/Potential Migration Pathway (PMP):** Low-permeability clays and silts of the Upper Cahokia Formation are present at the surface. This unit is considered a PMP at elevations similar to the base of the Ash Pond, and in places where thin discontinuous sand lenses occur within the Upper Cahokia Formation adjacent to the Ash Pond.
- **Uppermost Aquifer (UA):** Thin (generally less than 4 feet), moderate-permeability sand, silty sand, and clayey gravel material within the Lower Cahokia Formation, bedrock, and/or weathered shale bedrock, where present. In locations where higher-permeability materials and coarser-grained materials are absent, the Uppermost Aquifer is interpreted as the interface between the Lower Cahokia Formation and the Bedrock Confining Unit.
- **Bedrock Confining Unit (BCU):** Thick, very low-permeability shales and siltstones of the Carbondale and Modesto Formations. This unit was encountered at elevations ranging from approximately 400 to 422 feet NAVD88 with higher bedrock elevations occurring beneath the northern portion of the Ash Pond. In general, the Upper Cahokia Formation consists of low-permeability clays and silts, with limited occurrences of thin, discontinuous sand lenses. In several locations, generally near the southern and western portions of the unit, coarser-grained materials are present at the base of the Lower Cahokia Formation and/or the top of the bedrock is weathered, resulting in relatively higher hydraulic conductivities. Because the interface is laterally continuous and has relatively higher conductivity, the unlithified/lithified upper contact was designated as the Uppermost Aquifer.

Occasional sand lenses within the Upper Cahokia Formation and downgradient clay intervals present at elevations similar to the base of ash in the Ash Pond were identified as PMPs. The underlying BCU is interpreted as the confining base of the aquifer, with hydraulic conductivities generally two orders of magnitude lower than those measured in the Uppermost Aquifer (Ramboll 2021c).

Groundwater flows east to west in the central portion of the EAP, south/southeast at the south end of the EAP and to the north/northwest at the north end of the EAP (Ramboll 2021b) (**Figure 1**).

2.0 POTENTIAL GWPS EXCEEDANCES REVIEW

As required by Section 845.230 (d)(2)(M), an evaluation of the history of potential GWPS exceedances was completed for the Operating Permit application (Burns and McDonnell 2021 and Ramboll 2021b). Water quality data from groundwater samples collected from the EAP monitoring well network since February 2021 were evaluated using the statistical methods described in the Statistical Analysis Plan included in the Operating Permit application (Ramboll, 2021b). The following potential exceedances of the GWPSs were evaluated in this Technical Memorandum:

- <u>Barium at monitoring well AW-15C</u>: A barium exceedance (2.9 mg/L) in this well was reported based on calculation of a confidence interval around the mean of samples collected during 2021. AW-15C is located downgradient from the EAP and the screened interval is within a shale unit of the BCU.

- Chloride at monitoring well AP07D: A chloride exceedance (498 mg/L) in this well was reported based on calculation of a confidence interval around the mean of samples collected during 2021. AP07D is located downgradient from the Ash Pond; the screened interval is within a siltstone unit of the BCU.
- Lithium at monitoring well AP05D: A lithium exceedance (0.077 mg/L) in this well was reported based on calculation of a future median (i.e. a median of the three most recent samples) of samples collected during 2021. AP05D is located cross-gradient from the EAP and the screened interval is within a siltstone unit of the BCU.
- Lithium at monitoring well AP07D: A lithium exceedance (0.15 mg/L) in this well was reported based on calculation of a future median of samples collected during 2021. AP07D is located downgradient from the EAP and the screened interval is within a siltstone unit of the BCU.

3.0 COMPOSITIONAL ANALYSIS OF GEOLOGIC MATERIAL

3.1 Chemical Composition and Sequential Extraction

Results from sequential extractions and chemical analysis were used to determine the chemical composition of the BCU and the distribution of barium and lithium over various operationally-defined fractions in the BCU material. This testing was conducted on three samples collected from two boreholes (E-SB-05 and E-SB-07; Figure 1) advanced within the BCU. Results are presented in Section 4.0.

A description of the sequential extractions is presented in Footnote 1, Section 4.0. Metals extracted in steps 1 through 5 are considered environmentally available, whereas metals extracted in steps 6 and 7 are present in refractory fractions and are not expected to be released under conditions typically encountered in aquifers (Tessier et al. 1979). Total metal quantities from the sequential extraction are expressed as "SEP Total", extracted by a discrete total step (separate aliquot of same sample). The sum of the sequential extraction steps is also calculated but does not represent an analytically determined value. The leachates produced during each step of the sequential extractions and the total metals step were analyzed for metal concentrations using US EPA SW-846 Method 6010B.

3.2 Mineralogical Composition

Quantitative X-ray diffraction (XRD) with Rietveld refinement was used to identify and quantify minerals in three BCU samples collected from two borings (E-SB-05 and E-SB-07) during drilling activities. These samples were obtained to determine the mineralogical composition of the BCU and identify any naturally occurring minerals that have the potential to release constituents of potential concern into groundwater. The mineralogical results are presented in Table 1. The mineralogical composition primarily included quartz and feldspars (58 – 63%) and phyllosilicates muscovite, chlorite and biotite (33 – 36%). The samples also contained from less than 1% - 6% carbonates (e.g. dolomite, calcite, siderite) and 1% iron or titanium oxides.

4.0 EVIDENCE THAT POTENTIAL GWPS EXCEEDANCES ARE NOT RELATED TO THE EAP

Groundwater quality data for samples collected from monitoring wells that exhibited potential GWPS exceedances, background monitoring well AP05S, upgradient monitoring wells, and pore water samples from the EAP were evaluated. The review indicates that the GWPS exceedances are not related to the EAP, as described in the lines of evidence that follow:

- **In accordance with the procedures of the Statistical Analysis Plan, barium, chloride, or lithium did not occur statistically above the GWPS in any wells completed within the shallower UA and paired with or upgradient of AP05D, AP07D and AW-15C.**

Shallow paired wells are completed adjacent to AP05D (AP05S), AP07D (AP07S) and AW-15C (AW-15S and AW-15) in either the PMP or the UA. Groundwater samples collected from the shallow paired wells did not contain concentrations of barium, chloride, or lithium above the site GWPS (Table 2). In addition, wells between these locations and the Ash Pond (in a vertical migration pathway), or upgradient of these locations did not detect concentrations above the GWPS for these parameters. This includes AW-16 (upgradient of AW-15C), AW-21 and AW-22 (upgradient of AP07D). There are no monitoring wells directly upgradient of AP05D. A cross section location map and cross section showing the hydraulic positions of these wells is presented on Figures 2 and 3. The elevated concentrations of barium, chloride or lithium are not attributed to the Ash Pond because the migration pathway is not impacted (i.e. concentrations of the constituents in paired wells completed in the UA, which overlies the BCU, would be equal to or greater than the paired/exceedance wells completed in the BCU). Figures 4 to 6 show concentrations of barium, chloride and lithium in groundwater from the wells with GWPS exceedances; their respective paired wells AP05S, AP07S, AW-15, and AW-15S; and upgradient wells AW-16, AW-21, and AW-22.

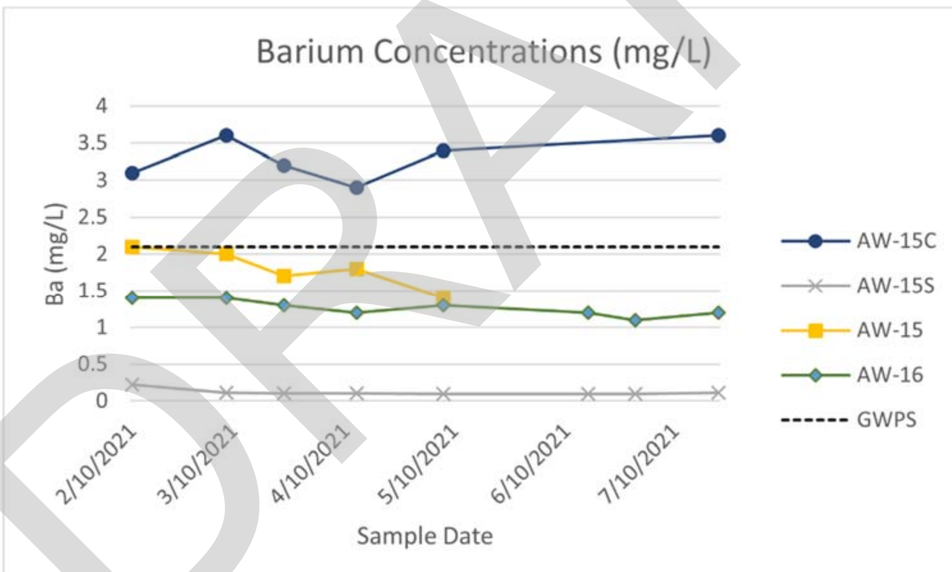


Figure 4. Barium (Ba) concentrations in groundwater from exceedance well AW-15C, shallow paired wells AW-15S and AW-15, and upgradient well AW-16

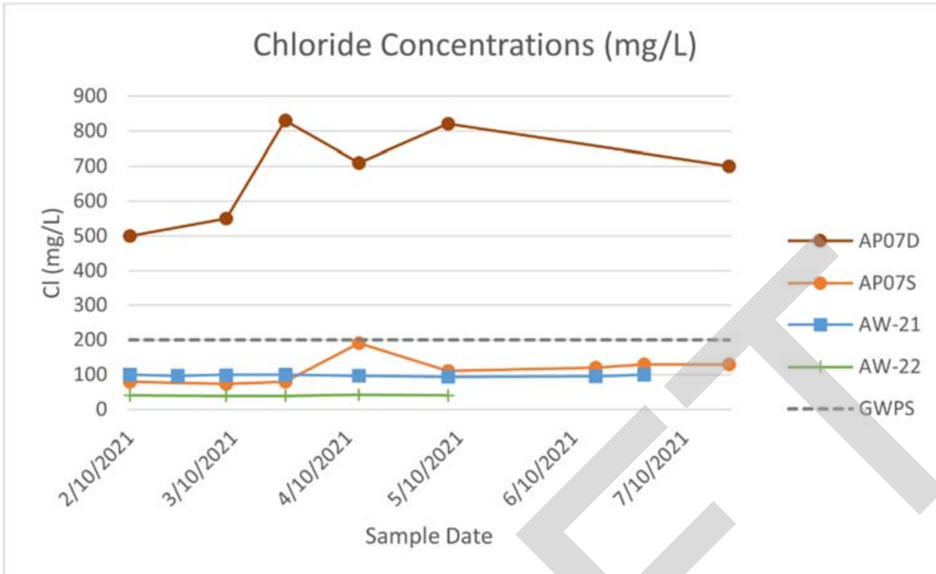


Figure 5. Chloride (Cl) concentrations in groundwater exceedance well AP07D, shallow paired well AP07S, and upgradient wells AW-21 and AW 22

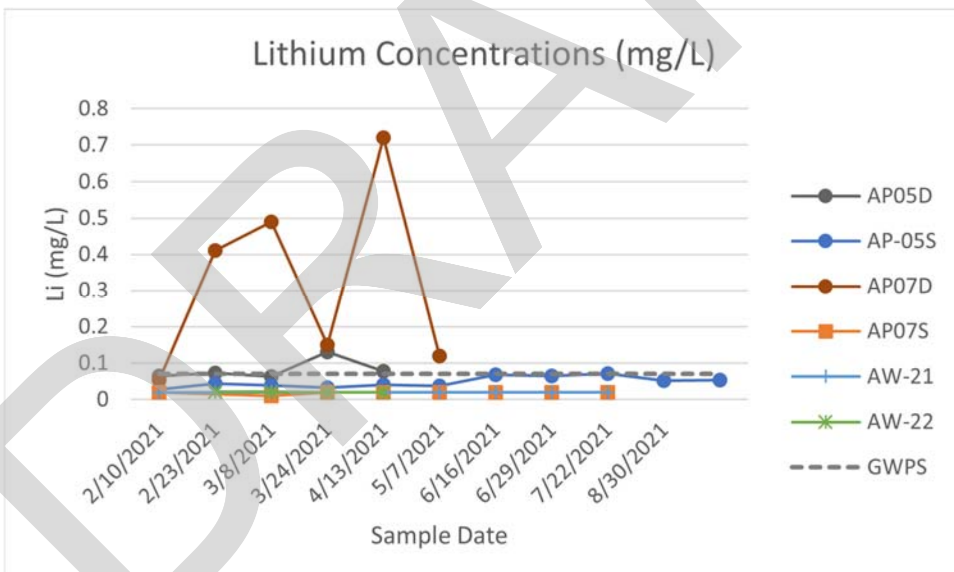


Figure 6. Lithium (Li) concentrations in groundwater exceedance wells AP05D and AP07D, shallow paired wells AP05S and AP07S, and upgradient wells AW21 and AW22

- **Concentrations of key CCR tracer constituents in EAP pore water samples differ significantly from groundwater in BCU monitoring wells AP05D, AP07D, and AW-15C.**

Concentrations of indicator parameters typically associated with the CCR managed in the EAP (e.g., boron, chloride, and sulfate) differ between porewater in the EAP and groundwater in the BCU wells AP05D, AP07D, and AW-15C. Data from the May 2021 sampling event for pore water, the BCU/exceedance wells, the shallow paired wells, and the background well are summarized in Table 3. Boron and sulfate concentrations are higher while chloride concentrations are lower in CCR porewater samples when compared to groundwater concentrations in the wells with GWPS exceedances and the background well. The relative proportions of these constituents in porewater versus the BCU/exceedance wells differ as well, as shown on the ternary diagram (Figure 7). The BCU/exceedance wells plot with the background well AP05S on the ternary diagram. The EAP porewater plots closer to the sulfate apex than the background and exceedance wells. Given the conservative behavior of sulfate and boron (see next paragraph for more detail on sulfate), if the EAP were the source, groundwater in the exceedance wells would plot in between the background groundwater and EAP pore water compositions. The concentrations of chloride in the porewater are consistently lower than in AP07D, as discussed in the next line of evidence

Sulfate, unlike boron and chloride, is sensitive to redox conditions (e.g., reduction of sulfate to sulfide) and may also be affected by the precipitation of sulfate-bearing minerals. These geochemical processes may alter sulfate concentrations in Site groundwater and affect the interpretive value of graphical methods such as ternary diagrams. To evaluate the potential for sulfate reactions in porewater and groundwater (which could affect the interpretation of sulfate concentration data), precipitation of sulfate-bearing minerals was evaluated with the help of the geochemical modeling code PHREEQC (Parkhurst and Appelo 2013), using a saturation index (SI) calculation:

$$SI = \log (IAP/Ksp)$$

The saturation index is the ratio of the ion activity product (IAP) of a mineral to the solubility product (Ksp). An SI value greater than zero indicates that the solution is supersaturated with respect to a particular mineral phase and, therefore, precipitation of this mineral may occur. An evaluation of precipitation kinetics is then required to determine whether the supersaturated mineral will indeed form. An SI value less than zero indicates the solution is undersaturated with respect to a particular mineral phase. An SI value close to zero indicates equilibrium conditions exist between the mineral and the solution. SI values between -0.5 and 0.5 are generally considered to represent ‘equilibrium’ in this report to account for the uncertainties inherent in the analytical methods and geochemical modeling (Nordstrom and Alpers 1999). The widely accepted thermodynamic database Minteq.v4, 2017 edition (USEPA 1998b, as amended), was used as a basis for the thermodynamic constants required for modeling, with additions and modifications from recent literature as required. Relevant sulfate-bearing minerals that were evaluated included gypsum, barite, and others that would be kinetically feasible to form under low-temperature conditions, as listed in Table 6.10 in Nordstrom and Alpers (1999). Calculated mineral SIs are presented in Table 4.

The geochemical modeling indicates that sulfate-bearing minerals are undersaturated across the Site, with the exception of barite. However, barite precipitation will be minimal, and is not expected to be a significant influence on sulfate concentrations in groundwater. Additionally, slightly oxidizing to oxidizing redox conditions were observed in Site groundwater (average Eh of +270 mV), indicating that reduction of sulfate to sulfide is not occurring. As such, sulfate in Site groundwater behaves conservatively and can be used as a tracer for potential EAP impacts.

These observations support that the GWPS exceedances of Ba in AW-15C, Li in AP05D, and Li and Cl in AP07D are not related to the EAP.

Table 3. Concentrations of boron, sulfate and chloride in exceedance wells and EAP pore water samples.

Well ID	Date	Boron (mg/L)	Sulfate (mg/L)	Chloride (mg/L)
Background Well				
AP-05S	5/7/2021	0.36	2.7	43
Bedrock Confining Unit Wells (GWPS Exceedance Wells)				
AP05D	5/7/2021	1.6	1.3	510
AP07D	5/5/2021	1.4	47	820
AW-15C	5/6/2021	0.63	<1	63
EAP Pore Water Samples				
XPW01A	5/4/2021	17	210	47
XPW02	5/4/2021	15	950	120
XPW03	5/4/2021	5.5	280	86

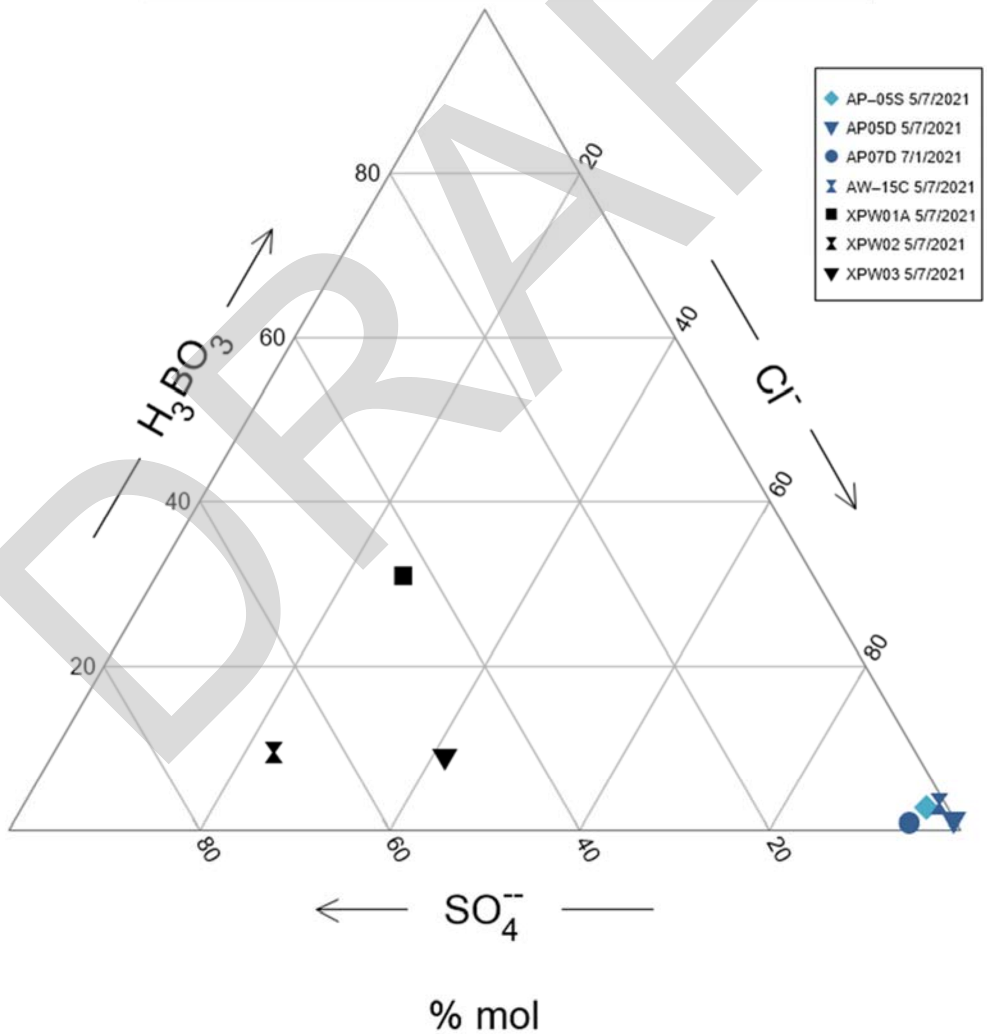


Figure 7: Ternary diagram showing relationships between CCR tracers boron, chloride, and sulfate.

- **Barium and chloride concentrations in CCR porewater are consistently lower than in BCU wells AW-15C and AP07D.**

Barium and chloride concentrations are consistently lower in CCR porewater than in BCU wells AW-15C and AP07D, as shown on **Figures 8 and 9**. Therefore, barium and chloride cannot be sourced from the CCR porewater.

