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DRAFT

GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS

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GROUNDWATER MODELING REPORT
COFFEEN POWER PLANT GMF GYPSUM STACK POND AND GMF RECYCLE POND

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ACRONYMS AND ABBREVIATIONS

§	Section
35 I.A.C.	Title 35 of the Illinois Administrative Code
AP1	Ash Pond No. 1
AP2	Ash Pond No. 2
bgs	below ground surface
CBR	closure by removal
CCR	coal combustion residual(s)
CIP	closure in place
cm/s	centimeter per second
CPP	Coffeen Power Plant
CSM	conceptual site model
DA	deep aquifer
DCU	deep confining unit
DEM	Digital Elevation Model
ft^2	square feet
ft/d	feet per day
ft/ft	feet per foot
Geosyntec	Geosyntec Consultants, Inc.
GHB	general head boundary conditions
GMF GSP	Gypsum Management Facility Gypsum Stack Pond
GMF RP	Gypsum Management Facility Recycle Pond
GMP	Groundwater Monitoring Plan
GMR	Groundwater Modeling Report
Golder	Golder Associates
GWPS	groundwater protection standard(s)
Hanson	Hanson Professional Services, Inc.
HCR	Hydrogeologic Site Characterization Report
HDPE	high density polyethylene
HELP	Hydrologic Evaluation of Landfill Performance
HFB	hydraulic flow boundary
HUC	Hydrologic Unit Code
ID	identification
IEPA	Illinois Environmental Protection Agency
in/yr	inches per year
IPGC	Illinois Power Generating Company - IPGC
ISGS	Illinois State Geological Survey
Kd	distribution coefficient
Kh/Kv	anisotropy ratio
LCU	lower confining unit
LF	Landfill
m	meter
mg/L	milligrams per liter
mil	One thousandth of an inch
mL/g	milliliters per gram
NAVD88	North American Vertical Datum of 1988

NID	National Inventory of Dams
No.	number
NPDES	National Pollutant Discharge Elimination System
NRT	Natural Resource Technology, Inc.
Part 845	35 I.A.C. § 845: Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments
R2	correlation coefficient
Ramboll	Ramboll Americas Engineering Solutions, Inc.
SI	surface impoundment(s)
SSR	sum of squared residuals
TDS	total dissolved solids
TR	transient model
TVD	total-variation-diminishing
UA	uppermost aquifer
UCU	upper confining unit
USDA/NRCS	United States Department of Agriculture/Natural Resources Conservation Service
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey

EXECUTIVE SUMMARY

Ramboll Americas Engineering Solutions, Inc. (Ramboll) has prepared this Groundwater Modeling Report (GMR) on behalf of the Coffeen Power Plant (CPP), operated by Illinois Power Generating Company - IPGC (IPGC), 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], 2021). This document presents the results of predictive groundwater modeling simulations for proposed closure scenarios for the coal combustion residuals (CCR) management units Gypsum Management Facility Gypsum Stack Pond (GMF GSP [Vistra Identification [ID] Number [No.] 103, IEPA ID No. W1350150004-03, and National Inventory of Dams [NID] No. IL50579]) and Gypsum Management Facility Recycle Pond (GMF RP [(Vistra ID No. 104, IEPA ID No. W1350150004-04, and NID No. IL50578]). The GMF GSP is a 77-acre, lined surface impoundment (SI), and the GMF RP is a 17-acre, lined SI, both of which are used to manage CCR waste streams at the CPP.

The CPP is located in Montgomery County, in central Illinois between the two lobes of Coffeen Lake (**Figure 1-1**), which was formed in 1963 by damming the McDavid Branch of the East Fork of Shoal Creek. Coffeen Lake encompasses approximately 1,100 acres and was created to provide a source of cooling water for the CPP. Coffeen Lake borders the CPP to the west, east, and south, and agricultural land is located to the north. Historically coal mines were operated at depth below the site. Mine shafts, processing facilities, and historic coal storage were located on the southern extent of the CPP, south of Coffeen Ash Pond Number No. 1 (AP1). The CPP operated as a coal-fired power plant from 1964 until November 2019 and has five CCR management units, with the GMF GSP and GMF RP being the subject of this GMR. Unlithified material present above the bedrock in the vicinity of the CPP was categorized into hydrostratigraphic units as part of the 2021 Hydrogeologic Site Characterization Reports (HCRs; Ramboll, 2021a; Ramboll, 2021b). In addition to the CCR, the hydrostratigraphic units occur in the following order (from ground surface downward) and include:

- **Upper Confining Unit (UCU):** Consists of the Loess Unit and the upper clayey portion of the Hagarstown Member which has generally lower vertical permeability. Construction of the GMF GSP and GMF RP required the excavation and removal of this layer within each unit's footprint and the UCU has been eroded east of the GMF GSP and GMF RP, near the Unnamed Tributary.
- **Uppermost Aquifer (UA):** The UA is the sandy portion of the Hagarstown Member which is classified as primarily sandy to gravelly silts and clays with thin beds of sands. Similar to the Loess Unit, the Hagarstown Member was excavated in some areas to facilitate construction of the GMF GSP and GMF RP and the Hagarstown Member is also absent in some locations near the Unnamed Tributary.
- **Lower Confining Unit (LCU):** Comprised of the Vandalia Member, Mulberry Grove Member, and Smithboro Member. These units include a sandy to silty till with thin, discontinuous sand lenses, a discontinuous and limited extent sandy silt which has infilled prior erosional features, and silty to clayey diamicton, respectively.
- **Deep Aquifer (DA):** Sand and sandy silt/clay units of the Yarmouth Soil, which include accretionary deposits of fine sediment and organic materials, typically less than five feet thick and discontinuous across the CPP.

- **Deep Confining Unit (DCU):** Comprised of the Banner Formation and generally consists of clays, silts, and sands. The Lierle Clay Member is the upper layer of the Banner Formation which was encountered at the CPP.

Flow of groundwater from central portions of the CPP to Coffeen Lake or the Unnamed Tributary through the UA are the primary pathways for contaminant migration. Groundwater elevations are primarily controlled by surface topography, geologic unit topography, and water levels within Coffeen Lake and the Unnamed Tributary. A groundwater divide trending north-south is observed running through the approximate center of the CPP. Phreatic surfaces or water elevations within the SIs are generally consistent and have not been observed to fluctuate with groundwater elevations, indicating limited hydraulic connection with the SIs.

The conceptual site model (CSM) for modeling the groundwater at the CPP is as follows:

- Most hydrostratigraphic layers are laterally continuous across the area. The flat to gently rolling uplands are dissected by deeply incised streams (into the materials of the UCU, UA, and LCU) that are tributaries to river systems in the area. Coffeen Lake was created by damming one of these tributary streams for use by the CPP.
- The GMF GSP and GMF RP are lined SIs which sit within the UCU and UA. The low permeability liner acts as a barrier to groundwater flow and transport.
- Surface recharge and groundwater migrate vertically through the low permeability sediments of the UCU. Groundwater migrates horizontally through the higher permeability sediments of the UA.
- Groundwater elevations and lake elevations indicates groundwater flows into Coffeen Lake from the UA.

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 HCRs (Ramboll, 2021a; Ramboll, 2021b). Concentration results presented in the HCRs and summarized in the History of Potential Exceedances (Ramboll, 2021c; Ramboll, 2021d) are considered potential exceedances because the methodology used to determine them is proposed in the Statistical Analysis Plan (Appendix A to the Groundwater Monitoring Plan [GMP], Ramboll, 2021e; Ramboll, 2021f), which has not been reviewed or approved by IEPA at the time of submittal of the Part 845 operating permit application. The following constituents with potential exceedances of the GWPS listed in 35 I.A.C. § 845.600 were identified: boron, sulfate, and total dissolved solids (TDS) (Ramboll, 2021d) at GMF RP; none were identified at the GMF GSP.

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

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

All available hydrological information were used to construct a CSM and numerical model of the CPP. A steady state, 5-layer numerical model, based on a previous groundwater model of the area, was constructed to characterize the long-term groundwater flow conditions at the site. The hydrostratigraphic units included in the model were the UCU, UA, and LCU. The DA and DCU were not included in the model. Calibration of the model focused on simulating mean groundwater elevations for 95 wells at the site by modifying hydraulic parameters for the different hydrostratigraphic units, alongside river and general head boundary conductance. The calibrated model represents a reasonable match to the observed head and sulfate concentration data.

The calibrated model was used to predict the sulfate concentration for two closure scenarios using information provided in the Draft CCR Final Closure Plan (Golder Associates [Golder], 2022) including:

- **Scenario 1:** closure in place (CIP) including removal of CCR from the GMF RP and the southern portion of the GSP, consolidation into the northern portion of the GSP, and construction of a cover system over the remaining CCR, and;
- **Scenario 2:** closure by removal (CBR) including removal of all CCR and SI liner and regrading of the removal area for both GMF GSP and GMF RP.

Prior to the simulation of these scenarios, a dewatering simulation was included which simulated the removal of free liquids from the GMF GSP and GMF RP prior to the implementation of the two closure scenarios.

There are limited differences in the timeframes to reach the GWPS for most monitoring wells at the GMF GSP and GMF RP between CIP and CBR. In general, the simulated groundwater concentrations in the monitoring wells within the UA will achieve the GWPS in 7 years for both the CIP and CBR closure scenarios at the GMF GSP. For the GMF RP, the simulated groundwater concentrations in the monitoring wells within the UA will achieve the GWPS in 2.5 years for both the CIP and CBR closure scenarios.

Results of groundwater fate and transport modeling conservatively estimate that groundwater concentrations will attain the GWPS for all constituents identified as potential exceedances of the GWPS in the UA monitoring wells within 7 years of closure implementation for both CIP and CBR. The residual sulfate plumes from the calibrated model associated with both the GMF GSP and GMF RP remain in close proximity to the CCR units and are simulated to decline below the GWPS (400 mg/L) in 14 and 9 years, respectively, for CIP and CBR.

1. INTRODUCTION

1.1 Overview

In accordance with the requirements of Part 845 (IEPA, 2021), Ramboll has prepared this GMR on behalf of the CPP, operated by IPGC. This report will apply specifically to the CCR units referred to as the GMF GSP and the GMF RP (**Figure 1-1**). However, information gathered to evaluate other CCR units at CPP regarding geology, hydrogeology, and groundwater quality is included, where appropriate. The GMF GSP is a 77-acre, lined SI, and the GMF RP is a 17-acre, lined SI , both of which are used to manage CCR waste streams at the CPP. This GMR presents and evaluates the results of predictive groundwater modeling simulations for two proposed closure scenarios, including CCR consolidation and CIP, and CBR scenarios summarized below:

- **Scenario 1:** CIP including removal of CCR from the GMF RP and the southern portion of the GMF GSP, consolidation into the northern portion of the GMF GSP, and construction of a cover system over the remaining CCR.
- **Scenario 2:** CBR including removal of all CCR and SI liner system and regrading of the removal area.

1.2 Previous Groundwater Modeling Reports

Several reports containing groundwater modeling have been completed at the CPP. The information presented in this GMR 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 an HCR (Ramboll, 2021a; Ramboll, 2021b). The HCRs were 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 various CCR units located at the CPP include, but are not limited to, the following:

- ***Natural Resources Technology, Inc. (NRT), January 24, 2017. Hydrostatic Modeling Report. Coffeen Power Station, Coffeen, Illinois.***
  Utilized the Hydrologic Evaluation of Landfill Performance (HELP) model to predict percolation from Coffeen Ash Pond No. 2 (AP2) and evaluate AP2 hydrostatic conditions in response to the proposed cover system as described in the Revised 30% Closure Design Package.
- ***NRT, January 24, 2017. Groundwater Modeling Report. Coffeen Power Station, Coffeen, Illinois.***
  Included simulations of the site hydrology, the extent of CCR leachate impacts on groundwater, and the effect of pond closure on groundwater quality.

1.3 Site Location and Background

The CPP is located in Montgomery County, in central Illinois, within Section 11 Township 7 North and Range 7 East (**Figure 1-1**). The CPP is approximately two miles south of the city of Coffeen and about eight miles southeast of the city of Hillsboro, Illinois. The GMF GSP and GMF RP are located between the two lobes of Coffeen Lake (identified as "Coffeen Lake" and "Unnamed Tributary" on **Figure 1-1** and **Figure 1-2**) to the west, east, and south, and is bordered by agricultural land to the north. The approximately 1,100-acre Coffeen Lake was built by damming the McDavid Branch of the East Fork of Shoal Creek in 1963 for use as an artificial cooling lake for the CPP. Historically, several coal mines were operated at depth in the vicinity of the CPP as well as the US Minerals processing facility located to the north. **Figure 1-2** is a site map showing the location of AP1, AP2, GMF GSP and GMF RP (Part 845 regulated CCR Units and subject of this GMR), and Coffeen Landfill (LF). A surface water pond southwest of the LF collects overflow from the LF, this feature does not contain CCR. The areas near the GMF GSP and GMF RP will hereinafter be referred to as the Site.

1.4 Site History and CCR Units

The CPP was a coal-fired electrical generating plant that began operation in 1964. The plant initially burned bituminous coal from Illinois and CCR from the coal fired units was disposed of in AP1. AP2 was also utilized in the early 1970's and AP1 was reconstructed in 1978. Both of these units were used until the mid-1980's. Beginning in 2010 CCR material was placed in the LF and GMF Units (*i.e.,* GMF GSP and GMF RP). All approximate dates of construction of each successive stage of the CCR Units at the CPP are included in the groundwater model and described here.

AP1: This SI (also known as the Bottom Ash/Recycle Pond) is a reclaimed ash pond that was reconstructed utilizing the existing earthen berms with reinforcement, as provided by Water Pollution Control Permit 1978-EA-389 issued by the IEPA on May 26, 1978. AP1 (existing unlined SI) covers an area of approximately 23 acres, has berms up to 41 feet above the surrounding land surface, and a volume of 300 acre-feet. It primarily received bottom ash and low volume wastes from floor drains in the main power block building. Several years ago, air heater wash and boiler chemical cleaning wastes were directed to AP1, but this practice was discontinued. The bottom ash was periodically removed for beneficial uses by a third-party contractor. Sluicing of waste to AP1 ceased prior to November 4, 2019.

AP2: AP2 is a closed (IEPA approved) SI with a surface area of approximately 60 acres and berms 47 feet higher than the surrounding land surface. AP2 was originally removed from service and capped in the mid 1980's. A clay and soil cap was placed on the surface of the pond with contouring and drainage provided to direct storm water to four engineered revetment down drain structures. Prior to capping, this pond was identified as Outfall 004 in the facility National Pollutant Discharge Elimination System (NPDES) operating permit, IL0000108. Additional closure activities include the construction of a geomembrane cover system that began in July 2019 and was completed on November 17, 2020. The construction was completed in accordance with the Closure and Post Closure Care Plan approved by the IEPA on January 30, 2018.

GMF GSP: The 77-acre GMF GSP received blowdown from the air emission scrubbers and was put into operation in 2010. Construction of the GMF GSP was in accordance with Water Pollution Control Permit 2008-EA-4661 and features a composite 60-one thousandths of an inch (mil) high-density polyethylene (HDPE) liner with 3 feet of recompacted soil with a hydraulic conductivity of 1×10^{-7} centimeters per second (cm/s) with internal piping and drains to collect contact water. Construction of the unit required excavation to approximately 603 feet North American Vertical Datum of 1988 (NAVD88), removal of the sands and silts of the UA prior to construction of the liner, and installation of a groundwater underdrain system to eliminate inward pressure on the liner prior to placement of CCR. The GMF GSP underdrain was actively pumped during construction but is no longer actively pumped. IPGC ceased receipt of waste to the GMF GSP prior to April 11, 2021.

GMF RP: The 17-acre GMF RP received blowdown from the air emission scrubbers and was put into operation in 2010. Construction of the GMF RP was in accordance with Water Pollution Control Permit 2008-EA-4661 and features a composite 60-mil HDPE liner with 3 feet of recompacted soil with a hydraulic conductivity of 1 x 10^{-7} cm/s with internal piping and drains to collect contact water. Construction of the unit required excavation to approximately 601 feet NAVD88, removal of the sands and silts of the UA prior to construction of the liner, and installation of a groundwater underdrain system to eliminate inward pressure on the liner prior to placement of CCR. The GMF RP underdrain is a passive, gravity drained system. IPGC ceased receipt of waste to the GMF RP prior to April 11, 2021.

LF: Fly ash was managed in a permitted composite lined landfill constructed in 2010. The LF has an active groundwater underdrain system that is currently being pumped. Additionally, the ash landfill leachate collection system is restricted by rule to no more than one foot of leachate on the composite liner. An IEPA groundwater monitoring program is in effect for the GMF GSP and GMF RP (under Bureau of Water), and LF (under Bureau of Land).

2. SITE GEOLOGY AND HYDROGEOLOGY

2.1 Stratigraphy

The geology and hydrogeology of the GMF GSP and GMF RP are described in detail in the HCRs (Ramboll, 2021a; Ramboll, 2021b) and summarized below.

The unlithified stratigraphy within and immediately surrounding the GMF GSP and GMF RP consists of the following in descending order: fill material and CCR; clays and silts (Loess Unit); gravelly clay till and sandy materials, absent in some locations (Hagarstown Member); a weathered till zone and sandy, silt, or clay till (Vandalia Member); silt and sandy silt/clay unit (Mulberry Grove Member); silty clay diamicton (Smithboro Member); sand and sandy silt/clay, absent in some locations (Yarmouth Soil); and clay and silt with some sand (Lierle Clay Member). The unlithified units overlay Pennsylvanian-age limestone, sandstone, and minor coal beds (Bond Formation). The Bond Formation bedrock was not encountered in any borings advanced at the CPP, so site-specific information is not available.

CCR consisting of gypsum, gypsum scrubber waste, and other non-CCR wastes are present within the lined GMF GSP and GMF RP. Borings were not advanced during the 2021 investigation in the GMF GSP or GMF RP due to safety concerns. Fill and CCR are estimated to be a maximum of 17 feet thick at the northern extent of the GMF GSP and a maximum of 13 feet thick in the western extent of the GMF RP as estimated from topography and the elevation of the base of the liner from available construction details (Ramboll, 2021a; Ramboll, 2021b; Hanson Professional Services, Inc. [Hanson], 2009). Non-CCR fill material consisting of silt, clay, and sand comprises the berms surrounding the GMF GSP and GMF RP.

The Loess Unit is the uppermost unlithified unit identified at the CPP. This unit is comprised of the combined Roxana and Peoria Silt and extends from beneath the topsoil, derived from the loess, to the top of the Hagarstown Member. The loess has been classified as silt or clayey silt, with minor amounts of sand. The Loess Unit ranges in thickness from 0 feet (absent) to 16 feet across the CPP, and was generally 3 to 14 feet thick, where present near the GMF GSP and GMF RP. The Loess Unit is generally considered unsaturated, and the UA is recharged by precipitation that percolates through this unit.

The Hagarstown Member (also referred to as Hagarstown Beds) exhibits two units: the first unit consisting of the gravelly clay till and the second consisting of sandy material overlying the Vandalia Member. The clay till portion had varying thicknesses ranging from approximately 2 to 6 feet as observed adjacent to the GMF GSP and GMF RP (Ramboll, 2021a; Ramboll, 2021b). The sandy portion of the Hagarstown, where present, was typically encountered between 6 and 25 feet below ground surface (bgs) near the GMF GSP and GMF RP, and is generally 1 to 4 feet thick, although thicknesses up to 7 feet have been observed north of the LF. The composition of the sandy portion of the Hagarstown unit varies across the CPP and has been classified as gravelly till, poorly sorted gravel, well sorted gravel, sand, and silty sand. Based on historic topography, the Hagarstown Member is not present in former drainage features present along the banks of Coffeen Lake and the Unnamed Tributary. During construction of the LF, GMF GSP, and the GMF RP, the Loess Unit and portions of the Hagarstown Member were excavated to facilitate construction.

The Vandalia (*i.e.,* till) Member is a sandy/silty till with thin, discontinuous lenses of silt, sand, and gravel. The Vandalia Member was encountered between 1.5 and 34 feet bgs in all borings advanced at the CPP. The Vandalia Member typically ranged in thickness from 11.7 feet in the northern portion of the CPP, to 31.0 feet between the GMF GSP and the GMF RP. Similar to the observed top elevation of the Hagarstown Member, the top of the Vandalia Member declines in elevation near Coffeen Lake and topographic drainage features. This unit is relatively thick throughout the CPP, with an average thickness of over 15 feet (Hanson, 2009).

The Mulberry Grove (*i.e.,* silt) Member typically consists of a thin, lenticular unit of gray sandy silt (Willman et al., 1975). It represents the interval between the retreat of the glacier that deposited the Smithboro Member and the advance of the glacier that deposited the Vandalia Member. At the CPP, the Mulberry Grove Member is represented by gray sandy silt layers deposited in depressions found in the surface of the underlying Smithboro Member. This unit was absent in many borings through the central portion of the CPP from south to north, and is generally less than 2 feet thick, but was measured at up to 4.9 feet thick near the GMF GSP (Hanson, 2009).

The Smithboro (*i.e.,* till) Member is described as a gray, compact, silty, clayey diamicton. The Smithboro Member ranges in thickness from 6.7 to 21.2 feet northwest of the LF.

The Yarmouth Soil is described as the weathered zone on the Kansan drift, but in some places, it consists of accretionary deposits of fine sediment and organic material that accumulated in poorly drained areas on the surface of the Kansan deposits. Historical borings in the northern portion of the CPP which encountered the Yarmouth were summarized previously by Hanson (2009) as ranging in thickness from 0 feet (absent) to 5.1 feet.

The Lierle Clay Member is the uppermost member of the Kansan Stage Banner Formation. It is described as an accretion gley with clay, silt, and some sand. It was encountered by Hanson (2009) in all but a few borings on site. During the 2021 investigation, the top of the Lierle Clay was observed between 54 and 57 feet bgs. No borings advanced at the CPP penetrated the full thickness of the Banner Formation.

Pennsylvanian-age Bond Formation bedrock was not encountered in any borings advanced at the CPP, so site-specific information is not available.

2.2 Hydrogeology

Regionally, the water table conforms to the topographic features of the land surface. Recharge occurs in the uplands and flows towards drainage features. Moderate thicknesses of unconsolidated materials fill shallow valleys or are present on the uplands bordering the main valleys. These materials contain thin and discontinuous deposits of sand and gravel.

2.2.1 Groundwater Flow

Monitoring well locations are illustrated in **Figure 2-1**. Monitoring well locations and construction details are summarized in **Table 2-1**. Overall groundwater flow within the UA is divided towards the two lobes of Coffeen Lake. Groundwater generally flows from the center of the CPP west towards Coffeen Lake, and east towards the Unnamed Tributary, the eastern lobe of Coffeen Lake, and the discharge flume, resulting in a groundwater divide (high) running through the middle of the CPP (**Figure 2-2** and **Figure 2-3**). Groundwater near the GMF GSP flows east and south from the groundwater divide present between the LF and the GMF GSP ultimately flowing toward the Unnamed Tributary. Groundwater near the GMF RP flows from the flow divide east toward the Unnamed Tributary . Although elevations vary seasonally, the groundwater flow direction in the UA is consistent and likely controlled by the proximity and hydraulic connection to Coffeen Lake.

2.2.2 Hydraulic Properties

Over 100 monitoring wells have been installed since 2006 to monitor groundwater conditions around the five CCR units at the CPP for both State and Federal groundwater compliance programs. Six hydrostratigraphic units were described in detail in the HCRs (Ramboll, 2021a; Ramboll, 2021b) and are summarized as follows:

- **CCR:** These units are composed of CCR, consisting primarily of gypsum scrubber waste. This also includes earthen fill deposits of predominantly silt and clay materials from on-site excavations that were used to construct berms and roads surrounding the various impoundments across the CPP. Laboratory testing of one CCR (ash) sample from the GMF GSP had a vertical hydraulic conductivity of 8.9 x 10^{-4} cm/s. No CCR samples were collected from within the GMF RP.
- **UCU**: Consists of the Loess Unit and the upper clayey portion of the Hagarstown Member which has generally lower vertical permeability and generally greater than 60 percent fines (Ramboll, 2021a; Ramboll, 2021b). This unit was encountered across most of the CPP, with the exception of near the Unnamed Tributary where the unit was eroded following deposition or locations where it has been excavated for construction. Vertical hydraulic conductivities based on laboratory testing ranged from 1.3 x 10^{-8} to 5.0 x 10^{-7} cm/s.
- **UA**: This unit consists primarily of sand and sandy silts and clays at the base of the Hagarstown Member and, in some locations, the uppermost weathered sandy clay portion of the Vandalia Member. This unit is absent in several locations due to weathering and in others due to excavation during construction of CCR Units. Field hydraulic conductivity tests indicated hydraulic conductivities ranged from 1.7 x 10^{-5} to 9.1 x 10^{-3} cm/s near AP1 (Ramboll, 2021g). Laboratory testing of one UA sample, collected near the GMF RP, had a vertical hydraulic conductivity of 1.6 x 10^{-4} cm/s. No samples were collected near the GMF GSP.
- **LCU**: This unit is composed of the sandy clay till of the Vandalia Member, the silt of the Mulberry Grove Formation, and the compacted clay till of the Smithboro Member. The unit underlies the UA and was encountered in all boring locations on the CPP. Results from laboratory tests completed for vertical hydraulic conductivity indicate the Vandalia Member has a very low vertical hydraulic conductivity. Field hydraulic conductivity tests indicated hydraulic conductivities from 4.0 x 10^{-8} to 3.4 x 10^{-5} cm/s; however, these likely reflect the isolated and discontinuous sandy lenses. Vertical hydraulic conductivities based on laboratory testing were from 1.3 x 10^{-8} to 5.0 x 10^{-7} cm/s.
- **DA**: This unit consists primarily of sandy silt and sands of the Yarmouth Soil, which are thin (less than 5 feet) and discontinuous across the CPP. Field hydraulic conductivity tests indicated hydraulic conductivities from 8.7 x 10^{-5} to 1.7 x 10^{-3} cm/s within the DA.
- **DCU**: This unit underlies the DA and is composed of the Banner Formation, of which the thick Lierle Clay is the first encountered unit. No boring penetrated the full thickness of this formation.

2.2.3 Groundwater Elevation Data

During the 2021 Part 845 investigation, groundwater elevations in the UA ranged from approximately 591 to 625 feet NAVD88 across the CPP. Groundwater elevations were typically highest towards the northern extent of the CPP, near the GMF GSP and GMF RP, except monitoring well G307 south of AP1, which consistently had the highest groundwater elevation. Groundwater elevations were lowest near the Unnamed Tributary and east of AP1 towards Coffeen Lake. Groundwater elevations in the vicinity of the GMF GSP were typically from 617 to 622 feet NAVD88, and between 601 and 623 feet in the vicinity of the GMF RP (**Figure 2-2** and **Figure 2-3**).

No seasonal variation has been observed in the UA monitoring wells, and any seasonal responses may be muted by the proximity and hydraulic connection to Coffeen Lake.

2.2.4 Mining Activity

Several coal mines, both strip and underground types, previously operated in Montgomery County, Illinois. Three mines - the Hillsboro Mine (Illinois State Geological Survey [ISGS] Mine No. 871), the Clover Leaf No. 4 Mine (ISGS Mine No. 442), and the Clover Leaf No. 1 Mine (ISGS Mine No. 3001) – were operated as room and pillar mines in the vicinity of the site beginning as early as 1889. The mines extracted coal from the Herrin (No. 6) Coal at depths of approximately 500 to 535 feet bgs (ISGS, 2019). All nearby mining operations ceased in 1983.

The Hillsboro Mine showed indications of small-scale faulting, roof stability issues and floor heaving. Mine shafts, processing facilities, and some historic coal storage associated with these historic mines were located south of AP1. The southernmost portion of the GMF GSP and GMF RP fall within the buffer zone of the Hillsboro Mine. The GMF GSP directly overlies the southernmost portion of the Clover Leaf No. 4 Mine and the GMF RP lie within the buffer zone. The GMF GSP and GMF RP are outside of the buffer zone of the Clover Leaf No. 1 mine (Ramboll, 2021a; Ramboll, 2021b).

3. GROUNDWATER QUALITY

3.1 Groundwater Classification

Per 35 I.A.C. § 620.210, groundwater within the UA at the GMF GSP and GMF RP meet the definition of a Class I - Potable Resource Groundwater based on the following criteria:

- Groundwater in the UA is located 10 feet or more below the land surface and
- Within a geologic material which is capable of a hydraulic conductivity of 1×10^{-4} cm/s or greater using a slug test.

Field hydraulic conductivity tests performed in the UA near the GMF GSP and GMF RP in 2021 had geometric means of 1.4×10^{-3} and 1.2×10^{-3} cm/s, respectively (Ramboll, 2021a; Ramboll, 2021b). Based on this information groundwater is classified as Class I – Potable Resource Groundwater.

3.2 Potential Groundwater Exceedances

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 HCRs (Ramboll, 2021a; Ramboll, 2021b). Concentration results presented in the HCRs 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 GMPs (Ramboll, 2021e; Ramboll, 2021f) attached to the operating permit application.

Groundwater concentrations from 2015 to 2021 are summarized in the History of Potential Exceedances (Ramboll, 2021c; Ramboll, 2021d) (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; Ramboll, 2021d), 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. No potential exceedances were present at the GMF GSP. The following potential exceedances were identified for the GMF RP:

- Boron - determined at well G275.
- Sulfate - determined at wells G273, G275, and G285.
- TDS - determined at wells G275 and G285.

Note that monitoring well G285 is located east of the Unnamed Tributary and screened within the LCU. Consequently, exceedances at G285 are not associated with the GMF GSP or GMF RP and are not discussed further in this GMR.

4. GROUNDWATER MODEL

4.1 Overview

Data collected at the Site from 2015 to the 2021 field investigation were used to update an existing groundwater model of the CPP (Natural Resource Technology [NRT], 2017b). The updated model was then used to evaluate the results of predictive groundwater modeling simulations for two proposed closure scenarios, including CCR consolidation and CIP, and CBR. The modeling results are summarized and evaluated in this GMR. The associated model files are included as **Appendix A**.

4.2 Description of Existing Model

The NRT (2017b) contaminant fate and transport model simulated boron and was performed to support closure of AP2 using MODFLOW and MT3DMS. AP1, GMF GSP, GMF RP, and LF were present within the previous model domain.

The NRT (2017b) modeling consisted of the following:

- Steady-state MODFLOW model was developed to represent site conditions for 2016. This model was calibrated to a set of groundwater elevation data collected during November 2016.
- The hydraulic properties from the steady-state model were used in the calibration of the transient MODFLOW and MT3DMS models which simulated groundwater flow and transport at the AP2 from 1970 to 2017. Boron concentrations collected in August 2016 were used to calibrate the transport model.
- Predictive simulations to estimate future boron concentrations for a baseline (no action) and capping closure scenario for AP2 were completed. Closure action was modeled over a period of 1500 years, beginning in January 2018.
- Predicted boron concentrations were simulated to reach compliance for CIP at AP2 after 101 years (NRT, 2017b). These modeling results were part of the closure plan IEPA approved on January 30, 2018.

4.3 Conceptual Model

The HCRs (Ramboll, 2021a; Ramboll, 2021b) form the foundation of the GMF GSP and GMF RP hydrogeological setting. The GMF GSP and GMF RP overlies the recharge area for the underlying geologic media, which are composed of unlithified deposits.

4.3.1 Hydrogeology

As discussed in **Section 2.2**, groundwater flow direction in the UA at the CPP is divided and flows towards the two lobes of Coffeen Lake. The loess of the UCU and sands of the UA are hydraulically connected. The groundwater flow in the silts and clays of the UCU and LCU are expected to be primarily vertical. The Hagarstown member is where the majority of the horizontal migration is expected to occur. The hydrogeological CSM consists of the following layers:

- Hagarstown Loess Unit (*i.e.,* UCU) – Loess unit and the upper clayey portion of the Hagarstown Member.

- Hagarstown Member (*i.e.,* UA) – sand and sandy silts and clays at the base of the Hagarstown Member and, in some locations, the uppermost weathered sandy clay portion of the Vandalia Member.
- Vandalia Member/Mulberry Grove Member (*i.e.,* LCU) – unweathered sandy clay till and discontinuous silts.
- Smithboro Till (*i.e.,* LCU) – compacted clay till of the Smithboro Member.

The hydrostratigraphic units included in the model were the UCU, UA, and LCU. The DA and DCU were not included in the model, which includes consistency with the original model (NRT, 2017b). No potential GWPS exceedances have been observed in the DA. This, coupled with the limited groundwater data available for the DA and DCU, meant that these layers were not included in the model. Therefore, the Smithboro Till (*i.e.,* LCU) represents the lower boundary of the CSM.

Surfaces for each of the three major geological units (Loess Unit, Hagarstown Member, Vandalia/Mulberry Grove Member and Smithboro Till Member) were taken from the NRT model (2017b). The NRT model (2017b) used available information from well logs to interpolate the top and base of the UA.

4.3.2 Extent and Boundaries

The United States Geological Survey (USGS) National Map places the CPP within the East Fork Shoal Creek watershed subbasin (Hydrologic Unit Code [HUC] 071402030303).

The CPP CSM extent is bounded by a hydrological catchment (watershed) divide to the east based on watershed data from USGS. The north, south, and east model boundary has been placed along known waterbodies as much as possible. As such, it is assumed groundwater inflow from adjacent watersheds is negligible through both the UA and LCU.

The Coffeen Lake water levels are managed at an average elevation 591.0 feet NAVD88. Coffeen Lake and Unnamed Tributary are the receiving body of water for surface water in the area encompassed by the CSM.

Infiltration of precipitation to the groundwater table is applied as recharge at the site. Groundwater in the UCU migrates downward into the Hagarstown Formation. As discussed in **Section 2.2.1**, the Hagarstown Formation is considered the UA for groundwater adjacent to the GMF GSP and GMF RP.

4.3.3 GMF Gypsum Stack Pond and GMF Recycle Pond

The GMF GSP and GMF RP were both constructed with an earthen berm and have a liner system which acts as a low permeability interface between the CCR contained within the GMF GSP and GMF RP and the ambient groundwater system. The liner system was installed along the inner faces of the GMF GSP and GMF RP (sides and base of the excavated area). The GMF RP has a passive gravity-driven underdrain system which was used to eliminate inward pressure on the liner prior to placement of CCR.

Findings from the HCRs (Ramboll, 2021a; Ramboll, 2021b) indicate that the GMF GSP and GMF RP do not appear to impact groundwater flow directions via recharge to groundwater. Given the low permeability of the liner system and the removal of the Hagarstown member (UA) below the units, it is more likely that the GMF GSP and GMF RP are barriers to groundwater flow within the UA, directing flow from upgradient areas through the underdrains beneath the units and/or around the perimeter of the GMF GSP and GMF RP toward the Unnamed Tributary and eastern lobe of Coffeen Lake.

Sulfate was selected for transport modeling. Sulfate is commonly used as an indicator parameter for contaminant transport modeling for CCR because: (i) it is commonly present in coal ash leachate; and (ii) it is mobile and typically not very reactive but conservative (*i.e.*, low rates of sorption or degradation) in groundwater.

4.5 Model Approach

4.5.1 Potential Groundwater Exceedances

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

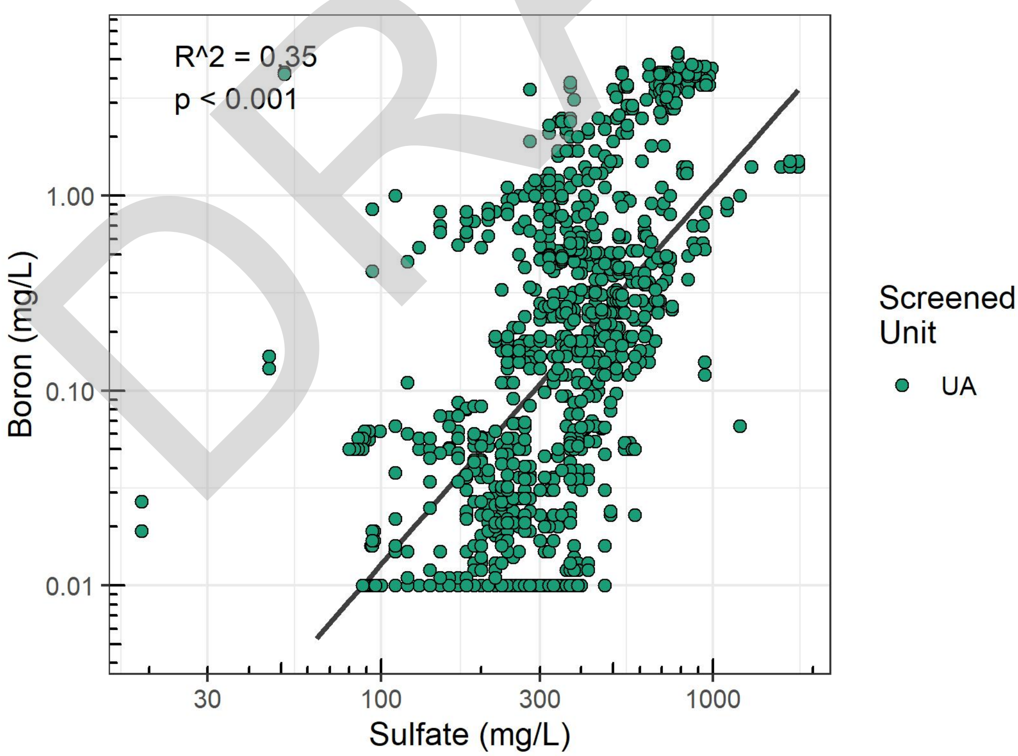

Figure A. Sulfate Correlation with Boron in UA Wells

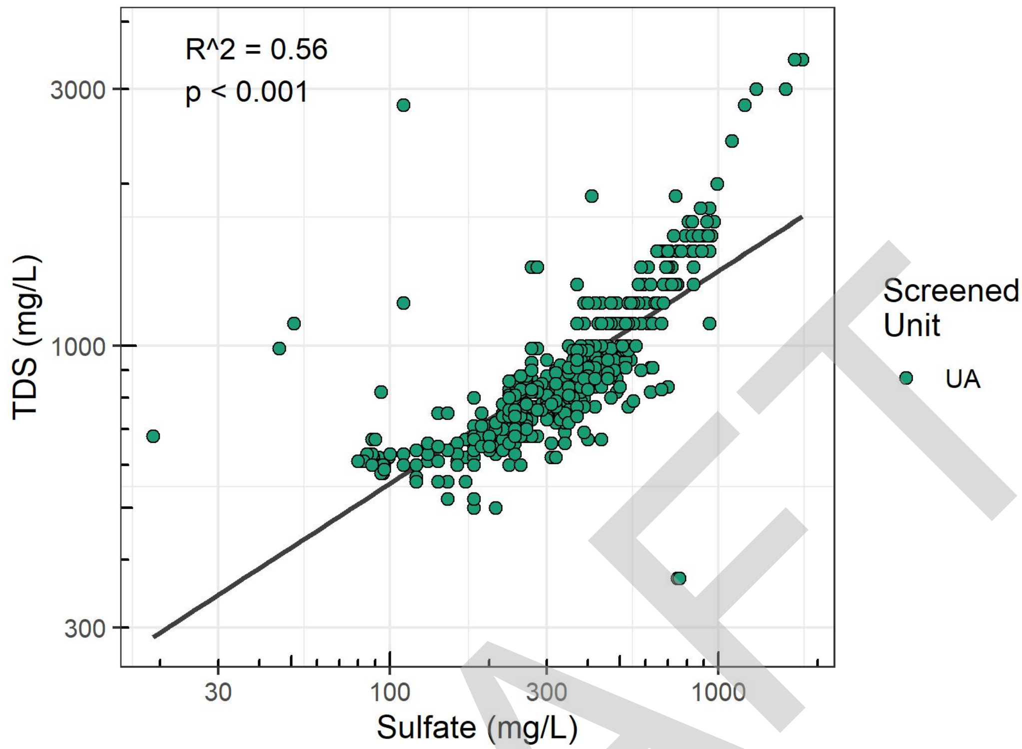

Figure B. Sulfate Correlation with TDS in UA Wells

4.5.2 Summary of Modeling Activities

A three-dimensional groundwater flow and transport model was calibrated to represent the conceptual flow system described above. Prediction simulations were performed to evaluate the effects of closure (source control) measures (CCR consolidation and CIP, and CBR scenarios) for the CCR units on groundwater quality following closure, which includes removal of free liquids (dewatering). **Figure 4-1** illustrates the calibration and predictive modeling timelines.

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) was modeled using the results of the HELP model.

