Intended for
**Dynegy Midwest Generation, LLC**

Date
**November 5, 2021**

Project No.
**1940100722**

# GROUNDWATER MODELING REPORT

## VERMILION POWER PLANT NORTH ASH POND AND OLD EAST ASH POND

## VERMILION POWER PLANT
## OAKWOOD, ILLINOIS

**DRAFT**

# GROUNDWATER MODELING REPORT
# VERMILION POWER PLANT NORTH ASH POND AND OLD EAST ASH POND

| | |
|---|---|
| Project Name | **Vermilion Power Plant North Ash Pond and Old East Ash Pond** |
| Project No. | **1940100722** |
| Recipient | **Dynegy Midwest Generation, LLC** |
| Document Type | **Groundwater Modeling Report** |
| Revision | **DRAFT** |
| Date | **November 5, 2021** |

Ramboll
234 W. Florida Street
Fifth Floor
Milwaukee, WI 53204
USA

T 414-837-3607
F 414-837-3608
https://ramboll.com

**Jake J. Walczak, PG**
**Senior Hydrogeologist**

**Brian G. Hennings, PG**
**Senior Managing Hydrogeologist**

# CONTENTS

## TABLES (IN TEXT)



## TABLES (ATTACHED)



## FIGURES (IN TEXT)



## FIGURES (ATTACHED)

## APPENDICES

# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| § | Section |
| 35 I.A.C. | Title 35 of the Illinois Administrative Code |
| BCU | bedrock confining unit |
| CBR | closure by removal |
| CCR | coal combustion residuals |
| cm/s | centimeters per second |
| Company Lake | Illinois Power Company Lake |
| CSM | conceptual site model |
| DMG | Dynegy Midwest Generation, LLC |
| ft/day | feet/foot per day |
| GHB | general head boundary conditions |
| GMP | Groundwater Monitoring Plan |
| GMR | Groundwater Model Report |
| GWPS | Groundwater Protection Standard |
| HCR | Hydrogeologic Site Characterization Report |
| HELP | Hydrologic Evaluation of Landfill Performance |
| ID | identification |
| IDNR | Illinois Department of Natural Resources |
| IEPA | Illinois Environmental Protection Agency |
| Kd | soil adsorption coefficient |
| $K_d$ | linear partition coefficients |
| $K_{dF}$ | Frendlich partition coefficients |
| Kelron | Kelron Environmental |
| Kh/Kv | vertical anisotropy |
| L/kg | liters per kilogram |
| LGU | lower groundwater unit |
| mg/L | milligrams per liter |
| MGU | middle groundwater unit |
| Middle Fork | Middle Fork of the Vermilion River |
| mL/g | milliliters per gram |
| MNA | monitored natural attenuation |

| | |
|---|---|
| NAP | North Ash Pond |
| NAVD88 | North American Vertical Datum of 1988 |
| NEAP | New East Ash Pond |
| 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. |
| OEAP | Old East Ash Pond |
| 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 |
| Site | combined area including NAP and OEAP |
| SU | standard units |
| TDS | total dissolved solids |
| TVD | total-variation-diminishing |
| UCU | upper confining unit |
| USEPA | United States Environmental Protection Agency |
| USGS | United States Geological Survey |
| UU | upper unit |
| VPP | Former Vermilion Power Plant |

# EXECUTIVE SUMMARY

Ramboll Americas Engineering Solutions, Inc. (Ramboll) has prepared this Groundwater Model Report (GMR) on behalf of the former Vermilion Power Plant (VPP), operated by Dynegy Midwest Generation, LLC (DMG), 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 North Ash Pond (NAP; Vistra identification [ID] number [No.] 910, IEPA ID No. W1838000002-01) and the Old East Ash Pond (OEAP; Vistra ID No. 911, IEPA ID No. W1838000002-03).

The NAP and OEAP (collectively referred to as the Site) are on the VPP property which is located four miles northeast of the Village of Oakwood in Vermilion County (**Figure 1-1**). The VPP property is situated in a predominantly agricultural area. The NAP and OEAP coal combustion residuals (CCR) units, which are the subject of this GMR, are located adjacent to each other in the northern portion of the VPP. The NAP is bordered to the north by fallow fields owned by Illinois Department of Natural Resources (IDNR); to the east by the Middle Fork of the Vermilion River (Middle Fork); to the south by the OEAP; and to the west by steep bluffs that include the Illinois Department of Conservation designated Orchid Hill Natural Heritage Landmark, which is partially within the VPP property boundary but is administered by IDNR. The OEAP is bordered to the north and northeast by the Middle Fork; to the southeast, south, and west by steep bluffs; and to the northwest by the NAP. The NAP and OEAP are both located on terraces adjacent to the Middle Fork, which is bordered to the east and west by steep bluffs.

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

- Fill Unit: comprised predominantly of CCR (primarily fly ash, bottom ash, and boiler slag) within the NAP and OEAP and occurs within saturated materials.
- Upper Unit (UU): includes mixed alluvial deposits of clay, silt, sand, and minor gravel of the Cahokia Alluvium.
- Middle Groundwater Unit (MGU): is composed of alluvial sand and gravel that corresponds to the lower portion of the Cahokia Formation in the bottomlands of the river valley. This unit is not present outside of the river valley. This is the uppermost coarse-grained deposit beneath the NAP and OEAP, and is considered the uppermost aquifer.
- Upper Confining Unit (UCU): comprised of clay, silt, and minor amounts of sand lenses within the Upper Till. The low permeability deposits of the UCU lie directly above the lower groundwater unit (LGU), inhibiting the vertical movement of groundwater between the MGU and the LGU.
- Lower Groundwater Unit (LGU): the LGU is composed of sand, gravel, silt, and some clay described as glacial outwash and re-worked glacial deposits. This unit has been identified as a potential migration pathway (PMP) for groundwater.

- Lower Confining Unit: composed of clay, silt, and some sand, is the lowermost unlithified confining unit at the Site described as the Lower Till Unit. The base of this unit is the top of bedrock.
- Bedrock Confining Unit (BCU): the lowermost unit identified at the Site, and underlies all unlithified deposits. This unit occurs within Pennsylvanian shale bedrock, which is the uppermost lithified unit at the Site. As presented by Kelron Environmental (Kelron, 2003), groundwater in the shale flows into the overlying alluvium and enters directly into the Middle Fork in some locations. Groundwater within the bedrock is at the end of its flow path as indicated by upward hydraulic gradients, high dissolved mineral content, and isotopic analysis indicating water is significantly older by 13,000 to 35,000 radiocarbon years before present than recent groundwater in the overlying unlithified deposits.

The NAP and OEAP overlie the recharge area for the underlying transmissive geologic media, which are composed of coarse grained unlithified deposits (*i.e.*, alluvium [MGU], and glacial outwash and re-worked glacial deposits [LGU]). The groundwater from all units flows toward the Middle Fork which is the receiving body of water for the area.

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). Groundwater concentrations presented in HCR Table 4-1 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 groundwater monitoring plan (Ramboll, 2021c) and has not been reviewed or approved by IEPA at the time of this submittal. The following constituents with potential exceedances of the GWPS listed in 35 I.A.C. § 845.600 were identified: boron, lithium, molybdenum, sulfate, and total dissolved solids (TDS) (Ramboll, 2021b).

Statistically significant correlations between boron concentrations and concentrations of other parameters identified as potential exceedances of the GWPS indicate boron is an acceptable surrogate for lithium, molybdenum, sulfate, and TDS in the groundwater model. It was assumed that boron would not significantly sorb or chemically react with aquifer solids (soil adsorption coefficient [Kd] was set to 0 milliliters per gram [mL/g]) which is a conservative estimate for predicting contaminant transport times. Site-specific partition coefficients were calculated as part of a study to evaluate whether monitored natural attenuation (MNA) is a feasible groundwater remedial alternative for the VPP (Geosyntec Consultants, Inc. [Geosyntec], 2021a) following completion of closure construction (*i.e.*, CCR removal). The anticipated effects on constituent behavior compared to the groundwater fate and transport model indicate the fate and transport model likely over-predicts the time to reach the GWPS for lithium and molybdenum.

Data collected from the 2021 field investigations were used to update the existing groundwater model which was initially developed in 2012 (Natural Resource Technology, Inc. [NRT], 2012a; NRT, 2012b), and later updated in 2014 (NRT, 2014a; NRT, 2014b). The updated MODFLOW and MT3DMS models were then used to evaluate three closure by removal (CBR) scenarios, including CBR utilizing either an onsite (CBR-Onsite) or offsite (CBR-Offsite) landfill, using information provided in the Draft CCR Final Closure Plan (Geosyntec, 2021b):

- Scenario 1: CBR-Onsite (groundwater collection trench [trench] removed at completion of CCR removal)
- Scenario 2: CBR-Onsite (trench remains after CCR is removed)
- Scenario 3: CBR-Offsite (trench remains after CCR is removed)

Predictive simulations of source control indicate groundwater in the primary transport zone (the MGU) will achieve the GWPS for Scenarios 1, 2, and 3 in 50, 47, and 43 years after implementation of the closure scenarios, respectively. From a modeling perspective, the difference between the predicted time to reach the GWPS for boron (2 milligrams per liter [mg/L]) in the MGU in Scenario 1 (50 years) versus Scenario 2 (47 years) is negligible. In other words, both scenarios are predicted to reach the GWPS after approximately 50 years, the simulated three-year difference between these two scenarios is not significant. These results also indicate there is no significant benefit in the modeled time to reach the GWPS for continued operation and maintenance of the groundwater collection trench beyond the completion of the removal.

Groundwater in the PMP (LGU) is predicted to achieve the GWPS for Scenarios 1, 2, and 3 in 112, 116, and 109 years after implementation of the closure scenarios, respectively. The longer response times simulated for the LGU are expected based on the conceptual site model (CSM). Because groundwater has a longer flow path and passes through low permeability deposits of the UCU before it reaches the LGU, it is expected that the concentrations in the LGU will take longer to respond to source control measures than wells in the MGU. From a modeling perspective, the differences among the predicted times to reach the GWPS for boron (2 mg/L) in the LGU for Scenarios 1, 2, and 3 in 112, 116, and 109 years after implementation of the closure scenarios, respectively, is negligible. All three scenarios are predicted to reach the GWPS after approximately 110 years; the simulated seven-year difference among these three scenarios after 100 years is not significant.

The predicted reductions in mass flux to the river cells (representing the Middle Fork) following source control for Scenarios 1, 2, and 3 indicate for all three scenarios that mass flux is predicted to be reduced by 50 percent approximately 10 years after implementation, by 80 percent within approximately 35 years after implementation, and by 95 percent within approximately 130 years after implementation.

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 the primary migration pathway (the MGU) within 50 years of closure implementation for all three Scenarios. The LGU, which has much lower boron concentrations (less mass), is estimated to take approximately 110 years to reach the GWPS due to the longer flow paths through low permeability deposits of the UCU before it reaches the LGU and ultimately the Middle Fork. Results of the groundwater fate and transport modeling also indicate that the flux of these constituents to the Middle Fork will reduce by 80 percent within 35 years of closure implementation for all three Scenarios. The anticipated effects of MNA on constituent behavior compared to the groundwater fate and transport model indicate the fate and transport model likely over-predicts the time to reach the GWPS for lithium and molybdenum.

# 1. INTRODUCTION

## 1.1 Overview

In accordance with requirements of Part 845 (IEPA, 2021), Ramboll has prepared this GMR on behalf of VPP, operated by DMG. This report will apply specifically to the CCR Units referred to as the NAP and OEAP (**Figure 1-1**). However, information gathered to evaluate other CCR units at the VPP regarding geology, hydrogeology, and groundwater quality is included, where appropriate. The 41-acre NAP is an expansion of the 21.3-acre OEAP. The southern end of the NAP overlies the northern end of the OEAP. Both are inactive, unlined CCR surface impoundments (SIs) that were used to manage CCR and non-CCR waste streams and to clarify process water prior to discharge in accordance with the plant's National Pollutant Discharge Elimination System (NPDES) permit (IL0004057) at the VPP. This GMR presents and evaluates the results of predictive groundwater modeling simulations for three proposed CBR closure scenarios, including CBR utilizing either an onsite (CBR-Onsite) or offsite (CBR-Offsite) landfill for the NAP and OEAP:

- Scenario 1: CBR-Onsite (trench removed at completion of CCR removal)
- Scenario 2: CBR-Onsite (trench remains after CCR is removed), and
- Scenario 3: CBR-Offsite (trench remains after CCR is removed).

## 1.2 Previous Groundwater Modeling Reports

The information presented in this GMR expands upon previous groundwater modeling completed at VPP and includes data collected in support of the previous groundwater models as well as data collected as part of 2021 field investigations to support development of a HCR (Ramboll, 2021a). The HCR was provided as an attachment to the Initial Operating Permit application required by 35 I.A.C. § 845.230. Previous groundwater modeling reports completed for the NAP and OEAP located at the VPP include the following (recent to oldest):

- ***NRT, 2014, Corrective Action Plan, North Ash Pond System, Vermilion Power Station, Oakwood, Illinois, Dynegy Midwest Generation, LLC, April 2, 2014.***

  A revised Corrective Action Plan (originally issued on March 27, 2012) that describes the physical setting of the NAP at the VPP and proposed actions necessary to close this facility consistent with 35 I.A.C. § 840, including a calibrated groundwater fate and transport model used to test the corrective action alternatives. The Corrective Action Plan was revised in response to the geotechnical study conducted by URS Corporation, "Geotechnical Report, North Ash Pond and Old East Ash Pond, Vermilion Site Embankment Evaluations, Oakwood, Illinois", dated November 18, 2013. This version, dated April 2, 2014, supersedes the version from March 2012.

- ***NRT, 2014, Corrective Action Plan, Old East Ash Pond, Vermilion Power Station, Oakwood, Illinois, Dynegy Midwest Generation, LLC, April 2, 2014.***

  A revised Corrective Action Plan (originally issued on March 27, 2012) that describes the physical setting of the OEAP at the VPP and proposed actions necessary to close this facility consistent with 35 I.A.C. § 840, including a calibrated groundwater fate and transport model used to test the corrective action alternatives. The Corrective Action Plan was revised in response to the geotechnical study conducted by URS Corporation, "Geotechnical Report, North Ash Pond and Old East Ash Pond, Vermilion Site Embankment Evaluations, Oakwood, Illinois", dated November 18, 2013. This version, dated April 2, 2014, supersedes the version from March 2012.

- ***NRT, 2012, Corrective Action Plan, North Ash Pond System, Vermilion Power Station, Oakwood, Illinois, Dynegy Midwest Generation, LLC, March 27, 2012.***

  A Corrective Action Plan that describes the physical setting of the NAP at the VPP and proposed actions necessary to close this facility consistent with 35 I.A.C. § 840, including a calibrated groundwater fate and transport model used to test the corrective action alternatives.

- ***NRT, 2012, Corrective Action Plan, Old East Ash Pond, Vermilion Power Station, Oakwood, Illinois, Dynegy Midwest Generation, LLC, March 27, 2012.***
  A Corrective Action Plan that describes the physical setting of the OEAP at the VPP and proposed actions necessary to close this facility consistent with 35 I.A.C. § 840, including a calibrated groundwater fate and transport model used to test the corrective action alternatives.

## 1.3 Site Location and Background

The VPP is located in east central Illinois in Vermilion County, approximately five miles northeast of the Village of Oakwood, located within Section 20, Township 20 North, Range 12 West (**Figure 1-1**). The VPP is an approximately 982-acre property consisting of 19 parcels, including a retired coal-fired power plant and SIs. The VPP ceased operations in 2011 when the power plant was retired.

The NAP and OEAP CCR Units, which are the subject of this GMR, are located adjacent to each other in the northern portion of the VPP. The NAP is bordered to the north by fallow fields owned by IDNR; to the east by the Middle Fork; to the south by the OEAP; and to the west by steep bluffs that include the Illinois Department of Conservation designated Orchid Hill Natural Heritage Landmark, which is partially within the VPP property boundary but is administered by IDNR. The OEAP is bordered to the north and northeast by the Middle Fork; to the southeast, south, and west by steep bluffs; and to the northwest by the NAP. The NAP and OEAP are both located on terraces adjacent to the Middle Fork, which is bordered to the east and west by steep bluffs.

**Figure 1-2** depicts the location of the inactive NAP and OEAP. The combined area including the NAP and OEAP will hereinafter be referred to as the Site.

## 1.4 Site History and CCR Units

All ash ponds at the VPP are out of service. Until the coal pile was substantially removed in March 2011, the NAP received inflows from coal-pile runoff. The NPDES-permitted outfalls to the Middle Fork are still in effect; however, the only flows from the NAP and OEAP are during significant periods of precipitation with controlled releases via Outfall 001, usually occurring once or twice a year.

The 41-acre NAP is an expansion of the 21.3-acre OEAP. The southern end of the NAP overlies the northern end of the OEAP. The OEAP was built as part of the original plant construction and put into service in the mid-1950's. The OEAP continued in operation until the NAP was constructed and put on-line in the mid-1970's. The NAP was utilized for sluiced coal ash disposal from the mid-1970's to approximately 1989/1990, at which time all ash disposal was diverted to the New

East Ash Pond (NEAP; Vistra ID No. 912, IEPA ID No. W1838000002-04, National Inventory of Dams [NID] No. IL50291). The NEAP was expanded in 2002.

The NAP was originally designed and operated for coal ash sedimentation and control. The pond received plant process wastewater, sluiced coal ash, and stormwater runoff from the pond embankments. Treated process wastewater was discharged through an overflow outlet structure. The approximate dates of construction of VPP CCR Units, are summarized in **Table A** below.

**Table A. History of Construction and Operation**

| Date | Event |
|---|---|
| mid-1950's | Construction of OEAP |
| mid-1970's | Construction of NAP; CCR disposal to OEAP ceased |
| 1989-1990 | Construction of original East Ash Pond (1989 pond footprint), CCR disposal at NAP ceased |
| 2002 | Embankment raised to expand the capacity of the East Ash Pond (1989 pond footprint) in 2002, forming the footprint of the present-day NEAP |
| 2011 | CCR disposal to NEAP ceased |

# 2. SITE GEOLOGY AND HYDROGEOLOGY

NAP and OEAP hydrogeologic and groundwater quality data was presented in the HCR (Ramboll, 2021a) and used to establish a CSM for this GMR, and is summarized below.

The six principal types of unlithified materials overlying bedrock present at the VPP consist of the following in descending order:

- **Fill and CCR:** (identified as Layer 1 [Kelron, 2012a; Kelron, 2012b]) CCR consisting primarily of fly ash with lesser amounts of bottom ash and slag. This layer also includes the constructed fill berms around the ash ponds, which contain variable compositions of CCR and re-worked native silt and clay.
- **Mixed deposits of the Cahokia Alluvium:** including silt deposits (identified as Layer 2a [Kelron, 2012a; Kelron, 2012b]), sand and gravel deposits with some intermittent silt (identified as Layer 2b [Kelron, 2012a; Kelron, 2012b]), and clay and silty clay (identified as Layer 3 [Kelron, 2012a; Kelron, 2012b]).
- **Alluvial sand and gravel with some silt:** composed of alluvial sand and gravel that corresponds to the lower portion of the Cahokia Formation in the bottomlands of the river valley (identified as Layer 4 [Kelron, 2012a; Kelron, 2012b]).
- **Upper Till Unit:** Wedron Formation till, including diamicton, consisting of clay and silty clay with occasional sand lenses (identified as Layer 5 and Layer 7, respectively [Kelron, 2012a; Kelron, 2012b]).
- **Glacial outwash and re-worked glacial deposits:** with sand, silty sand, and clayey sand predominating (identified as Layer 6 [Kelron, 2012a; Kelron, 2012b]).
- **Lower Till Unit:** Glasford Formation till, consisting of primarily clay, silty clay, and sandy clay with occasional sand lenses (identified as Layer 8 [Kelron, 2012a; Kelron, 2012b]).

Prior to 2021, there were 11 monitoring wells around the NAP and 7 monitoring wells around the OEAP for monitoring groundwater. Nine additional monitoring wells (36 through 44, and 07R) were installed in 2021 around the perimeter of the NAP and OEAP to meet the requirements of Part 845 and 10 monitoring wells (101 through 105, and 101S through 105S) were completed in the upland areas south and west of the NAP and OEAP to characterize upland hydrogeologic conditions. Construction details for monitoring wells and piezometers are provided in **Table 2-1** and depicted in **Figure 2-1**. Boring logs, monitoring well and piezometer construction forms are provided in Appendix B of the HCR.

Seven distinct water-bearing units have been identified in the vicinity of the NAP and OEAP based on stratigraphic relationships and common hydrogeologic characteristics. The units are described as follows:

- **Fill Unit** (identified as Unit 0 [Kelron, 2012a; Kelron, 2012b]): comprised predominantly of CCR (primarily fly ash, bottom ash, and boiler slag) within the NAP and OEAP and occurs within saturated materials. Fill materials are present at elevations ranging from 651 to 571 feet North American Vertical Datum of 1988 (NAVD88). The base of this unit is the base of ash within the NAP and OEAP presented on Figure 2-8 in the HCR (Ramboll, 2021a). Water levels (the phreatic surface) measured in piezometer ND3 within the fill unit indicate the phreatic surface is greater than the elevation of the water levels in the underlying MGU (**Figure 2-2; Table 2-2**).

- **UU** (identified as Unit 1 [Kelron, 2012a; Kelron, 2012b]): includes mixed alluvial deposits of clay, silt, sand, and minor gravel of the Cahokia Alluvium. This unit is composed of primarily fine grained unlithified natural geologic materials of the Cahokia Alluvium that occur at elevations ranging from 595 to 571 feet National Geodetic Vertical Datum of 1929 (NGVD29). The UU is the uppermost native material present in the bottomlands within the river valley. This unit may be covered by the fill material of the NAP and OEAP and may be very thin or absent beneath portions of the NAP (Kelron, 2012a; Kelron, 2012b). There is only one monitoring well installed within the UU (MW-06R) located north of the NAP.
- **MGU** (identified as Unit 2 [Kelron, 2012a; Kelron, 2012b]): the MGU is composed of alluvial sand and gravel that corresponds to the lower portion of the Cahokia Formation in the bottomlands of the river valley. This unit is not present outside of the river valley. These alluvial deposits lie unconformably on top of the underlying glacial till and terminate laterally along the western bluffs of the river valley where the deposits rest unconformably against the till that comprises the uplands. This moderate permeability layer has a thickness ranging from 5 to 26 feet, with a median thickness of 9.8 feet, is the uppermost coarse-grained deposit beneath the NAP and OEAP, and is considered the uppermost aquifer.
- **UCU** (identified as Upland Confining Unit [Unit 5a] and Middle Confining Unit [Unit 3] [Kelron, 2012a; Kelron, 2012b]): comprised of clay, silt, and minor amounts of sand lenses within the Upper Till Unit. The low permeability deposits of the UCU lie directly above the LGU, inhibiting the vertical movement of groundwater between the MGU and the LGU (Kelron, 2012a; Kelron, 2012b). Wells 101S, 102S, 103S, 104S, and 105S are screened within discontinuous sand lenses observed in the upland area west of the NAP and OEAP. These sand lenses are present at elevations above the pre-construction ground surface in the NAP and OEAP. These wells went dry during development and 103S did not contain enough water to sample, indicating that the lateral continuity and extent of these sand lenses is limited. Well 44, located west of the NAP along the bluff, is also screened within a discontinuous sand lens of the UCU below the preconstructed ground surface for the NAP and OEAP above the LGU.
- **LGU** (identified as Units 4 and 5b [Kelron, 2012a; Kelron, 2012b]): the LGU is composed of sand, gravel, silt, and some clay described as glacial outwash and re-worked glacial deposits. Soil borings and monitoring wells 101 through 105, completed in 2021, confirmed the presence of a laterally continuous sand unit between the elevations of 553 and 560 feet NAVD88 in the upland that is in connection with the LGU in the river valley. Although overlain and underlain by confining units, the LGU is in lateral connection across the Site at upgradient locations (01, 21, 42, 43, 101, 102, 103, 104, and 105) along the southwest side of the Middle Fork Valley and in downgradient wells (02, 03R, 34, and 37). The thickness of the LGU ranges from 2 to 18 feet in the bottomlands, with average and median thicknesses of approximately 10 feet. The uppermost elevation of the top of this unit is 565 feet NGVD29 (observed in the upland areas) and the lowermost base elevation is 536 feet NGVD29 (observed in the bottomlands). Thirteen monitoring wells are screened within the LGU (**Table 2-1**).
- **Lower Confining Unit** (identified as Unit 6 [Kelron, 2012a; Kelron, 2012b]): composed of clay, silt, and some sand, is the lowermost unlithified confining unit at the Site described as the Lower Till Unit. It extends across the upland and bottomland areas, except at locations

where it is missing due to non-deposition or erosion. At locations where this unit is missing, the lower confining unit is the shale bedrock. It ranges in thickness from zero (not present) to greater than 16 feet and has average and median thicknesses of greater than 8 and greater than 5 feet, respectively, since most borings stopped short of its base. The highest elevation at which this unit was intercepted by borings at the Site was 562 feet NGVD29 and the lowest elevation was 520 feet NGVD29. The base of this unit is the top of bedrock.

- **BCU** (identified as Unit 7 [Kelron, 2012a; Kelron, 2012b]): the lowermost unit identified at the Site, and underlies all unlithified deposits. This unit occurs within Pennsylvanian shale bedrock, which is the uppermost lithified unit at the Site. As presented by Kelron (2003), groundwater in the shale flows into the overlying alluvium and enters directly into the Middle Fork in some locations. Groundwater within the bedrock is at the end of its flow path as indicated by upward hydraulic gradients, high dissolved mineral content, and isotopic analysis indicating water is significantly older by 13,000 to 35,000 radiocarbon years before present than recent groundwater in the overlying unlithified deposits.

Groundwater flow direction (**Figure 2-2 and Figure 2-3**) and gradients have not changed significantly since the first hydrogeologic study of the NAP/OEAP was completed in 1983, and recent data supports the existing CSM which has been refined to incorporate additional data as follows:

- The NAP/OEAP overlies the UU in most areas of the Site, with the exception of the northern portion and western boundary of the NAP, where the UU is absent.
- Groundwater migrates within high permeability sands and gravels of the MGU and LGU that flow to the east under normal river conditions. There is the potential for short duration and temporary flow direction reversal during periods of high river stage.
- Groundwater flows into the Middle Fork through the MGU and LGU, which are the primary pathways that contaminant migration could occur. Upward gradients measured in the underlying shale bedrock indicate that the Middle Fork is a regional discharge area (HCR, Ramboll, 2021a).
- Vertical gradients measured between the bedrock, LGU, and MGU are generally upward near the Middle Fork, indicating that it is a regional discharge area (HCR, Ramboll, 2021a).

# 3. GROUNDWATER QUALITY

The classification of groundwater at NAP and OEAP has been evaluated and based on the detailed geologic information provided in the 2012 hydrogeologic investigations (Kelron, 2012a; Kelron, 2012b) for the MGU (*i.e.*, uppermost aquifer), the NAP and OEAP can be classified as Class I - Potable Resource Groundwater. The MGU is comprised of predominantly sand and gravel with some silt and is the primary groundwater transport pathway. Based on the 2012 hydrogeologic investigations, the thickness of the MGU ranges from 5 to 26 feet, with an average thickness of 10.1 feet (Kelron, 2012a; Kelron, 2012b). Field hydraulic conductivity tests performed on the MGU indicate a geometric mean hydraulic conductivity of 2.1 x $10^{-3}$ centimeters per second (cm/s) (Kelron, 2012a; Kelron, 2012b). Sands and gravels with thicknesses greater than 5 feet or with a hydraulic conductivity of greater than 1 x $10^{-4}$ cm/s meets the provisions of Class I - Potable Resource Groundwater (35 I.A.C. § 620.210).

Groundwater quality investigations were completed intermittently at the NAP and OEAP from 1983 to 2018. In 2021, additional wells were installed to comply with Part 845 requirements, specifically to reduce the lateral spacing between monitoring points and to further characterize the upland bluff and PMPs. Wells were sampled for the parameters listed in 35 I.A.C. § 845.600. 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:

- Boron – determined at wells 01, 03R, 04, 05, 07R, 08R, 17, 36, 40, 41 and 104.
- Lithium – determined at wells 04, 05, 07R, 08R, 36, and 40.
- Molybdenum – determined at wells 03R, 07R, and 08R.
- pH – determined at well 40 as an exceedance of the lower limit. Porewater sample results provided in Table 2-3 of the HCR indicate the minimum pH reading from samples collected from the NAP (location ND3) and the OEAP (location OED1) was 7.9 standard units (SU); therefore, the low pH (less than 6.5 SU) determined in the history of potential exceedances is not attributable to either the NAP or OEAP. No further discussion of pH is provided in this GMR.

- Sulfate – determined at wells 01, 03R, 07R, 17, 36, and 40.
- TDS – determined at wells 01, 07R, 17, 36, and 40.

# 4. GROUNDWATER MODEL

## 4.1 Overview

Data collected at the Site from the 2021 field investigation were used to update the existing groundwater model which was initially developed in 2012 (NRT, 2012a; NRT, 2012b), and later updated in 2014 (NRT, 2014a; NRT, 2014b). The updated model was then used to evaluate CBR closure scenarios, including CBR utilizing either an onsite (CBR-Onsite) or offsite (CBR-Offsite) landfill. The results of the CBR closure scenarios are summarized and evaluated in this GMR. Associated model files are included as **Appendix A.**

## 4.2 Conceptual Site Model

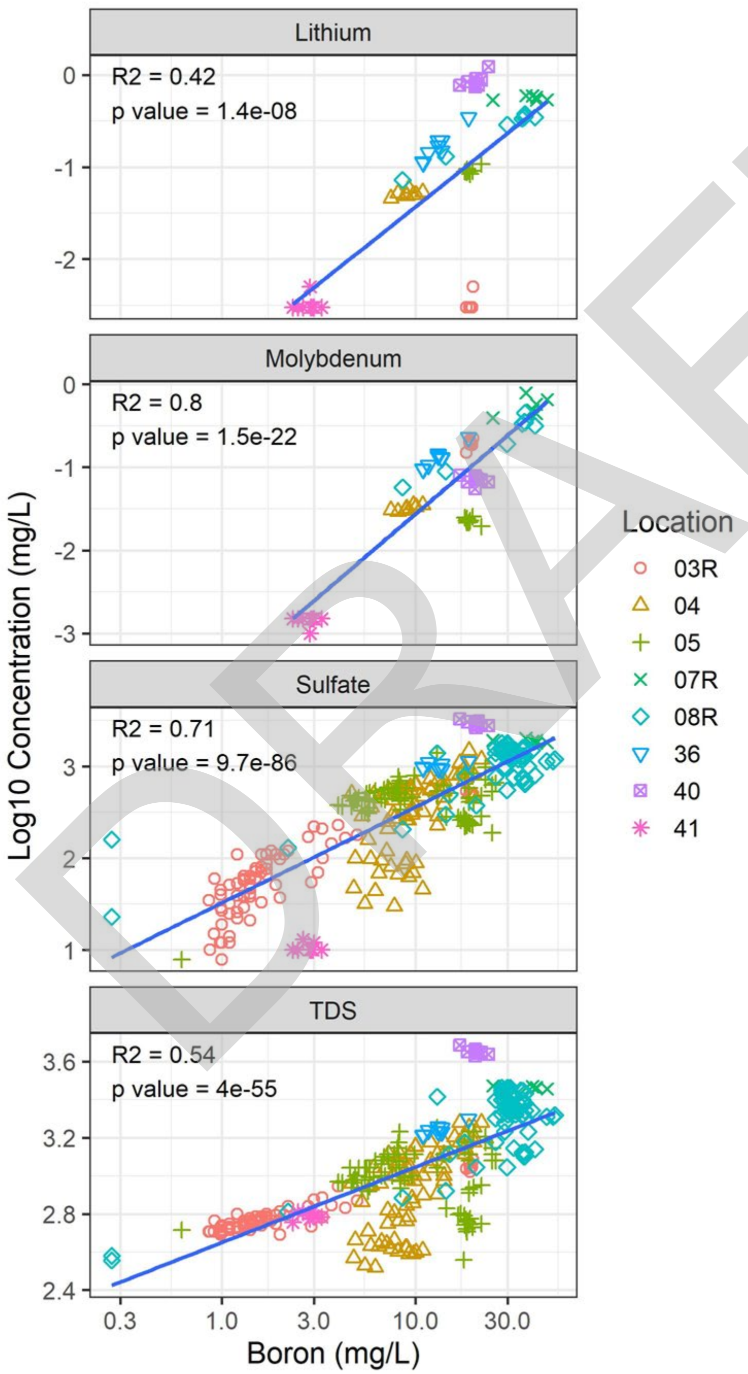
The hydrogeologic investigation reports (Kelron, 2012a; Kelron, 2012b) are the foundation of the site setting and CSM that describes groundwater flow at the Site, which was refined with additional data collected in the 2021 field investigation and presented in the HCR. The NAP and OEAP overlie the recharge area for the underlying transmissive geologic media, which are composed of coarse grained unlithified deposits (*i.e.,* alluvium [MGU], and glacial outwash and re-worked glacial deposits [LGU]). Groundwater enters the model domain vertically via recharge, and there is also a small component of groundwater that flows into the system via thin water bearing strata in the upland glacial deposits upgradient of the NAP and OEAP (*i.e.,* upgradient portions of LGU that are not within the model domain). The groundwater from the MGU and LGU flows into the Middle Fork.

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 sources of boron are the NAP and OEAP. The NEAP is constructed over shale bedrock, and groundwater does not flow toward the NAP and OEAP from the vicinity of the NEAP. 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 toward the Middle Fork. The primary transport pathway is the MGU as indicated by groundwater observations. The LGU is also a PMP, although the amount of mass in this unit is limited by the UCU that separates the MGU and LGU (Kelron, 2012a; Kelron, 2012b).

## 4.3 Model Approach

Comparisons of observed lithium, molybdenum, sulfate, and TDS concentrations to boron (**Figure A**, below) indicate statistically significant correlations between these parameters at downgradient wells with identified potential exceedances 03R, 04, 05, 07R, 08R, 36, 40, and 41. 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**. Higher R2 values (*i.e.*, closer to 1) indicate stronger correlation between parameters. A correlation is considered statistically significant when the p value is lower than 0.05. All four correlations have p values less than the target of 0.05, indicating correlations are statistically significant. The correlations are strongest between molybdenum and boron, sulfate and boron, and TDS and boron. The correlation with lithium is not as strong, primarily due to the absence of lithium exceedances observed at well 03R (*i.e.*, the cluster of points is well below the trendline on **Figure A**). The statistically significant correlations associated with boron concentrations indicate boron is an acceptable surrogate for lithium, molybdenum, 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 Lithium, Molybdenum, Sulfate, and TDS in Downgradient 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 sufficient period (40 years) to allow modeled boron concentrations in the primary transport layer (MGU) to achieve steady concentrations. The model was calibrated to match groundwater elevation and concentration observed during the 2021 field investigation. Prediction simulations were then performed to evaluate the effects of CBR closure scenarios for the NAP and OEAP on groundwater quality for a period of 120 to 126 years following initial corrective action measures, which include dewatering of the NAP and OEAP, removal of all CCR, and construction of a groundwater collection trench north of the OEAP. 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 removal at the NAP and OEAP 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.

MODFLOW was developed by USGS (McDonald and Harbaugh, 1988) and has been updated several times. Major assumptions of the 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 NAP and OEAP. 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 areas.

## 5.2 Flow and Transport Model Setup

The modeled area was approximately 7,900 feet by 9,950 feet with the NAP and OEAP located in the northeast quadrant. The eastern edge of the model is bounded by the Middle Fork. The north, west, and south edges of the model were selected to maintain sufficient distance from the NAP and OEAP to reduce boundary interference with model calculations, while not extending too far past the extent of available calibration data. The north, west, and south edges of the model also approximate topographic highs, surface water divides, watershed boundaries, and/or Illinois Power Company Lake (Company Lake) boundaries when possible. The model grid and boundary conditions are displayed in **Figure 5-1 through Figure 5-9**.