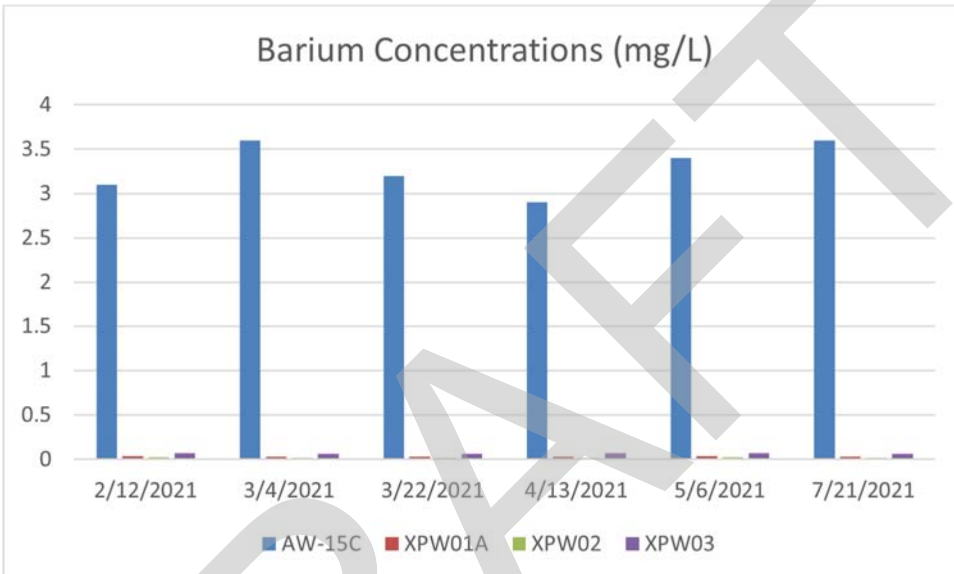


Figure 8. Barium concentrations in monitoring well AW-15C and CCR porewater samples XPW01A, XPW02 and XPW03.

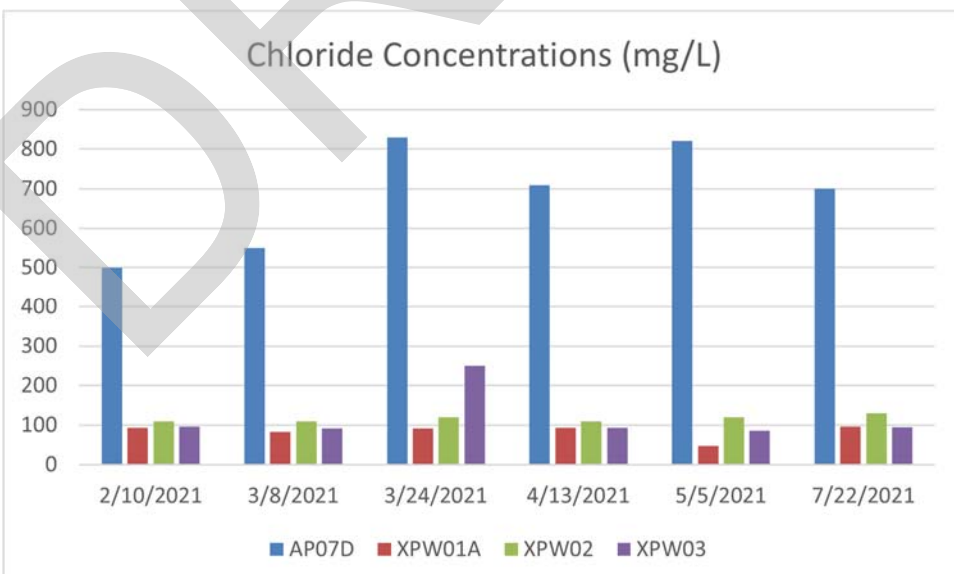


Figure 9. Chloride concentrations in monitoring well AP07D and CCR porewater samples XPW01A, XPW02 and XPW03.

- **Barium, lithium and chloride are naturally occurring constituents of the BCU.**

Barium, lithium, and chloride occur naturally within the BCU. Samples collected from the BCU aquifer matrix were analyzed for total concentrations and sequential extractions[1] were performed for barium and lithium. Total concentrations were between 390 and 480 mg/kg and 42 and 49 mg/kg for barium and lithium, respectively. For comparison, consensus average crustal barium and lithium concentrations are very similar, at 430 mg/kg and 30 mg/kg, respectively, with ranges of 179 to 1,070 mg/kg and 18 to 65 mg/kg (Smith and Huyck 1999). According to Hem (1985), average concentrations of barium and lithium in typical shale, such as the shale that comprises the BCU (Section 1.1) are 250 and 46 mg/kg, respectively.

The results of the sequential extractions are summarized in **Figures 10** and **11** for barium and lithium, respectively. As indicated in the figures, the majority of barium and lithium is present in fractions that have limited environmental availability under typical groundwater conditions, i.e. the acid/sulfide fraction and the residual fraction (and organic fraction for barium). The remainder of the barium and lithium occurs within the environmentally available fractions (exchangeable, carbonate, amorphous and metal hydroxide). As such, a natural reservoir for these parameters is present, albeit that their release from aquifer solids will likely be slow.

[1] Sequential extraction of metals from overburden samples consisted of seven discrete steps for this investigation:

Step 1 - Exchangeable Fraction: This extraction includes trace elements that are reversibly adsorbed to overburden minerals, amorphous solids, and/or organic material by electrostatic forces.

Step 2 - Carbonate Fraction: This extraction targets trace elements that are adsorbed or otherwise bound to carbonate minerals (carbonate minerals comprised between 1-6 percent of BCU samples).

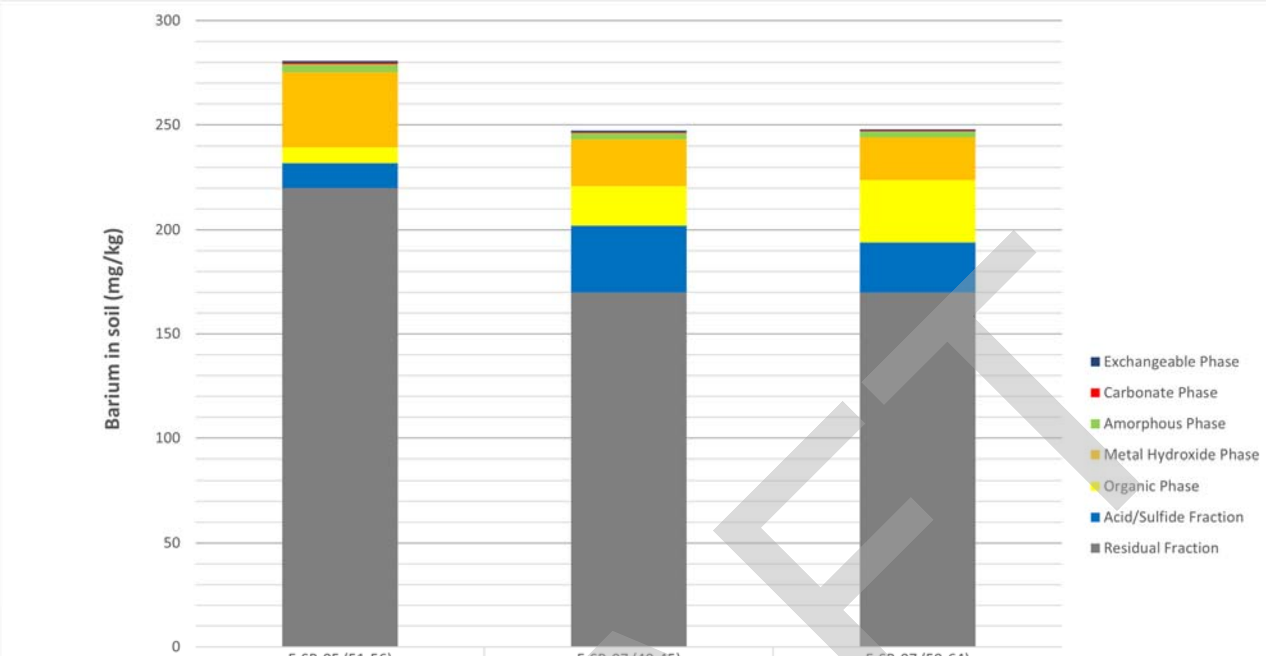
Step 3 - Non-Crystalline Materials Fraction: This extraction targets trace elements that are complexed by amorphous minerals (e.g., iron).

Step 4 - Metal Hydroxide Fraction: Trace elements bound to hydroxides of iron, manganese, and/or aluminum.

Step 5 - Organic Fraction: This extraction targets trace elements strongly bound via chemisorption to organic material.

Step 6 - Acid/Sulfide Fraction: The extraction is used to identify trace elements precipitated as sulfide minerals.

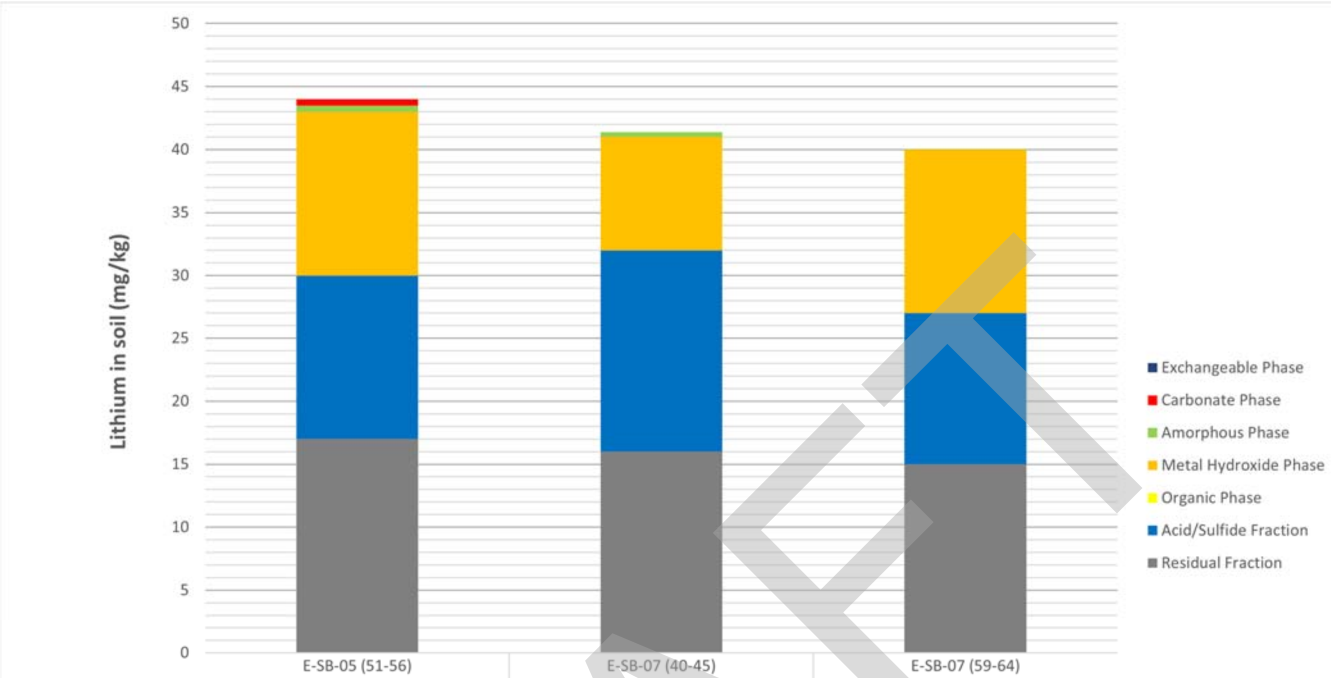
Step 7 - Residual Fraction: Trace elements remaining in the overburden after the previous extractions will be distributed between silicates, phosphates, and refractory oxides (silicates and refractory oxides comprised between 94-99% of BCU samples).



	E-SB-05 (51-56)	E-SB-07 (40-45)	E-SB-07 (59-64)
Exchangeable Phase	0.93	0.72	0.61
Carbonate Phase	0.75	0.42	0.39
Amorphous Phase	3.8	3.2	2.9
Metal Hydroxide Phase	36	22	20
Organic Phase	7.3	19	30
Acid/Sulfide Fraction	12	32	24
Residual Fraction	220	170	170

Borehole and depth below ground surface (Barium in mg/kg soil)

Figure 10. Sequential extraction results for barium. Concentrations in mg/kg are shown at the bottom of the figure, with the distribution presented in the bar graphs.



	E-SB-05 (51-56)	E-SB-07 (40-45)	E-SB-07 (59-64)
Exchangeable Phase	0	0	0
Carbonate Phase	0.53	0	0
Amorphous Phase	0.47	0.37	0.04
Metal Hydroxide Phase	13	9	13
Organic Phase	0	0	0
Acid/Sulfide Fraction	13	16	12
Residual Fraction	17	16	15

Borehole and depth below ground surface (Lithium in mg/kg soil)

Figure 11. Sequential extraction results for lithium. Concentrations in mg/kg are shown at the bottom of the figure, with the distribution presented in the bar graphs.

Although chloride in aquifer matrix samples was not analyzed in the sequential extraction, chlorides are naturally occurring within shale of marine origin such as that which comprises the BCU. Hem (1985) discusses the geochemistry of various geologic materials. Typical chloride concentrations of shale are indicated as approximately 170 mg/kg in Hem (1985). In addition, the groundwater samples collected from the BCU occurs within a weathered zone of the BCU that is overlain and underlain by very low-permeability shales and siltstones. The constituents released as a product of the weathering process have the potential to increase due to long residence time and limited recharge.

5.0 SUMMARY

The evaluation presented in this document demonstrates that the GWPS exceedances of lithium in well AP05D and AP07D, chloride in well AP07D, and barium in well AW-15C are not attributable to the EAP based on the following lines of evidence:

- The migration pathway between Ash Pond and the wells with GWPS exceedances is not impacted with Ba, Li and/or Cl. Evaluations of groundwater water quality data in accordance with the procedures of the

Statistical Analysis Plan indicate that barium, lithium, and/or chloride do not occur above the GWPS the shallow UA wells paired with, or upgradient of AP05D, AP07D and AW-15C.

- Concentrations and relative proportions of key CCR indicator parameters differ significantly between AP porewater and groundwater from monitoring wells AP05D, AP07D and AW-15C.
- Barium and chloride concentrations in CCR porewater are consistently lower than in BCU wells AW-15C and AP07D.
- Barium, lithium, and chloride occur naturally in the aquifer minerals and/or connate water of siltstones and shales including those of the BCU.

6.0 CLOSING

Golder appreciates the opportunity to serve as your consultant on this project. If you have any questions concerning this Technical Memorandum or need additional information, please contact the undersigned.

Golder Associates USA Inc.

Roberta Russell
Senior Geologist

Patrick J. Behling
Principal, Practice Leader

RR/JSI/PJN/RV/PJB

Attachments: Table 1 – Summary of Rietveld Quantitative Analysis X-Ray Diffraction Results
Table 2 – Evaluation of Potential GWPS Exceedances
Table 4 – Gypsum Saturation Indices

Figure 1 – Edwards Well Locations and Typical Groundwater Flow Direction
Figure 2 – Generalized Fence Diagram Location
Figure 3 – Generalized Fence Diagram of Monitoring Wells

7.0 REFERENCES

Burns and McDonnell 2021. Initial Operating Permit, Edwards Power Plan Ash Pond. October 25.

Hem, John D, 1985. Study and Interpretation of the Chemical Characteristics of Natural Water. United States Geological Survey Water-Supply Paper 2254.

Parkhurst, D. and Appelo, C. 2013. Description of input and examples for PHREEQC version 3: a computer program for speciation, batch-reaction, one-dimensional transport, and inverse geochemical calculations (No. 6-A43). US Geological Survey.

Ramboll, 2021a. Groundwater Sampling and Analysis Program. Ash Pond, Edwards Power Plant, Bartonville, Illinois. October 25.

Ramboll, 2021b. History of Known Groundwater Exceedances. Ash Pond, Edwards Power Plant, Bartonville, Illinois.

Ramboll 2021c. Hydrogeologic Site Characterization Report. Ash Pond, Edwards Power Plant, Bartonville, Illinois. October 25.

Smith, K. and Huyck, H. 1999. An Overview of the Abundance, Relative Mobility, Bioavailability, and Human Toxicity of Metals. The Environmental Geochemistry of Mineral Deposits, Reviews in Economic Geology Vol. 6A, pp.29-70.

Tessier, A., Campbell, P.G. and Bisson, M., 1979. Sequential extraction procedure for the speciation of particulate trace metals. Analytical chemistry, 51(7), pp.844-851.

Tables

Table 1
Evaluation of Potential Exceedances
Summary of Rietveld Quantitative Analysis X-Ray Diffraction Results
Edwards Ash Pond, Peoria County, IL

wsp GOLDER

Mineral	Mineral Formula	E-SB-07 40-45 ft bgs	E-SB-07 59-64 ft bgs	E-SB-05 51-56 ft bgs
Quartz	SiO_2	44.9	43.6	38.7
Albite	$NaAlSi_3O_8$	14.7	15.6	15.0
Microcline	$KAlSi_3O_8$	2.9	3.4	4.3
Chlorite	$(Fe,(Mg,Mn)_5,Al)(Si_3Al)O_{10}(OH)_8$	8.1	9.4	7.5
Muscovite	$KAl_2(AlSi_3O_{10})(OH)_2$	22.4	22.5	24.1
Biotite	$K(Mg,Fe)_3(AlSi_3O_{10})(OH)_2$	2.5	3.8	3.7
Ankerite	$CaFe(CO_3)_2$	0.0	0.0	0.1
Dolomite	$CaMg(CO_3)_2$	0.0	0.0	0.8
Calcite	$CaCO_3$	0.4	0.5	0.3
Siderite	$FeCO_3$	3.1	0.2	5.0
Hematite	Fe_2O_3	0.0	0.0	0.0
Magnetite	Fe_3O_4	0.3	0.3	0.4
Ilmenite	$FeTiO_3$	0.1	0.0	0.1
Rutile	TiO_2	0.7	0.6	0.3
Diopside	$CaMgSi_2O_6$	-	-	-
Actinolite	$Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2$	-	-	-
Epidote	$Ca_2(Al,Fe)Al_2O(SiO_4)(Si_2O_7)(OH)$	-	-	-
Kaolinite	$Al_2Si_2O_5(OH)_4$	-	-	-
Mullite	$\sim Al_6Si_3O_{15}$	-	-	-
Anorthite	$CaAl_2Si_2O_8$	-	-	-
TOTAL		100	100	100

Notes:
1.) Results provided in weight percentage - percent by weight of each mineral.
2.) ft bgs - feet below ground surface.
3.) Non-detect minerals within a sample are represented by "-".
4.) Zero values indicate that the mineral was included in the refinement, but the calculated concentration is below a measurable value.
5.) Samples were collected by Golder in August 2021.

Created by: CWK
Checked by: RJR
Reviewed by: PJB

Table 2
Evaluation of Potential GWPS Exceedances
Constituent Concentrations
Edwards Ash Pond
Peoria County, Illinois

Well ID	Sample Date	Barium mg/L	Lithium mg/L	Chloride mg/L
Part 845 Groundwater Protection Standards				
Site Background[1]		2.1	0.071	56
Part 845 Standard		2	0.04	200
Part 845 GWPS		2.1	0.071	200
Bedrock Confining Unit Wells				
AP05D	5/7/2021	1.3	0.077	510
AP05D	Statistical Result[2]	0.044	0.077	122
AP07D	5/5/2021	8.6	0.72	820
AP07D	Statistical Result	-1.15	0.15	498
AW-15C	5/6/2021	3.4	0.047	63
AW-15C	Statistical Result	2.9	0.047	46
Wells Paired with Bedrock Confining Unit Wells[3]				
AP05S	5/7/2021	1.2	0.037	43
AP07S	5/5/2021	0.15	<0.02	110
AW-15S	5/6/2021	0.098	<0.02	40
AW-15	5/6/2021	1.8	0.033	41
Wells Upgradient from Bedrock Confining Wells				
AW-16	5/5/2021	1.3	0.039	53
AW-21	5/5/2021	0.067	<0.02	96
AW-22	5/5/2021	0.8	<0.02	40
EAP Pore Water Samples				
XPW01A	5/4/2021	0.034	0.67	47
XPW02	5/4/2021	0.022	0.3	120
XPW03	5/4/2021	0.07	0.16	86

1. Site background is for the uppermost aquifer (UA).
2. Calculated in accordance with Statistical Analysis Plan using constituent concentrations observed at monitoring well during all sampling events from February-July 2021
3. Paired wells are completed in the UA.
4. mg/L - milligrams per liter.
5. EAP - Edwards Ash Pond.
6. GWPS - Groundwater Protection Standard.