Modeling steps are summarized below:

- A steady state model was created in MODFLOW 2005 and used to simulate the mean groundwater flow conditions at the site. The model was calibrated to match mean groundwater elevations observed between 2015 to 2021 (**Table 4-1**).
- Transient flow models based off of the calibrated steady state model were used to simulate groundwater flow and transport for 42 years using MODFLOW 2005 and MT3DMS to simulate

changes in site conditions through time and match currently observed concentrations of sulfate in groundwater (**Table 4-1**).

- Prediction simulations began with a 2-year dewatering period simulated in MODFLOW 2005 and MT3DMS where heads were reduced within the CCR unit and concentrations were removed from CCR removal areas.

- Prediction simulations resumed for CIP and CBR following the 2-year dewatering period using the results of HELP modeling as input values for recharge rates in the construction areas.

- The prediction simulations were run using MODFLOW 2005 and MT3DMS to estimate the time for sulfate concentrations to meet the GWPS in the compliance wells; and, to evaluate the differences between the two closure scenarios.

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 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 since. 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 this model. 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) completed for the groundwater model were used to estimate the hydraulic flux from closure construction.

5.2 Flow and Transport Model Setup

The 2017 flow and transport models were retained and revised as appropriate to perform simulations for the GMF GSP and GMF RP.

The modeled area was approximately 10,000 feet by 15,025 feet (150,250,000 square feet [ft^2]) centered on the CPP (**Figure 5-1**). The model boundaries along the northern and eastern edges of the model were selected to maintain sufficient distance from the CPP to reduce boundary interference with model calculations, while not extending too far past the extent of available calibration data. The eastern edge of the model also approximates topographic highs, surface water divides, and watershed boundaries.

The steady state MODFLOW model was calibrated to mean groundwater elevations collected from 2015 to 2021 and are presented in **Table 4-1**. MT3DMS was run on the transient flow model and model-simulated concentrations were calibrated to observed sulfate concentration values at the monitoring wells from January 2015 to July 2021 and are presented in **Table 4-1**. Multiple iterations of MODFLOW and MT3DMS calibration were performed to achieve an acceptable match to observed flow and transport data. For GMF GSP and GMF RP, the calibrated flow and transport models were used in predictive modeling to evaluate the CIP and CBR closure scenarios. Prior to simulation of CIP and CBR, a dewatering phase, which simulated the removal of free liquid from the CCR material in the GMF GSP and GMF RP was completed. Closure scenarios were simulated by removing saturated ash cells from removal areas and using HELP modeled recharge values to simulate changes proposed in the closure scenarios.

5.2.1 Grid and Boundary Conditions

A five-layer, 326 x 211 node grid was established with a variable grid spacing between 25 and 100 feet (**Figures 5-2 through Figure 5-6**), with a total number of 284,575 active cells.

The main body of Coffeen Lake is immediately adjacent to CPP on the west and south and the Unnamed Tributary borders CPP to the east. These surface water features form the southern, eastern, and western boundaries of the model. The northern boundary of the model domain is a general head boundary. Vertically, the model domain extends from the top of the saturated zone to the base of the Smithboro Member. The thick clays of the Banner Formation are relatively impermeable compared to the overlying unconsolidated sediments and provides a base for the model.

The northern boundaries for layers 3, 4, and 5 are general head boundaries placed to simulate flow in the sandier soils of the Hagarstown Member, Vandalia Member, and Smithboro Till composing the UA (layer 3) and LCU (layer 4 and 5). The northern boundary represents the regional flow conditions within these units. The eastern edge is a no-flow boundary in all model layers.

Coffeen Lake is represented as a constant head boundary based on an average surface water elevation of 591.0 feet NAVD88. The constant head boundary was simulated with an elevation equal to 591.0 feet. The lake is in hydraulic connection with multiple layers within the model.

The bottom of the model was also a no-flow boundary. The top of the model was a time-dependent specified flux boundary, with specified flux rates equal to the recharge rate. A specified mass flux boundary was used to simulate downward percolation of solute mass from the GMF GSP and GMF RP. This boundary condition assigns a specified concentration to recharge water entering the cells within the GMF GSP and GMF RP, and the resulting concentration in the GMF GSP and GMF RP cells 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

Evaluation of monitoring well data for the CPP has not identified statistically significant seasonal trends in groundwater flow or quality which could affect model applicability for prediction of transport. The MODFLOW model was calibrated to mean groundwater elevations from 2015 to 2021. Multiple iterations of MODFLOW calibration were performed to achieve an acceptable match to observed flow data.

Sensitivity analysis was conducted by changing input values and observing changes in the sum of squared residuals (SSR). Horizontal conductivity, vertical conductivity, and river and general head conductance terms were all varied by one order of magnitude (*i.e.*, between one-tenth and ten times) of the calibrated values. Recharge terms were varied between one-half and two times calibrated values. River stage was obtained from the 10 meter (m) Digital Elevation Model (DEM) from the United States Department of Agriculture/Natural Resources Conservation Service (USDA/NRCS) National Geospatial Center of Excellence (USDA/NRCS, 2022). The vertical error of the 10 m DEM is 0.82 m (2.7 feet); therefore, the stream stage was varied by adding and subtracting 2.7 feet. Where appropriate, drain stage was modified based on the DEM error, where this was inappropriate drain stage increased and decreased by 2 feet. General head boundary head terms were varied between 90 and 110 percent of calibrated values. The hydraulic flow boundary was varied by increasing the hydraulic conductivity by a factor of 100 and 1000. When the calibrated model was tested, the SSR was 351. Sensitivity test results were categorized into negligible, low, moderate, moderately high, and high sensitivity based on the change in the SSR as summarized in the notes in **Table 5-1**.

5.2.2.1 Layer Top/Bottom

The top of the saturated zone was used as the top of the model. The elevations for the base of each hydrostratigraphic layer were obtained from the NRT model (2017b) and were imported as grid data into MODFLOW. The upper Loess Unit of the Hagarstown Member (UCU) was divided into two layers to accommodate the explicit inclusion of the CCR in AP1 and AP2. The sand and silts of the Hagarstown Member which form the UA were represented using a single layer. The LCU was represented by two layers, the upper LCU (layer 4) represents the unweathered Vandalia/Mulberry Grove Member and the lower LCU (layer 5) represents the Smithboro Member.

The UCU layer was split into two layers (layers 1 and 2) to simulate the construction of AP1 and AP2. Within AP1 and AP2, layer 1 represents ash fill and layer 2 represents the UCU present below the ash and above the UA. Outside of AP1 and AP2, both layers 1 and 2 represent the UCU. Layer 3 represents the UA and the LCU is present in layers 4 and 5. **Figures 5-7 through 5-11** show the bottom elevations of the five model layers. The resulting model layers represent the distribution and change in thickness of each water-bearing unit across the model domain.

Table A below provides elevation and thickness information for the model layers and hydrostratigraphic units used in the model.

Table A. Flow Model Layer Descriptions

Layer	Hydrostratigraphic Unit Name	Hydrostratigraphic Unit Used to Determine Layer Thickness	Top Elevation [1]	Bottom Elevation [1]	Thickness (feet)
			Mean (Minimum – Maximum)		
1&2	UCU and CCR	Loess Unit of Hagarstown Member and CCR	640 (-)	607.73 (604.0-614.15)	27.1 (26.0-29.85)
3	UA	Hagarstown Member	607.73 (604.0-614.15)	600.9 (580.0-612.0)	5.2 (2.0-34.0)
4	LCU	Vandalia/Mulberry Grove Member	600.9 (580.0-612.0)	588.5 (578.0-594.0)	18.83 (2.0-30.0)
5	LCU	Base of Coffeen Lake	588.5 (578.0-594.0)	540.0 (-)	48.4 (38.0-51.1)

Notes:
[1] Elevation is measured in feet, referenced to NAVD88.

5.2.2.2 Hydraulic Conductivity

Hydraulic conductivity values and sensitivity results are summarized in **Table 5-1**. The spatial distribution of the hydraulic conductivities within the UCU, UA and LCU were considered homogenous. **Figures 5-12 through 5-16** show the spatial distribution of the hydraulic conductivity zones, GMF GSP and GMF RP, and other units on site for each of the five model layers. Construction of the GMF units (*i.e.,* GMF GSP and GMF RP) removed the sands and silts of the UA prior to construction of the liner; therefore, the UA is absent beneath these units and liner hydraulic properties are assigned. Conductivity zones that did not have representative site data (*i.e.,* zones 19 and 21, representing the cells above the river cells and the disturbed sediments between the LF and GMF GSP, respectively) were determined through model calibration.

Where available, hydraulic conductivity values were derived from field measured or laboratory tested values reported in the HCRs (Ramboll, 2021a; Ramboll, 2021b) (**Section 2.2.2**). No horizontal anisotropy was assumed. Vertical anisotropy was applied to conductivity zones to simulate preferential flow in the horizontal direction in these materials, and are presented as anisotropy ratio (Kh/Kv) in **Table 5-1**.

The model was highly sensitive to changes in horizontal and vertical hydraulic conductivity in zones 1 (UCU), 2 (UA), and 3 (LCU - unweathered Vandalia), and moderately sensitive to changes in horizontal and vertical hydraulic conductivity in zones 10 (CCR fill-AP1) and 19 (UCU-fill). The model exhibited a negligible to low sensitivity in the remaining zones for both horizontal and vertical conductivity.

5.2.2.3 Recharge

Recharge rates were determined through calibration of the model to observed groundwater elevations. For the calibration model, recharge was applied to the uppermost active layer and the rates varied based on different units, namely the AP1, AP2, GMF GSP, GMF RP, LF, Surface Water Pond, and Cooling Pond. Model inputs are summarized in **Table 5-1**. The distribution of recharge is shown in **Figure 5-17**. Changes in operational history, such as the addition of AP1 to the site in 1977 and the GMF units in 2010 as illustrated in **Figures 5-18 through 5-21**, have been incorporated into the transient model simulation (**Table 5-2**), see **Section 5.2.3.1** for additional discussion of time discretization.

The model had a high sensitivity to changes in recharge in zones 1 (UCU) and 7 (CCR fill–AP1). The model had negligible to low sensitivity to changes in recharge in the remaining zones, with the exception of zone 6 (CCR fill-AP2), where the sensitivity was moderate.

5.2.2.1 Storage and Specific Yield

The flow calibration model did not use these terms because it was run at steady state. For the transport model, which was run as a transient simulation, 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 5.2.3.5**. 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 5.2.3.6**.

5.2.2.2 River Parameters

Five river reaches were included in the model as head dependent flux boundaries that required inputs for elevation of the surface water, bottom of the stream, width, bed thickness, and bed hydraulic conductivity (**Table 5-1**). The five river reaches were the Unnamed Tributary east of the CPP (reach 0 and reach 5), the Unnamed Tributary west of the CPP (reach 1), ponded surface water west of the LF (reach 2), and the condenser cooling water discharge flume (reach 3). The river and drain information is summarized in **Table B** below.

Table B. River and Drain Information

Name	Boundary Type	Length (feet)	Slope (ft/ft)
Unnamed Tributary East	River	8959.0	-0.0031
Unnamed Tributary East – downstream reach	River	1438.3	-0.0026
Unnamed Tributary West	River	3436.5	-0.0098
Ponded Surface Water West	River	-	-
Condenser Cooling Flume	River	-	-
Active Landfill Underdrain	Drain	2147.0	-
Gravity Drain Recycle Pond	Drain	2181.8	-
North Drain	Drain	3032.0	-

Notes:
ft/ft = feet per foot

In the absence of river geometry information, the DEM was used to estimate stream stage at the upstream and downstream limits of the Unnamed Tributary east of the CPP and the Unnamed Tributary west of the CPP. The surface water stages for the ponded surface water west of the LF and the Condenser Cooling Flume were constant (not sloped) and were also obtained from the DEM. For both Unnamed Tributaries (east and west), the slope of the river was then linearly interpolated along the reaches, providing an estimation of stream stage along the length of each reach for each model grid cell though which the river flows. Bed thickness was set at 2 foot and river width was set at 10 feet. The river bottom is set 3 feet below the stage for both the Unnamed Tributaries. The downstream reach (reach 5) of the Unnamed Tributary is located in layer 5 of the model adjacent to the SI unit AP2, this layer represents the LCU-Smithboro till and has a low hydraulic conductivity. To increase connectivity of the tributary to the overlying layers the hydraulic conductivity of the streambed was modified during calibration.

The Condenser Cooling flume stage is maintained at 604.0 feet and the ponded surface water west of the LF was maintained at 617.5 feet, and bed thicknesses for these reaches were set to 1 foot. The width of the Cooling Flume (approximately 52 feet) and ponded surface water west of the LF are larger than the grid cell dimensions (25 feet by 25 feet), therefore the conductance term for both were based on the area of the cells which coincide with the flume and ponded water.

The model had low to moderate sensitivity to changes in river stage. The model had low to moderately high sensitivity to changes in river conductance, with the exceptions of reach 0 (Unnamed Tributary East) and reach 3 (Condenser Cooling Flume) which had high sensitivity.

5.2.2.3 Drain Parameters

The LF has an active underdrain, which is actively pumped to prevent more than 1-foot of groundwater head above the liner. This was estimated to be 603.5 feet. The GMF RP has a passive drain beneath the liner which discharges water towards the Unnamed Tributary east of the unit. This was estimated to be 600.5 feet. Both the active LF drain and passive GMF RP drain were placed in layer 4 (LCU) below the low hydraulic conductivity zones which represent the base of the lined units. A surface water drain in the north of the model was also included; the placement of this northern drain was determined using google earth imagery. The Northern drain appears to be a man-made feature and no hydrological data are available as to its flow conditions. Therefore, its implementation in the model as a drain makes the fewest assumptions of its interaction with the aquifer. This surface water drain is located in layer 1 and has an elevation of 622.0 feet.

The model had low sensitivity to changes in drain stage. The model had negligible to moderate sensitivity to changes in drain conductance, with the exception of reach 0 (Active LF Underdrain) where the model had moderately high sensitivity to changes in drain conductance.

5.2.2.4 GMF Unit Parameters

All GMF units (GMF GSP, GMF RP, and LF) have a similar liner construction (**Table C** below); they were all implemented into the model using a hydraulic flow barrier to present the liner system on the sides of the units. The bottom of the liner is implemented by assigning the liner system hydraulic conductance to model layer 3 within the footprint of the pond. The base elevation of layer 3 within the footprint of the GMF units simulates the base elevation of the liner. The thickness of model layer 3 within the footprint of the pond was set to three feet. Removal of the sands and silts below the GMF units (as described in **Sections 1.4** and **2.1**) means that the liner is in direct contact with the Vandalia Member. The groundwater flow dynamics beneath/around the Ash Landfill and GMF Units is affected by several factors, including: removal of the Hagarstown Member from beneath the Units; presence of the construction dewatering systems around the units; and the lateral variability of lithology within the Hagarstown Member (Hanson

2016). Drains discussed above were used to represent the underdrains associated with the GMF units. The hydraulic properties within the GMF units were set to represent the CCR.

Estimates of the hydraulic properties of each of the components within the liner system were derived using values from the HELP model; see **Section 5-1** for more information about HELP. For flow perpendicular to the layer orientation, as is the case in the liner where the hydraulic gradient is vertical for the base and horizontal for the sides of the pond, the harmonic mean was used to obtain the effective hydraulic conductivity (K_{eff}) (Fetter, 1988). The harmonic mean was determined by:

$$K_{eff} = \frac{\sum b}{\sum \frac{b}{K}}$$

Where b is the layer thickness and K is the horizontal hydraulic conductivity.

Hydraulic flow boundary input parameters are presented in **Table 5-1**. The model had low to moderate sensitivity to changes in the hydraulic conductivity in the horizontal flow barrier (HFB).

Table C. Liner System Properties From Top to Bottom for the GMF GSP, GMF RP, and LF

Liner Component	Thickness (feet)	Hydraulic Conductivity (cm/s)	Hydraulic Conductivity (feet/day)
HDPE geomembrane (60 mm)	0.06	2.0×10^{-13}	5.7×10^{-10}
Recompacted Soil	3.0	1.0×10^{-7}	2.8×10^{-4}
Vertical Harmonic Mean of Liner System	**NA**	**NA**	**2.89×10^{-8}**

* Estimated based on available information
NA = not applicable

5.2.2.5 General Head Boundary

General head boundary conditions (GHB) were used along the northern boundary of the model for layer 3 through 5 (**Figures 5-4 through 5-6**). The GHB at the northern limit of the model represents groundwater entering the model domain from upgradient areas, the GHB is present in layers 3 through 5 was used to simulate groundwater flow into the model via the UA and LCU. The groundwater levels used for the northern boundary of the model in layers 3 through 5 were estimated using the Dupuit equation for steady state flow in an unconfined aquifer with recharge.

The DEM of the site provided estimates of the surface water levels for Coffeen Lake on the west boundary of the model (591 feet), and Rocky Ford Sportsman Club North Lake (604 feet) on the east of the model domain (**Figure 5-1**). The calibrated ambient recharge to the UCU was used in the calculation of the groundwater level distribution at the northern boundary. The hydraulic conductivity value used in the Dupuit equation was estimated during model calibration.

This GHB was only applied to cells along the northern boundary where the base of the cell was below the calculated groundwater head for a given distance from the constant head boundaries, the head was determined by the Dupuit equation. Cell conductance was then calculated using the cells' saturated thickness and cell width, and hydraulic conductivity were based on cell hydraulic conductivities and adjusted if appropriate during calibration.

The GHB elevation for northern boundary in the UA was established during calibration (**Table 5-1**). The distance to the GHB head was set to 1, and the GHB conductivity was calculated using the cell width, cell thickness, and calibrated hydraulic conductivity from the model.

The sensitivity to changes in specified head was low to moderate, with the exception of reach 3 (Northern Model Boundary in LCU Layer 4) where the model sensitivity was high. The flow calibration model had negligible sensitivity to changes in conductance.

5.2.3 Transport Model

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

Groundwater transport was calibrated to groundwater sulfate concentration ranges at each well as measured from the monitoring wells between 2015 (where available) and 2021. The transport model calibration targets are summarized in **Table 4-1**.

Sensitivity analysis was conducted by changing input values and observing percent change in sulfate concentration at each well from the calibrated model sulfate 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 dispersivity values in the calibrated model were increased by a factor of 5 and 10. The sensitivity of the transport model to changes in the liner conductance was also investigated by increasing and decreasing the hydraulic conductivity of the liner by one order of magnitude (*i.e.*, between one-tenth and ten times).

The transport model generally had a low to moderately high sensitivity to changes in storage and specific yield (**Table 5-3**) as discussed in **Section 5.2.3.6**, not including monitoring locations where the calibration concentration was less than 10.0 mg/L. The transport model generally ranged from low to moderate sensitivity to effective porosity and low to high sensitivity to dispersivity as discussed in **Sections 5.2.3.5** and **5.2.3.7**, respectively. The transport model generally had a low to high sensitivity to changes in the liner conductivity as discussed in **Section 5.2.3.2.**

5.2.3.1 Time Discretization and Stress Periods

The evolution of the CPP required changes to the hydraulic properties within the model; this is not possible in a single model where hydraulic properties are assumed to remain constant. As a result, the changes in the site (*e.g.,* inclusion of the GMF units) are simulated in three consecutive numerical models, as summarized in **Table D** on the following page. The simulation length was revised from the existing model to extend to the current time (2022).

Table D. Transient Model Setup and Time Discretization

Date	Model	Stress Period	Operational Change	Previous model
Pre-1970	Steady-State	NA	No CCR units present	Not applicable
1970-2010	Transient (TR-1)	1:1970-1985	AP2 only	Steady State Pre-1970 flow
		2:1985-2010	AP2 and AP1 in operation	
2010-2018	Transient (TR-2)	1:2010-2018.	AP1, GMF GSP and GMF RP in operation.	TR-1 as initial flow and concentrations
2018-2022	Transient (TR-3)	1:2018-2022	Modification to lined units GMF GSP and GMF RP, AP2 capped	TR-2 as initial flow and concentrations

Notes:
TR = transient model

5.2.3.2 GMF Units

Groundwater chemistry data from wells G215 (located adjacent to the GMF GSP), and wells G275 and G279 (located adjacent to the GMF RP), indicate an increase in sulfate concentrations post 2018 when compared with sulfate concentrations in adjacent wells. Sulfate concentrations in G215 have experienced further increases since 2021. Sulfate concentrations around the GMF RP tend to be higher than those around the GMF GSP, with elevated sulfate concentrations observed since 2015 (the earliest sampling date). Elevated sulfate concentrations along the southern boundary of the GMF RP are associated with historic groundwater impacts from AP2. However, wells G275 and G279 are located along the eastern boundary of the pond and have elevated sulfate concentrations. To simulate observed sulfate concentrations at these isolated wells (GMF GSP well G215 and GMF RP wells G275 and G279), the hydraulic conductivity of the liner (simulated using hydraulic flow boundary [HFB] cells) was increased to allow sulfate migration from the CCR unit in the transient model TR-3, as shown in **Figure C** below and **Table D** above.

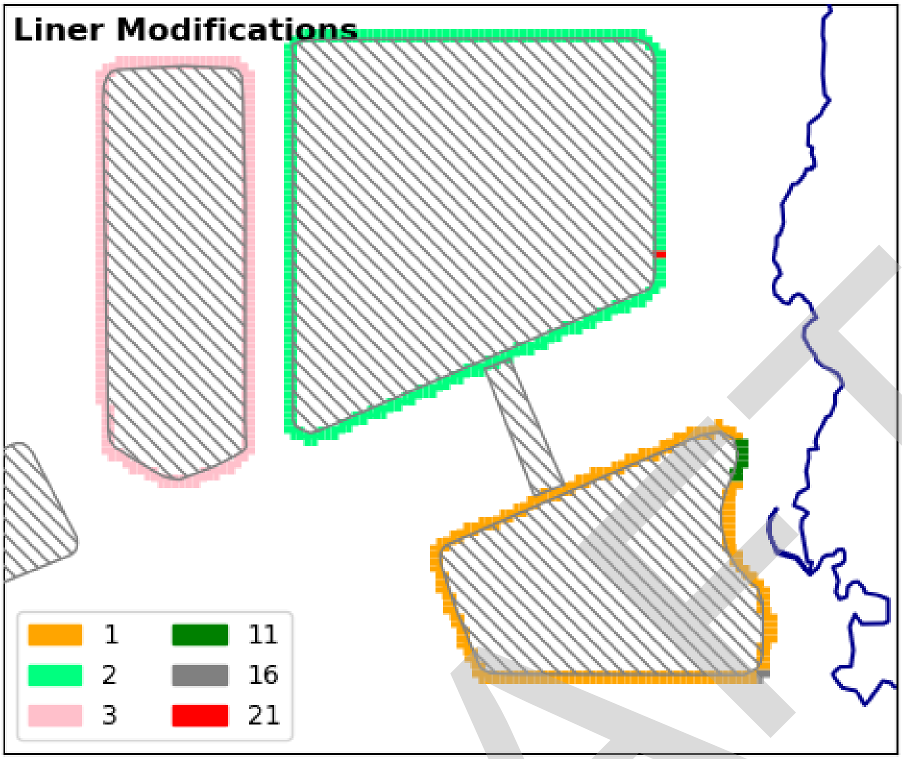

Figure C. Liner Modification Zones

As part of the transport calibration process, the hydraulic conductivity of HFB reaches 11, 16, and 21 were modified to simulate the observed rises in sulfate. The changes are summarized in **Table 5-2**.

The model had a negligible to high sensitivity to changes in the HFB values, not including monitoring locations where the calibration concentration was less than 10.0 mg/L (*i.e.*, G102, G103, G105, G106, G206, G207, G208, G210, G211, G212, G216, G217, G218, G270, and G280) (**Table 5-3**). An increase in the liner conductance produces the greatest sensitivity in monitoring wells G215, G275, G276 and G279. This high sensitivity is anticipated given that the liner properties were modified to match observed sulfate concentrations in the vicinity of these wells (**Table 5-2** and **Table 5-3**).

5.2.3.3 Initial Concentration

No initial concentrations were placed in the steady state flow calibration model. The flow model was run as transient and concentration was added to the model through recharge starting at the same time as the transient flow simulation. Modeling was performed for a sufficient period (42 years) to allow modeled concentrations in the primary transport layer (*i.e.,* UA) to reach recently observed levels.

Modeling was performed over three numerical models which mirror the operational developments at the CPP. **Table 5-2** provides an overview of how the source concentrations and recharge rates change through time.

5.2.3.4 Source Concentration

Five sources in the form of vertical percolation (recharge) and constant concentration cells were simulated in the CCR material for calibration (**Table 5-2**) (in chronological order): (i) percolation through CCR in AP2 (1970-2022), (ii) percolation through CCR in AP1 (1978-2022), (iii) percolation through CCR in GMF RP (2010-2022), (iv) percolation through CCR in GMF GSP (2010-2022), and (v) percolation through CCR in GMF LF (2010-2022). All five sources were simulated by assigning concentration to the recharge input. The CCR sources were also simulated with constant concentration cells placed where CCR was present (**Figures 5-18 through 5-21**) to simulate saturated CCR conditions. From the model perspective, this means that when the simulated water level is above the base of these cells, water that passes through the cell will take on the assigned concentration. All source concentrations were calibrated in the transport model to the sulfate concentration data collected from November 2015 to August 2021. The source concentrations applied to the recharge zones and saturated ash cells immediately below the recharge zones have the same concentration values. **Table 4-1** indicates that the background sulfate concentrations (identified with a "B" for background in the "CCR unit" column) at CPP show considerable variability across the site, from 11 mg/L (G286) to 770.0 mg/L (G288). No background sulfate concentration was applied to recharge beyond the source areas in the model.

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.

5.2.3.5 Effective Porosity

Effective porosity for each modeled hydraulic conductivity zones were based on the NRT model (2017b), data from the HCRs (Ramboll, 2021a; Ramboll, 2021b), and literature values (Fetter, 2001) and are presented in **Table 5-2**.

The model had a negligible to moderate sensitivity to changes in porosity values, not including monitoring locations where the calibration concentration was less than 10.0 mg/L (*i.e.*, G102, G103, G105, G106, G206, G207, G208, G210, G211, G212, G216, G217, G218, G270, and G280) (**Table 5-3**). For wells with calibration concentrations greater than 10.0 mg/L, the greatest sensitivity for porosity was moderate for both the low and high porosity sensitivity tests at monitoring locations G213, G214, G215, G271, G272, and G276.

5.2.3.6 Storage and Specific Yield

The transport model had a negligible to high sensitivity to changes in storage and specific yield, not including monitoring locations where the calibration concentration was less than 10.0 mg/L (*i.e.*, G102, G103, G105, G106, G206, G207, G208, G210, G211, G212, G216, G217, G218, G270, and G280). Monitoring wells G213, G214, G215, and G271 had moderately high to high sensitivity to changes in storage and specific yield. Of these wells only G215 had simulated sulfate concentrations in both the calibrated model and sensitivity models which exceed the GWPS of 400 mg/L (**Table 5-3**).

5.2.3.7 Dispersivity and Diffusion

Physical attenuation (dilution and dispersion) of contaminants is simulated in MT3DMS. Dispersion in porous media refers to the spreading of contaminants over a greater region than would be predicted solely from the average groundwater velocity vectors (Anderson, 1979;

Anderson, 1984). Dispersion is caused by both mechanical dispersion, a result of deviations of actual velocity at a microscale from the average groundwater velocity, and molecular diffusion driven by concentration gradients. Molecular diffusion is generally secondary and negligible compared to the effects of mechanical dispersion and only becomes important when groundwater velocity is very low. The sum of mechanical dispersion and molecular diffusion is termed hydrodynamic dispersion, or simply dispersion (Zheng and Wang, 1998).

Longitudinal dispersivity was 10 feet in the UA and 1 foot in the UCU and LCU, with transverse and vertical dispersion coefficients assuming a ratio of 1/10 and 1/100.

The model had a low to high sensitivity to changes in porosity values, not including monitoring locations where the calibration concentration was less than 10.0 mg/L (*i.e.*, G102, G103, G105, G106, G206, G207, G208, G210, G211, G212, G216, G217, G218, G270, and G280) (**Table 5-3**). For wells with calibration concentrations greater than 10.0 mg/L, the greatest sensitivity for dispersivity was high sensitivity at monitoring locations G213, G214, and G271.

5.2.3.8 Retardation and Decay

It was assumed that sulfate would not significantly sorb or chemically react with aquifer solids (distribution coefficient [Kd] was set to 0 mL/g) which is a conservative estimate for estimating contaminant transport times. Boron, sulfate, and TDS transport is likely to be affected by both chemical and physical attenuation mechanisms (i.e., adsorption and/or precipitation reactions as well as dilution and dispersion). Batch adsorption testing was conducted to generate site specific partition coefficient results for boron and sulfate (Geosyntec, 2022, **Appendix B**) for location G215. Results of the testing are summarized below:

- Boron: A boron partition coefficient was not determined for any isotherm for the boron amended with microcosms. Both the linear and linearized Langmuir isotherms yielded negative partition coefficients, and the linearized Freundlich could not be calculated as the data were not conducive to log transformation. Other studies have reported low partition coefficients for boron ranging from 0.19 to 1.3 L/kg, depending on pH conditions and the amount of sorbent present (EPRI, 2005; Strenge & Peterson, 1989).
- Sulfate: A sulfate partition coefficient was not determined for any isotherm for the sulfate amended microcosms. The linear isotherm yielded a partition coefficient of 0.1 L/kg but had a very poor goodness-of-fit, and the Langmuir isotherm yielded a negative coefficient. As in the boron-amended microcosms, the Freundlich isotherm could not be calculated because the data were not conducive to log transformation. These results are consistent with the findings of Strenge & Peterson (1989), who found that partition coefficients for sulfate are 0.0 L/kg, regardless of pH conditions and the amount of sorbent present.

The results from site samples did not provide representative isotherms which supports modeling sulfate without retardation. The potential exceedances identified in groundwater (boron, sulfate, and TDS) are affected by natural attenuation processes in multiple ways and to varying degrees. Further assessment of these processes and how they may be applied as a potential groundwater remedy will be completed as part of future remedy selection evaluations, as necessary. For the purposes of this GMR, and as mentioned at the beginning of this section, no retardation was applied to sulfate transport in the model (i.e., Kd was set to 0). Sensitivity tests were not run for retardation.

5.3 Flow and Transport Model Assumptions and Limitations

Simplifying assumptions were made while developing this model:

- Leading up to 2022, the groundwater flow system cannot be simulated as steady state.
- Natural recharge is constant over the long term.
- Fluctuations in lake 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 AP1, GMF GSP, GMF RP, and LF were developed with Golder using soil borings and historic topographic maps.
- Source concentrations are assumed to remain constant over time.
- Sulfate 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 located near the units on site, 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 Model

The groundwater model was manually calibrated to best approximate the mean groundwater elevations in 95 wells at the site. The mean elevations used for calibration and locations of wells within the flow model are summarized in **Table 4-1** Well locations are shown in **Figure 2-1**. This involved modifying the hydraulic conductivities of the different hydrostratigraphic units, recharge rate, and conductance of the drains, rivers, and general head boundaries within the model to minimize the difference between the mean observed groundwater elevation and simulated groundwater elevation. Where possible, the range of the parameter values used during calibration were based on observed values (*i.e.,* for the range in hydraulic conductivity estimates from the HCRs). Where this was not possible, such as for the drain and general head boundary conductance, the range of parameter values were based on other site information or inferred from knowledge from similar sites. Where data were limited, the parameter values were less constrained during calibration (*e.g.,* parameter values had wider ranges). The SSR was used as a metric to identify the optimal values for the different parameters.

5.5 Calibration Flow and Transport Model Results

Results of the MODFLOW modeling are presented below. The model files accompany this report (**Appendix A**). **Table 5-1** shows the calibrated hydraulic conductivity for the different units shown in **Figures 5-12 through 5-16**.

Groundwater model calibration results are presented in **Figure 5-22** and **Figure 5-23**, which shows the observed and simulated groundwater elevations and the observed groundwater elevation versus residuals. The near-linear relationship between observed and simulated values presented on **Figure 5-22** indicates that the model adequately represents the calibration dataset. The root mean squared error of the simulated groundwater elevation across all wells was

1.92 feet. The mass balance error for the flow model was 0.00 percent and the ratio of the residual standard deviation to the range of heads was 9.0 percent, which is below the desired target value of 10 percent. Another flow model calibration goal is that residuals are evenly distributed such that there is no bias affecting modeled flow. The observed heads are plotted versus the simulated heads in **Figure 5-23** and simulated values are evenly distributed above and below observed values. The mean residual was also near zero with a value of 0.10 feet, indicating a small bias towards underestimating the groundwater elevation in the calibrated model; this is also illustrated in the observed versus residuals plot in **Figure 5-23**.

The simulated groundwater elevations within the UA (layer 3) for the entire site are shown in **Figure 5-24**. **Figure 5-25** shows the simulated groundwater elevations in proximity to the GMF GSP and GMF RP. In general, the model is able to simulate the groundwater flow patterns in the UA (**Figure 2-2** and **Figure 2-3**) at the GMF GSP and GMF RP interpreted from the site well data for April and July 2021, respectively.

In general, the model is able to simulate the groundwater flow patterns in the UA around the GMF units (**Figure 2-2** and **Figure 2-3**). The removal of the UA sands beneath the units and presence of a low hydraulic conductivity of the liner and underdrain beneath the GMF RP does appear to increase flow towards the Unnamed Tributary, particularly in the southeast corner of the GMF RP.

Twelve wells provided calibration targets for the simulated groundwater levels around the GMF RP (**Figure 5-25**). The simulated groundwater levels are within 2 feet for all wells except G274 at the southeast corner, which is underpredicted by 2.5 feet. The simulated groundwater levels are within 1 foot for nine of the wells and within 2 feet for two wells. There is a tendency for the model to overestimate the groundwater levels to the east of the GMF RP close to the Unnamed Tributary, and underestimate the groundwater levels to the south of the GMF RP.

Twenty-two wells provided calibration targets for the simulated groundwater levels around the GMF GSP (**Figure 5-25**). The simulated groundwater levels to the south of the GMF GSP are generally underestimated. Of the ten wells located along this boundary, the simulated groundwater levels in two wells are within 1 foot of the observed groundwater levels, five wells are within 2 feet, and two wells are within 3 feet. One well at the southeast corner is underestimated by 3.34feet; however, this is directly adjacent to a well whose simulated groundwater level is within 2 feet of the observed groundwater level. On the eastern boundary of the GMF GSP, the simulated groundwater levels are underestimated in the southeast and overestimated in the northeast. Of the five wells located along this boundary, the simulated groundwater level for two wells is within 1 foot, and the remaining three wells are within 2 feet of the observed groundwater elevation. There are five wells located along the western boundary of the GMF GSP. The simulated groundwater levels for two wells are within 1 foot (G106 and G102), and one well is within 2 feet (G103). The remaining two wells, G105 and R105, are simulated within 2.61 feet and 3.89 feet, respectively. Two wells, MW11S and T202, provide calibration targets to the north of the GMF GSP with the simulated groundwater levels which are overestimated by 0.55 and 3.39 feet, respectively.

Construction of the lined GMF units, combined with partial to complete removal of the UA beneath the unit footprints along with installation of undrain systems, created a significant disturbance to the subsurface flow pattern. Capturing this change in a groundwater flow model is challenging. The changes in subsurface hydraulic properties in proximity to the units may be considerable. For example, the inclusion of a zone which represents the area between the GMF GSP and LF was created to capture the unique conditions between these two CCR units. The zonation currently applied to disturbed materials is a simple representation based on available soil borings near the GMF units. The general flow pattern in and around the GMF units is in good agreement with the observed flow patterns in the area (**Figure 2-2** and **Figure 2-3**).

The range of observed sulfate concentrations for transport calibration locations are summarized in **Table 4-1**. The goals of the transport model calibration were to have predicted concentrations fall within the range of observed concentrations and to have predicted concentrations above and below the GWPS for sulfate (400 mg/L) match observed concentrations above or below the standard at each well. For the GMF RP, one or both of these goals were achieved at all of the transport calibration location wells, except G276 where concentrations were overpredicted (**Figure 5-26**). Deviations from the observed ranges are discussed below. The distribution of sulfate concentrations in the calibrated model are presented on **Figure 5-27**. The elevation of the basal liner system influences the distribution of sulfate concentration within the footprint of the GMF RP. **Figure 5-8** illustrates the bottom elevation of model layer 2 which represents the top of the liner system. Within the footprints of both the GMF GSP and GMF RP, the base of the liner incorporates part of the bounding berm system for each of the units. As a result of the increase in elevation at the edges of the SIs, high sulfate concentrations are simulated. This is most notable at the south end of the GMF GSP in **Figure 5-27**.

G276 has a maximum observed sulfate concentration of 310 mg/L, and the simulated sulfate concentration is 543 mg/L. G276 is located 140 feet downgradient of G275 where sulfate concentrations ranged from 650 to 940 mg/L. The observed and simulated flow direction around the southeastern corner of the GMF RP is northeasterly. This flow direction leads to sulfate transport in a northeasterly direction from G275 towards G276. The lower observed sulfate concentration at G276 as compared to G275 may be the result of subsurface heterogeneity within the UA that is not captured in the model.

The model under predicts concentrations in G271, G272, G273, and G274. The observed sulfate concentrations in these wells ranges from 260 and 690 mg/L. For all wells, modeled and minimum observed sulfate concentrations are both below 400 mg/L, so one of the two calibration goals was satisfied.

Modification to the liner conductivity for the GMF RP enabled the simulated sulfate concentrations to reasonably match the observed concentrations in calibration wells G275 and G279. **Table 5-2** provides the changes to the hydraulic conductivity for the discrete reaches within the liner. During calibration the hydraulic conductivity was increased from 2.89×10^{-8} feet per day (ft/d) to 3.0×10^{-4} ft/d for reach 11 and 6.5×10^{-4} ft/d for reach 16.

For the GMF GSP, one or both of these goals were achieved at all of the transport calibration location wells (**Figure 5-26**). The model tends to underestimate the sulfate concentrations in the GMF GSP wells, excluding G215 where the simulated sulfate concentration is within the observed range. The variability in observed sulfate concentrations in the GMF GSP wells, excluding G215, is within the range of the sulfate concentrations in the background wells, as presented in **Section 5.2.3.4**. No background sulfate concentration was applied to the model, which results in general underestimation of observed sulfate concentrations.

Only calibration well G215 has observed sulfate concentration above the GWPS (400 mg/L), the remaining calibration wells are below the GWPS. Modifications to the liner conductivity of the GMF GSP have enabled the simulated sulfate concentrations to match the observed concentrations in these wells (**Table 5-2**). During calibration, the hydraulic conductivity was increased from 2.89 x 10^{-8} ft/d to 6.0 x 10^{-4} ft/d for reach 21.

In general, the calibrated transport model was able to simulate the sulfate concentrations in the remaining wells with observations above the standard GWPS for sulfate (400 mg/L) from January 2015 to October 2021 which had calibrated concentrations above the GWPS.

6. PREDICTIVE SIMULATIONS

6.1 Overview and Prediction Model Development

Prediction simulations were performed to evaluate the effects of closure (source control measures) for the GMF GSP and GMF RP on groundwater quality. The prediction simulations evaluated changes in groundwater sulfate concentrations from Scenario 1: CIP (removal of CCR from the GMF RP and southern portion of the GMF GSP and consolidation in the northern portion of the GMF GSP) and Scenario 2: CBR (removal of all CCR material from both the GMF GSP and GMF RP). As discussed in **Section 5.2.3.7**, physical attenuation (dilution and dispersion) of contaminants in groundwater is simulated in MT3DMS, which captures the physical process of natural attenuation as part of corrective actions for both closure scenarios simulated. No retardation was applied to sulfate transport in the model (*i.e.*, Kd was set to 0) as discussed in **Section 5.2.3.8**.

Closure scenarios were simulated by initially removing free liquids from the CCR material over the course of 2 years by placing drain cells within GMF GSP and GMF RP with an elevation of 610 feet and applying zero recharge to simulate dewatering of the CCR units.

HELP-calculated percolation rates, based on removal and final soil backfill grading designs provided in the Draft CCR Final Closure Plans for Coffeen AP1, GMF GSP, and GMF RP (Golder, 2022), were applied for the different closure scenarios. HELP modeling input and output values are summarized in **Table 6-1** and described in detail below.