Evaluation of monitoring well data for the NAP and OEAP 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 median groundwater elevation collected from March to July 2021 presented in **Table 2-2**. MT3DMS was run on the calibrated flow model and model-simulated concentrations were calibrated to the median observed boron concentration values at the monitoring wells calculated from boron concentrations results from March to July 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 NAP and OEAP, the calibrated flow and transport models were used in predictive modeling to evaluate the 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 seven layer, 316 x 398 node grid was established with 25 foot grid spacing (**Figure 5-1** and **Figure 5-2**). Boundary conditions are illustrated in **Figure 5-3 through Figure 5-9**. The north, south and west edges of the model are no-flow (Neumann) boundaries in all layers of the model with the exceptions of the southern edge in Layer 4, where a river (Mixed) boundary represents the Company Lake, and the western and southern edges in Layer 5, where a general head (Dirichlet) boundary was placed to simulate flow in the coarse-grained glacial deposits composing the LGU. The eastern edges of the model are no-flow (Neumann) boundaries in Layers 1 through 2, and either no-flow (Neumann) or river (Mixed) boundaries that represent the Middle Fork in Layers 3 through 7. No-flow (Neumann) boundaries were used to reduce the occurrence of dry cells near the surface where layer thickness is thin within the UCU in Layers 1 through 3 on the western edge of the model. 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 NAP and OEAP. 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 impoundments) 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 flow model calibration targets (*i.e.*, median groundwater elevations from March to July 2021 and target well locations) are summarized in **Table 2-2**. In the flow calibration model, the target for MGU well 18 was placed in layer 2. Layer 2 (UU) is more representative of the materials screened at well 18 and resulted in an improved flow calibration for the target elevation at well 18. Wells 101S, 102S, 103S, 104S, and 105S are screened within discontinuous sand lenses observed in the upland area west of the NAP and OEAP. These sand lenses are present at elevations above the pre-construction ground surface in the NAP and OEAP. These wells went dry during development and 103S did not contain enough water to sample, indicating that the lateral continuity and extent of these sand lenses is limited. Groundwater elevations measured at wells 101S, 102S, 103S, 104S, and 105S were not included as flow model calibration targets. Low groundwater elevations monitored between March and July 2021 indicated well 102 did not fully recover to static groundwater levels following development; therefore, the median groundwater elevation at well 102 was not used as a flow model calibration target. Several flow model calibration targets were added to the model that were outside the immediate vicinity of the NAP and OEAP to improve overall flow calibration both horizontally and vertically across the model domain, and include groundwater elevation targets at monitoring well locations 10, 19, 22, 35D, 35S, 101, 103, 104 and 105.

Sensitivity analysis was conducted by changing input values and observing changes in the sum of squared residuals. 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 and general head boundary head terms were varied between 90 and 110 percent of calibrated values. When the calibrated model was tested, the sum of squared residuals was 440.8. Sensitivity test results were categorized into negligible, low, moderate, moderately high, and high sensitivity based on the change in the sum of squared residuals as summarized in the notes in **Table 5-1**.

##### 5.2.2.1 Model Layers

The bottom elevation of the BCU in layer 7 was flat lying and assumed to be an elevation of 430 feet NAVD88. In the previous 2012 and 2014 models, the layers of the model grid were all flat lying and thicknesses were approximated from hydrostratigraphic unit thicknesses presented in the 2012 Hydrogeologic Investigation (Kelron, 2012a; Kelron, 2012b), including the bottom of the fill (ash) layer. In the current model, all available boring log data included in the HCR (Ramboll, 2021a) was used to develop surfaces utilizing Surfer® software for each of the seven distinct water-bearing units described in **Section 2**. The approximate base of ash surface in the NAP/OEAP was developed from information provided by Geosyntec and presented in the HCR (Ramboll, 2021a). 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 2021 NAP and OEAP HCR (Ramboll, 2021a), 2021 NEAP HCR (Ramboll, 2021d), 2012

Hydrogeologic Investigation (Kelron, 2012a and Kelron, 2012b) and the Regional and Local Hydrogeology and Geochemistry: Vermilion Power Plant, Illinois (Kelron, 2003) 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 10, representing the lower till unit and cells above the river cells, 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 2021 NAP and OEAP HCR (Ramboll, 2021a), 2021 NEAP HCR (Ramboll, 2021d), 2012 Hydrogeologic Investigation (Kelron, 2012a; Kelron, 2012b) and the Regional and Local Hydrogeology and Geochemistry: Vermilion Power Plant, Illinois (Kelron, 2003) indicate vertical conductivity values that are generally lower than horizontal.

The spatial distribution of the hydraulic conductivity zones (**Figure 5-10 through Figure 5-16**) in each layer simulates the distribution of hydrostratigraphic units as reported in the HCR (Ramboll, 2021a). The limits of the fill unit hydraulic conductivity zone (zone 2) in the current model were updated to reflect the limits of the ash fill determined from data provided by Geosyntec and presented in the HCR (Ramboll, 2021a). This adjustment to 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 distribution of all other hydraulic conductivity zones was determined through analysis of each of the seven distinct water-bearing unit layer surfaces within Surfer® software and importing zone distribution data from Surfer® into the model. Conductivity zone 10 was also placed above river cells representing the Middle Fork 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 3 (UCU), 5 (MGU), 8 (BCU), and 9 (NEAP Berm), where the model was moderately sensitive to horizontal conductivity in the remaining hydrostratigraphic units and negligible in zone 10 (the zone placed above the river cells to improve communication with the river). The model was highly sensitive to changes in vertical conductivity in zone 1 (UU [western - includes mixed alluvial deposits of clay, silt, sand, and minor gravel of the Cahokia Alluvium in the vicinity of the NAP and OEAP]) and zone 8 (BCU), while the model exhibited a negligible to moderate sensitivity in the remaining zones.

#### 5.2.2.3 Recharge

Recharge rates were determined through calibration in the 2012 and 2014 models and were adjusted during calibration of current model to the groundwater elevation and groundwater quality data collected in 2021 (**Table 5-1**). The spatial distribution of recharge zones were based on the location and type of material present at land surface (**Figure 5-17**). Nine different zones were created to simulate recharge in the model area. The recharge occurring through the ash fill placed in the NAP and OEAP was split into four different values. Zones 2 and 6 represent recharge in NAP and OEAP areas. Increased recharge was simulated in an area between the NAP and OEAP (zone 8); and, decreased recharge was simulated in an area within the OEAP where the fill unit materials are underlain by the UCU materials (zone 9). Recharge zone (zone 5) was used to simulate recharge through the NAP Secondary Pond. A recharge zone (zone 7) was also used to simulate recharge occurring through the ash fill placed in the NEAP. The remaining three zones were created to simulate recharge through the UU alluvium (eastern, zone 4 and western, zone 1) and the UCU (zone 3).

The model had a high sensitivity to changes in recharge in zones 1 (UU) and 7 (fill unit - NEAP). The model had low to moderate sensitivity to changes in recharge in the remaining zones, with the exception of zone 9 (fill unit – OEAP area underlain by UCU), where sensitivity was negligible.

#### 5.2.2.4 Storage and Specific Yield

As in the 2012 and 2014 models, the current 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 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 Middle Fork was simulated using head-dependent flux nodes in modeled river reaches 1 through 3 that required inputs for river stage, width, bed thickness, and bed hydraulic conductivity (**Table 5-1**). These river parameters were developed in the 2012 and 2014 models, and only the river stage parameter was modified in development of the current calibration model. 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 of the 2012 and 2014 models, while bed thickness was set at 1 foot and river width was set at 100 feet. Final hydraulic conductivity value was set at 1 foot per day (ft/day). The length of the modeled river from the 2012 and 2014 models was extended further south to the southeastern edge of the model domain (downstream of the NEAP) using river reach 3. The modeled river stage in the current calibration model was based on available Middle Fork field data (Kelron, 2003; Geosyntec, 2021b). The river boundary was placed in layers 3 through 7 corresponding with simulated river elevation (**Figure 5-5 through Figure 5-9**).

The approximate stage and slope of the river were originally developed in the 2012 and 2014 models. The stage of the river was adjusted during calibration of the current model to reflect updated groundwater elevations collected in 2021, while the slope approximated in the 2012 and 2014 models was maintained. The slope for the section of river that extended further south to the southeastern edge of the model domain (downstream of the NEAP) was estimated based on available data from Kelron (2003) and applied to river reach 3 in the current model.

The model had a high sensitivity to changes in river stage and a negligible sensitivity to changes in river conductance in river reaches 1 through 3.

Company Lake was simulated using head-dependent flux nodes in modeled river reach 4 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 of the current model. River width, length, and bed thickness were set at 1 foot. Final hydraulic conductivity value was set at 0.0001 ft/day to be similar in magnitude to the vertical hydraulic conductivity of the UCU underlying Company Lake. The Company Lake river stage was based on the median elevation collected from Company Lake staff gage SG01 from March to July 2021 presented in **Table 2-2**. Company Lake modeled river reach 4 was placed in layers 3 and 4. Sensitivity was not tested for river reach 4 as this feature is not hydraulically connected to the MGU or LGU in the NAP and OEAP.

#### 5.2.2.6 General Head Boundary Parameters

General head boundary conditions (GHB) were used along the western boundary of the model as well as, along the southern boundary of the model in layer 5 (**Figure 5-7**). The GHB at the western limit of the model (reach 0) was used to simulate groundwater flow entering the model domain upgradient of the model limits in the LGU. The GHB at the southern limit of the model (reach 1) was used to simulate the horizontal hydraulic gradient or change in groundwater elevation in the LGU along the southern limit of the model. GHB elevation, conductance, and distance were established during calibration (**Table 5-1**). GHB cell width, distance to the GHB head, and saturated thickness of the cell were set at 1 foot. Final hydraulic conductivity value was set at 5 ft/day to be similar in magnitude to the horizontal hydraulic conductivity of the LGU. The GHB at the western limit of the model (reach 0) and the southern limit of the model (reach 1) were placed in layer 5 with a constant elevation of 599 feet NAVD88 and a variable elevation ranging from 598.78 to 570.51 feet NAVD88 from west to east. The sensitivity to changes in specified head was moderately high for reach 0 and high for reach 1. The flow calibration model had a low sensitivity to changes in GHB 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**.

In the previous 2012 and 2014 models, groundwater transport was calibrated to groundwater boron concentration ranges at each well as measured from the monitoring wells in 2011. The current model was calibrated to groundwater boron concentration ranges at each well as measured from March to July 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. The transport model had a negligible to low sensitivity to changes in storage and specific yield (**Table 5-3**).

#### 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 a sufficient period (40 years, **Figure 4-1**) to allow modeled concentrations in the primary transport layer (*i.e.,* MGU) to achieve steady levels.

#### 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**): (i) percolation through CCR in the northern portion of the NAP (recharge zone 2), (ii) percolation through CCR in the NAP Secondary Pond (recharge zone 5), (iii) percolation through CCR in the northern portion of the OEAP (recharge zone 6), (iv) percolation through the CCR near the center of the impoundments (recharge zone 8), and (v) percolation through the CCR in the southern portion of the OEAP, where CCR is underlain by UCU materials (recharge zone 9)(**Figure 5-17**). 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 (**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 recalibrated in the current transport model to the boron concentration data collected in 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 changes in porosity values, not including monitoring locations where the calibration concentration was 0.0 mg/L (*i.e.*, 05, 20, 21, 34, and 38) (**Table 5-3**). The greatest sensitivity for porosity was moderately high for the low porosity sensitivity test at monitoring locations 03R and 37.

#### 5.2.3.4 Storage and Specific Yield Sensitivity

The model had a negligible to moderate sensitivity to changes in storage and specific yield values. Results at monitoring locations where the calibration concentration was 0.0 mg/L and remained less than 0.0 were assigned low sensitivity (*i.e.,* 05, 20, 21, 34, and 38) (**Table 5-3**). The greatest sensitivity for storage and specific yield was moderate for both low and high storage and specific yield sensitivity tests at monitoring location 44.

#### 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 and 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 an approximate travel distance of 100 feet for groundwater from the source to the receiving body of water, 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 (Kd was set to 0 mL/g) which is a conservative estimate for estimating contaminant transport times. Boron, lithium, molybdenum, 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). Site-specific partition coefficients were calculated as part of the study to evaluate whether MNA is a feasible groundwater remedial alternative for the VPP. The following Site-specific partition coefficients and their anticipated effect on constituent behavior compared to the groundwater fate and transport model are described below.

Either linear ($K_d$) or Frendlich ($K_{dF}$) partition coefficients were selected based on the results of batch adsorption testing; additional details are available in the MNA report prepared by Geosyntec (2021a).

- A $K_{dF}$ value of 0.43 liters per kilogram (L/kg) was calculated for boron. This value is low, indicating limited chemical attenuation of boron. The effect of chemical attenuation on transport rates for boron in groundwater is limited, and the time to achieve GWPS predicted by the fate and transport model is likely not to be affected by attenuation mechanisms.
- A $K_d$ value of 8.53 L/kg was calculated for lithium. This value is moderate, indicating some chemical attenuation of lithium, which would affect transport rates in groundwater. The fate and transport model likely over-estimates the time to achieve the lithium GWPS.
- A $K_{dF}$ value of 109 L/kg was calculated for molybdenum. This value is high, indicating significant chemical attenuation of molybdenum, which would affect transport rates in groundwater. The fate and transport model likely over-estimates the time to achieve the molybdenum GWPS.
- A $K_d$ value of 9.97 L/kg was calculated for sulfate. This value is moderate; however, desorption testing completed as part of the MNA evaluation found that almost all sulfate attenuation in the batch testing was reversible (Geosyntec, 2021a). These results indicate the effect of chemical attenuation on transport rates for sulfate in groundwater is limited, and the time to achieve GWPS predicted by the fate and transport model is likely not to be affected by attenuation mechanisms. As noted in the MNA report (Geosyntec, 2021a), sulfate is a primary contributor to TDS at the Site. Declines in groundwater sulfate concentrations will result in a concurrent decline in TDS concentrations.

## 5.3 Flow and Transport Model Assumptions and Limitations

Simplifying assumptions were made while developing this model:

- Leading up to 2021, 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 NAP and OEAP was developed from information provided by Geosyntec and presented in the HCR (Ramboll, 2021a). Observed concentrations in groundwater exhibit no long-term trend.
- Source concentrations are assumed to remain constant over time.
- 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 NAP and OEAP, 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 in 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.

Flow model calibration results are presented in **Figure 5-16 through Figure 5-25**. The mass balance error for the flow model was -0.09 percent and the ratio of the residual standard deviation to the range was 9.7 percent; these values are within the targets for these criteria of 1 percent and 10 percent, respectively. 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 5-24**. The near-linear relationship between observed and simulated values indicates that the model adequately represents the calibration dataset. The residual mean was 1.52 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 5-25**; however, some simulated values were significantly underpredicted in the areas far west of the NAP and OEAP, in the vicinity of the NEAP, or in layers that were not the focus of this model (*e.g.*, BCU).

The range of observed boron concentrations in 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 five of the transport calibration location wells, including 05, 02, 42, 43, and 44 (**Figure 5-26**). Deviations from the observed ranges are discussed below.

- The model under-predicts concentration in well 05, which is screened in the MGU. Monitoring well 05 is positioned sidegradient to the NAP source area. Since the only receiving body is the Middle Fork and the model was developed to represent groundwater flow from the fill units to the Middle Fork, a localized change in flow direction from east to north would be necessary to simulate transport of boron concentration from the NAP to well 05 in the model. The calibrated flow and transport model accurately represent conditions at wells 04 and 41 which are located downgradient of NAP and well 05. For these reasons, the observed groundwater flow directions were maintained and a localized component of northerly flow was not incorporated into the model to move boron towards well 05.

- The model over-predicts boron concentrations at monitoring well 02 and under-predicts boron concentration at monitoring well 03R. Both wells are designated as LGU monitoring wells. Although 03R did meet the transport calibration criteria of matching observed concentrations above or below the standard, the concentration was under-predicted compared to observed concentrations in 2021 (6 mg/L in the model versus median observed concentration of 19.5 mg/L). In general, observed concentrations in the LGU monitoring wells are below the GWPS for boron (2 mg/L), with the exception of monitoring wells 01 and 03R. The 2021 boron concentrations observed at 03R are closer in magnitude to nested MGU well 08R than the other LGU monitoring wells, indicating 03R has a greater connection with the MGU than other LGU wells. The flow and transport model was calibrated to achieve concentration above the standard at LGU downgradient monitoring well 03R, resulting in over-predicted concentrations at LGU monitoring well 02.
- In general, the model over-predicts boron concentrations at upgradient monitoring wells immediately adjacent to the NAP with simulated concentrations above the GWPS for boron when they were observed to be below the standard in 2021. This occurs at monitoring wells 42, 43, and 44. Monitoring wells 42 and 43 are upgradient LGU monitoring wells. Well 44 nested with well 43 is located west of the NAP along the bluff and is screened within a discontinuous sand lens of the UCU below the preconstructed ground surface for the NAP and OEAP above the LGU. The over-predicted concentrations at these upgradient monitoring wells are likely a result of proximity to the overlying fill unit in the model due to discretization of model cells.

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) match observed concentrations above or below the standard at each well. MGU well 08R, located downgradient of the NAP, where the highest concentrations downgradient of the NAP were observed, was also calibrated near the median concentration of the observed values from March to July 2021. Similarly, MGU wells 07R and 40 located downgradient of the OEAP, where the highest concentrations downgradient of the OEAP were observed, were also calibrated just below the minimum of the observed range and near the median concentration of observed values from March to July 2021, respectively. The calibration result for wells 08R, 07R and 40 indicate the transport calibration model was able to simulate the highest observed concentrations downgradient of the NAP and OEAP in the MGU, which is designated as the uppermost aquifer. The distribution of boron concentrations in the calibrated model are presented on **Figure 5-27**. Observed concentrations of boron within the LGU are below the standard of 2 mg/L in all downgradient wells with the exception of 03R. While the model over-predicts concentrations at 02 and underpredicts concentration at 03R, the modeled concentrations at 37 are adequately calibrated to match boron concentrations just below 2 mg/L.

# 6. SIMULATION OF CLOSURE SCENARIO

## 6.1 Overview and Prediction Model Development

Prediction simulations were performed to evaluate the effects of source control measures (CBR closure scenarios; CBR-Onsite and CBR-Offsite) for the NAP and OEAP on groundwater quality following initial corrective action measures, which include dewatering of the NAP and OEAP, as well as construction and operation of a groundwater collection trench north of the OEAP (**Figure 4-1**). As discussed in **Sections 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 all three closure scenarios simulated. Chemical attenuation is also occurring as discussed in **Section 5.2.3.6** and the anticipated effects on constituent behavior compared to the groundwater fate and transport model indicate the fate and transport model likely over-predicts the time to reach the GWPS for lithium and molybdenum. Closure scenarios were simulated by adding a drain boundary condition in the MGU to simulate operation of the groundwater collection trench (drain input parameters approximated groundwater collection trench designs provided in the Draft CCR Final Closure Plan (Geosyntec, 2021b), applying reduced recharge to simulate dewatering of the NAP and OEAP, and applying HELP-calculated percolation rates based on removal and final soil backfill grading designs also provided in the Draft CCR Final Closure Plan (Geosyntec, 2021b). 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 three closure scenarios, including Scenario 1: CBR-Onsite (trench removed at completion of CCR removal), Scenario 2: CBR-Onsite (trench remains after CCR is removed), and Scenario 3: CBR-Offsite (trench remains after CCR is removed). The following simplifying assumptions were made during the simulations:

- In the three 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 CBR.
- Groundwater collection trench construction (simulated with the drain boundary condition) has an instantaneous effect on groundwater flow.
- Changes in recharge resulting from dewatering (assumed to decrease calibration model recharge rates by 90 percent) and ash fill removal/ final soil backfill 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 leachate.
- The start of each closure prediction simulation was initiated at the end of the calibration model period of 40 years plus 2.5 years to complete initial corrective action measures. For example, the simulation of Scenario 1: CBR-Onsite begins at 42.5 years (40 years for calibration plus 2.5 years of no changes until construction of the groundwater collection trench is completed and dewatering is initiated). The prediction modeling timeline for each scenario is illustrated in **Figure 4-1**.

- 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 (Geosyntec, 2021b).
- All saturated ash (constant concentration cells) 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 UCU materials (clay) replaced ash fill in areas of removal.
- Local fill materials applied to the prediction models have similar hydraulic properties as the UCU 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 NAP and OEAP areas for three ash fill removal scenarios. HELP input and output files are included electronically and attached to this report.

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 Decatur, Illinois (the closest weather station included in the HELP database). Precipitation, temperature, and solar radiation was simulated based on the latitude of the NAP and OEAP. Thickness of soil backfill and soil runoff input parameters were developed for the ash fill removal scenarios using data provided the Draft CCR Final Closure Plan (Geosyntec, 2021b).

HELP model results (**Table 6-1**) indicated 3.17 inches of percolation per year for the NAP soil backfill area, 1.75 inches of percolation per year for OEAP soil backfill area, 3.32 inches of percolation per year for the NAP Secondary Pond soil backfill area, and 1.74 inches of percolation per year for the NEAP soil backfill area. The differences in HELP model runs for each area included the following parameters: evaporation zone thickness (limited by soil backfill thickness in the OEAP and NEAP), 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 three closure scenarios by adding a drain to simulate the construction of a groundwater collection trench north of the OEAP, decreasing recharge to simulate dewatering of the ash fill prior to removal, and changing recharge rates to simulate ash fill removal areas at the NAP and OEAP. Removal of leachate inputs from the ash removal areas (source control) was simulated by reducing the boron concentrations associated with recharge in the areas to 0 mg/L. Constant concentration cells that represent areas with potentially saturated ash were also removed from the ash removal areas.

Each prediction scenario was simulated as a continuation of the calibration model until the completion of the estimated construction period of the groundwater collection trench and the start of dewatering as part of the initial corrective action measures had been reached (40 years calibration plus 2.5 years of no changes until construction of the groundwater collection trench is completed and dewatering is initiated). Once the construction of the groundwater collection trench was complete and dewatering was initiated, a drain boundary condition was added to the prediction models and changes to recharge to simulate dewatering were introduced as part of the initial corrective action measures (**Figure 4-1**). Corrective action conditions were maintained until completion of CCR removal, at which time recharge zones were modified to represent ash fill removal areas for each scenario. The prediction model input values are summarized in **Table 6-2** and illustrated in **Figure 6-1** and **Figure 6-2**. As illustrated in **Figure 6-1** additional concentration observation wells, 07R_T and 40_T, were included in the prediction models north of the drain boundary condition cells to replace observation wells 07R and 40, which are located within the trench alignment. Additional observation wells 07R_t and 40_T are used in the model to observe predicted changes in concentration between the trench and the Middle Fork. The three closure scenarios are discussed in this report based on predicted changes in boron concentrations as described below.

### 6.3.1 Closure Scenario 1 Predicted Boron Concentrations

The design for Scenario 1: CBR-Onsite (trench removed at completion of CCR removal) includes initial corrective action measures (construction of a groundwater collection trench north of the OEAP and dewatering) and CBR utilizing an onsite landfill (estimated to be complete 10 years after the start of corrective action measures) (**Figure 4-1**).

Predicted concentrations start to decline once the initial corrective action measures are initiated within the prediction model. These declines occur as recharge is reduced from dewatering and additional cells become dry within the modeled fill unit. The reduced recharge leads to an increasing number of saturated ash cells (constant concentration cells) becoming inactive and no longer contributing boron source concentrations to the model domain. Also, as a result of dewatering, downward percolation of solute mass from the NAP and OEAP is reduced, which decreases the boron concentration entering the model domain. The prediction model indicates modeled drain cells in the MGU north of the OEAP that represent the groundwater collection trench reduce transport of boron concentrations to the river cells. Following the initial corrective action measures, CBR is initiated in the prediction model and boron concentrations are no longer entering the model domain from recharge or from saturated ash cells (constant concentration cells).

At all downgradient wells in the MGU, except well 36, concentrations in Scenario 1: CBR-Onsite (trench removed at completion of CCR removal) were predicted to decrease rapidly following completion of groundwater collection trench construction and initial dewatering 2.5 years after closure scenario implementation (**Figure 6-3**). At well 36 the model indicates concentrations will increase for a period of time following implementation of corrective measures before decreases are predicted. The predicted increase in concentration at well 36 is likely a result of the proximity of well 36 to the modeled groundwater collection trench. In the model, the groundwater collection trench creates a capture zone which redirects groundwater carrying boron concentration toward the trench and well 36, which increases the predicted concentrations in this area. Predicted concentrations at well 36 increase until the source concentrations are removed and/or the groundwater collection trench is removed. A second increase in concentrations was predicted at monitoring well 36 following the end of the initial corrective action measures (i.e., trench removal and dewatering) and the start of CBR, and is likely the result of changes in localized groundwater flow in response to changes in recharge and hydraulic properties of fill materials and/or removal of the groundwater collection trench at the start of CBR. Following the second simulated increase of concentration at monitoring well 36, concentrations continue to decrease to concentrations below the GWPS for boron following CBR. Well 36 was the last remaining downgradient MGU well to reach concentrations below the GWPS for boron (2 mg/L) after a period of approximately 50 years after implementation of Scenario 1: CBR-Onsite (trench removed at completion of CCR removal).

The prediction model indicated that wells 04, 07R_T, and 40_T, which had concentrations above the GWPS for boron (2 mg/L) prior to closure scenario implementation, will decrease to concentrations below the GWPS for boron within the 10-year initial corrective action measures period and prior to CBR. The prediction model indicated that MGU wells 08R and 41 will not reach the GWPS for boron within the initial corrective action measures period, but will reach the standard within approximately 26 and 16 years, respectively. The predicted extent of the footprint of the boron plume over 2 mg/L after 50 years following implementation of Scenario 1: CBR-Onsite (trench removed at completion of CCR removal) within the MGU illustrated in **Figure 6-4** indicates the plume will be limited to an area on the southwest portion of the NAP and an area on the southcentral portion of the OEAP, where the MGU plume no longer intersects the river.

As discussed previously, the model over-predicts boron concentrations at monitoring well 02, under-predicts boron concentration at monitoring well 03R, and is adequately calibrated at well 37. All three wells are downgradient LGU monitoring wells. Prediction model results (**Figure 6-5**) for wells 02 and 03R are not reasonable given the lack of model calibration at these locations. Results for well 37 are reasonable and behave as expected based on the conceptual site model. Because groundwater has a longer flow path and passes through low permeability deposits of the UCU before it reaches the LGU it is expected that the concentrations in the LGU will take longer to respond to source control measures than wells in the MGU. The predicted time to reach the GWPS for boron (2 mg/L) downgradient of the NAP and OEAP in the LGU is based on prediction model results for downgradient LGU well 37, where concentrations were calibrated to just above the maximum observed boron concentration from March to July 2021. The prediction model indicated well 37 would reach concentrations below the GWPS for boron approximately 112 years after closure scenario implementation (**Figure 6-5**).

### 6.3.2 Closure Scenario 2 Predicted Boron Concentrations

The design for Scenario 2: CBR-Onsite (trench remains after CCR is removed) includes initial corrective action measures (construction of a groundwater collection trench north of the OEAP and dewatering) and CBR utilizing an onsite landfill (estimated to be complete 10 years after the start of corrective action measures) (**Figure 4-1**) with continued operation of the groundwater collection trench. The only difference between Scenario 1 and Scenario 2 is the continued operation of the groundwater collection trench following CBR in Scenario 2.

Like Scenario 1, at all downgradient wells in the MGU except well 36, concentrations in Scenario 2: CBR-Onsite (trench remains when CCR is removed) were predicted to decrease rapidly following completion of groundwater collection trench construction and initial dewatering 2.5 years after closure scenario implementation (**Figure 6-6**). At well 36, the model indicates concentrations will increase for a period of time following implementation of initial corrective measures before decreases are predicted associated with the capture zone created by the collection trench, as discussed in **Section 6.3.1** for Scenario 1. Unlike Scenario 1, a second increase in concentrations was not predicted at monitoring well 36 as a result of the continued operation of the trench. Following the predicted increase in concentration, well 36 is predicted to reach concentrations below the GWPS for boron approximately 47 years after implementation of Scenario 2: CBR-Onsite (trench remains after CCR is removed).

The prediction model indicated that wells 04, 07R_T, and 40_T, which had concentrations above the GWPS for boron (2 mg/L) prior to closure scenario implementation, will decrease to concentrations below the GWPS for boron within the 10-year initial corrective action measures period and prior to CBR. Like Scenario 1, the prediction model indicated that MGU wells 08R and 41 will not reach the GWPS for boron within the initial corrective action measures period, but will meet the GWPS within approximately 26 and 18 years, respectively. The predicted extent of the footprint of the boron plume over 2 mg/L after 47 years following implementation of Scenario 2: CBR-Onsite (trench remains after CCR is removed) within the MGU illustrated in **Figure 6-7** indicates the plume was limited to an area on the south and west portion of the NAP and an area on the southcentral portion of the OEAP, where the MGU plume only intersects the river at a single model cell that became isolated from the remaining plume. From a modeling perspective, the difference between the predicted time to reach the GWPS for boron (2mg/L) in the MGU in Scenario 1 (50 years) versus Scenario 2 (47 years) is negligible. In other words, both scenarios are predicted to reach the GWPS after approximately 50 years, the simulated three-year difference between these two scenarios is not significant (**Section 5.3**). These results also indicate there is no significant benefit in the modeled time to reach the GWPS for continued operation and maintenance of the groundwater collection trench beyond the required initial corrective action measures period.

As described in **Section 6.3.1** for Scenario 1, prediction model results (**Figure 6-8**) for wells 02 and 03R are not reasonable given the lack of model calibration at these locations. Results for well 37 are reasonable and behave as expected based on the CSM. The prediction model indicates well 37 will reach concentrations below the GWPS for boron approximately 116 years after closure scenario implementation.

### 6.3.3 Closure Scenario 3 Predicted Boron Concentrations

The design for Scenario 3: CBR-Offsite (trench remains after CCR is removed) includes initial corrective action measures (construction of a groundwater collection trench north of the OEAP and dewatering) and CBR utilizing an offsite landfill (estimated to be complete 4 years after the start of corrective action measures) (**Figure 4-1**) with continued operation of the groundwater collection trench. The only difference between Scenario 2 and Scenario 3 is the reduced initial corrective action measures period (the time to start CBR following initial corrective action measures is reduced by 6 years [from 10 years in Scenario 1 and Scenario 2 to 4 years in Scenario 3]).

Like Scenario 1 and Scenario 2, at all downgradient wells in the MGU except well 36, concentrations in Scenario 3: CBR-Offsite (trench remains after CCR is removed) are predicted to decrease rapidly following completion of groundwater collection trench construction and initial dewatering 2.5 years after closure scenario implementation (**Figure 6-9**). At well 36, the model indicates concentrations will increase for a period of time following implementation of initial corrective measures before decreases are predicted associated with the capture zone created by the collection trench, as discussed in **Section 6.3.1** for Scenario 1. In Scenario 3, a short-term decrease in concentrations was observed at monitoring well 36 following the end of the initial corrective action measures and the start of CBR, which is likely the result of changes in localized groundwater flow in response to changes in recharge and hydraulic properties of fill materials after CBR. Following the short-term decrease observed at monitoring well 36, concentrations continue to increase until approximately 13 years after closure implementation then decrease to concentrations below the GWPS approximately 43 years after implementation of Scenario 3: CBR-Offsite (trench remains after CCR is removed).

The prediction model indicated that wells 04, 07R_T, and 40_T, which had concentrations above the GWPS for boron (2 mg/L) prior to closure scenario implementation, will decrease to concentrations below the GWPS for boron within the 4-year initial corrective action measures period and prior to CBR. Like Scenario 1 and Scenario 2, the prediction model indicates that MGU wells 08R and 41 will not reach the GWPS for boron within the initial corrective action measures period, but will reach the GWPS within approximately 22 and 12 years, respectively. The predicted extent of the footprint of the boron plume over 2 mg/L after 43 years following implementation of Scenario 3: CBR-Offsite (trench remains after CCR is removed) within the MGU illustrated in **Figure 6-10** indicates the plume will be limited to an area in the south and west portion of the NAP and an area in the southcentral portion of the OEAP, where the MGU plume only intersects the river at two separated model cells.

As described in **Section 6.3.1** for Scenario 1, prediction model results (**Figure 6-11**) for wells 02 and 03R are not reasonable given the lack of model calibration at these locations. Results for well 37 are reasonable and behave as expected based on the CSM. The prediction model indicates well 37 will reach concentrations below the GWPS for boron approximately 109 years after closure scenario implementation.

From a modeling perspective, the differences among the predicted times to reach the GWPS for boron (2 mg/L) in the LGU for Scenarios 1, 2, and 3 in 112, 116, and 109 years after implementation of the closure scenarios, respectively, is negligible. All three scenarios are predicted to reach the GWPS after approximately 110 years; the simulated seven-year difference among these three scenarios after 100 years is not significant. The differences are not considered significant as the reliability of model predictions decreases with increasing time from the calibrated model conditions (**Section 5.3**).

### 6.3.4 Evaluation of Mass Flux to the Middle Fork

Consistent with the CSM, the calibration model simulates the flow of groundwater through the site toward the Middle Fork. Within the model, mass (representing boron) from the NAP and OEAP enters the groundwater and is transported to the Middle Fork where it enters river boundary cells and leaves the model domain. The predicted reductions in mass flux to the river cells following source control for Scenarios 1, 2, and 3 were obtained from the model and presented on **Figure 6-12**. Boron flux was normalized to the total flux removed by river cells at implementation of the closure scenarios (model year 40) to illustrate reductions in mass following initial closure and corrective action activities. In all three scenarios, mass flux is predicted to be reduced by 50 percent approximately 10 years after implementation, 80 percent within approximately 35 years after implementation, and 95 percent within approximately 130 years after implementation.

# 7. CONCLUSIONS

This GMR has been prepared to evaluate how proposed CBR closure scenarios will achieve compliance with the applicable groundwater standards at the VPP. Data collected from the recent 2021 field investigations were used to update the existing groundwater model, which was initially developed in 2012 (NRT, 2012a; NRT, 2012b), and later updated in 2014 (NRT, 2014a; NRT, 2014b). The updated MODFLOW and MT3DMS models were then used to evaluate three CBR scenarios using information provided in the Draft CCR Final Closure Plan (Geosyntec, 2021b):

- Scenario 1: CBR-Onsite (trench removed at completion of CCR removal)
- Scenario 2: CBR-Onsite (trench remains after CCR is removed)
- Scenario 3: CBR-Offsite (trench remains after CCR is removed)

Predictive simulations of source control and corrective action indicate groundwater in the primary transport zone (the MGU) will achieve the GWPS for Scenarios 1, 2, and 3 in 50, 47, and 43 years, respectively, after implementation of the closure scenarios and corrective action. From a modeling perspective, the difference between the predicted time to reach the GWPS for boron (2mg/L) in the MGU in Scenario 1 (50 years) versus Scenario 2 (47 years) is negligible. In other words, both scenarios are predicted to reach the GWPS after approximately 50 years; the simulated three-year difference between these two scenarios is not significant. These results also indicate there is no significant benefit in the modeled time to reach the GWPS for continued operation and maintenance of the groundwater collection trench beyond the completion of the removal.

Groundwater in the PMP (LGU) is predicted to achieve the GWPS for Scenarios 1, 2, and 3 in 112, 116, and 109 years after implementation of the closure scenarios, respectively. The longer response times simulated for the LGU are expected based on the CSM. Because groundwater has a longer flow path and passes through low permeability deposits of the UCU before it reaches the LGU, it is expected that the concentrations in the LGU will take longer to respond to source control measures than wells in the MGU. From a modeling perspective, the differences among the predicted times to reach the GWPS for boron (2 mg/L) in the LGU for Scenarios 1, 2, and 3 in 112, 116, and 109 years after implementation of the closure scenarios, respectively, is negligible. All three scenarios are predicted to reach the GWPS after approximately 110 years; the simulated seven-year difference among these three scenarios after 100 years is not significant.

The predicted reductions in mass flux to the river cells (representing the Middle Fork) following source control for Scenarios 1, 2, and 3 indicate for the three scenarios that mass flux is predicted to be reduced by 50 percent approximately 10 years after implementation, 80 percent within approximately 35 years after implementation, and 95 percent within approximately 130 years after implementation.

Statistically significant correlations between boron concentrations and concentrations of other parameters identified as potential exceedances of the GWPS indicate boron is an acceptable surrogate for lithium, molybdenum, sulfate, and TDS 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 (Kd was set to 0 mL/g), which is a conservative estimate for estimating contaminant transport times.

Boron, lithium, molybdenum, sulfate, and TDS transport are likely to be affected by both chemical and physical attenuation mechanisms (*i.e.*, adsorption and/or precipitation reactions, as well as dilution and dispersion). 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 all three closure scenarios simulated. Site-specific partition coefficients (chemical attenuation) were calculated as part of the study to evaluate whether MNA is a feasible groundwater remedial alternative for the VPP. The anticipated effects on constituent behavior compared to the groundwater fate and transport model summarized below indicate the fate and transport model likely over-predicts the time to reach the GWPS:

- The effect of chemical attenuation on transport rates for boron in groundwater is limited, and the time to achieve GWPS predicted by the fate and transport model is likely not to be affected by attenuation mechanisms.
- Some chemical attenuation of lithium is expected and the fate and transport model likely over-estimates the time to achieve the lithium GWPS.
- Significant chemical attenuation of molybdenum is expected which would affect transport and the fate and transport model likely over-estimates the time to achieve the molybdenum GWPS.
- The effect of chemical attenuation on transport rates for sulfate in groundwater is limited, and the time to achieve GWPS predicted by the fate and transport model is likely not to be affected significantly by chemical attenuation mechanisms relative to physical attenuation. Sulfate is a primary contributor to TDS at the site and declines in groundwater sulfate concentrations will result in concurrent declines in TDS 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 the primary migration pathway (the MGU) within 50 years of closure implementation for all three Scenarios. The LGU, which has much lower boron concentrations (less mass), is estimated to take approximately 110 years to reach the GWPS due to the longer flow paths through low permeability deposits of the UCU before it reaches the LGU and ultimately the Middle Fork. Results of the groundwater fate and transport modeling also indicate that the flux of these constituents to the Middle Fork will reduce by 80 percent within 35 years of closure implementation for all three Scenarios. The anticipated effects of MNA on constituent behavior compared to the groundwater fate and transport model indicate the fate and transport model likely over-predicts the time to reach the GWPS for lithium and molybdenum.