Created by: RR
Checked by: BTT
Reviewed by: PJB

Table 4
Evaluation of Potential GWPS Exceedances
Gypsum Saturation Indices
Edwards Ash Pond, Peoria County, Illinois

WSP GOLDER

MINERAL PHASES - Saturation Indices		APW-1	AP-05S	AP05D	AW-05	AW-06	AP07S	AP07D	AW-09	AW-14	AW-15
Gypsum	$CaSO_4{:}2H_2O$	-1.03	-3.13	-4.10	-1.02	-2.06	-0.73	-2.47	-3.52	-3.45	-3.53
Barite	$BaSO_4$	**0.95**	**-0.14**	**-0.50**	**0.77**	**0.08**	**0.99**	**1.33**	-1.03	-0.82	**-0.41**

MINERAL PHASES - Saturation Indices		AW-15S	AW-15C	AW-16	AW-17	AW-18	AW-19	AW-20	AW-21	AW-22
Gypsum	$CaSO_4{:}2H_2O$	-0.62	-3.60	-3.55	-3.59	-2.92	-1.98	-1.83	-1.14	-3.62
Barite	$BaSO_4$	**1.03**	**-0.09**	-0.59	-0.59	**-0.09**	**0.19**	**0.09**	**0.63**	-0.64

Notes:

1) SI values between -0.5 and 0.5 are generally considered to represent 'equilibrium' in this report to account for the uncertainties inherent in the analytical methods and geochemical modeling (Nordstrom and Alpers 1999).

2) SI values greater than -0.5 identified by red bold type and grey shading.

Created by: CWK
Checked by: PJN
Reviewed by: PJN

Figures

Path: C:\Users\BTalbert\Golder Associates\21454831, Vistra IL MNA Part 845 Support - Project Files\5 Technical Work\Phase2 - Edwards\2.10-Figures\MNA Eval Figures\Figure 1 - Edwards Site Map - DRAFT - 11x17 - Vertical.mxd

LEGEND

Ash Pond

Soil Boring Location

Monitoring Wells

Monitoring Well Screened in Bedrock

Monitoring Well Screened in CCR Material

Monitoring Well Screened in the Upper Cahokia Formation

Monitoring Well Screened in the Uppermost

Typical Groundwater Flow Direction

Potential Exceedance

NOTES

1. SOIL BORING LOCATIONS SURVEYED BY INGENAE ON SEPTEMBER 23, 2021.
2. ALL LOCATIONS AND BOUNDARIES ARE APPROXIMATE.
3. GWPS - GROUNDWATER PROTECTION STANDARD

REFERENCE

1. BURNS AND MCDONNELL 2021, INITIAL OPERATING PERMIT - EDWARDS POWER PLANT ASH POND. AVAILABLE ONLINE AT HTTPS://WWW.LUMINANT.COM/ILLINOIS-CCR/

0 500 1,000 Feet

CLIENT
ILLINOIS POWER RESOURCES GENERATING, LLC.

PROJECT
EDWARDS POWER PLANT - EVALUATION OF POTENTIAL GWPS EXCEEDANCES

TITLE
EDWARDS WELL LOCATIONS AND TYPICAL GROUNDWATER FLOW DIRECTION

CONSULTANT

YYYY-MM-DD	2022-02-17
PREPARED	BTT
DESIGN	BTT
REVIEW	JSI
APPROVED	PJB

PROJECT No.	PHASE	FIGURE
21454831	0002A	1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:

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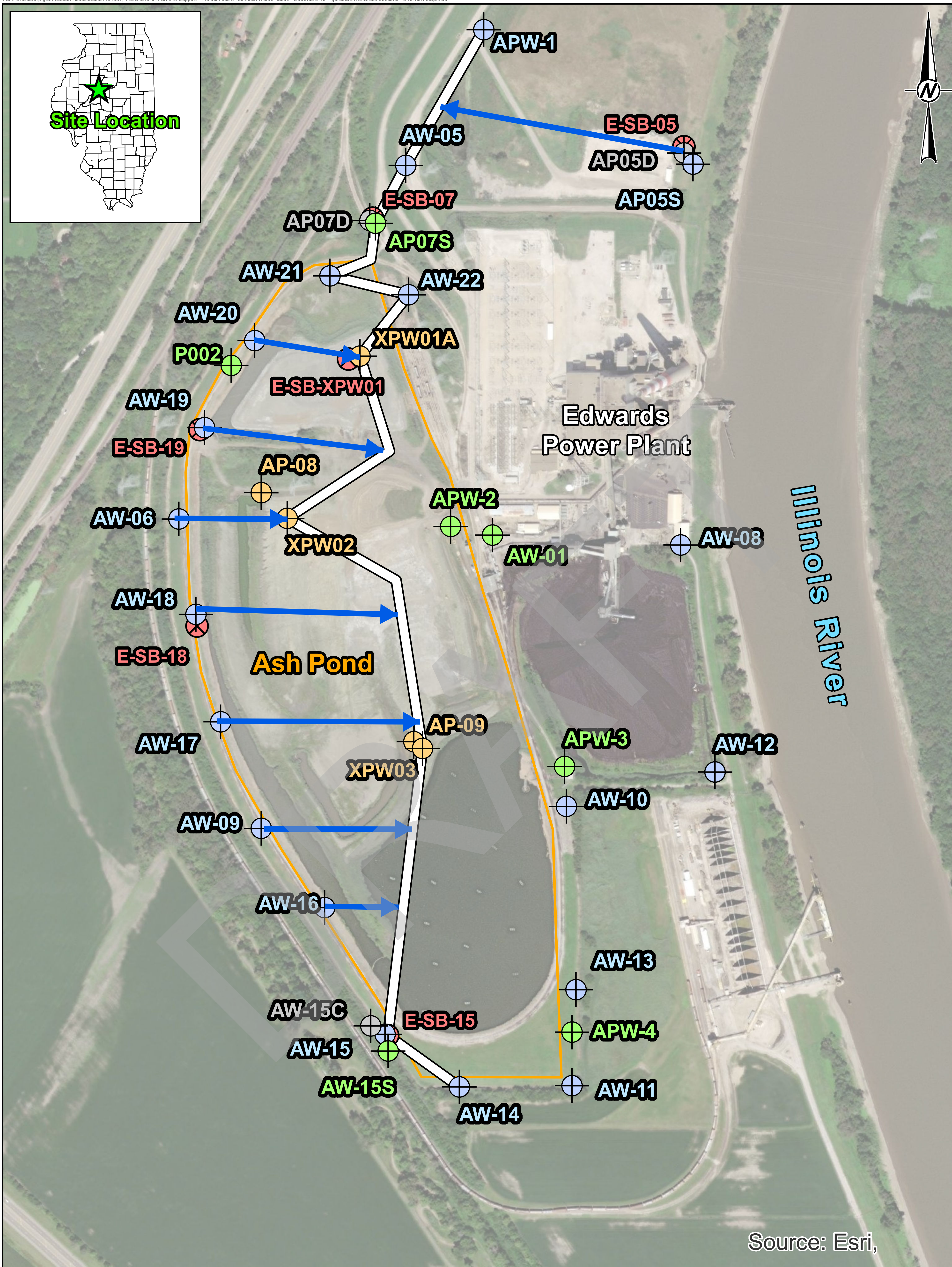


LEGEND

Ash Pond

Golder Soil Boring Location

Monitoring Wells Projected onto the Generalized Fence Diagram Line

Generalized Fence Diagram Line

Monitoring Wells

Monitoring Well Screened in Bedrock

Monitoring Well Screened in CCR Material

Monitoring Well Screened in the Upper Cahokia Formation

Monitoring Well Screened in the Uppermost Aquifer

NOTES

1. SOIL BORING LOCATIONS SURVEYED BY INGENAE ON SEPTEMBER 23, 2021.
2. ALL LOCATIONS AND BOUNDARIES ARE APPROXIMATE.

REFERENCE

1. BURNS AND MCDONNELL 2021, INITIAL OPERATING PERMIT - EDWARDS POWER PLANT ASH POND. AVAILABLE ONLINE AT HTTPS://WWW.LUMINANT.COM/ILLINOIS-CCR/

0 500 1,000 Feet

CLIENT
ILLINOIS POWER RESOURCES GENERATING, LLC.

PROJECT
EDWARDS POWER PLANT - EVALUATION OF POTENTIAL GWPS EXCEEDANCES

TITLE
GENERALIZED FENCE DIAGRAM LOCATION

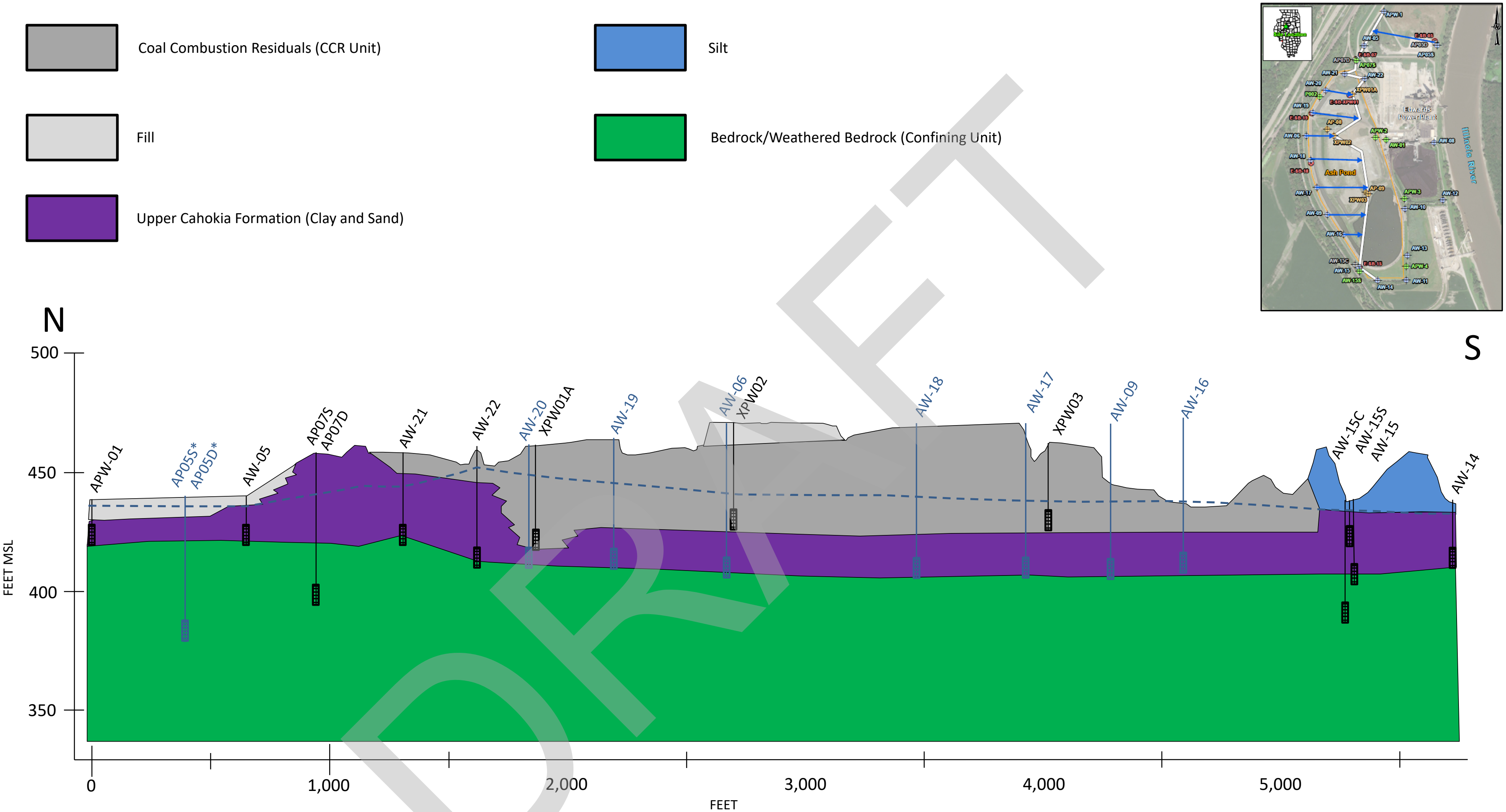
CONSULTANT

WSP GOLDER

YYYY-MM-DD	2022-02-17
PREPARED	JSI
DESIGN	JSI
REVIEW	BTT
APPROVED	PJB

PROJECT No. 21454831 PHASE 0002 FIGURE 2

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:



Notes
1) mg/L – Milligrams per liter, MSL – mean sea level
2) Wells in blue text indicate wells projected onto the cross section. Well screen location for projected wells are based on geologic unit, not elevation.
3) Wells in black text indicate wells located along the tie line. Well screen locations are based on elevation.
4) Generalized fence diagram based on generalized cross section from Ramboll (2021).
5) * indicates well is upgradient of the Edwards Ash Pond, near the Illinois River north of the plant.
6) Sizes and distances not to scale.
7) GWPS – Groundwater Protection Standards

CLIENT
ILLINOIS POWER RESOURCES GENERATING, LLC.

CONSULTANT
WSP GOLDER

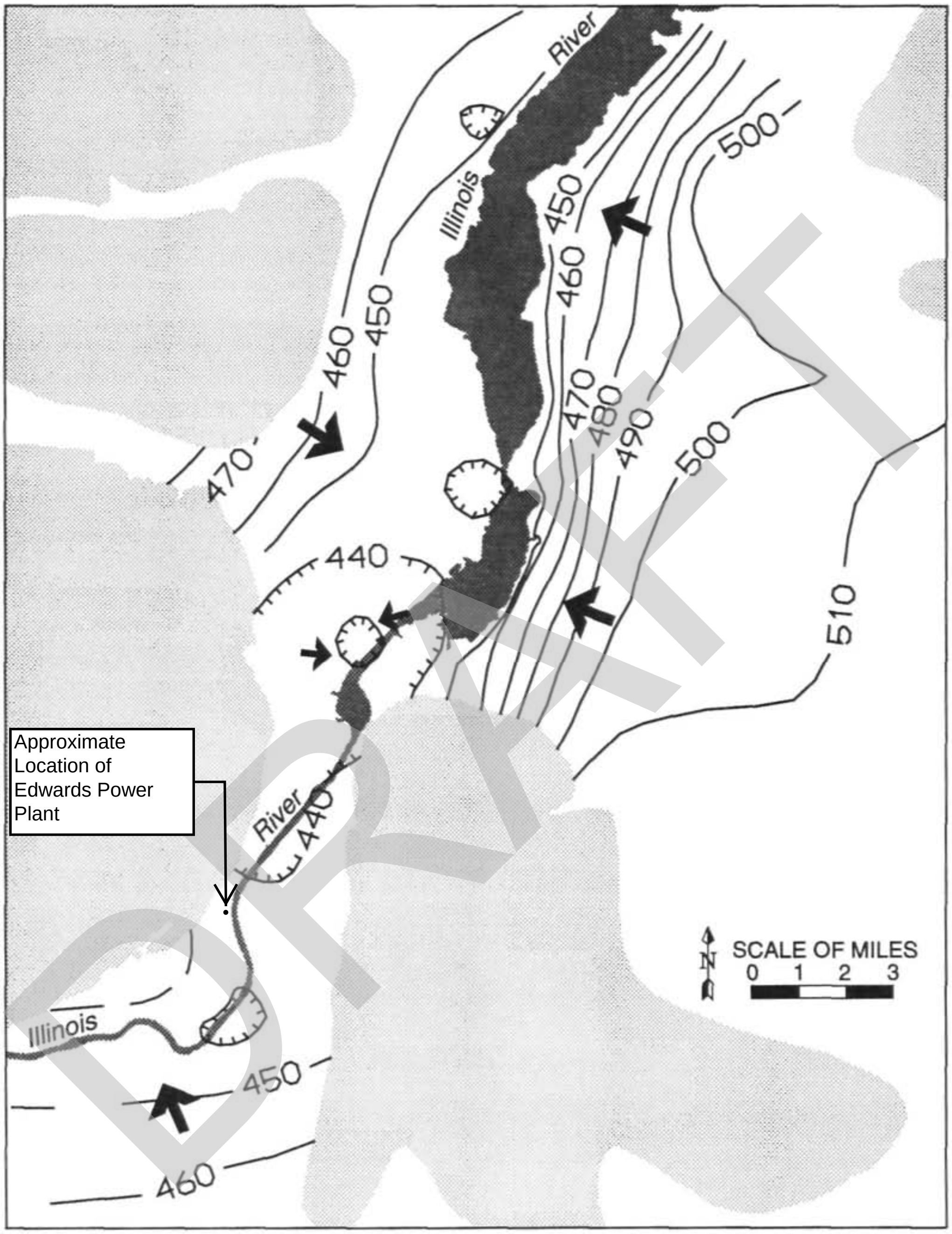
YYYY-MM-DD	2022-03-16
PREPARED	BTT
DESIGNED	JSI
REVIEWED	GTM
APPROVED	PJB

PROJECT
EDWARDS POWER PLANT – EVALUATION OF POTENTIAL GWPS EXCEEDANCES

TITLE
Generalized Fence Diagram of Monitoring Wells

PROJECT NO.	PHASE	REV.	FIGURE
21454831	0002		3

APPENDIX B
FIGURE 5 AND FIGURE 6 OF *BURCH, S. L. AND D. J. KELLY., 1993. PEORIA-PEKIN REGIONAL GROUND-WATER QUALITY ASSESSMENT. ILLINOIS STATE WATER SURVEY (ISWS), CHAMPAIGN, RESEARCH REPORT 124.*



Contours in feet, msl

Areas where aquifer is not present

Figure 5. Elevation of potentiometric surface and direction of regional ground-water flow for the Peoria-Pekin region: 1990-1991 data

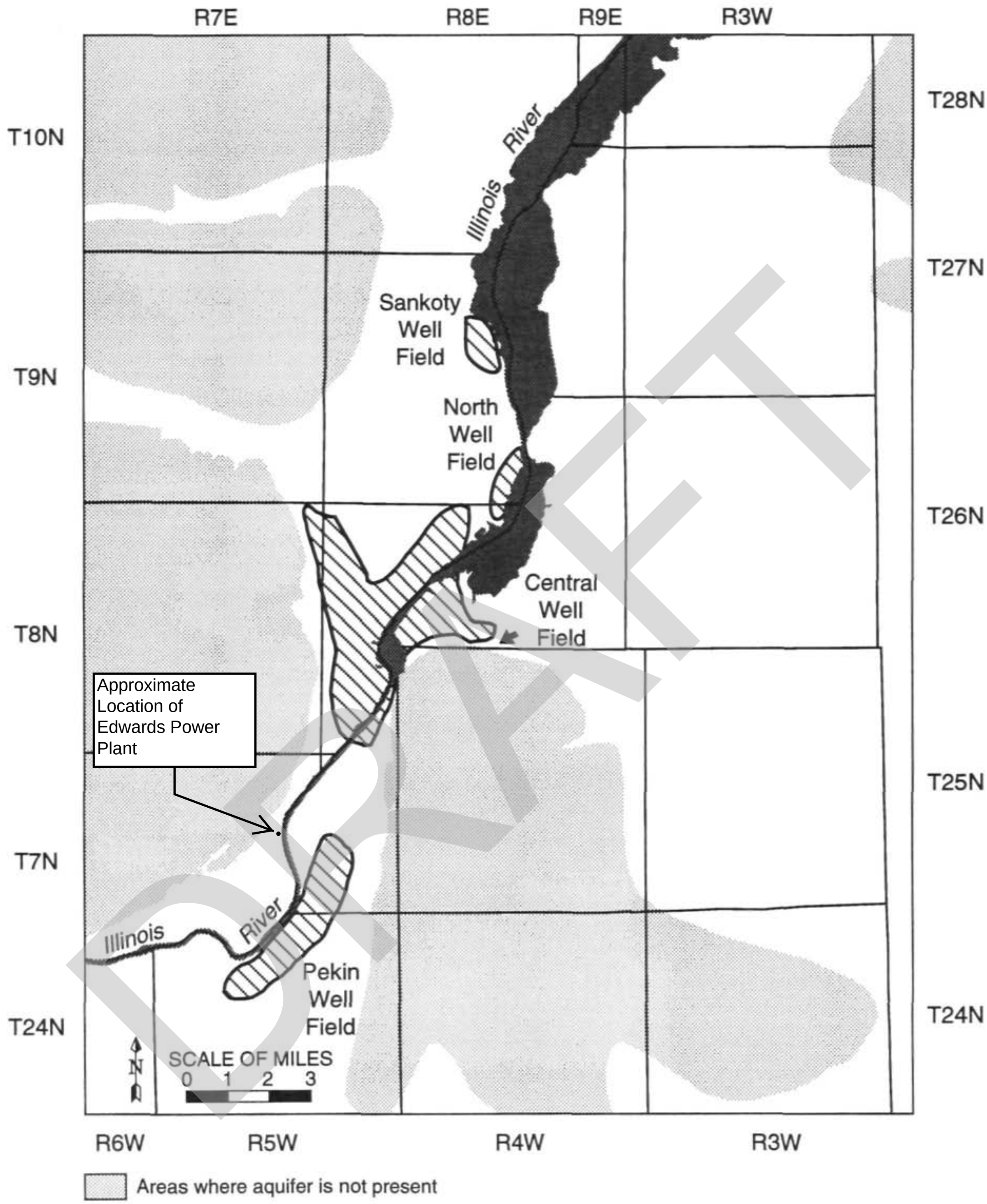


Figure 6. Locations of the Sankoty, North, Central, and Pekin municipal well fields

APPENDIX C
MODFLOW, MT3DMS, AND HELP MODEL FILES
(ELECTRONIC ONLY)

APPENDIX D
EVALUATION OF PARTITION COEFFICIENT RESULTS
(GOLDER ASSOCIATES USA INC., 2022)

TECHNICAL MEMORANDUM

DATE March 30, 2022

Project No. 21454831

TO David Mitchell, Stu Cravens, Vic Modeer
Illinois Power Resources Generating, LLC

CC Brian Henning - Ramboll

FROM Golder Associates USA Inc.