The CIP and CBR scenarios were simulated for a 100-year period. The following simplifying assumptions were made during the simulations:

- Removal of free liquids from CCR takes place prior to the CIP and CBR closure scenarios. Drain cells were placed within the units to simulate the removal of free water within the ponds; and recharge was set to zero.
- In the CIP and CBR 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 the duration of the closure scenario prediction model runs following CCR dewatering period.
- Changes in recharge resulting from removal of free liquids (decrease calibration model recharge rates to zero) and CCR 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.
- Sulfate source concentrations were assumed to be negligible (0 mg/L) in CCR removal areas in both the CIP and CBR scenarios. The spatial distribution of CCR concentrations within the consolidation area for the CIP scenario were maintained from the initial transport simulation.
- Cap construction in CIP scenario was assumed to be completed with a cover system consisting of the following (listed from ground surface down): a vegetative cover (6 inches thick), rooting zone (18 inches thick), a 200-mil geocomposite drainage layer and a 40-mil linear HDPE geomembrane.
- The start of each closure prediction simulation was initiated at the end of the calibration model period of 42 years plus 2 years to complete removal of free liquids. For example, the

simulation of Scenario 1: CIP begins at 44 years (42 years for calibration plus 2 years). The prediction modeling timeline for each scenario is illustrated in **Figure 4-1**.

- CCR consolidation/removal areas were assumed to be graded and include proper drainage controls to remove excess water from the surface using the design drawings provided (Golder, 2022).
- The CIP scenario includes the placement of a stormwater pond within the removal area. The outflow elevation for both the GMF GSP and GMF RP are 615 feet, which will discharge into the Unnamed Tributary adjacent to the GMF GSP and GMF RP. This is represented as a drain in the model whose elevation is equal to the outflow elevation. All saturated CCR (constant concentration cells) in the transport calibration model were removed instantaneously in all CCR removal areas for all prediction models.
- Local fill materials applied to the prediction models have similar hydraulic properties as the UCU materials used in the transport calibration models. However, the local fill materials were assumed to have reduced vertical anisotropy ratios, approaching isotropic, due to reworking of the material as it is placed as backfill (Kh/Kv decreased from measured values of 10 to 1 for reworked material).

6.2 HELP Model Setup and Results

HELP (Version 4.0; Tolaymat and Krause, 2020) was used to estimate percolation through the GMF GSP areas of CCR consolidation with final cover system and expected LF cover system. 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 Belleville Scott Air Force Base in Belleville, Illinois (the closest weather station included in the HELP database). Precipitation, temperature, and solar radiation was simulated based on the latitude of CPP. Thickness of soil backfill and soil runoff input parameters were developed for the ash fill removal scenarios using data provided in the Preliminary Closure Concepts for Coffeen AP1, GMF GSP, and GMF RP (Golder, 2022).

HELP model results (**Table 6-1**) indicated 0.00019 inches of percolation per year for GMF GSP through the CCR and final cover system for the CIP scenario. No recharge rate was calculated for removal areas in both the CIP and CBR scenario as removal areas are subject to stormwater controls. HELP model results (**Table 6-1**) indicated 0.000012 inches of percolation per year for the LF through the CCR and final cover system. The differences in HELP model runs for each area included the following parameters: area, soil backfill thickness, slopes, and soil runoff slope length; all other HELP model input parameters were the same for each simulated area. HELP input data and results are provided in **Appendix A.**

6.3 Simulation of Closure Scenarios

The calibrated model was used to evaluate the effectiveness of the two closure scenarios by defining CCR removal and consolidation areas, reducing head to simulate removal of free liquids, removing source concentrations from the removal areas, adding drain cells and removing recharge to simulate stormwater management within the removal areas, and applying reduced recharge in the CCR consolidation areas to simulate the effects of the cover system on flow and transport. Removal of source inputs from the ash removal areas was simulated by reducing the sulfate concentrations associated with recharge in the areas to 0 mg/L and removing constant concentration cells.

Each prediction scenario was simulated as a continuation of the GMF GSP and GMF RP dewatering simulation which followed the transient calibrated model. The prediction model input values are summarized in **Table 6-2,** and the modifications to the recharge zones and drain placement for the CIP scenario are illustrated in **Figure 6-1**. **Figure 6-2** illustrates the CCR removal area for the CBR at the GMF GSP and GMF RP. The two closure scenarios are discussed in this report based on predicted changes in sulfate concentrations as described below and results are presented in **Figure 6-3 to Figure 6-6**.

6.3.1 Closure in Place Model Results

The design for Scenario 1: CIP includes an initial 2-year dewatering period to remove free liquids followed by CCR removal from the GMF GSP and GMF RP, consolidation of CCR from both the GMF GSP and GMF RP in the northern area of GMF GSP, and construction of a cover system over the remaining CCR (**Figure 6-1**). No CCR material remains in the GMF RP (Golder, 2022).

A general decline in sulfate concentration occurs where CCR is removed and saturated ash cells (constant concentration cells) are reduced in the area of the highest modeled source concentrations. Following removal of CCR in the southern area of the GMF GSP and entire footprint of the GMF RP, sulfate is no longer entering the model domain from recharge or from saturated ash cells (constant concentration cells). Dewatering also reduces the head within the GMF GSP and GMF RP. These low heads are maintained following completion of closure by the drain cells that simulate storm water management designs within the removal areas in both the GMF GSP and GMF RP, and limited infiltration rates (recharge) from the ash consolidation area. As a result of the reduced heads and recharge, downward percolation of solute mass from the GMF GSP is reduced and no future downward percolation of solute mass is simulated for GMF RP, which decreases the sulfate concentration entering the model domain.

6.3.1.1 GMF GSP

The predicted concentrations at the GMF GSP show a brief period of concentration increases post closure, after which there is a rapid decline in sulfate concentration. The sulfate concentrations at monitoring well G215 drive groundwater compliance, which indicate sulfate concentrations rapidly decline once the impact of the closure actions are established within the prediction model (**Figure 6-3**). Fluctuations in simulated concentration are caused by the removal of concentration during the dewatering phase and the subsequent reestablishment of groundwater flow patterns after the liner is removed from the model and the stormwater drain is established. Similar initial fluctuations in concentration are also apparent in some of the GMF RP wells, namely G279 and G275 (**Figure 6-5**).

Of the GMF GSP wells, only G215 has observations above the GWPS for sulfate (400 mg/L) at the end of the transport calibration model. The prediction model indicates that G215 will decline and reach the GWPS (400 mg/L) in approximately 6.4 years (**Figure 6-3**) following closure. The maximum extent of the plume in all layers of the model at 6.4 years is also illustrated in **Figure 6-4.** The results illustrate how sulfate concentrations above the GWPS remain within the liner of the GMF GSP consolidation area. These concentrations remain confined to the lined and capped area of the GMF GSP (zone 16 in model layer 3) throughout the simulation period of 100 years and decrease with time. The reduced recharge rate, and therefore significantly lower addition of sulfate mass into the model, leads to gradual reduction in sulfate concentration in the base of the liner over time. The residual sulfate plume from the calibrated model remains in close proximity to the GMF GSP and declines below the GWPS approximately 14 years after closure.

6.3.1.2 GMF RP

The predictive model indicates that GMF RP wells within the UA will reach the GWPS (400 mg/L) in approximately 2.5 years, after closure (**Figure 6-5**). The maximum extent of the plume in all layers of the model at this time is illustrated in **Figure 6-6**. The predicted concentrations in G275 and G279 with the greatest observed sulfate concentrations are both below the GWPS within 2.5 years. Similar to the GMF GSP, the prediction model indicates the residual sulfate plume from the calibration model remains in close proximity to the GMF RP and declines below the GWPS approximately 9 years after closure.

6.3.2 Closure by Removal

The design for Scenario 2: CBR includes an initial 2-year dewatering period followed by CCR removal from the GMF GSP and GMF RP (**Figure 6-2**).

The prediction model shows a general decline in sulfate concentration as all CCR is removed from the GMF GSP and GMF RP, and saturated ash cells (constant concentration cells) are removed. Following removal of CCR and the liner system in both the GMF GSP and GMF RP, sulfate is no longer entering the model domain from recharge or from saturated ash cells (constant concentration cells); all source concentrations are removed. Dewatering through removal of free liquids also reduces the head within the GMF GSP and GMF RP. These low heads are maintained following completion of closure by the drain cells that simulate stormwater management designs within the GMF GSP and GMF RP.

6.3.2.1 GMF GSP

Of the GMF GSP wells, the prediction model indicates that G215 will reach the GWPS (400 mg/L) in approximately 7.4 years, after closure (**Figure 6-3**). This result is 1 year longer than the estimate for CIP which predicted 6.4 years to reach the GWPS. This is attributed to the minor differences in the predicted groundwater flow patterns associated with each scenario. **Figure 6-3** and **Figure 6-4** illustrate very little difference in the extent of the plume in the UA and the maximum extent of the plume in all model layers after 6.4 years, respectively. Similar to CIP, the residual sulfate plume from the calibrated model remains in close proximity to the GMF GSP and declines below the GWPS approximately 14 years after closure.

6.3.2.2 GMF RP

The implementation of the CIP scenario and CBR scenario are identical with regard to the GMF RP. All CCR materials and liner system are removed from the GMF RP in both the CIP and CBR scenarios. Therefore, simulation results are very similar to those discussed in **Section 6.3.1**. In both scenarios, the time for wells to reach the GWPS is 2.5 years (**Figure 6-5**). The maximum extent of the plume in all layers of the model at this time is illustrated in **Figure 6-6**. All monitoring wells with observations above the standard GWPS for sulfate (400 mg/L) are predicted to be below the GWPS 2.5 years for the GMF RP, after closure implementation.

The residual sulfate plumes associated with the GMF RP in the CBR prediction model behave similarly to the plume in the CIP prediction model. The prediction model indicates the residual sulfate plume from the calibration model remains in close proximity to the GMF RP and declines below the GWPS approximately 9 years after closure.

7. CONCLUSIONS

This GMR has been prepared to evaluate how proposed CIP and CBR scenarios will achieve compliance with the applicable groundwater standards at the CPP for the lined CCR units GMF GSP and GMF RP. An existing groundwater model was updated to include data collected from the recent 2021 field investigations and used to predict the impacts of the closure scenarios on groundwater quality at the CPP. Statistically significant correlations between sulfate concentrations and concentrations of boron and TDS identified as potential exceedances of the GWPS indicate sulfate is an acceptable surrogate for these parameters in the groundwater model. It was assumed that sulfate would not significantly sorb or chemically react with aquifer solids (Kd was set to 0 mL/g) which is a conservative estimate for predicting contaminant transport times in the model. The MODFLOW and MT3DMS models were used to evaluate two scenarios including information provided in the Draft CCR Final Closure Plan (Golder, 2022):

- **Scenario 1:** CIP including removal of CCR from the GMF RP and the southern portion of the GMF GSP, consolidation into the northern portion of the GMF GSP, and construction of a cover system over the remaining CCR.
- **Scenario 2:** CBR including removal of all CCR and SI liner system and regrading of the removal area.

There are limited differences in the timeframes for groundwater to reach the GWPS for most monitoring wells at the GMF GSP and GMF RP between CIP and CBR.

- In general, the simulated groundwater concentrations in the monitoring wells within the UA will achieve the GWPS in approximately 7 years for both the CIP and CBR closure scenarios at the GMF GSP.
    - A minor difference exists in the predicted timeframes for the GMF GSP, such that the timeframes to reach the GWPS differs by 1.0 year, with the CIP predicting 6.4 years to reach the GWPS and the CBR predicting 7.4 years. This difference in timeframe is not significant and can be attributed to the minor differences in the predicted groundwater flow patterns associated with the scenarios.
- For the GMF RP, the simulated groundwater concentrations in the monitoring wells within the UA will achieve the GWPS in approximately 2.5 years for both the CIP and CBR closure scenarios.
- The residual sulfate plumes from the calibrated model associated with both the GMF GSP and GMF RP remain in close proximity to the CCR units and are simulated to decline below the GWPS (400 mg/L) in 14 and 9 years respectively.

Results of groundwater fate and transport modeling conservatively estimate that groundwater concentrations will attain the GWPS for all constituents identified as potential exceedances of the GWPS in the UA monitoring wells within 7 years of closure implementation for both CIP and CBR.

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TABLES

TABLE 2-1. MONITORING WELL LOCATIONS AND CONSTRUCTION DETAILS

GROUNDWATER MODELING REPORT

COFFEEN POWER PLANT

GMF GYPSUM STACK POND AND GMF RECYCLE POND

COFFEEN, ILLINOIS

Well Number	HSU	Date Constructed	Top of PVC Elevation (ft)	Measuring Point Elevation (ft)	Measuring Point Description	Ground Elevation (ft)	Screen Top Depth (feet bgs)	Screen Bottom Depth (feet bgs)	Screen Top Elevation (feet)	Screen Bottom Elevation (feet)	Well Depth (feet bgs)	Bottom of Boring Elevation (feet)	Screen Length (feet)	Screen Diameter (inches)	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)
G045D	LCU	08/17/2016	623.81	623.81	Top of PVC	620.94	31.88	41.52	589.06	579.42	41.92	578.90	9.6	2	39.064349	-89.396281
G046D	LCU	08/19/2017	625.24	625.24	Top of PVC	621.91	41.61	51.26	580.30	570.65	51.65	569.90	9.7	2	39.060305	-89.398524
G101	UA	02/02/2010	--	627.60	Top of Disk	625.27	15.68	20.32	609.59	604.95	20.89	603.40	4.6	2	39.071386	-89.400107
G102	UA	04/28/2006	--	629.04	Top of Disk	626.18	12.02	16.78	614.16	609.40	17.15	609.00	4.8	2	39.071387	-89.398991
G103	UA	02/15/2010	--	633.80	Top of Disk	627.94	15.88	20.67	612.06	607.27	21.09	606.90	4.8	2	39.070412	-89.399107
G104	UA	02/15/2010	--	632.94	Top of Disk	627.96	14.91	19.61	613.05	608.35	20.08	605.80	4.7	2	39.069451	-89.399104
G105	UA	02/16/2010	--	632.08	Top of Disk	626.86	16.11	20.90	610.75	605.96	21.37	604.40	4.8	2	39.068491	-89.3991
G106	UA	02/16/2010	--	631.15	Top of Disk	625.96	14.37	18.96	611.59	607.00	19.44	605.50	4.6	2	39.06753	-89.399097
G107	UA	02/17/2010	630.22	630.22	Top of Disk	628.20	13.87	18.50	614.33	609.70	19.00	607.50	4.6	2	39.067106	-89.399646
G108	UA	02/12/2010	--	630.22	Top of Disk	625.58	16.82	21.50	608.76	604.08	22.00	603.60	4.7	2	39.066984	-89.400035
G109	UA	02/11/2010	--	629.76	Top of Disk	624.79	15.39	19.93	609.40	604.86	20.50	604.30	4.5	2	39.067045	-89.400423
G110	UA	02/11/2010	--	629.65	Top of Disk	624.81	15.05	19.59	609.76	605.22	20.16	604.70	4.5	2	39.067172	-89.400704
G111	UA	02/11/2010	--	629.90	Top of Disk	625.28	14.61	19.15	610.67	606.13	19.72	605.60	4.5	2	39.067292	-89.40097
G119	UA	02/09/2010	--	631.55	Top of Disk	626.57	17.29	21.83	609.28	604.74	22.38	604.20	4.5	2	39.068986	-89.401213
G120	UA	02/08/2010	--	631.87	Top of Disk	627.21	15.10	19.62	612.11	607.59	20.21	605.10	4.5	2	39.069479	-89.401214
G121	UA	02/04/2010	--	632.83	Top of Disk	627.94	16.79	21.47	611.15	606.47	21.95	603.80	4.7	2	39.069781	-89.401216
G122	UA	02/04/2010	--	632.69	Top of Disk	628.05	16.51	21.05	611.54	607.00	21.66	606.20	4.5	2	39.070098	-89.401218
G123	UA	02/04/2010	--	632.96	Top of Disk	628.12	20.94	25.46	607.18	602.66	26.07	602.10	4.5	2	39.070399	-89.401219
G124	UA	02/03/2010	--	633.39	Top of Disk	628.70	15.98	20.51	612.72	608.19	21.06	606.70	4.5	2	39.070715	-89.40122
G125	UA	02/03/2010	--	633.51	Top of Disk	628.85	17.03	21.56	611.82	607.29	22.04	606.80	4.5	2	39.071003	-89.401221
G126	UA	02/10/2010	--	625.39	Top of Disk	622.96	12.89	17.43	610.07	605.53	18.00	605.00	4.5	2	39.067304	-89.401274
G151	UA	12/19/2011	--	625.93	Top of Disk	622.82	15.34	19.84	607.48	602.98	20.46	602.40	4.5	2	39.0672	-89.40159
G152	UA	12/20/2011	--	626.52	Top of Disk	623.06	13.59	18.09	609.47	604.97	18.57	604.50	4.5	2	39.066275	-89.401289
G153	UA	12/15/2011	626.35	626.40	Top of Disk	623.23	15.90	20.34	607.33	602.89	20.80	602.50	4.4	2	39.065857	-89.402567
G154	UA	12/16/2011	--	626.35	Top of Disk	623.52	14.26	18.76	609.26	604.76	19.10	603.50	4.5	2	39.067089	-89.403574
G155	UA	12/19/2011	--	625.86	Top of Disk	622.89	15.09	19.58	607.80	603.31	23.23	599.70	4.5	2	39.067493	-89.402659
G200	UA	02/25/2008	--	625.94	Top of Disk	623.27	12.19	16.98	611.08	606.29	17.36	605.30	4.8	2	39.075139	-89.395009
G201	UA	02/25/2008	627.15	627.15	Top of Riser	624.19	13.01	17.80	611.18	606.39	18.15	606.00	4.8	2	39.075141	-89.397829
G205	UA	02/21/2008	--	624.34	Top of Disk	622.10	10.04	14.53	612.06	607.57	15.07	606.10	4.5	2	39.068596	-89.394147
G206	UA	10/14/2010	--	632.82	Top of Disk	630.53	17.51	21.92	613.02	608.61	22.42	606.50	4.4	2	39.067399	-89.398548
G206D	DA	01/25/2021	634.14	634.14	Top of PVC	631.41	49.20	59.00	582.21	572.41	59.39	571.41	9.8	2	39.067428	-89.398493
G207	UA	10/08/2010	--	633.21	Top of Disk	630.61	18.24	22.77	612.37	607.84	23.30	606.60	4.5	2	39.067568	-89.397952
G208	UA	10/07/2010	--	633.16	Top of Disk	630.57	17.53	22.06	613.04	608.51	22.60	606.60	4.5	2	39.067743	-89.397402
G209	UA	10/07/2010	--	632.91	Top of Disk	630.57	17.74	22.28	612.83	608.29	22.81	606.60	4.5	2	39.067923	-89.39685
G210	UA	10/06/2010	--	632.99	Top of Disk	630.48	19.39	23.93	611.09	606.55	24.46	605.50	4.5	2	39.068088	-89.396322
G211	UA	10/11/2010	--	632.64	Top of Disk	630.31	17.34	21.88	612.97	608.43	22.41	606.30	4.5	2	39.068263	-89.395792
G212	UA	10/11/2010	--	632.89	Top of Disk	630.59	16.74	21.29	613.85	609.30	21.81	606.60	4.6	2	39.06843	-89.395318
G213	UA	10/12/2010	--	632.81	Top of Disk	630.34	16.75	21.29	613.59	609.05	21.82	606.30	4.5	2	39.068585	-89.394822
G214	UA	10/14/2010	--	632.85	Top of Disk	630.39	17.75	22.14	612.64	608.25	22.65	606.40	4.4	2	39.068919	-89.393982

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G215	UA	10/13/2010	--	633.06	Top of Disk	630.48	19.41	23.80	611.07	606.68	24.31	606.20	4.4	2	39.069309	-89.39394
G216	UA	10/13/2010	--	632.76	Top of Disk	630.28	20.04	24.42	610.24	605.86	24.93	604.30	4.4	2	39.069765	-89.393946
G217	UA	10/12/2010	--	633.10	Top of Disk	630.67	20.49	24.88	610.18	605.79	25.38	604.70	4.4	2	39.07034	-89.393959
G218	UA	10/12/2010	--	633.11	Top of Disk	630.64	20.33	24.77	610.31	605.87	25.27	604.60	4.4	2	39.070876	-89.393956
G270	UA	02/26/2008	--	625.86	Top of Disk	623.73	13.13	17.92	610.60	605.81	18.27	605.50	4.8	2	39.066564	-89.397403
G271	UA	09/10/2009	--	625.57	Top of Disk	622.89	9.96	14.31	612.93	608.58	14.79	606.90	4.4	2	39.065007	-89.395587
G272	UA	09/10/2009	--	623.81	Top of Disk	620.72	9.11	13.98	611.61	606.74	14.32	606.40	4.9	2	39.064989	-89.394785
G273	UA	09/10/2009	--	623.02	Top of Disk	620.17	9.08	14.56	611.09	605.61	15.10	604.20	5.5	2	39.064985	-89.393973
G274	UA	09/16/2009	--	624.04	Top of Disk	621.67	12.90	17.67	608.77	604.00	18.06	603.60	4.8	2	39.064991	-89.393198
G275	UA	09/16/2009	--	618.26	Top of Disk	616.14	8.22	12.62	607.92	603.52	13.19	603.00	4.4	2	39.065151	-89.392561
G275D	DA	01/14/2021	620.31	620.31	Top of PVC	617.52	49.76	59.55	567.76	557.97	59.89	517.80	9.8	2	39.065121	-89.392595
G276	UA	09/16/2009	--	632.00	Top of Disk	629.14	22.41	27.22	606.73	601.92	27.65	601.10	4.8	2	39.065534	-89.392617
G277	UA	09/14/2009	--	623.08	Top of Disk	620.79	14.29	18.77	606.50	602.02	19.24	600.80	4.5	2	39.065927	-89.392572
G278	UA	09/11/2009	631.19	631.17	Top of Disk	628.85	18.93	23.70	609.92	605.15	24.06	604.80	4.8	2	39.066737	-89.393161
G279	UA	09/10/2009	--	632.04	Top of Disk	629.19	22.40	26.79	606.79	602.40	27.30	601.20	4.4	2	39.067156	-89.392998
G280	UA	02/26/2008	625.35	625.35	Top of Riser	623.11	12.79	17.63	610.32	605.48	17.98	605.10	4.8	2	39.067216	-89.394992
G281	UA	09/08/2015	--	626.36	Top of Disk	623.82	15.51	20.16	608.31	603.66	20.30	603.50	4.7	2	39.065405	-89.399322
G283	LCU	01/14/2021	610.75	610.75	Top of PVC	608.30	8.39	18.17	599.91	590.13	18.36	589.90	9.8	2	39.064645	-89.392119
G284	UA	02/03/2021	618.42	618.42	Top of PVC	615.33	8.08	12.85	607.25	602.48	13.23	601.30	4.8	2	39.065487	-89.390631
G285	LCU	01/25/2021	613.52	613.52	Top of PVC	610.54	13.68	23.45	596.86	587.09	23.83	584.50	9.8	2	39.066513	-89.391474
G286	UA	01/18/2021	613.13	613.13	Top of PVC	609.97	3.37	8.16	606.60	601.81	8.50	600.00	4.8	2	39.067277	-89.391883
G287	UA	01/20/2021	617.45	617.45	Top of PVC	614.34	5.43	10.25	608.91	604.09	10.59	602.50	4.8	2	39.068297	-89.392388
G288	UA	01/19/2021	620.07	620.07	Top of PVC	617.08	7.59	12.26	609.49	604.82	12.75	603.10	4.7	2	39.067834	-89.390082
G301	UA	09/04/2015	--	622.65	Top of Disk	620.88	11.31	15.96	608.96	604.31	16.21	604.10	4.7	2	39.05951	-89.395415
G302	UA	09/04/2015	--	620.04	Top of Disk	618.52	13.21	17.86	604.74	600.09	18.39	599.60	4.7	2	39.059544	-89.393192
G303	UA	08/26/2010	--	622.02	Top of Disk	619.33	10.00	20.00	609.07	599.07	20.40	598.70	10	2	39.057144	-89.391721
G304	UA	08/26/2010	--	626.72	Top of Disk	623.32	10.00	20.00	613.32	603.32	20.40	602.90	10	2	39.057205	-89.395663
G305	UA	05/03/2016	625.67	625.67	Top of PVC	623.23	13.44	18.27	609.10	604.27	18.50	604.10	4.8	2	39.056558	-89.396798
G306	UA	05/03/2016	625.91	625.91	Top of PVC	623.57	13.07	17.68	609.77	605.16	17.90	604.80	4.6	2	39.056494	-89.393556
G307	UA	07/27/2016	624.60	624.60	Top of PVC	624.73	12.96	17.80	609.12	604.28	18.22	603.90	4.8	2	39.057214	-89.395545
G307D	LCU	01/19/2021	624.88	624.88	Top of PVC	622.51	48.98	58.75	573.53	563.76	59.60	562.50	9.8	2	39.05721	-89.39552
G308	UA	01/18/2021	624.59	624.59	Top of PVC	621.59	10.10	14.89	611.49	606.70	15.24	605.80	4.8	2	39.057379	-89.397134
G309	UA	01/21/2021	625.88	625.88	Top of PVC	622.77	12.97	17.75	609.80	605.02	18.10	604.70	4.8	2	39.058508	-89.397243
G310	UA	02/09/2021	622.87	622.87	Top of PVC	619.89	10.24	15.03	609.65	604.86	15.38	604.00	4.8	2	39.059532	-89.396907
G311	UA	01/13/2021	621.04	621.04	Top of PVC	618.32	9.27	14.04	609.05	604.28	14.40	603.90	4.8	2	39.059513	-89.394363
G311D	LCU	01/12/2021	621.24	621.24	Top of PVC	618.39	50.16	60.10	568.23	558.29	60.58	557.80	9.9	2	39.059513	-89.394312
G312	UA	01/15/2021	619.78	619.78	Top of PVC	616.92	9.79	14.58	607.13	602.34	14.93	601.70	4.8	2	39.059558	-89.391983
G313	UA	02/05/2021	614.30	614.30	Top of PVC	611.51	6.30	11.11	605.21	600.40	11.46	599.50	4.8	2	39.058773	-89.391124
G314	LCU	02/05/2021	613.88	613.88	Top of PVC	611.11	14.56	19.58	596.55	591.53	20.02	591.10	5	2	39.05782	-89.390964

TABLE 2-1. MONITORING WELL LOCATIONS AND CONSTRUCTION DETAILS
GROUNDWATER MODELING REPORT
COFFEEN POWER PLANT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN, ILLINOIS

Well Number	HSU	Date Constructed	Top of PVC Elevation (ft)	Measuring Point Elevation (ft)	Measuring Point Description	Ground Elevation (ft)	Screen Top Depth (feet bgs)	Screen Bottom Depth (feet bgs)	Screen Top Elevation (feet)	Screen Bottom Elevation (feet)	Well Depth (feet bgs)	Bottom of Boring Elevation (feet)	Screen Length (feet)	Screen Diameter (inches)	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)
G314D	DA	02/04/2021	613.70	613.70	Top of PVC	610.87	39.34	49.11	571.53	561.76	49.47	510.60	9.8	2	39.057852	-89.390958
G315	UA	01/14/2021	623.52	623.52	Top of PVC	620.94	9.69	14.48	611.25	606.46	14.85	605.00	4.8	2	39.057165	-89.393667
G316	LCU	02/26/2021	602.59	602.59	Top of PVC	599.64	10.02	14.82	589.62	584.82	15.16	583.90	4.8	2	39.057847	-89.389698
G317	UA	02/12/2021	641.93	641.93	Top of PVC	638.85	30.14	34.93	608.71	603.92	35.28	602.90	4.8	2	39.056727	-89.390148
G401	UA	09/14/2015	--	625.57	Top of Disk	623.03	14.36	18.79	608.67	604.24	19.29	603.70	4.4	2	39.060259	-89.395295
G402	UA	08/27/2010	--	613.37	Top of Disk	610.36	10.00	20.00	600.36	590.36	20.40	590.00	10	2	39.060207	-89.391712
G403	UA	09/11/2015	--	626.47	Top of Disk	623.81	13.11	17.78	610.70	606.03	18.15	605.70	4.7	2	39.063167	-89.398779
G404	UA	05/01/2007	--	615.67	Top of Disk	613.57	6.42	11.17	607.15	602.40	11.62	601.60	4.8	2	39.064329	-89.392493
G405	UA	05/01/2007	--	623.63	Top of Disk	621.40	9.01	13.76	612.39	607.64	14.21	607.20	4.8	2	39.064345	-89.396234
G406	UA	08/19/2016	625.36	625.36	Top of PVC	621.86	13.56	18.37	608.30	603.49	18.75	603.10	4.8	2	39.060309	-89.398508
G407	UA	08/16/2016	621.32	621.32	Top of PVC	618.35	13.78	18.61	604.57	599.74	19.04	598.40	4.8	2	39.061574	-89.402004
G410	UA	02/23/2018	--	619.79	Top of Disk	617.21	8.89	13.68	608.32	603.53	14.09	603.10	4.8	2	39.061572	-89.403763
G411	UA	02/22/2018	--	623.25	Top of Disk	620.49	11.21	16.07	609.28	604.42	16.47	604.00	4.9	2	39.063979	-89.404033
MW01D	DA	05/03/2006	609.02	609.02	Top of PVC	607.08	33.29	38.05	573.79	569.03	38.41	567.10	4.8	2	39.067068	-89.402747
MW02S	UA	05/05/2006	627.12	627.12	Top of PVC	624.16	10.34	15.12	613.82	609.04	15.51	608.70	4.8	2	39.071017	-89.403648
MW02D	LCU	05/05/2006	626.99	626.99	Top of PVC	624.14	22.03	26.83	602.11	597.31	27.22	596.90	4.8	2	39.071031	-89.403649
MW03D	DA	04/27/2006	629.01	629.01	Top of PVC	625.86	52.29	57.06	573.57	568.80	57.40	567.90	4.8	2	39.071386	-89.398976
MW04S	UA	05/11/2006	625.89	625.89	Top of PVC	622.63	9.83	14.26	612.80	608.37	14.77	607.90	4.4	2	39.075356	-89.399232
MW05S	UA	05/17/2006	625.95	625.95	Top of PVC	622.65	12.66	17.41	609.99	605.24	17.71	604.90	4.8	2	39.075866	-89.40333
MW05D	DA	05/17/2006	625.91	625.91	Top of PVC	622.65	45.57	50.33	577.08	572.32	50.72	568.70	4.8	2	39.075863	-89.403313
MW06S	UA	05/04/2006	626.15	626.15	Top of PVC	623.37	11.04	15.62	612.33	607.75	16.08	607.30	4.6	2	39.078189	-89.403644
MW07S	UA	05/09/2006	627.60	627.60	Top of PVC	624.90	9.91	13.79	614.99	611.11	14.39	610.50	3.9	2	39.0786	-89.399383
MW08S	UA	05/10/2006	628.01	628.01	Top of PVC	625.09	11.51	16.00	613.58	609.09	16.60	608.00	4.5	2	39.080234	-89.399079
MW09S	UA	05/03/2006	627.62	627.62	Top of PVC	624.70	11.21	15.62	613.49	609.08	16.20	608.50	4.4	2	39.079954	-89.394899
MW09D	LCU	05/03/2006	627.61	627.61	Top of PVC	624.68	45.81	50.57	578.87	574.11	51.00	570.70	4.8	2	39.07994	-89.394899
MW10S	UA	05/02/2006	624.45	624.45	Top of PVC	621.43	11.28	15.76	610.15	605.67	16.30	605.10	4.5	2	39.07601	-89.394068
MW10D	LCU	05/01/2006	624.47	624.47	Top of PVC	621.33	41.74	46.57	579.59	574.76	47.02	572.60	4.8	2	39.075995	-89.39407
MW11S	UA	04/28/2006	625.27	625.27	Top of PVC	622.04	8.89	13.63	613.15	608.41	14.08	608.00	4.7	2	39.071888	-89.393913
MW11D	LCU	04/28/2006	625.52	625.52	Top of PVC	622.19	28.31	33.04	593.88	589.15	33.50	585.90	4.7	2	39.071888	-89.393894
MW12S	UA	05/10/2006	625.31	625.31	Top of PVC	622.24	10.61	15.18	611.63	607.06	15.61	606.60	4.6	2	39.068514	-89.394199
MW12D	DA	05/10/2006	625.21	625.21	Top of PVC	622.24	42.46	46.99	579.78	575.25	47.47	572.20	4.5	2	39.068501	-89.394199
MW13S	UA	05/09/2006	625.96	625.96	Top of PVC	622.80	11.43	16.23	611.37	606.57	16.62	606.20	4.8	2	39.066297	-89.40118
MW13D	DA	05/09/2006	625.86	625.86	Top of PVC	622.85	49.81	54.60	573.04	568.25	55.00	567.90	4.8	2	39.066293	-89.401163
MW14S	UA	05/02/2006	626.88	626.88	Top of PVC	624.62	12.26	17.02	612.36	607.60	17.38	607.20	4.8	2	39.069153	-89.400442
MW15S	UA	04/25/2006	626.66	626.66	Top of PVC	623.83	14.41	19.16	609.42	604.67	19.62	604.20	4.8	2	39.069772	-89.397088
MW15D	LCU	04/25/2006	626.44	626.44	Top of PVC	623.83	33.68	38.45	590.15	585.38	38.80	585.00	4.8	2	39.06977	-89.397073
MW16S	UA	04/25/2006	629.47	629.47	Top of PVC	626.32	14.59	19.41	611.73	606.91	19.76	606.40	4.8	2	39.073571	-89.397006
MW16D	DA	04/25/2006	629.38	629.38	Top of PVC	626.37	45.90	50.34	580.47	576.03	50.78	575.40	4.4	2	39.073571	-89.397036
MW17S	UA	05/04/2006	630.56	630.56	Top of PVC	627.28	14.02	23.56	613.26	603.72	24.11	603.20	9.5	2	39.07715	-89.396978

TABLE 2-1. MONITORING WELL LOCATIONS AND CONSTRUCTION DETAILS

GROUNDWATER MODELING REPORT

COFFEEN POWER PLANT

GMF GYPSUM STACK POND AND GMF RECYCLE POND

COFFEEN, ILLINOIS

Well Number	HSU	Date Constructed	Top of PVC Elevation (ft)	Measuring Point Elevation (ft)	Measuring Point Description	Ground Elevation (ft)	Screen Top Depth (feet bgs)	Screen Bottom Depth (feet bgs)	Screen Top Elevation (feet)	Screen Bottom Elevation (feet)	Well Depth (feet bgs)	Bottom of Boring Elevation (feet)	Screen Length (feet)	Screen Diameter (inches)	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)
MW17D	DA	05/04/2006	630.29	630.29	Top of PVC	627.47	48.82	53.32	578.65	574.15	53.87	573.60	4.5	2	39.077151	-89.396958
MW18S	UA	05/11/2006	628.66	628.66	Top of PVC	625.69	11.31	15.79	614.38	609.90	16.40	609.30	4.5	2	39.077033	-89.401698
MW20S	UA	05/01/2007	622.90	622.90	Top of PVC	620.26	8.41	13.22	611.85	607.04	13.67	604.30	4.8	2	39.064968	-89.394322
R104	UA	10/08/2010	--	632.84	Top of Disk	629.03	14.59	19.32	614.44	609.71	19.85	609.20	4.7	2	39.069474	-89.399109
R201	UA	10/08/2010	--	626.34	Top of Disk	624.02	14.59	19.32	609.43	604.70	19.85	604.20	4.7	2	39.075142	-89.397855
R205	UA	03/20/2017	--	624.52	Top of Disk	621.91	11.32	16.01	610.59	605.90	16.42	605.50	4.7	2	39.068593	-89.394164
T127	UA	02/10/2010	--	630.96	Top of Disk	625.53	17.53	22.07	608.00	603.46	22.64	602.90	4.5	2	39.068119	-89.40121
T128	UA	02/09/2010	631.03	630.93	Top of Disk	626.27	16.53	21.04	609.74	605.23	21.64	602.20	4.5	2	39.068532	-89.401211
T202	UA	10/15/2010	--	628.63	Top of Disk	626.22	12.27	16.65	613.95	609.57	17.21	608.20	4.4	2	39.071776	-89.397705
T408	LCU	08/17/2016	624.08	624.08	Top of PVC	621.09	20.66	25.49	600.43	595.60	25.92	595.20	4.8	2	39.064353	-89.396307
T409	LCU	08/19/2016	625.01	625.01	Top of PVC	621.85	21.79	26.59	600.06	595.26	26.99	594.90	4.8	2	39.0603	-89.398538
TA31	UA	10/28/2014	626.55	626.55	Top of PVC	623.89	15.09	19.57	608.80	604.32	20.19	603.70	4.5	2	39.071368	-89.401366
TA32	UA	10/27/2014	621.42	621.42	Top of PVC	618.93	11.31	15.68	607.62	603.25	16.47	602.50	4.4	2	39.074093	-89.402223
TA33	UA	06/02/2015	625.27	625.27	Top of PVC	622.51	12.23	16.89	610.28	605.62	17.44	605.10	4.7	2	39.071556	-89.403506
TA34	UA	06/03/2015	626.52	626.52	Top of PVC	624.10	10.92	15.41	613.18	608.69	16.10	608.00	4.5	2	39.069631	-89.402759
TR32	UA	07/02/2021	621.68	621.68	Top of PVC	619.28	11.00	15.68	608.28	603.60	16.17	603.11	4.68	2	39.074064	-89.397758
NE Riser	S	--	--	626.13	--	--	--	--	--	--	--	--	--	--	39.071111	-89.393889
SG-02	SW	--	--	605.87	Top of Protective Casing	605.87	--	--	--	--	--	--	--	--	39.059695	-89.391429
SG-03	SW	--	--	594.94	Top of Protective Casing	594.94	--	--	--	--	--	--	--	--	39.059092	-89.390342
SG-04	SW	--	--	599.52	Top of Protective Casing	599.52	--	--	--	--	--	--	--	--	39.064146	-89.390504

Notes:

All elevation data are presented relative to the North American Vertical Datum 1988 (NAVD88), GEOID 12A