# 8. REFERENCES

Anderson, M.P. 1979. *Using models to simulate the movement of contaminants through groundwater flow systems*. CRC Critical Rev. Environ. Control., 9(2), p. 97-156.

Anderson, M.P. 1984. *Movement of contaminants in groundwater: groundwater transport -- advection and dispersion*. Groundwater Contamination. National Academy Press, Washington, D.C. p. 37-45.

Environmental Simulations, Inc., 2017. Groundwater Vistas 7 Software.

Fetter, C.W., 1988. *Applied Hydrogeology*. Merrill Publishing Company, Columbus, Ohio.

Geosyntec Consultants, Inc. (Geosyntec), 2021a. Draft Monitored Natural Attenuation Evaluation Vermilion Power Plant, attached to the Draft Construction Permit Application to which this report is also attached, November 2021.

Geosyntec Consultants, Inc. (Geosyntec), 2021b. Draft CCR Final Closure Plan, attached to the Draft Construction Permit Application to which this report is also attached, November 2021.

Heath, R.C., 1983. *Basic ground-water hydrology*, U.S. Geological Survey Water-Supply Paper 2220, 86p.

Illinois Environmental Protection Agency (IEPA), 2021. *In the Matter of: Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments: Title 35 Illinois Administration Code 845, Addendum*. April 15, 2021.

Kelron Environmental (Kelron), 2003. *Regional and Local Hydrogeology and Geochemistry, Vermilion Power Plant, Illinois, Dynegy Midwest Generation, Inc.* November 30, 2003.

Kelron Environmental (Kelron), 2012a. *Hydrogeology and Groundwater Quality of the North Ash Pond System, Vermilion Power Station, Oakwood, Illinois, Dynegy Midwest Generation, LLC*. March 15, 2012.

Kelron Environmental (Kelron), 2012b. *Hydrogeology and Groundwater Quality of the Old East Ash Pond, Vermilion Power Station, Oakwood, Illinois, Dynegy Midwest Generation, LLC*. March 15, 2012.

McDonald, M.G., and A.W. Harbaugh, 1988. *A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model: Techniques of Water-Resources Investigations, Techniques of Water-Resources of the United States Geological Survey*. Book 6, Chapter A1.

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.

Natural Resource Technology, Inc. (NRT), 2012a. *Corrective Action Plan, North Ash Pond System, Vermilion Power Station, Oakwood, Illinois, Dynegy Midwest Generation, LLC.* March 27, 2012.

Natural Resource Technology, Inc. (NRT), 2012b. *Corrective Action Plan, Old East Ash Pond, Vermilion Power Station, Oakwood, Illinois, Dynegy Midwest Generation, LLC*. March 27, 2012.

Natural Resource Technology, Inc. (NRT), 2014a. *Corrective Action Plan, North Ash Pond System, Vermilion Power Station, Oakwood, Illinois, Dynegy Midwest Generation, LLC*. April 2, 2014.

Natural Resource Technology, Inc. (NRT), 2014b. *Corrective Action Plan, Old East Ash Pond, Vermilion Power Station, Oakwood, Illinois, Dynegy Midwest Generation, LLC.* April 2, 2014.

URS Corporation, 2013. *Geotechnical Report, North ash Pond and Old East Ash Pond, Vermilion Site, Embankment Evaluations, Oakwood, Illinois, Dynegy Midwest Generation, LLC*. November 18, 2013.

Ramboll Americas Engineering Solutions, Inc. (Ramboll), 2021a. *Hydrogeologic Characterization Report, North Ash Pond and Old East Ash Pond, Vermilion Power Plant, Oakwood, Illinois*. October 25, 2021.

Ramboll Americas Engineering Solutions, Inc. (Ramboll), 2021b. *History of Potential Exceedances, North Ash Pond and Old East Ash Pond, Vermilion Power Plant, Oakwood, Illinois*. October 25, 2021.

Ramboll Americas Engineering Solutions, Inc. (Ramboll), 2021c. *Groundwater Monitoring Plan, North Ash Pond and Old East Ash Pond, Vermilion Power Plant, Oakwood, Illinois*. October 25, 2021.

Ramboll Americas Engineering Solutions, Inc. (Ramboll), 2021d. *Hydrogeologic Characterization Report, New East Ash Pond, Vermilion Power Plant, Oakwood, Illinois*. October 25, 2021.

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.

Zheng, Z., and P.P. Wang, 1998. *MT3DMS, a Modular Three-Dimensional Multispecies Transport Model,* Model documentation and user's guide prepared by the University of Alabama Hydrogeology Group for the US Army Corps of Engineers.

# TABLES

**TABLE 2-1. MONITORING WELL LOCATIONS AND CONSTRUCTION DETAILS**
GROUNDWATER MODELING REPORT
VERMILION POWER PLANT
NORTH ASH POND AND OLD EAST ASH POND
OAKWOOD, ILLINOIS

| Well Number | Monitored Hydrogeologic Unit | 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) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 01 | LGU | 10/29/1982 | 661.69 | 661.69 | Top of PVC | 660.09 | 99.60 | 104.40 | 560.60 | 555.80 | 119.00 | 541.20 | 4.8 | 2 | 40.18086 | -87.746898 |
| 02 | LGU | 11/03/1982 | 593.87 | 593.87 | Top of PVC | 590.39 | 30.10 | 39.70 | 560.30 | 550.70 | 39.70 | 549.40 | 9.6 | 2 | 40.182334 | -87.743855 |
| 03R | LGU | 12/07/1993 | 589.86 | 589.86 | Top of PVC | 587.83 | 29.00 | 34.00 | 558.80 | 553.80 | 35.30 | 551.30 | 5 | 2 | 40.184122 | -87.746092 |
| 04 | MGU | 11/04/1982 | 590.89 | 590.89 | Top of PVC | 587.38 | 8.70 | 13.50 | 578.70 | 573.90 | 13.50 | 573.90 | 4.8 | 2 | 40.186394 | -87.74493 |
| 05 | MGU | 11/04/1982 | 595.65 | 595.65 | Top of PVC | 592.28 | 9.10 | 13.90 | 583.10 | 578.30 | 13.90 | 578.30 | 4.8 | 2 | 40.187159 | -87.747129 |
| 06R | UU | 11/23/1999 | 592.43 | 592.43 | Top of PVC | 589.69 | 8.40 | 13.50 | 581.20 | 576.10 | 13.50 | 575.60 | 5.1 | 2 | 40.189082 | -87.74491 |
| 07R | MGU | 04/27/2021 | 594.50 | 594.50 | Top of PVC | 591.83 | 11.00 | 21.00 | 580.83 | 570.83 | 21.00 | 551.83 | 20 | 2 | 40.182309 | -87.743853 |
| 08R | MGU | 12/06/1993 | 589.86 | 589.86 | Top of PVC | 587.92 | 9.50 | 14.50 | 578.50 | 573.50 | 18.00 | 570.00 | 5 | 2 | 40.184136 | -87.746095 |
| 10 | UCU | 04/29/1987 | 659.09 | 659.09 | Top of PVC | 656.33 | 46.60 | 56.60 | 609.70 | 599.70 | 56.60 | 581.40 | 10 | 2 | 40.178985 | -87.739824 |
| 17 | MGU | 12/06/1993 | 623.19 | 623.19 | Top of PVC | 619.62 | 54.00 | 59.00 | 565.60 | 560.60 | 60.00 | 547.60 | 5 | 2 | 40.182087 | -87.746641 |
| 19 | MGU | 12/10/1993 | 595.79 | 595.79 | Top of PVC | 593.34 | 10.00 | 15.00 | 583.10 | 578.10 | 16.00 | 576.10 | 5 | 2 | 40.188206 | -87.747135 |
| 20 | MGU | 12/08/1993 | 592.27 | 592.27 | Top of PVC | 590.18 | 12.50 | 17.50 | 577.70 | 572.70 | 18.50 | 571.20 | 5 | 2 | 40.186949 | -87.743335 |
| 21 | LGU | 12/08/1993 | 672.71 | 672.71 | Top of PVC | 670.69 | 104.00 | 109.00 | 566.40 | 561.40 | 110.00 | 558.40 | 5 | 2 | 40.179682 | -87.744962 |
| 22 | BCU | 12/05/2001 | 658.62 | 658.62 | Top of PVC | 655.93 | 80.00 | 100.00 | 576.00 | 556.00 | 100.00 | 556.00 | 20 | 2 | 40.178997 | -87.73985 |
| 34 | LGU | 10/21/2010 | 592.45 | 592.45 | Top of PVC | 590.11 | 49.10 | 54.10 | 540.90 | 535.88 | 54.30 | 535.70 | 5 | 2 | 40.186921 | -87.743359 |
| 35S | UU | 03/01/2017 | 584.92 | 584.92 | Top of PVC | 581.64 | 3.50 | 8.50 | 577.65 | 572.65 | 8.50 | 572.70 | 5 | 2 | 40.17977 | -87.735586 |
| 35D | BCU | 03/03/2017 | 584.14 | 584.14 | Top of PVC | 581.77 | 35.00 | 45.00 | 546.25 | 536.25 | 45.00 | 535.50 | 10 | 2 | 40.179762 | -87.735575 |
| 36 | MGU | 03/03/2021 | 589.96 | 589.96 | Top of PVC | 587.82 | 16.00 | 21.00 | 571.82 | 566.82 | 21.00 | 565.80 | 5 | 2 | 40.183141 | -87.745676 |
| 37 | LGU | 03/03/2021 | 589.71 | 589.71 | Top of PVC | 587.84 | 48.00 | 53.00 | 539.84 | 534.84 | 53.00 | 525.80 | 5 | 2 | 40.183133 | -87.745668 |
| 38 | MGU | 03/02/2021 | 591.69 | 591.69 | Top of PVC | 589.14 | 21.00 | 31.00 | 568.14 | 558.14 | 31.00 | 552.10 | 10 | 2 | 40.189062 | -87.744898 |
| 40 | MGU | 10/03/2018 | 592.27 | 592.27 | Top of PVC | 589.57 | 12.50 | 17.50 | 577.07 | 572.07 | 17.50 | -- | 5 | 2 | 40.182269 | -87.742987 |
| 41 | MGU | 03/04/2021 | 587.17 | 587.17 | Top of PVC | 585.07 | 21.00 | 31.00 | 564.07 | 554.07 | 31.00 | 548.10 | 10 | 2 | 40.185445 | -87.745262 |
| 42 | LGU | 03/07/2021 | 608.40 | 608.40 | Top of PVC | 605.41 | 50.00 | 60.00 | 555.41 | 545.41 | 60.00 | 545.40 | 10 | 2 | 40.182788 | -87.748374 |

**TABLE 2-1. MONITORING WELL LOCATIONS AND CONSTRUCTION DETAILS**
GROUNDWATER MODELING REPORT
VERMILION POWER PLANT
NORTH ASH POND AND OLD EAST ASH POND
OAKWOOD, ILLINOIS

| Well Number | Monitored Hydrogeologic Unit | 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) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 43 | LGU | 03/07/2021 | 607.84 | 607.84 | Top of PVC | 605.30 | 55.00 | 65.00 | 550.30 | 540.30 | 65.00 | 530.30 | 10 | 2 | 40.184888 | -87.750015 |
| 44 | UCU | 03/08/2021 | 607.89 | 607.89 | Top of PVC | 605.37 | 40.00 | 45.00 | 565.37 | 560.37 | 45.00 | 560.40 | 5 | 2 | 40.184879 | -87.750003 |
| 101S | UCU | 03/16/2021 | 707.21 | 707.21 | Top of PVC | 704.13 | 61.00 | 66.00 | 643.14 | 638.14 | 66.00 | 616.10 | 5 | 2 | 40.179169 | -87.754114 |
| 101 | LGU | 03/05/2021 | 706.67 | 706.67 | Top of PVC | 704.09 | 141.00 | 151.00 | 563.09 | 553.09 | 151.00 | 544.10 | 10 | 2 | 40.179149 | -87.754113 |
| 102S | UCU | 03/16/2021 | 705.90 | 705.90 | Top of PVC | 702.92 | 72.00 | 77.00 | 630.92 | 625.92 | 77.00 | 612.90 | 5 | 2 | 40.17787 | -87.750289 |
| 102 | LGU | 03/06/2021 | 589.86 | 589.86 | Top of PVC | 702.98 | 148.00 | 158.00 | 554.98 | 544.98 | 158.00 | 543.00 | 10 | 2 | 40.177887 | -87.750283 |
| 103S | UCU | 03/15/2021 | 721.00 | 721.00 | Top of PVC | 717.62 | 65.00 | 70.00 | 652.62 | 647.62 | 70.00 | 637.60 | 5 | 2 | 40.179854 | -87.749047 |
| 103 | LGU | 03/09/2021 | 720.38 | 720.38 | Top of PVC | 717.38 | 155.00 | 165.00 | 562.38 | 552.38 | 165.00 | 540.40 | 10 | 2 | 40.179842 | -87.748995 |
| 104S | UCU | 03/15/2021 | 705.71 | 705.71 | Top of PVC | 703.10 | 76.00 | 86.00 | 627.10 | 617.10 | 86.00 | 613.10 | 10 | 2 | 40.17768 | -87.748823 |
| 104 | LGU | 03/08/2021 | 705.88 | 705.88 | Top of PVC | 703.24 | 152.00 | 162.00 | 551.24 | 541.24 | 162.00 | 533.20 | 10 | 2 | 40.177681 | -87.748843 |
| 105S | UCU | 03/16/2021 | 702.10 | 702.10 | Top of PVC | 698.97 | 65.00 | 75.00 | 633.97 | 623.97 | 75.00 | 609.00 | 10 | 2 | 40.17853 | -87.745412 |
| 105 | LGU | 03/05/2021 | 705.88 | 705.88 | Top of PVC | 698.46 | 129.00 | 139.00 | 569.46 | 559.46 | 139.00 | 538.50 | 10 | 2 | 40.178557 | -87.745392 |
| ND3 | CCR | 02/05/2019 | 614.55 | 614.55 | Top of PVC | 610.78 | 8.65 | 23.31 | 602.13 | 587.48 | 23.87 | 586.91 | 14.66 | 2 | 40.1831 | -87.747349 |
| OED1 | CCR | 02/06/2019 | 630.41 | 630.41 | Top of PVC | 627.29 | 23.68 | 43.34 | 603.61 | 583.95 | 43.83 | 583.46 | 19.66 | 2 | 40.181608 | -87.745161 |
| SG01 | SW | 04/01/2021 | 689.32 | 689.32 | Top of PVC | 689.32 | -- | -- | -- | -- | 689.30 | -- | 0 | 2 | 40.173756 | -87.745091 |

**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
LGU = lower groundwater unit
MGU = middle groundwater unit
PVC = polyvinyl chloride
SW = surface water
UCU = upper confining unit
UU = upper unit

generated 11/04/2021, 6:41:24 PM CDT

**TABLE 2-2. FLOW AND TRANSPORT MODEL CALIBRATION TARGETS**

GROUNDWATER MODELING REPORT

VERMILION POWER PLANT

NORTH ASH POND AND OLD EAST ASH POND

OAKWOOD, ILLINOIS

| Well ID | Monitored Hydrogeologic Unit | Modeled Target Location (Layer Number) | Flow Model Target Groundwater Elevation Median Value March 2021 to July 2021 (feet NAVD88) | Transport Model Target Boron Concentrations March 2021 to July 2021 (mg/L) | | |
|---|---|---|---|---|---|---|
| | | | | Minimum | Median | Maximum |
| 01 | LGU | 5 | 582.90 | 1.2 | 3.4 | 4.8 |
| 02 | LGU | 5 | 575.77 | 0.3 | 0.3 | 0.4 |
| 03R | LGU | 5 | 582.64 | 18.4 | 19.5 | 19.9 |
| 04 | MGU | 3 | 584.18 | 7.5 | 9.1 | 10.1 |
| 05 | MGU | 3 | 588.66 | 18.0 | 18.5 | 22.0 |
| 06R | UU | 2 | 588.47 | No Target | | |
| 07R | MGU | 3 | 578.96 | 25.2 | 40.4 | 42.4 |
| 08R | MGU | 3 | 577.67 | 8.6 | 35.7 | 37.0 |
| 17 | MGU | 3 | 585.75 | 1.4 | 4.1 | 6.6 |
| 18 | MGU | 2 | 598.58 | 11.0 | 11.8 | 15.7 |
| 19 | MGU | 3 | 589.56 | No Target | | |
| 20 | MGU | 3 | 579.00 | 0.5 | 0.7 | 1.1 |
| 21 | LGU | 5 | 581.60 | 0.8 | 0.9 | 1.0 |
| 34 | LGU | 5 | 579.03 | 0.5 | 0.5 | 0.7 |
| 36 | MGU | 3 | 576.47 | 10.9 | 13.1 | 18.8 |
| 37 | LGU | 5 | 582.48 | 1.1 | 1.3 | 1.5 |
| 38 | MGU | 3 | 588.06 | 0.4 | 0.5 | 0.6 |
| 40 | MGU | 3 | 578.36 | 17.0 | 20.4 | 23.9 |
| 41 | MGU | 3 | 581.74 | 2.3 | 2.9 | 3.3 |
| 42 | LGU | 5 | 583.48 | 0.8 | 0.9 | 1.0 |
| 43 | LGU | 5 | 592.42 | 0.9 | 1.2 | 1.2 |
| 44 | UCU | 4 | 593.85 | 1.2 | 1.4 | 1.4 |
| 101 | LGU | 5 | 598.26 | No Target | | |
| 103 | LGU | 5 | 583.27 | No Target | | |

**TABLE 2-2. FLOW AND TRANSPORT MODEL CALIBRATION TARGETS**

GROUNDWATER MODELING REPORT
VERMILION POWER PLANT
NORTH ASH POND AND OLD EAST ASH POND
OAKWOOD, ILLINOIS

| Well ID | Monitored Hydrogeologic Unit | Modeled Target Location (Layer Number) | Flow Model Target Groundwater Elevation Median Value March 2021 to July 2021 (feet NAVD88) | Transport Model Target Boron Concentrations March 2021 to July 2021 (mg/L) | | |
|---|---|---|---|---|---|---|
| | | | | Minimum | Median | Maximum |
| 104 | LGU | 5 | 580.56 | No Target | | |
| 105 | LGU | 5 | 586.01 | No Target | | |
| 10 | UCU | 4 | 609.54 | No Target | | |
| 22 | BCU | 7 | 603.60 | No Target | | |
| 35D | BCU | 7 | 577.51[1] | No Target | | |
| 35S | UU | 6 | 573.12[1] | No Target | | |
| ND3 | CCR | NA | 599.18[2] | 28.5[2] | 30.6[2] | 32.0[2] |
| OED1 | CCR | NA | 589.57[2] | 35.0[2] | 46.1[2] | 46.7[2] |
| SG01 | SW | NA | 680.77[2] | No Target | | |

[O: JJW 10/31/21; C: KLT 11/4/21; C: BGH 11/4/21]

**Notes:**

[1] Target groundwater elevations presented are from data collected on March 29, 2021, groundwater elevations collected after this date were recovering between sampling events and do not represent static groundwater conditions at wells 35S and 35D.

[2] Value not used as calibration target

ID = identification
mg/L = milligrams per liter
NA = not applicable
NAVD88 = North American Vertical Datum of 1988

**Hydrogeologic Unit:**

BCU = bedrock confining unit
CCR = coal combustion residuals
LGU = lower groundwater unit
MGU = middle groundwater unit
SW = surface water
UCU = upland confining unit
UU = upper unit

**TABLE 5-1. FLOW MODEL INPUT AND SENSITIVITY ANALYSIS RESULTS**
GROUNDWATER MODELING REPORT
VERMILION POWER PLANT
NORTH ASH POND AND OLD EAST ASH POND
OAKWOOD, ILLINOIS

| Zone | Hydrostratigraphic Unit | Materials | ft/d | cm/s | Kh/Kv | Value Source | Sensitivity[1] |
|---|---|---|---|---|---|---|---|
| **Horizontal Hydraulic Conductivity** | | | **Calibration Model** | | | **Calibration Model** | |
| 1 | UU (western) | mixed alluvial deposits in the vicinity of the NAP and OEAP | 0.8 | 2.82E-04 | NA | Calibrated - Within Range of Field Test Results (Kelron, 2012a and Kelron, 2012b) | moderate |
| 2 | Fill Unit | CCR | 0.22 | 7.76E-05 | NA | Geomean of Field Test Results (Ramboll, 2021a) | moderate |
| 3 | UCU | clay and silt | 0.033 | 1.16E-05 | NA | Calibrated - near Field Test Result for Upper Confining Unit at NEAP (Ramboll, 2021b) | high |
| 4 | UU (eastern) | mixed alluvial deposits in the vicinity of the NEAP | 30 | 1.06E-02 | NA | Geomean of Field Test Results at NEAP (Ramboll, 2021b) | moderate |
| 5 | MGU | alluvial deposits | 20 | 7.06E-03 | NA | Calibrated - Within Range Field Test Results and near Geomean of Field Test Results (Ramboll, 2021a) | high |
| 6 | LGU | sand, gravel, silt | 4.4 | 1.55E-03 | NA | Calibrated - Within Range Field Test Results and near Geomean of Field Test Results (Ramboll, 2021a) | moderate |
| 7 | LCU | clay and silt | 0.0085 | 3.00E-06 | NA | Calibrated | moderate |
| 8 | BCU | shale | 0.003 | 1.06E-06 | NA | Minimum of Field Test Results at NEAP (Ramboll, 2021b) | high |
| 9 | NEAP Berm | UCU borrow material | 0.025 | 8.82E-06 | NA | Field Test Result for Upper Confining Unit at NEAP (Ramboll, 2021b) | high |
| 10 | UU (western) above River Boundary Condition | NA | 4 | 1.41E-03 | NA | Calibrated - Conductivity Value to Allow Groundwater Flow from UU to River Boundary Condition | negligible |
| **Vertical Hydraulic Conductivity** | | | **Calibration Model** | | | **Calibration Model** | |
| 1 | UU (western) | mixed alluvial deposits in the vicinity of the NAP and OEAP | 0.0022 | 7.76E-07 | 364 | Calibrated - Within Range Laboratory Test Results and near Geomean of Laboratory Test Results (Ramboll, 2021a) | high |
| 2 | Fill Unit | CCR | 0.048 | 1.69E-05 | 5 | Geomean of Laboratory Test Results (Ramboll, 2021a) | negligible |
| 3 | UCU | clay and silt | 0.00033 | 1.16E-07 | 100 | Calibrated - Within Range Laboratory Test Results (Ramboll, 2021a) | moderate |
| 4 | UU (eastern) | mixed alluvial deposits in the vicinity of the NEAP | 2.3 | 8.11E-04 | 13 | Geomean of Laboratory Test Results at NEAP (Ramboll, 2021b) | low |
| 5 | MGU | alluvial deposits | 0.35 | 1.23E-04 | 57 | Geomean of Laboratory Test Results (Ramboll, 2021a) | low |
| 6 | LGU | sand, gravel, silt | 0.03 | 1.06E-05 | 147 | Calibrated - Within Range Laboratory Test Results and near Geomean of Laboratory Test Results (Ramboll, 2021a) | moderate |
| 7 | LCU | clay and silt | 0.00043 | 1.52E-07 | 20 | Geomean of Laboratory Test Results (Ramboll, 2021a) | negligible |
| 8 | BCU | shale | 0.00014 | 4.94E-08 | 21 | Maximum of Reported Laboratory Values (Kelron, 2003) | high |
| 9 | MCU | alluvial and re-worked glacial | 0.0033 | 1.16E-06 | 8 | Geomean of Laboratory Test Results for Upper Confining Unit (Ramboll, 2021a) | low |
| 10 | UU (western) above River Boundary Condition | NA | 4 | 1.41E-03 | 1 | Calibrated - Conductivity Value to Allow Groundwater Flow from UU to River Boundary Condition | negligible |

**TABLE 5-1. FLOW MODEL INPUT AND SENSITIVITY ANALYSIS RESULTS**
GROUNDWATER MODELING REPORT
VERMILION POWER PLANT
NORTH ASH POND AND OLD EAST ASH POND
OAKWOOD, ILLINOIS

| Zone | Hydrostratigraphic Unit | Materials | ft/d | in/yr | Kh/Kv | Value Source | Sensitivity[1] |
|---|---|---|---|---|---|---|---|
| **Recharge** | | | **Calibration Model** | | | **Calibration Model** | |
| 1 | UU (western) | mixed alluvial deposits in the vicinity of the NAP and OEAP | 1.40E-03 | 6.13 | NA | Calibrated | high |
| 2 | Fill Unit - NAP | CCR | 1.40E-03 | 6.13 | NA | Calibrated | low |
| 3 | UCU | clay and silt | 8.50E-06 | 0.04 | NA | Calibrated | moderate |
| 4 | UU (eastern) | mixed alluvial deposits in the vicinity of the NEAP | 1.68E-04 | 0.74 | NA | Calibrated | low |
| 5 | Fill Unit - NAP Secondary Pond | CCR | 6.00E-03 | 26.28 | NA | Calibrated | low |
| 6 | Fill Unit - OEAP | CCR | 1.40E-03 | 6.13 | NA | Calibrated | low |
| 7 | Fill Unit - NEAP | CCR | 4.00E-04 | 1.75 | NA | Calibrated | high |
| 8 | Fill Unit -Area Between NAP and OEAP | CCR | 6.00E-03 | 26.28 | NA | Calibrated | moderate |
| 9 | Fill Unit - OEAP Area Underlain by UCU | CCR | 1.00E-05 | 0.04 | NA | Calibrated | negligible |
| **Storage** | | | | | | | |
| 1 | UU (western) | mixed alluvial deposits in the vicinity of the NAP and OEAP | *Not used in steady-state calibration model* | | | *Not used in steady-state calibration model* | |
| 2 | Fill Unit | CCR (all) | | | | | |
| 3 | UCU | clay and silt | | | | | |
| 4 | UU (eastern) | mixed alluvial deposits in the vicinity of the NEAP | | | | | |
| 5 | MGU | alluvial deposits | | | | | |
| 6 | LGU | sand, gravel, silt | | | | | |
| 7 | LCU | clay and silt | | | | | |
| 8 | BCU | shale | | | | | |
| 9 | NEAP Berm | alluvial and re-worked glacial | | | | | |

**TABLE 5-1. FLOW MODEL INPUT AND SENSITIVITY ANALYSIS RESULTS**
GROUNDWATER MODELING REPORT
VERMILION POWER PLANT
NORTH ASH POND AND OLD EAST ASH POND
OAKWOOD, ILLINOIS

**River Parameters**

| | Relative Location | River Width (feet) | Length of River (feet) | Bed Thickness (feet) | Hydraulic Conductivity (ft/d) | Stage (feet) | River Conductance ($ft^2/d$) |
|---|---|---|---|---|---|---|---|
| Reach 1 | Upstream of NEAP | 100 | 25 | 1 | 1 | 578.94 - 572.62 | 2500 |
| Sensitivity[1] | NA | - - - | - - - | - - - | - - - | high | negligible |
| Reach 2 | North of NEAP and Northeastern River Meander | 100 | 25 | 1 | 1 | 572.56 - 565.40 | 2500 |
| Sensitivity[1] | NA | - - - | - - - | - - - | - - - | high | negligible |
| Reach 3 | East of NEAP and Downstream (River Bottom at BCU) | 100 | 25 | 1 | 1 | 565.33 - 551.79 | 2500 |
| Sensitivity[1] | NA | - - - | - - - | - - - | - - - | high | negligible |
| Reach 4 | Company Lake | 1 | 1 | 1 | 0.0001 | 680 | 0.0001 |
| Sensitivity[1] | NA | - - - | - - - | - - - | - - - | - - - | - - - |
| Value Source | NA | Calibrated | Calibrated | Calibrated | Calibrated | Calibrated - Middle Fork Stage Modified from Field Data (Kelron, 2003; and July 2021 Field Data from Geosyntec);<br>Company Lake Stage Based on Median Elevation Collected from Staff Gage SG01 March 2021 to July 2021 | Calibrated |

**General Head Parameters**

| | Relative Location | Width of General Head Boundary Cell (feet) | Distance to General Head Boundary Head (feet) | Saturated Thickness of Cell (feet) | Hydraulic Conductivity (ft/d) | Head (feet) | General Head Boundary Conductance ($ft^2/d$) |
|---|---|---|---|---|---|---|---|
| Reach 0 | Western Model Boundary in LGU | 1 | 1 | 1 | 5 | 599 | 5 |
| Sensitivity[1] | NA | - - - | - - - | - - - | - - - | moderately high | low |
| Reach 1 | Southern Model Boundary in LGU | 1 | 1 | 1 | 5 | 598.78 - 570.51 | 5 |
| Sensitivity[1] | NA | - - - | - - - | - - - | - - - | high | low |
| Value Source | NA | Calibrated | Calibrated | Calibrated | Calibrated | Estimated based on Groundwater Elevation Targets in LGU west of NAP and OEAP | Calibrated |

[O: JJW 10/31/21; C: BGH 11/04/21]

**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
NAP = North Ash Pond
NEAP = New East Ash Pond
OEAP = Old East Ash Pond

**Hydrostratigraphic Unit**
BCU = bedrock confining unit
LCU = lower confining unit
LGU = lower groundwater unit
MCU = middle confining unit
MGU = middle groundwater unit
UCU = upland confining unit
UU = upper unit

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

GROUNDWATER MODELING REPORT

VERMILION POWER PLANT

NORTH ASH POND AND OLD EAST ASH POND

OAKWOOD, ILLINOIS

**References:**


Kelron Environmental (Kelron), 2003, Regional and Local Hydrogeology and Geochemistry, Vermilion Power Plant, Illinois, Dynegy Midwest Generation, Inc., November 30, 2003.

Kelron Environmental (Kelron), 2012a, Hydrogeology and Groundwater Quality of the North Ash Pond System, Vermilion Power Station, Oakwood, Illinois, Dynegy Midwest Generation, LLC, March 15, 2012.

Kelron Environmental (Kelron), 2012b, Hydrogeology and Groundwater Quality of the Old East Ash Pond, Vermilion Power Station, Oakwood, Illinois, Dynegy Midwest Generation, LLC, March 15, 2012.

Ramboll Americas Engineering Solutions, Inc. (Ramboll), October 25, 2021a, Hydrogeologic Site Characterization Report, Vermilion Power Plant North Ash Pond and Old East Ash Pond.

Ramboll Americas Engineering Solutions, Inc. (Ramboll), October 25, 2021b, Hydrogeologic Site Characterization Report, Vermilion Power Plant New East Ash Pond.

**TABLE 5-2. TRANSPORT MODEL INPUT VALUES (CALIBRATION)**
GROUNDWATER MODELING REPORT
VERMILION POWER PLANT
NORTH ASH POND AND OLD EAST ASH POND
OAKWOOD, ILLINOIS

| Zone | Hydrostratigraphic Unit | Materials | Calibration Model | | | | |
|---|---|---|---|---|---|---|---|
| | | | Boron Concentration (mg/L) | | | Value Source | Sensitivity |
| **Initial Concentration** | | | | | | | |
| Entire Domain | NA | NA | 0 | | | NA | - - - |
| **Source Concentration (recharge)** | | | | | | | |
| 1 | UU (western) | mixed alluvial deposits in the vicinity of the NAP and OEAP | 0 | | | NA | - - - |
| 2 | Fill Unit - NAP | CCR | 45 | | | calibrated | - - - |
| 3 | UCU | clay and silt | 0 | | | NA | - - - |
| 4 | UU (eastern) | mixed alluvial deposits in the vicinity of the NEAP | 0 | | | NA | - - - |
| 5 | Fill Unit - NAP Secondary Pond | CCR | 15 | | | calibrated | - - - |
| 6 | Fill Unit - OEAP | CCR | 35 | | | calibrated | - - - |
| 7 | Fill Unit - NEAP | CCR | 0 | | | NA | - - - |
| 8 | Fill Unit -Area Between NAP and OEAP | CCR | 5 | | | calibrated | - - - |
| 9 | Fill Unit - OEAP Area Underlain by UCU | CCR | 35 | | | calibrated | - - - |
| **Source Concentration (constant concentration cells)** | | | | | | | |
| Reach 2 | Fill Unit - NAP | CCR | 45 | | | calibrated | - - - |
| Reach 5 | Fill Unit - NAP Secondary Pond | CCR | 15 | | | calibrated | - - - |
| Reach 6 | Fill Unit - OEAP | CCR | 35 | | | calibrated | - - - |
| Reach 8 | Fill Unit -Area Between NAP and OEAP | CCR | 5 | | | calibrated | - - - |
| **Storage, Specific Yield and Effective Porosity** | | | Calibration Model | | | | |
| **Zone** | **Hydrostratigraphic Unit** | **Materials** | **Storage** | **Specific Yield** | **Effective Porosity** | **Value Source** | **Sensitivity** |
| 1 | UU (western) | mixed alluvial deposits in the vicinity of the NAP and OEAP | 0.003 | 0.175 | 0.175 | 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 | Fill Unit | CCR (all) | 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 |
| 3 | UCU | clay and silt | 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 |
| 4 | UU (eastern) | mixed alluvial deposits in the vicinity of the NEAP | 0.003 | 0.27 | 0.27 | 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 | MGU | alluvial deposits | 0.003 | 0.27 | 0.27 | 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 | LGU | sand, gravel, silt | 0.003 | 0.18 | 0.18 | 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 | LCU | clay and silt | 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 |
| 8 | BCU | shale | 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 |
| 9 | NEAP Berm | alluvial and re-worked glacial | 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 |
| **Dispersivity** | | | | | | | |
| **Applicable Region** | **Hydrostratigraphic Unit** | **Materials** | **Longitudinal (feet)** | **Transverse (feet)** | **Vertical (feet)** | **Value Source** | **Sensitivity** |
| Entire Domain | NA | NA | 3 | 0.3 | 0.03 | calibrated | - - - |

[O: JJW 10/31/21; C: BGH 11/04/21]





RAMBOLL

**TABLE 5-2. TRANSPORT MODEL INPUT VALUES (CALIBRATION)**
GROUNDWATER MODELING REPORT
VERMILION POWER PLANT
NORTH ASH POND AND OLD EAST ASH POND
OAKWOOD, ILLINOIS

**Notes:**
[1] The concentrations from the end of the calibrated transport model were imported as initial concentrations for the prediction model runs.
- - - = not tested
CCR = coal combustion residuals
mg/L = milligrams per liter
NA = not applicable
NAP = North Ash Pond
NEAP = New East Ash Pond
OEAP = Old East Ash Pond

**Hydrostratigraphic Unit**
BCU = bedrock confining unit
LCU = lower confining unit
LGU = lower groundwater unit
MCU = middle confining unit
MGU = middle groundwater unit
UCU = upland confining unit
UU = upper unit