EMAIL **Jeffrey_Ingram@golder.com**

EVALUATION OF PARTITION COEFFICIENT RESULTS, EDWARDS ASH POND (CCR UNIT 301), EDWARDS POWER PLANT, PEORIA COUNTY, ILLINOIS

1.0 INTRODUCTION

Illinois Power Resource Generating, LLC (IPRG) operates the Edwards Power Plant (EPP) located in Peoria County, Illinois. The Edwards Ash Pond (EAP or Site), Illinois Environmental Protection Agency [IEPA] ID No. W1438050005 - 01) is a 91-acre unlined surface impoundment used to manage coal combustion residuals (CCRs) at the EPP. The EAP is regulated under Part 845 *"Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments"* (State CCR Rule or Part 845) which was promulgated by the Illinois Pollution Control Board (IPCB) on April 21, 2021. WSP Golder (Golder) is assisting IPRG with Part 845 compliance at the Site.

IPRG is currently preparing a Construction Permit application for the EAP as required under Section 845.220. As a part of the Construction Permit application, groundwater modeling is being completed for known potential exceedances of groundwater protection standards (GWPS) as outlined in the Operating Permit application for the EAP (Burns and McDonnell, 2021). In the Operating Permit (October 2021), Ramboll Americas Engineering Solutions, Inc. (Ramboll) identified potential GWPS exceedances for several compounds potentially associated with the EAP, including barium, boron, lithium, sulfate and total dissolved solids (TDS). Batch adsorption testing was conducted to generate site-specific partition coefficient results for these parameters for use in the groundwater models. This Technical Memorandum summarizes the results of the batch adsorption testing.

2.0 OVERVIEW

In August 2021, Golder conducted a field investigation at the EPP which included the completion of six (6) soil/rock borings ranging in depth from 40 to 64 feet below ground surface. As a part of that investigation, soil and groundwater samples were submitted to SiREM laboratories (Guelph, ON) for batch solid/liquid partitioning testing. A summary of the soil samples used for the batch testing is provided in Table 1.

Table 1: Batch Attenuation Testing Data Summary

Groundwater Sample ID	Soil Sample ID	Soil: Water Ratio
AW-15S	E-SB-05 (30.0-33.5 ft bgs)	2:1
		1:1

Groundwater Sample ID	Soil Sample ID	Soil: Water Ratio
		1:5
		1:10
		1:20
AW-19	E-SB-05 (30.0-33.5 ft bgs)	2:1
		1:1
		1:5
		1:10
		1:20

Notes:

1) Ft bgs – Feet below ground surface

Site-specific partitioning coefficients were determined for contaminants of interest (COIs) identified based on statical evaluation of potential groundwater exceedances calculated at the Site: barium, boron, lithium, and sulfate (Burns & McDonnell, 2021). Two groundwater samples (AW-15S and AW-19) and one soil sample (E-SB-05) were used for batch attenuation testing at various ratios (Table 1). For each treatment, 0.1 L of groundwater was brought in contact with an amount of soil (0.2 to 2 kg, depending on the ratio) over a seven-day period. Each contact water/soil microcosm was amended (spiked) with barium hydroxide, boric acid, sodium chloride, lithium chloride, and sodium sulfate to a target concentration of barium, boron, lithium, and sulfate, respectively (Table 2). After the seven-day contact period, COI concentrations were analyzed in the contact water. The control samples (i.e., groundwater samples AW-15S and AW-19) were only analyzed at the initiation of testing. The oxidation/reduction potential (redox) and pH were measured for each batch test at the beginning and end of the contact period and in the control samples.

Table 2: Microcosm amendment and target concentration for COIs

COI	Amendment	Target Concentration (mg/L)
Barium	1.75 mL of a 1 g/L $Ba(OH)_2 \cdot 8H_2O$ solution	0.5
Boron	36.43 mL of a 2 g/L H_3BO_3 solution	12
Lithium	5.97 mL of a 1 g/L LiCl solution	0.5
Sulfate	1769.5 mg of Na_2SO_4	1,100

Notes:

1) Mg/L – milligrams per liter
2) $Ba(OH)_2 \cdot 8H_2O$ - barium hydroxide
3) H_3BO_3 - boric acid
4) LiCl - lithium chloride
5) Na_2SO_4 - sodium sulfate

The results of batch attenuation testing (Tables 3 and 4) were used to calculate the following adsorption isotherms for each COI:

- Linear: $q_e = K_D * C_e$

- Langmuir: $C_e/q_e = 1/(K_L * q_m) + C_e/q_m$
- Freundlich: $\log(q_e) = \log(K_F) + (1/n)\log(C_e)$

Where

K_D, K_L, and K_F = the linear, Langmuir, and Freundlich partition coefficients, respectively (in liters per kilogram; L/kg).

q_e = concentration of the adsorbate in soil

C_e = aqueous concentration of the adsorbate

q_m = 1/slope in the linear expression of the isotherm

n = non-linearity constant

3.0 SUMMARY OF RESULTS

Figures that show the linear, Langmuir, and Freundlich isotherms for each COI are provided in Appendix A. The partition coefficient values for AW-15S and AW-19 are presented in Tables 5 and 6, respectively. The results of the batch adsorption testing can be summarized as follows:

- **Barium**: The calculated K_D and K_L values for both AW-15S and AW-19 were negative (AW-15S: -22.9 and -6.5E+8 L/kg; AW-19: -12.4 and -8.5E+8 L/kg), indicating an inverse relationship between the concentration of barium in solution and the concentration of barium in soil. The K_F values for AW-15S and AW-19 were 736 and 738 L/kg, respectively. For comparison, in Strenge and Peterson (1989), partition coefficients for barium range from 53 to 16,000 L/kg, depending on pH conditions and the amount of sorbent (i.e. clay, organic matter, and iron and aluminum oxyhydroxide) present.
- **Boron**: Calculated K_D values for AW-15S and AW-19 were 1.50 and -0.19 L/kg, respectively, K_L values 3.8E+4 and -2E+5 L/kg, respectively, and K_F values 82 and 215 L/kg, respectively. In Strenge and Peterson (1989), partition coefficients for boron range from 0.19 to 1.3 L/kg, depending on pH conditions and the amount of sorbent present.
- **Lithium**: Calculated K_D values for AW-15S and AW-19 were 1.89 and -1.27 L/kg, respectively, K_L values 2.6E+8 and -2.4E+8 L/kg, respectively, and K_F values 234 and 230 L/kg, respectively. In Strenge and Peterson (1989), partition coefficients for lithium range from 0 to 0.8 L/kg, depending on pH conditions and the amount of sorbent present.
- **Sulfate**: Calculated K_D values for AW-15S and AW-19 were 0.47 and -1.0 L/kg, respectively, and K_L values 778 and -2,950 L/kg, respectively. The K_F values for AW-15S and AW-19 were 63 and 1.2 L/kg, respectively. In Strenge and Peterson (1989), partition coefficients for sulfate are 0.0 L/kg, regardless of pH conditions and the amount of sorbent present.
- **pH and Redox**: Generally, after the seven-day contact time, the pH of each contact water was consistent with the pH of the control (6.95 to 6.96), ranging from 6.83 to 6.99 across the batch tests. The redox value of the control sample after the seven-day contact time was +65 mV for AW-15S and +51 for AW-19. The redox value of contact water ranged from -71 to +71 mV across treatments.

4.0 REFERENCES

Burns & McDonnell, 2021. Initial Operating Permit Edwards Power Plant Ash Pond.

Strenge, D. and Peterson, S. 1989. Chemical Data Bases for the Multimedia Environmental Pollutant Assessment System (MEPAS) (No. PNL-7145). Pacific Northwest Lab., Richland, WA (USA).

5.0 CLOSING

Golder appreciates the opportunity to serve as your consultant on this project. If you have any questions concerning this technical memorandum or need additional information, please contact the undersigned.

Golder Associates USA Inc.

Jeffrey Ingram
Senior Consultant, Geologist

Pat Behling
Practice Leader

CK/CK/JSI/PJB

Attachments Appendix A – Partition Coefficient Graphs

Table 3: Batch Attenuation Testing Results, AW-15S

Geologic Material Sample ID	Treatment	Date	Day	Replicate	Dissolved Barium	Dissolved Boron	Dissolved Lithium	Dissolved Sulfate	pH	ORP
					mg/L	mg/L	mg/L	mg/L	SU	mV
	Groundwater Only Control	1/14/2022	0	AW-15S-1a	0.31	12	0.47	390	7.07	202
				AW-15S-2a	0.36	13	0.48	397	7.06	181
				Average Concentration (mg/L)	**0.33**	**13**	**0.48**	**394**	**7.07**	**192**
		1/21/2022	7	AW-15S-1a	0.069	13	0.49	395	6.95	64
				AW-15S-2a	0.074	13	0.48	392	6.96	66
				Average Concentration (mg/L)	**0.072**	**13**	**0.49**	**394**	**6.96**	**65**
AW-15S E-SB-05 (30.0-33.5)	2:1 Soil:Water Ratio	1/14/2022	0							
		1/21/2022	7	E-SB-05 (30.0-33.5): AW-15S 2:1-1	0.39	4.6	0.15	266	6.89	-60
				E-SB-05 (30.0-33.5): AW-15S 2:1-2	0.32	4.4	0.12	274	6.93	-75
				Average Concentration (mg/L)	**0.35**	**4.5**	**0.14**	**270**	**6.91**	**-68**
	1:1 Soil:Water Ratio	1/14/2022	0							
		1/21/2022	7	E-SB-05 (30.0-33.5): AW-15S 1:1-1	0.23	6.5	0.21	313	6.83	-68
				E-SB-05 (30.0-33.5): AW-15S 1:1-2	--	--	--	--	--	--
				Average Concentration (mg/L)	**0.23**	**6.5**	**0.21**	**313**	**6.83**	**-68**
	1:5 Soil:Water Ratio	1/14/2022	0							
		1/21/2022	7	E-SB-05 (30.0-33.5): AW-15S 1:5-1	0.13	10	0.36	375	6.89	15
				E-SB-05 (30.0-33.5): AW-15S 1:5-2	0.12	10	0.36	370	6.86	72
				Average Concentration (mg/L)	**0.13**	**10**	**0.36**	**373**	**6.88**	**44**
	1:10 Soil:Water Ratio	1/14/2022	0							
		1/21/2022	7	E-SB-05 (30.0-33.5): AW-15S 1:10-1	0.12	11	0.42	382	6.91	73
				E-SB-05 (30.0-33.5): AW-15S 1:10-2	0.11	12	0.43	375	6.94	68
				Average Concentration (mg/L)	**0.11**	**11**	**0.43**	**379**	**6.93**	**71**
	1:20 Soil:Water Ratio	1/14/2022	0							
		1/21/2022	7	E-SB-05 (30.0-33.5): AW-15S 1:20-1	0.10	12	0.45	393	6.99	96
				E-SB-05 (30.0-33.5): AW-15S 1:20-2	0.11	12	0.44	383	6.96	42
				Average Concentration (mg/L)	**0.11**	**12**	**0.45**	**388**	**6.98**	**69**

Notes:
1) mg/L- Miligrams per liter
2) SU - Standard Units
3) mV -milivolts
4) ORP - Oxidation Reduction Potential

Table 4: Batch Attenuation Testing Results, AW-19

Geologic Material Sample ID	Treatment	Date	Day	Replicate	Dissolved Barium	Dissolved Boron	Dissolved Lithium	Dissolved Sulfate	pH	ORP
					mg/L	mg/L	mg/L	mg/L	SU	mV
	Groundwater Only Control	1/14/2022	0	AW-19-1a	0.22	12	0.46	386	7.08	156
				AW-19-2a	0.27	12	0.45	380	7.07	133
				Average Concentration (mg/L)	**0.25**	**12**	**0.46**	**383**	**7.08**	**145**
		1/21/2022	7	AW-19-1a	0.048	12	0.48	375	6.98	39
				AW-19-2a	0.049	12	0.51	390	6.92	62
				Average Concentration (mg/L)	**0.049**	**12**	**0.50**	**383**	**6.95**	**51**
AW-19 E-SB-05 (30.0-33.5)	2:1 Soil:Water Ratio	1/14/2022	0							
		1/21/2022	7	E-SB-05 (30.0-33.5): AW-19 2:1-1	0.27	4.3	0.11	270	6.93	-58
				E-SB-05 (30.0-33.5): AW-19 2:1-2	0.51	4.4	0.15	269	6.94	-71
				Average Concentration (mg/L)	**0.39**	**4.4**	**0.13**	**270**	**6.94**	**-65**
	1:1 Soil:Water Ratio	1/14/2022	0							
		1/21/2022	7	E-SB-05 (30.0-33.5): AW-19 1:1-1	0.24	6.6	0.24	314	6.98	-60
				E-SB-05 (30.0-33.5): AW-19 1:1-2	0.32	6.3	0.22	308	6.99	-82
				Average Concentration (mg/L)	**0.28**	**6.5**	**0.23**	**311**	**6.99**	**-71**
	1:5 Soil:Water Ratio	1/14/2022	0							
		1/21/2022	7	E-SB-05 (30.0-33.5): AW-19 1:5-1	0.16	10	0.36	358	6.92	-42
				E-SB-05 (30.0-33.5): AW-19 1:5-2	0.19	10	0.38	360	6.95	-32
				Average Concentration (mg/L)	**0.18**	**10**	**0.37**	**359**	**6.94**	**-37**
	1:10 Soil:Water Ratio	1/14/2022	0							
		1/21/2022	7	E-SB-05 (30.0-33.5): AW-19 1:10-1	0.17	10	0.40	365	6.92	-48
				E-SB-05 (30.0-33.5): AW-19 1:10-2	0.14	11	0.45	389	6.95	-52
				Average Concentration (mg/L)	**0.16**	**11**	**0.43**	**377**	**6.94**	**-50**
	1:20 Soil:Water Ratio	1/14/2022	0							
		1/21/2022	7	E-SB-05 (30.0-33.5): AW-19 1:20-1	0.11	12	0.46	381	7.00	-3
				E-SB-05 (30.0-33.5): AW-19 1:20-2	0.16	12	0.47	387	6.97	-45
				Average Concentration (mg/L)	**0.13**	**12**	**0.47**	**384**	**6.99**	**-24**

Notes:
1) mg/L- Miligrams per liter
2) SU - Standard Units
3) mV -milivolts
4) ORP - Oxidation Reduction Potential

Table 5: Partition Coefficient Results, AW-15S

Analyte	Isotherm	Variable	With Soil Mass
Barium	Raw Data R^2		0.46
	Linear K_D (L/kg)		-22.85
	Langmuir	R^2	1.00
		q_m (mg/g)	0.498
		K_L (L/kg)	-6.48E+08
	Freundlich	R^2	0.55
		1/n	-0.01
		K_F (L/kg)	736.03
Boron	Raw Data R^2		0.99
	Linear K_D (L/kg)		1.50
	Langmuir	R^2	0.79
		q_m (mg/g)	0.068
		K_L (L/kg)	3.79E+04
	Freundlich	R^2	0.98
		1/n	0.764
		K_F (L/kg)	82.21
Lithium	Raw Data R^2		0.80
	Linear K_D (L/kg)		1.89
	Langmuir	R^2	1.00
		q_m (mg/g)	0.035
		K_L (L/kg)	2.58E+08
	Freundlich	R^2	0.79
		1/n	0.014
		K_F (L/kg)	234.30
Sulfate	Raw Data R^2		0.54
	Linear K_D (L/kg)		0.47
	Langmuir	R^2	0.07
		q_m (mg/g)	0.88
		K_L (L/kg)	7.78E+02
	Freundlich	R^2	0.56
		1/n	0.8
		K_F (L/kg)	63.43

Note(s):
K_D: linear partition coefficient
K_L: Langmuir partition coefficient
K_F: Freundlich partition coefficient
qm: 1/slope in the linear expression of the isotherm
n: non-linearity constant

Table 6: Partition Coefficient Results, AW-19

Analyte	Isotherm	Variable	With Soil Mass
Barium	Raw Data R^2		0.51
	Linear K_D (L/kg)		-12.44
	Langmuir	R^2	1.00
		q_m (mg/g)	0.498
		K_L (L/kg)	-8.45E+08
	Freundlich	R^2	0.62
		1/n	-0.007
		K_F (L/kg)	737.55
Boron	Raw Data R^2		0.01
	Linear K_D (L/kg)		-0.19
	Langmuir	R^2	0.35
		q_m (mg/g)	0.002
		K_L (L/kg)	-1.99E+05
	Freundlich	R^2	0.07
		1/n	-0.578
		K_F (L/kg)	215.36
Lithium	Raw Data R^2		0.19
	Linear K_D (L/kg)		-1.27
	Langmuir	R^2	1.00
		q_m (mg/g)	0.034
		K_L (L/kg)	-2.37E+08
	Freundlich	R^2	0.119
		1/n	-0.008
		K_F (L/kg)	230.26
Sulfate	Raw Data R^2		0.28
	Linear K_D (L/kg)		-1.00
	Langmuir	R^2	0.16
		q_m (mg/g)	-0.021
		K_L (L/kg)	-2.95E+03
	Freundlich	R^2	0.16
		1/n	2.40
		K_F (L/kg)	1.16

Note(s):
K_D: linear partition coefficient
K_L: Langmuir partition coefficient
K_F: Freundlich partition coefficient
qm: 1/slope in the linear expression of the isotherm
n: non-linearity constant

APPENDIX A

Partition Coefficient Graphs

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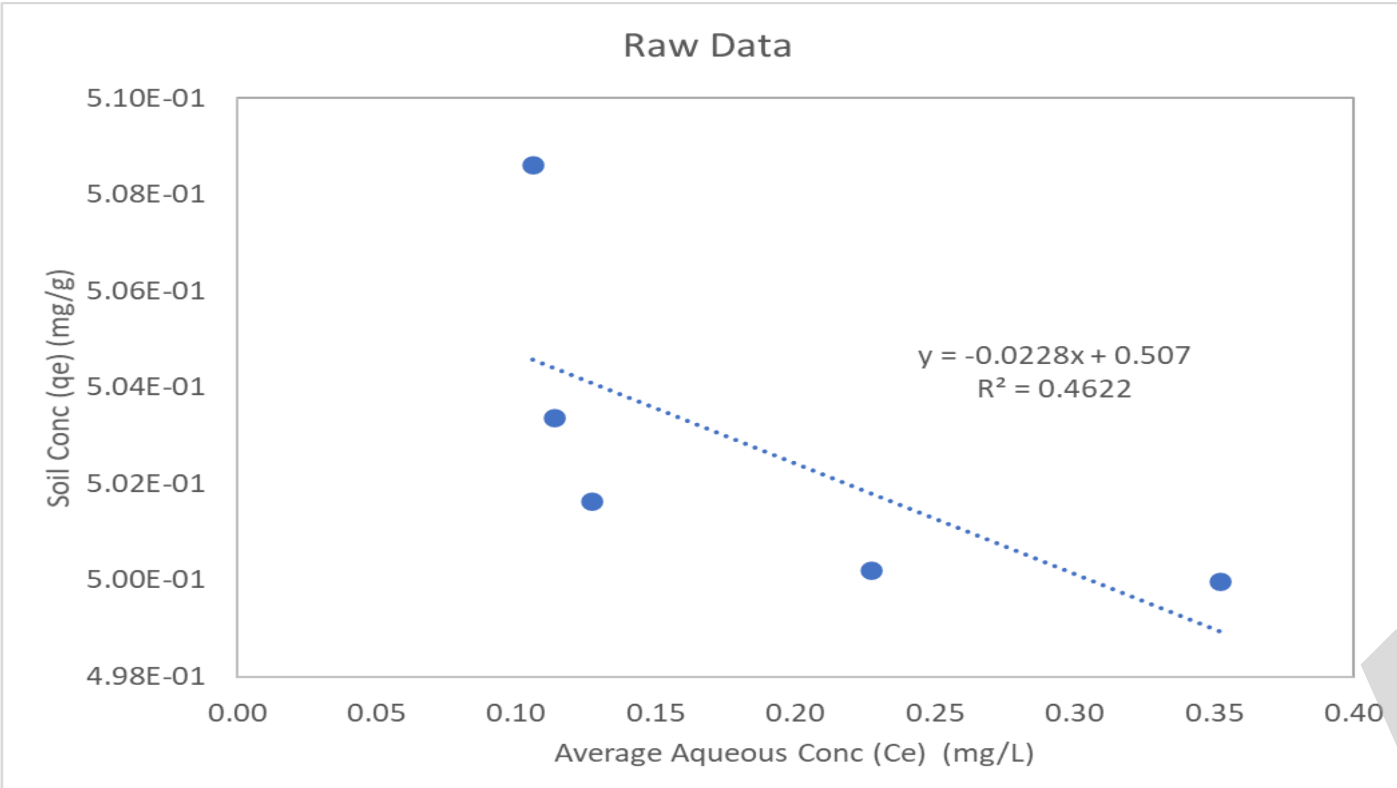