-- = data not available

bgs = below ground surface

DA = deep aquifer

ft = foot or feet

HSU = hydrostratigraphic Unit

LCU = lower confining unit

PVC = polyvinyl chloride

S = source water

SW = surface water

UA = uppermost aquifer

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RAMBOLL

TABLE 4-1. FLOW AND TRANSPORT MODEL CALIBRATION TARGETS

GROUNDWATER MODELING REPORT

COFFEEN POWER PLANT

GMF GYPSUM STACK POND AND GMF RECYCLE POND

COFFEEN, ILLINOIS

					Flow Targets								Transport Targets							
Well Name	Easting	Northing	HSU	CCR Unit	Number of Samples	mean GWL[1] (feet)	std GWL[1] (feet)	min GWL[1] (feet)	max GWL[1] (feet)	Earliest Sample Date	Latest Sample Date	Flow Calibration Wells	Number of Samples	mean Sulfate (mg/L)	std Sulfate (mg/L)	min Sulfate (mg/L)	max Sulfate (mg/L)	Earliest Sample Date	Latest Sample Date	Transport Calibration Well
G101	2514214.26	876551.76	UA	LF	20	617.989	2.504194166	612.95	623.65	15/01/2019	16/11/2015	Yes	-	-	-	-	-	-	-	-
G102	2514531.1	876554.8	UA	GSP	25	622.8612	1.751842649	618.96	627.12	15/01/2019	16/11/2015	Yes	19	90.6	29.7	49	140	04/08/2015	01/26/2021	Yes
G103	2514501.17	876199.41	UA	GSP	19	622.0884211	1.754825927	617.95	624.93	15/01/2019	11/12/2016	Yes	3	66.3	11.2	54	76	04/08/2015	10/06/2015	Yes
G105	2514509.06	875499.78	UA	GSP	19	622.0884211	2.178504235	613.96	624	15/01/2019	11/12/2016	Yes	3	116.7	11.5	110	130	04/08/2015	10/06/2015	Yes
G106	2514512.87	875149.77	UA	GSP	20	620.763	1.194844628	617.46	622.6	15/01/2019	16/11/2015	Yes	19	66.1	23.3	36	140	04/08/2015	01/26/2021	Yes
G107	2514358.3	874994.03	UA	LF	19	619.1036842	1.658802147	615.46	622.33	15/01/2019	11/12/2016	Yes	-	-	-	-	-	-	-	-
G108	2514248.22	874948.67	UA	LF	19	619.4994737	1.31911786	616.24	622.22	15/01/2019	11/12/2016	Yes	-	-	-	-	-	-	-	-
G109	2514137.87	874969.96	UA	LF	19	618.7294737	1.25543031	615.7	620.84	15/01/2019	11/12/2016	Yes	-	-	-	-	-	-	-	-
G110	2514057.7	875015.54	UA	LF	20	618.104	1.590105591	613.27	620.65	15/01/2019	16/11/2015	Yes	-	-	-	-	-	-	-	-
G111	2513981.81	875058.61	UA	LF	19	616.9310526	1.267626368	613.16	618.53	15/01/2019	11/12/2016	Yes	-	-	-	-	-	-	-	-
G119	2513907.62	875675	UA	LF	19	615.9689474	1.16332328	612.24	617.45	15/01/2019	11/12/2016	Yes	-	-	-	-	-	-	-	-
G120	2513905.82	875854.56	UA	LF	19	614.3242105	1.834418817	612.13	617.69	15/01/2019	16/11/2015	Yes	-	-	-	-	-	-	-	-
G121	2513904.33	875964.54	UA	LF	18	614.6861111	2.034979806	611.93	618.73	15/01/2019	11/12/2016	Yes	-	-	-	-	-	-	-	-
G122	2513902.79	876080	UA	LF	18	615.3283333	2.095957594	612.94	620.41	15/01/2019	11/12/2016	Yes	-	-	-	-	-	-	-	-
G123	2513901.58	876189.62	UA	LF	18	614.5494444	3.842648401	610.31	622.79	15/01/2019	11/12/2016	Yes	-	-	-	-	-	-	-	-
G124	2513900.33	876304.71	UA	LF	19	617.8857895	2.128430083	615.09	622.86	15/01/2019	11/12/2016	Yes	-	-	-	-	-	-	-	-
G125	2513899.16	876409.6	UA	LF	20	619.676	2.365809976	614.6	622.96	15/01/2019	16/11/2015	Yes	-	-	-	-	-	-	-	-
G126	2513895.46	875062.25	UA	LF	19	614.87	1.340053896	612.28	616.87	15/01/2019	11/12/2016	Yes	-	-	-	-	-	-	-	-
G151	2513806.06	875023.62	UA	LF	16	614.468125	0.894980214	612.13	615.49	15/01/2019	11/12/2016	Yes	-	-	-	-	-	-	-	-
G152	2513894.35	874687.44	UA	SW	16	615.421875	1.122949799	612.77	617.44	15/01/2019	11/12/2016	Yes	-	-	-	-	-	-	-	-
G153	2513532.77	874532.15	UA	SW	16	614.5425	1.204416871	612.37	616.3	15/01/2019	11/12/2016	Yes	-	-	-	-	-	-	-	-
G154	2513243.08	874978.46	UA	SW	16	614.16	1.731546515	610.33	618.28	15/01/2019	11/12/2016	Yes	-	-	-	-	-	-	-	-
G155	2513501.64	875127.78	UA	SW	16	613.686875	1.278998143	609.91	615.99	15/01/2019	11/12/2016	Yes	-	-	-	-	-	-	-	-
G200	2515650.03	877930.9	UA	B	26	621.4965385	1.461968378	618.16	623.29	15/01/2019	16/11/2015	Yes	25	101.2	8.3	87	120	01/20/2015	07/28/2021	-
G205	2515915	875549.93	UA	GSP	8	619.71	1.482912193	616.33	621.45	02/04/2017	11/12/2016	Yes	-	-	-	-	-	-	-	-
G206	2514669.15	875103.38	UA	GSP	25	621.286	1.444036588	616.61	622.76	15/01/2019	16/11/2015	Yes	20	119.4	24.7	32	150	01/21/2015	01/27/2021	Yes
G207	2514837.85	875166.36	UA	GSP	19	621.9526316	1.135658605	619.41	623.39	15/01/2019	11/12/2016	Yes	4	44.5	30.1	16	72	01/21/2015	10/07/2015	Yes
G208	2514993.46	875231.42	UA	GSP	19	622.0989474	1.175154339	618.97	624.07	15/01/2019	11/12/2016	Yes	4	53.5	37.7	33	110	01/21/2015	10/07/2015	Yes
G209	2515149.64	875298.3	UA	GSP	25	621.6212	1.211081885	617.76	623.18	15/01/2019	16/11/2015	Yes	20	248.8	51.6	95	310	01/21/2015	01/27/2021	Yes
G210	2515299.04	875359.67	UA	GSP	19	620.8747368	1.372254303	616.82	622.5	15/01/2019	11/12/2016	Yes	4	90.3	6.5	84	99	01/21/2015	10/07/2015	Yes
G211	2515448.98	875424.68	UA	GSP	19	621.1094737	1.148145721	618.14	622.45	15/01/2019	11/12/2016	Yes	4	79.8	5.4	74	87	01/21/2015	10/07/2015	Yes
G212	2515583.04	875486.65	UA	GSP	25	620.7644	1.197814259	617.19	622.12	15/01/2019	16/11/2015	Yes	20	55.9	4.2	49	66	01/21/2015	01/26/2021	Yes
G213	2515723.38	875544.3	UA	GSP	19	620.6210526	0.889262458	618.62	621.72	15/01/2019	11/12/2016	Yes	4	53.3	3.3	50	57	01/21/2015	10/07/2015	Yes
G214	2515960.85	875667.97	UA	GSP	19	617.8473684	1.193332598	614.52	619.39	15/01/2019	11/12/2016	Yes	4	71.3	3.9	68	76	01/21/2015	10/07/2015	Yes
G215	2515971.56	875810.11	UA	GSP	25	617.9504	1.033285537	615.48	619.51	15/01/2019	16/11/2015	Yes	21	167.1	109.9	100	490	01/21/2015	06/29/2021	Yes
G216	2515968.45	875976.18	UA	GSP	19	617.8368421	1.365349172	614.37	619.86	15/01/2019	11/12/2016	Yes	4	217.5	9.6	210	230	01/21/2015	10/07/2015	Yes
G217	2515962.98	876185.57	UA	GSP	19	617.5063158	1.127668246	614.32	619.13	15/01/2019	11/12/2016	Yes	4	132.5	5.0	130	140	01/21/2015	10/07/2015	Yes
G218	2515962.17	876380.8	UA	GSP	25	618.3172	1.25211328	614.46	620.1	01/15/2019	11/16/2015	Yes	20	135.8	34.0	94	220	01/21/2015	01/26/2021	Yes
G270	2514996.81	874802.01	UA	RP	26	620.3503846	2.547542315	614.45	623.38	01/15/2019	11/16/2015	Yes	21	69.8	25.8	49	140	01/20/2015	03/30/2021	Yes
G271	2515517.24	874239.3	UA	RP	25	615.7952	1.212807075	613.31	617.95	01/15/2019	11/16/2015	Yes	6	455.0	89.6	340	610	08/10/2018	02/01/2021	Yes

TABLE 4-1. FLOW AND TRANSPORT MODEL CALIBRATION TARGETS

GROUNDWATER MODELING REPORT

COFFEEN POWER PLANT

GMF GYPSUM STACK POND AND GMF RECYCLE POND

COFFEEN, ILLINOIS

					Flow Targets								Transport Targets							
Well Name	Easting	Northing	HSU	CCR Unit	Number of Samples	mean GWL[1] (feet)	std GWL[1] (feet)	min GWL[1] (feet)	max GWL[1] (feet)	Earliest Sample Date	Latest Sample Date	Flow Calibration Wells	Number of Samples	mean Sulfate (mg/L)	std Sulfate (mg/L)	min Sulfate (mg/L)	max Sulfate (mg/L)	Earliest Sample Date	Latest Sample Date	Transport Calibration Well
G272	2515745.01	874234.68	UA	RP	19	614.3836842	1.271854335	611.45	616.88	01/15/2019	12/11/2016	Yes	4	332.5	45.7	270	380	01/21/2015	10/08/2015	Yes
G273	2515975.58	874235.18	UA	RP	25	611.5884	1.339299195	608.82	614.2	01/15/2019	11/16/2015	Yes	20	475.0	89.5	360	690	01/21/2015	02/01/2021	Yes
G274	2516195.61	874239.23	UA	RP	19	610.4968421	1.009549144	607.79	612	01/15/2019	12/11/2016	Yes	4	322.5	53.2	260	390	01/21/2015	10/08/2015	Yes
G275	2516375.98	874299.05	UA	RP	19	604.7021053	0.833210517	602.97	605.97	01/15/2019	12/11/2016	Yes	3	780.0	147.3	650	940	01/21/2015	07/23/2015	Yes
G276	2516358.89	874438.41	UA	RP	24	604.3108333	0.781508667	603.11	606.6	01/15/2019	11/16/2015	Yes	19	223.6	59.6	19	310	01/21/2015	06/28/2021	Yes
G277	2516370.45	874581.65	UA	RP	15	602.6546667	0.949126415	601.23	603.79	01/15/2019	12/11/2016	Yes	-	-	-	-	-	-	-	-
G278	2516200.7	874875.24	UA	RP	19	605.7357895	1.268819731	604.29	608.15	01/15/2019	12/11/2016	Yes	-	-	-	-	-	-	-	-
G279	2516245.69	875028.24	UA	RP	24	607.4420833	2.205378759	599.69	611.08	01/15/2019	11/16/2015	Yes	20	569.0	336.3	170	1600	01/21/2015	01/28/2021	Yes
G280	2515679.35	875045.28	UA	RP	26	618.8873077	1.884508546	614.47	622.33	01/15/2019	11/16/2015	Yes	27	78.1	12.2	52	94	01/21/2015	07/27/2021	Yes
G281	2514455.52	874375.28	UA	B	27	619.6537037	1.162395233	616.41	621.68	01/15/2019	11/16/2015	Yes	24	296.3	34.2	250	380	11/20/2015	07/27/2021	-
G283	2516503.05	874115.82	LCU	AP2	9	605.86	1.027898341	604.56	607.8	03/29/2021	08/16/2021	Yes	8	242.5	7.1	230	250	03/31/2021	07/27/2021	Yes
G284	2516922.93	874426.1	UA	B	9	607.9777778	1.492646792	606.17	611.14	03/29/2021	08/16/2021	Yes	8	69.5	10.8	60	95	03/30/2021	07/27/2021	-
G285	2516680.39	874797.74	LCU	B	9	606.5866667	1.509014579	604.33	608.62	03/29/2021	08/16/2021	Yes	8	570.0	40.0	490	620	03/30/2021	07/27/2021	-
G286	2516561.89	875075	UA	B	6	606.6166667	1.448346183	604.68	609.08	03/29/2021	12/07/2021	Yes	8	13.5	2.1	11	16	03/31/2021	07/27/2021	-
G287	2516415.34	875445.28	UA	B	7	608.9657143	1.217249045	607.59	610.83	03/29/2021	08/16/2021	Yes	8	44.4	2.7	41	50	03/29/2021	07/27/2021	-
G288	2517071.51	875282.23	UA	B	9	613.6466667	1.259801572	611.9	616.32	03/29/2021	08/16/2021	Yes	8	200.5	302.5	29	770	03/30/2021	07/27/2021	-
G301	2515583.06	872237.64	UA	AP1	25	615.0272	1.602722995	610.39	618.07	01/15/2019	11/16/2015	Yes	16	742.5	79.8	570	860	11/20/2015	01/27/2021	Yes
G302	2516214.19	872255.38	UA	AP1	25	609.8508	2.621329052	604.64	615.41	01/15/2019	11/16/2015	Yes	16	414.4	86.0	260	530	11/20/2015	01/27/2021	Yes
G303	2516639.34	871384.83	UA	AP1	25	615.7748	1.750197894	611.18	618.05	01/15/2019	11/16/2015	Yes	16	770.0	76.2	600	870	11/20/2015	01/26/2021	Yes
G304	2515519.76	871397.53	UA	AP1	2	623.99	0.113137085	623.91	624.07	08/02/2016	09/05/2016	Yes	3	1033.3	57.7	1000	1100	11/20/2015	05/20/2016	-
G305	2515199.45	871159.15	UA	AP1	23	618.0413043	1.084004798	615.3	620.49	01/15/2019	12/11/2016	Yes	5	864.0	87.6	710	930	05/19/2016	11/17/2016	Yes
G306	2516120.28	871143.66	UA	AP1	26	618.9373077	1.290400117	616.12	621.73	01/15/2019	12/11/2016	Yes	24	284.0	113.3	5.9	700	05/19/2016	07/27/2021	Yes
G307	2515553.24	871401.09	UA	AP1	17	624.0317647	1.239890294	619.33	624.6	01/15/2019	12/11/2016	Yes	13	1029.2	113.1	850	1300	08/16/2016	01/27/2021	Yes
G308	2515101.51	871457.36	UA	AP1	11	619.7218182	0.671190259	618.54	621.03	03/29/2021	08/16/2021	Yes	8	1125.0	46.3	1100	1200	03/29/2021	07/27/2021	Yes
G309	2515067.07	871868.3	UA	AP1	11	618.9445455	0.814350829	617.89	621.09	03/29/2021	08/16/2021	Yes	8	787.5	38.8	740	840	03/29/2021	07/27/2021	Yes
G310	2515159.33	872242.06	UA	AP1	11	614.4509091	1.049528032	613.2	617.27	03/29/2021	08/16/2021	Yes	8	990.0	552.5	420	2300	03/29/2021	07/28/2021	Yes
G311	2515881.77	872241.27	UA	AP1	11	613.6636364	1.07212194	612.45	616.54	03/29/2021	08/16/2021	Yes	8	811.3	35.6	750	860	03/30/2021	07/27/2021	Yes
G312	2516557.45	872263.4	UA	AP1	11	608.9363636	1.307511168	606.99	612.19	03/29/2021	08/16/2021	Yes	8	838.8	143.6	600	1000	03/30/2021	07/27/2021	Yes
G314	2516852.2	871632.87	UA	AP1	10	605.13	3.49532386	596.4	608.6	03/29/2021	08/16/2021	Yes	8	1953.8	473.9	830	2400	03/30/2021	07/27/2021	Yes
G315	2516086.68	871387.77	UA	AP1	10	620.529	0.69468538	619.17	621.24	03/29/2021	08/16/2021	Yes	8	908.8	81.1	850	1100	03/30/2021	07/28/2021	Yes
G316	2517211.62	871645.773	UA	AP1	10	590.022	3.016792999	581.54	591.63	03/29/2021	08/16/2021	-	8	691.3	156.1	330	840	03/30/2021	07/27/2021	Yes
G317	2517087.32	871236.763	UA	AP1	10	609.619	1.740890258	606.57	611.75	03/29/2021	08/16/2021	-	8	952.5	93.6	780	1100	03/30/2021	07/28/2021	Yes
G401	2515614.82	872510.72	UA	AP2	18	607.6811111	1.846264556	603.94	609.8	01/15/2019	11/16/2015	Yes	-	-	-	-	-	-	-	-
G402	2516632.39	872500.43	UA	AP2	20	603.743	1.213286533	600.77	605.36	01/15/2019	11/16/2015	Yes	-	-	-	-	-	-	-	-
G403	2514616.58	873561.48	UA	AP2	20	621.055	1.263622612	618.36	622.45	01/15/2019	11/16/2015	Yes	-	-	-	-	-	-	-	-
G404	2516397.84	873999.83	UA	AP2	20	610.838	1.183783408	607.58	612.14	01/15/2019	11/16/2015	Yes	-	-	-	-	-	-	-	-
G405	2515335.58	873996.63	UA	AP2	20	617.8585	1.158348529	614.47	619.28	01/15/2019	11/16/2015	Yes	-	-	-	-	-	-	-	-
G406	2514702.32	872521.21	UA	AP2	16	615.141875	1.675395351	611.27	617.52	01/15/2019	12/11/2016	Yes	-	-	-	-	-	-	-	-
G407	2513705.74	872973.57	UA	B	16	613.60625	0.84114109	612.11	614.86	01/15/2019	12/11/2016	Yes	-	-	-	-	-	-	-	-
MW04S	2514450.47	877999.78	UA	B	19	618.2110526	2.142835335	613.88	621.62	01/15/2019	12/11/2016	Yes	-	-	-	-	-	-	-	-

TABLE 4-1. FLOW AND TRANSPORT MODEL CALIBRATION TARGETS

GROUNDWATER MODELING REPORT

COFFEEN POWER PLANT

GMF GYPSUM STACK POND AND GMF RECYCLE POND

COFFEEN, ILLINOIS

					Flow Targets								Transport Targets							
Well Name	**Easting**	**Northing**	**HSU**	**CCR Unit**	**Number of Samples**	**mean GWL[1] (feet)**	**std GWL[1] (feet)**	**min GWL[1] (feet)**	**max GWL[1] (feet)**	**Earliest Sample Date**	**Latest Sample Date**	**Flow Calibration Wells**	**Number of Samples**	**mean Sulfate (mg/L)**	**std Sulfate (mg/L)**	**min Sulfate (mg/L)**	**max Sulfate (mg/L)**	**Earliest Sample Date**	**Latest Sample Date**	**Transport Calibration Well**
MW05S	2513285.52	878175.73	UA	B	19	617.8810526	1.843543975	613.32	620.92	01/15/2019	12/11/2016	Yes	-	-	-	-	-	-	-	-
MW10S	2515914.48	878250.4	UA	B	18	617.255	1.690963004	614.36	620.43	01/15/2019	12/11/2016	Yes	-	-	-	-	-	-	-	-
MW11S	2515971.24	876749.49	UA	GSP	24	620.7020833	1.218373753	617.19	622.19	01/15/2019	12/11/2016	Yes	-	-	-	-	-	-	-	-
MW12S	2515900.49	875519.94	UA	GSP	24	617.9708333	2.049907562	611.42	620.48	01/15/2019	12/11/2016	Yes	-	-	-	-	-	-	-	-
MW16S	2515087.93	877355.01	UA	B	24	622.0208333	2.003932908	618.34	625.59	01/15/2019	12/11/2016	Yes	-	-	-	-	-	-	-	-
MW20S	2515876.54	874228.14	UA	B	19	612.0194737	1.76501959	607.74	615.4	01/15/2019	12/11/2016	Yes	-	-	-	-	-	-	-	-
R104	2514503.48	875857.78	UA	B	20	623.479	1.640654234	619.38	625.92	01/15/2019	11/16/2015	Yes	7	74.4	2.2	72	77	04/08/2015	08/03/2016	-
R201	2514842.05	877925.14	UA	B	26	621.8242308	1.348306117	618.3	623.52	01/15/2019	11/16/2015	Yes	28	211.0	55.8	89	370	01/20/2015	07/28/2021	-
T127	2513911.13	875359.24	UA	B	20	615.954	1.042297058	612.33	617.05	01/15/2019	11/16/2015	Yes	-	-	-	-	-	-	-	-
T128	2513909.58	875509.65	UA	B	19	615.1989474	1.45420805	611.33	617.25	01/15/2019	12/11/2016	Yes	-	-	-	-	-	-	-	-
T202	2514895.01	876699.56	UA	GSP	19	620.5410526	2.211231167	615.31	624.22	01/15/2019	12/11/2016	Yes	-	-	-	-	-	-	-	-
T408	2515314.82	873999.37	UA	B	16	617.25875	1.507615667	614.45	619.46	01/15/2019	12/11/2016	Yes	-	-	-	-	-	-	-	-
T409	2514693.83	872517.86	UA	B	16	615.403125	1.232908316	612.16	617.16	01/15/2019	12/11/2016	Yes	-	-	-	-	-	-	-	-
TA31	2513856.87	876542.19	UA	B	19	619.7289474	2.10867756	614.89	622.93	01/15/2019	12/11/2016	Yes	-	-	-	-	-	-	-	-
TA32	2513605.22	877532.63	UA	B	10	615.309	1.097172629	612.42	616.3	01/20/2020	12/11/2016	Yes	-	-	-	-	-	-	-	-
TA33	2513248.73	876605.56	UA	B	19	617.2257895	1.90237663	612.91	620.35	01/15/2019	12/11/2016	Yes	-	-	-	-	-	-	-	-
TA34	2513466.7	875906.23	UA	B	19	617.0926316	1.535020239	613.48	619.58	01/15/2019	12/11/2016	Yes	-	-	-	-	-	-	-	-

Notes:

[O: SLN 04/20/22; C: EGP 4/29/22]

[1] Groundwater Elevation
AP1 = Ash Pond No. 1
AP2 = Ash Pond No. 2
B = Background
GSP = Gypsum Management Facility Gypsum Stack Pond
GWL = groundwater elevation
LF = Landfill
max = maximum
mg/L = milligrams per liter
min = minimum
RP = Gypsum Management Facility Gypsum Recycle Pond
std = standard deviation from the mean

HSU = Hydrostratigraphic Unit
CCR = coal combustion residuals
UA = uppermost aquifer
LCU = lower confining unit

TABLE 5-1. FLOW MODEL INPUT AND SENSITIVITY ANALYSIS RESULTS
GROUNDWATER MODELING REPORT
COFFEEN POWER PLANT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN, ILLINOIS

Zone	Hydrostratigraphic Unit	Materials	ft/d	cm/s	Kh/Kv	Value Source	Sensitivity[1]
Horizontal Hydraulic Conductivity			**Calibration Model**				
1	UCU	loess and clay	0.51	1.80E-04	NA	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	High
2	UA	sand and sandy silt	4.04	1.43E-03	NA	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	High
3	LCU (unweathered Vandalia)	sand clay till	0.83	2.93E-04	NA	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	High
4	LCU (Smithboro Formation)	sand clay till	0.0014	4.94E-07	NA	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	Low
5	SW Pond	NA	2.89E-09	1.02E-12	NA	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	Negligible
6	LF-CCR	CCR	13.6	4.80E-03	NA	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	Negligible
7	GSP-CCR	CCR	13.6	4.80E-03	NA	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	Negligible
8	RP-CCR	CCR	13.6	4.80E-03	NA	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	Negligible
9	AP2	CCR	13.6	4.80E-03	NA	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	Negligible
10	AP1	CCR	13.6	4.80E-03	NA	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	Moderate
11	Cooling Pond	clay and silt	0.51	1.80E-04	NA	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	Low
12	GSP-RP connector	lined channel within UCU	0.51	1.80E-04	NA	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	Negligible
13	AP2 -berm	loess and clay	0.51	1.80E-04	NA	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	Negligible
14	AP1-berm	loess and clay	0.51	1.80E-04	NA	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	Negligible
15	Pond (west)	loess and clay	0.51	1.80E-04	NA	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	Negligible
16	GSP-liner	liner	2.89E-08	1.02E-11	NA	Harmonic mean of liner layers	Negligible
17	RP-liner	liner	2.89E-08	1.02E-11	NA	Harmonic mean of liner layers	Negligible
18	LF-liner	liner	2.89E-08	1.02E-11	NA	Harmonic mean of liner layers	Negligible
19	UCU- fill (drain/river)	NA	10	3.53E-03	NA	Calibrated - Conductivity Value to Allow Groundwater Flow from UCU to River and Drain Boundary Conditions	Moderate
21	LF-GSP shared embankment	reworked silts and clays	0.01	3.53E-06	NA	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	Negligible
Vertical Hydraulic Conductivity			**Calibration Model**				
1	UCU	loess and clay	0.0510	1.80E-05	10	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	High
2	UA	sand and sany silt	0.4040	1.43E-04	10	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	High
3	LCU (unweathered Vandalia)	sand clay till	0.0830	2.93E-05	10	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	High
4	LCU (Smithboro Formation)	sand clay till	0.0001	4.94E-08	10	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	Low
5	SW Pond	lined	2.89E-09	1.02E-12	1	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	Negligible
6	LF-CCR	CCR	0.2500	8.82E-05	54	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	Negligible
7	GSP-CCR	CCR	0.2500	8.82E-05	54	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	Negligible
8	RP-CCR	CCR	0.2500	8.82E-05	54	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	Negligible
9	AP2	CCR	0.2500	8.82E-05	54	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	Negligible
10	AP1	CCR	0.2500	8.82E-05	54	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	Moderate
11	Cooling Pond	clay and silt	0.0510	1.80E-05	10	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	Low
12	GSP-RP connector	lined channel within UCU	0.0510	1.80E-05	10	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	Negligible
13	AP2 -berm	loess and clay	0.0510	1.80E-05	10	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	Negligible
14	AP1-berm	loess and clay	0.0510	1.80E-05	10	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	Negligible
15	Pond (west)	loess and clay	0.0510	1.80E-05	10	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	Negligible
16	GSP-liner	liner	2.89E-08	1.02E-11	1	Harmonic mean of liner layers	Negligible
17	RP-liner	liner	2.89E-08	1.02E-11	1	Harmonic mean of liner layers	Negligible

TABLE 5-1. FLOW MODEL INPUT AND SENSITIVITY ANALYSIS RESULTS
GROUNDWATER MODELING REPORT
COFFEEN POWER PLANT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN, ILLINOIS

Zone	Hydrostratigraphic Unit	Materials	ft/d	cm/s	Kh/Kv	Value Source	Sensitivity[1]
Vertical Hydraulic Conductivity (Continued)			**Calibration Model**				
18	LF-liner	liner	2.89E-08	1.02E-11	1	Harmonic mean of liner layers	Negligible
19	UCU- fill (drain/river)	NA	10.0000	3.53E-03	1	Calibrated - Conductivity Value to Allow Groundwater Flow from UCU to Riverand Drain Boundary Conditions	Moderate
21	LF-GSP shared embankment	reworked silts and clays	0.0100	3.53E-06	1	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	Negligible
Zone	**Hydrostratigraphic Unit**	**Materials**	**ft/d**	**in/yr**	**Kh/Kv**	**Value Source**	**Sensitivity[1]**
Recharge			**Calibration Model**				
1	UCU	clay and silt	0.00055	2.41	NA	Calibrated	High
2	SW Pond	clay and silt	1.50E-08	6.57E-05	NA	Calibrated	Negligible
3	LF	CCR	8.00E-08	3.50E-04	NA	Calibrated	Negligible
4	GSP	CCR	8.00E-08	3.50E-04	NA	Calibrated	Negligible
5	RP	CCR	8.00E-08	3.50E-04	NA	Calibrated	Negligible
6	AP2	CCR	0.0005	2.19	NA	Calibrated	Moderate
7	AP1	CCR	0.0024	10.51	NA	Calibrated	High
8	Cooling pond	clay and silt	1.40E-05	0.06	NA	Calibrated	Negligible
9	GSP-RP connector	clay and silt	0.00055	2.41	NA	Calibrated	Low
10	AP2-Berm	clay and silt	0.00055	2.41	NA	Calibrated	Negligible
11	AP1-Berm	clay and silt	0.00055	2.41	NA	Calibrated	Negligible
12	Pond (west)	clay and silt	5.50E-04	2.41	NA	Calibrated	Negligible
Storage							
1	UCU	loess and clay					
2	UA	sand and sandy silt					
3	LCU (unweathered Vandalia)	sand clay till					
4	LCU (Smithboro Formation)	sand clay till					
5	SW Pond	lined					
6	LF-CCR	CCR					
7	GSP-CCR	CCR					
8	RP-CCR	CCR					
9	AP2	CCR					
10	AP1	CCR					
11	Cooling Pond	clay and silt				*Not used in steady-state calibration model*	
12	GSP-RP connector	lined channel within UCU					
13	AP2 -berm	loess and clay					
14	AP1-berm	loess and clay					
15	Pond (west)	loess and clay					
16	GSP-liner	liner					
17	RP-liner	liner					
18	LF-liner	liner					
19	UCU- fill (drain/river)	NA					
21	LF-GSP shared embankment	reworked silts and clays					

TABLE 5-1. FLOW MODEL INPUT AND SENSITIVITY ANALYSIS RESULTS
GROUNDWATER MODELING REPORT
COFFEEN POWER PLANT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN, ILLINOIS

River Parameters							
	Relative Location	**River Width (feet)**	**River depth (feet)**	**Bed Thickness (feet)**	**Hydraulic Conductivity (ft/d)**	**Head (feet)**	**River Boundary Conductance (ft^2/d)**
Reach 0	Unnamed Tributary East Coffeen Lake	10	3	2	4.00E-02	594.7-621.84	0.08-20.4
Sensitivity1	NA	- - -	- - -	- - -	- - -	Moderate	High
Reach 5	Unnamed Tributary East Coffeen Lake - downstream in layer 5	10	3	2	4.00E-01	591.0-594.7	1.5-109.2
Sensitivity1		- - -	- - -	- - -	- - -	Moderate	Low
Reach 1	Unnamed Tributary West Coffeen Lake	10	3	2	4.80E-02	591.0-622.45	0.04-12.3
Sensitivity1	NA	- - -	- - -	- - -	- - -	Low	Moderately High
Reach 2	Pond (west)	cell dimensions	3	1	3.20E-03	617.50	4.0
Sensitivity1	NA	- - -		- - -		Low	Low
Reach 3	Condenser Cooling Flume	cell dimensions	4	1	5.00	604.00	5.00
Sensitivity1	NA	- - -	- - -	- - -	- - -	Moderate	High
Value Source	NA	Calibrated	Calibrated	Calibrated	Calibrated	Estimated based on DEM	Calibrated
Drain Parameters							
	Name	**Drain Width (feet)**	**Drain depth (feet)**	**Bed Thickness (feet)**	**Hydraulic Conductivity (ft/d)**	**Stage (feet)**	**Drain Conductance (ft^2/d)**
Reach 0	Active LF Underdrain	2	2	1.5	2.40E-02	603.5	6.6e-5-0.47
Sensitivity1	NA	- - -	- - -	- - -	- - -	Low	Moderately High
Reach 1	Gravity Driven RP Drain	cell dimensions	2	1.5	2.50E-02	600.5	9.7e-5-0.51
Sensitivity1	NA	- - -	- - -	- - -	- - -	Low	Moderate
Reach 2	Northern Drain	cell dimensions	2	1.5	2.00E+00	622	5.1-135.46
Sensitivity1	NA	- - -	- - -	- - -	- - -	Low	Negligible
Value Source	NA	Calibrated	Calibrated	Calibrated	Calibrated	Estimated based on DEM	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 2	Northern Model Boundary in UA	*variable*	1	variable	4.54	591-610.66	1.4-7032.9
Sensitivity1	NA	- - -	- - -	- - -	- - -	**Moderate**	**Negligible**
Reach 3	Northern Model Boundary in LCU Layer 4	*variable*	1	variable	0.83	591-610.66	166-1812.6
Sensitivity1	NA	- - -	- - -	- - -	- - -	**High**	**Negligible**
Reach 4	Northern Model Boundary in LCU Layer 5	*variable*	1	variable	0.0014	591-610.66	1.61-6.0
Sensitivity1	NA	- - -	- - -	- - -	- - -	Low	Negligible
Value Source	NA	Calibrated	Calibrated	Calibrated	Calibrated	Estimated based on Groundwater Elevation Targets in UA around the GSP/GRP/LF	Calibrated

TABLE 5-1. FLOW MODEL INPUT AND SENSITIVITY ANALYSIS RESULTS
GROUNDWATER MODELING REPORT
COFFEEN POWER PLANT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN, ILLINOIS

Hydraulic Flow Boundary Parameters			
	Relative Location	**Width of HFB (feet)[2]**	**Hydraulic Conductivity (feet)**
Reach 1	GSP	1	2.89E-08
Sensitivity[1]	NA	- - -	
Reach 2	RP	1	2.89E-08
Sensitivity[1]	NA	- - -	
Reach 3	LF	1	2.89E-08
Sensitivity[1]	NA	- - -	Harmonic mean of construction material
Value Source	NA	Calibrated	Harmonic mean of construction material

[O: SLN 04/01/22; C: 4/29/22]

Notes:
[1] Sensitivity Explanation:
Negligible - SSR changed by less than 1%
Low - SSR change between 1% and 10%
Moderate - SSR change between 10% and 50%
Moderately High - SSR change between 50% and 100%
High - SSR change greater than 100%
[2] Liner thickness accounted for in harmonic mean calculation
- - - = not tested
AP1 = Ash Pond No. 1
AP2 = Ash Pond No. 2
CCR = coal combustion residuals
cm/s = centimeters per second
ft/d = feet per day
ft^2/d = feet squared per day
GSP = Gypsum Management Facility Gypsum Stack Pond
in/yr = inches per year
Kh/Kv = anisotropy ratio
LF = Landfill
NA = not applicable
RP = Gypsum Management Facility Gypsum Recycle Pond
SSR = sum of squared residuals
SW = surface water

HSU = Hydrostratigraphic Unit
UCU = upper confining unit
UA = uppermost aquifer
LCU = lower confining unit

TABLE 5-2. TRANSPORT MODEL INPUT VALUES (CALIBRATION)
GROUNDWATER MODELING REPORT
COFFEEN POWER PLANT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN, ILLINOIS

Zone	Hydrostratigraphic Unit	Materials	Calibration Model									
			Recharge (ft/d)				Sulfate Concentration (mg/L)				Value Source	Sensitivity
Initial Concentration												
Entire Domain	NA	NA	0.00055				0				NA	- - -
Source Concentration (recharge and constant concentration cells)												
			Pre-GMF		**Post-GMF**		**Pre-GMF**		**Post-GMF**			
	Model Name and Stress Period		**TR1 - STP 1**	**TR1 - STP 2**	**TR2 - STP 1**	**TR3 - STP 1**	**TR1 - STP 1**	**TR1 - STP 2**	**TR2 - STP 1**	**TR3 - STP 1**		
	Time Period		**1970-1984**	**1985-2009**	**2010-2017**	**2018-2022**	**1970-1984**	**1985-2009**	**2010-2017**	**2018-2022**		
6	AP2	CCR	0.0005	0.0005	0.0005	0.00027	1,600	1,600	1,600	0	Leachate sulfate concentrations	- - -
13	AP2 Northwest seep area	-	0.002	0.002	0.002	0.00055	1,600	1,600	1,600	0	Based on previous model	- - -
14	AP2 East and Southwest seep area	-	0.01	0.01	0.01	0.00055	300	300	300	0	Based on previous model	- - -
13	AP2 closure structures	-									Based on previous model	- - -
7	AP1	CCR	0.00055	0.00240	0.00240	0.00240	0	1,000	1,000	1,000	Calibrated	- - -
5	RP	CCR	NA	NA	8.00E-08	8.00E-08	NA	NA	15,000	15,000	Leachate sulfate concentrations	- - -
4	GSP	CCR	NA	NA	8.00E-08	8.00E-08	NA	NA	11,000	11,000	Leachate sulfate concentrations	- - -
3	LF	CCR	NA	NA	8.00E-08	8.00E-08	NA	NA	7,500	7,500	Leachate sulfate concentrations	- - -
GMF Units liner modification (HFB)												
		Well Data	**Hydraulic Conductivity (ft/d)**									
			Pre-GMF		**Post-GMF**							
	Model Name and Stress Period		**TR1 - STP 1**	**TR1 - STP 2**	**TR2 - STP 1**	**TR3 - STP 1**						
	Time Period		**1970-1984**	**1985-2009**	**2010-2017**	**2018-2022**						
1	RP		NA	NA	2.89E-08	2.89E-08					Harmonic Mean	see Table 5-3
11	RP-northeast	G279	NA	NA	2.89E-08	3.00E-04					Calibrated	see Table 5-3
16	RP-southeast	G275	NA	NA	2.89E-08	6.54E-04					Calibrated	see Table 5-3
2	GSP		NA	NA	2.89E-08	2.89E-08					Harmonic Mean	see Table 5-3
21	GSP-seep 1 east	G215	NA	NA	2.89E-08	6.00E-04					Calibrated	see Table 5-3
3	LF		NA	NA	2.89E-08	2.89E-08					Harmonic Mean	see Table 5-3

TABLE 5-2. TRANSPORT MODEL INPUT VALUES (CALIBRATION)
GROUNDWATER MODELING REPORT
COFFEEN POWER PLANT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN, ILLINOIS

Storage, Specific Yield and Effective Porosity				**Calibration Model**				
Zone	**Hydrostratigraphic Unit**	**Materials**	**Storage**	**Specific Yield**	**Effective Porosity**		**Value Source**	**Sensitivity**
1	UCU	Loess and clay	0.0034	0.35	0.35	NA	Ramboll (2021a) HCR	see Table 5-3
2	UA	sand and sandy silt	0.0034	0.16	0.16		Ramboll (2021a) HCR	see Table 5-3
3	LCU (unweathered Vandalia)	sand clay till	0.0034	0.19	0.19		Ramboll (2021a) HCR	see Table 5-3
4	LCU (Smithboro Formation)	sand clay till	0.0034	0.28	0.28		Ramboll (2021a) HCR	see Table 5-3
5	SW Pond	NA	0.0034	0.35	0.35		Ramboll (2021a) HCR	see Table 5-3
6	Landfill-CCR	CCR	0.0034	0.19	0.19		Ramboll (2021a) HCR	see Table 5-3
7	GSP-CCR	CCR	0.0034	0.19	0.19		Ramboll (2021a) HCR	see Table 5-3
8	RP-CCR	CCR	0.0034	0.19	0.19		Ramboll (2021a) HCR	see Table 5-3
9	AP2	CCR	0.0034	0.19	0.19		Ramboll (2021a) HCR	see Table 5-3
10	AP1	CCR	0.0034	0.19	0.19		Ramboll (2021a) HCR	see Table 5-3
11	Cooling Pond	clay and silt	0.0034	0.35	0.35		Ramboll (2021a) HCR	see Table 5-3
12	GSP-RP connector	lined channel within UD	0.0034	0.35	0.35		Ramboll (2021a) HCR	see Table 5-3
13	AP2 -berm	Loess and clay	0.0034	0.35	0.35		Ramboll (2021a) HCR	see Table 5-3
14	AP1-berm	Loess and clay	0.0034	0.35	0.35		Ramboll (2021a) HCR	see Table 5-3
15	Pond (west)	Loess and clay	0.0034	0.35	0.35		Ramboll (2021a) HCR	see Table 5-3
16	GSP-liner	liner	0.0034	0.16	0.16		Ramboll (2021a) HCR	see Table 5-3
17	RP-liner	liner	0.0034	0.16	0.16		Ramboll (2021a) HCR	see Table 5-3
18	Landfill-liner	liner	0.0034	0.16	0.16		Ramboll (2021a) HCR	see Table 5-3
19	UCU- fill (drain/river)	NA	0.0034	0.5	0.5		Calibrated	see Table 5-3
21	Landfill-GSP shared embankment	reworked silts and clays	0.0034	0.16	0.16		Calibrated	see Table 5-3
Dispersivity								
Applicable Region	**Hydrostratigraphic Unit**	**Materials**	**Longitudinal (feet)**	**Transverse (feet)**	**Vertical (feet)**		**Value Source**	**Sensitivity**
1	UCU	Loess and clay	1	0.1	0.01	NA	calibrated	see Table 5-3
2	UA	sand and sandy silt	10	1	0.1		calibrated	see Table 5-3
3	LCU (unweathered Vandalia)	sand clay till	1	0.1	0.01		calibrated	see Table 5-3
4	LCU (Smithboro Formation)	sand clay till	1	0.1	0.01		calibrated	see Table 5-3

[O: SLN 04/01/22; C: 4/29/22]

Notes:
[1] The concentrations from the end of the calibrated transport model were imported as initial concentrations for the prediction model runs.
- - - = not tested
AP1 = Ash Pond No. 1
AP2 = Ash Pond No. 2
CCR = coal combustion residuals
ft/day = feet per day
GMF = Gympsum Management Facility
GSP = Gypsum Management Facility Gypsum Stack Pond
LF = Landfill
mg/L = milligrams per liter
NA = not applicable
RP = Gypsum Management Facility Gypsum Recycle Pond
SS = steady state model
STP = Stress Period
SW = surface water
TR = Transient model

Hydrostratigraphic Unit
UCU = upper confining unit
UA = upper aquifer
LCU = lower confining unit

TABLE 5-3. TRANSPORT MODEL INPUT SENSITIVITY (CALIBRATION)
GROUNDWATER MODELING REPORT
COFFEEN POWER PLANT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN, ILLINOIS