**References:**

Fetter, C.W., 1988, Applied Hydrogeology, Merrill Publishing Company, Columbis, 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
VERMILION POWER PLANT
NORTH ASH POND AND OLD EAST ASH POND
OAKWOOD, ILLINOIS

| Well ID | Calibration Concentration (mg/L) | Storage and Specific Yield | | | | Effective Porosity | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | File Name | | File Name | | File Name | | File Name | |
| | | 2021_VER_ConcCal_500_s_sy_low.gwv | | 2021_VER_ConcCal_500_s_sy_high.gwv | | 2021_VER_ConcCal_500_Por_low.gwv | | 2021_VER_ConcCal_500_Por_high.gwv | |
| | | Concentration (mg/L) | Sensitivity [1] | Concentration (mg/L) | Sensitivity [1] | Concentration (mg/L) | Sensitivity [1] | Concentration (mg/L) | Sensitivity [1] |
| 05 | 0.0 | 0.0 | low | 0.0 | low | 0.0 | low | 0.0 | low |
| 04 | 7.1 | 6.6 | low | 6.6 | low | 6.7 | low | 6.6 | low |
| 08R | 34.5 | 34.3 | negligible | 34.3 | negligible | 34.6 | negligible | 34.1 | low |
| 17.0 | 5.0 | 5.0 | negligible | 5.0 | negligible | 5.0 | negligible | 5.0 | negilgible |
| 18.0 | 5.0 | 5.0 | negligible | 5.0 | negligible | 5.0 | negligible | 5.0 | negilgible |
| 20.0 | 0.0 | 0.0 | low | 0.0 | low | 0.0 | low | 0.0 | low |
| 01 | 3.3 | 3.2 | low | 3.2 | low | 3.9 | moderate | 2.4 | moderate |
| 21.0 | 0.0 | 0.0 | low | 0.0 | moderate | 0.1 | high | 0.0 | moderately high |
| 02 | 17.7 | 17.7 | negligible | 17.7 | negligible | 20.7 | moderate | 15.1 | moderate |
| 03R | 4.2 | 4.3 | low | 4.3 | low | 7.3 | moderately high | 2.8 | moderate |
| 34.0 | 0.0 | 0.0 | low | 0.0 | low | 0.0 | low | 0.0 | low |
| 07R | 23.1 | 23.4 | low | 23.4 | low | 23.7 | low | 23.0 | negilgible |
| 36 | 6.0 | 5.9 | low | 5.9 | low | 5.9 | low | 5.9 | low |
| 37 | 1.9 | 1.9 | low | 1.9 | low | 3.3 | moderately high | 1.2 | moderate |
| 38 | 0.0 | 0.0 | low | 0.0 | low | 0.0 | low | 0.0 | low |
| 40 | 22.7 | 22.3 | low | 22.3 | low | 22.7 | negligible | 21.9 | low |
| 41 | 9.8 | 9.7 | negligible | 9.7 | negligible | 9.8 | negligible | 9.7 | low |
| 42 | 2.2 | 2.1 | low | 2.1 | low | 3.3 | moderate | 1.5 | moderate |
| 43 | 5.1 | 5.3 | low | 5.3 | low | 6.9 | moderate | 4.3 | moderate |
| 44 | 35.6 | 28.9 | moderate | 28.8 | moderate | 36.9 | low | 22.3 | moderate |
| | | S*0.1 Sy*0.5 | | S*10 Sy*2[2] | | Porosity-0.05 | | Porosity+0.05 | |

[O: JJW 10/31/21; C: BGH 11/04/21]

**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] Transient flow model did not converge, sensitivity test used steady state flow and transient transport
ID = identification
mg/L = milligrams per liter
S = storativity
Sy = specific yield

**TABLE 6-1. HELP MODEL INPUT AND OUTPUT VALUES**
GROUNDWATER MODELING REPORT
VERMILION POWER PLANT
NORTH ASH POND AND OLD EAST ASH POND
OAKWOOD, ILLINOIS

| Closure Scenario Number (Drainage Length) | NAP - Removal Area | OEAP - Removal Area | NAP Secondary Pond - Removal Area | NEAP - Removal Area | Notes |
|---|---|---|---|---|---|
| **Input Parameter** | | | | | |
| **Climate-General** | | | | | |
| City | Decatur, IL | Decatur, IL | Decatur, IL | Decatur, IL | Nearby city to the Site within HELP database |
| Latitude | 40.18 | 40.18 | 40.18 | 40.18 | Site latitude |
| Evaporative Zone Depth | 21 | 12* | 21 | 12* | 21 - fair grass (*reduced for layers less than 21 inches thick) |
| Maximum Leaf Area Index | 2 | 2 | 2 | 2 | 2 - fair stand of grass (Schroeder, 1994) |
| Growing Season Period, Average Wind Speed, and Quarterly Relative Humidity | Decatur, IL | Decatur, IL | Decatur, IL | Decatur, IL | Nearby city to the Site within HELP database |
| Number of Years for Synthetic Data Generation | 30 | 30 | 30 | 30 | |
| Temperature, Evapotranspiration, and Precipitation | Precipitation, temperature, and solar radiation was simulated based on HELP V4 weather simulation for: Lat/Long: 40.18/-87.75 | Precipitation, temperature, and solar radiation was simulated based on HELP V4 weather simulation for: Lat/Long: 40.18/-87.75 | Precipitation, temperature, and solar radiation was simulated based on HELP V4 weather simulation for: Lat/Long: 40.18/-87.75 | Precipitation, temperature, and solar radiation was simulated based on HELP V4 weather simulation for: Lat/Long: 40.18/-87.75 | |
| **Soils-General** | | | | | |
| % where runoff possible | 100 | 100 | 100 | 100 | |
| Area (acres) | 41 | 21.3 | 5 | 30 | Unit area |
| Specify Initial Moisture Content | No | No | No | No | |
| Surface Water/Snow | Model Calculated | Model Calculated | Model Calculated | Model Calculated | |
| **Soils-Layers** | | | | | |
| 1 | Clay | Clay | Clay | Clay | |
| **Soil Parameters--soil fill** | | | | | |
| Type | 1 | 1 | 1 | 1 | vertical percolation layer |
| Thickness (in) | 69 | 12 | 121 | 12 | Approximated from Geosyntec provided design cross sections |
| Texture | 43 | 43 | 43 | 43 | defaults used |
| Description | Clay | Clay | Clay | Clay | |
| **Soils--Runoff** | | | | | |
| Runoff Curve Number | 87.8 | 87.9 | 88.8 | 88.1 | HELP-computed curve number |
| Slope | 0.01% | 0.01% | 0.01% | 0.01% | |
| Length (ft) | 1582 | 1302 | 294 | 975 | |
| Texture | 43 | 43 | 43 | 43 | |
| Vegetation | fair | fair | fair | fair | fair indicating fair stand of grass on surface of soil backfill (Hydroseed) |
| **Execution Parameters** | | | | | |
| Years | 30 | 30 | 30 | 30 | |
| Report Daily | No | No | No | No | |
| Report Monthly | No | No | No | No | |
| Report Annual | Yes | Yes | Yes | Yes | |
| **Output Parameter** | | | | | |
| **Percolation Rate (in/yr)** | **3.17** | **1.75** | **3.32** | **1.74** | |

[JJW 11/1/21; C: KLT 11/5/21]





RAMBOLL

**TABLE 6-1. HELP MODEL INPUT AND OUTPUT VALUES**
GROUNDWATER MODELING REPORT
VERMILION POWER PLANT
NORTH ASH POND AND OLD EAST ASH POND
OAKWOOD, ILLINOIS

**Notes:**
% = percent
ft = feet
HELP = Hydrologic Evaluation of Landfill Performance
in = inches
in/yr = inches per year
Lat = latitude
Long = longitude

**TABLE 6-2. PREDICTION MODEL INPUT VALUES**
GROUNDWATER MODELING REPORT
VERMILION POWER PLANT
NORTH ASH POND AND OLD EAST ASH POND
OAKWOOD, ILLINOIS

**Scenario 1: CBR-Onsite (trench removed at completion of CCR removal)**

| Prediction Model | Construction Period (years) | Hydrostratigraphic Unit | Recharge Zone | Boron Recharge Concentration (mg/L) | Recharge (ft/day) | Recharge (in/yr) | Constant Concentration (mg/L) |
|---|---|---|---|---|---|---|---|
| No Action | 0 | Fill Unit - NAP | 2 | 45 | 1.4E-03 | 6.13 | 45 |
| No Action | 0 | Fill Unit - NAP Secondary Pond | 5 | 15 | 6.0E-03 | 26.28 | 15 |
| No Action | 0 | Fill Unit - OEAP | 6 | 35 | 1.4E-03 | 6.13 | 35 |
| No Action | 0 | Fill Unit - NEAP | 7 | 0 | 4.0E-04 | 1.75 | -- |
| No Action | 0 | Fill Unit -Area Between NAP and OEAP | 8 | 5 | 6.0E-03 | 26.28 | 5 |
| No Action | 0 | Fill Unit - OEAP Area Underlain by UCU | 9 | 35 | 1.0E-05 | 0.04 | 35 |
| Dewatering/GCT | 2.5 | Fill Unit - NAP | 2 | 45 | 1.4E-04 | 0.61 | 45 |
| Dewatering/GCT | 2.5 | Fill Unit - NAP Secondary Pond | 5 | 15 | 6.0E-04 | 2.63 | 15 |
| Dewatering/GCT | 2.5 | Fill Unit - OEAP | 6 | 35 | 1.4E-04 | 0.61 | 35 |
| Dewatering/GCT | 2.5 | Fill Unit - NEAP | 7 | 0 | 4.0E-05 | 0.18 | -- |
| Dewatering/GCT | 2.5 | Fill Unit -Area Between NAP and OEAP | 8 | 5 | 6.0E-04 | 2.63 | 5 |
| Dewatering/GCT | 2.5 | Fill Unit - OEAP Area Underlain by UCU | 9 | 35 | 1.0E-06 | 0.004 | 35 |
| CBR-Onsite | 12.5 | Fill Unit - NAP | 2 | 0 | 7.2E-04 | 3.15 | -- |
| CBR-Onsite | 12.5 | Fill Unit - NAP Secondary Pond | 5 | 0 | 7.6E-04 | 3.33 | -- |
| CBR-Onsite | 12.5 | Fill Unit - OEAP | 6 | 0 | 4.0E-04 | 1.75 | -- |
| CBR-Onsite | 12.5 | Fill Unit - NEAP | 7 | 0 | 4.0E-04 | 1.75 | -- |
| CBR-Onsite | 12.5 | Fill Unit -Area Between NAP and OEAP | 8 | 0 | 7.2E-04 | 3.15 | -- |
| CBR-Onsite | 12.5 | Fill Unit - OEAP Area Underlain by UCU | 9 | 0 | 1.0E-05 | 0.04 | -- |

| 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) |
|---|---|---|---|---|---|---|---|
| No Action | 0 | Fill Unit (CCR) | 2 | 0.22 | 7.76E-05 | 0.048 | 1.69E-05 |
| Dewatering/GCT | 2.5 | Fill Unit (CCR) | 2 | 0.22 | 7.76E-05 | 0.048 | 1.69E-05 |
| CBR-Onsite | 12.5 | Fill Unit (Soil Backfill) | 2 | 0.033 | 1.16E-05 | 0.00033 | 1.16E-07 |

| Prediction Model | Construction Period (years) | Hydrostratigraphic Unit | Storage, Specific Yield and Effective Porosity Zone | Storage | Specific Yield | Effective Porosity |
|---|---|---|---|---|---|---|
| No Action | 0 | Fill Unit (CCR) | 2 | 0.003 | 0.2 | 0.2 |
| Dewatering/GCT | 2.5 | Fill Unit (CCR) | 2 | 0.003 | 0.2 | 0.2 |
| CBR-Onsite | 12.5 | Fill Unit (Soil Backfill) | 2 | 0.003 | 0.135 | 0.135 |

| 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) |
|---|---|---|---|---|---|---|---|
| No Action | 0 | -- | -- | -- | -- | -- | -- |
| Dewatering/GCT | 2.5 | 2.5 | 10 - 32 | 13.8 - 25.8 | 10 | 572.93 - 566.07 | 11.6 - 43.3 |
| CBR-Onsite | 12.5 | -- | -- | -- | -- | -- | -- |

**TABLE 6-2. PREDICTION MODEL INPUT VALUES**
GROUNDWATER MODELING REPORT
VERMILION POWER PLANT
NORTH ASH POND AND OLD EAST ASH POND
OAKWOOD, ILLINOIS

| **Scenario 2: CBR-Onsite (trench remains after CCR is removed)** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Prediction Model** | **Construction Period (years)** | **Hydrostratigraphic Unit** | **Recharge Zone** | **Boron Recharge Concentration (mg/L)** | **Recharge (ft/day)** | **Recharge (in/yr)** | **Constant Concentration (mg/L)** |
| No Action | 0 | Fill Unit - NAP | 2 | 45 | 1.4E-03 | 6.13 | 45 |
| No Action | 0 | Fill Unit - NAP Secondary Pond | 5 | 15 | 6.0E-03 | 26.28 | 15 |
| No Action | 0 | Fill Unit - OEAP | 6 | 35 | 1.4E-03 | 6.13 | 35 |
| No Action | 0 | Fill Unit - NEAP | 7 | 0 | 4.0E-04 | 1.75 | -- |
| No Action | 0 | Fill Unit -Area Between NAP and OEAP | 8 | 5 | 6.0E-03 | 26.28 | 5 |
| No Action | 0 | Fill Unit - OEAP Area Underlain by UCU | 9 | 35 | 1.0E-05 | 0.04 | 35 |
| Dewatering/GCT | 2.5 | Fill Unit - NAP | 2 | 45 | 1.4E-04 | 0.61 | 45 |
| Dewatering/GCT | 2.5 | Fill Unit - NAP Secondary Pond | 5 | 15 | 6.0E-04 | 2.63 | 15 |
| Dewatering/GCT | 2.5 | Fill Unit - OEAP | 6 | 35 | 1.4E-04 | 0.61 | 35 |
| Dewatering/GCT | 2.5 | Fill Unit - NEAP | 7 | 0 | 4.0E-05 | 0.18 | -- |
| Dewatering/GCT | 2.5 | Fill Unit -Area Between NAP and OEAP | 8 | 5 | 6.0E-04 | 2.63 | 5 |
| Dewatering/GCT | 2.5 | Fill Unit - OEAP Area Underlain by UCU | 9 | 35 | 1.0E-06 | 0.004 | 35 |
| CBR-Onsite | 12.5 | Fill Unit - NAP | 2 | 0 | 7.2E-04 | 3.15 | -- |
| CBR-Onsite | 12.5 | Fill Unit - NAP Secondary Pond | 5 | 0 | 7.6E-04 | 3.33 | -- |
| CBR-Onsite | 12.5 | Fill Unit - OEAP | 6 | 0 | 4.0E-04 | 1.75 | -- |
| CBR-Onsite | 12.5 | Fill Unit - NEAP | 7 | 0 | 4.0E-04 | 1.75 | -- |
| CBR-Onsite | 12.5 | Fill Unit -Area Between NAP and OEAP | 8 | 0 | 7.2E-04 | 3.15 | -- |
| CBR-Onsite | 12.5 | Fill Unit - OEAP Area Underlain by UCU | 9 | 0 | 1.0E-05 | 0.04 | -- |
| **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)** |
| No Action | 0 | Fill Unit (CCR) | 2 | 0.22 | 7.76E-05 | 0.048 | 1.69E-05 |
| Dewatering/GCT | 2.5 | Fill Unit (CCR) | 2 | 0.22 | 7.76E-05 | 0.048 | 1.69E-05 |
| CBR-Onsite | 12.5 | Fill Unit (Soil Backfill) | 2 | 0.033 | 1.16E-05 | 0.00033 | 1.16E-07 |
| **Prediction Model** | **Construction Period (years)** | **Hydrostratigraphic Unit** | **Storage, Specific Yield and Effective Porosity Zone** | | **Storage** | **Specific Yield** | **Effective Porosity** |
| No Action | 0 | Fill Unit (CCR) | 2 | | 0.003 | 0.2 | 0.2 |
| Dewatering/GCT | 2.5 | Fill Unit (CCR) | 2 | | 0.003 | 0.2 | 0.2 |
| CBR-Onsite | 12.5 | Fill Unit (Soil Backfill) | 2 | | 0.003 | 0.135 | 0.135 |
| **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)** |
| No Action | 0 | -- | -- | -- | -- | -- | -- |
| Dewatering/GCT | 2.5 | 2.5 | 10 - 32 | 13.8 - 25.8 | 10 | 572.93 - 566.07 | 11.6 - 43.3 |
| CBR-Onsite | 12.5 | 2.5 | 10 - 32 | 13.8 - 25.8 | 10 | 572.93 - 566.07 | 11.6 - 43.3 |

**TABLE 6-2. PREDICTION MODEL INPUT VALUES**

GROUNDWATER MODELING REPORT

VERMILION POWER PLANT

NORTH ASH POND AND OLD EAST ASH POND

OAKWOOD, ILLINOIS

**Scenario 3: CBR-Offsite (trench remains after CCR is removed)**

| Prediction Model | Construction Period (years) | Hydrostratigraphic Unit | Recharge Zone | Boron Recharge Concentration (mg/L) | Recharge (ft/day) | Recharge (in/yr) | Constant Concentration (mg/L) |
|---|---|---|---|---|---|---|---|
| No Action | 0 | Fill Unit - NAP | 2 | 45 | 1.4E-03 | 6.13 | 45 |
| No Action | 0 | Fill Unit - NAP Secondary Pond | 5 | 15 | 6.0E-03 | 26.28 | 15 |
| No Action | 0 | Fill Unit - OEAP | 6 | 35 | 1.4E-03 | 6.13 | 35 |
| No Action | 0 | Fill Unit - NEAP | 7 | 0 | 4.0E-04 | 1.75 | -- |
| No Action | 0 | Fill Unit -Area Between NAP and OEAP | 8 | 5 | 6.0E-03 | 26.28 | 5 |
| No Action | 0 | Fill Unit - OEAP Area Underlain by UCU | 9 | 35 | 1.0E-05 | 0.04 | 35 |
| Dewatering/GCT | 2.5 | Fill Unit - NAP | 2 | 45 | 1.4E-04 | 0.61 | 45 |
| Dewatering/GCT | 2.5 | Fill Unit - NAP Secondary Pond | 5 | 15 | 6.0E-04 | 2.63 | 15 |
| Dewatering/GCT | 2.5 | Fill Unit - OEAP | 6 | 35 | 1.4E-04 | 0.61 | 35 |
| Dewatering/GCT | 2.5 | Fill Unit - NEAP | 7 | 0 | 4.0E-05 | 0.18 | -- |
| Dewatering/GCT | 2.5 | Fill Unit -Area Between NAP and OEAP | 8 | 5 | 6.0E-04 | 2.63 | 5 |
| Dewatering/GCT | 2.5 | Fill Unit - OEAP Area Underlain by UCU | 9 | 35 | 1.0E-06 | 0.004 | 35 |
| CBR-Offsite | 6.5 | Fill Unit - NAP | 2 | 0 | 7.2E-04 | 3.15 | -- |
| CBR-Offsite | 6.5 | Fill Unit - NAP Secondary Pond | 5 | 0 | 7.6E-04 | 3.33 | -- |
| CBR-Offsite | 6.5 | Fill Unit - OEAP | 6 | 0 | 4.0E-04 | 1.75 | -- |
| CBR-Offsite | 6.5 | Fill Unit - NEAP | 7 | 0 | 4.0E-04 | 1.75 | -- |
| CBR-Offsite | 6.5 | Fill Unit -Area Between NAP and OEAP | 8 | 0 | 7.2E-04 | 3.15 | -- |
| CBR-Offsite | 6.5 | Fill Unit - OEAP Area Underlain by UCU | 9 | 0 | 1.0E-05 | 0.04 | -- |
| **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)** |
| No Action | 0 | Fill Unit (CCR) | 2 | 0.22 | 7.76E-05 | 0.048 | 1.69E-05 |
| Dewatering/GCT | 2.5 | Fill Unit (CCR) | 2 | 0.22 | 7.76E-05 | 0.048 | 1.69E-05 |
| CBR-Offsite | 6.5 | Fill Unit (Soil Backfill) | 2 | 0.033 | 1.16E-05 | 0.00033 | 1.16E-07 |
| **Prediction Model** | **Construction Period (years)** | **Hydrostratigraphic Unit** | **Storage, Specific Yield and Effective Porosity Zone** | | **Storage** | **Specific Yield** | **Effective Porosity** |
| No Action | 0 | Fill Unit (CCR) | 2 | | 0.003 | 0.2 | 0.2 |
| Dewatering/GCT | 2.5 | Fill Unit (CCR) | 2 | | 0.003 | 0.2 | 0.2 |
| CBR-Offsite | 6.5 | Fill Unit (Soil Backfill) | 2 | | 0.003 | 0.135 | 0.135 |
| **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 ($ft^2/d$)** |
| No Action | 0 | -- | -- | -- | -- | -- | -- |
| Dewatering/GCT | 2.5 | 2.5 | 10 - 32 | 13.8 - 25.8 | 10 | 572.93 - 566.07 | 11.6 - 43.3 |
| CBR-Offsite | 6.5 | 2.5 | 10 - 32 | 13.8 - 25.8 | 10 | 572.93 - 566.07 | 11.6 - 43.3 |

[JJW 11/1/21; C: BGH 11/5/21]

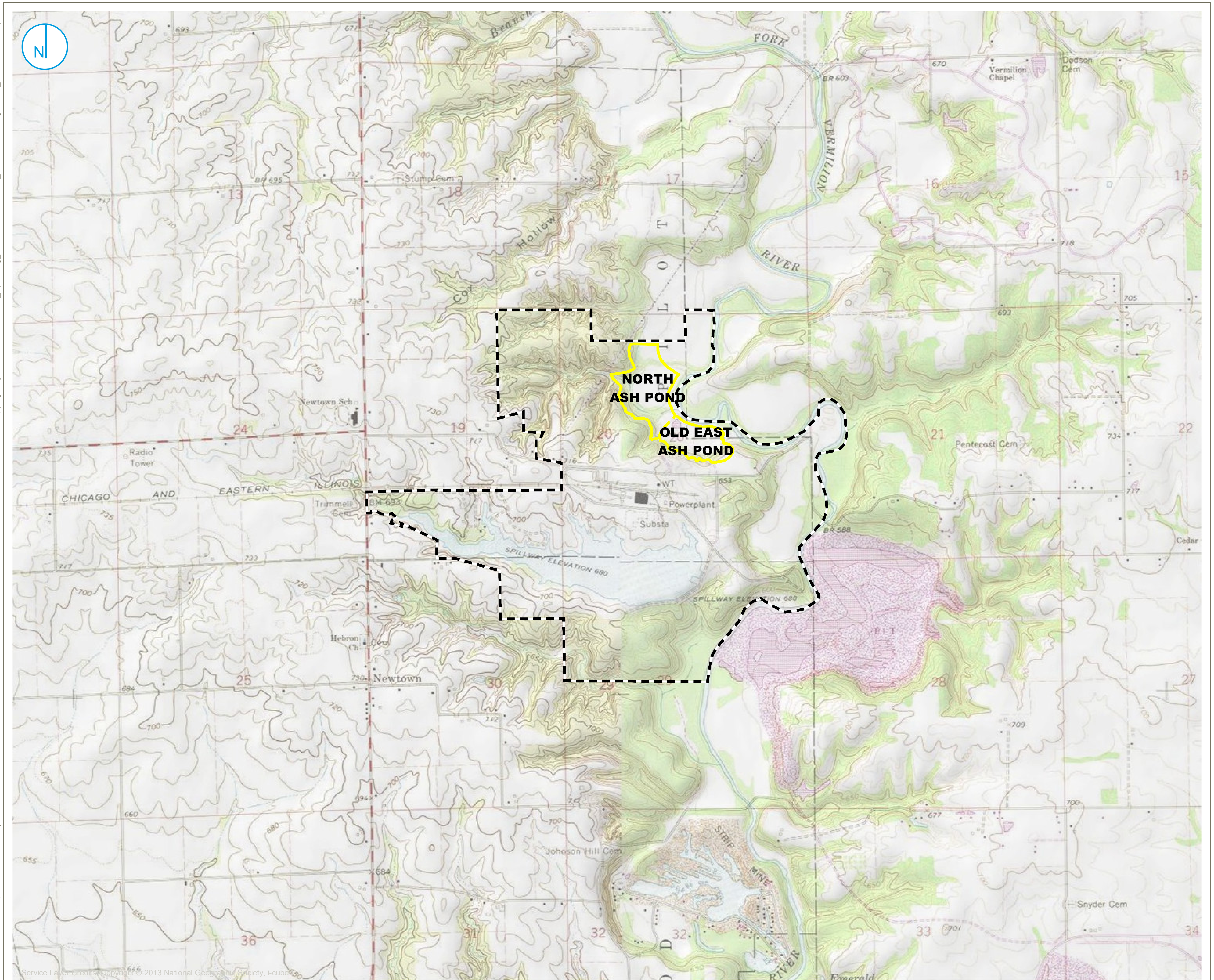
**TABLE 6-2. PREDICTION MODEL INPUT VALUES**

GROUNDWATER MODELING REPORT
VERMILION POWER PLANT
NORTH ASH POND AND OLD EAST ASH POND
OAKWOOD, ILLINOIS

**Notes:**

-- = boundary condition not included in prediction model
CBR-Onsite = CBR utilizing an onsite landfill
CBR-Offsite = CBR utilizing an offsite landfill
CCR = coal combustion residuals
ft/day = feet per day
in/yr = inches per year
mg/L = milligrams per liter
NAP = North Ash Pond
OEAP = Old East Ash Pond
CBR = Closure By Removal
GCT = Groundwater Collection Trench
UCU = Upper Confining Unit
cm/s = centimeters per second

## FIGURES




PART 845 REGULATED UNIT (SUBJECT UNIT)
PROPERTY BOUNDARY

0 1,000 2,000 Feet

DRAFT

## SITE LOCATION MAP

**GROUNDWATER MODELING REPORT**
**NORTH ASH POND AND OLD EAST ASH POND**
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

## FIGURE 1-1

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

RAMBOLL

Y:\Mapping\Projects\22\2285\MXD\845_Operating_Permit\Vermilion\NAP_OEAP\GWMR\Figure 1-1_Site Location Map.mxd

PROJECT: 169000XXXX | DATED: 11/1/2021 | DESIGNER: STOLZSD


PART 845 REGULATED UNIT (SUBJECT UNIT)
SITE FEATURE
PROPERTY BOUNDARY

0 200 400 Feet



## SITE MAP

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

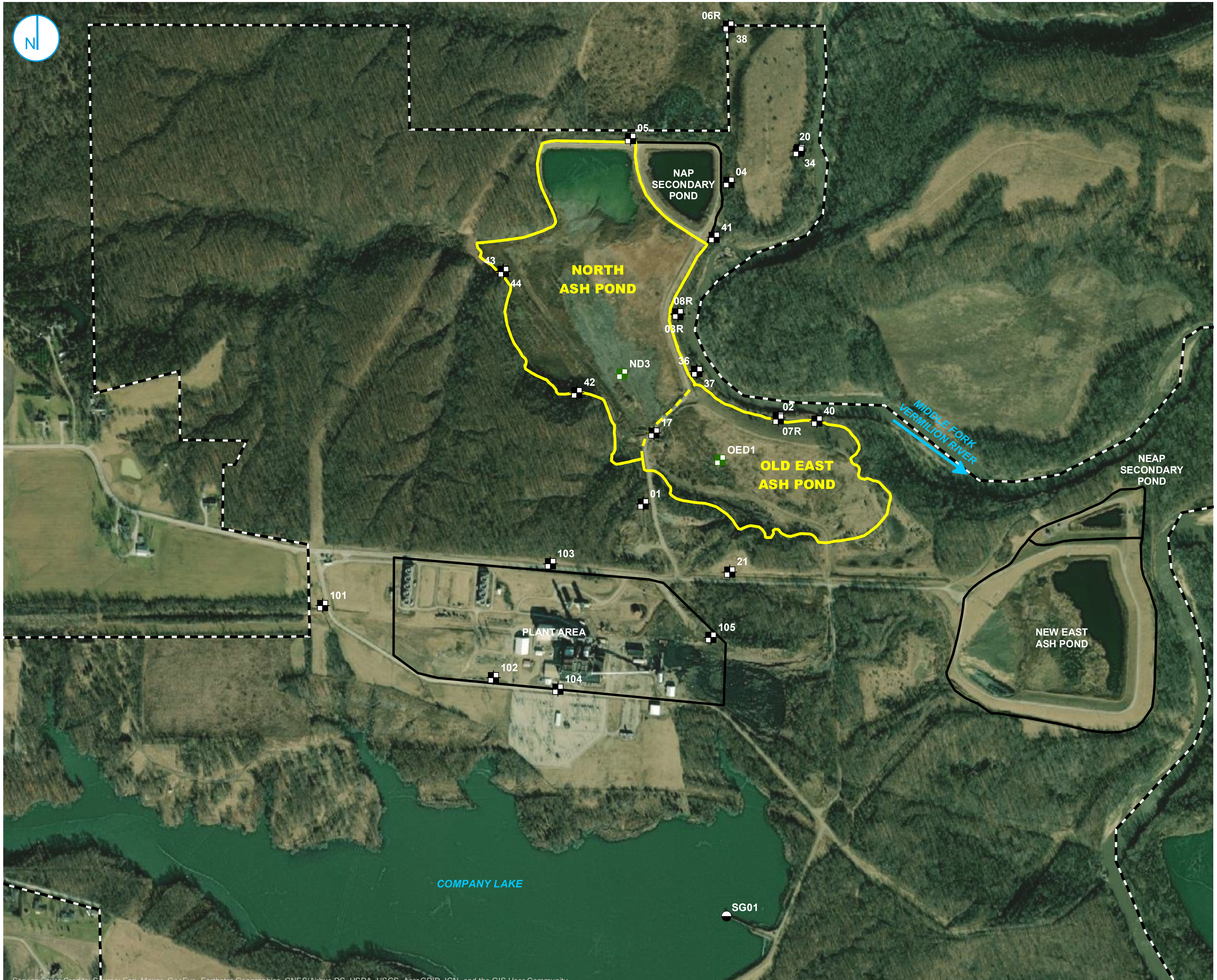
## FIGURE 1-2

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

RAMBOLL

Y:\Mapping\Projects\22\2285\MXD\845_Operating_Permit\Vermilion\NAP_OEAP\GWMR\Figure 1-2_Site Map.mxd

PROJECT: 169000XXXX | DATED: 11/1/2021 | DESIGNER: STOLZSD




MONITORING WELL
SOURCE SAMPLE
STAFF GAGE
PART 845 REGULATED UNIT (SUBJECT
SITE FEATURE
PROPERTY

0 300 600 Feet



## MONITORING WELL LOCATION MAP

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

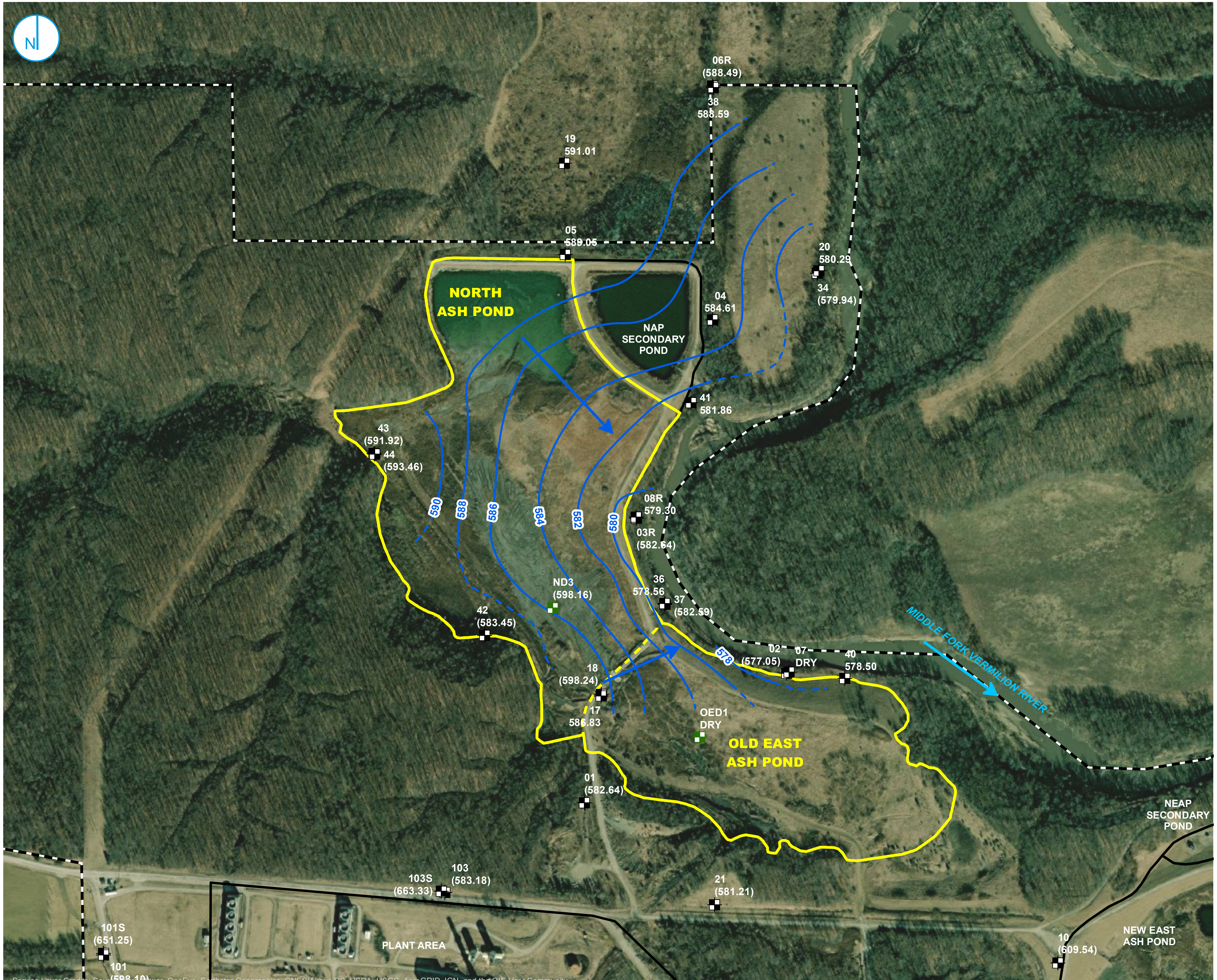
## FIGURE 2-1

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

RAMBOLL

Y:\Mapping\Projects\2222285\MXD\845_Operating_Permit\Vermilion\NAP_OEAP\GWMR\Figure 2-1_Monitoring Well Location Map.mxd

PROJECT: 169000XXXX | DATED: 11/1/2021 | DESIGNER: STOLZSD




MONITORING WELL

SOURCE SAMPLE LOCATION

GROUNDWATER ELEVATION CONTOUR (2-FT CONTOUR INTERVAL, NAVD88)

INFERRED GROUNDWATER ELEVATION CONTOUR

GROUNDWATER FLOW DIRECTION

PART 845 REGULATED UNIT (SUBJECT UNIT)

SITE FEATURE

PROPERTY BOUNDARY

DRAFT

NOTE:
ELEVATIONS IN PARENTHESIS WERE NOT USED FOR CONTOURING.
NM = NOT MEASURED

0 200 400 Feet

## UPPERMOST AQUIFER GROUNDWATER ELEVATION CONTOURS
## MARCH 29, 2021

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

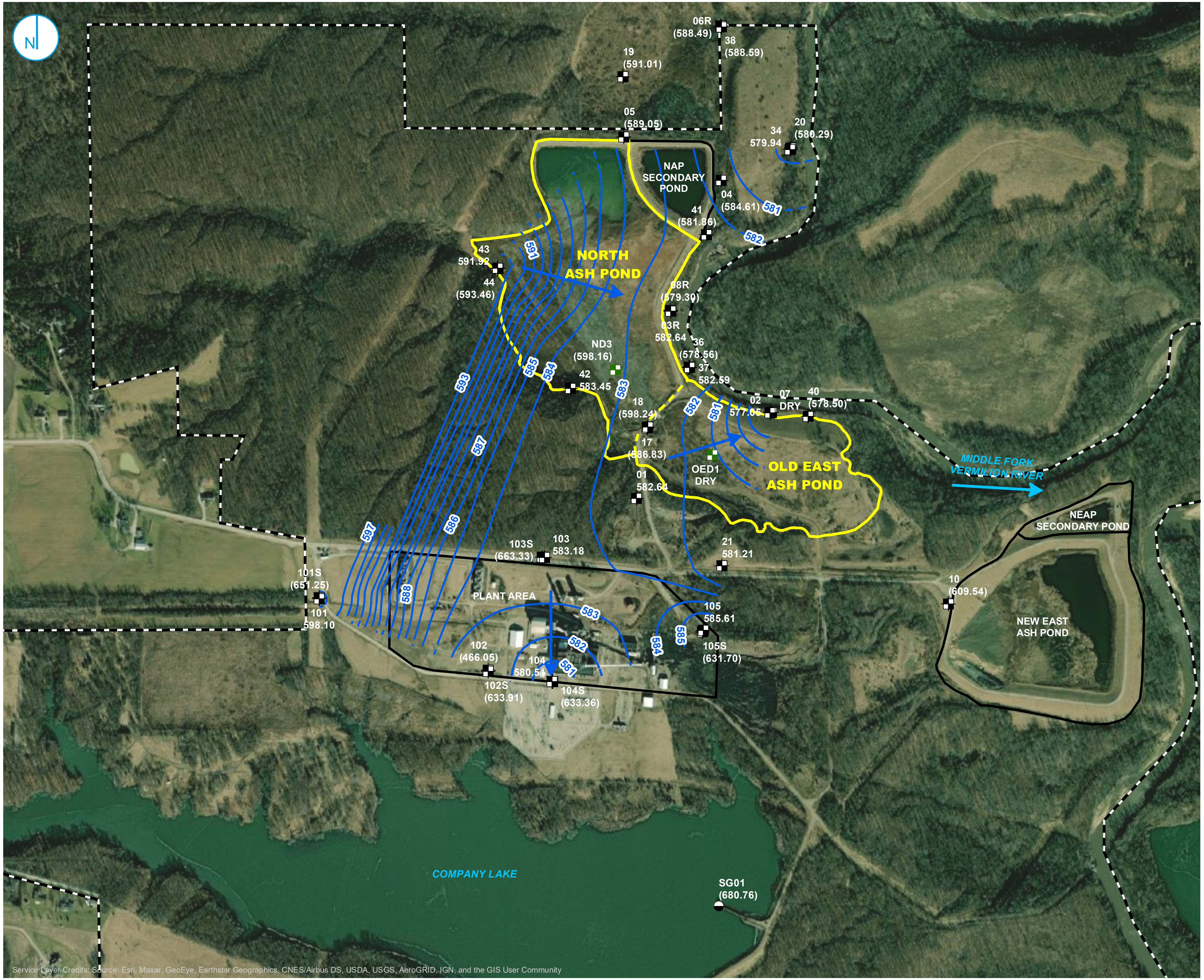
FIGURE 2-2

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

RAMBOLL

Y:\Mapping\Projects\22\2285\MXD\845_Operating_Permit\Vermilion\NAP_OEAP\GWMR\Figure 2-2_UA_GWE Contours_20210329.mxd

PROJECT: 169000XXXX | DATED: 11/1/2021 | DESIGNER: STOLZSD




Y:\Mapping\Projects\22\2285\MXD\845_Operating_Permit\Vermilion\NAP_OEAP\GWMR\Figure 2-3_PMP_GWE Contours_20210329.mxd

PROJECT: 169000XXXX | DATED: 11/1/2021 | DESIGNER: STOLZSD

MONITORING WELL
SOURCE SAMPLE LOCATION
STAFF GAGE
GROUNDWATER ELEVATION CONTOUR (1-FT CONTOUR INTERVAL, NAVD88)
INFERRED GROUNDWATER ELEVATION
GROUNDWATER FLOW
PART 845 REGULATED UNIT (SUBJECT
SITE FEATURE
PROPERTY BOUNDARY

NOTE:
ELEVATIONS IN PARENTHESIS WERE NOT USED FOR CONTOURING.
NM = NOT MEASURED

0 300 600 Feet

DRAFT

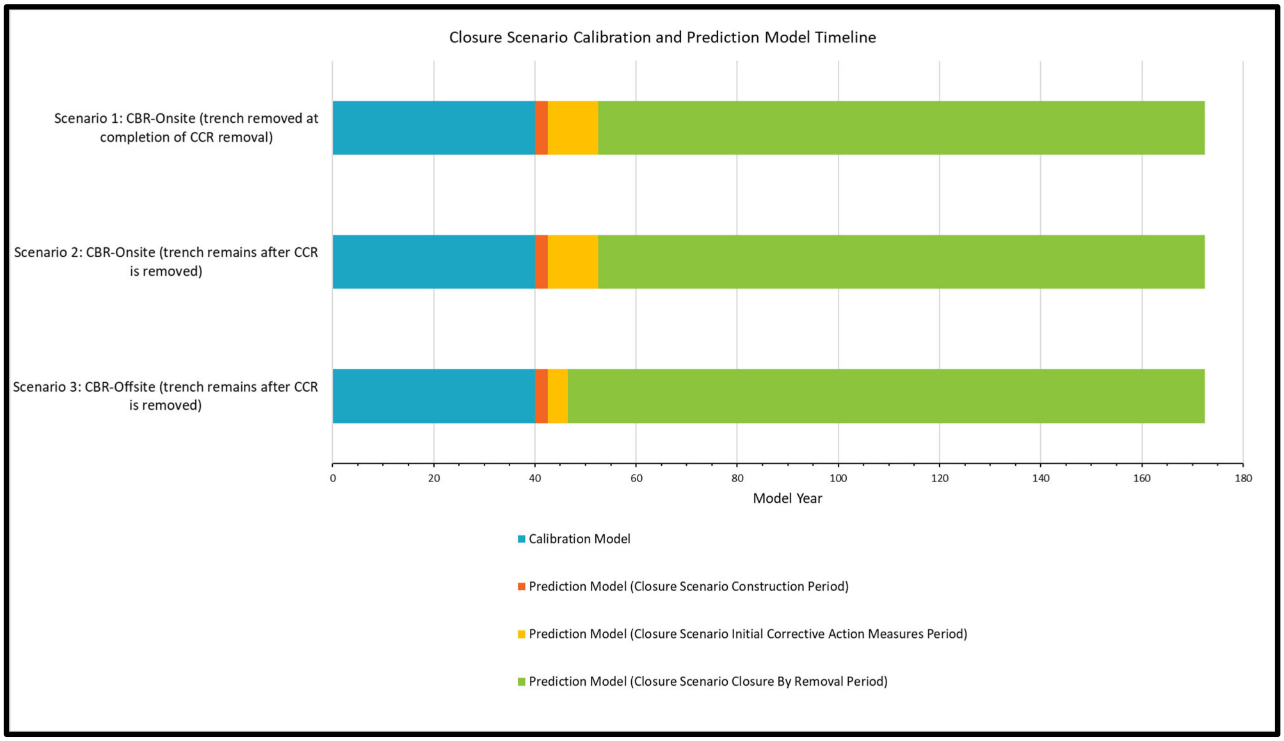
**POTENTIAL MIGRATION PATHWAY GROUNDWATER ELEVATION CONTOURS MARCH 29, 2021**

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

**FIGURE 2-3**

RAMBOLL AMERICAS ENGINEERING SOLUTIONS, INC.