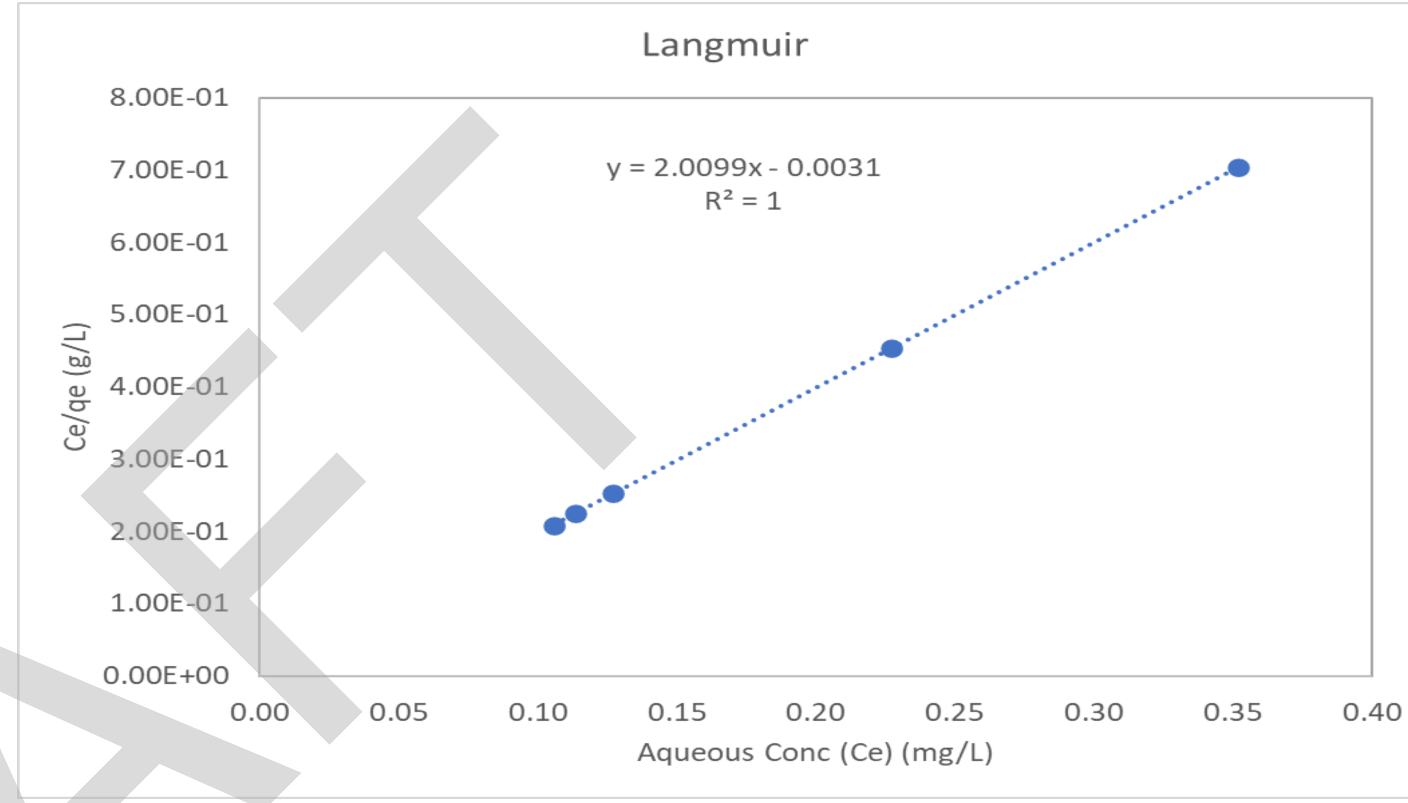

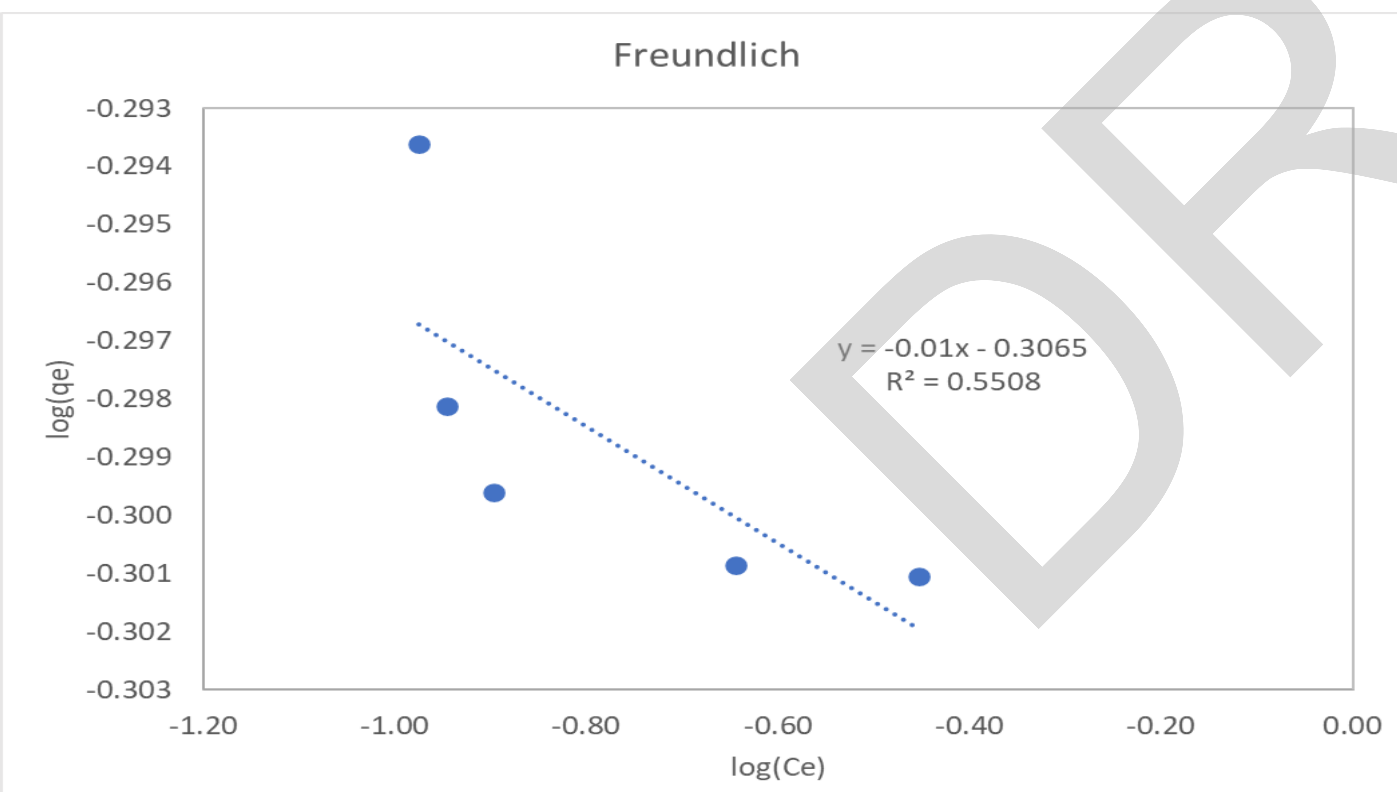

Note(s):
mg/L: milligrams per liter
mg/g: milligrams per gram
g/L: grams per liter
Ce: aqueous concentration of the adsorbate

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EDWARDS ASH POND (CCR UNIT 301)

PROJECT
EVALUATION OF PARTITION COEFFICIENT RESULTS EAP

CONSULTANT
WSP GOLDER

TITLE
AW-15S BARIUM PARTITION COEFFICIENTS

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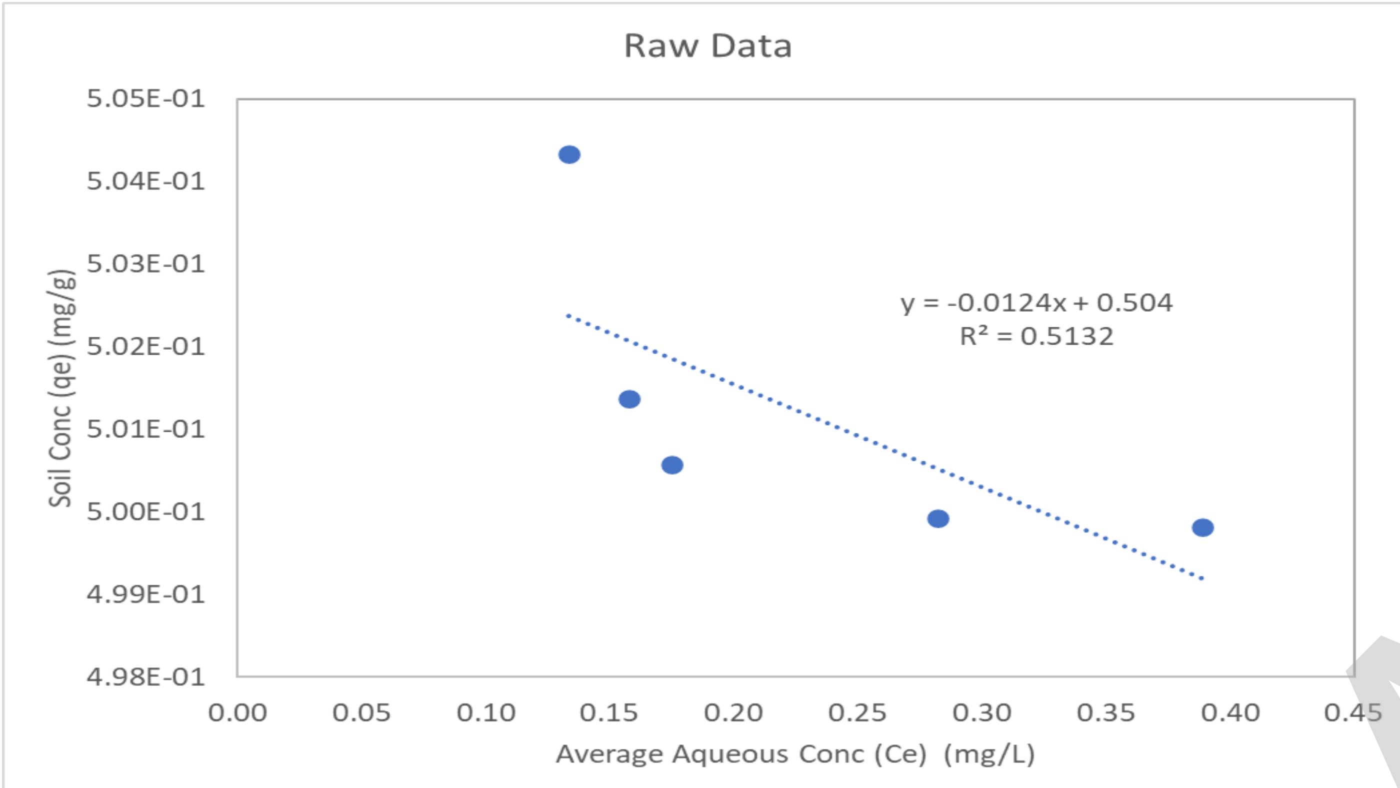

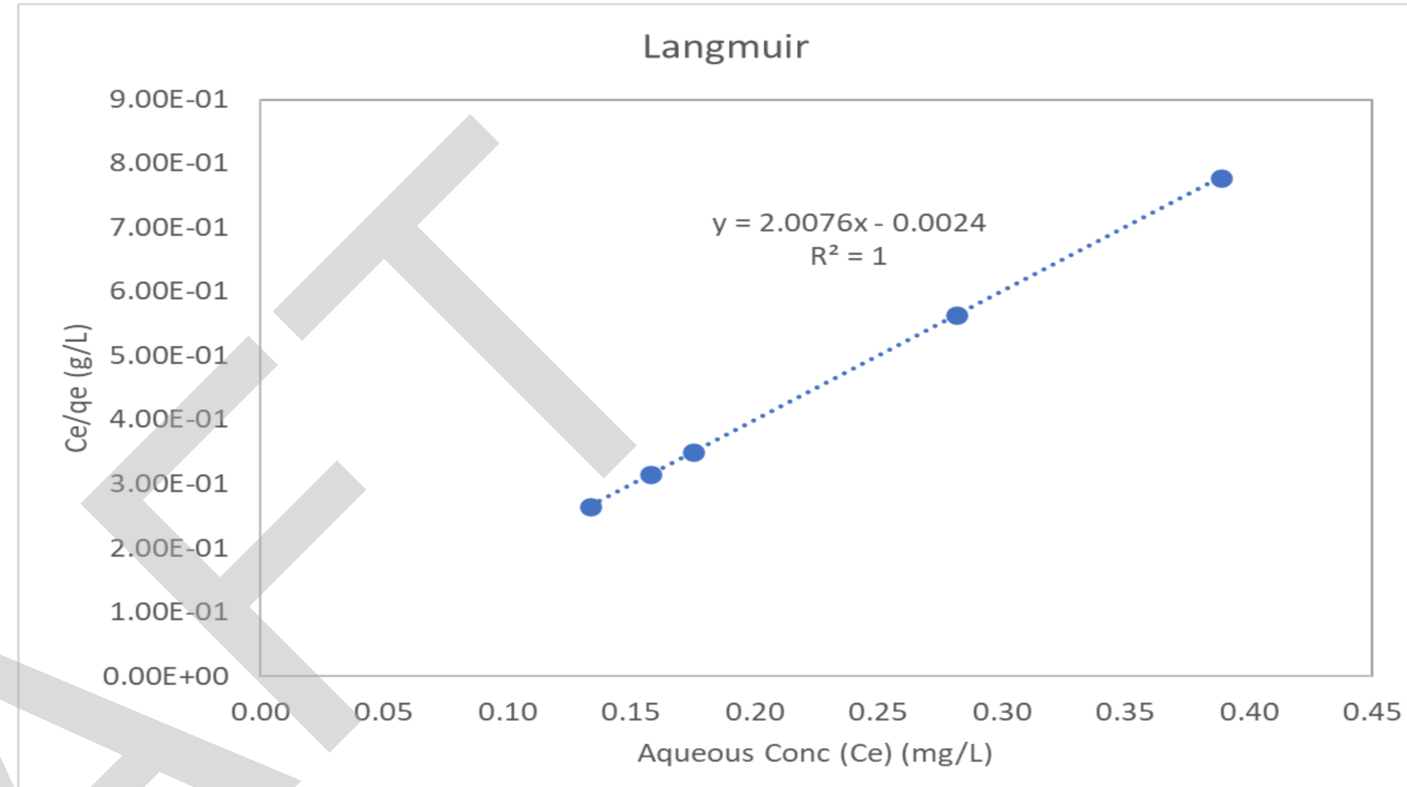

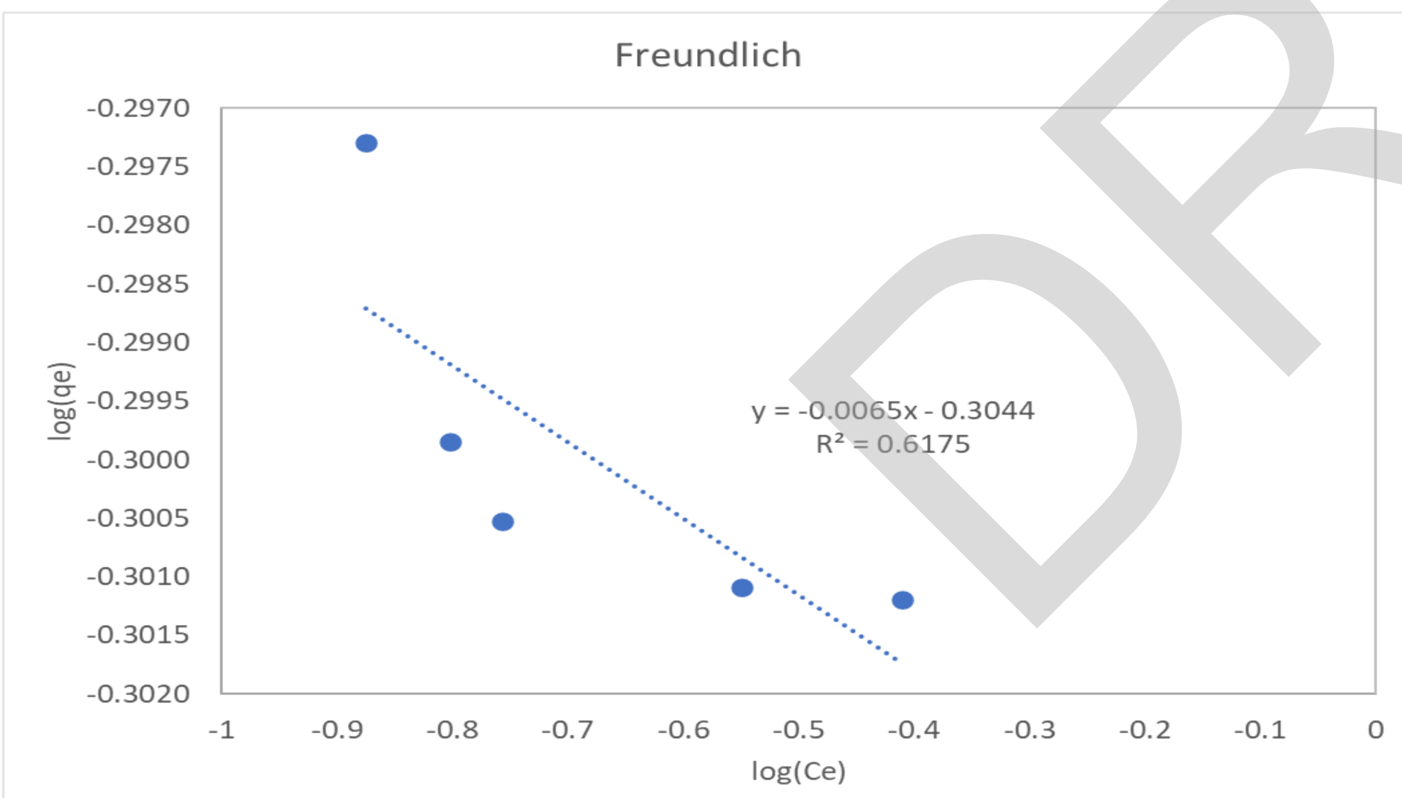

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WSP GOLDER

TITLE
AW-19 BARIUM PARTITION COEFFICIENTS

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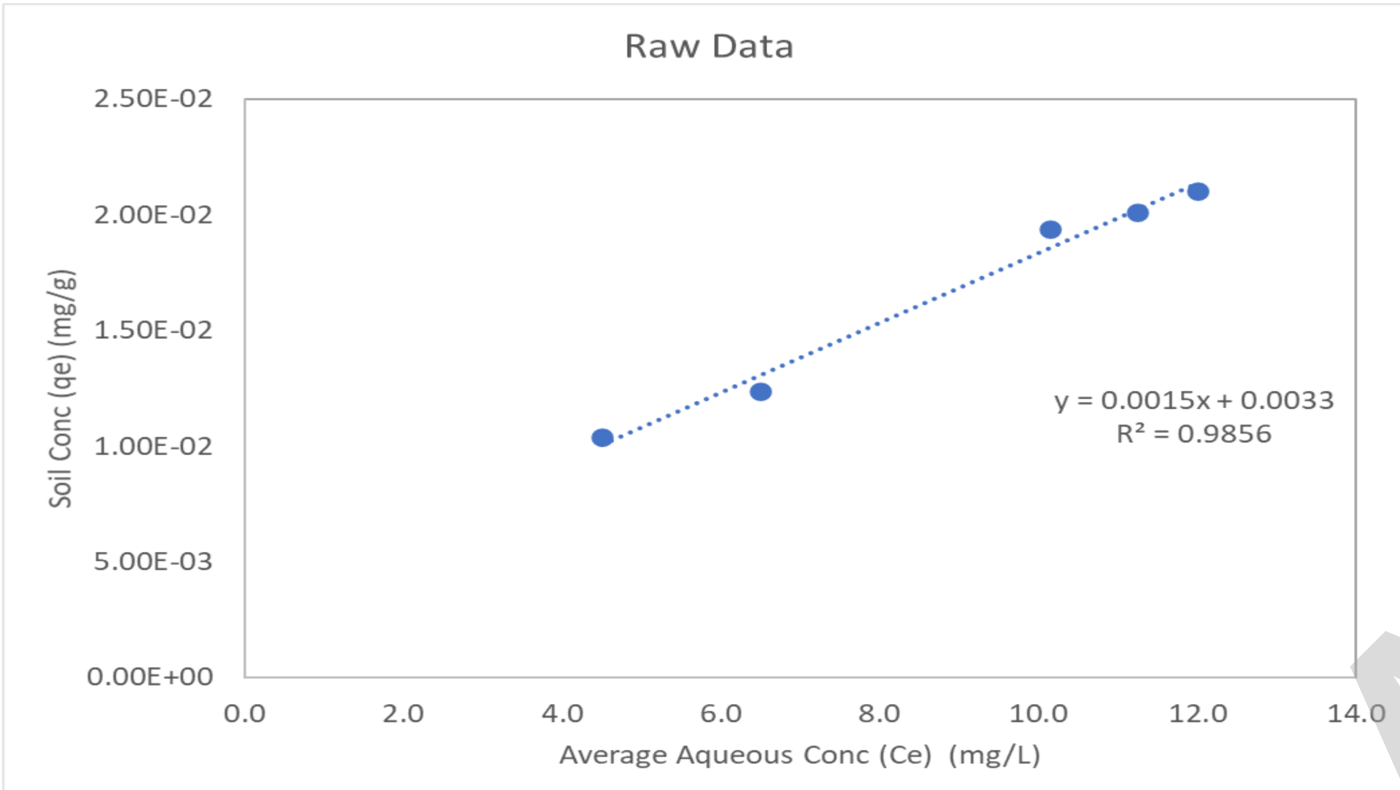

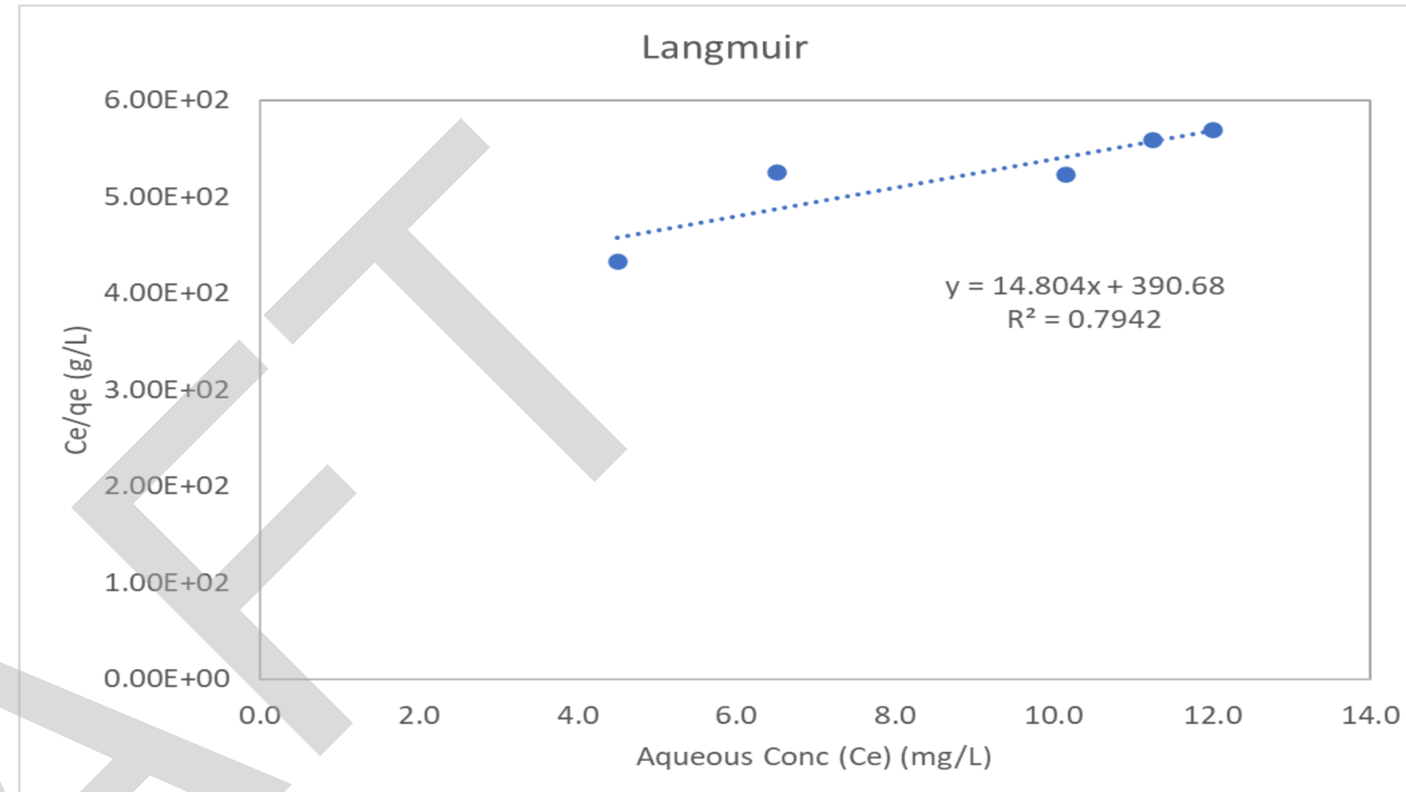

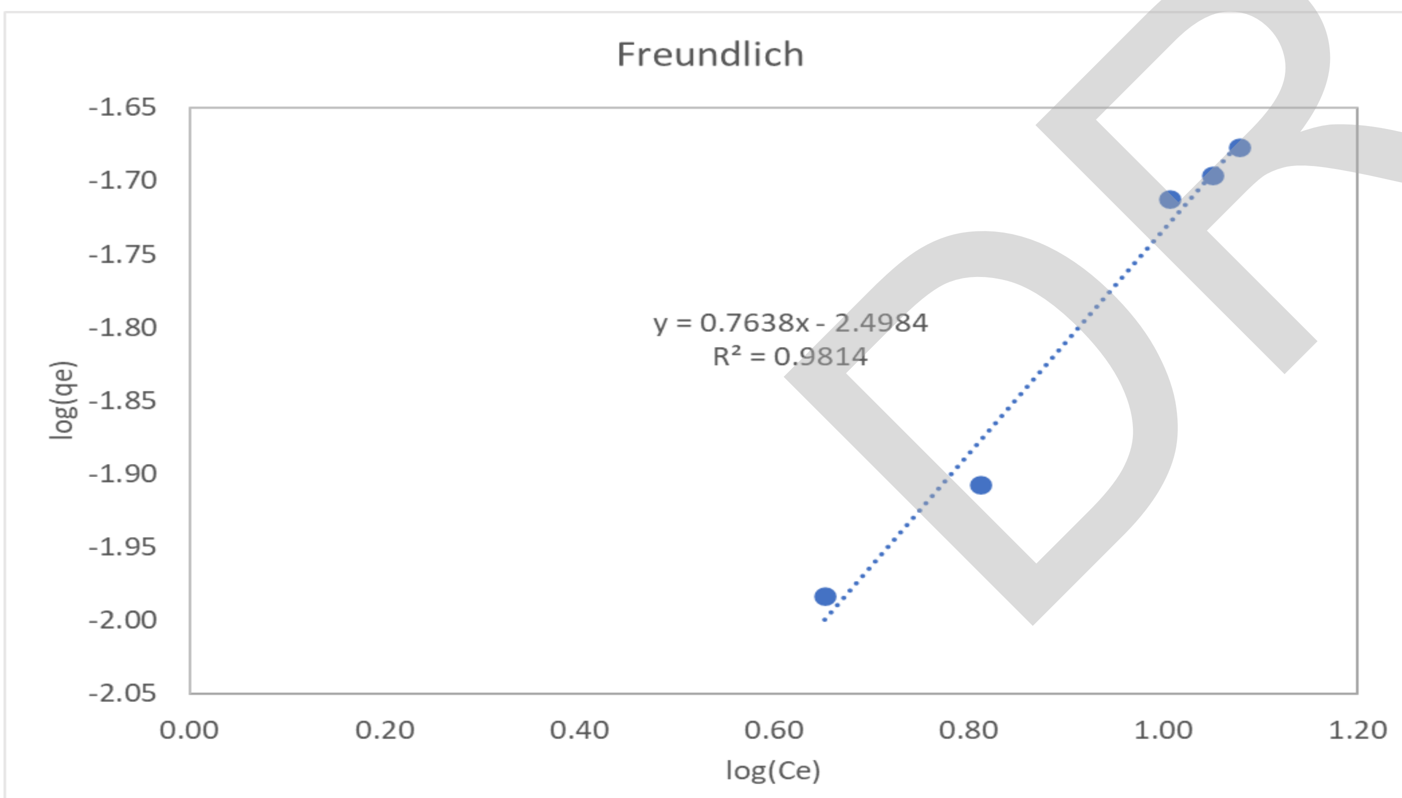

Note(s):
mg/L: milligrams per liter
mg/g: milligrams per gram
g/L: grams per liter
Ce: aqueous concentration of the adsorbate

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TITLE
AW-15S BORON PARTITION COEFFICIENTS

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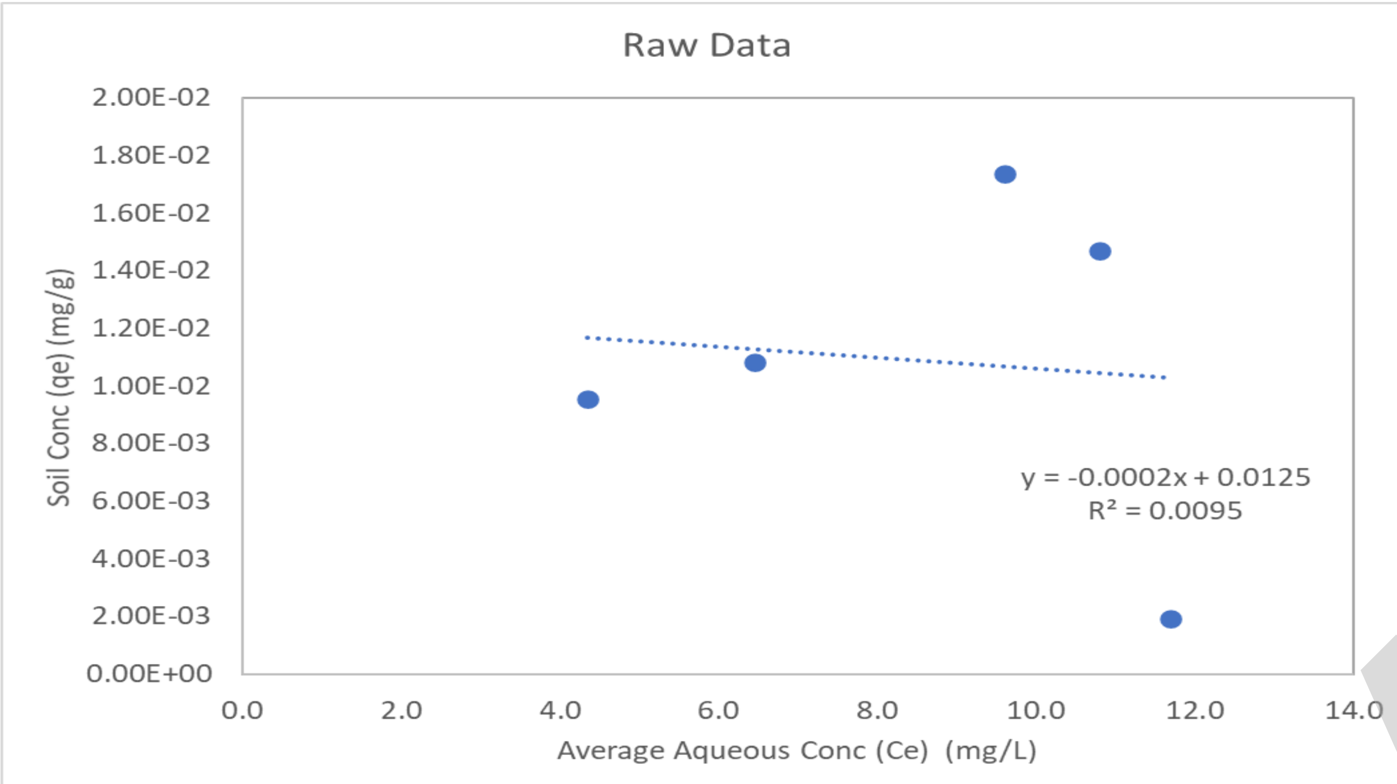

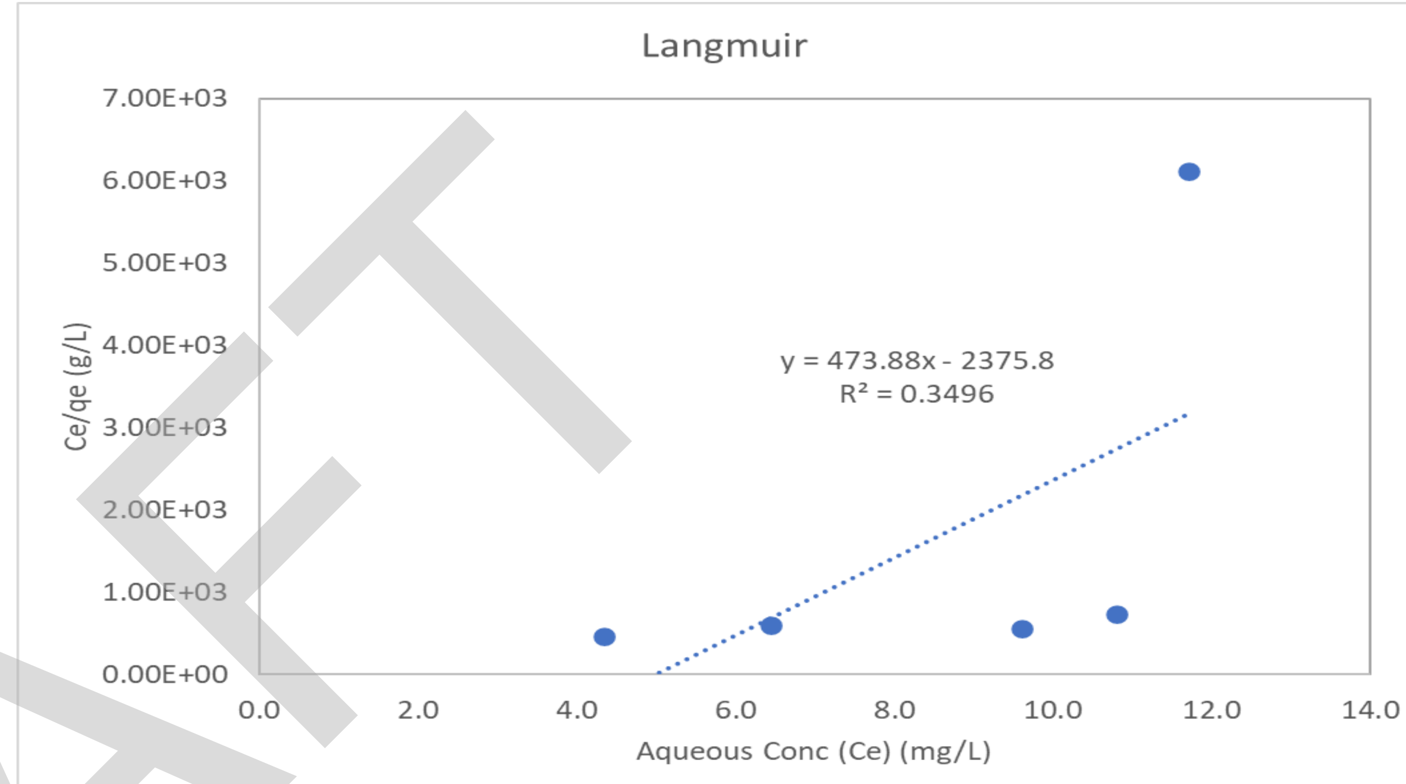

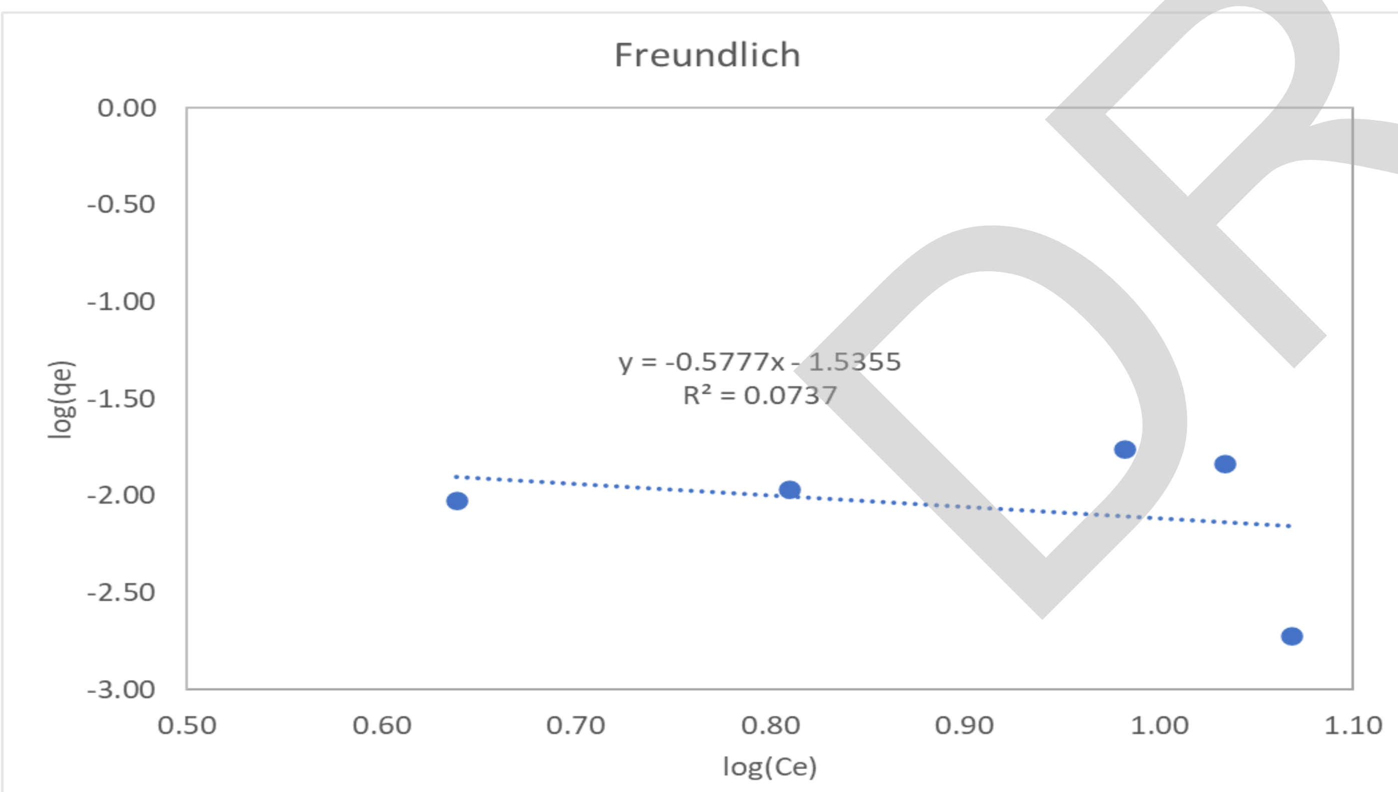

Note(s):
mg/L: milligrams per liter
mg/g: milligrams per gram
g/L: grams per liter
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CONSULTANT WSP GOLDER	TITLE **AW-19 BORON PARTITION COEFFICIENTS**