# FIGURE 4-1

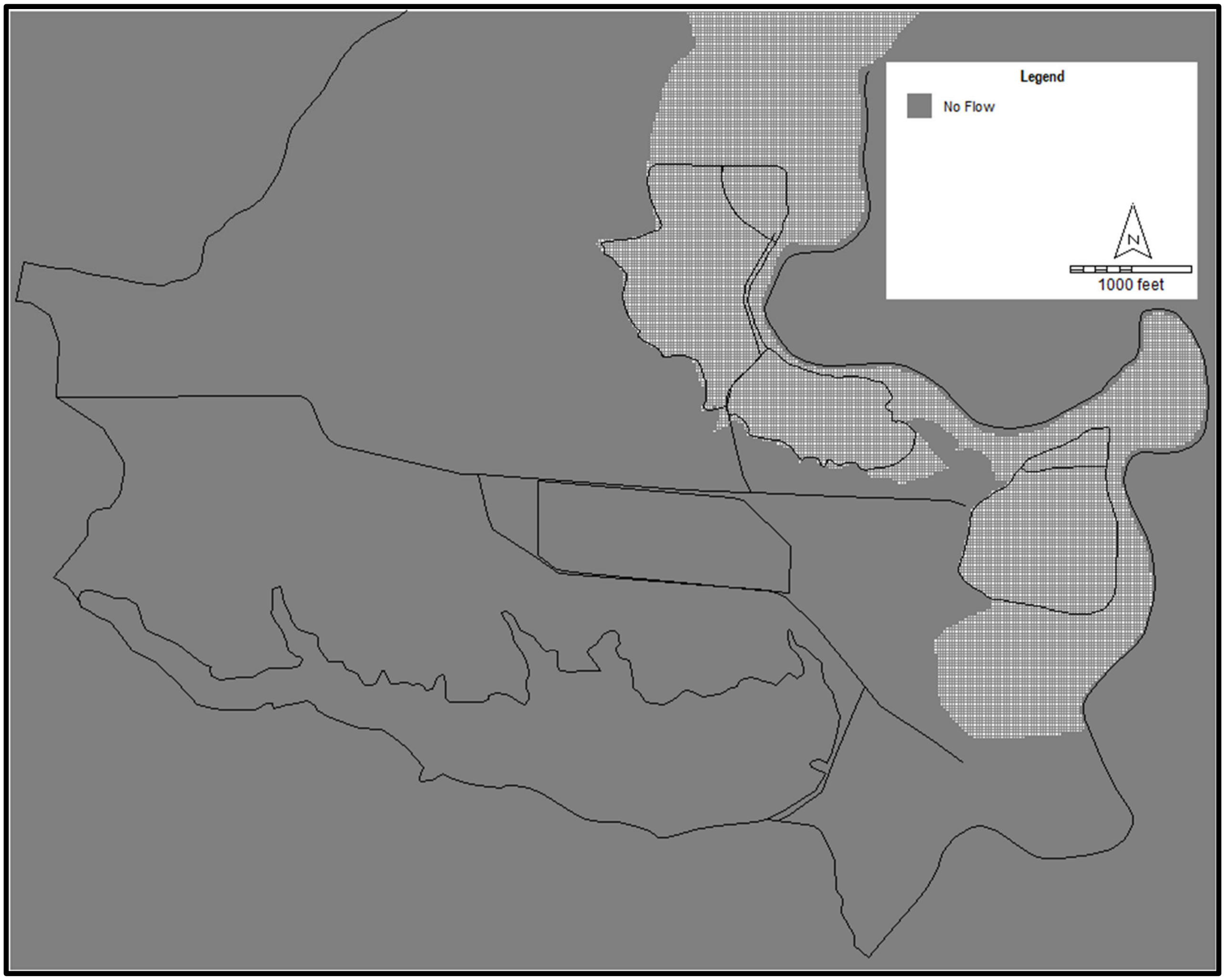



CLOSURE SCENARIO CALIBRATION AND PREDICTION MODEL TIMELINE

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

RAMBOLL

# FIGURE 5-1






MODEL GRID FOR LAYERS 1 THROUGH 3

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

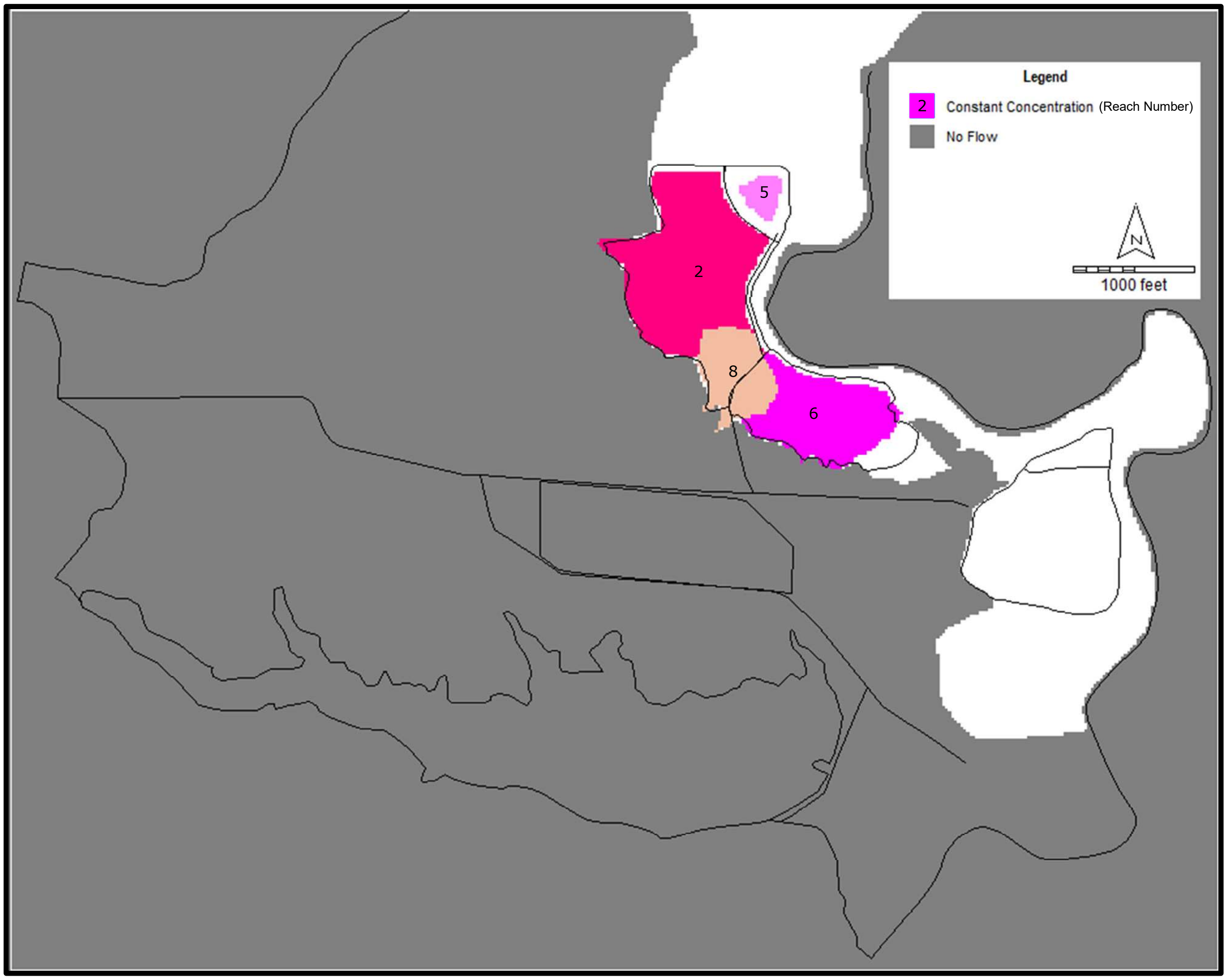
RAMBOLL

FIGURE 5-2


MODEL GRID FOR LAYERS 4 THROUGH 7

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

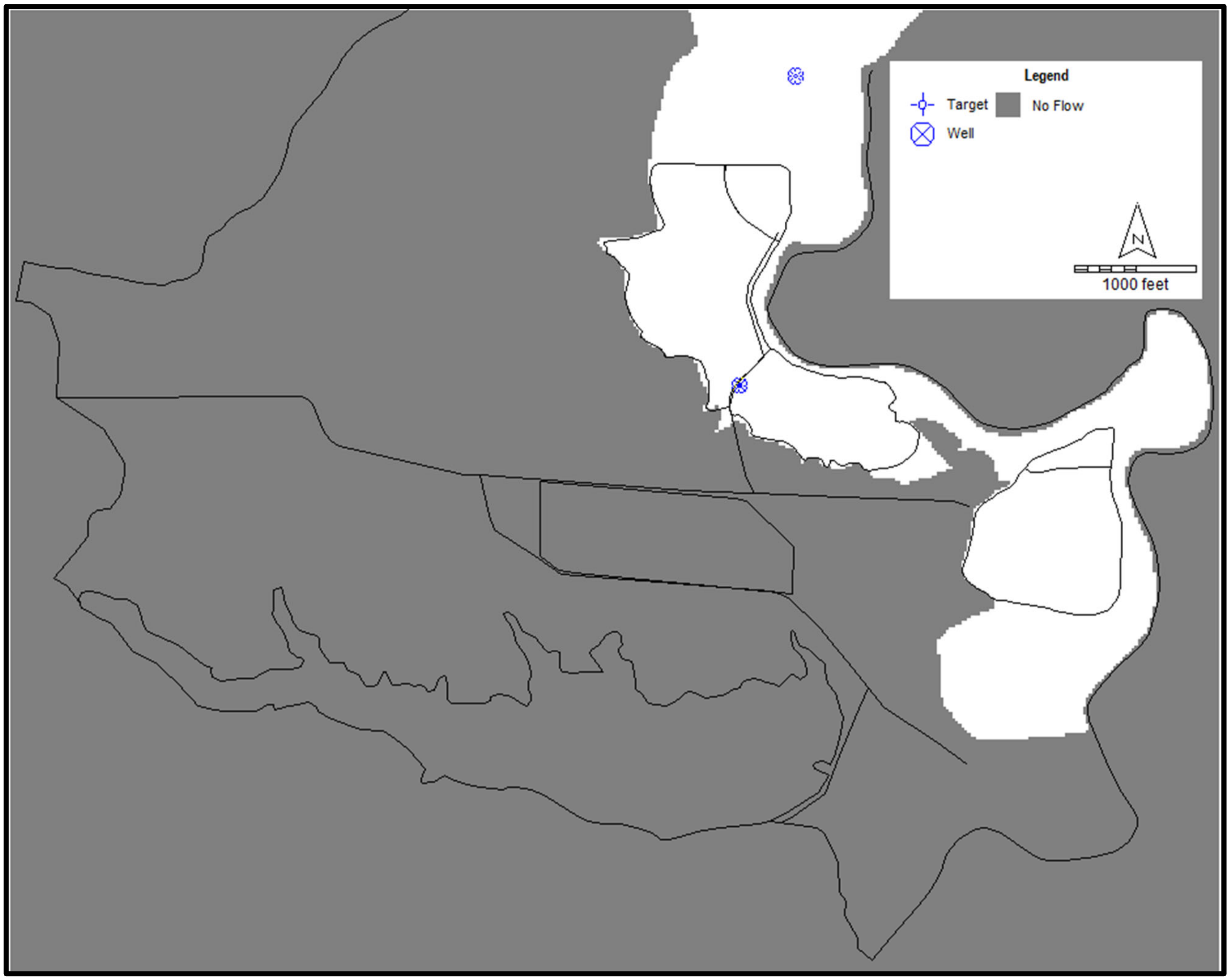
RAMBOLL




BOUNDARY CONDITIONS FOR LAYER 1

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

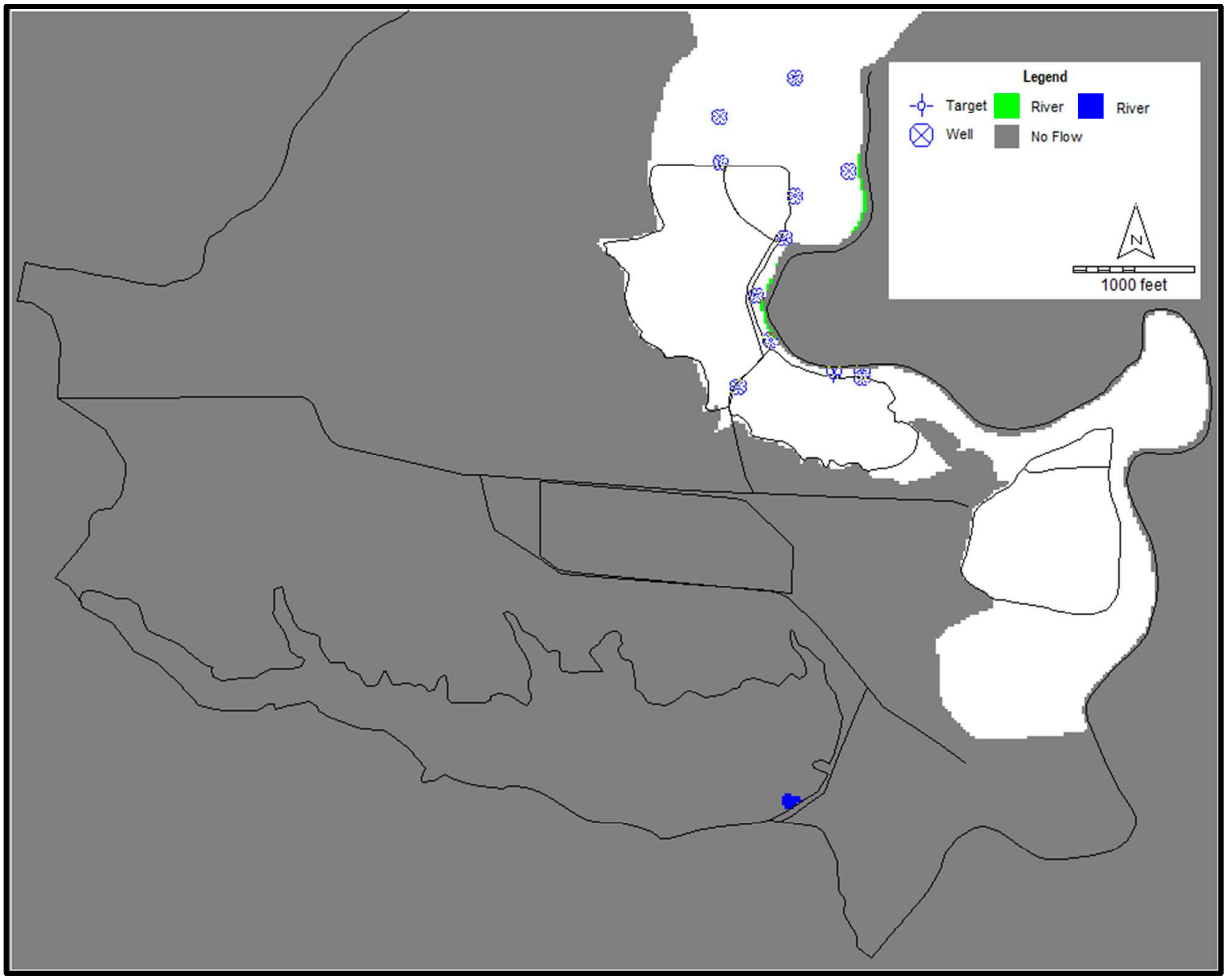
# FIGURE 5-4




BOUNDARY CONDITIONS FOR LAYER 2

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

RAMBOLL

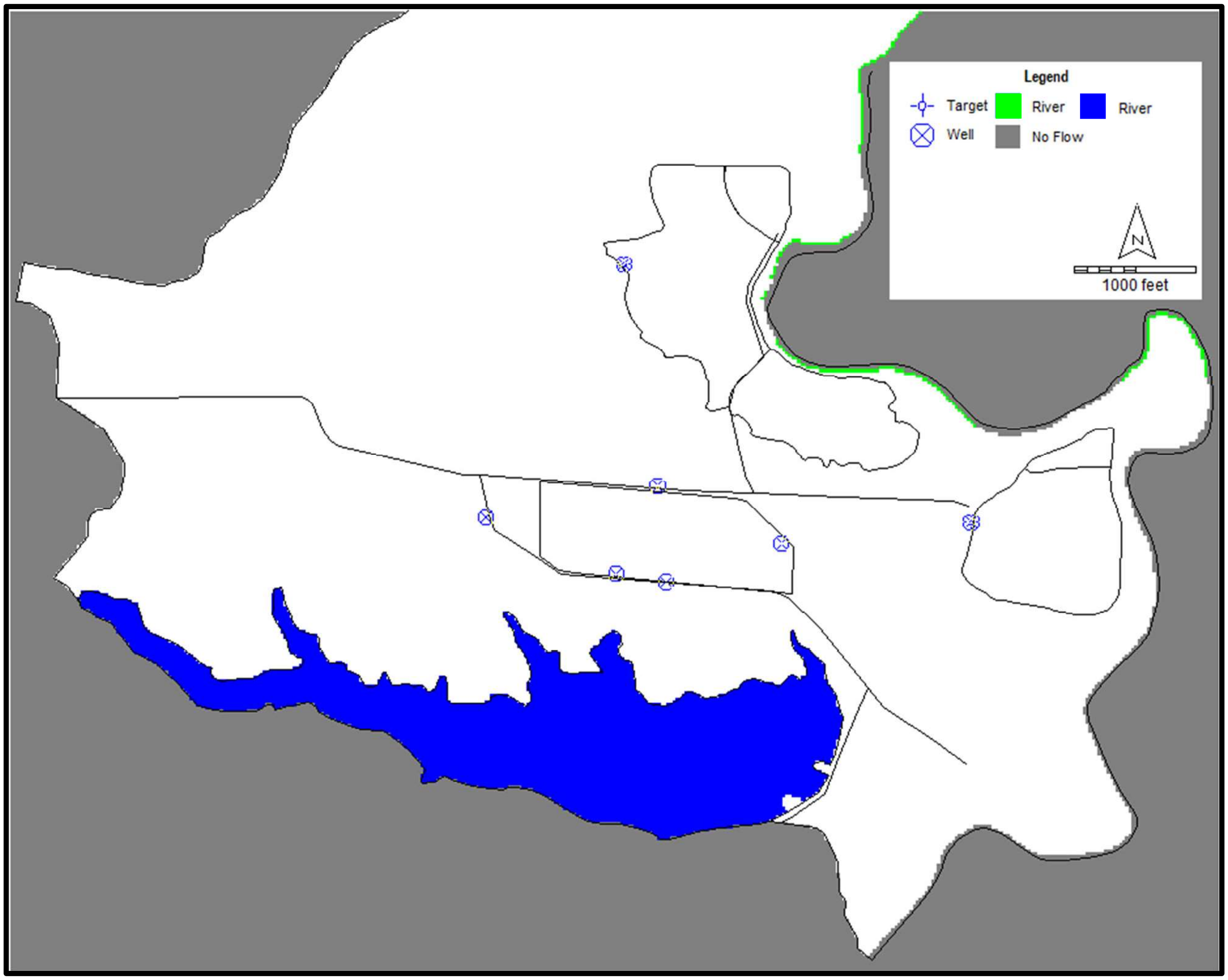





BOUNDARY CONDITIONS FOR LAYER 3

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

RAMBOLL

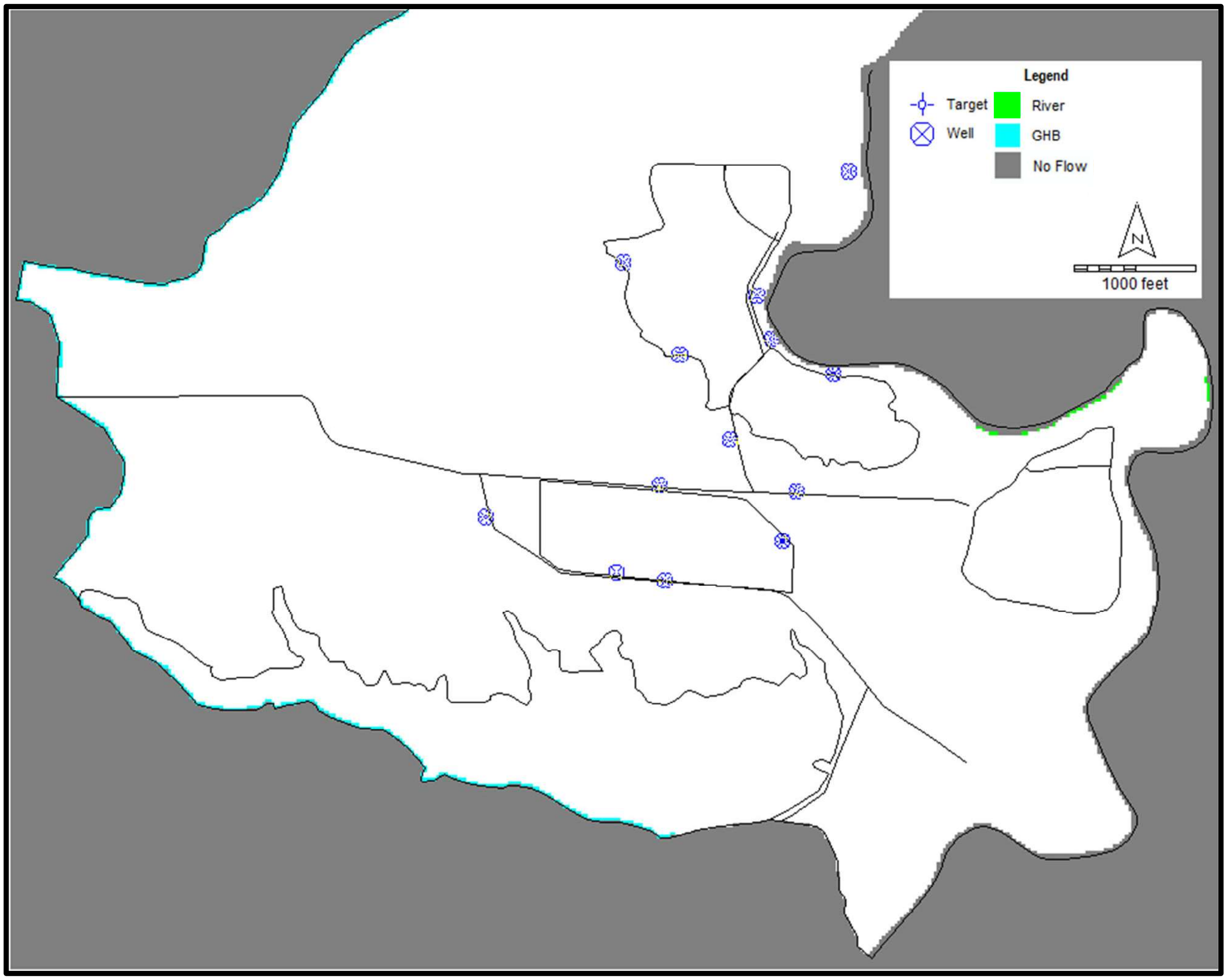



BOUNDARY CONDITIONS FOR LAYER 4

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

RAMBOLL

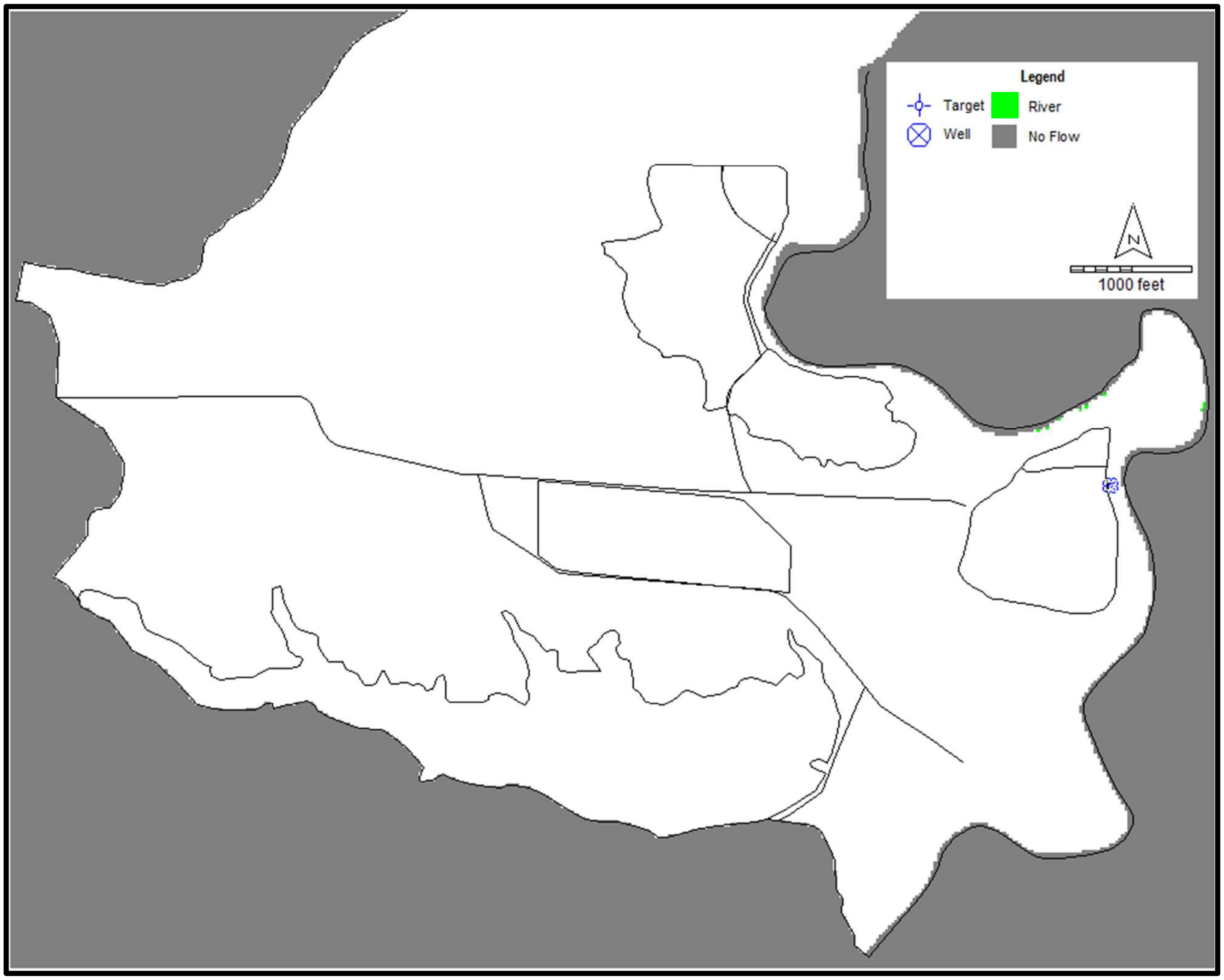
# FIGURE 5-7




BOUNDARY CONDITIONS FOR LAYER 5

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

RAMBOLL

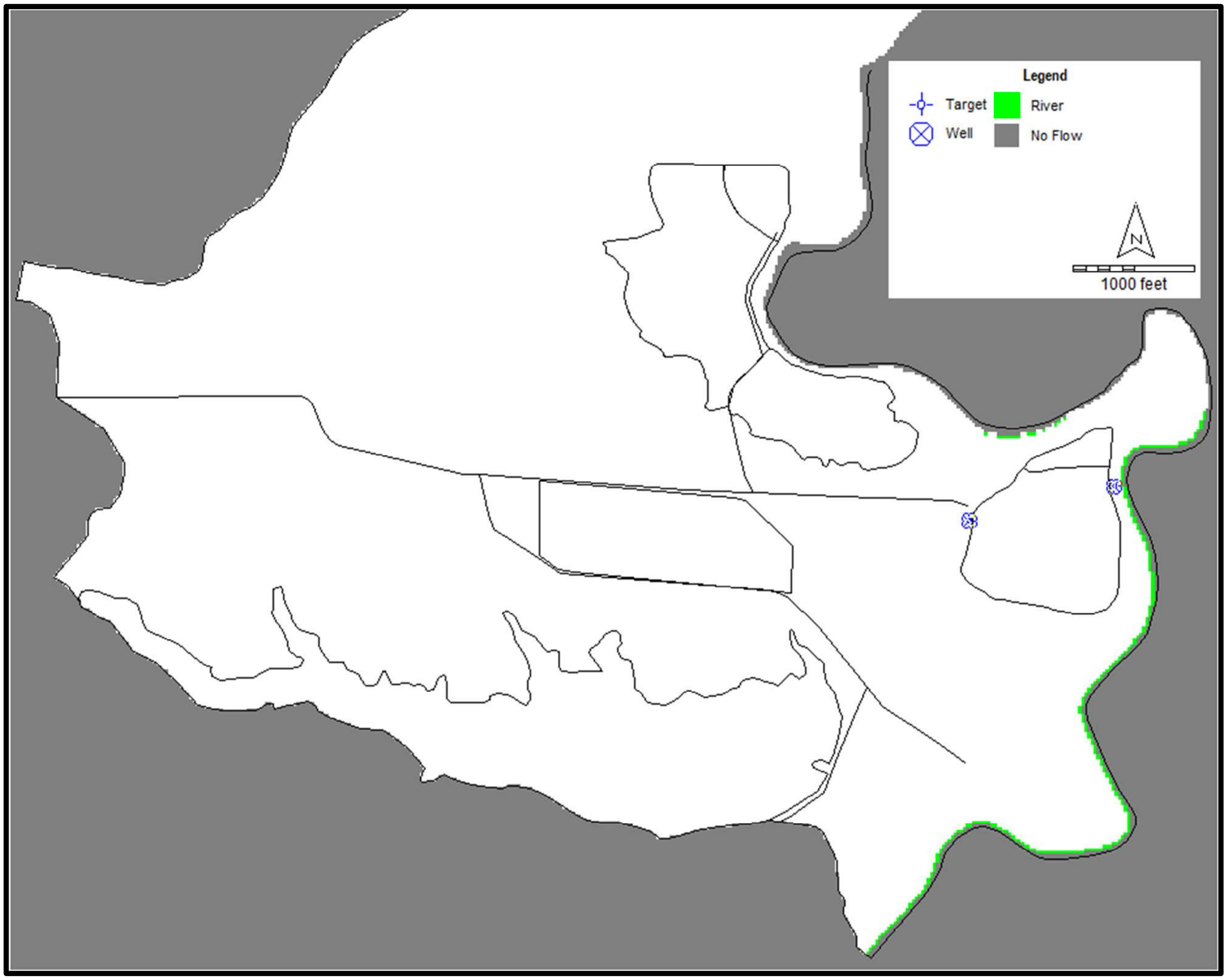



BOUNDARY CONDITIONS FOR LAYER 6

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

RAMBOLL

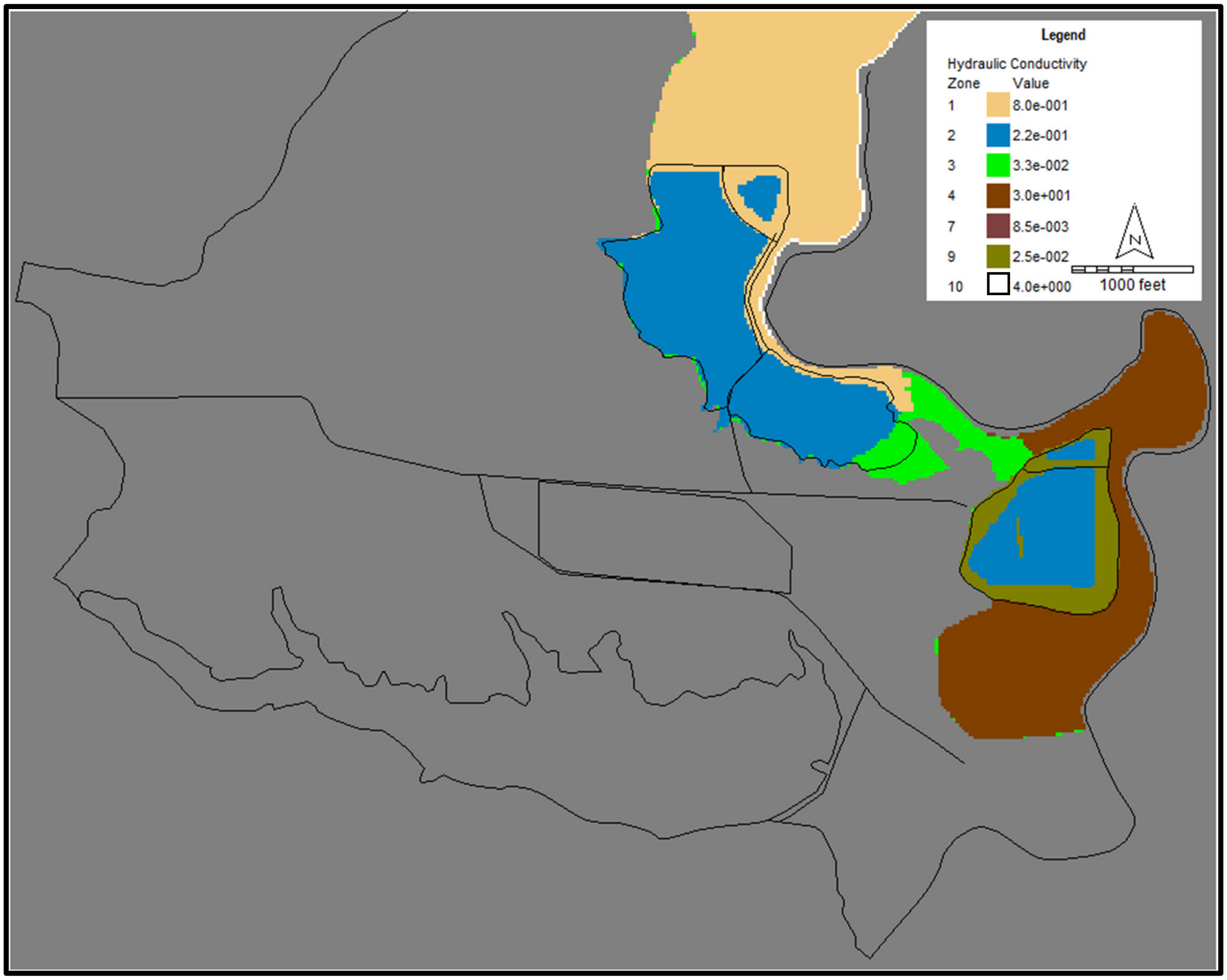
FIGURE 5-9




BOUNDARY CONDITIONS FOR LAYER 7

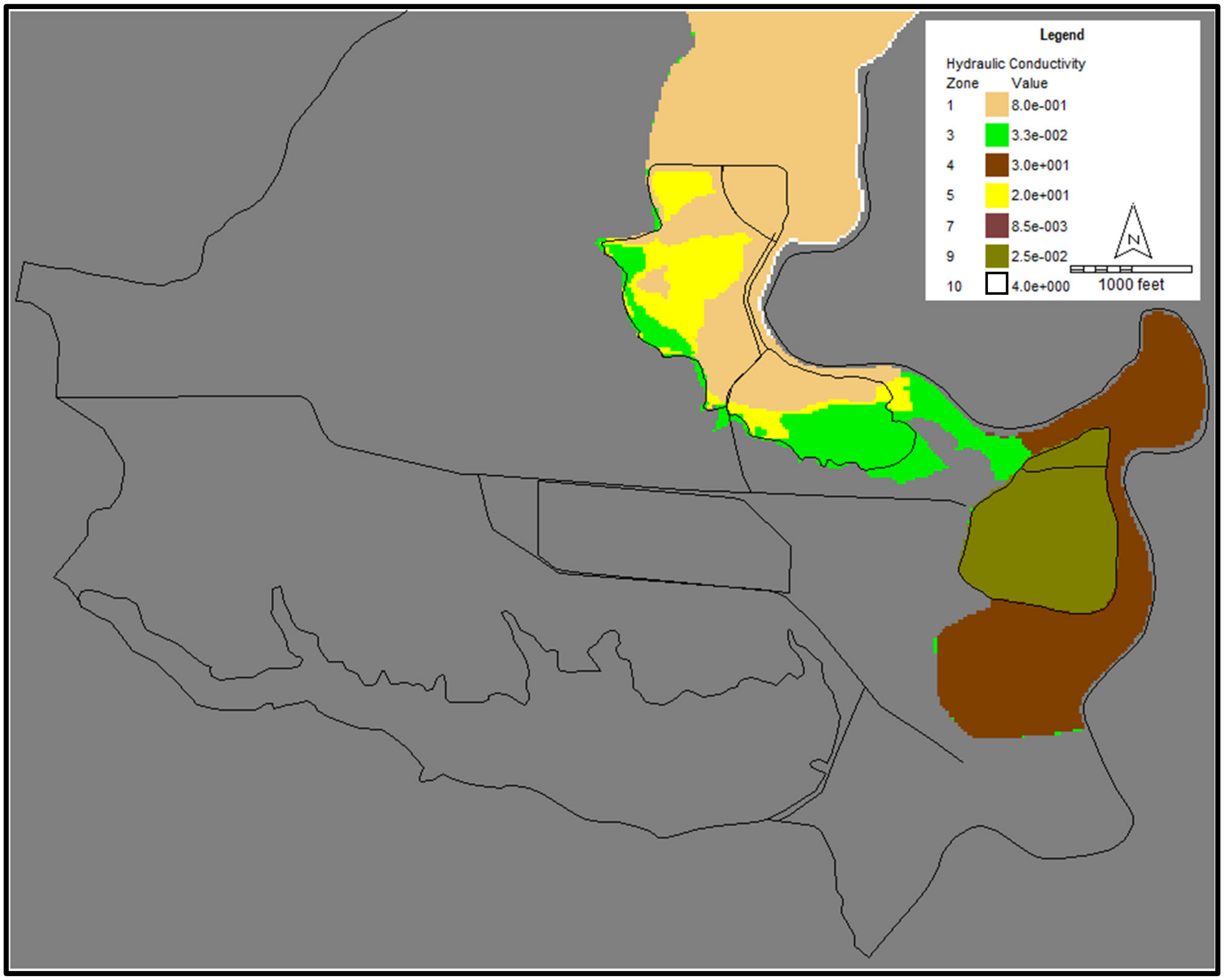
GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

RAMBOLL




DISTRIBUTION OF HYDRAULIC CONDUCTIVITY ZONES (feet/day) FOR LAYER 1

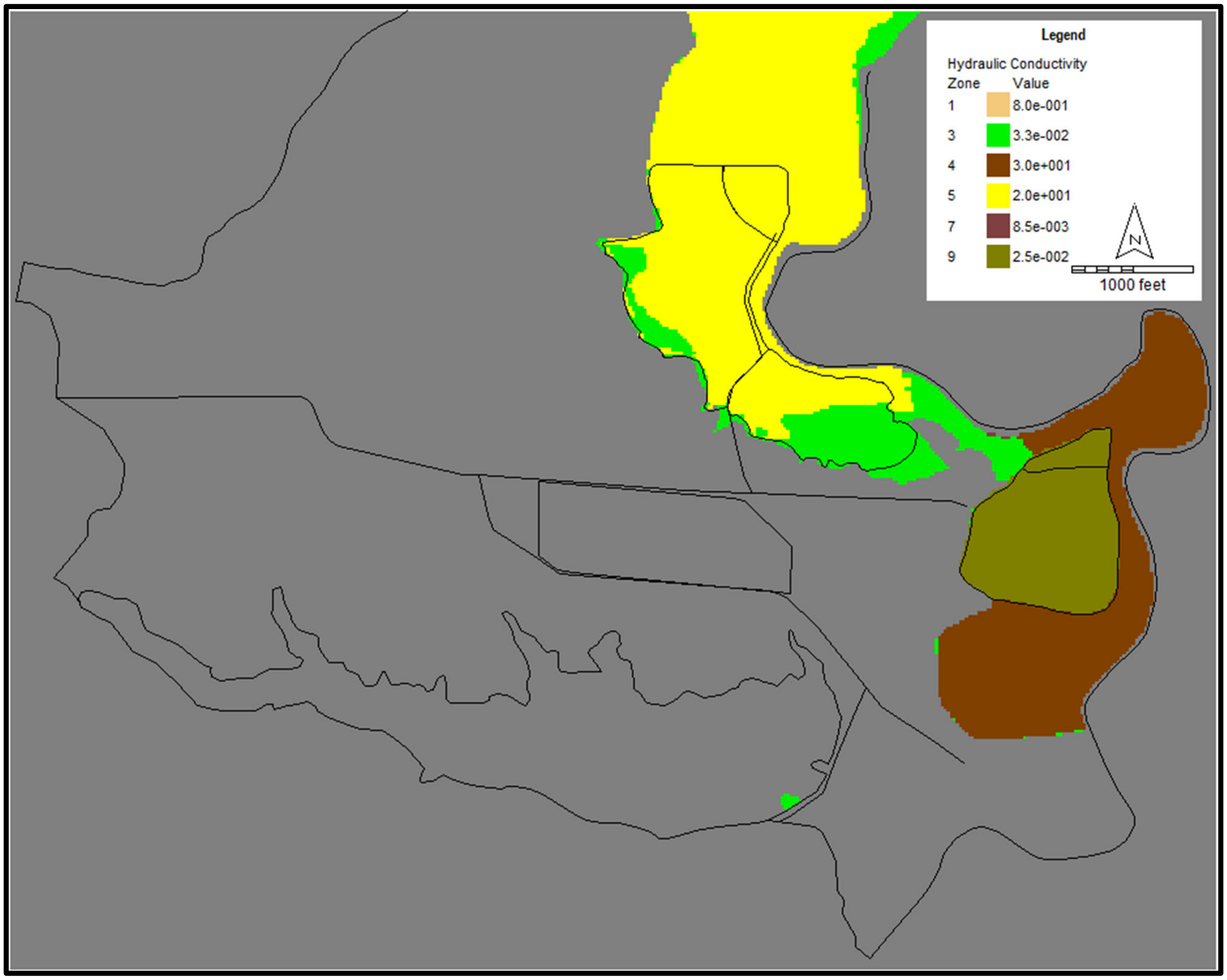
GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS




DISTRIBUTION OF HYDRAULIC CONDUCTIVITY ZONES (feet/day) FOR LAYER 2

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

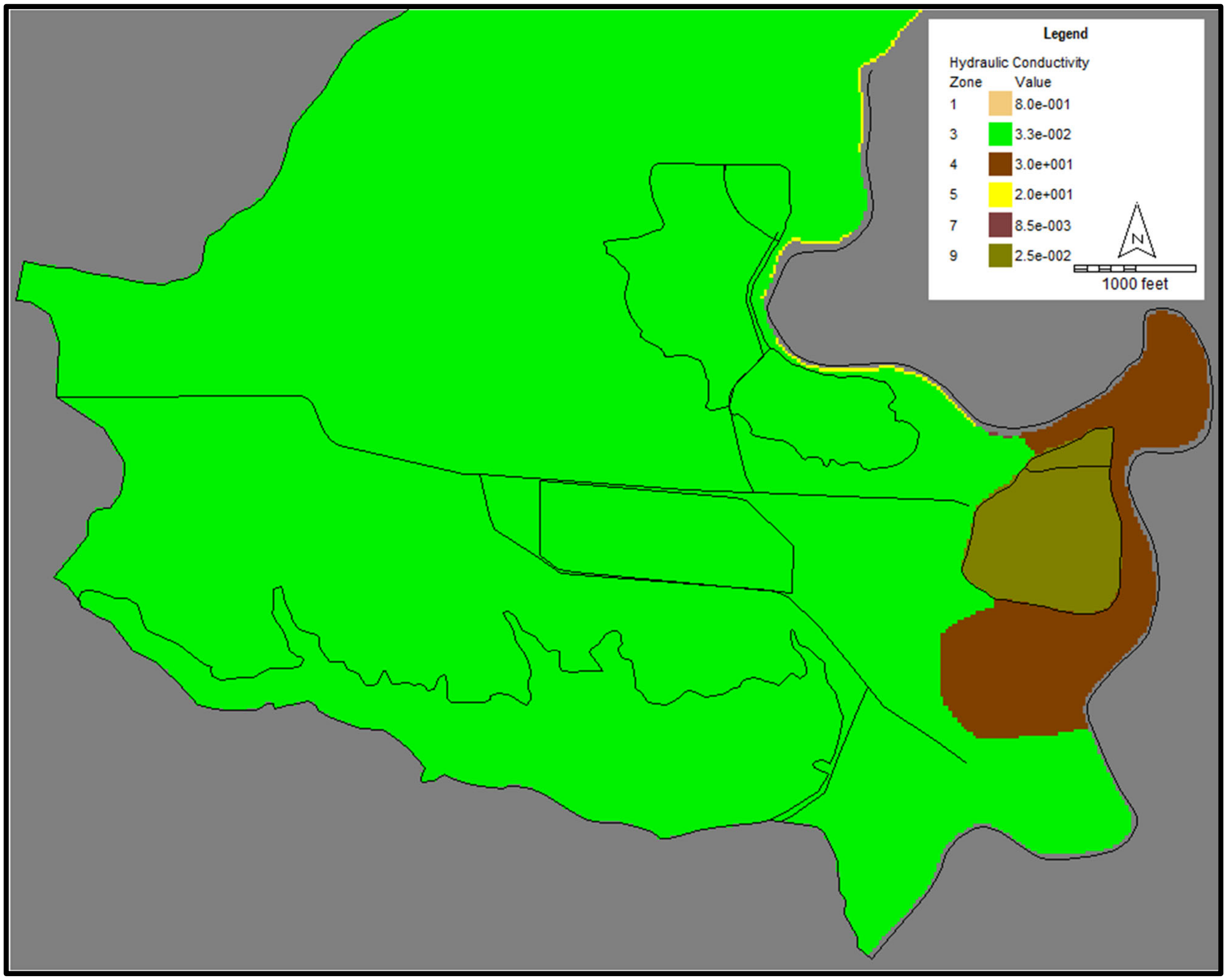
RAMBOLL




DISTRIBUTION OF HYDRAULIC CONDUCTIVITY ZONES (feet/day) FOR LAYER 3

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

RAMBOLL



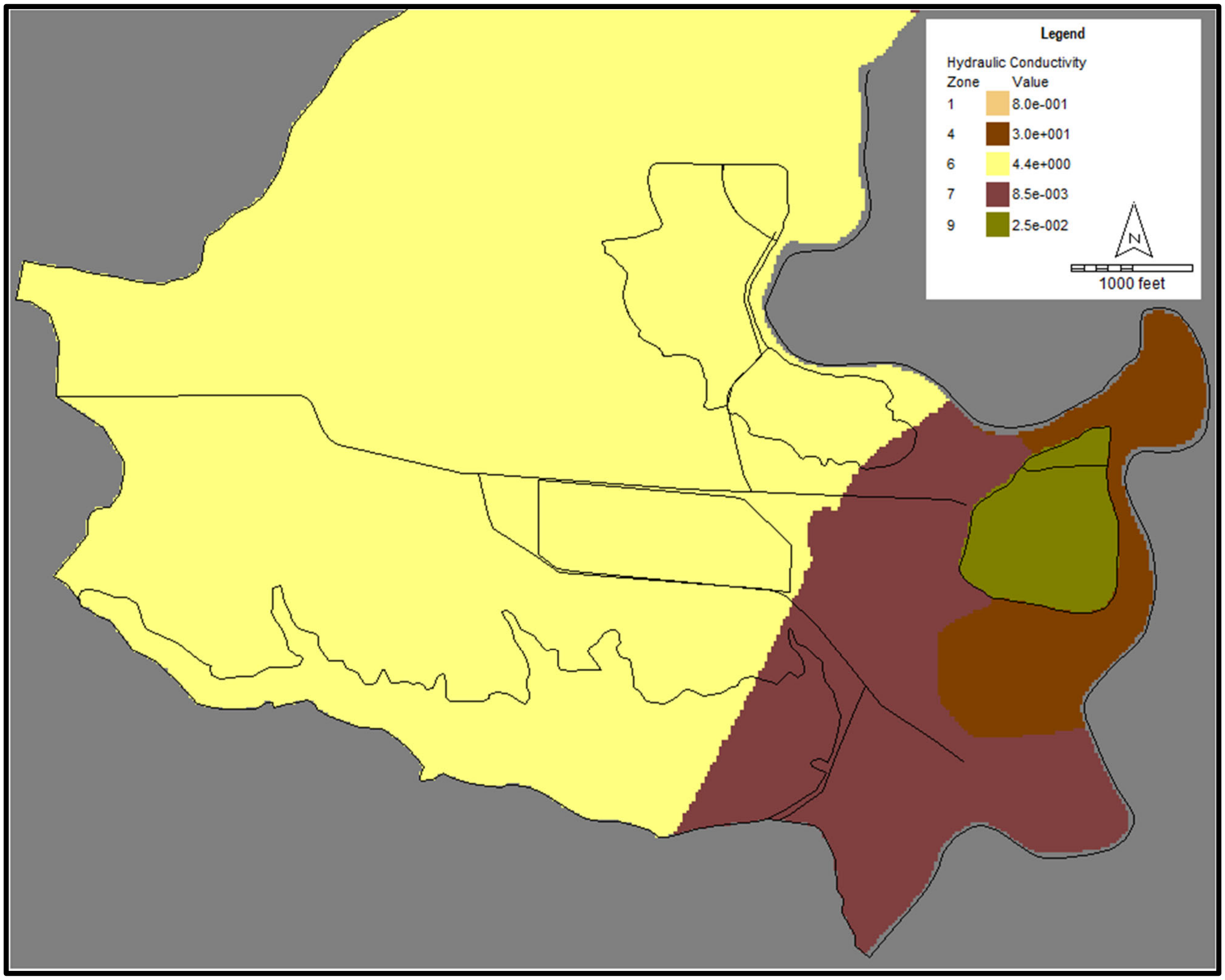



DISTRIBUTION OF HYDRAULIC CONDUCTIVITY ZONES (feet/day) FOR LAYER 4

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

RAMBOLL

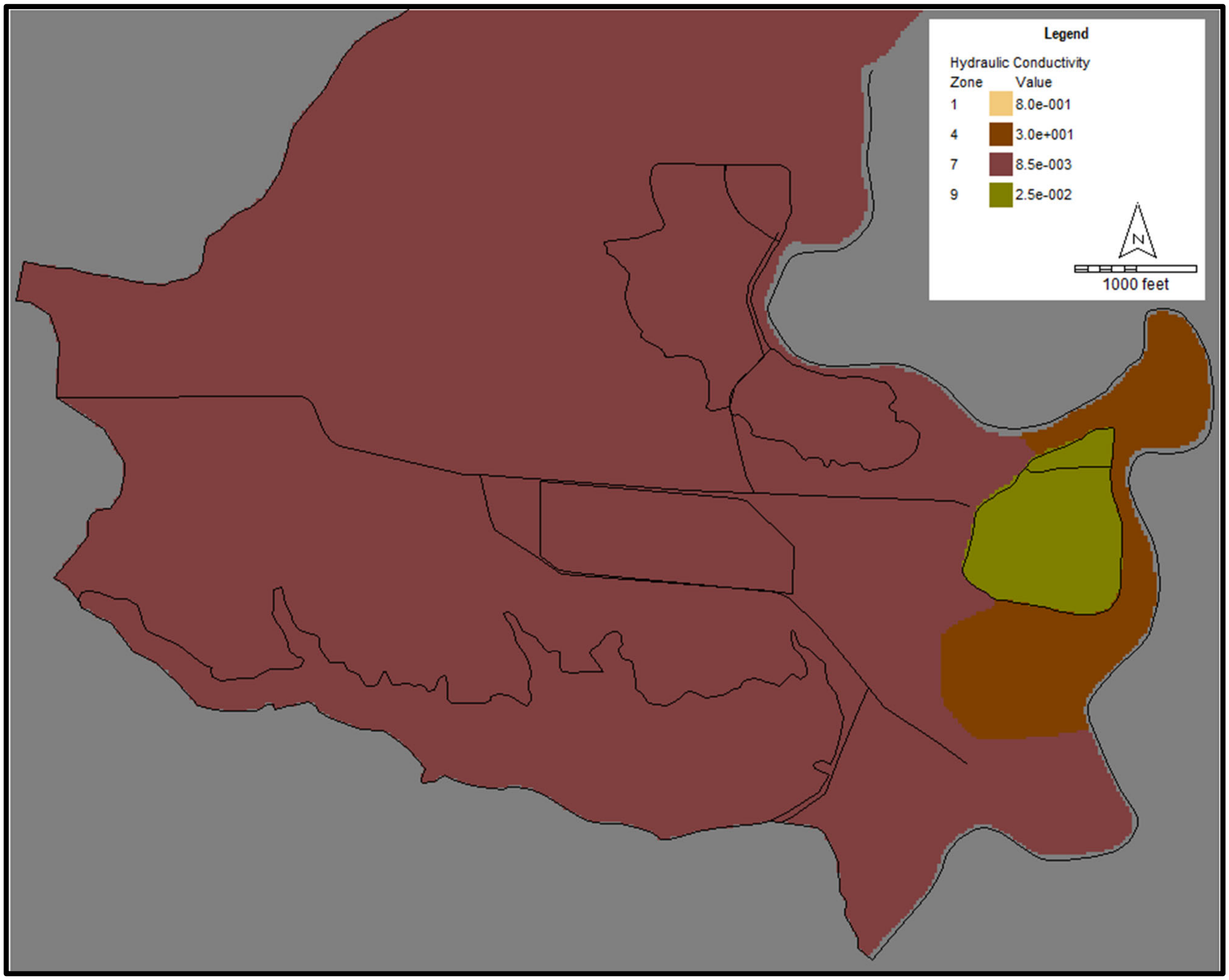
## FIGURE 5-14




DISTRIBUTION OF HYDRAULIC CONDUCTIVITY ZONES (feet/day) FOR LAYER 5

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

RAMBOLL

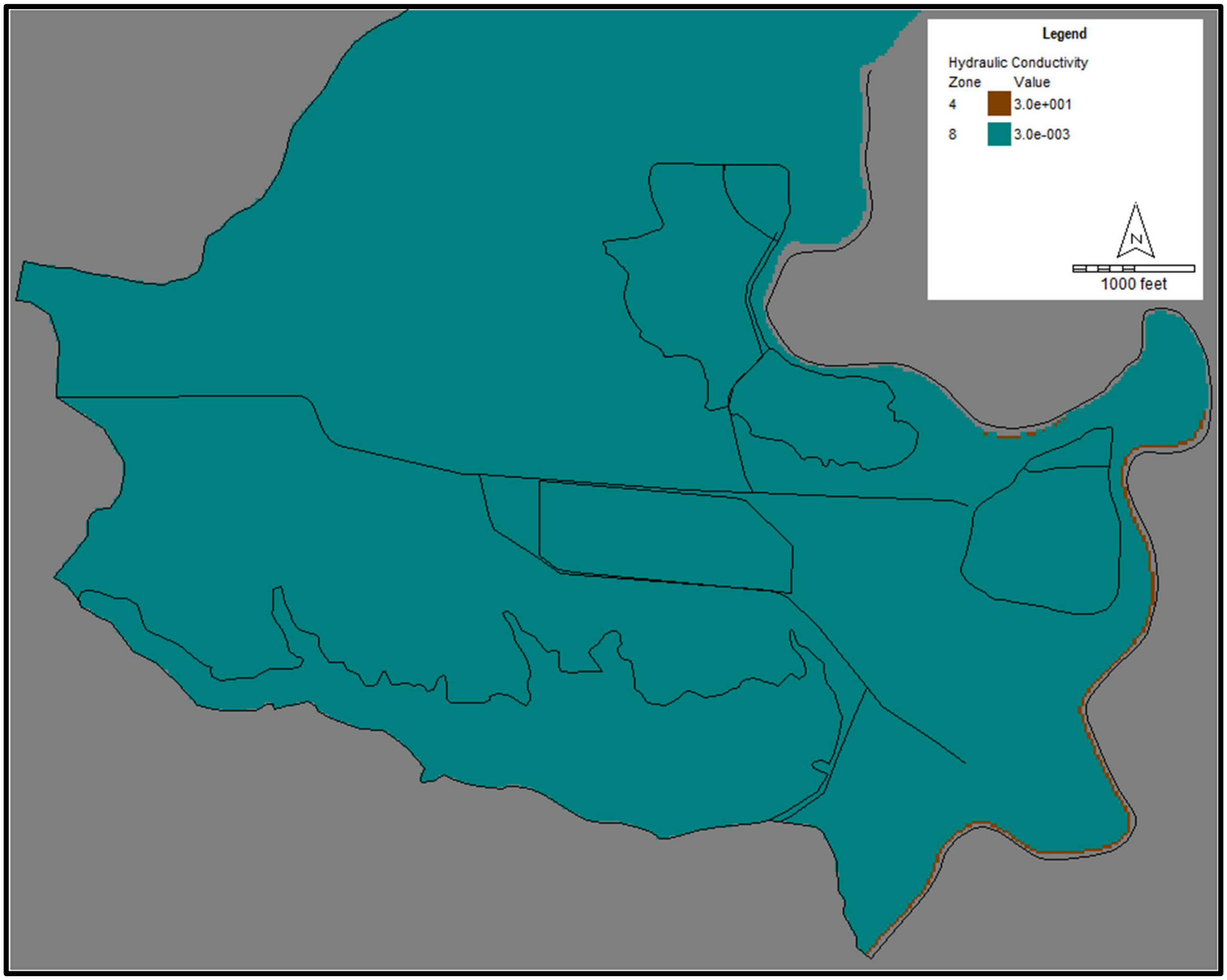





DISTRIBUTION OF HYDRAULIC CONDUCTIVITY ZONES (feet/day) FOR LAYER 6

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

RAMBOLL

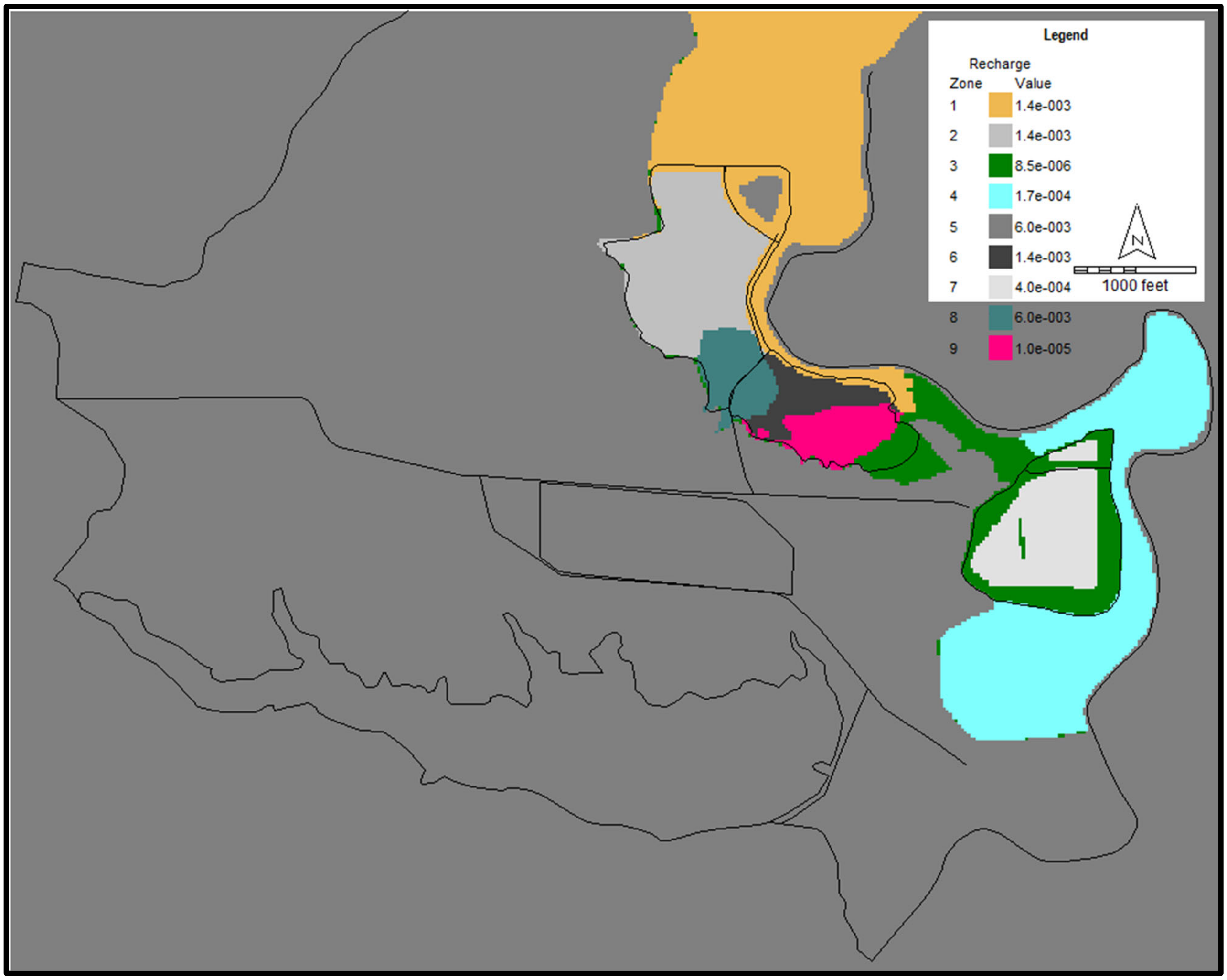



DISTRIBUTION OF HYDRAULIC CONDUCTIVITY ZONES (feet/day) FOR LAYER 7

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

RAMBOLL

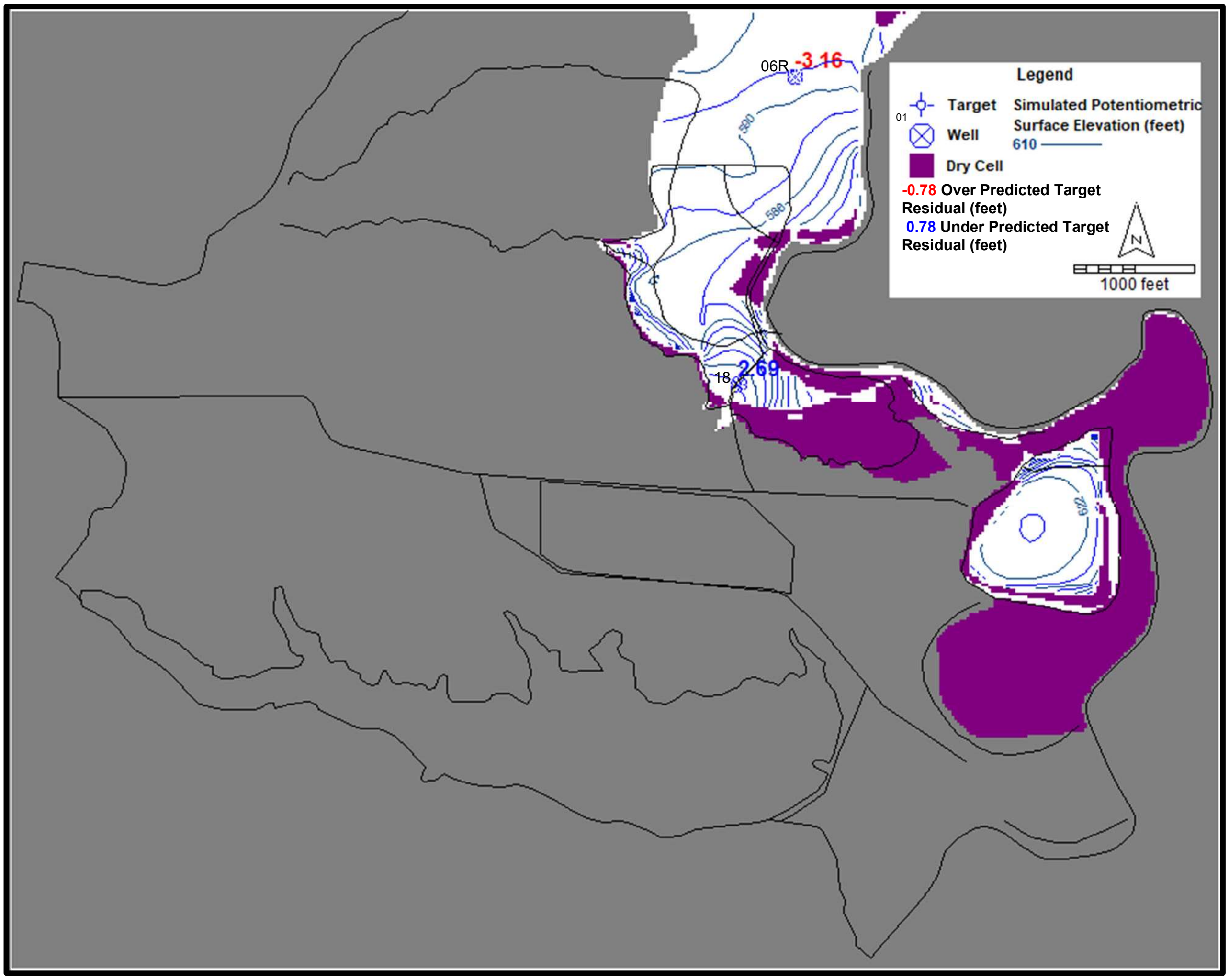
FIGURE 5-17




DISTRIBUTION OF RECHARGE ZONES (feet/day)