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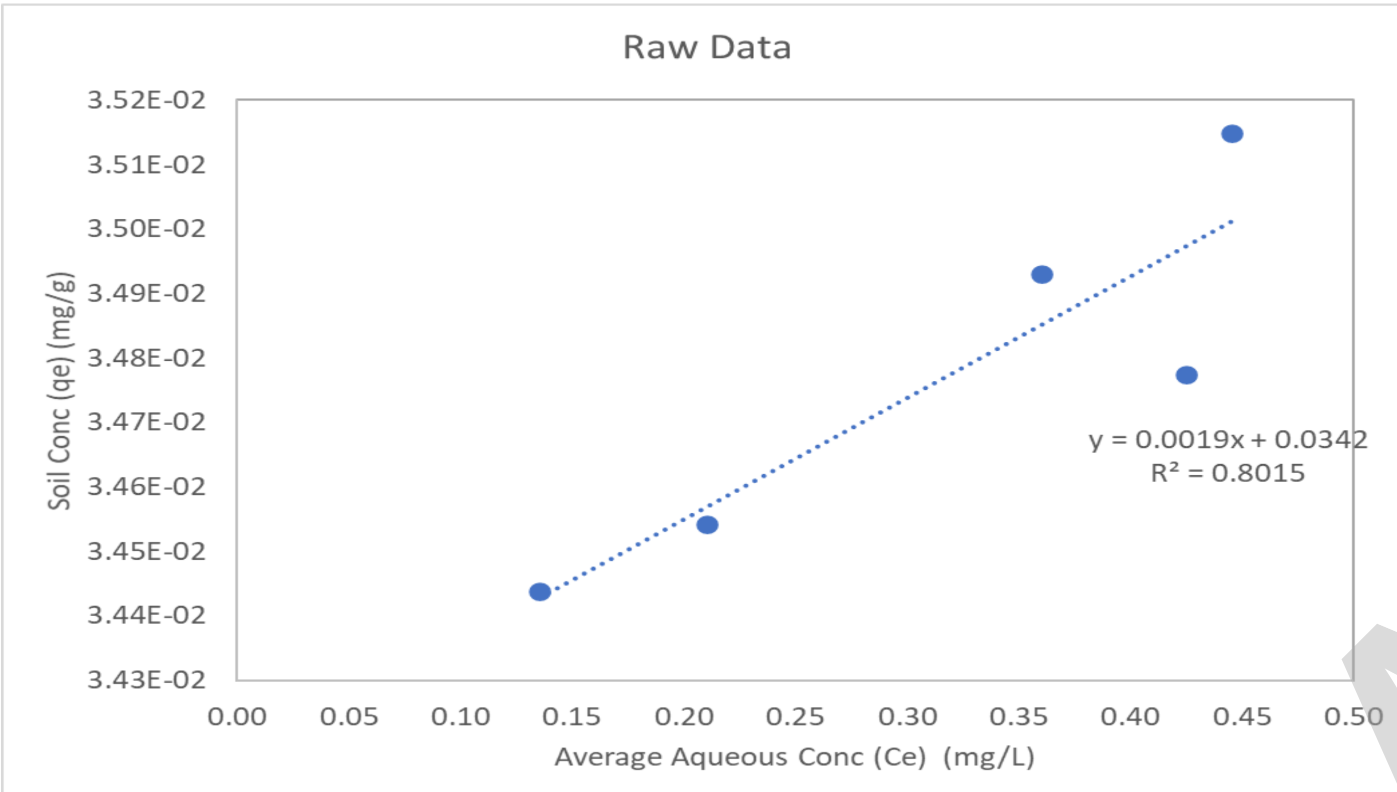

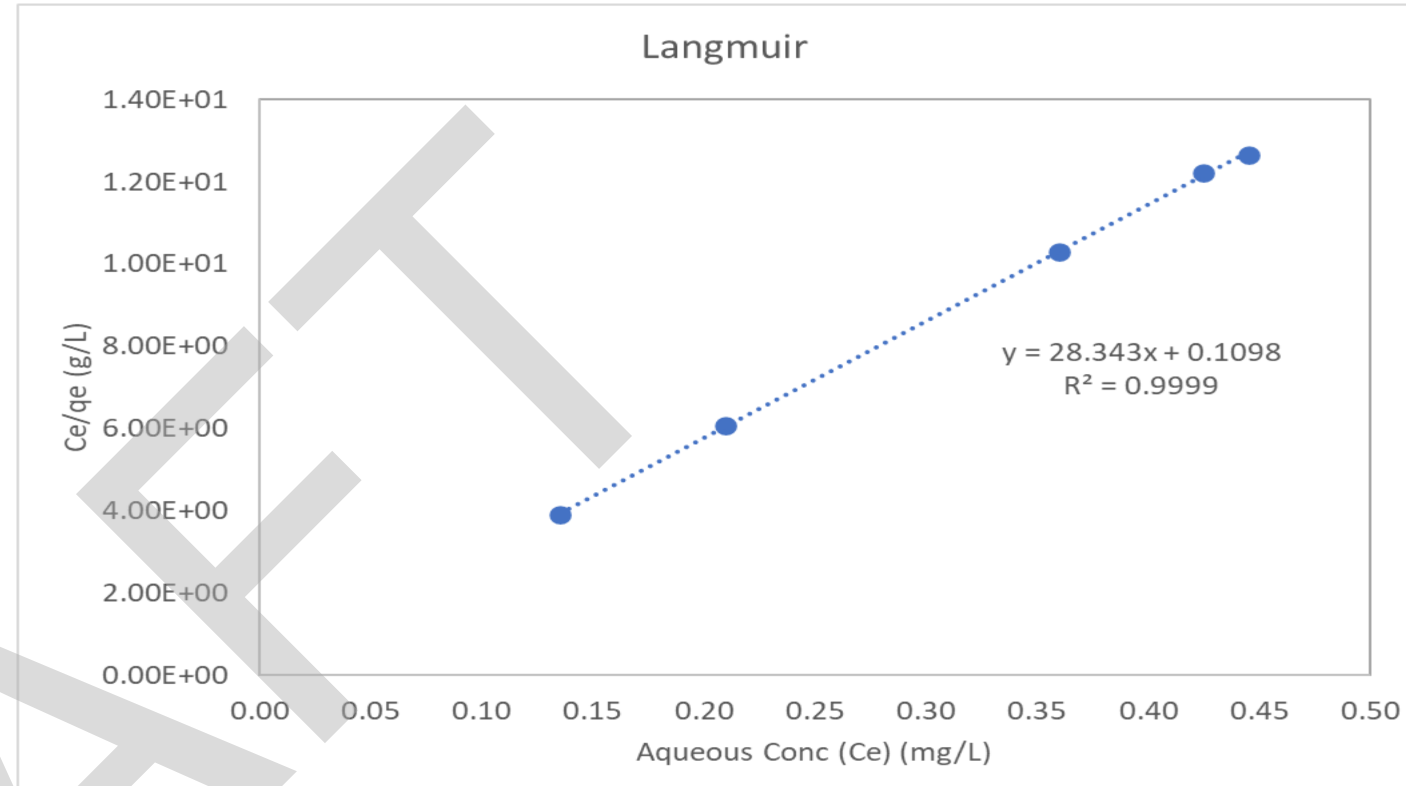

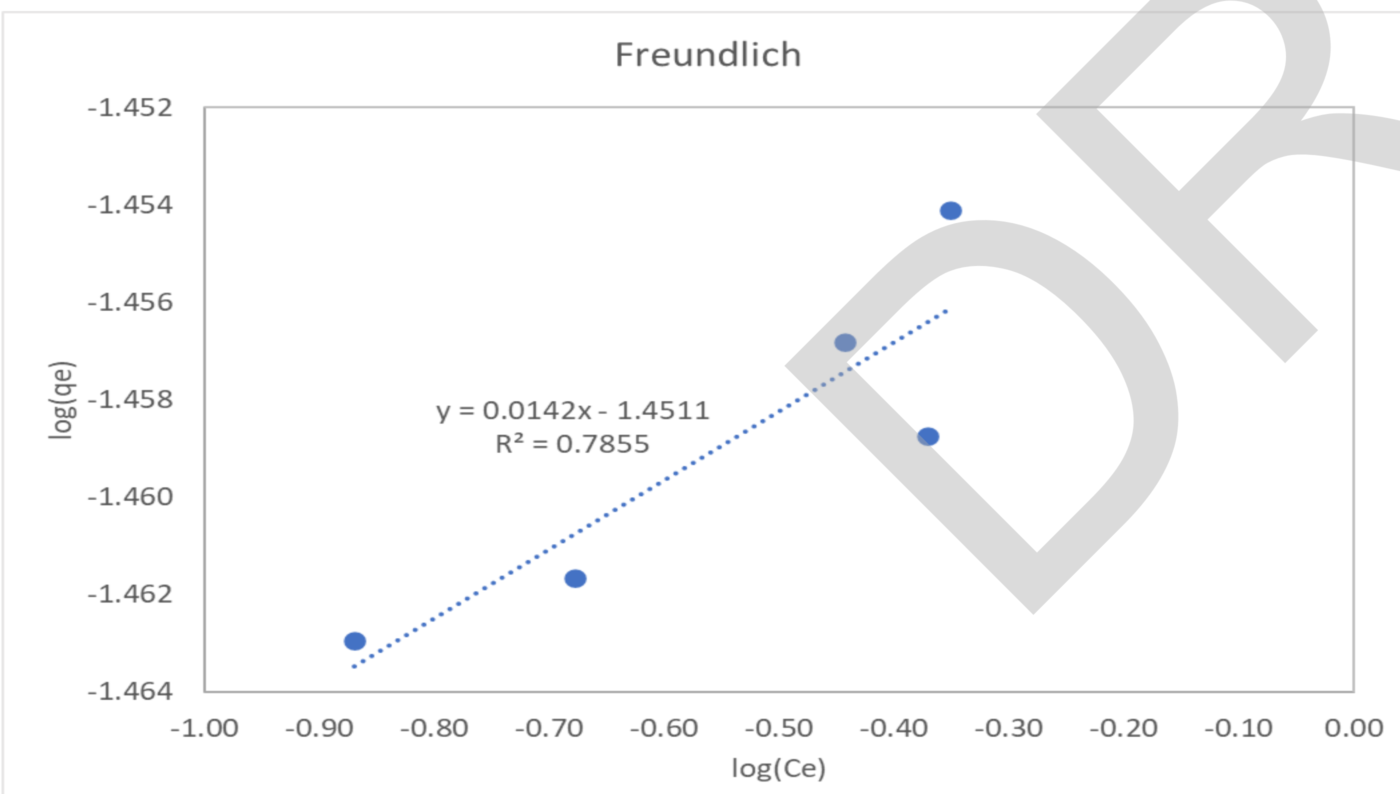

Note(s):
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TITLE
AW-15S LITHIUM PARTITION COEFFICIENTS

PROJECT NO.	PHASE	REV.	FIGURE
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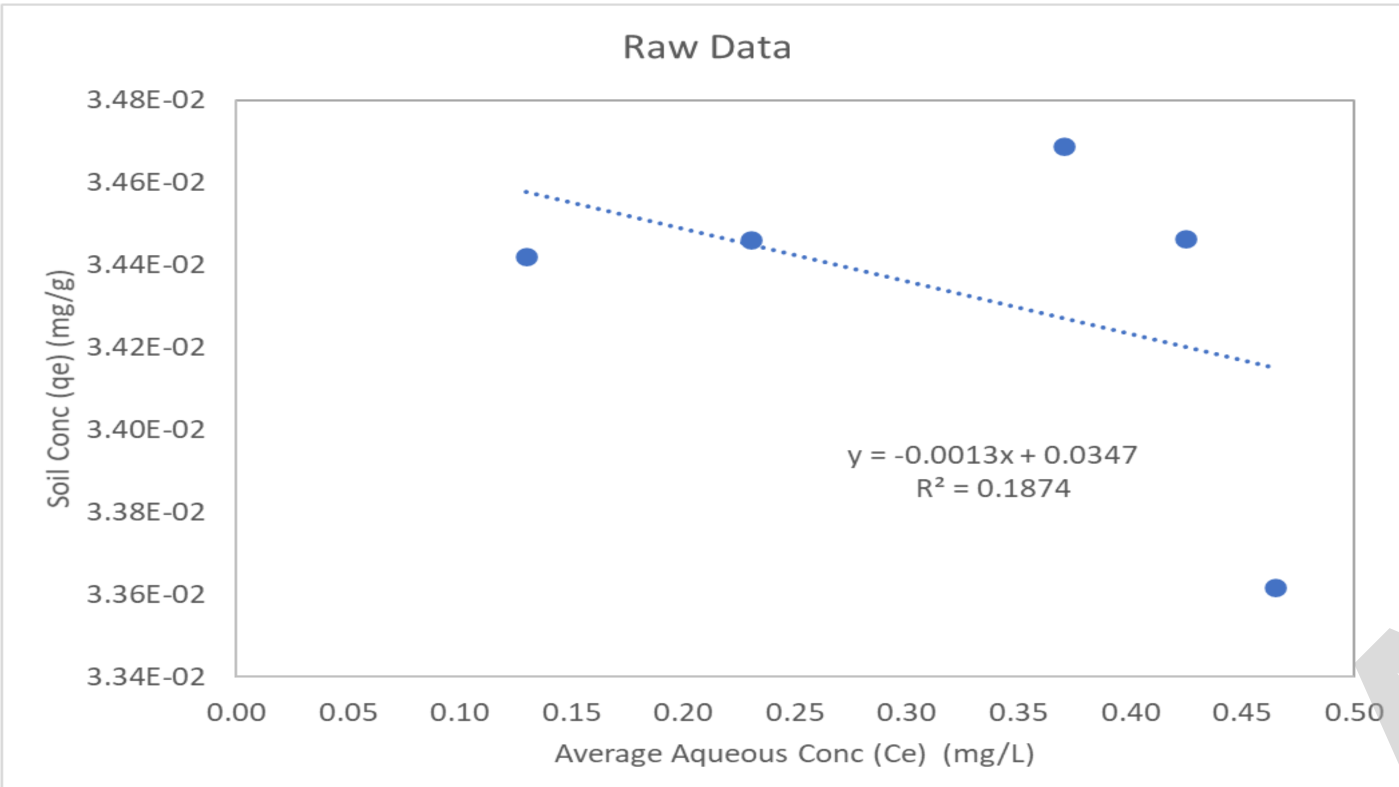

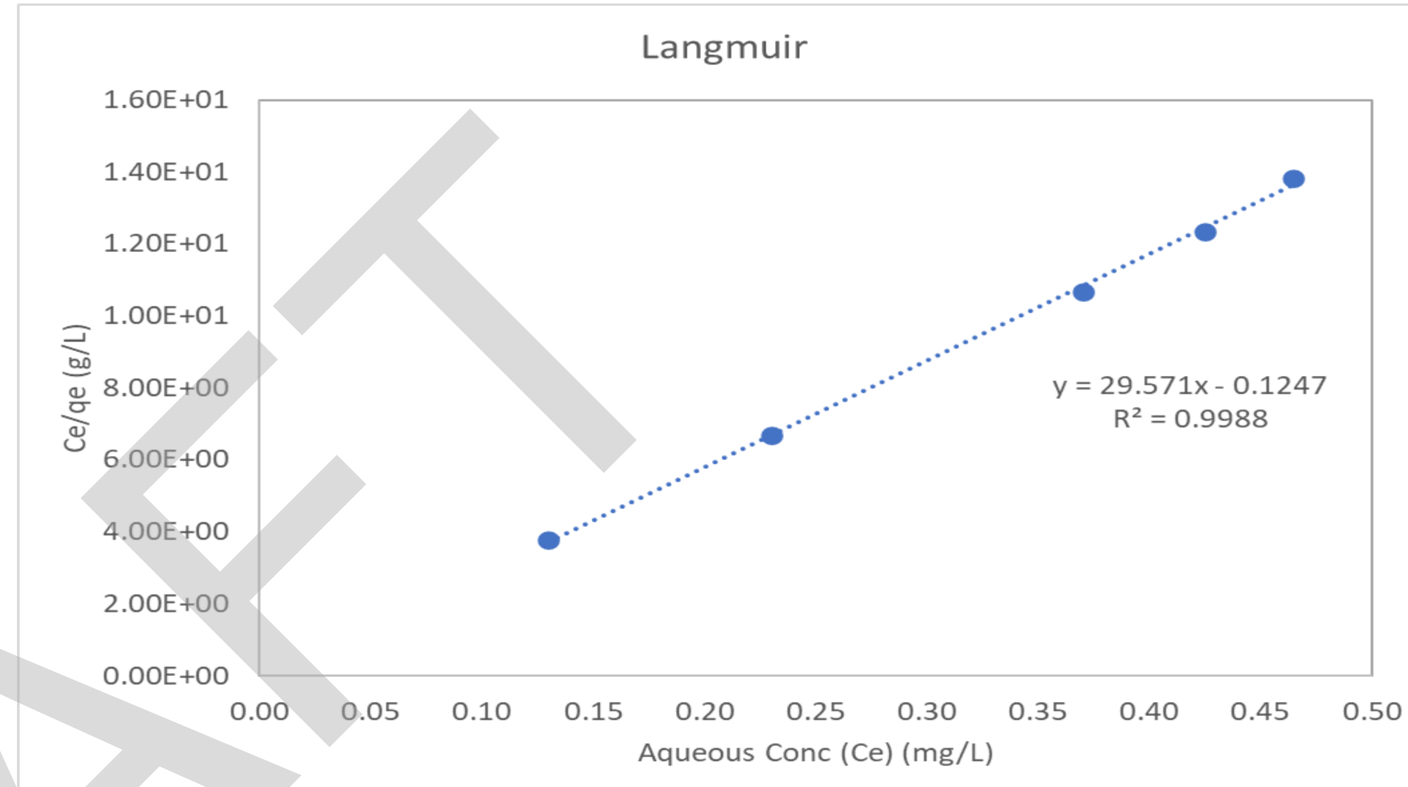

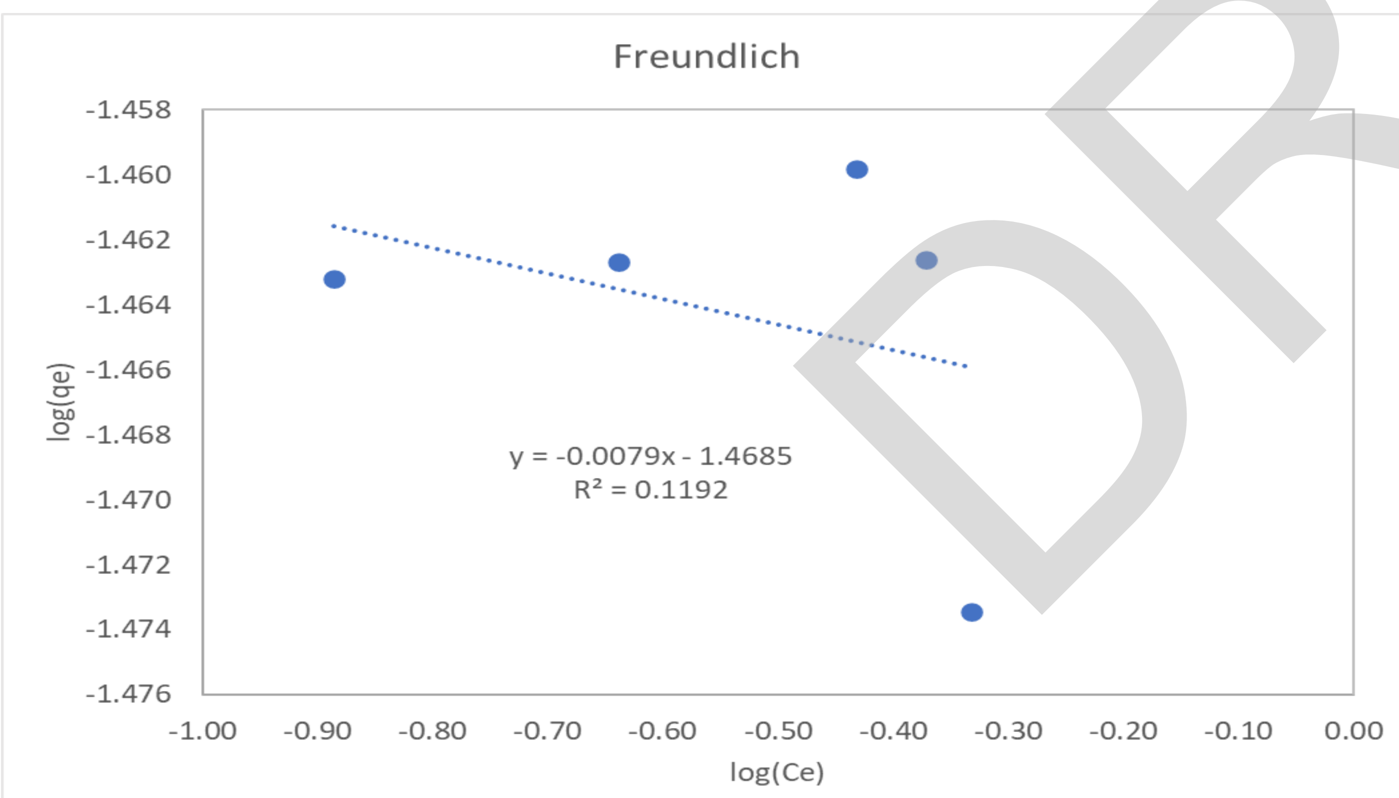

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Note(s):
mg/L: milligrams per liter
mg/g: milligrams per gram
g/L: grams per liter
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TITLE
AW-19 LITHIUM PARTITION COEFFICIENTS