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

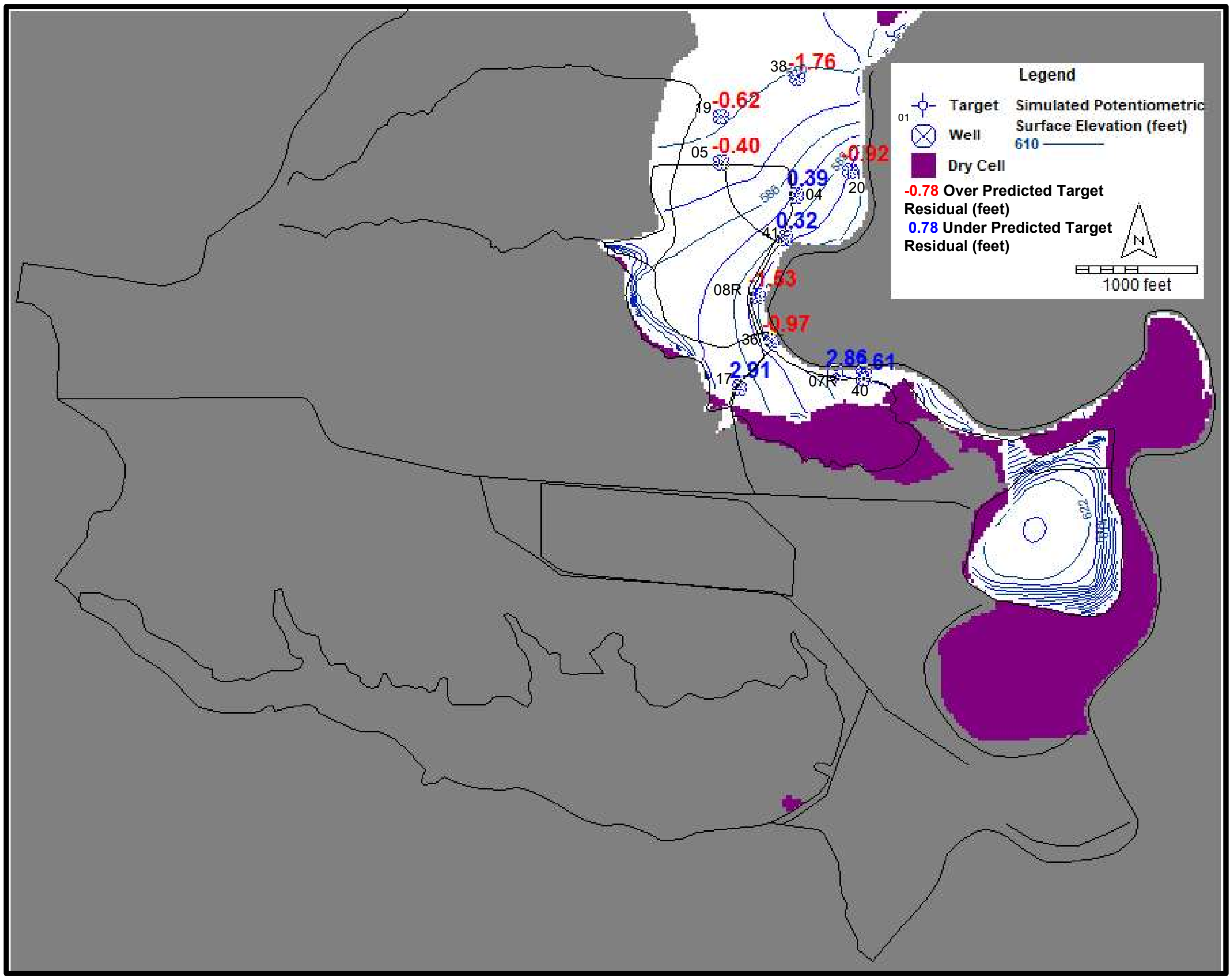
RAMBOLL




OBSERVED VERSUS SIMULATED GROUNDWATER ELEVATIONS LAYER 2

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

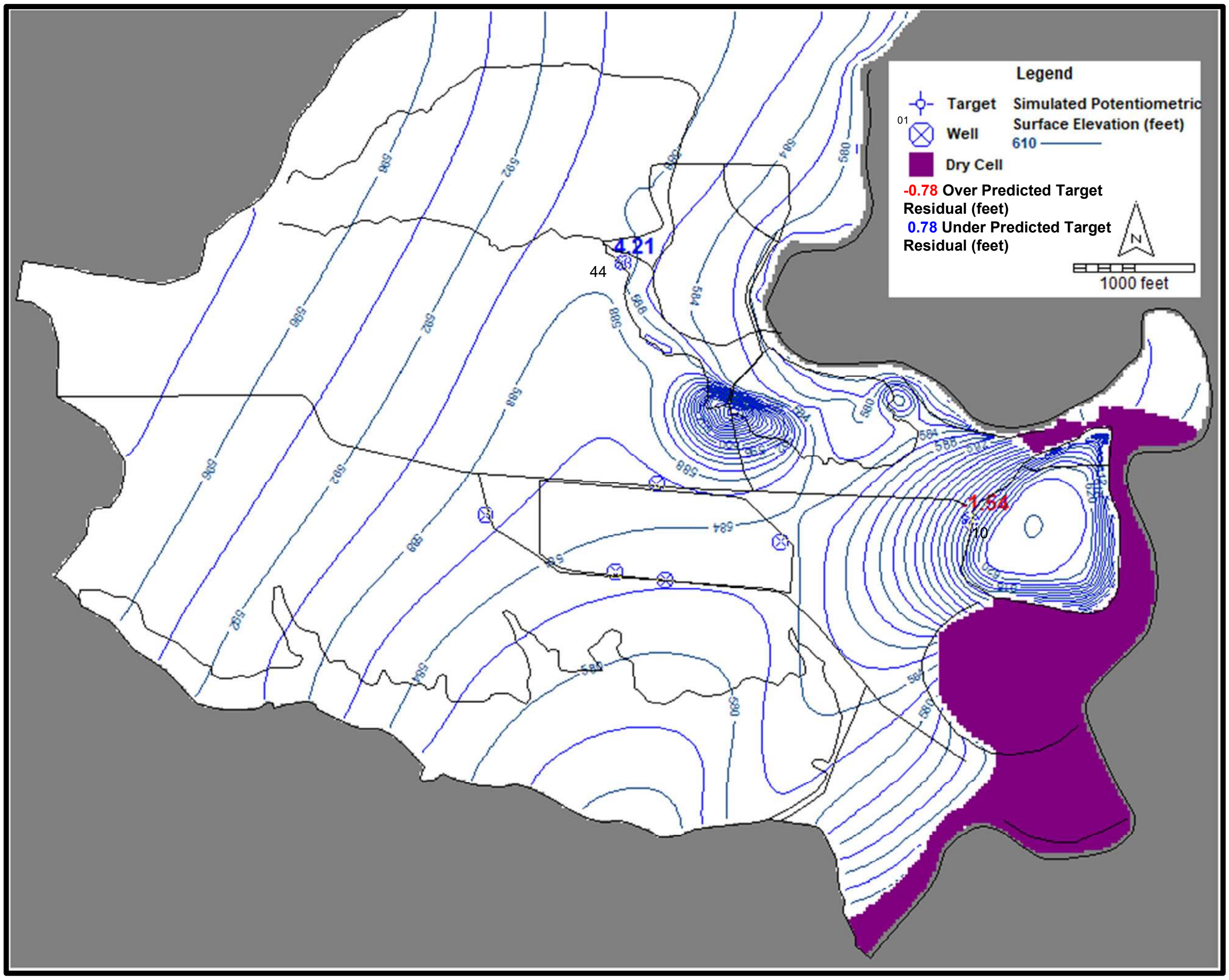
RAMBOLL




OBSERVED VERSUS SIMULATED GROUNDWATER ELEVATIONS LAYER 3

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

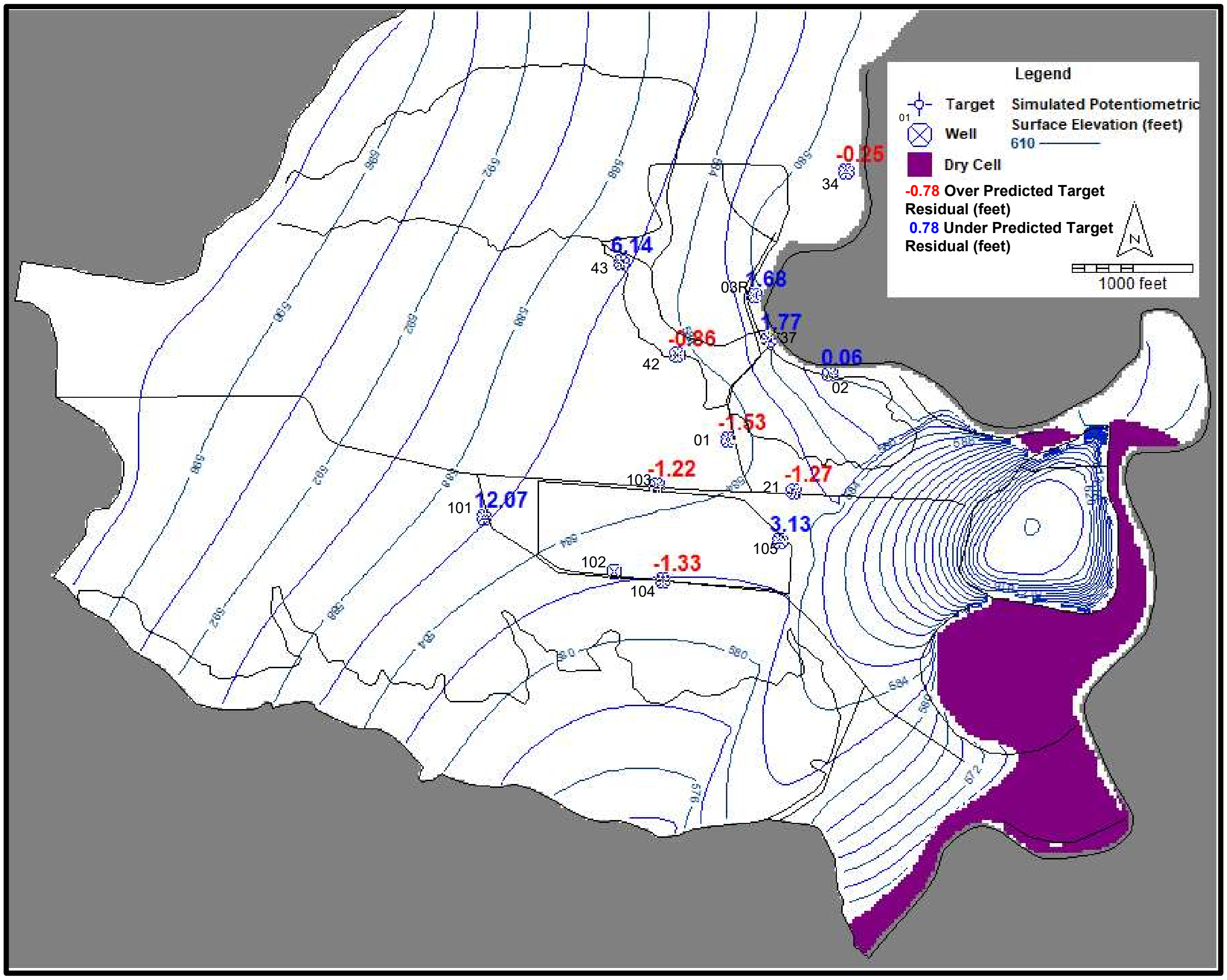
RAMBOLL




OBSERVED VERSUS SIMULATED GROUNDWATER ELEVATIONS LAYER 4

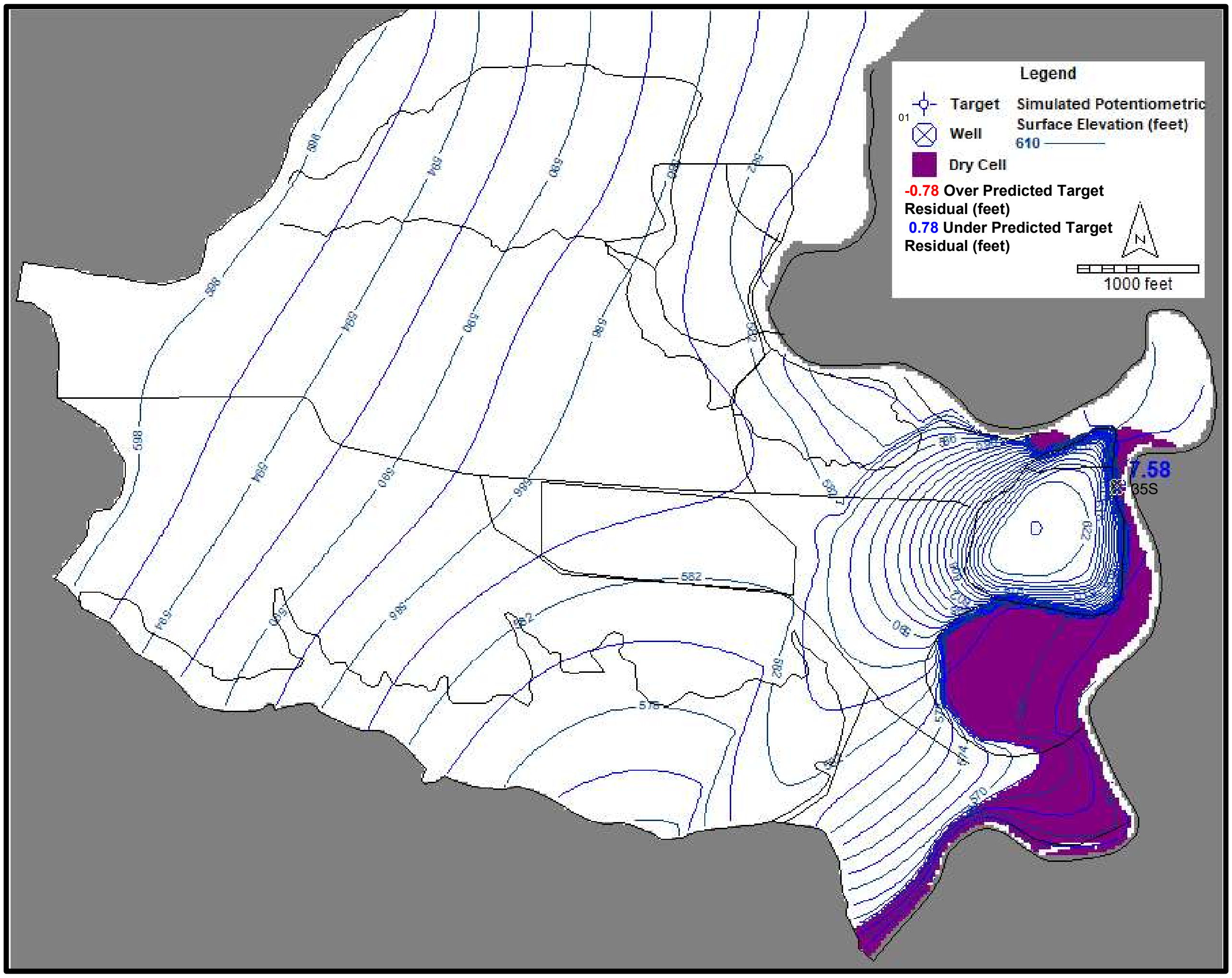
GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

RAMBOLL




OBSERVED VERSUS SIMULATED GROUNDWATER ELEVATIONS LAYER 5

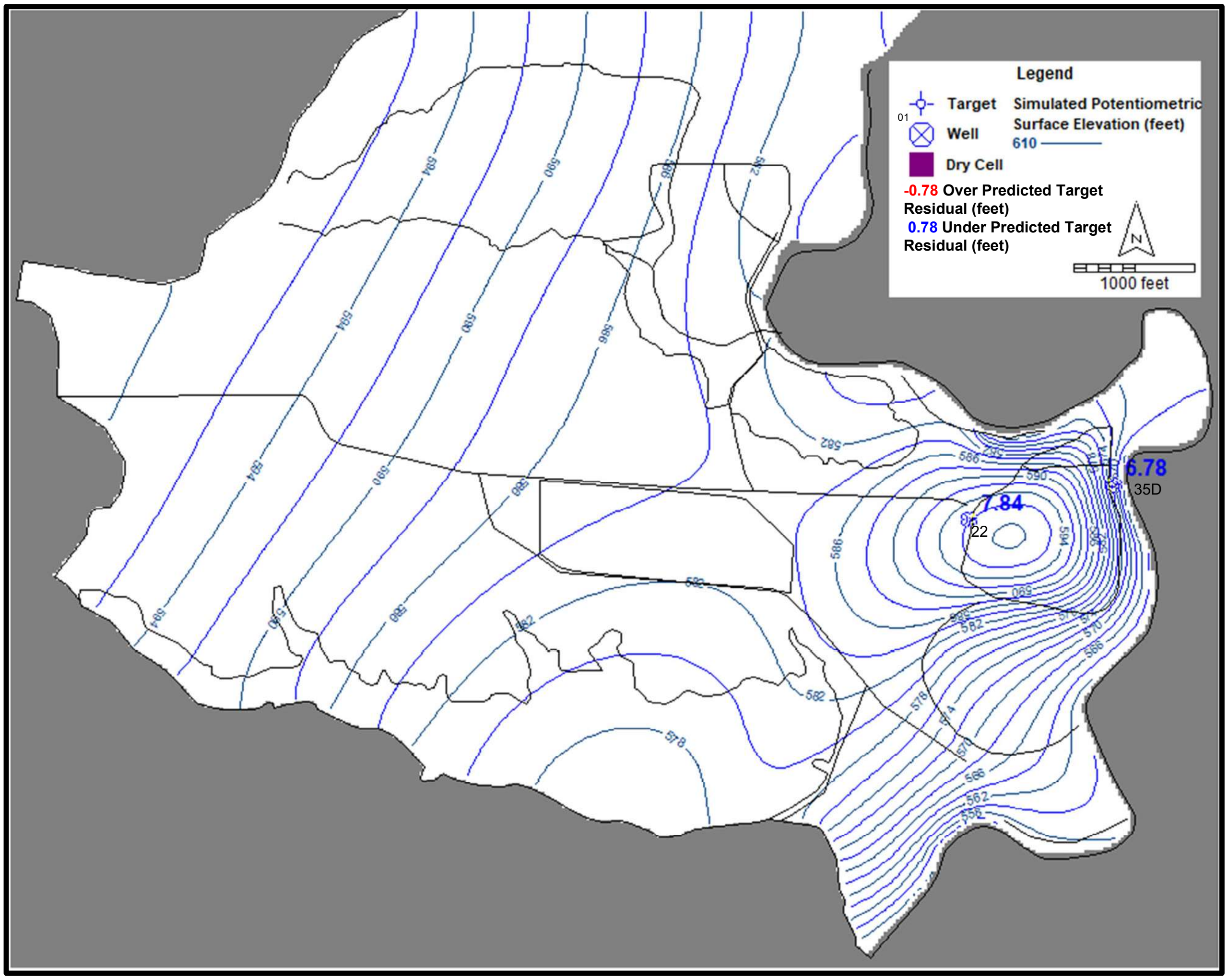
GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS






OBSERVED VERSUS SIMULATED GROUNDWATER ELEVATIONS LAYER 6

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

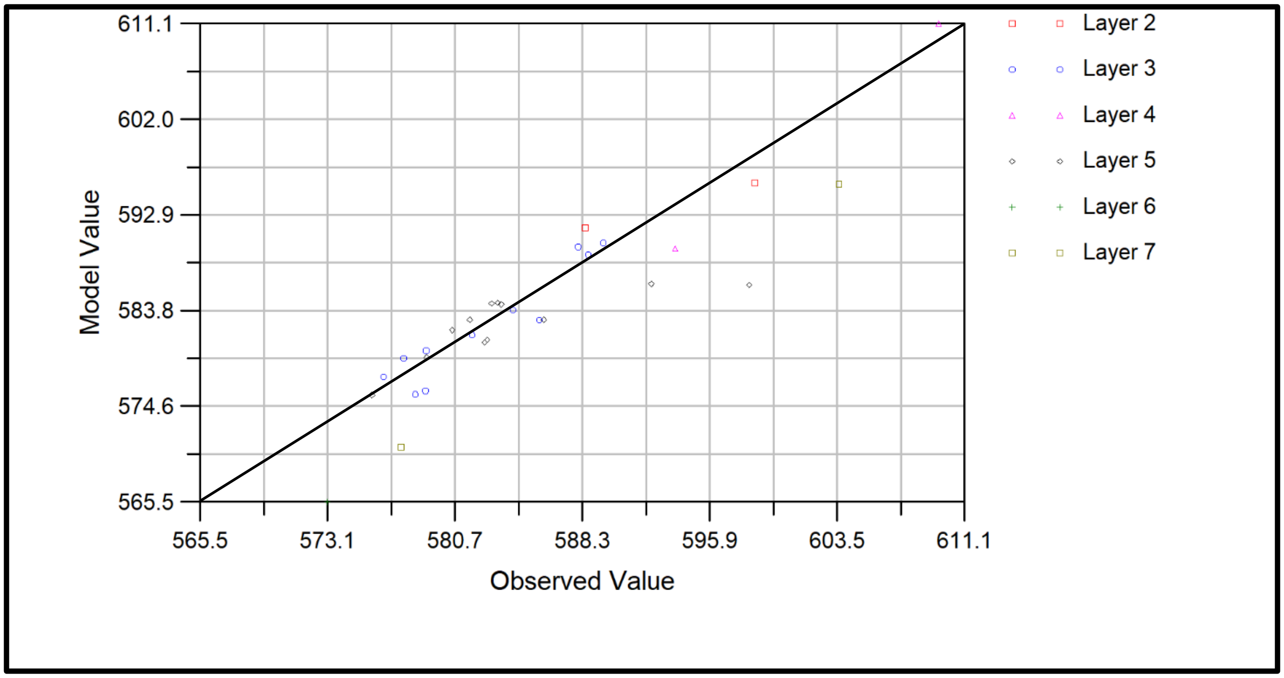



OBSERVED VERSUS SIMULATED GROUNDWATER ELEVATIONS LAYER 7

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS



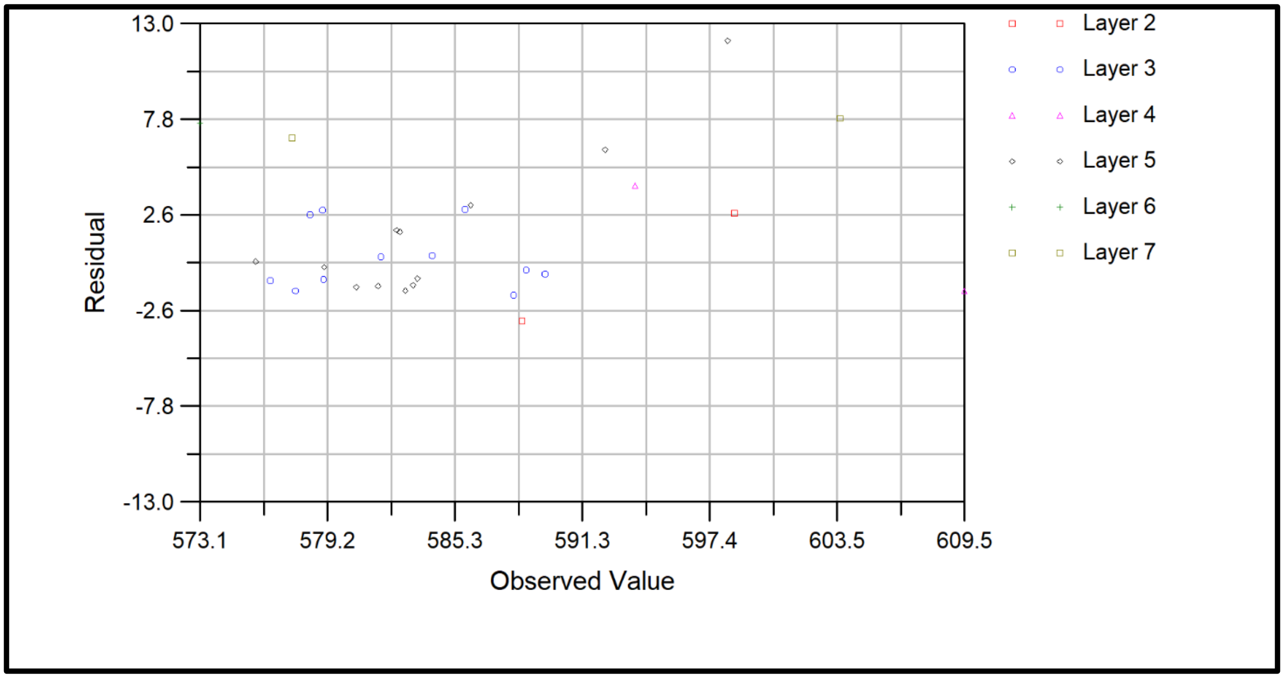
RAMBOLL




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

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

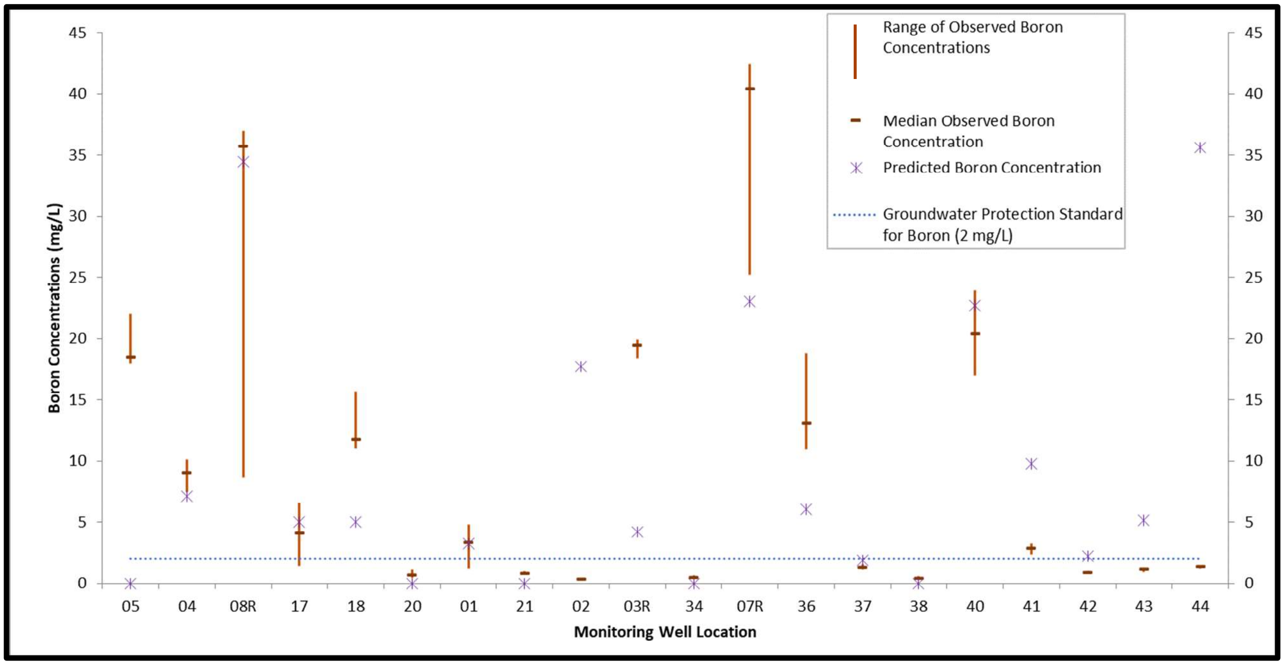
RAMBOLL




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

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

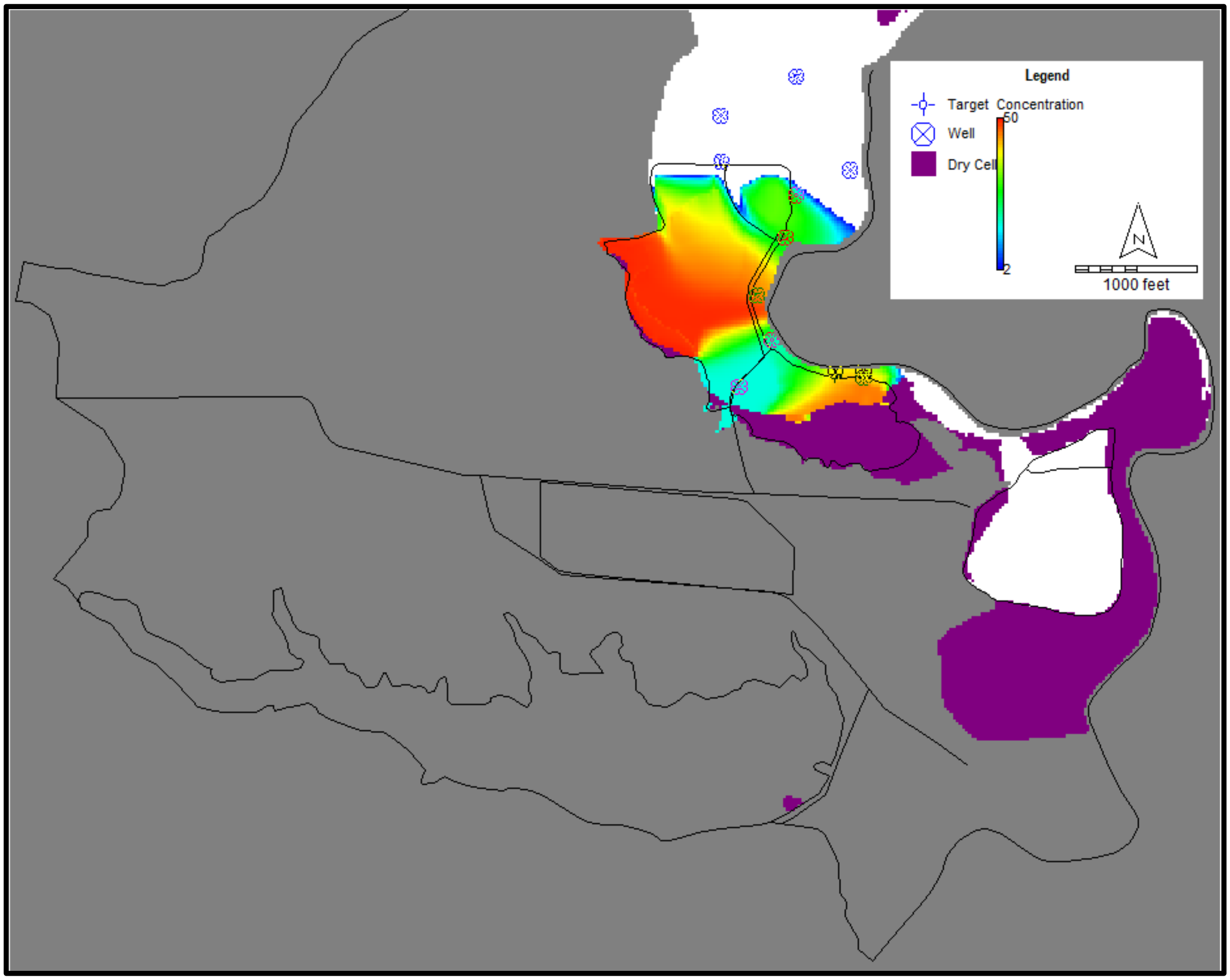
RAMBOLL




OBSERVED AND SIMULATED BORON CONCENTRATIONS (mg/L)

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

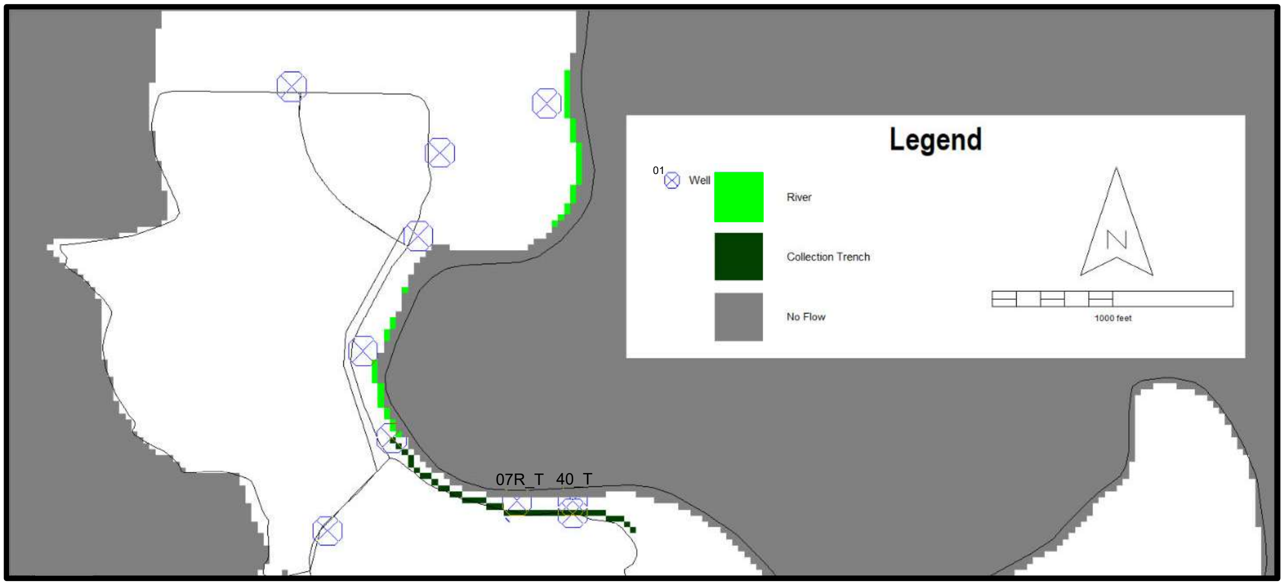
RAMBOLL




DISTRIBUTION OF BORON CONCENTRATION (mg/L) IN THE CALIBRATED MODEL (MGU)

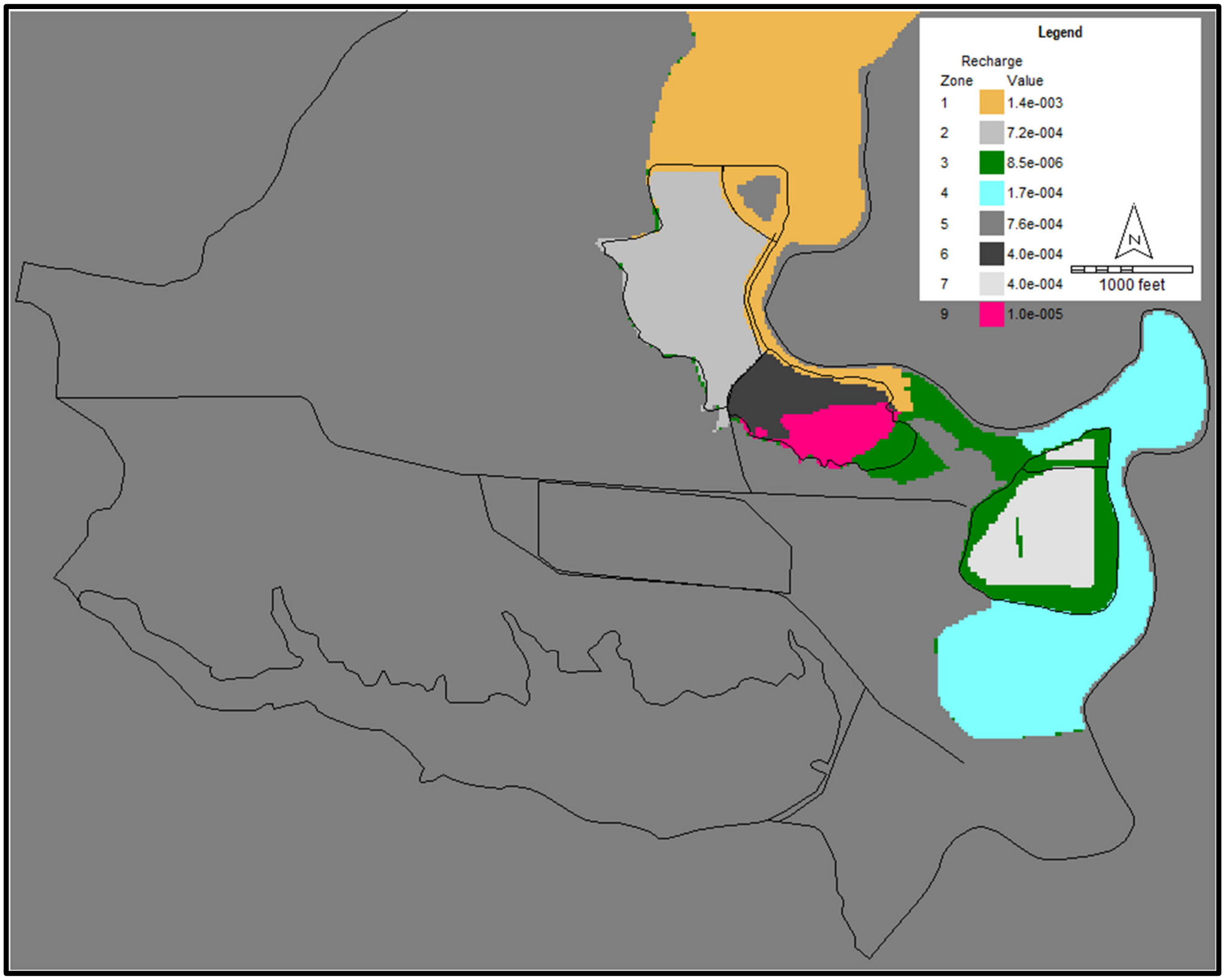
GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

RAMBOLL




SEEPAGE COLLECTION TRENCH ALIGNMENT WITH REPLACEMENT OBSERVATION WELLS

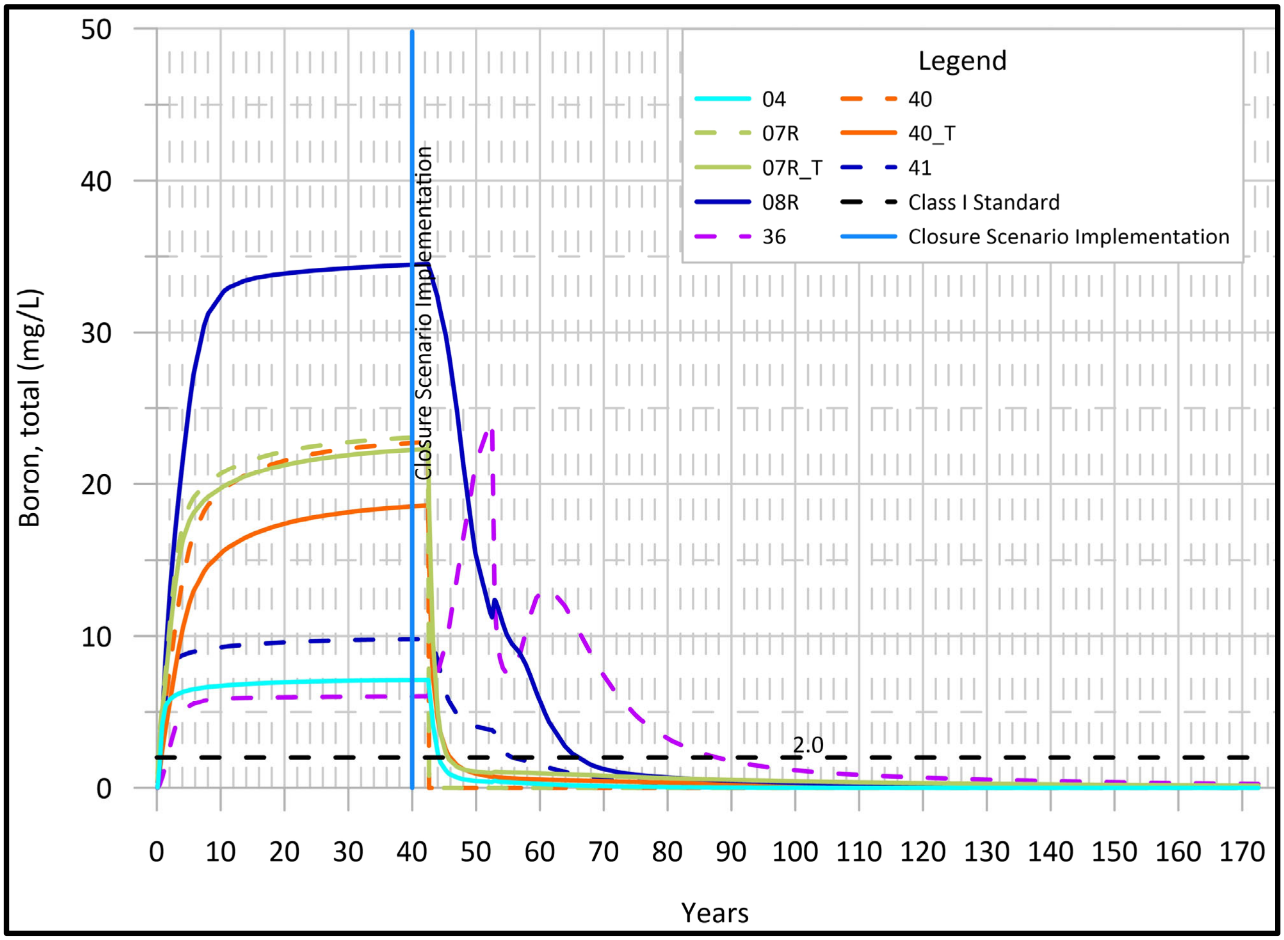
GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS