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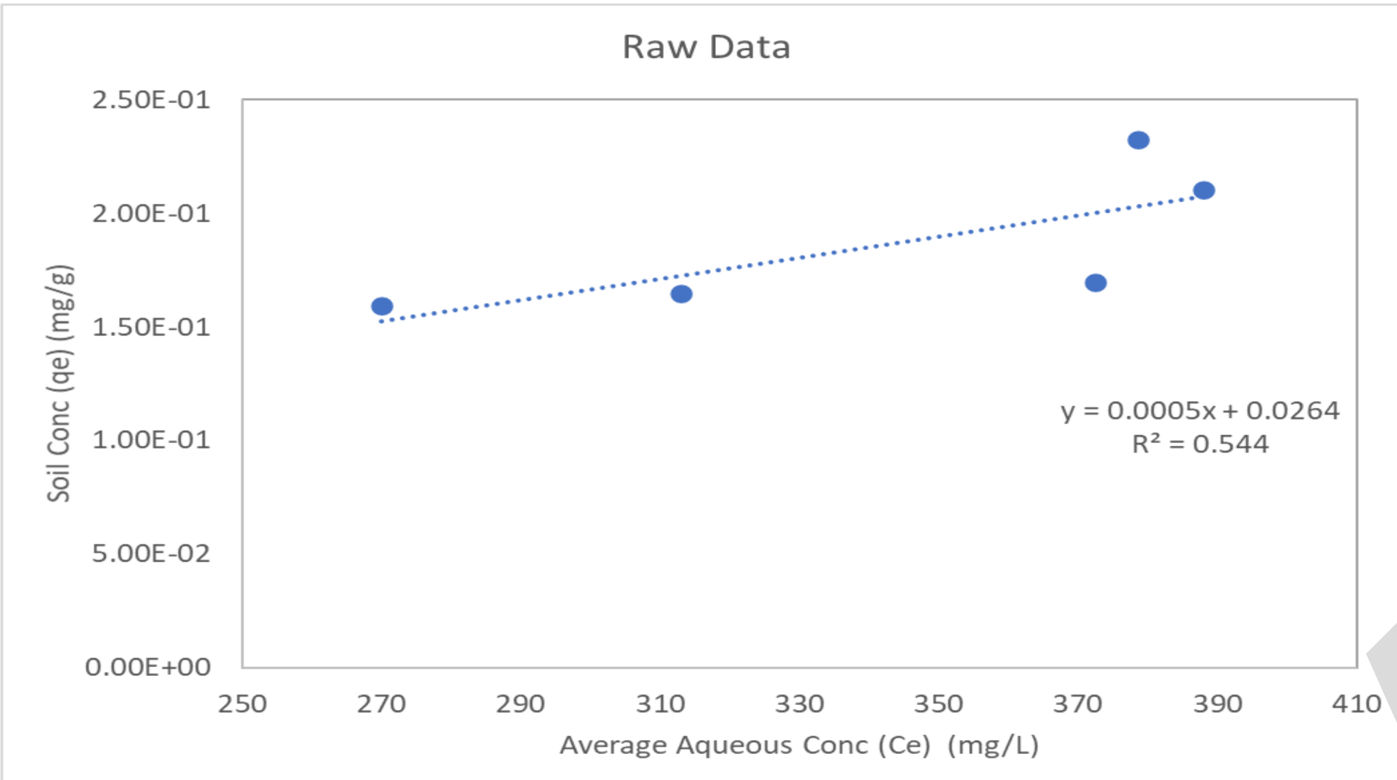

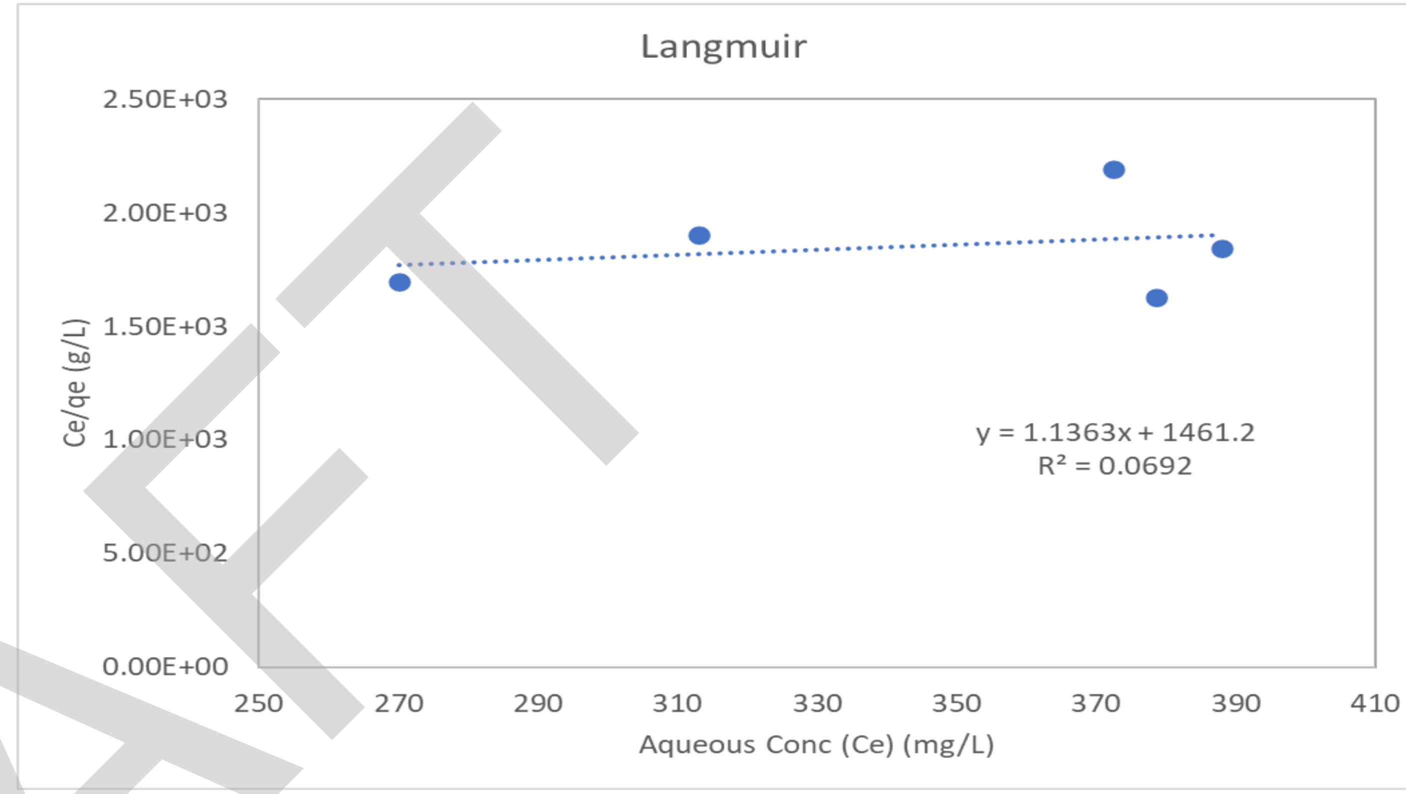

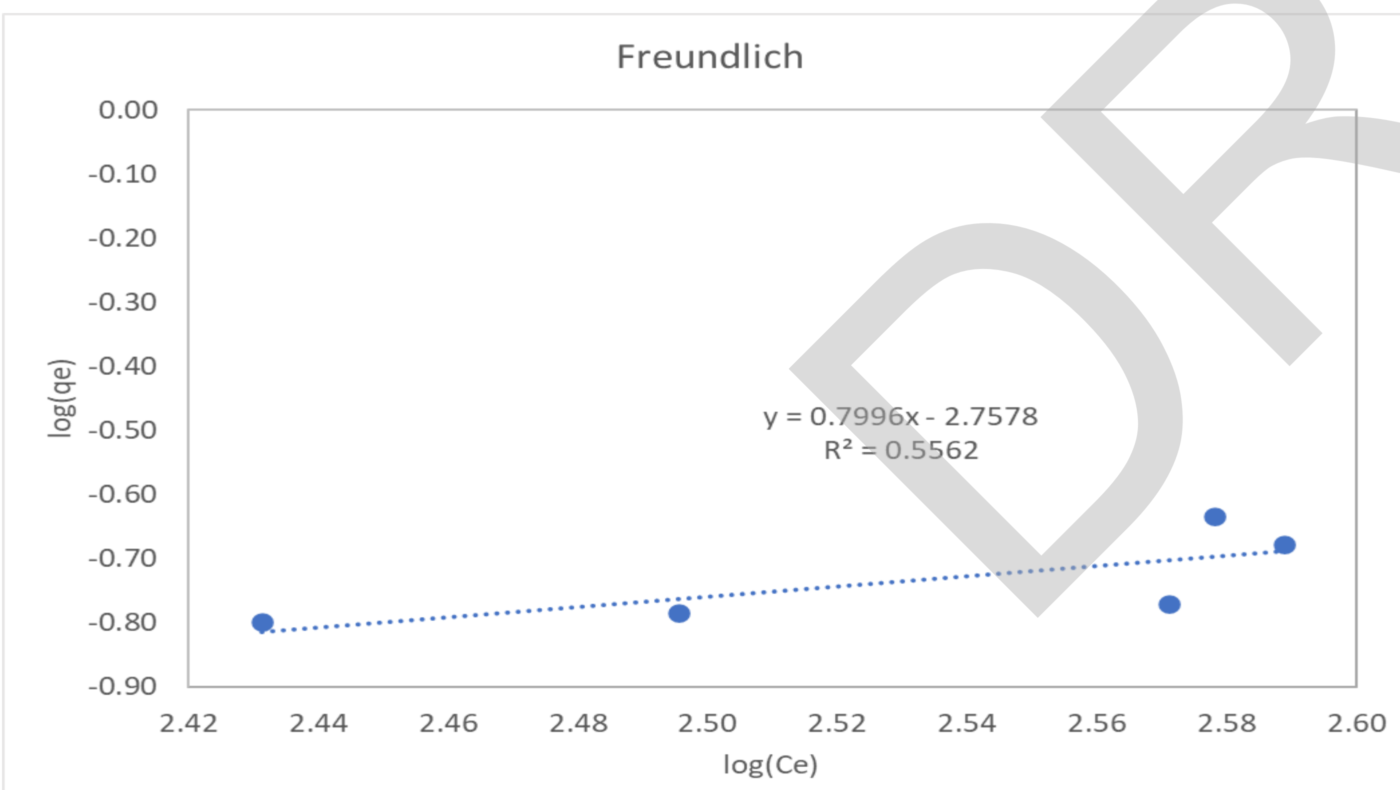

Note(s):
mg/L: milligrams per liter
mg/g: milligrams per gram
g/L: grams per liter
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EVALUATION OF PARTITION COEFFICIENT RESULTS EAP

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TITLE
AW-15S SULFATE PARTITION COEFFICIENTS

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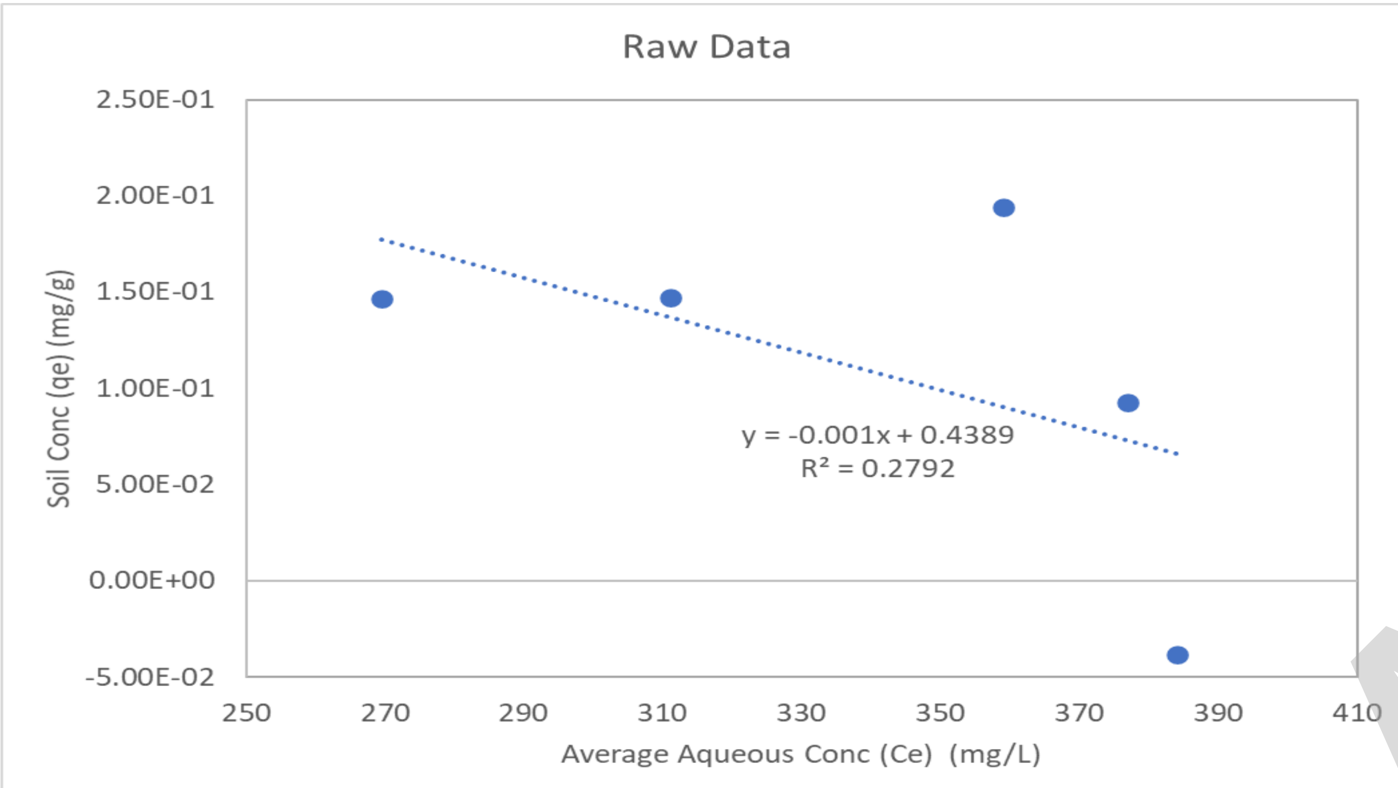
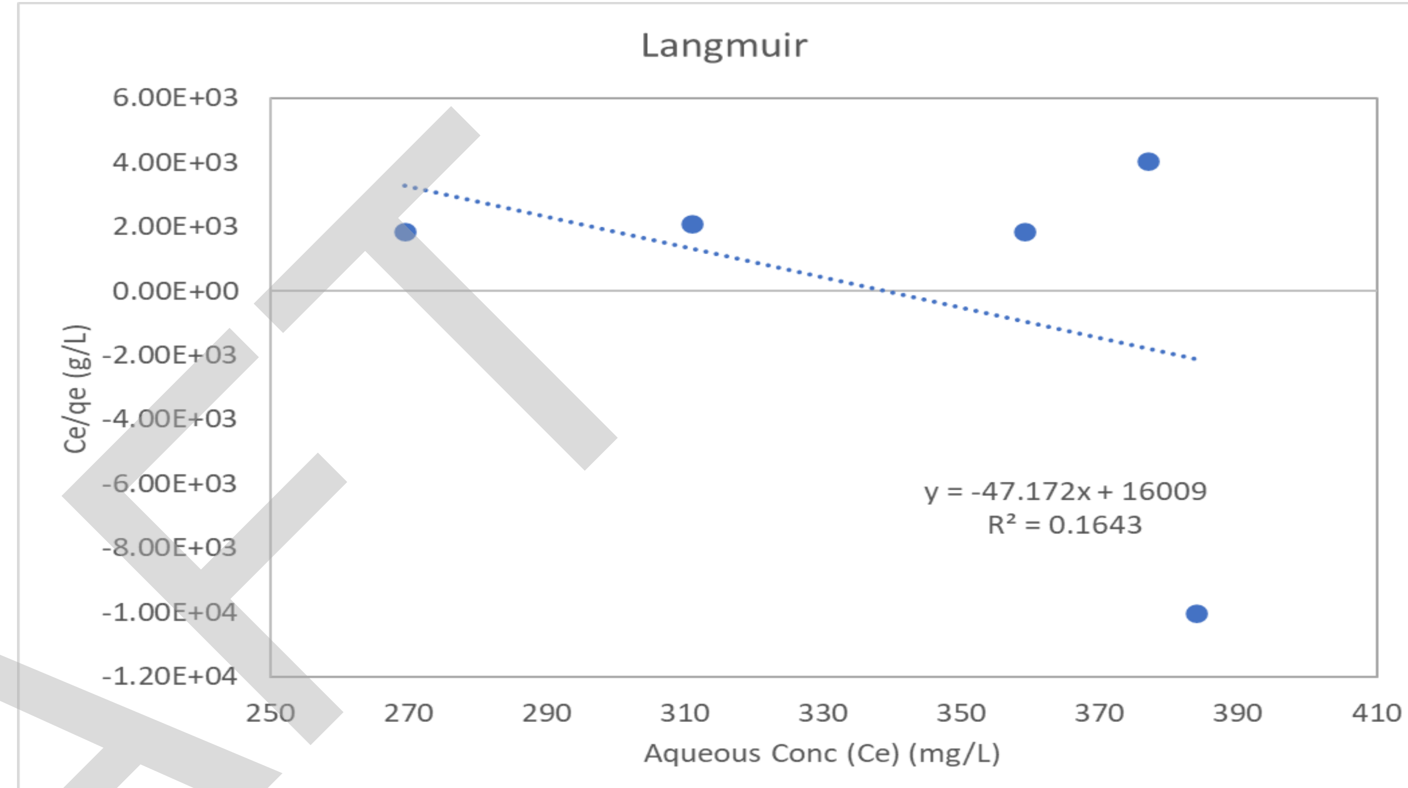
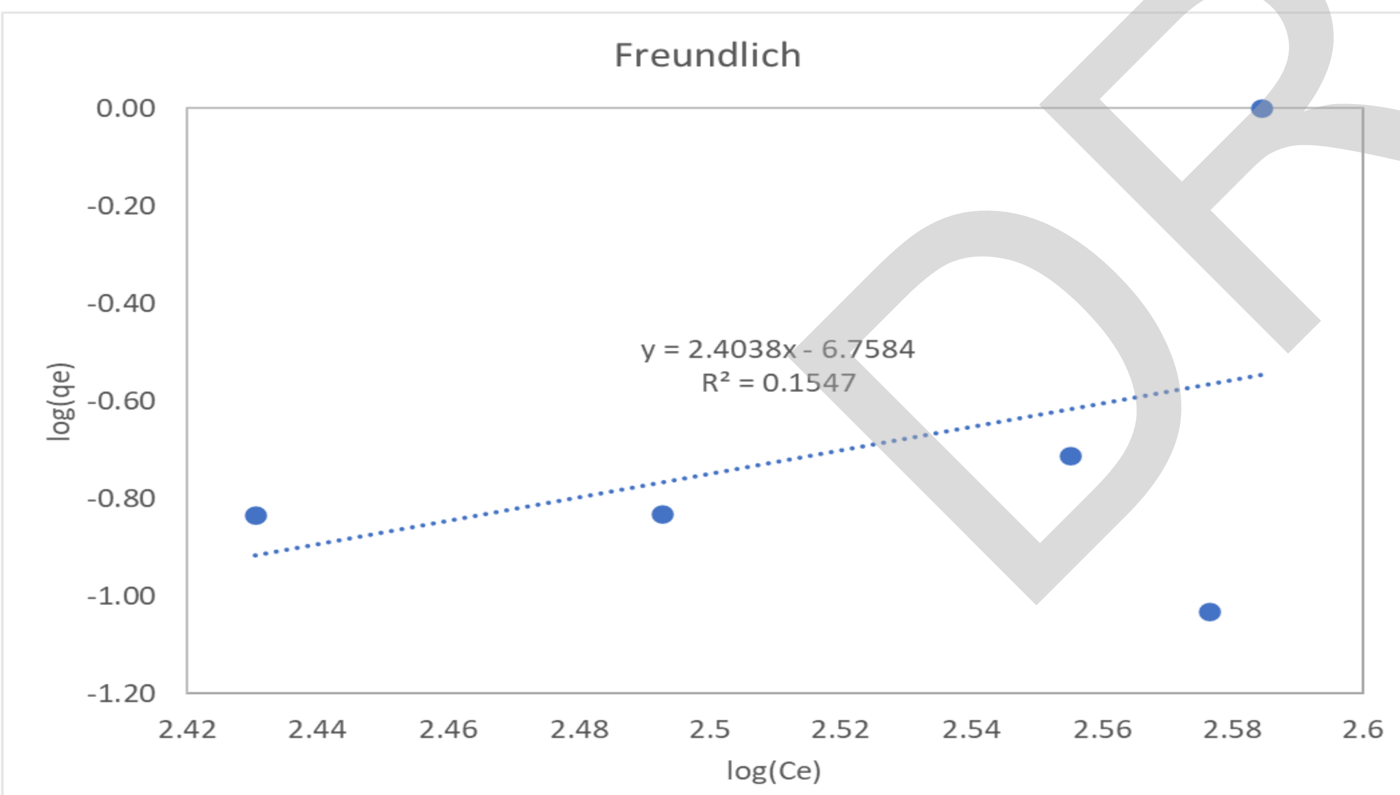
21454831	002	0	A-7







Note(s):
mg/L: milligrams per liter
mg/g: milligrams per gram
g/L: grams per liter
Ce: aqueous concentration of the adsorbate

CLIENT
ILLIONIS POWER RESOURCES GENERATING, LLC
EDWARDS ASH POND (CCR UNIT 301)

PROJECT
EVALUATION OF PARTITION COEFFICIENT RESULTS EAP

CONSULTANT
WSP GOLDER

TITLE
AW-19 SULFATE PARTITION COEFFICIENTS

PROJECT NO.	PHASE	REV.	FIGURE
21454831	002	0	A-8