DISTRIBUTION OF RECHARGE ZONES (feet/day) FOR ALL CLOSURE SCENARIOS

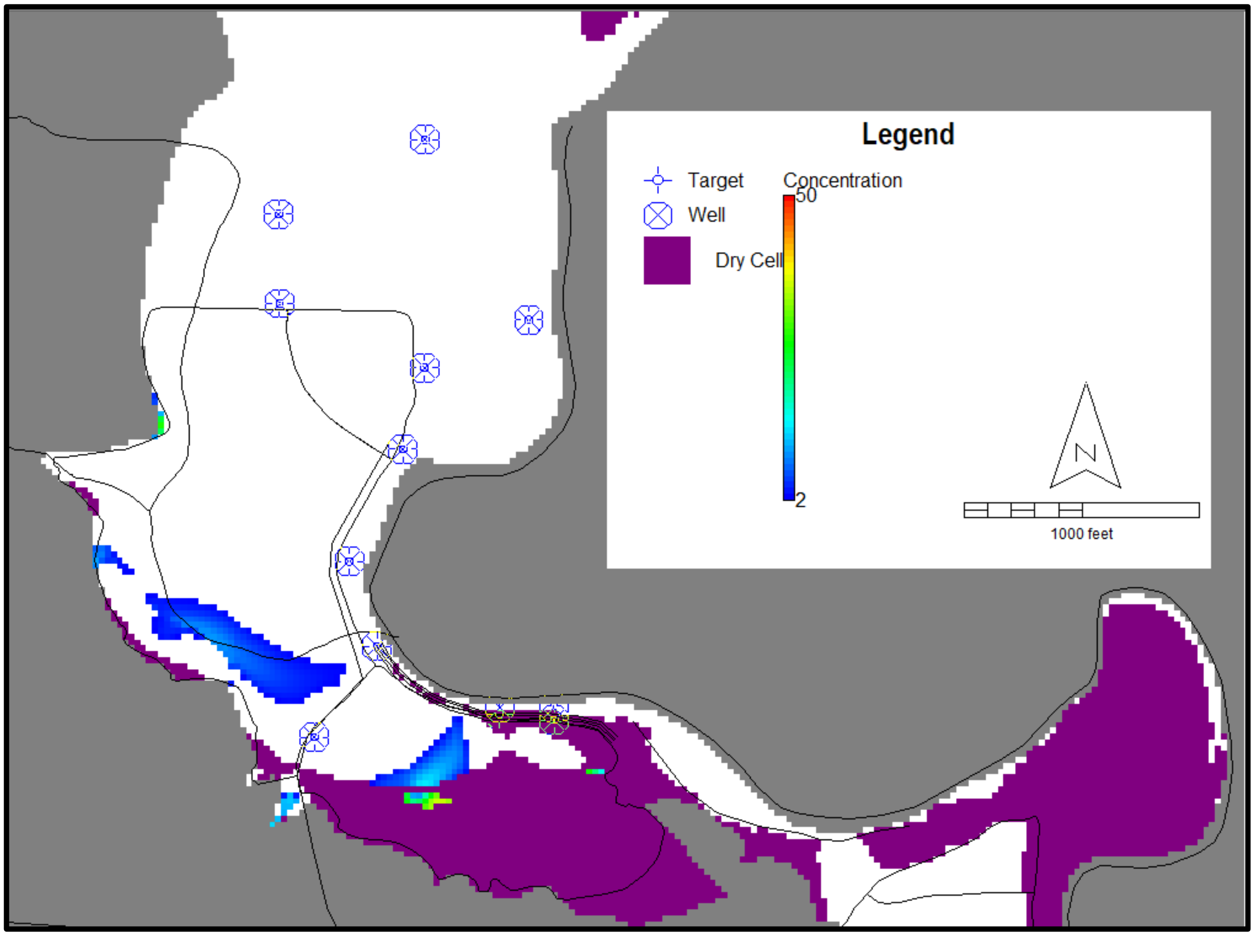
GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

RAMBOLL




CBR-ONSITE (SCENARIO 1, MGU) - MODEL PREDICTED BORON CONCENTRATION IN MIDDLE GROUNDWATER UNIT

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

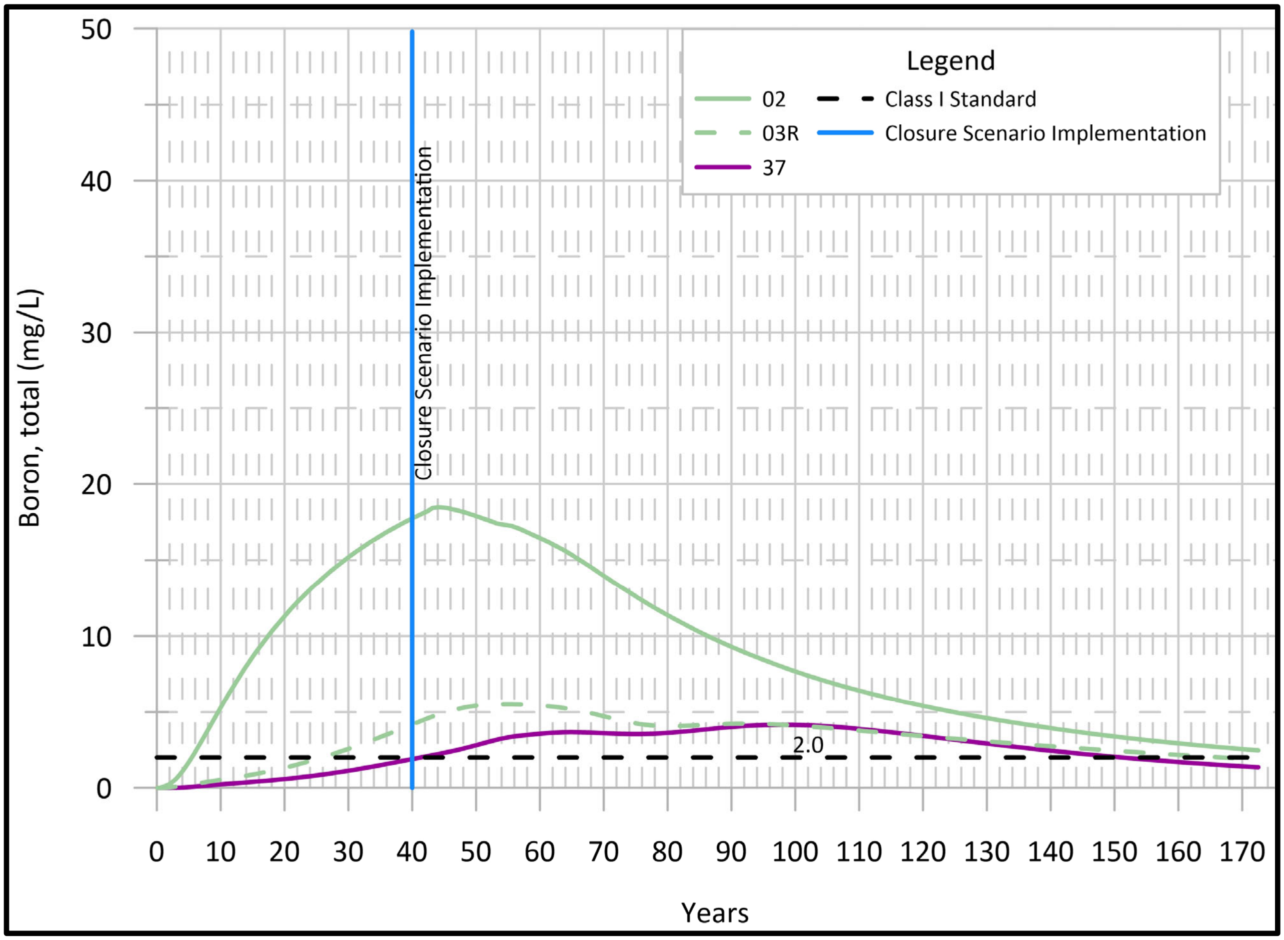



CBR-ONSITE (SCENARIO 1, MGU) – MODEL PREDICTED BORON PLUME IN MIDDLE GROUNDWATER UNIT APPROXIMATELY 50 YEARS AFTER IMPLEMENTATION

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

RAMBOLL

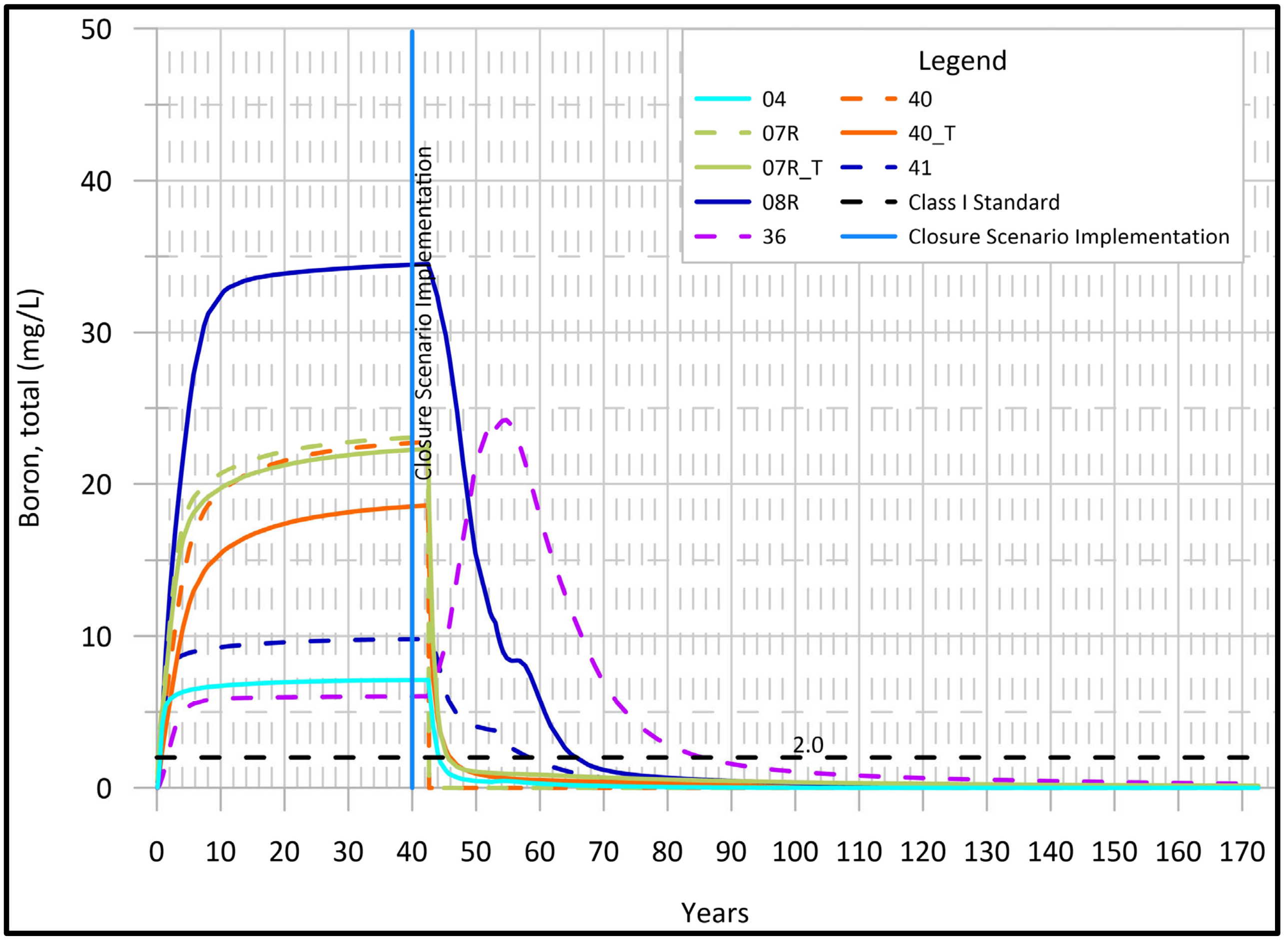
# FIGURE 6-5




CBR-ONSITE (SCENARIO 1, LGU) - MODEL PREDICTED BORON CONCENTRATION IN LOWER GROUNDWATER UNIT

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

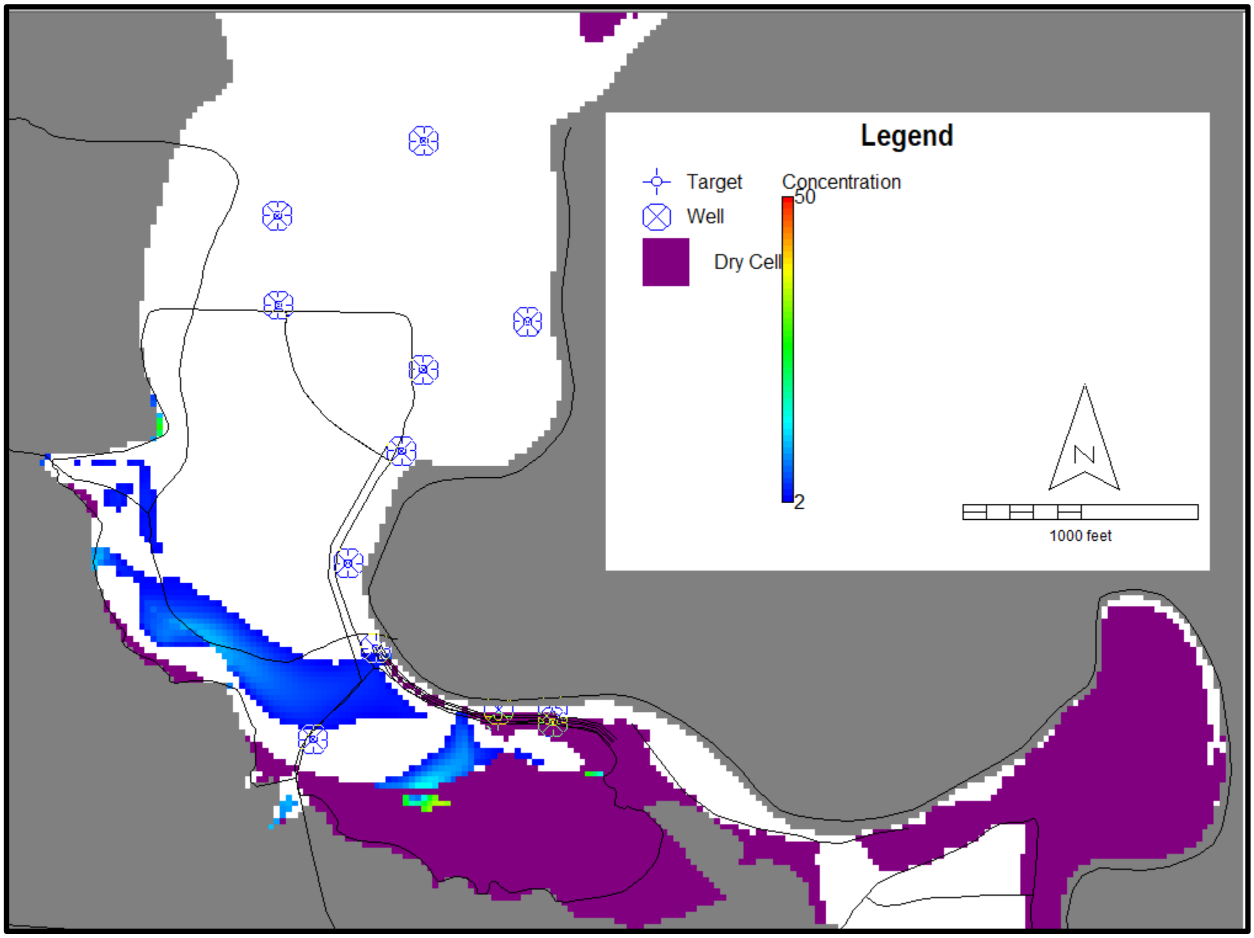
RAMBOLL




CBR-ONSITE (SCENARIO 2, MGU) - MODEL PREDICTED BORON CONCENTRATION IN MIDDLE GROUNDWATER UNIT

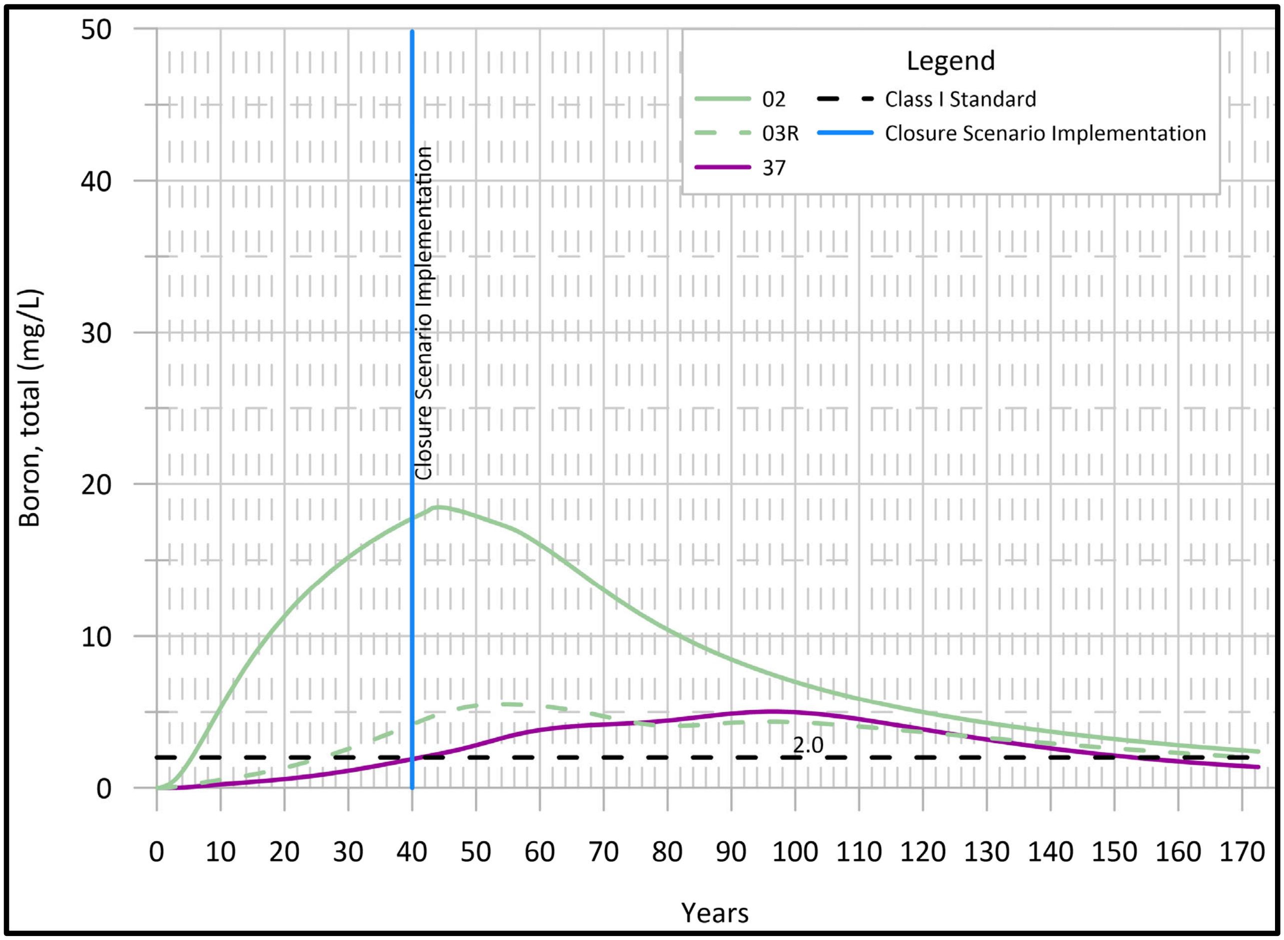
GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

RAMBOLL



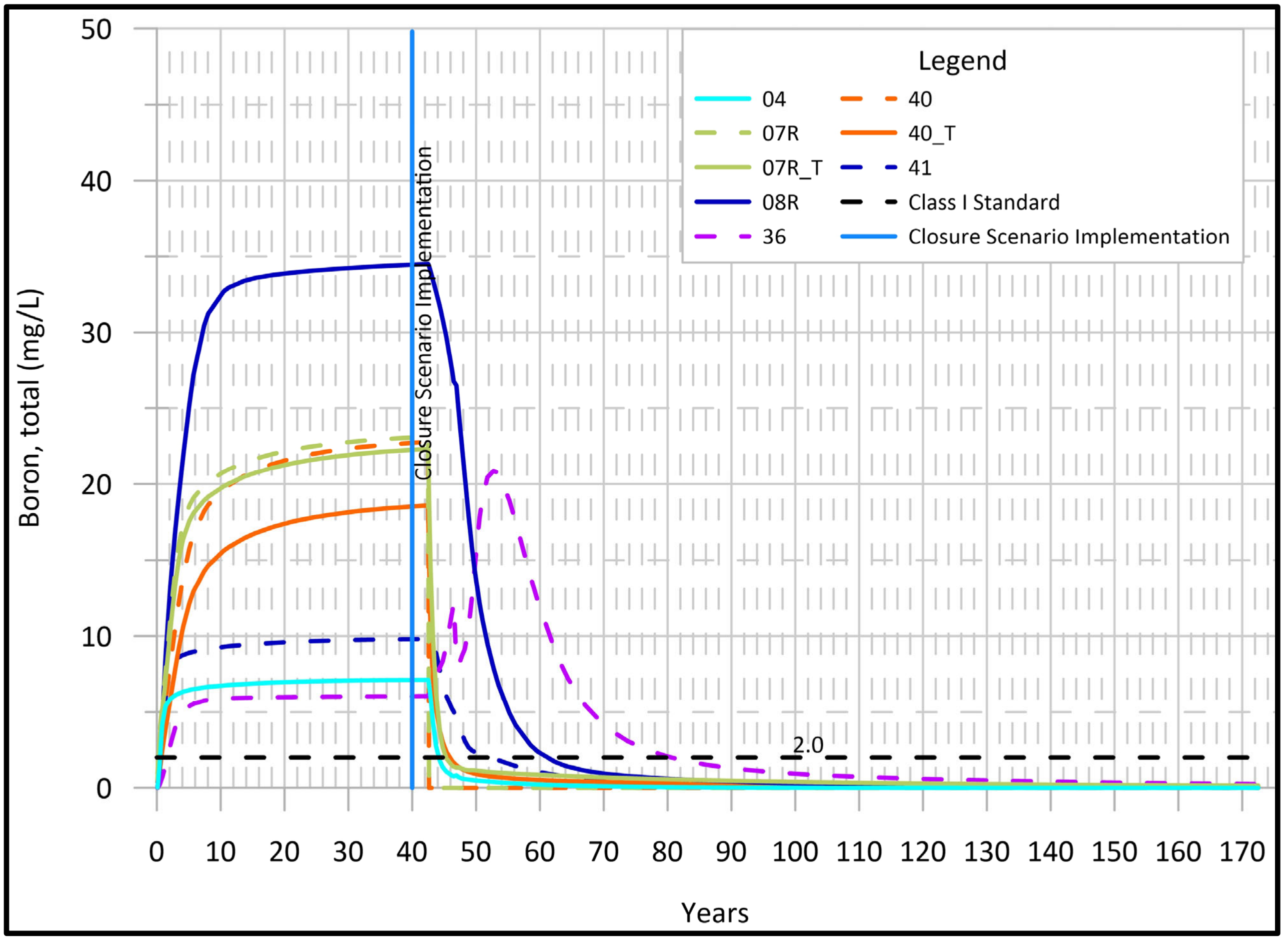

CBR-ONSITE (SCENARIO 2, MGU) - MODEL PREDICTED BORON PLUME IN MIDDLE GROUNDWATER UNIT APPROXIMATELY 47 YEARS AFTER IMPLEMENTATION

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS




CBR-ONSITE (SCENARIO 2, LGU) - MODEL PREDICTED BORON CONCENTRATION IN LOWER GROUNDWATER UNIT

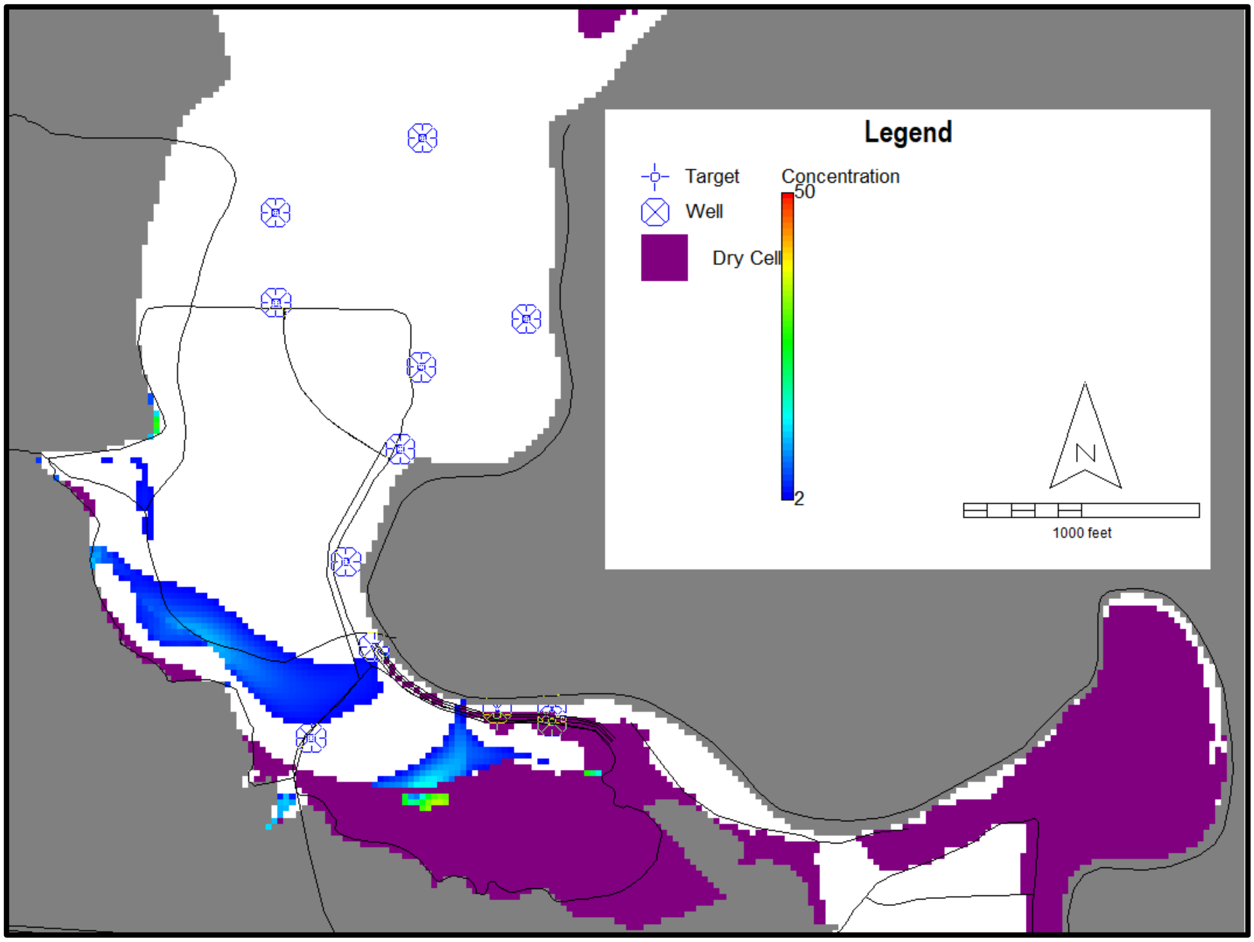
GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS




CBR-OFFSITE (SCENARIO 3, MGU) - MODEL PREDICTED BORON CONCENTRATION IN MIDDLE GROUNDWATER UNIT

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

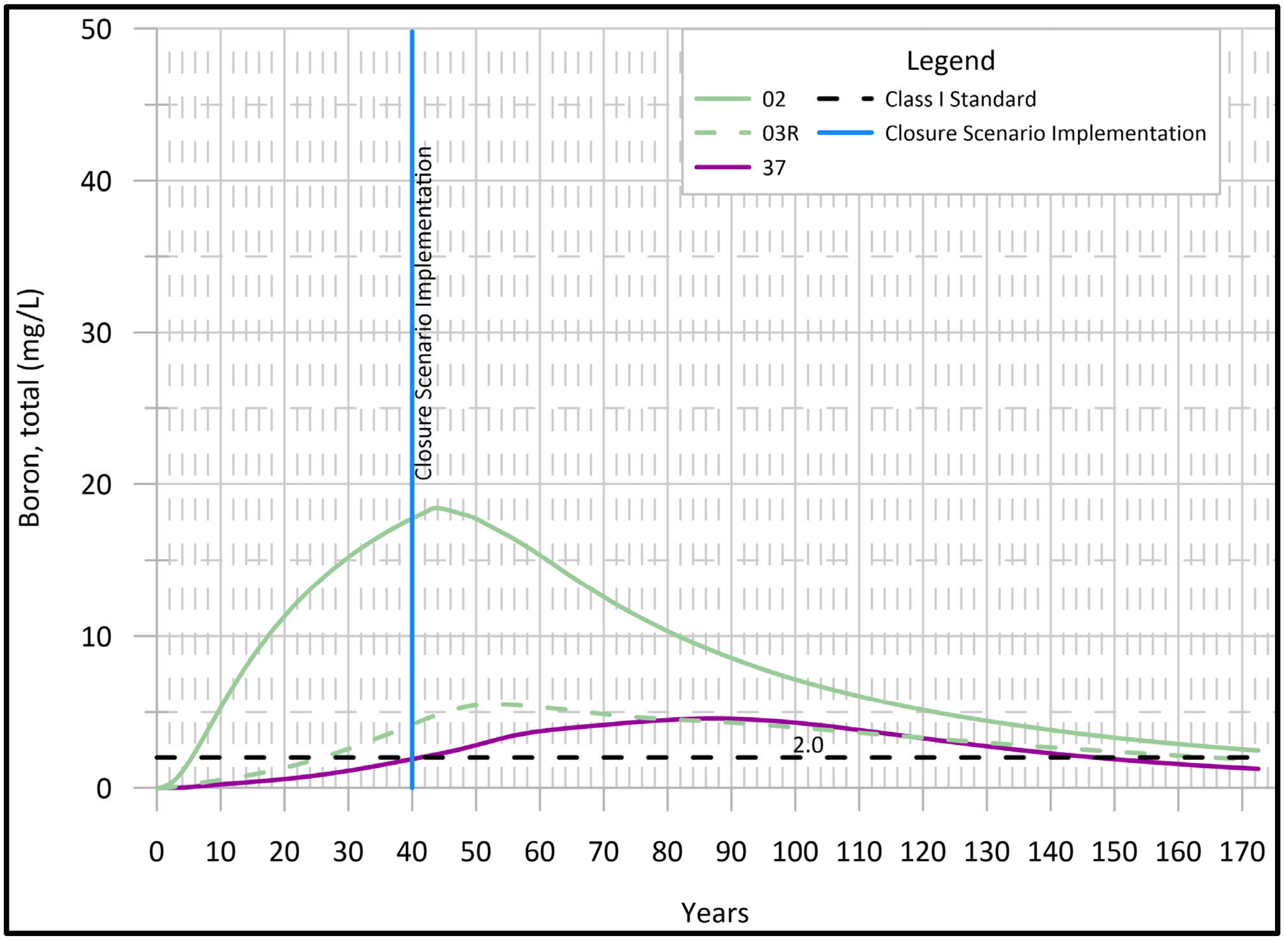
RAMBOLL




CBR-OFFSITE (SCENARIO 3, MGU) – MODEL PREDICTED BORON PLUME IN MIDDLE GROUNDWATER UNIT APPROXIMATELY 43 YEARS AFTER IMPLEMENTATION

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

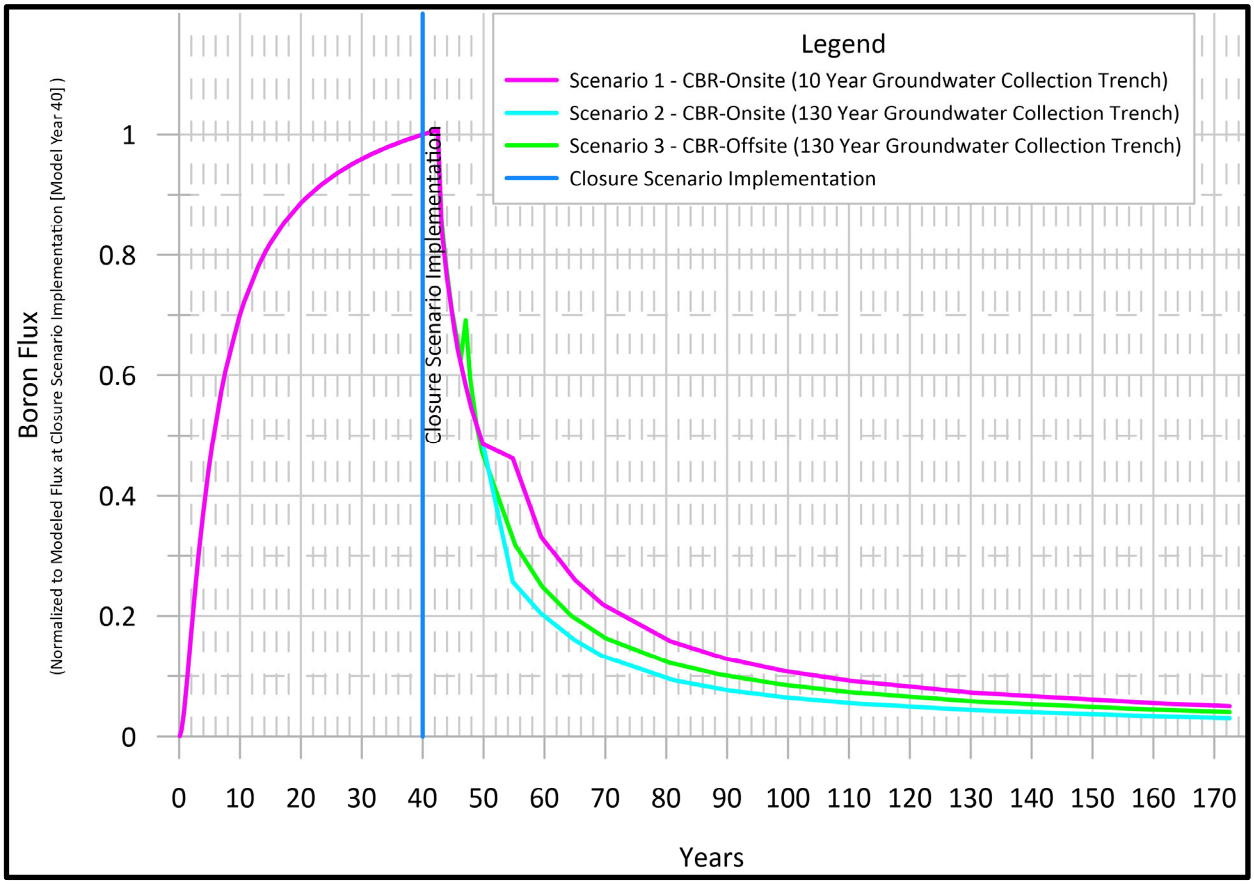
RAMBOLL




CBR-OFFSITE (SCENARIO 3, LGU) - MODEL PREDICTED BORON CONCENTRATION IN LOWER GROUNDWATER UNIT

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

RAMBOLL




NORMALIZED MODEL PREDICTED BORON FLUX TO MIDDLE FORK

GROUNDWATER MODELING REPORT
NORTH ASH POND AND OLD EAST ASH POND
VERMILION POWER PLANT
OAKWOOD, ILLINOIS

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