			Storage and Specific Yield				Effective Porosity			
Well ID	**SI**	**Calibration on Sulfate Concentration (mg/L)**	**Sulfate Concentration (mg/L)**	**Sensitivity [1]**	**Sulfate Concentration (mg/L)**	**Sensitivity [1]**	**Sulfate Concentration (mg/L)**	**Sensitivity [1]**	**Sulfate Concentration (mg/L)**	**Sensitivity [1]**
G102	GSP	0.0*	0.0*	Negligible	0.2	Negligible	0.0*	Negligible	0.0*	Negligible
G103	GSP	0.7	0.3	Moderately High	1.6	High	1.4	Moderately High	0.4	Moderate
G105	GSP	0.4	0.1	Moderately High	0.8	Moderately High	0.9	High	0.2	Moderately High
G106	GSP	0.0*	0.0*	Negligible	0.6	Negligible	0.0*	Negligible	0.0*	Negligible
G206	GSP	0.0*	0.0*	Negligible	0.1	Negligible	0.0*	Negligible	0.0*	Negligible
G207	GSP	0.0*	0.0*	Negligible	0.0*	Negligible	0.0*	Negligible	0.0*	Negligible
G208	GSP	0.0*	0.0*	Negligible	0.0*	Negligible	0.0*	Negligible	0.0*	Negligible
G209	GSP	0.0*	0.0*	Negligible	0.2	Negligible	1.3	Negligible	0.0*	Negligible
G210	GSP	0.0*	0.0*	Negligible	6.8	Negligible	0.0*	Negligible	0.0*	Negligible
G211	GSP	2.9	2.6	Low	27.6	High	6.0	High	0.8	Moderately High
G212	GSP	8.9	7.0	Moderate	33.9	High	12.4	Moderate	6.3	Moderate
G213	GSP	24.3	20.6	Moderate	51.2	High	28.9	Moderate	20.5	Moderate
G214	GSP	19.3	16.2	Moderate	34.6	Moderately High	25.9	Moderate	15.2	Moderate
G215	GSP	477.8	825.2	Moderately High	182.0	Moderately High	607.8	Moderate	381.7	Moderate
G216	GSP	9.3	10.9	Moderate	20.9	High	15.2	Moderately High	5.8	Moderate
G217	GSP	0.0*	6.1	Negligible	0.0*	Negligible	3.8	Negligible	0.0*	Negligible
G218	GSP	0.0*	3.3	Negligible	0.0*	Negligible	1.0	Negligible	0.0*	Negligible
G270	RP	0.0*	0.0*	Negligible	0.0*	Negligible	0.0*	Negligible	0.0*	Negligible
G271	RP	28.2	54.1	Moderately High	16.0	Moderate	40.0	Moderate	21.1	Moderate
G272	RP	123.7	148.8	Moderate	99.9	Moderate	140.0	Moderate	108.4	Moderate
G273	RP	164.4	175.6	Low	159.6	Low	164.9	Negligible	161.0	Low
G274	RP	196.5	197.8	Negligible	183.8	Low	194.5	Negligible	196.8	Negligible
G275	RP	859.1	1224.8	Moderate	636.2	Moderate	918.8	Low	801.1	Low
G276	RP	543.0	513.5	Low	521.7	Low	636.4	Moderate	468.6	Moderate
G279	RP	1,561.1	2,019.9	Moderate	1,175.2	Moderate	1,727.5	Moderate	1,412.5	Low
G280	RP	1.9	1.1	Moderate	3.6	Moderately High	2.0	Low	1.7	Moderate
G283	RP	385.7	329.6	Moderate	384.6	Negligible	409.8	Low	373.8	Low
			S*0.1 Sy*0.5		S*10 Sy*2		Porosity-0.05		Porosity+0.05	

TABLE 5-3. TRANSPORT MODEL INPUT SENSITIVITY (CALIBRATION)
GROUNDWATER MODELING REPORT
COFFEEN POWER PLANT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN, ILLINOIS

		Dispersivity				HFB (GMF GSP and GMF RP Liner)			
Well ID	**SI**	**Sulfate Concentration (mg/L)**	**Sensitivity [1]**	**Sulfate Concentration (mg/L)**	**Sensitivity [1]**	**Sulfate Concentration (mg/L)**	**Sensitivity [1]**	**Sulfate Concentration (mg/L)**	**Sensitivity [1]**
G102	GSP	0.0*	Negligible	0.0*	Negligible	0.0*	Negligible	0.0*	Negligible
G103	GSP	14.0	High	30.0	High	0.7	Negligible	0.8	Moderate
G105	GSP	9.0	High	20.2	High	0.4	Negligible	0.5	Moderate
G106	GSP	1.5	Negligible	4.2	Negligible	0.0*	Negligible	0.0*	Negligible
G206	GSP	0.0*	Negligible	1.3	Negligible	0.0*	Negligible	0.0*	Negligible
G207	GSP	7.6	Negligible	29.8	Negligible	0.0*	Negligible	0.0*	Negligible
G208	GSP	9.5	Negligible	62.5	Negligible	0.0*	Negligible	0.0*	Negligible
G209	GSP	79.6	Negligible	171.1	Negligible	0.0*	Negligible	0.0*	Negligible
G210	GSP	16.5	Negligible	48.6	Negligible	0.0*	Negligible	0.0*	Negligible
G211	GSP	45.8	High	91.3	High	2.8	Low	3.8	Moderate
G212	GSP	50.1	High	102.5	High	8.7	Low	10.2	Moderate
G213	GSP	97.0	High	180.3	High	24.0	Low	27.5	Moderate
G214	GSP	100.9	High	196.8	High	20.1	Low	24.5	Moderate
G215	GSP	665.3	Moderate	752.7	Moderately High	30.2	Moderately High	7,063.8	High
G216	GSP	85.4	High	146.4	High	9.2	Negligible	14.1	Moderately High
G217	GSP	67.1	Negligible	142.7	Negligible	0.0*	Negligible	1.5	Negligible
G218	GSP	56.6	Negligible	132.9	Negligible	0.0*	Negligible	0.0*	Negligible
G270	RP	0.0*	Negligible	0.0*	Negligible	0.0*	Negligible	0.0*	Negligible
G271	RP	109.4	High	178.5	High	26.2	Low	45.2	Moderately High
G272	RP	186.7	Moderately High	231.2	Moderately High	123.5	Negligible	124.5	Negligible
G273	RP	200.4	Moderate	230.2	Moderate	164.4	Negligible	165.4	Negligible
G274	RP	238.7	Moderate	303.2	Moderately High	195.9	Negligible	201.0	Low
G275	RP	805.1	Low	777.2	Low	252.3	Moderately High	5,918.0	High
G276	RP	590.0	Low	708.5	Moderate	219.4	Moderately High	3,701.6	High
G279	RP	1,767.5	Moderate	1778.0	Moderate	134.2	Moderately High	11,990.8	High
G280	RP	24.9	High	54.1	High	1.9	Low	2.5	Moderate
G283	RP	363.4	Low	381.1	Low	387.0	Negligible	376.9	Low
		Disp*5		Disp*10		HFB*0.1		HFB*10	

Notes:
[O: SLN 04/10/22; C: EGP 5/5/22]

* corrected to zero due to numerical errors producing simulated negative concentrations
[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] sensitivity test used transient transport

AP1 = Ash Pond No. 1
AP2 = Ash Pond No. 2
Disp = dispersivity
GSP = Gypsum Management Facility Gypsum Stack Pond
HFB = Horizontal Flow Boundary
ID = identification
LF = Landfill
mg/L = milligrams per liter
RP = Gypsum Management Facility Gypsum Recycle Pond
S = storativity
SI = surface impoundment
Sy = specific yield

TABLE 6-1. HELP MODEL INPUT AND OUTPUT VALUES
GROUNDWATER MODELING REPORT
COFFEEN POWER PLANT
GMF GYPSUM STACK POND AND LANDFILL
COFFEEN, ILLINOIS

Closure Scenario Number (Drainage Length)	GMF Gypsum Stack Pond - CIP Consolidation Area	Landfill Closure In Place	Notes
Input Parameter			
Climate-General			
City	Coffeen, Illinois	Coffeen, Illinois	Nearby city to the Site within HELP database
Latitude	39.06	39.06	Site latitude
Evaporative Zone Depth	18	18	Estimated based on geographic location (Illinois) and uppermost soil type (Tolaymat, T. and Krause, M 2020)
Maximum Leaf Area Index	4.5	4.5	Maximum for geographic location (Illinois) (Tolaymat, T. and Krause, M, 2020)
Growing Season Period, Average Wind Speed, and Quarterly Relative Humidity	Belleville Scott Air Force Base Belleville, Illinois	Belleville Scott Air Force Base Belleville, Illinois	Nearby city to the Coffeen Power Plant within HELP database
Number of Years for Synthetic Data Generation	30	30	
Temperature, Evapotranspiration, and Precipitation	Precipitation, temperature, and solar radiation was simulated based on HELP V4 weather simulation for: Lat/Long: 39.06/-89.39	Precipitation, temperature, and solar radiation was simulated based on HELP V4 weather simulation for: Lat/Long: 39.06/-89.39	
Soils-General			
% where runoff possible	100	100	
Area (acres)	12.4	13.5	CBR - Removal Area based on HCR (Ramboll, 2021); CIP - Consolidation and Cover System Area based on construction drawing for GMF GSP; Landfill Consolidation Area based on HDR drawings
Specify Initial Moisture Content	No	No	
Surface Water/Snow	Model Calculated	Model Calculated	
Soils-Layers			
1	Vegetative Soil Layer (HELP Final Cover Soil [topmost layer])	Protective Cover Layer (HELP Final Cover Soil [topmost layer])	Layers details for CIP and Landfill areas based on grading plans, construction drawings, and cover system design for GMF GSP and Landfill
2	Protective Cover Layer (HELP Vertical Percolation Layer)	Protective Cover Layer (HELP Vertical Percolation Layer)	
3	Geocomposite Drainage Layer (HELP Geosynthetic Drainage Net)	Geocomposite Drainage Layer (HELP Geosynthetic Drainage Net)	
4	Geomembrane Liner	Geomembrane Liner	
5	Unsaturated CCR Material (HELP Waste)	Unsaturated CCR Material (HELP Waste)	
6	Geomembrane Liner	Geomembrane Liner	
7	Clay Liner	Clay Liner	
Soil Parameters--Layer 1			
Type	1	1	Vertical Percolation Layer (Cover Soil)
Thickness (in)	6	6	For CIP removal areas, layer 1 thickness is the average thickness of unsaturated backfill material placed after removal
Texture	10	10	Defaults used
Description	Sandy Clay Loam	Sandy Clay Loam	
Saturated Hydraulic Conductivity (cm/s)	1.20E-04	1.20E-04	Defaults used
Soil Parameters--Layer 2			
Type	1	1	Vertical Percolation Layer
Thickness (in)	18	18	design thickness
Texture	14	14	Defaults used
Description	Silty Clay	Silty Clay	
Saturated Hydraulic Conductivity (cm/s)	2.50E-05	2.50E-05	Defaults used
Soil Parameters--Layer 3			
Type	2	2	Lateral Drainage Layer
Thickness (in)	0.2	0.2	design thickness
Texture	20	20	Defaults used
Description	Drainage Net (0.5cm)	Drainage Net (0.5cm)	
Saturated Hydraulic Conductivity (cm/s)	1.00E+01	1.00E+01	Defaults used

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TABLE 6-1. HELP MODEL INPUT AND OUTPUT VALUES
GROUNDWATER MODELING REPORT
COFFEEN POWER PLANT
GMF GYPSUM STACK POND AND LANDFILL
COFFEEN, ILLINOIS

Closure Scenario Number (Drainage Length)	**GMF Gypsum Stack Pond - CIP Consolidation Area**	**Landfill Closure In Place**	**Notes**
Soil Parameters--Layer 4			
Type	4	4	Flexible Membrane Liner
Thickness (in)	0.04	0.04	design thickness
Texture	36	36	Defaults used
Description	HDPE Membrane	HDPE Membrane	
Saturated Hydraulic Conductivity (cm/s)	2.00E-13	2.00E-13	Defaults used
Soil Parameters--Layer 5			
Type	1	1	Vertical Percolation Layer (Waste)
Thickness (in)	144	720	design thickness
Texture	83	83	Defaults used
Description	Gypsum Waste Material (Sandy Loam)	Landfill CCR Material	
Saturated Hydraulic Conductivity (cm/s)	6.70E-04	2.69E-04	defaults used
Soil Parameters--Layer 6			
Type	4	4	Flexible Membrane Liner (GSP and Landfill)
Thickness (in)	0.06	0.06	Background clay thickness (Ash Pond No. 1) design thickness (GSP and Landfill)
Texture	36	36	Defaults used (GSP and Landfill)
Description	HDPE Membrane	HDPE Membrane	
Saturated Hydraulic Conductivity (cm/s)	2.00E-13	2.00E-13	Defaults used (GSP and Landfill)
Soil Parameters--Layer 7			
Type	3	3	Drainage Liner
Thickness (in)	36	36	design thickness
Texture	16	16	Defaults used
Description	Liner Soil (High)	Liner Soil (High)	
Saturated Hydraulic Conductivity (cm/s)	6.80E-07	6.80E-07	Defaults used
Soils--Runoff			
Runoff Curve Number	85.4	86.7	HELP-computed curve number
Slope	4.00%	25.00%	Estimated from construction design drawings
Length (ft)	650	250	estimated maximum flow path
Vegetation	fair	fair	fair indicating fair stand of grass on surface of soil backfill
Execution Parameters			
Years	30	30	
Report Daily	No	No	
Report Monthly	No	No	
Report Annual	Yes	Yes	
Output Parameter			
Unsaturated Percolation Rate (in/yr)	**0.00019**	**0.000012**	

Notes:
% = percent
CBR = closure by removal
CCR = coal combustion residuals
CIP = closure in place
cm = centimeters
cm/s = centimeters per second
ft = feet
MGMF = Gypsum Management Facility
GSP = Gypsum Stack Pond
HDPE = high density polyethylene
HELP = Hydrologic Evaluation of Landfill Performance
in = inches
in/yr = inches per year

References:

Tolaymat, T. and Krause, M, 2020. Hydrologic Evaluation of Landfill Performance: HELP 4.0 User Manual . United States Environmental Protection Agency, Washington, DC, EPA/600/B 20/219
Ramboll Americas Engineering Solutions, Inc. (Ramboll), 2021. Hydrogeologic Site Characterization Report. AP1, GMF GSP, Coffeen Power Plant. Coffeen, Illinois.

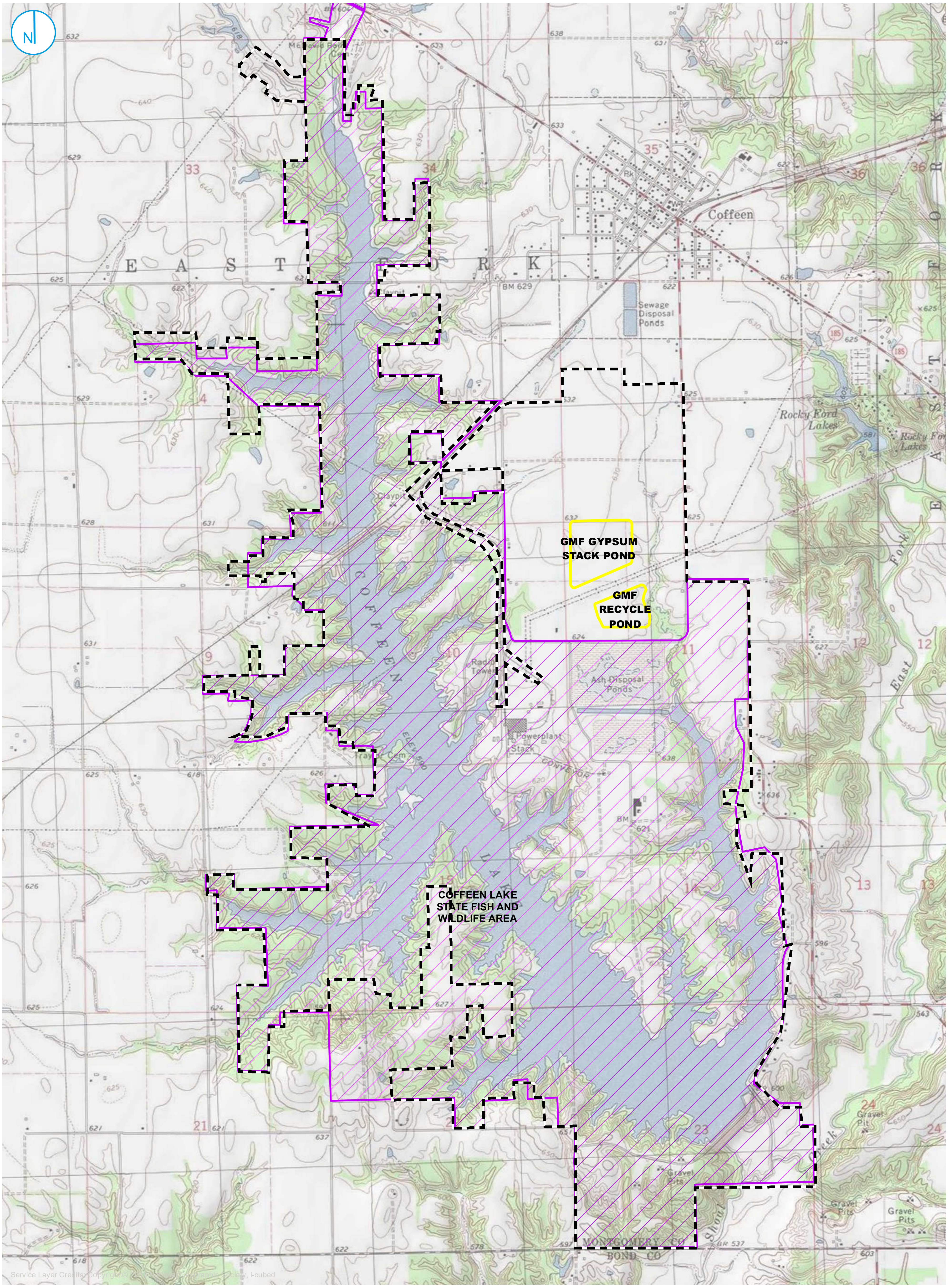
TABLE 6-2. PREDICTION MODEL INPUT VALUES
GROUNDWATER MODELING REPORT
COFFEEN POWER PLANT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN, ILLINOIS

Hydrostratigraphic Unit/Recharge Area	Notes	Recharge Zone	Sulfate Concentration (mg/L)	Recharge (ft/day)	Recharge (inches/yr)	Constant Concentration Layer	Constant Concentration (mg/L)
Scenario 1: CIP							
GMF RP - removal area	FILL	5	- - -	- - -	- - -		
GMF GSP - removal area	CCR	3	- - -	- - -	- - -	- - -	- - -
GMF GSP - consolidation area	CCR	4	11,000	4.34E-08	1.90E-04	- - -	- - -
LF - consolidation area	CCR	7	7,500	2.74E-09	1.20E-05	- - -	
Scenario 2: CBR							
GMF RP - removal area	FILL	5	- - -	- - -	- - -		
GMF GSP - removal area	FILL	4	- - -	- - -	- - -		
LF - consolidation area	CCR	3	7,500	2.74E-09	1.20E-05	- - -	- - -

[O: SLN 04/01/22; C: EGP 4/29/22]

Notes:
- - - = not included
CBR = closure by removal
CCR = coal combustion residuals
CIP = closure in place
ft/day = feet per day
GMF GSP = Gypsum Management Facility Gypsum Stack Pond
GMF RP = Gypsum Management Facility Gypsum Recycle Pond
inches/yr = inches per year
LF = Landfill
mg/L = milligrams per liter

FIGURES



PART 845 REGULATED UNIT (SUBJECT UNIT)
PROPERTY BOUNDARY
COFFEEN LAKE STATE FISH AND WILDLIFE AREA

0 1,000 2,000 Feet

SITE LOCATION MAP

FIGURE 1-1

GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS

RAMBOLL AMERICAS ENGINEERING SOLUTIONS, INC.

RAMBOLL

- COAL MINE SHAFT
- PART 845 REGULATED UNIT (SUBJECT UNIT)
- SITE FEATURE
- LIMITS OF FINAL COVER
- PROPERTY BOUNDARY

0 275 550 Feet

SITE MAP

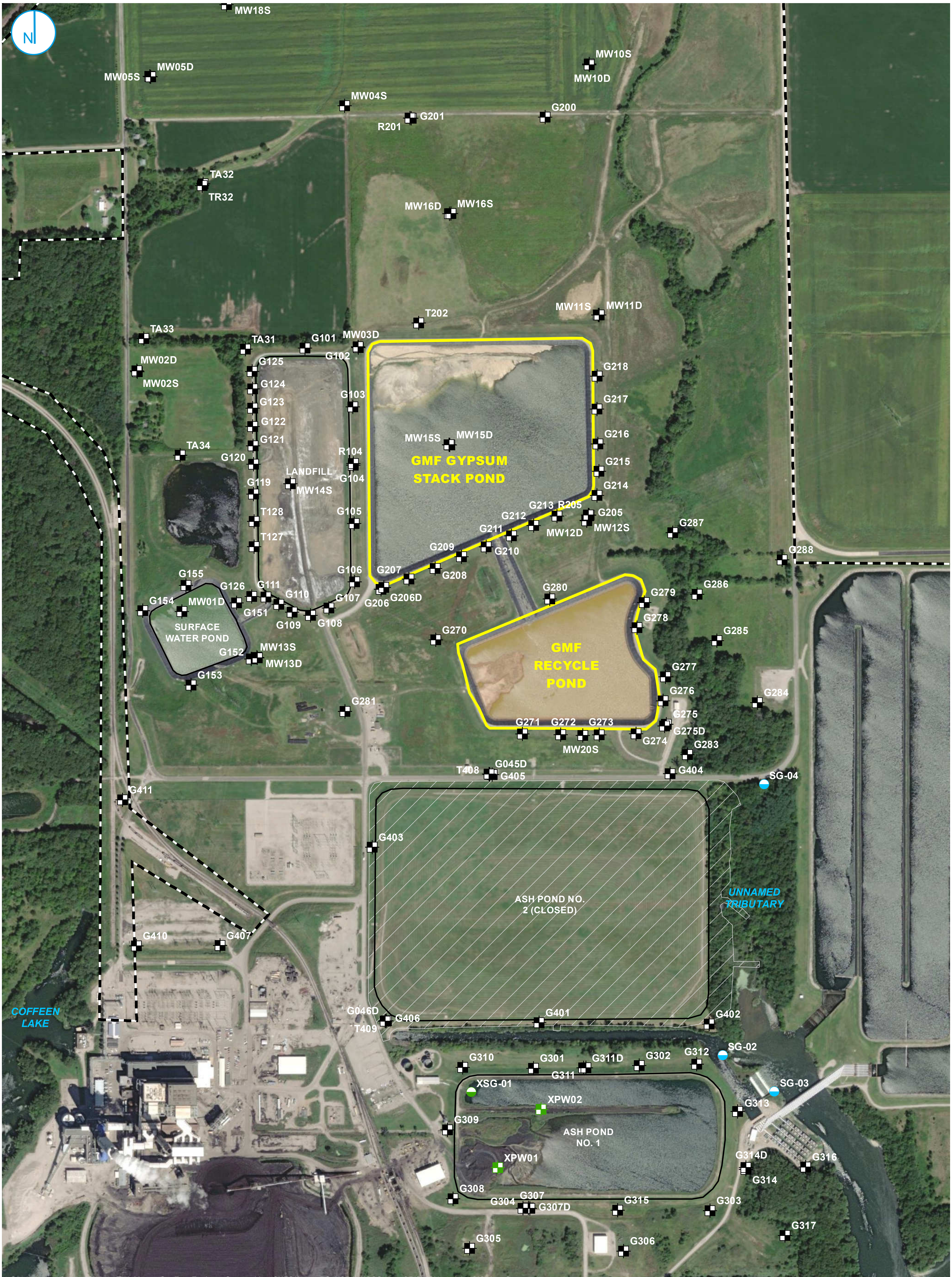
FIGURE 1-2

GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

RAMBOLL

PROJECT: 169000XXXX | DATED: 4/29/2022 | DESIGNER: galarnmc Y:\Mapping\Projects\22\2285\MXD\Model_Figures\Coffeen\GMF_GSP_RP\Figure 2-1_Monitoring Well Location Map.mxd



MONITORING WELL
PORE WATER WELL
STAFF GAGE, RIVER
STAFF GAGE, CCR UNIT
PART 845 REGULATED UNIT (SUBJECT UNIT)
SITE FEATURE
LIMITS OF FINAL COVER
PROPERTY BOUNDARY

0 275 550 Feet

DRAFT

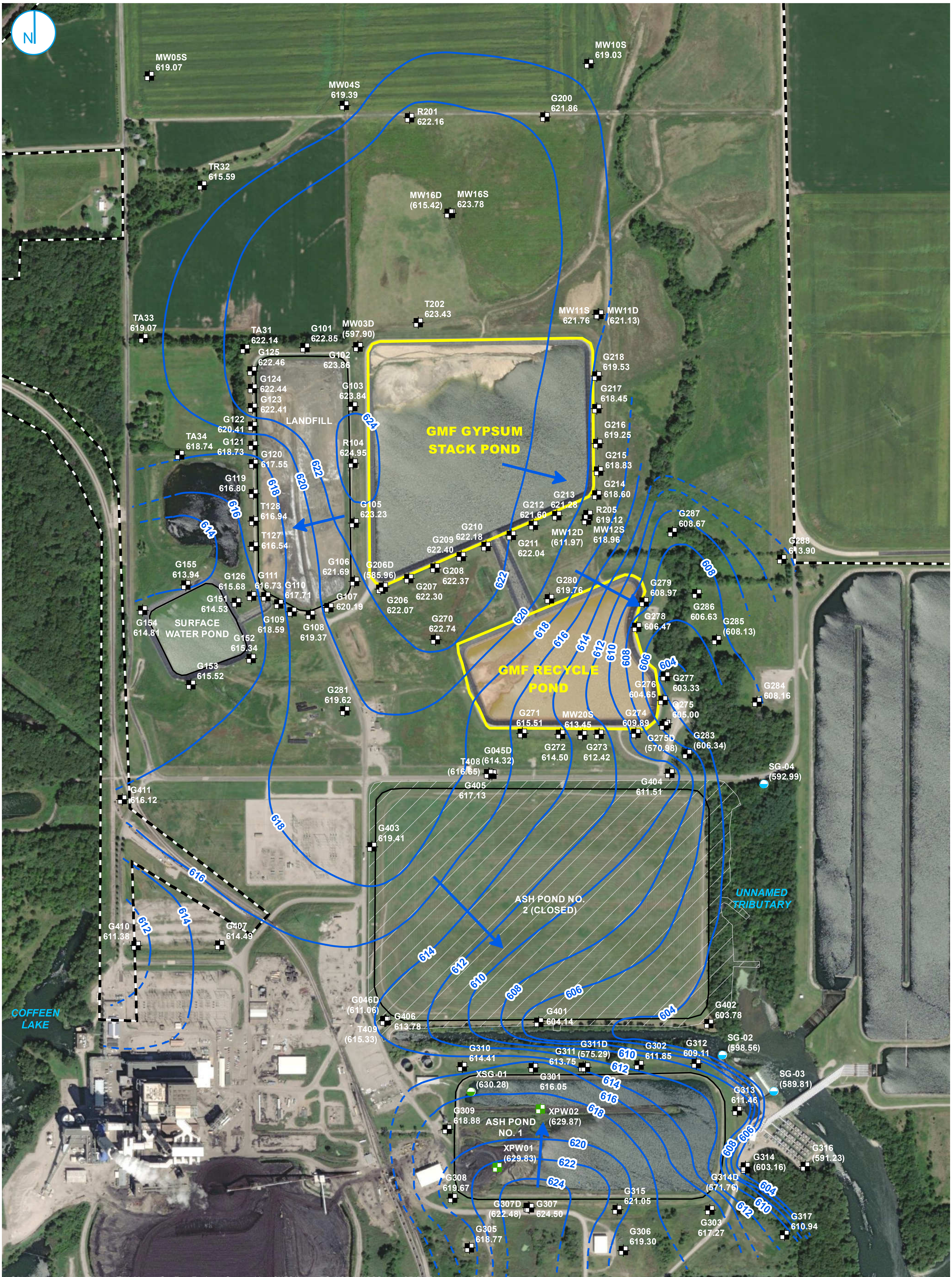
MONITORING WELL LOCATION MAP

FIGURE 2-1

GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS

RAMBOLL AMERICAS ENGINEERING SOLUTIONS, INC.

RAMBOLL



MONITORING WELL
PORE WATER WELL
STAFF GAGE, RIVER
STAFF GAGE, CCR UNIT
PART 845 REGULATED UNIT (SUBJECT UNIT)
LIMITS OF FINAL COVER
PROPERTY BOUNDARY

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

0 275 550 Feet

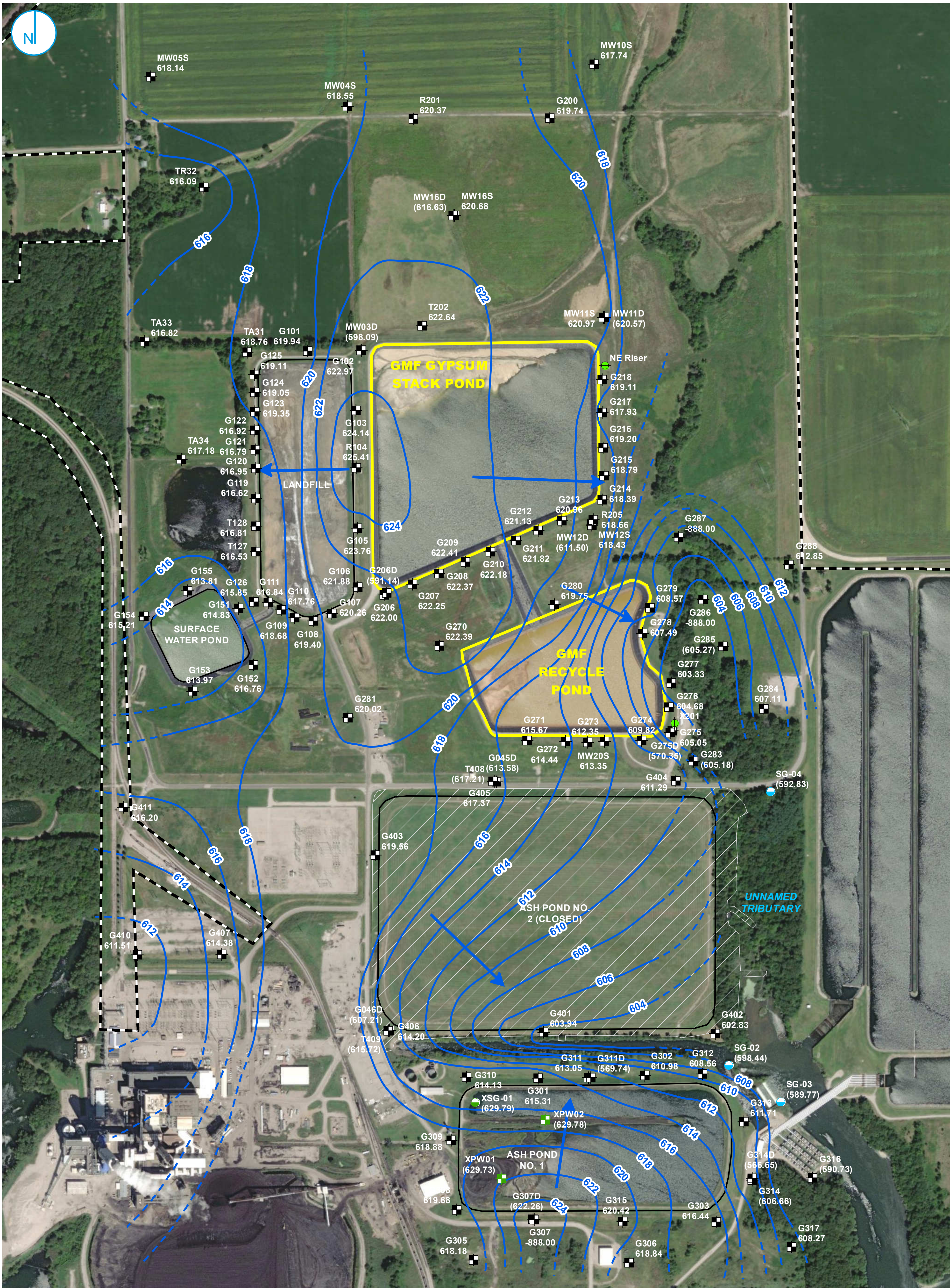
NOTE:
ELEVATIONS IN PARENTHESES WERE NOT USED FOR CONTOURING.

UPPERMOST AQUIFER POTENTIOMETRIC SURFACE MAP
APRIL 20, 2021

GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS

FIGURE 2-2

RAMBOLL AMERICAS ENGINEERING SOLUTIONS, INC.



- MONITORING WELL
- PORE WATER WELL
- LEACHATE WELL
- STAFF GAGE, RIVER
- STAFF GAGE, CCR UNIT
- PART 845 REGULATED UNIT (SUBJECT UNIT)
- LIMITS OF FINAL COVER
- PROPERTY BOUNDARY
- GROUNDWATER ELEVATION CONTOUR (2-FT CONTOUR INTERVAL, NAVD88)
- INFERRED GROUNDWATER ELEVATION CONTOUR
- GROUNDWATER FLOW DIRECTION

0 275 550 Feet

NOTE:
ELEVATIONS IN PARENTHESES WERE NOT USED FOR CONTOURING.

UPPERMOST AQUIFER POTENTIOMETRIC SURFACE MAP
JULY 26, 2021

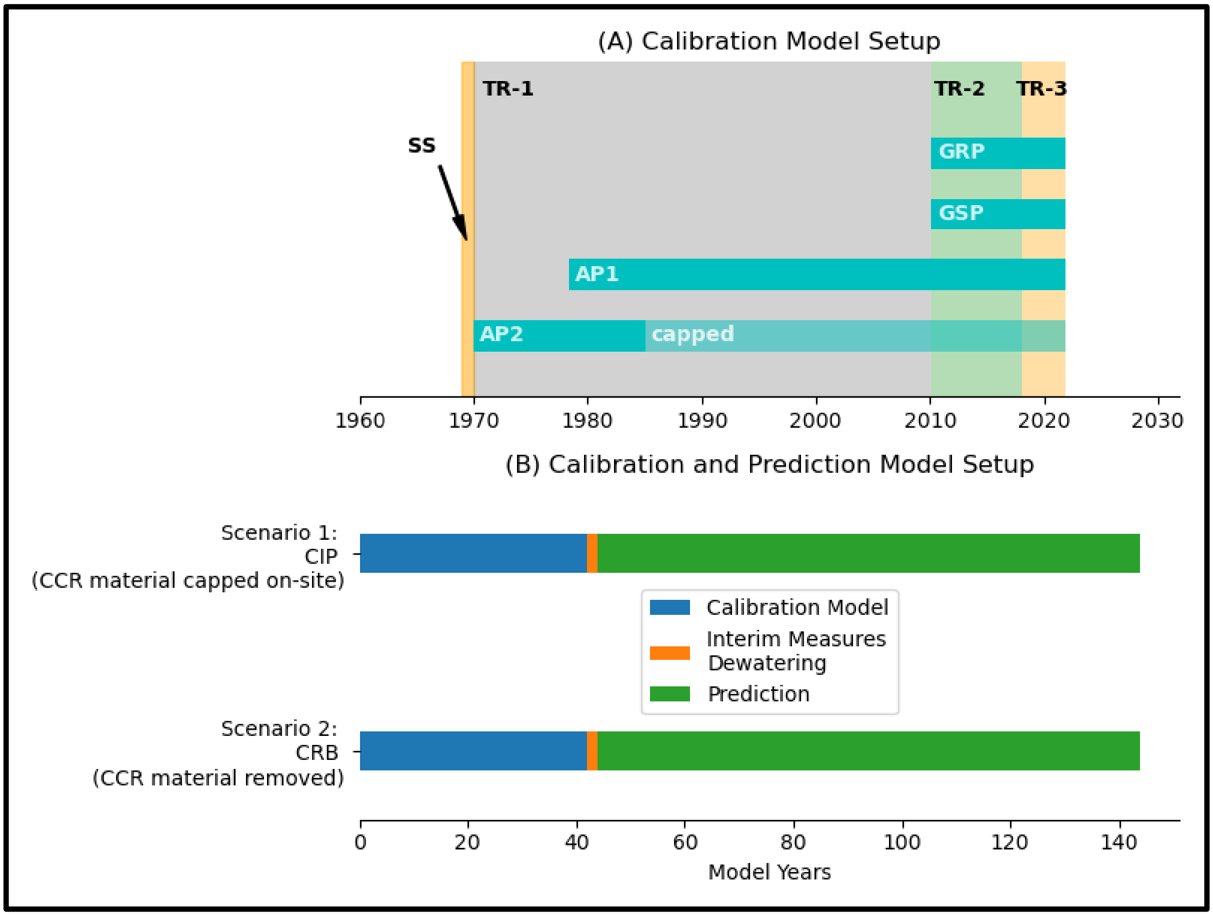
FIGURE 2-3

DRAFT

GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS

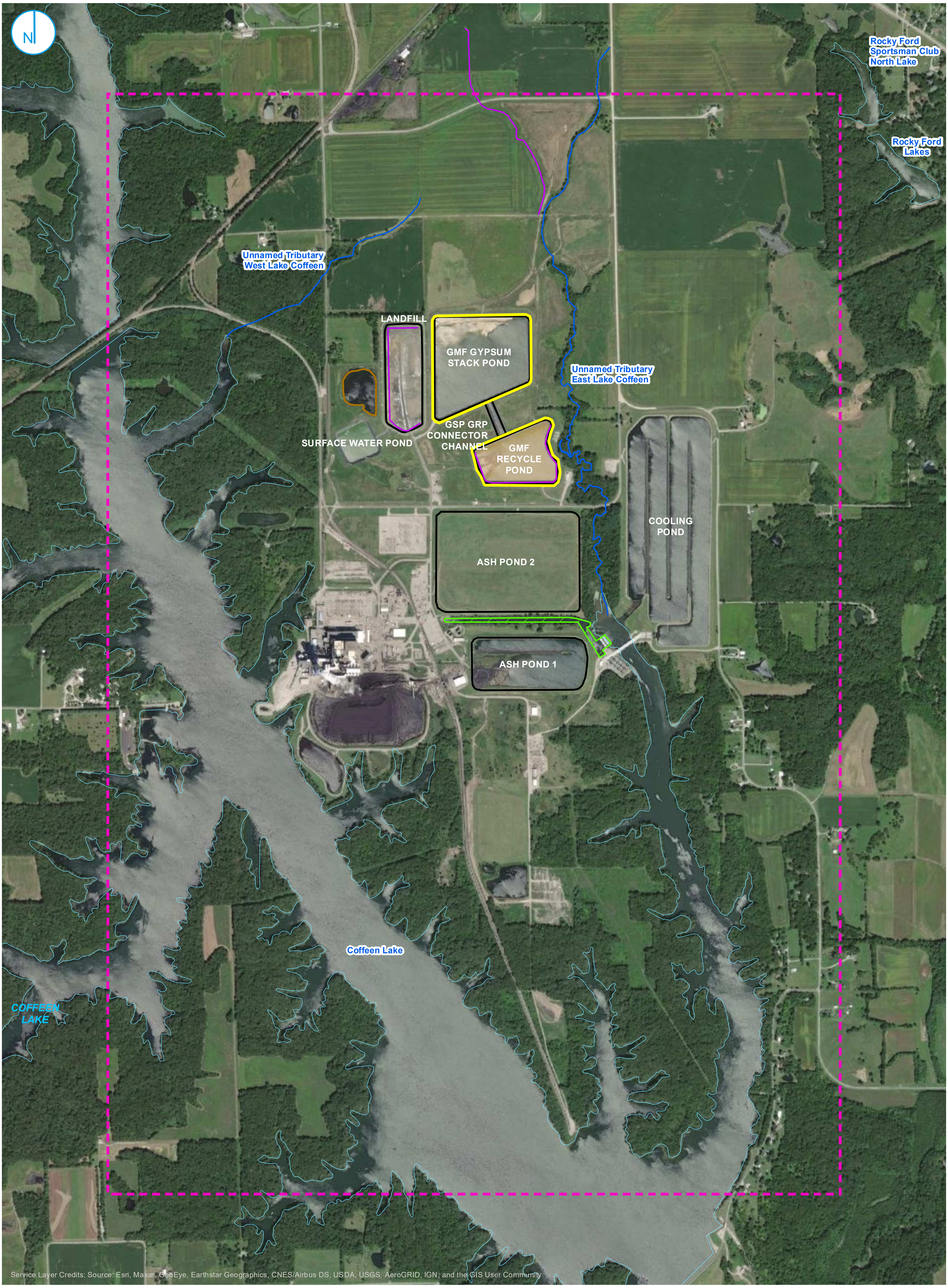
RAMBOLL AMERICAS ENGINEERING SOLUTIONS, INC.

RAMBOLL



CALIBRATION AND PREDICTIVE TIMELINE (SS = STEADY STATE MODEL AND TR = TRANSIENT MODEL).

GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS



DRAIN
STREAM
LAKE
COOLING CONDENSER FLUME
SI UNIT
POND
MODEL GRID
PART 845 REGULATED UNIT (SUBJECT UNIT)

0 625 1,250 Feet

DRAFT

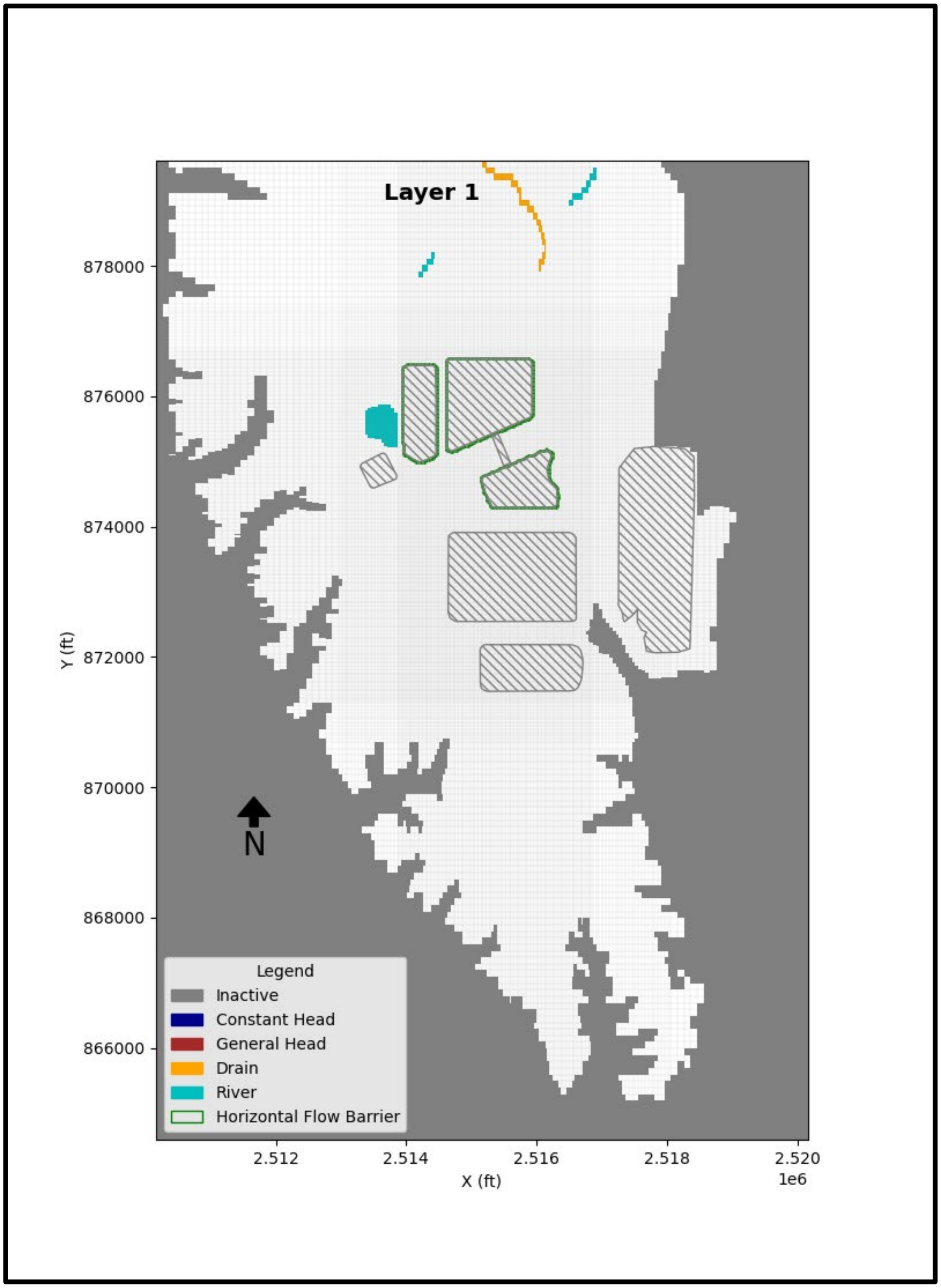
MODEL AREA MAP

FIGURE 5-1

GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

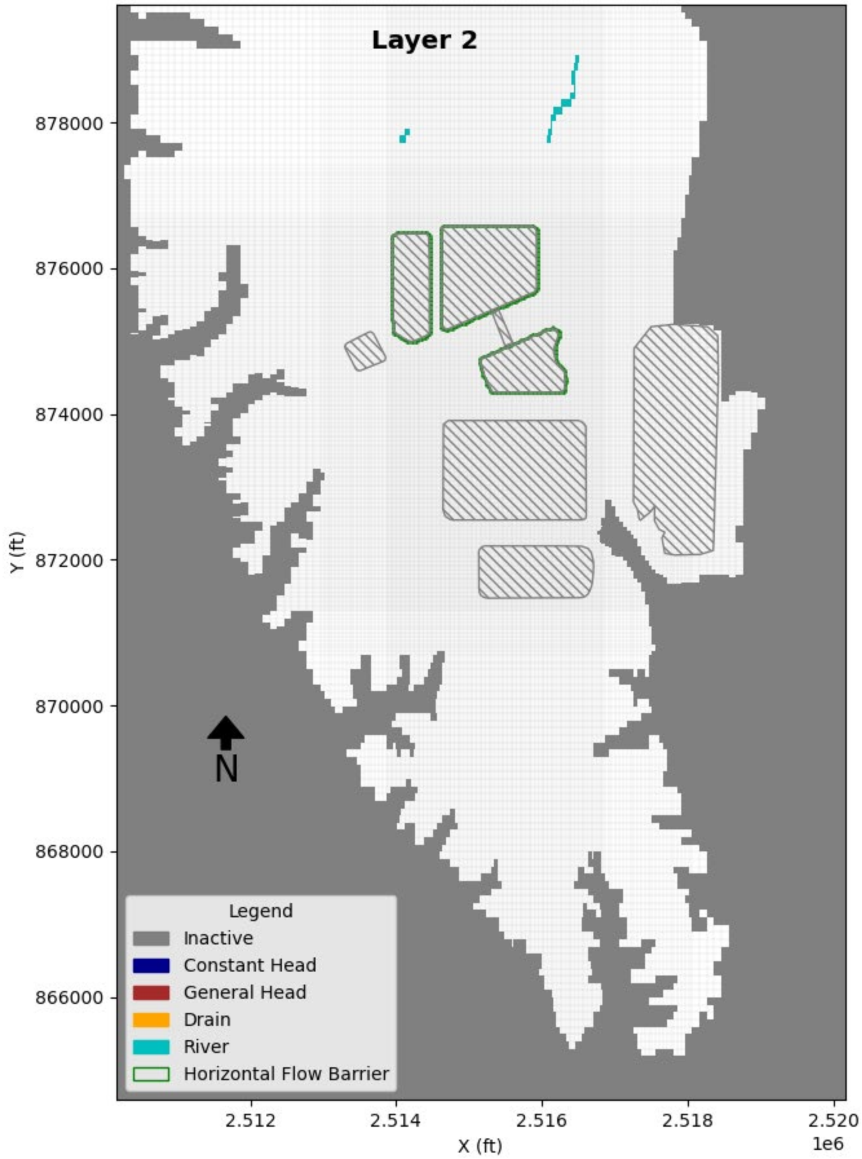
RAMBOLL



BOUNDARY CONDITIONS FOR LAYER 1

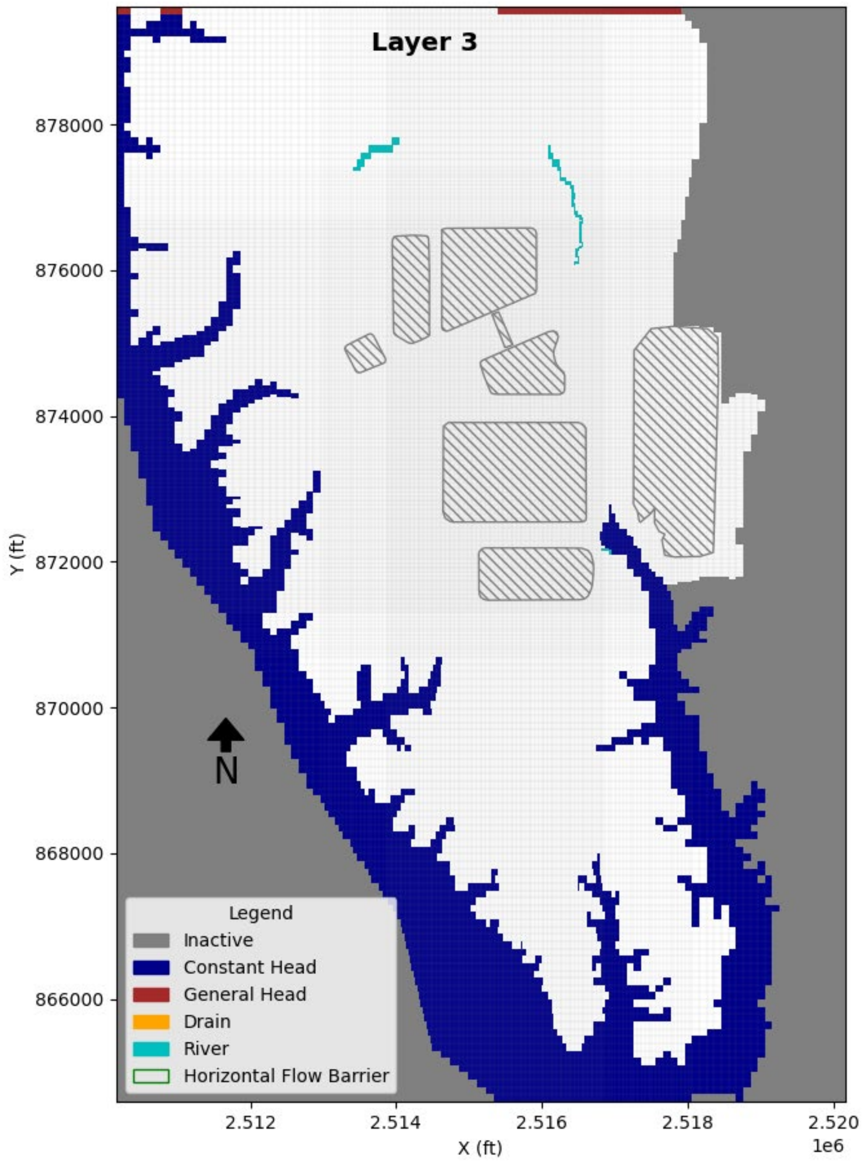
GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS

RAMBOLL



BOUNDARY CONDITIONS FOR LAYER 2

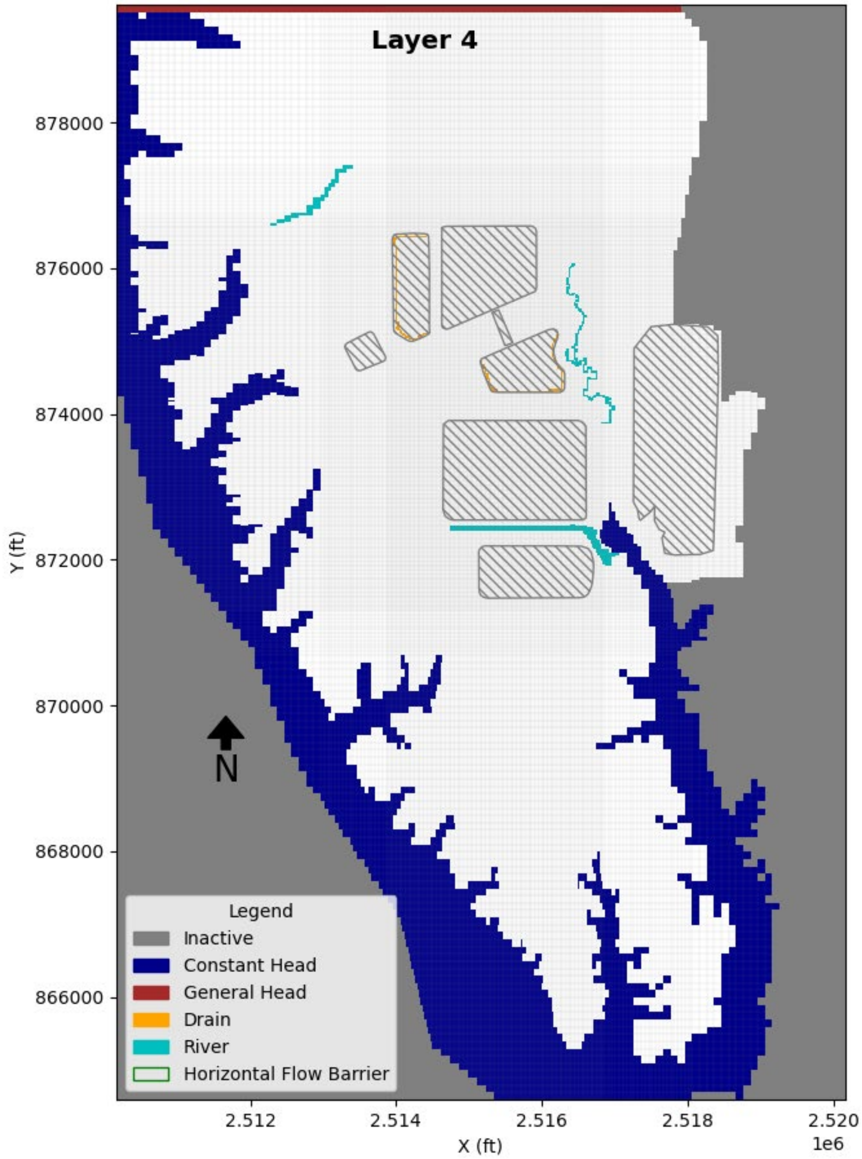
GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS



BOUNDARY CONDITIONS FOR LAYER 3

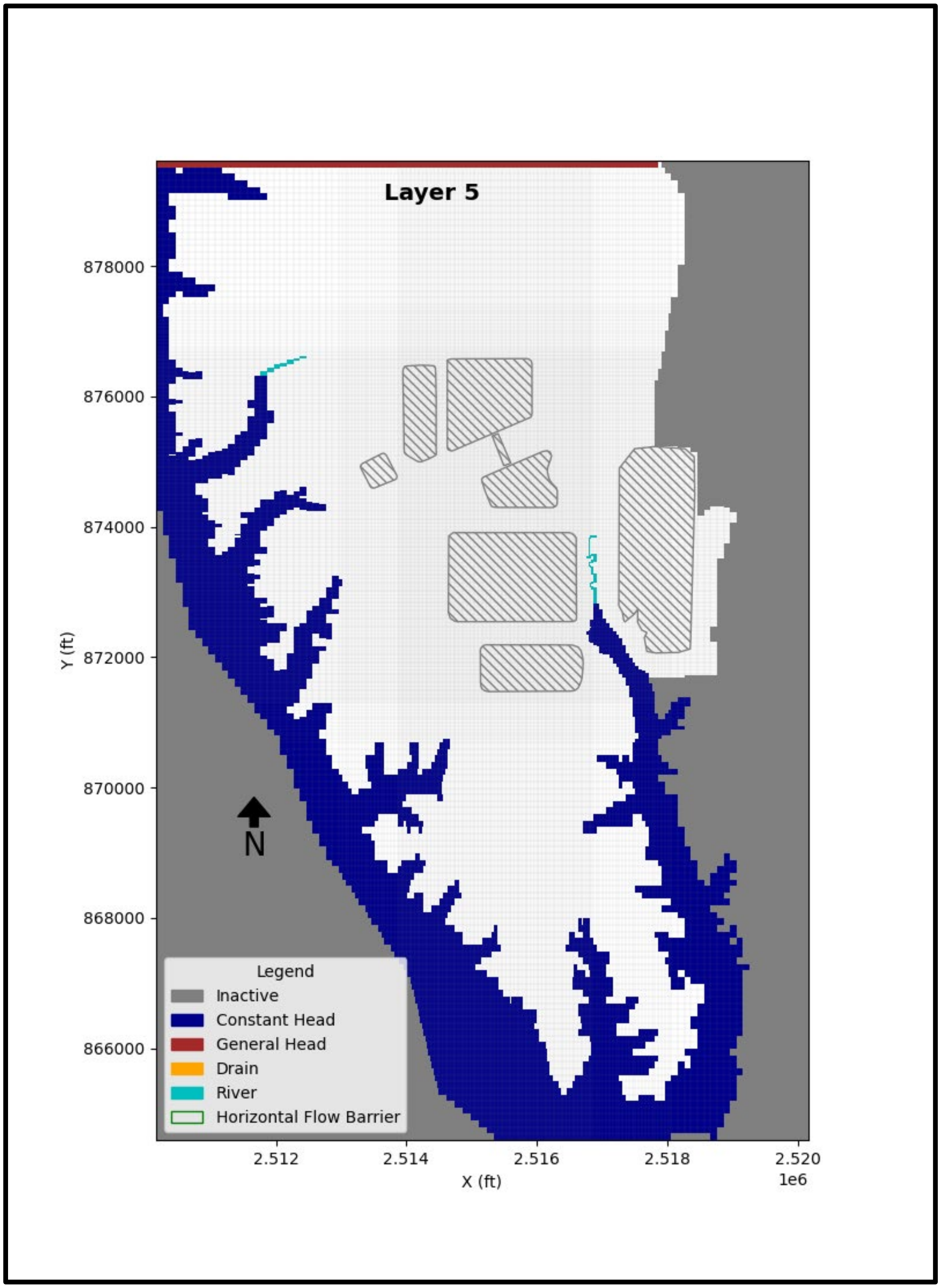
GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS

RAMBOLL



BOUNDARY CONDITIONS FOR LAYER 4

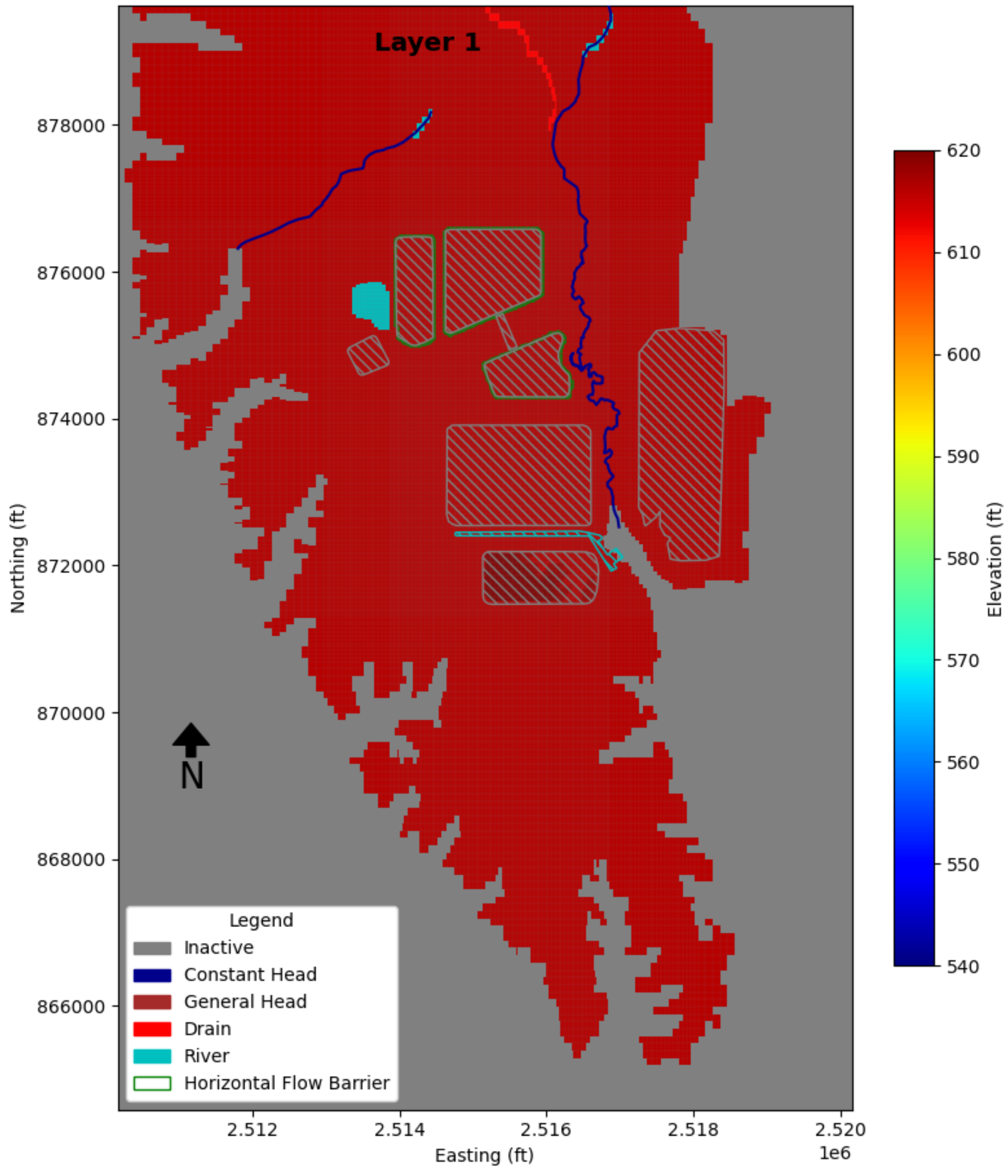
GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS



BOUNDARY CONDITIONS FOR LAYER 5

GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS

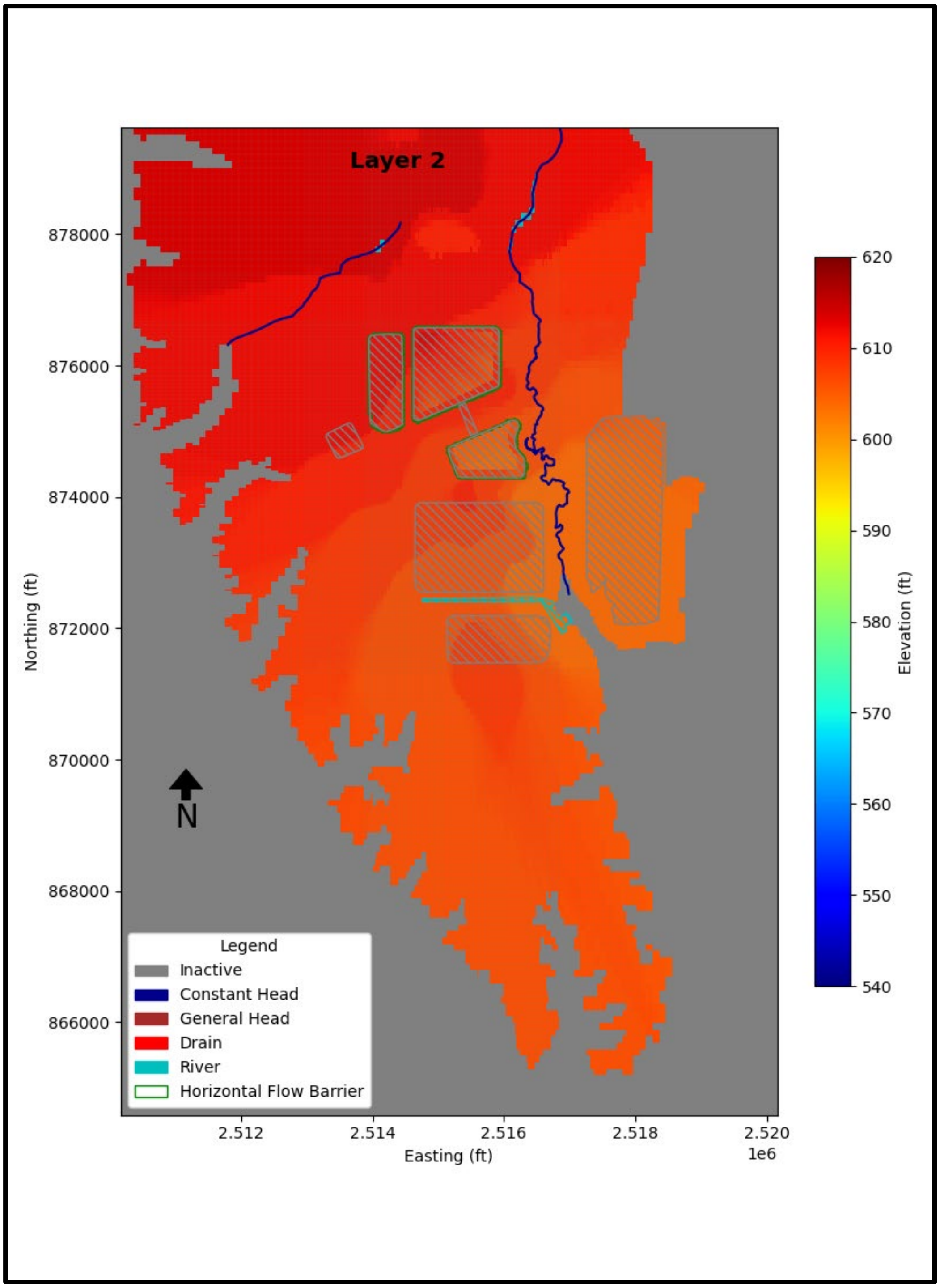
RAMBOLL



BASE OF MODEL FOR LAYER 1

GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS

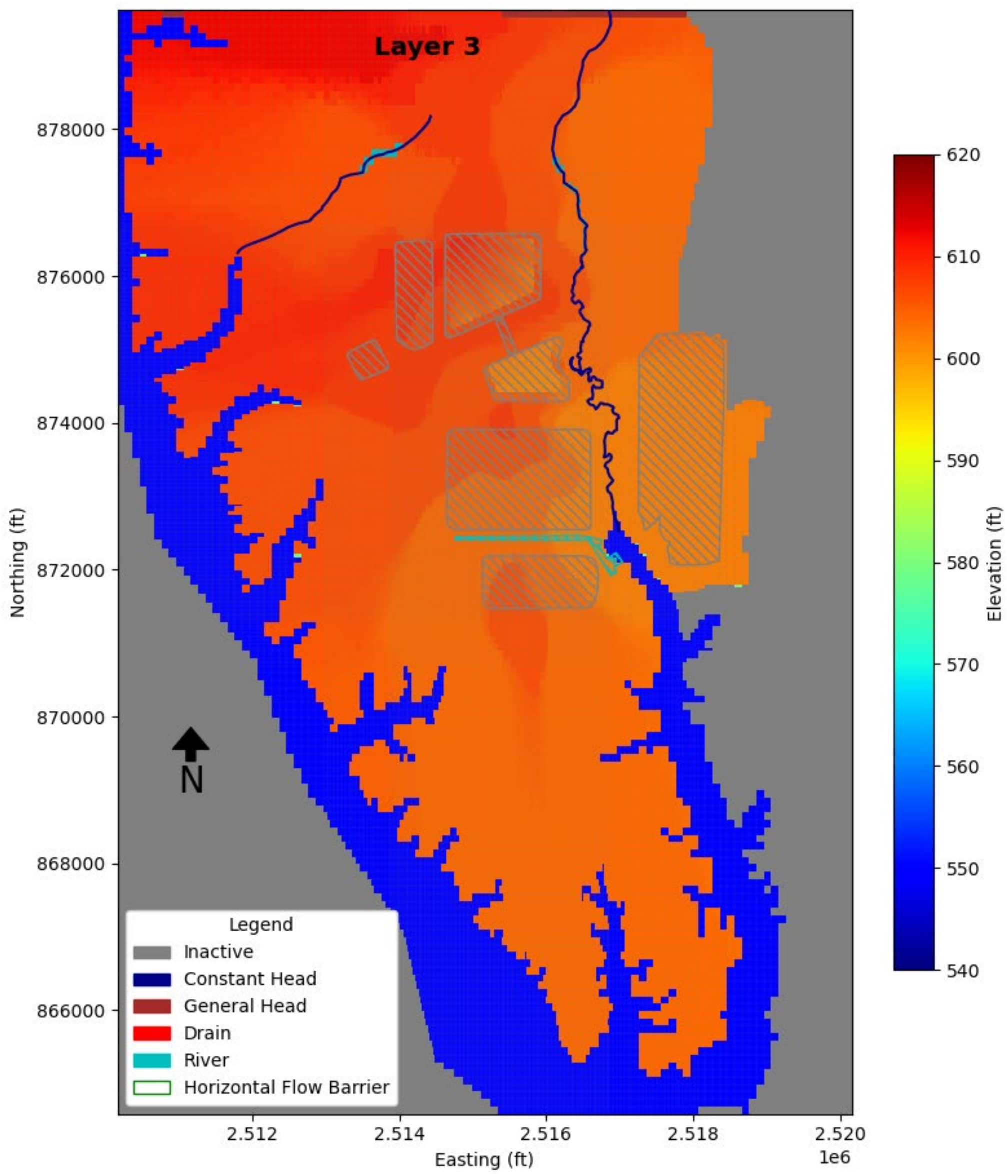
RAMBOLL



BASE OF MODEL FOR LAYER 2

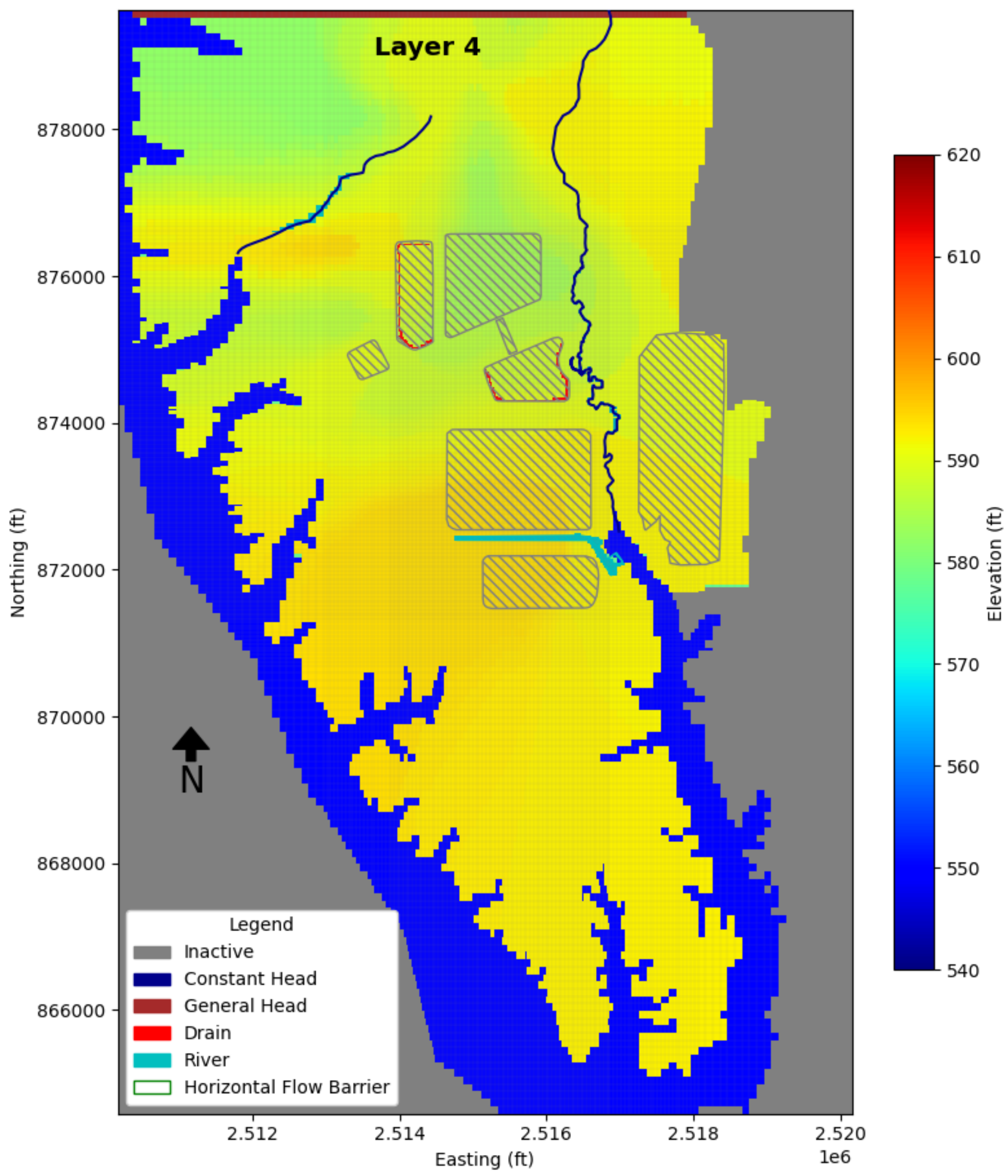
GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS

RAMBOLL



BASE OF MODEL FOR LAYER 3

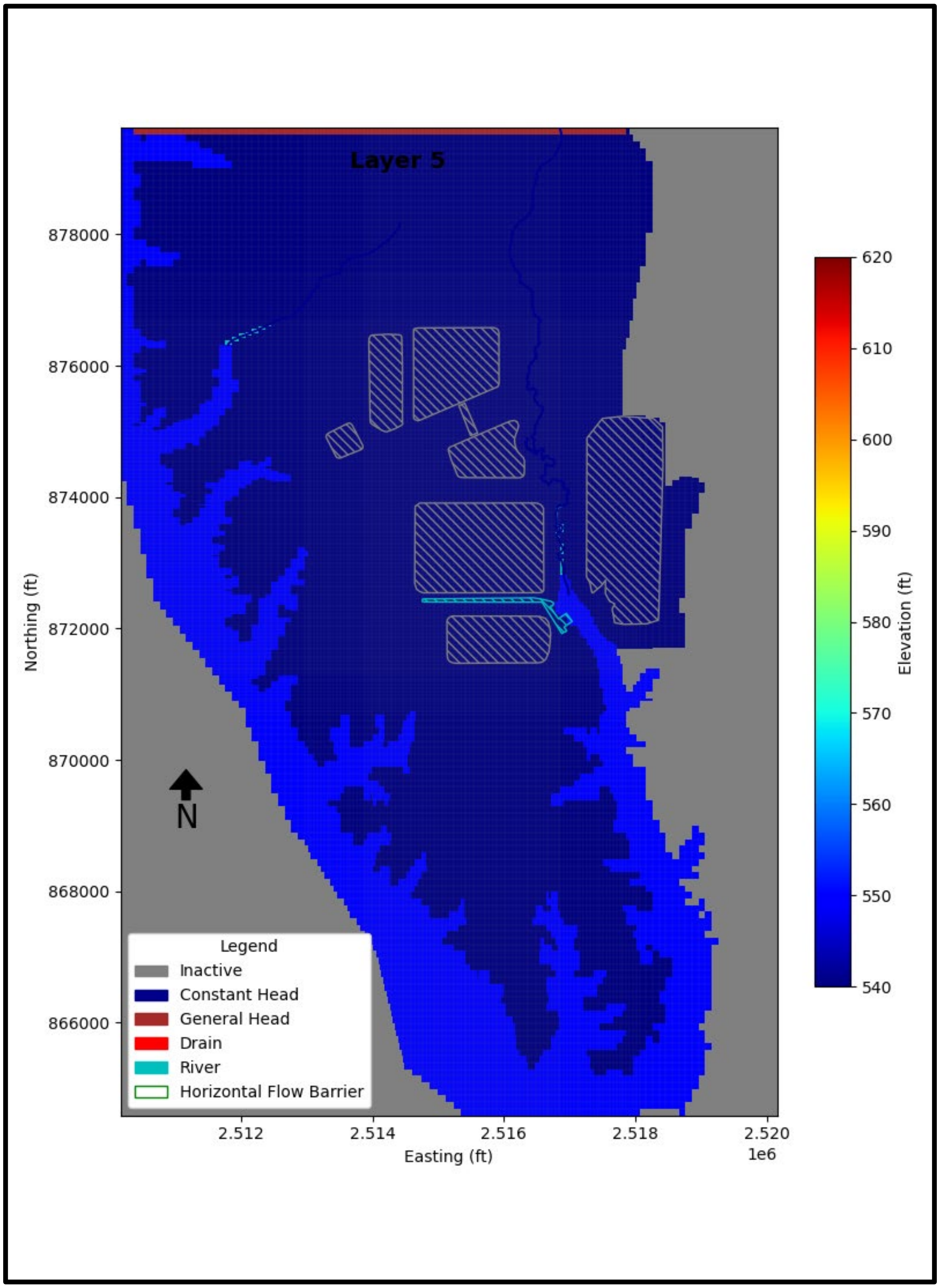
GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS



BASE OF MODEL FOR LAYER 4

GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS

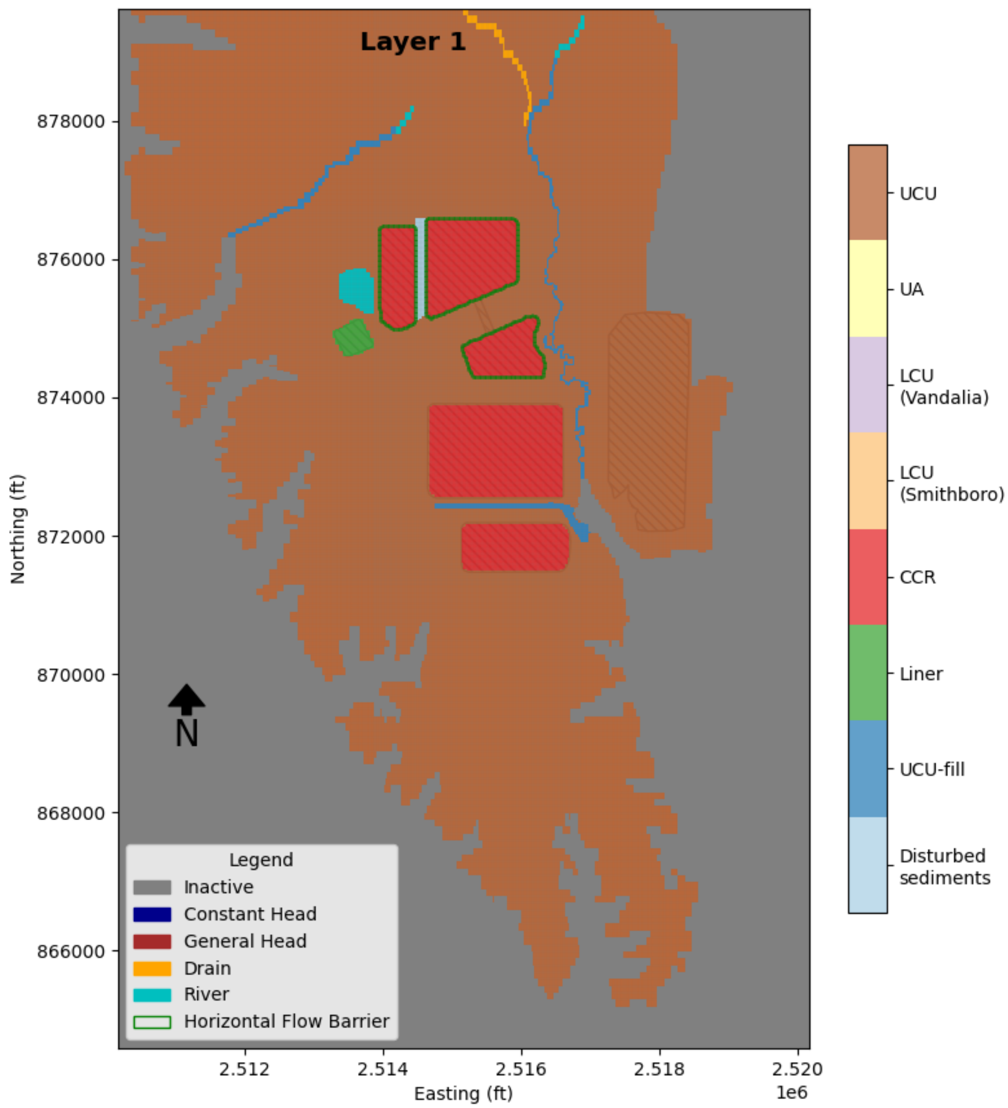
RAMBOLL



BASE OF MODEL FOR LAYER 5

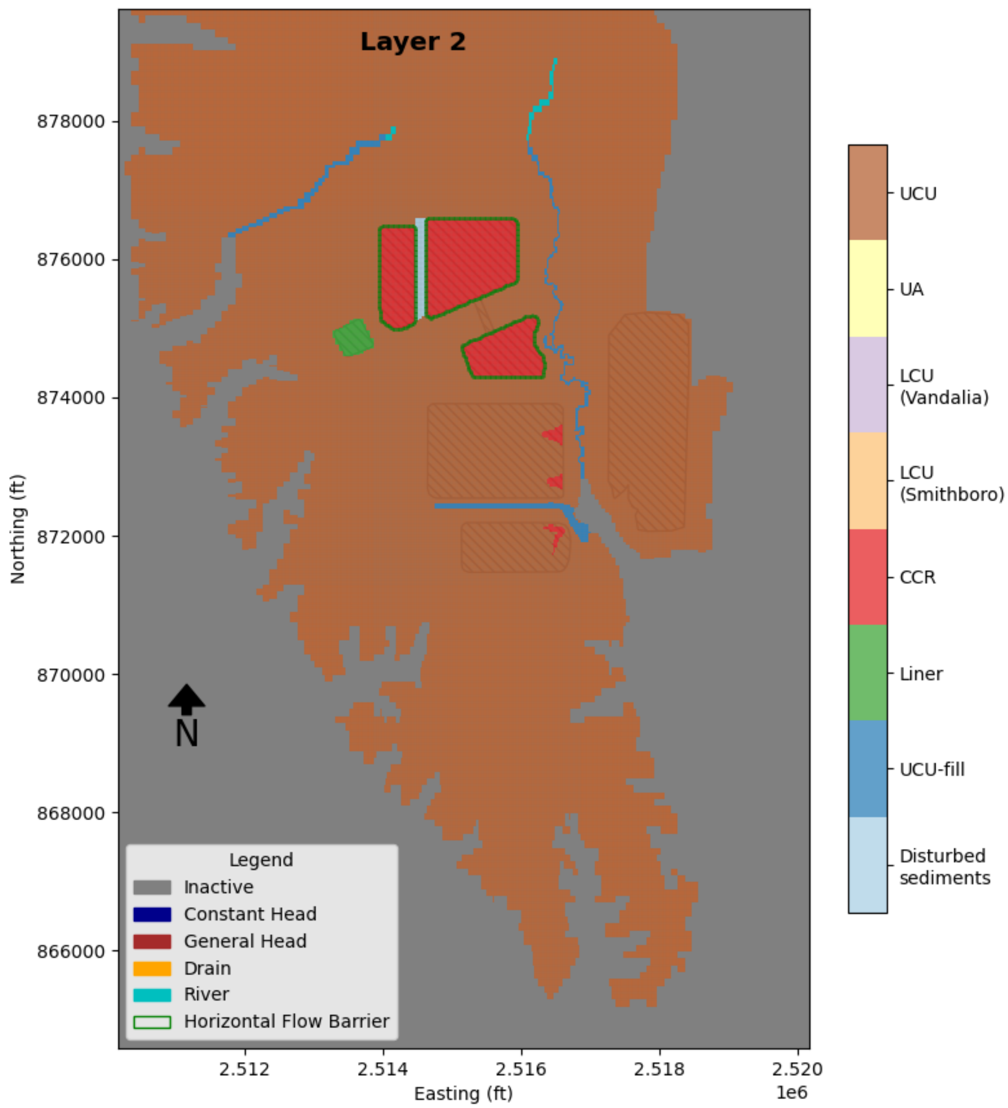
GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS

RAMBOLL



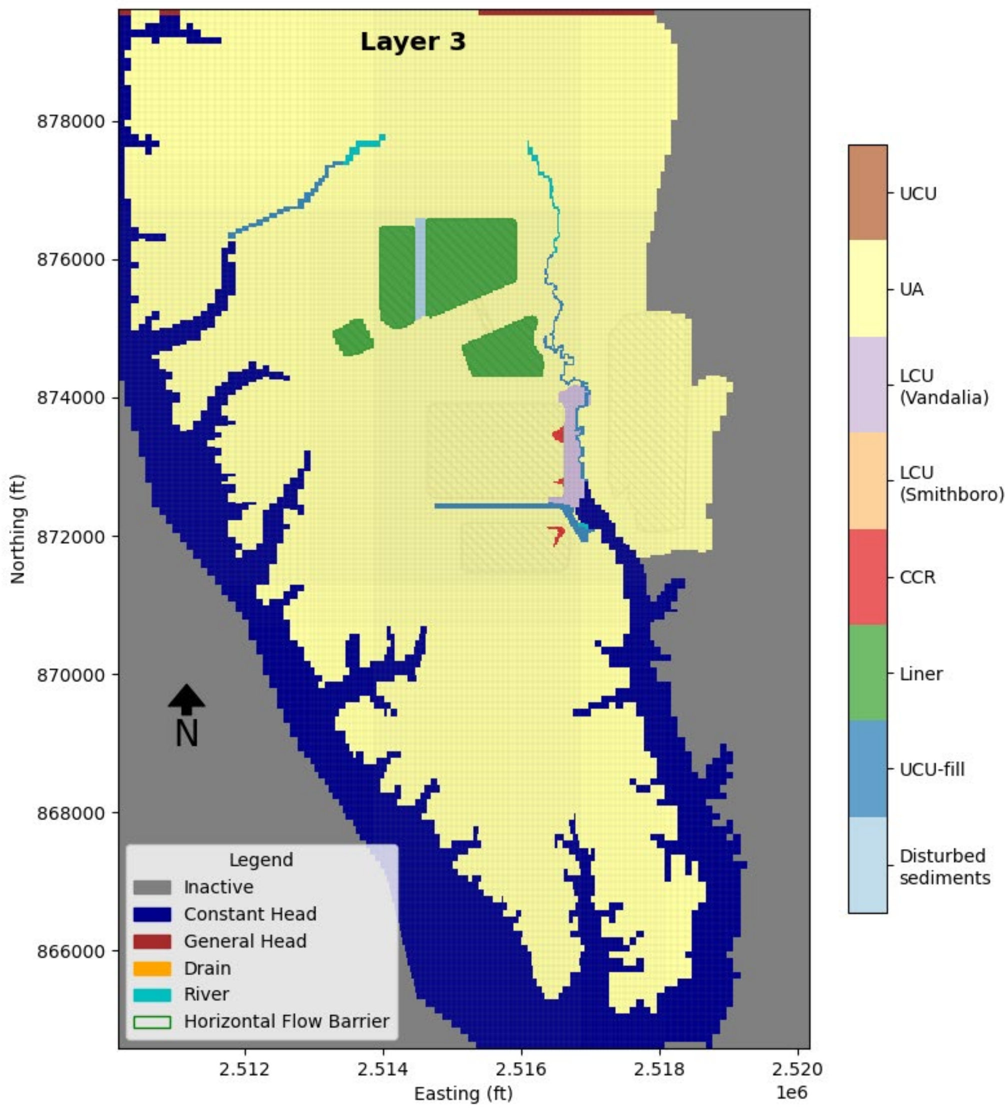
HYDRAULIC CONDUCTIVITY ZONES FOR LAYER 1

GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS



HYDRAULIC CONDUCTIVITY ZONES FOR LAYER 2

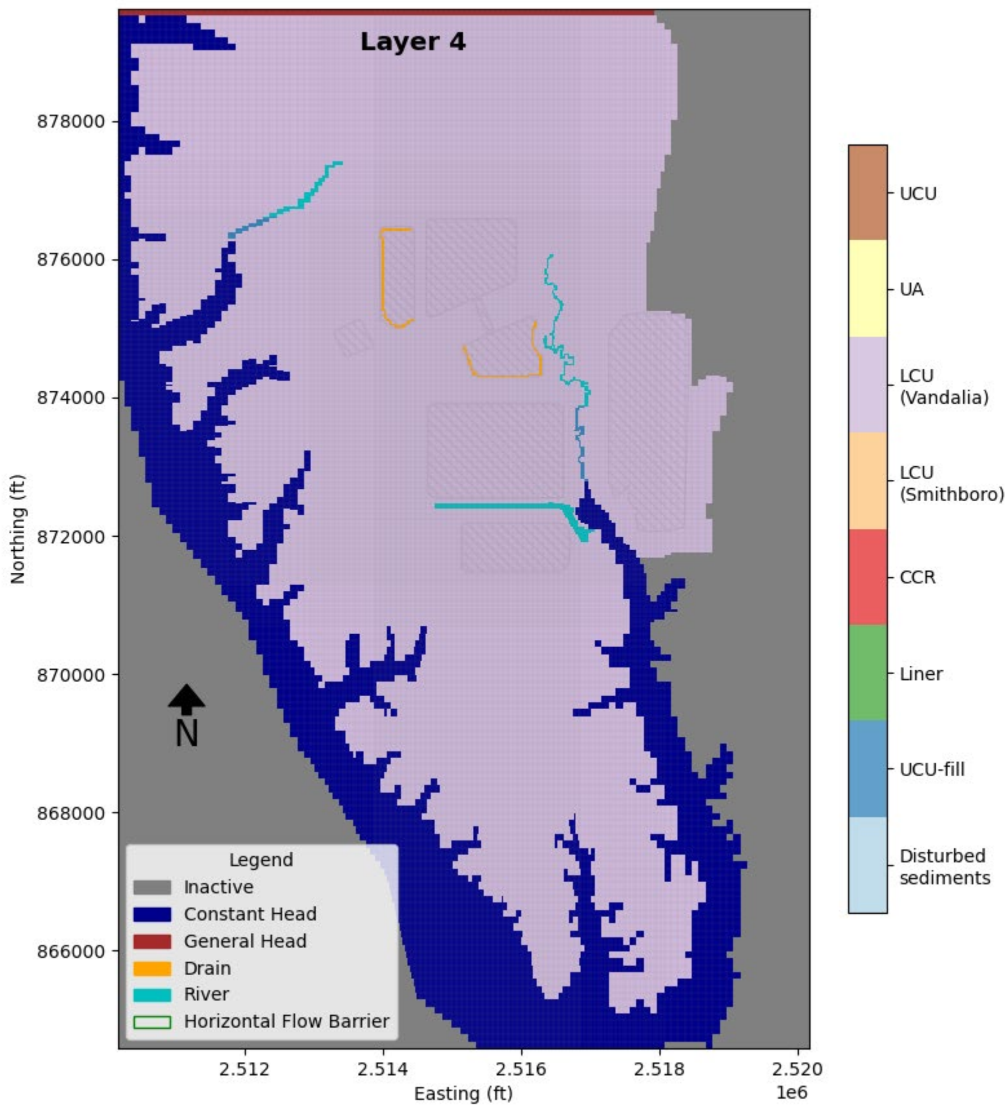
GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS



HYDRAULIC CONDUCTIVITY ZONES FOR LAYER 3

GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS

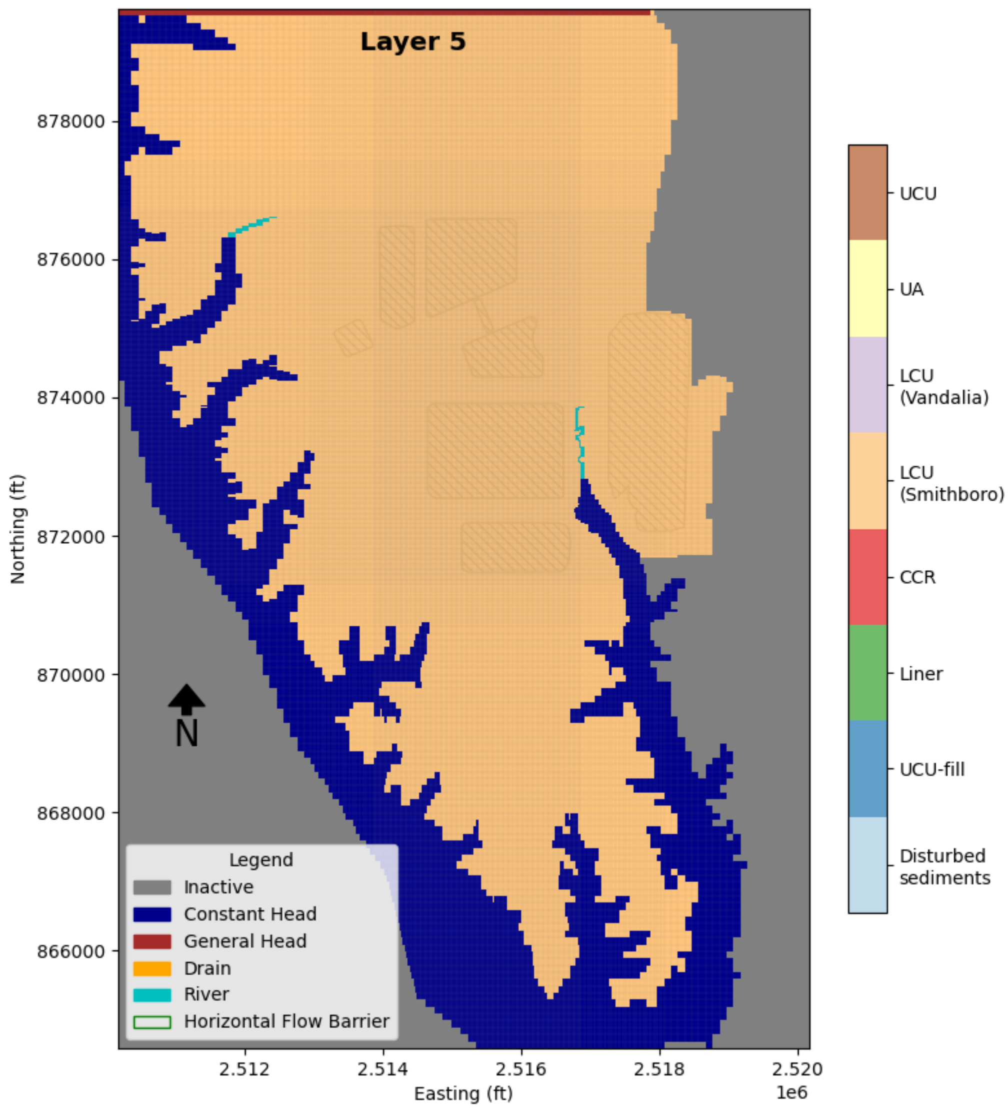
RAMBOLL



HYDRAULIC CONDUCTIVITY ZONES FOR LAYER 4

GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS

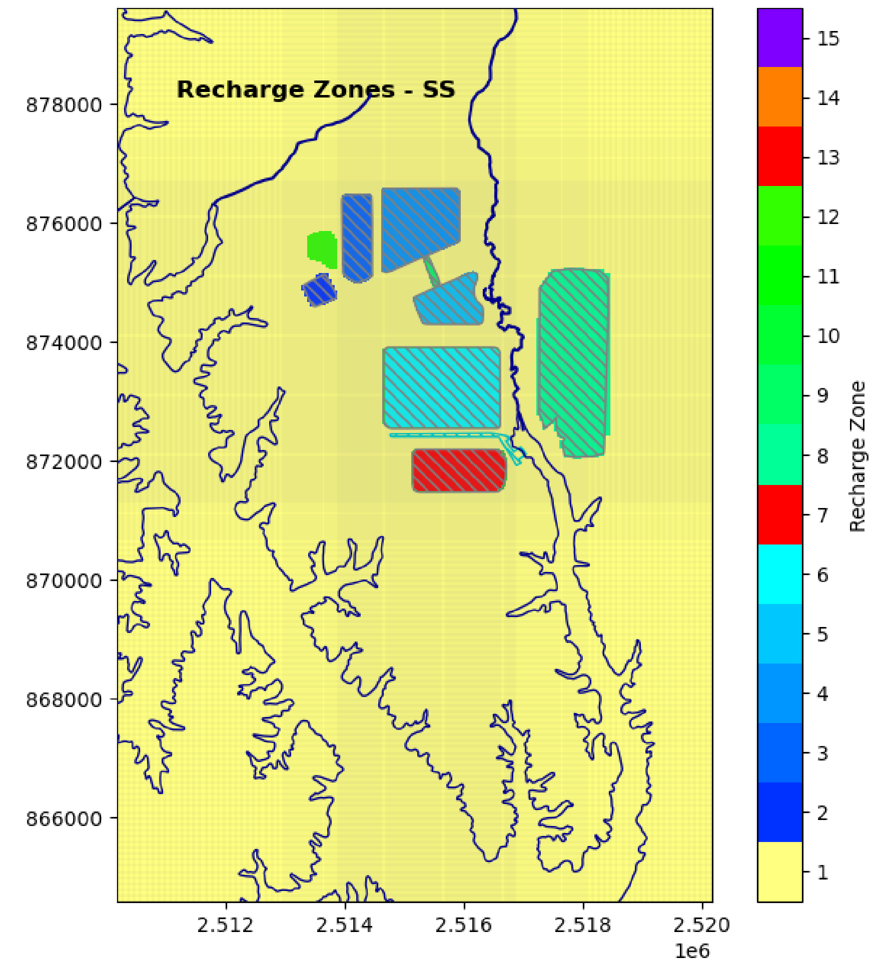
RAMBOLL



HYDRAULIC CONDUCTIVITY ZONES FOR LAYER 5

GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS

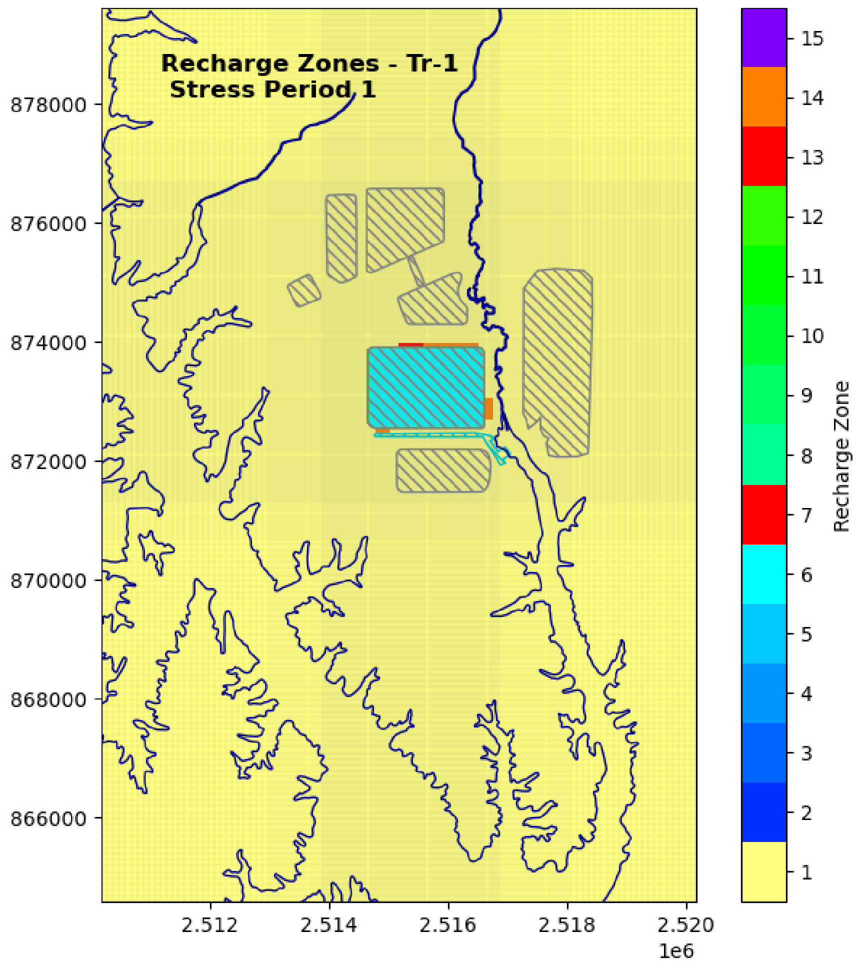
RAMBOLL



MODEL RECHARGE DISTRIBUTION STEADY STATE (SS) MODEL

GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS

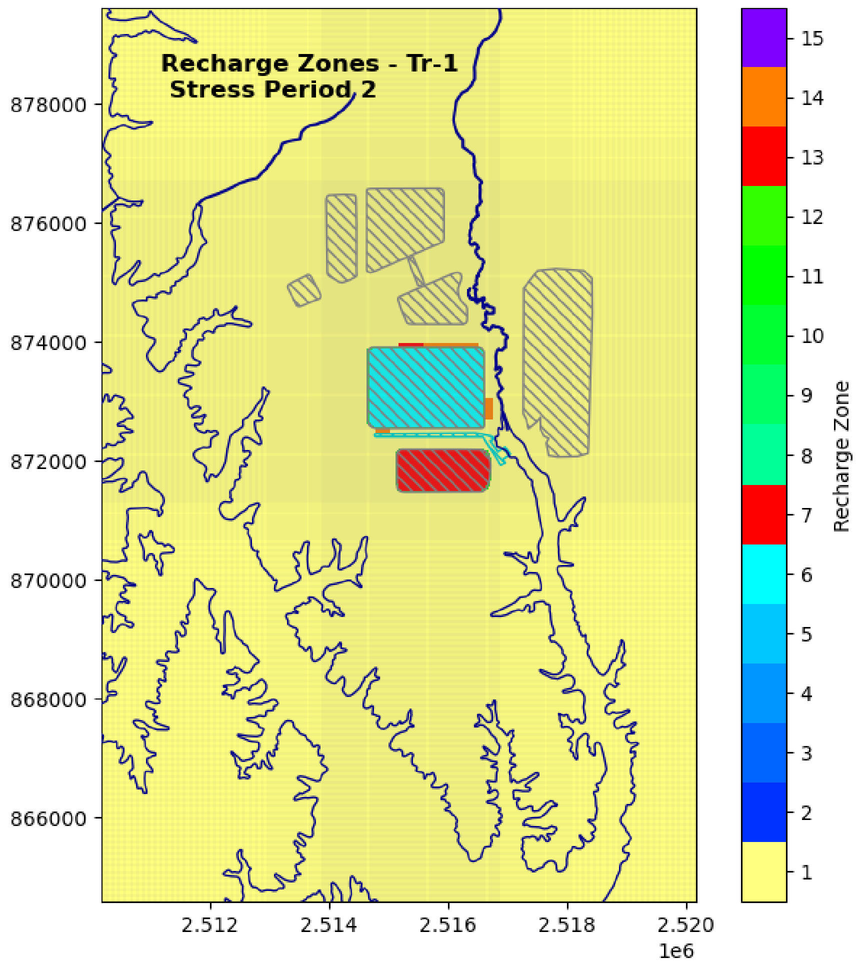
FIGURE 5-18



MODEL RECHARGE DISTRIBUTION FOR THE TRANSIENT (TR) MODEL TR-1
STRESS PERIOD 1

GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS

RAMBOLL

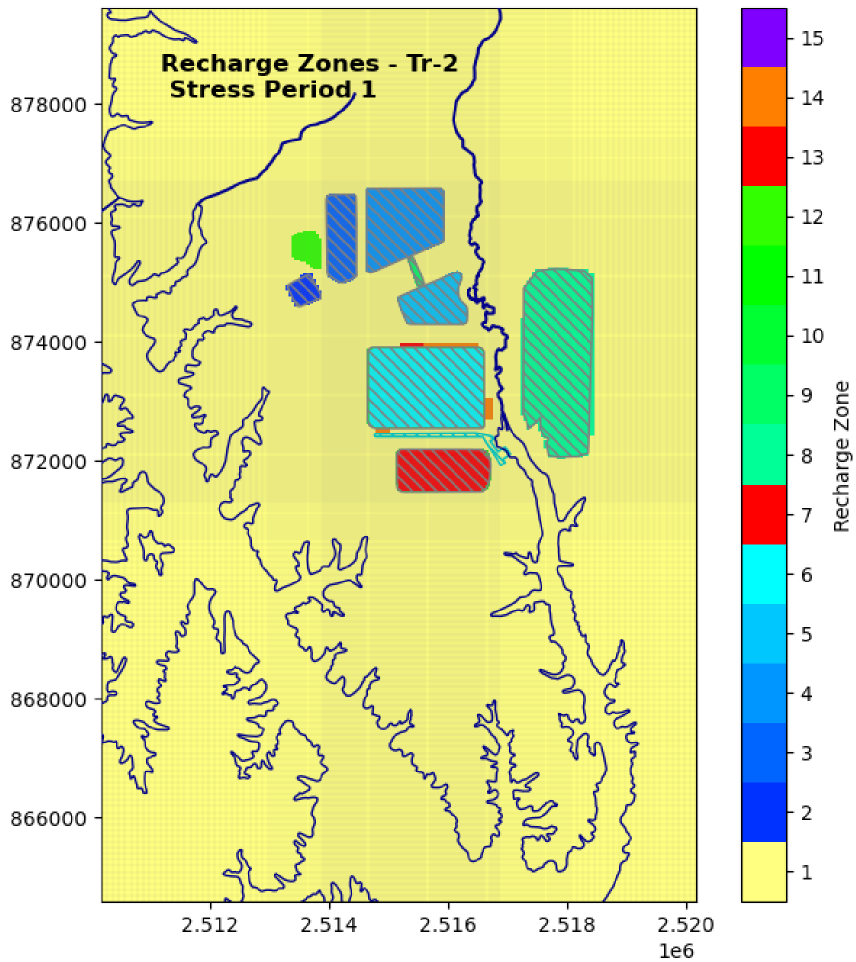


MODEL RECHARGE DISTRIBUTION FOR THE TRANSIENT (TR) MODEL TR-1
STRESS PERIOD 2

GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS

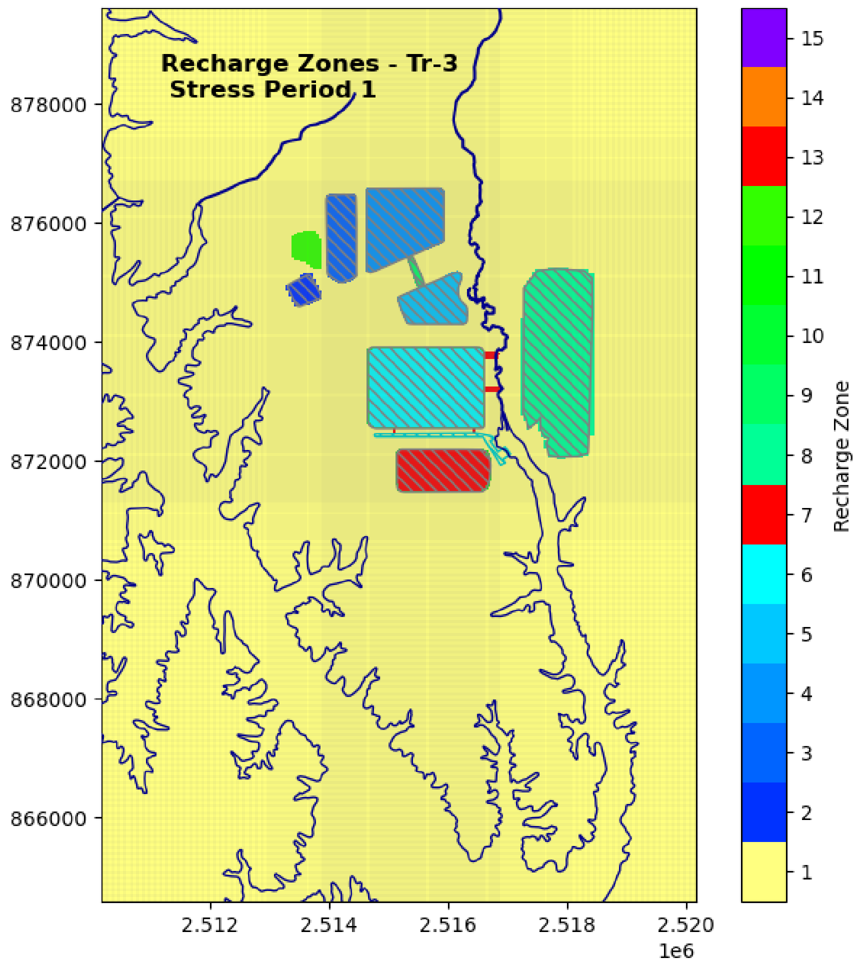
RAMBOLL

FIGURE 5-20



MODEL RECHARGE DISTRIBUTION FOR THE TRANSIENT (TR) MODEL TR-2
STRESS PERIOD 1

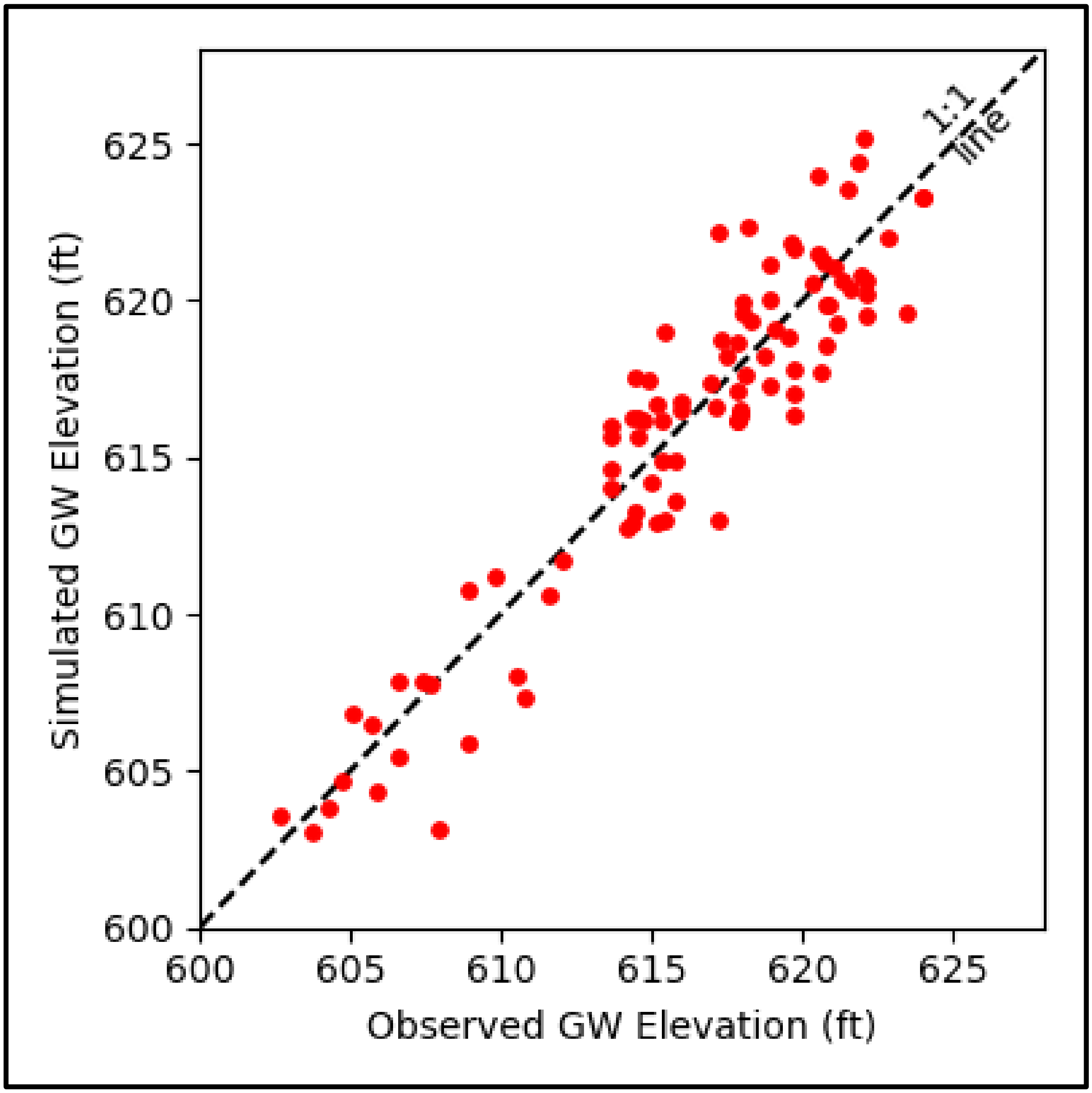
GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS



MODEL RECHARGE DISTRIBUTION FOR THE TRANSIENT (TR) MODEL TR-3
STRESS PERIOD 1

GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS

RAMBOLL

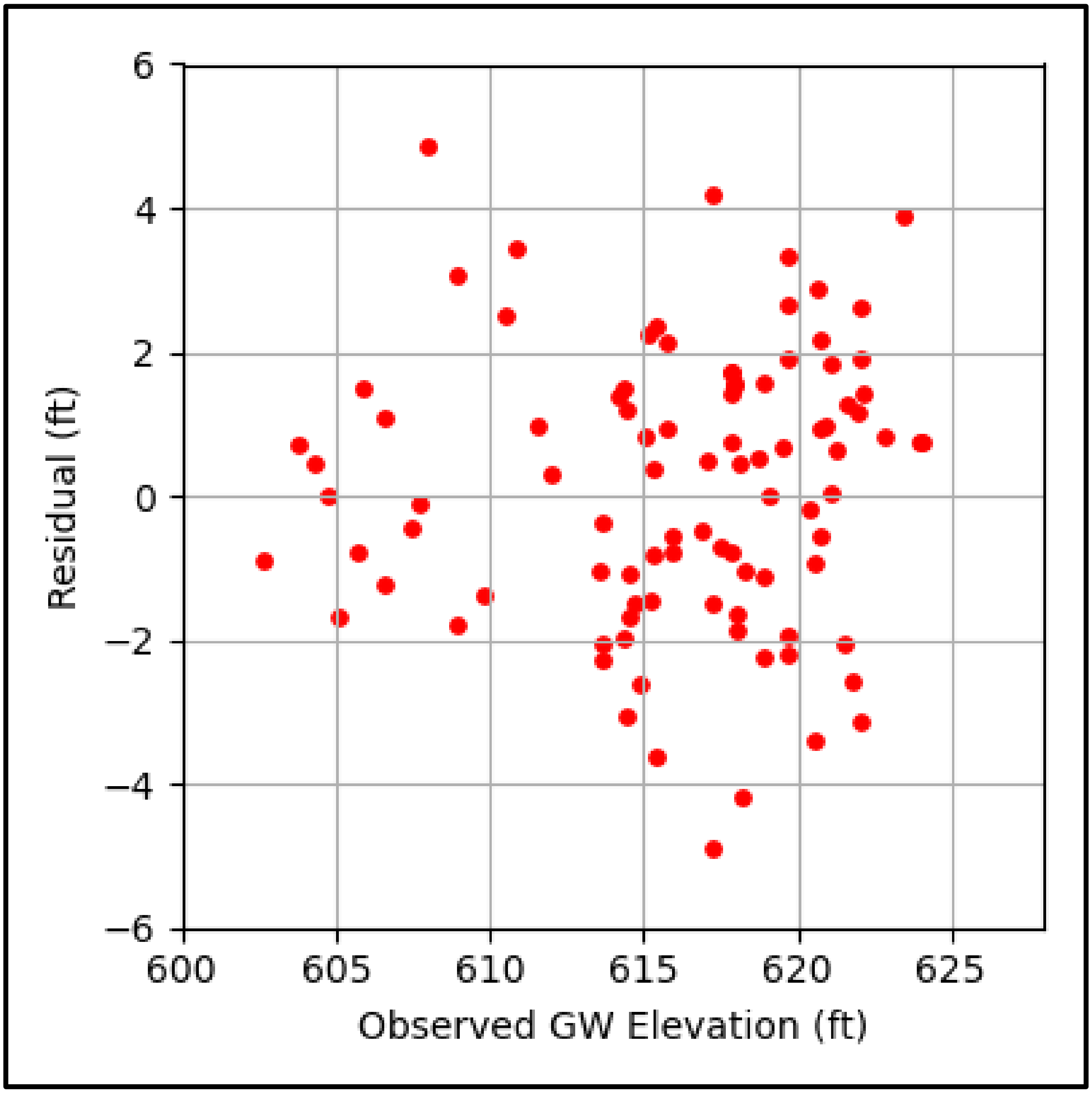


OBSERVED VERSUS SIMULATED STEADY STATE GROUNDWATER LEVELS FROM THE CALIBRATED MODEL

GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS

RAMBOLL

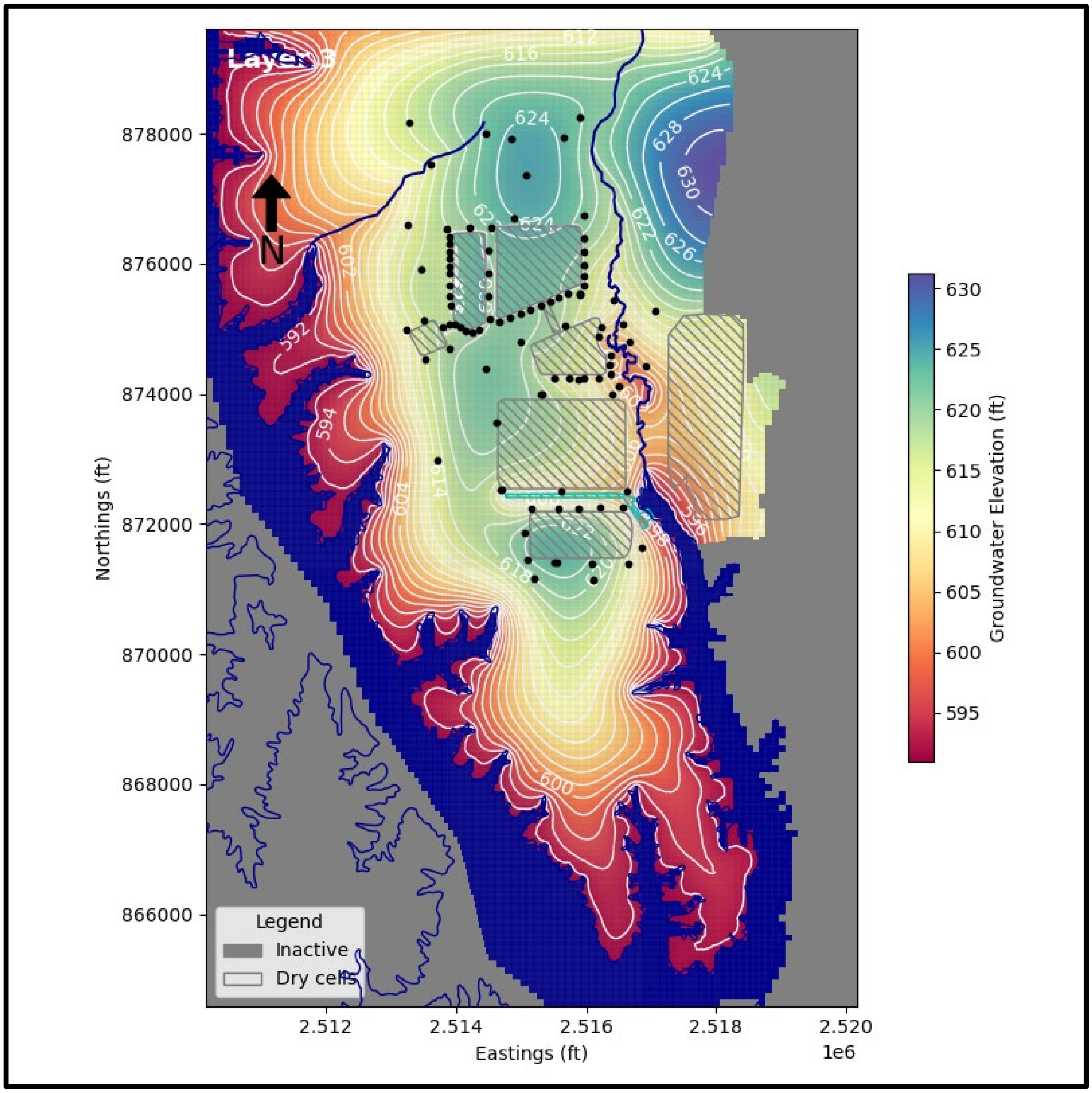
FIGURE 5-23



SIMULATED GROUNDWATER LEVEL RESIDUALS FROM THE CALIBRATED MODEL

GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS

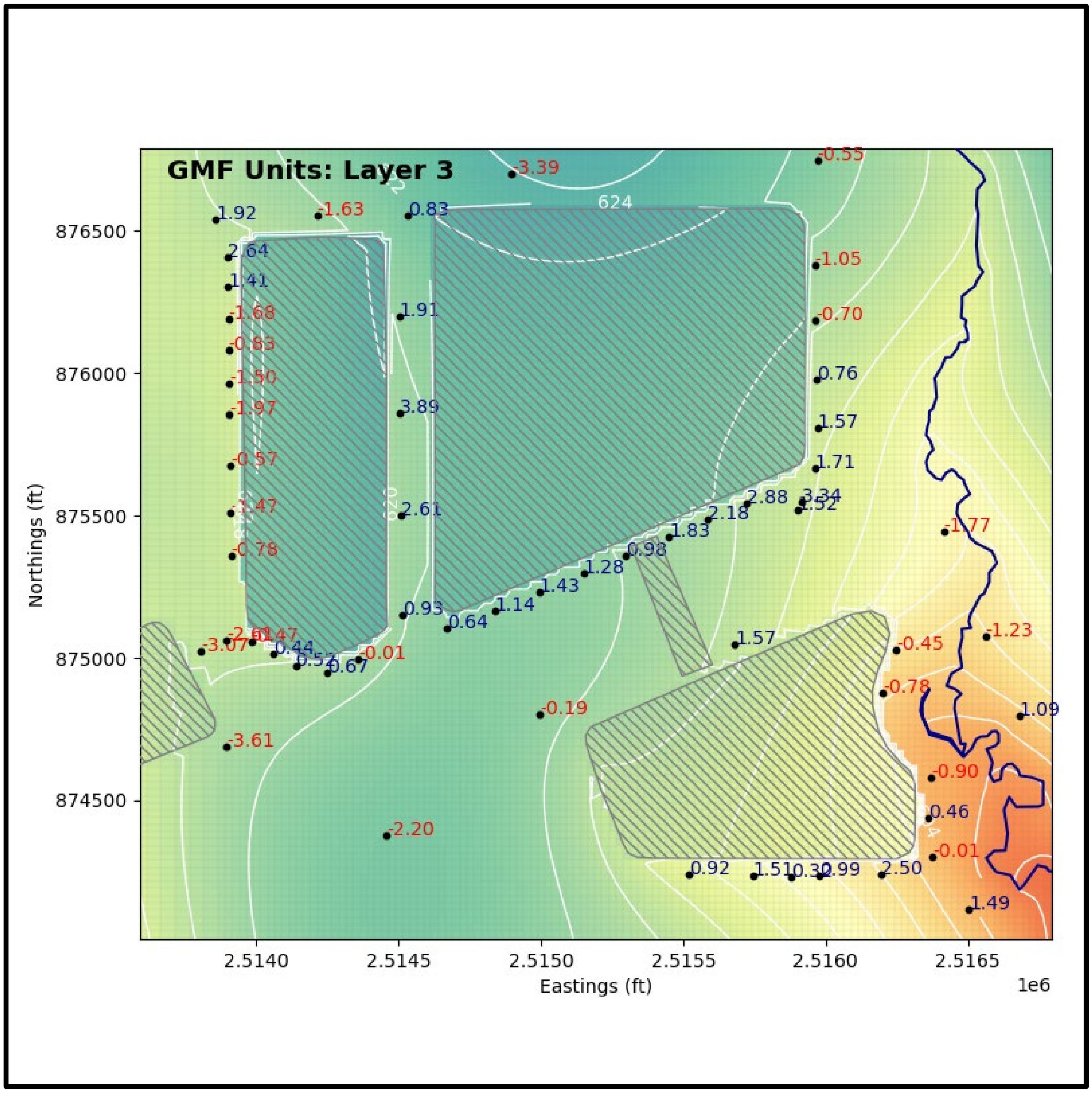
RAMBOLL



SIMULATED STEADY STATE GROUNDWATER LEVEL CONTOURS FROM UA (LAYER 3) FROM THE CALIBRATED MODEL

GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS

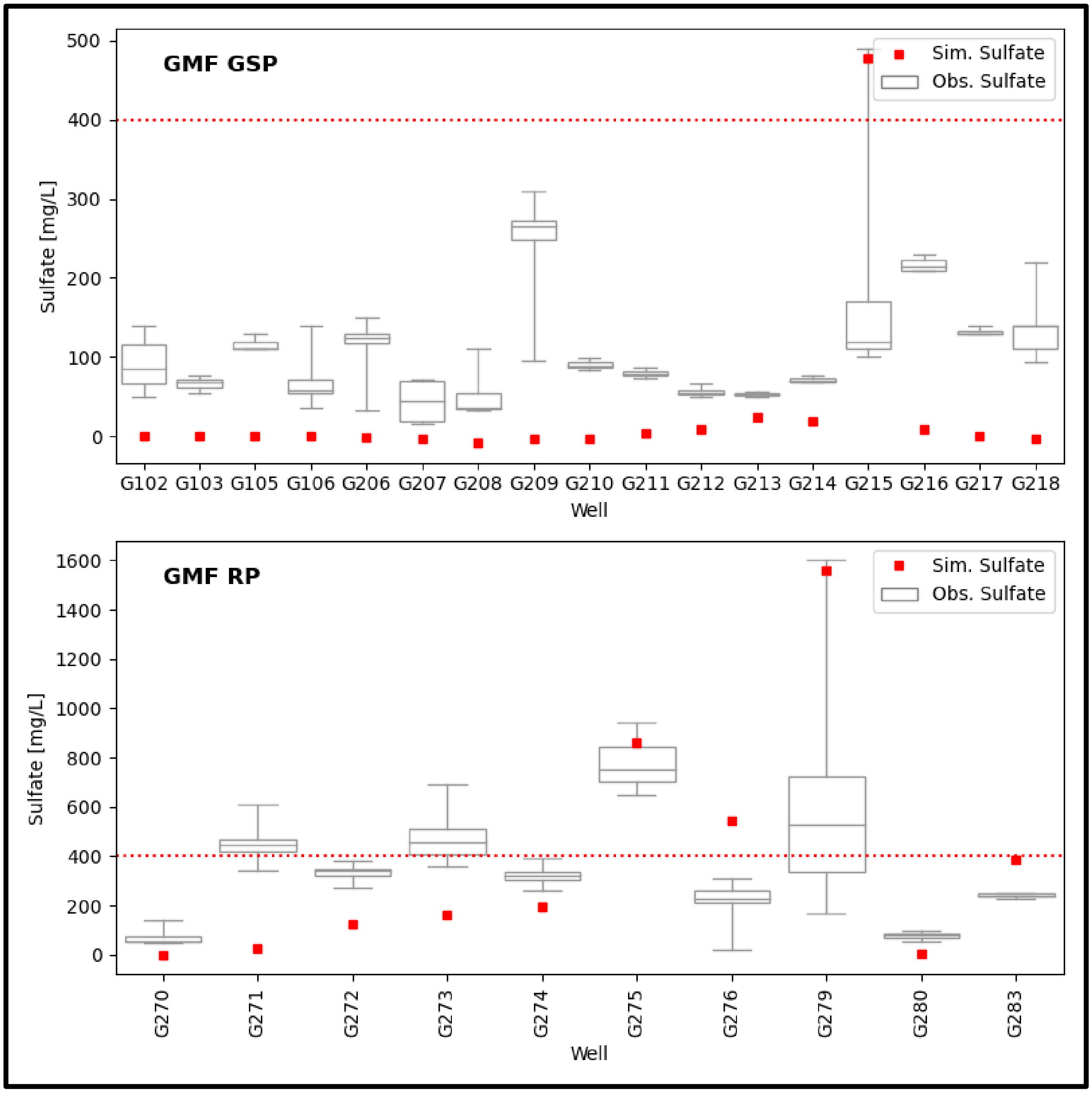
RAMBOLL



SIMULATED STEADY STATE GROUNDWATER LEVEL CONTOURS IN PROXIMITY TO THE GMF GSP AND GMF RP FROM UA (LAYER 3) FROM THE CALIBRATED MODEL

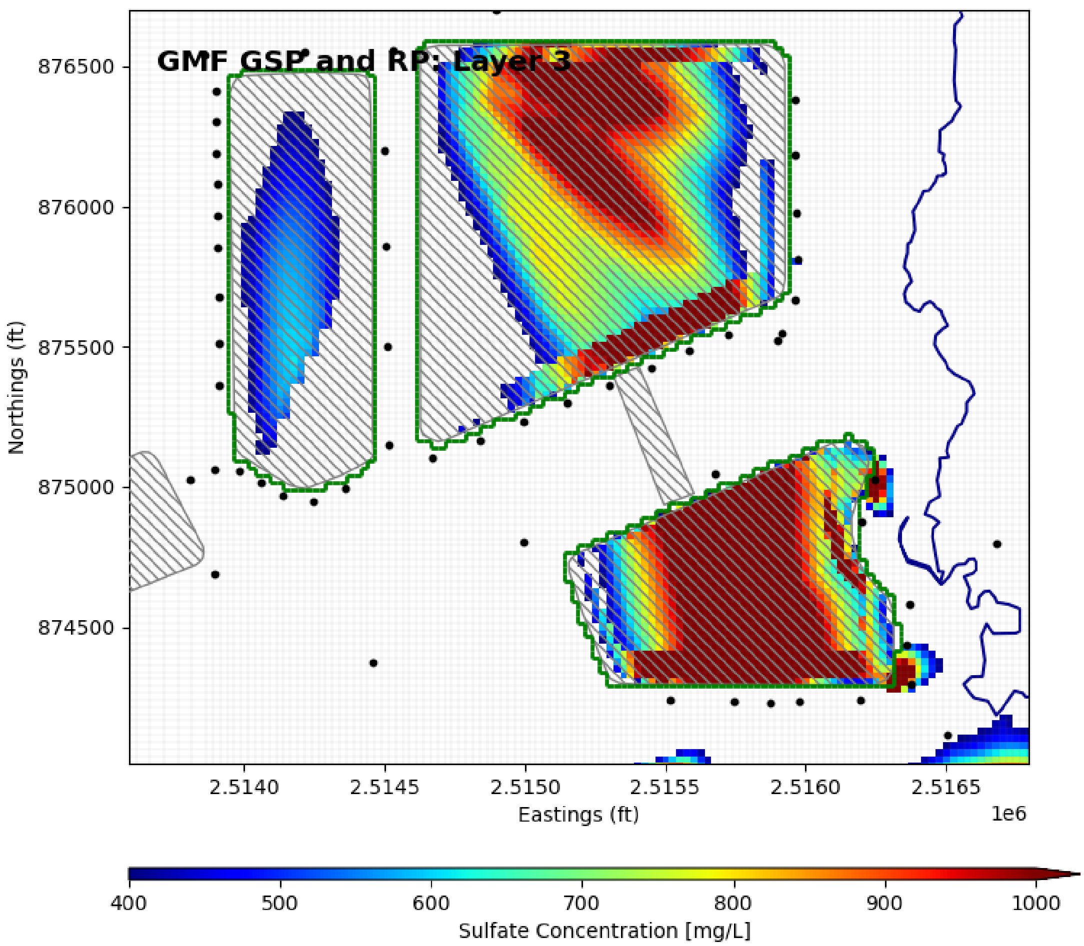
GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS

RAMBOLL



OBSERVED AND SIMULATED SULFATE CONCENTRATIONS FOR THE GMF GSP AND GMF RP [mg/L]

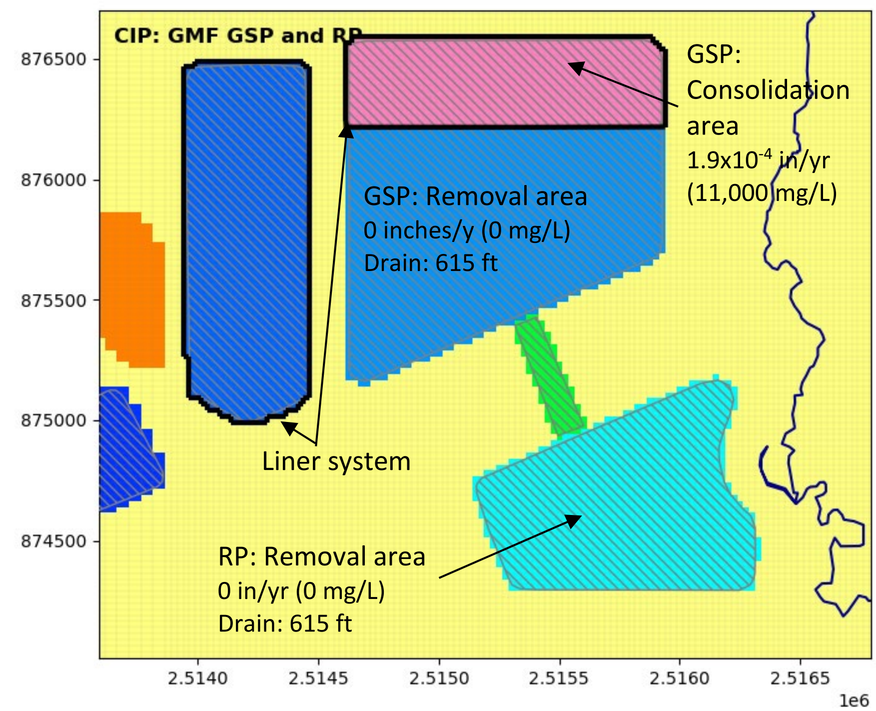
GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS



SIMULATED SULFATE PLUME IN THE UA FROM THE TRANSIENT MODEL

GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS

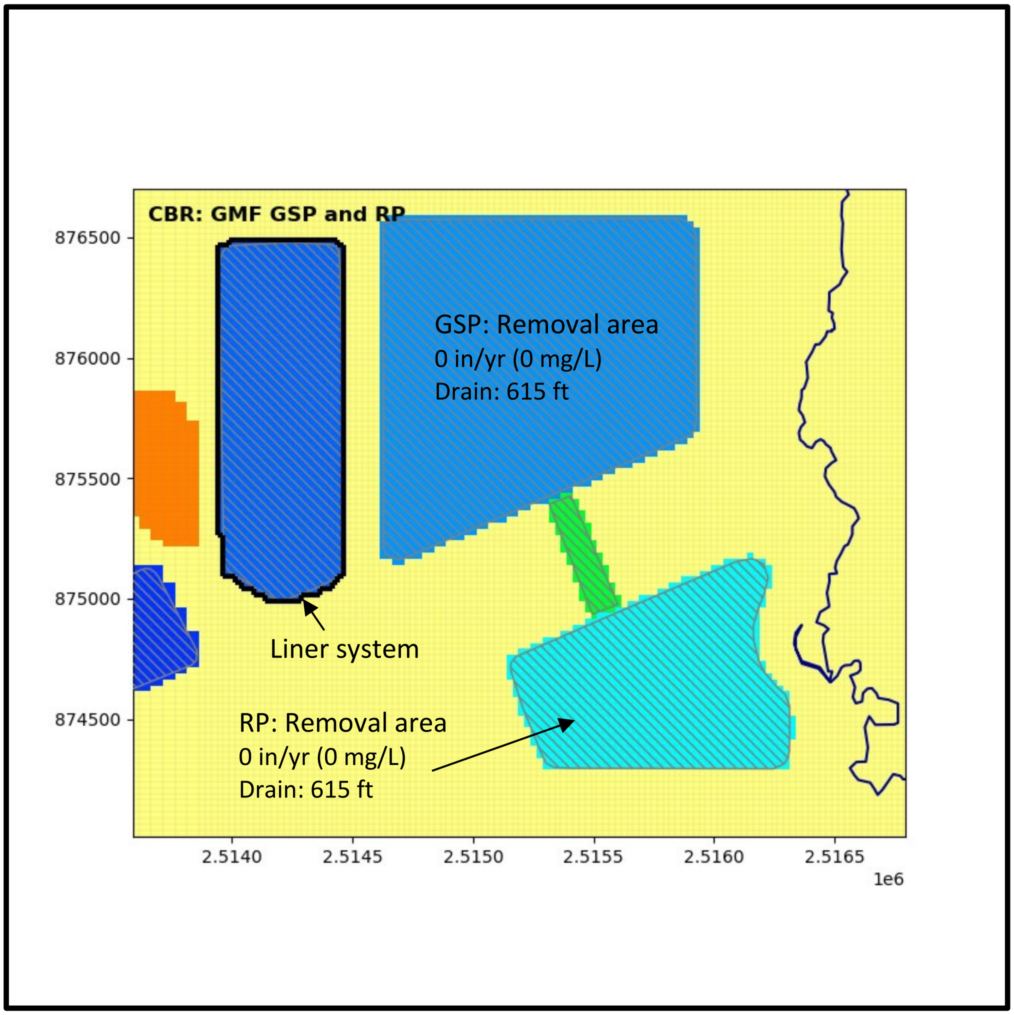
RAMBOLL



CIP RECHARGE AND STORMWATER POND MODIFICATIONS

GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS

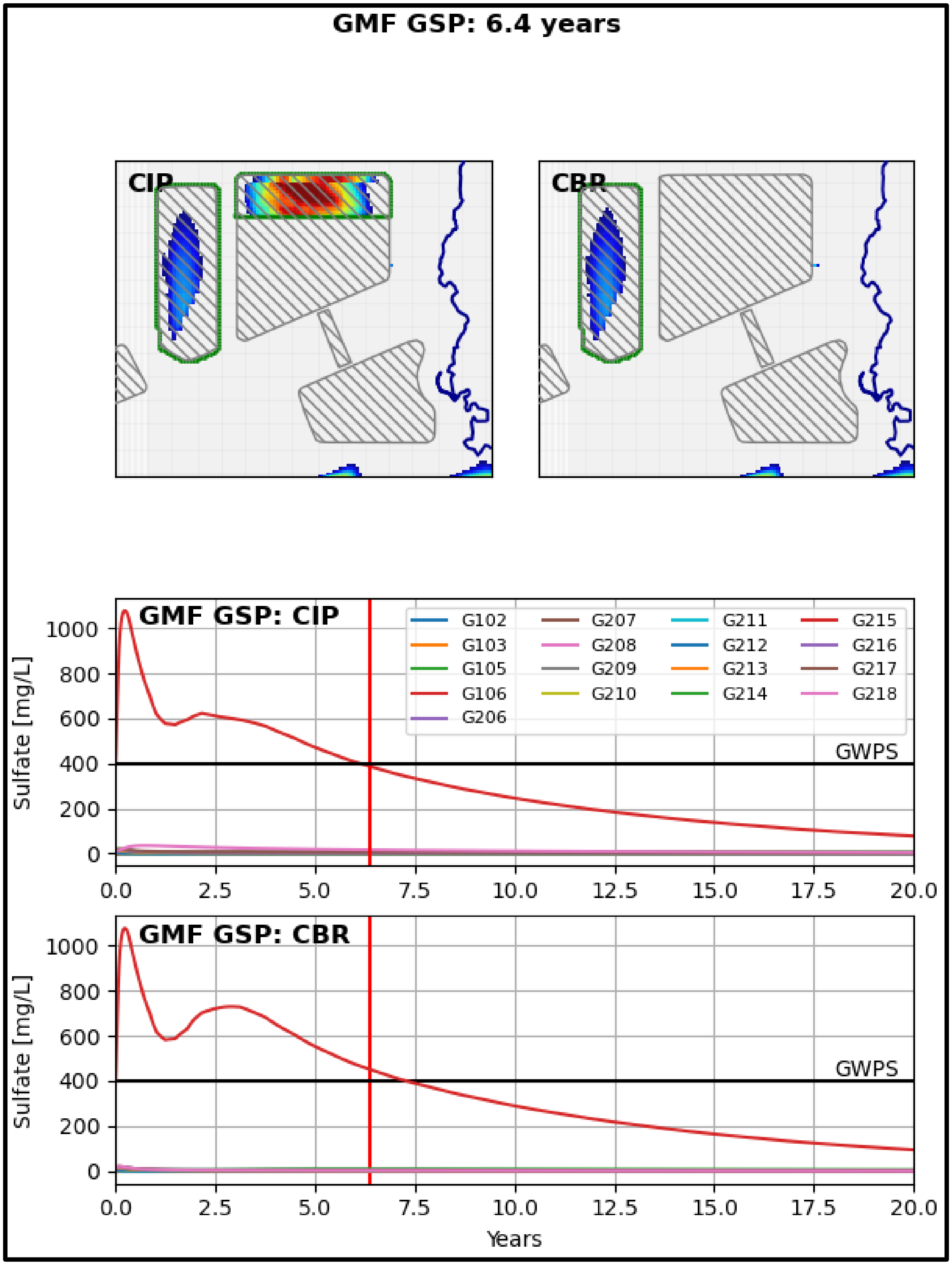
RAMBOLL



CBR RECHARGE AND STORMWATER POND MODIFICATIONS

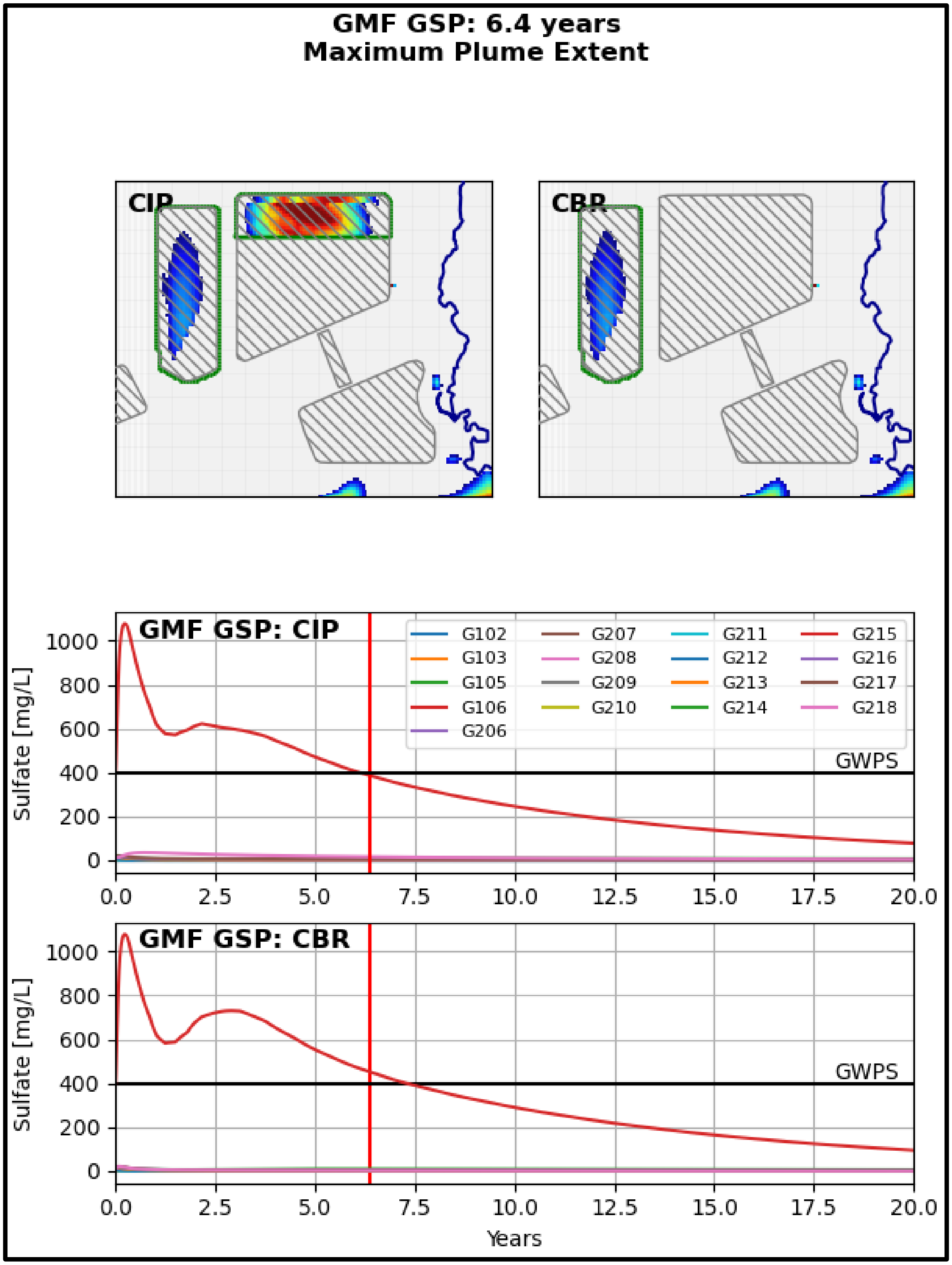
GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS

RAMBOLL



SIMULATED SULFATE PLUME OF THE UA FOR THE CIP AND CBR SCENARIOS AT GMF GSP AFTER 6.4 YEARS

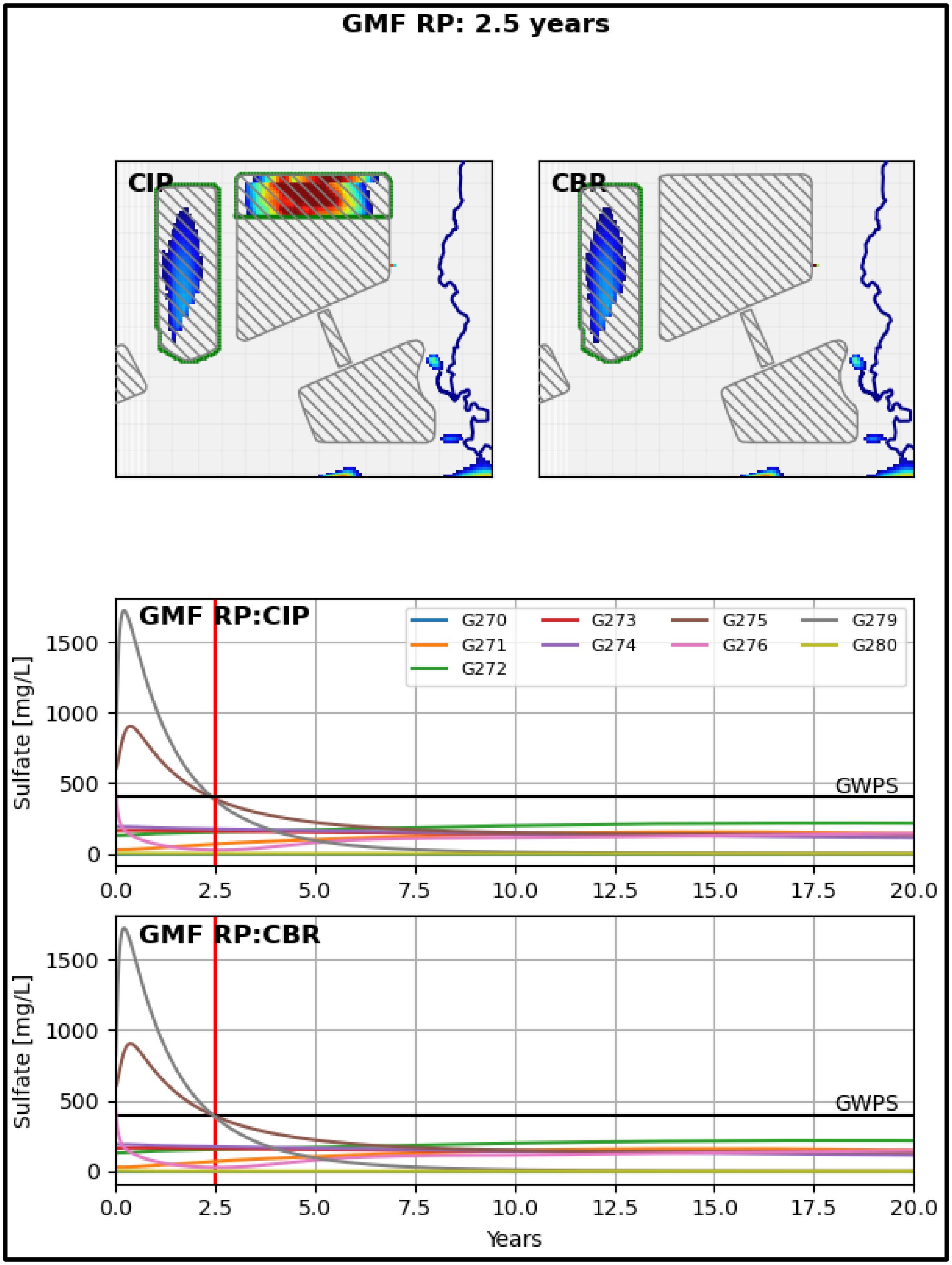
GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS



SIMULATED MAXIMUM EXTENT SULFATE PLUME FOR THE CIP AND CBR SCENARIOS AT GMF GSP AFTER 6.4 YEARS

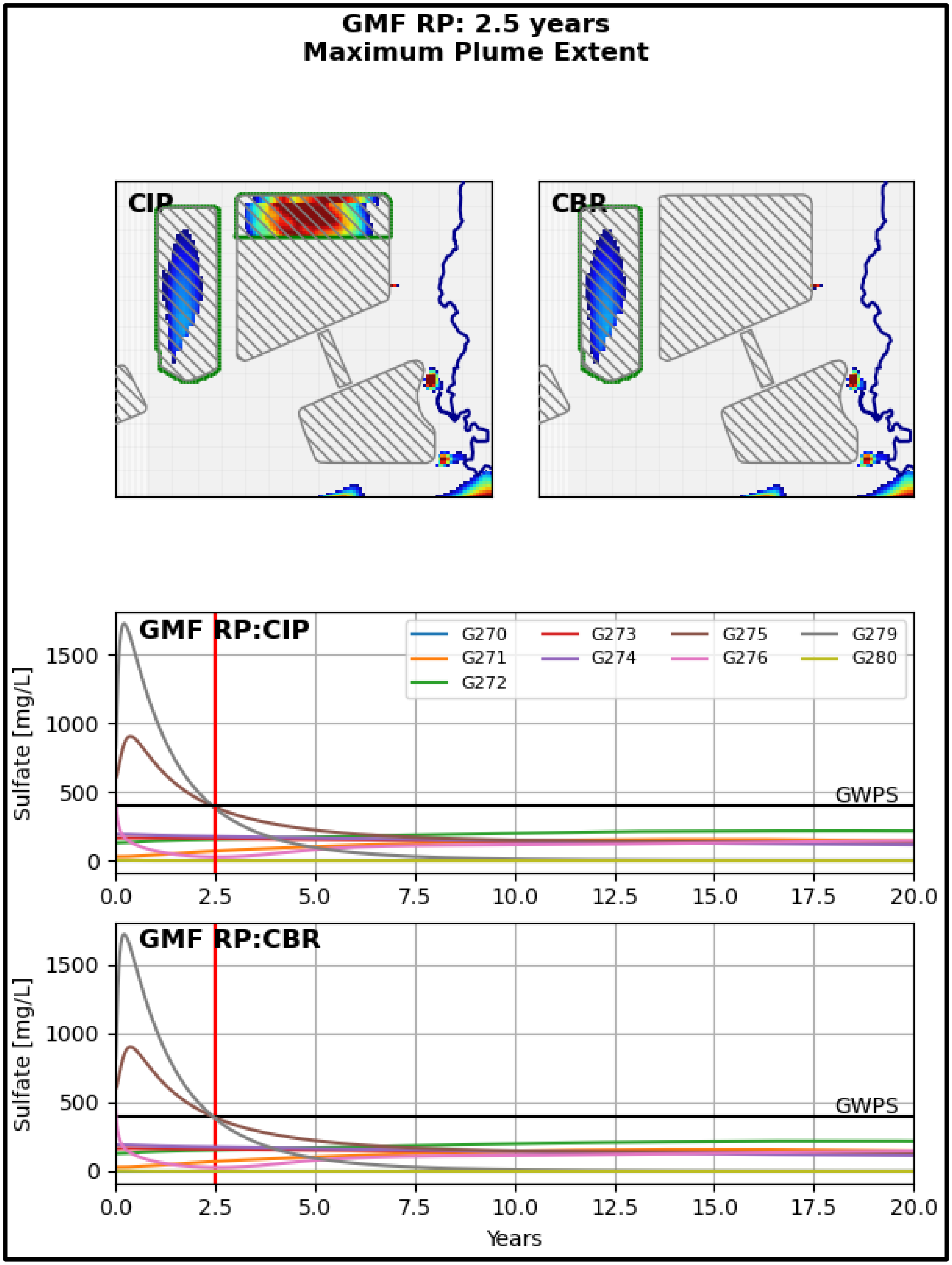
GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS

RAMBOLL



SIMULATED SULFATE PLUME OF THE UA FOR THE CIP AND CBR SCENARIOS AT GMF RP AFTER 2.5 YEARS

GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS



SIMULATED MAXIMUM EXTENT SULFATE PLUME FOR THE CIP AND CBR SCENARIOS AT GMF RP AFTER 2.5 YEARS

GROUNDWATER MODELING REPORT
GMF GYPSUM STACK POND AND GMF RECYCLE POND
COFFEEN POWER PLANT
COFFEEN, ILLINOIS

RAMBOLL

APPENDICES

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

APPENDIX B
EVALUATION OF PARTITION COEFFICIENT RESULTS (GEOSYNTEC CONSULTANTS, INC., 2022)

Geosyntec consultants

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Chesterfield, MO 63005
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Memorandum

Date:	May 11, 2022
To:	David Mitchell, Stu Cravens, Vic Modeer Illinois Power Generating Company
Copies to:	Brian Hennings - Ramboll
From:	Allison Kreinberg, Ryan Fimmen – Geosyntec Consultants, Inc.
Subject:	Draft Evaluation of Partition Coefficient Results – Coffeen GMF Recycle Pond CCR Unit 104, Coffeen Power Plant, Coffeen, Illinois

INTRODUCTION

The Illinois Power Generation Company (IPGC) currently operates the Coffeen Power Plant (CPP) in Coffeen, Illinois. The coal combustion residuals (CCR) Unit referred to as the Gypsum Management Facility (GMP) Recycle Pond (RP) (Vistra identification [ID] number [No.] 104; Illinois Environmental Protection Agency [IEPA] ID No. W1350150004-04; National Inventory of Dams [NID] No. IL50578) is a 17-acre pond that receives blowdown from the air emission scrubber. The pond was in operation starting in 2010 until April 11, 2021, when IPGC ceased receipt of waste to the GMF RP. Geosyntec Consultants (Geosyntec) is assisting IPGC with Part 845 compliance at the Site.

IPGC is currently preparing a Construction Permit application for the GMF RP as required under Section 845.220. As part of the Construction Permit application, groundwater modeling is being completed for known potential exceedances of groundwater protection standards (GWPS) as outlined in the Operating Permit (Burns & McDonnell, 2021). In the Operating Permit (October 2021), Burns & McDonnell identified potential GWPS exceedances for several compounds potentially associated with the GMF RP, including boron, sulfate, and total dissolved solids (TDS). Batch adsorption testing was conducted for boron and sulfate to generate site-specific partition coefficients. This technical memorandum summarizes the results of the batch adsorption testing and calculation of partition coefficients.

BATCH ATTENUATION TESTING

In 2021 Geosyntec conducted a field investigation at the GMF RP which included completion of two (2) soil/rock borings ranging in depth from 18 to 28 feet below ground surface. As part of that investigation, soil and groundwater samples were submitted to SiREM Laboratories (Guelph, ON) for batch solid/liquid partitioning testing. A summary of the soil samples used for the batch testing is provided in **Table 1**.

One groundwater sample (G215) and one soil sample (SB-215) were used for batch attenuation testing at five (5) soil:solution ratios (**Table 1**), each ran in duplicate. For each treatment, 0.1 L of groundwater was brought into contact with varying amounts of soil (0.004 to 0.2 kg, depending on the ratio) and equilibrated over a seven-day period. One set of microcosms was amended (i.e., spiked) with sodium sulfate (Na_2SO_4) and another with boric acid (H_3BO_3) to achieve target concentrations of sulfate and boron, respectively (**Table 2**).

An initial sample of the stock solution for each experimental design was collected on Day 0, and a control sample (i.e., only amended G215 groundwater with no aquifer solids) was collected on Day 7 after tumbling in polypropylene bottleware to evaluate any loss to interactions with the bottleware or ambient conditions. Duplicates were constructed for each microcosm, including the control samples. After seven days of contact time, an aliquot of the free liquid was collected and filtered through a 0.45 micron (µm) filter prior to analysis for dissolved concentrations of sulfate and/or boron. The oxidation/reduction potential (redox) and pH were measured for each batch test at the beginning and end of the contact period and in the control samples.

Data obtained from the tests (**Tables 3** and **4**) were used to construct isotherms for boron and sulfate; 5-point isotherms were constructed by averaging duplicate results for each soil:solution ratio. Mathematical fitting was used to calculate the partition coefficients (K_d), assuming linear adsorption. The linear adsorption equation was used:

$$q_e = K_d \times C_e \quad \text{Eq. 1}$$

where q_e is the mass of constituent adsorbed to the solid phase at equilibrium, C_e is the remaining aqueous constituent concentration at equilibrium, and K_d is the linear sorption coefficient (reported in liters per kilogram [L/kg]). Some of the data showed a deviation from a linear trend, and so were also fitted using non-linear isotherms. The non-linear Langmuir isotherm was used:

$$q_e = \frac{q_m K_L C_e}{1 + K_L C_e} \quad \text{Eq. 2}$$

where q_m is the inverse of the slope and K_L is the Langmuir partition coefficient. The adsorption data were linearized according to:

$$\frac{C_e}{q_e} = \frac{1}{(K_L \times q_m)} + \frac{C_e}{q_m} \qquad \text{Eq. 3}$$

A common non-linear Freundlich equation was also used:

$$q_e = K_F (C_e)^{1/n} \qquad \text{Eq. 4}$$

where q_e is the mass of constituent adsorbed to the solid phase at equilibrium, C_e is the remaining aqueous constituent concentration at equilibrium, K_F is the Freundlich partition coefficient, and *1/n* is a non-linearity constant. The adsorption data were plotted as log-transformed values to perform the non-linear isotherm fitting using the linearized Freundlich equation:

$$log(q_e) = \log(K_F) + (1/n)\log(C_e) \qquad \text{Eq. 5}$$

The calculated linear, Langmuir, and Freundlich partition coefficients (K_d, K_L, and K_F, respectively) and 1/*n* values are shown in **Table 5**.

SUMMARY OF RESULTS

The partition coefficient values for each amendment (denoted as G215-SO_4 when amended with sodium sulfate and G215-B when amended with boric acid) are presented in **Table 5**. Figures which show the linear, Langmuir, and Freundlich isotherms for boron and sulfate are provided in **Appendix A**. Measurements of soil boron concentrations in SB-215 are pending; a surrogate value of 0 mg/kg was used, consistent with soil boron concentrations from other areas at the CPP.

A boron partition coefficient was not determined for any isotherm for the boron amended microcosms. Both the linear and linearized Langmuir isotherms yielded negative partition coefficients, and the linearized Freundlich could not be calculated as the data were not conducive to log transformation. Other studies have reported low partition coefficients for boron ranging from 0.19 to 1.3 L/kg, depending on pH conditions and the amount of sorbent present (EPRI, 2005; Strenge & Peterson, 1989).

A sulfate partition coefficient was not determined for any isotherm for the sulfate amended microcosms. The linear isotherm yielded a partition coefficient of 0.1 L/kg but had a very poor goodness-of-fit, and the Langmuir isotherm yielded a negative coefficient. As in the boron-amended microcosms, the Freundlich isotherm could not be calculated because the data were not conducive to log transformation These results are consistent with the findings of Strenge and Peterson (1989), who found that partition coefficients for sulfate are 0.0 L/kg, regardless of pH conditions and the amount of sorbent present.

REFERENCES

EPRI, 2005. *Chemical constituents in coal combustion product leachate: boron. Final Report 1005258.*

Burns & McDonnell. 2021. Initial Operating Permit Coffeen GMF Recycle Pond. October

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

TABLES

Table 1 - Batch Attenuation Testing Data Summary
Coffeen GMF RP

Groundwater Sample ID	Soil Sample ID	Soil: Water Ratio
G215	SB-215 (19-24.5 ft bgs) Sodium Sulfate Amendment	2:1.5
		1:1.3
		1:5.8
		1:11.5
		1:27.2
G215	SB-215 (19-24.5 ft bgs) Boric Acid Amendment	2:1.5
		1:1.3
		1:5.8
		1:11.5
		1:28.1

Notes:

ft bgs = feet below ground surface

Table 2 - Microcosm Amendment and Target Concentrations
Coffeen GMF RP

Groundwater Sample ID	Soil Sample ID	Compound	Amendment	Target Concentration (mg/L)
G215	SB-215 (19-24.5 ft bgs)	Boron	31.93 mL of a 2 g/L H_3BO_3	6
		Sulfate	3.41 g of Na_2SO_4	1500

Notes:
ft bgs - feet below ground surface
mg/L - milligrams per liter
Na_2SO_4 - sodium sulfate
H_3BO_3 - boric acid

Table 3 - Batch Attenuation Testing Results
Coffeen GMF RP - Sodium Sulfate Amendment

Groundwater Sample ID	Geologic Material Sample ID	Treatment	Date	Day	Replicate	Dissolved Sulfate	pH	ORP
						mg/L	SU	mV
G215	--	Groundwater Only Control	25-Jan-22	0	G215-1a (SO_4^{2-})	1,589	6.98	83
					G215-2a (SO_4^{2-})	1,826	6.99	79
					Average Concentration (mg/L)	**1,708**	**6.99**	**81**
			7-Feb-22	7	G215-1 (SO_4^{2-})	1,617	6.8	26
					G215-2 (SO_4^{2-})	1,478	6.81	13
					Average Concentration (mg/L)	**1,548**	**6.81**	**20**
	G215 SB-215 Geologic Material	2:1 Soil:Water Ratio	31-Jan-22	0				
			7-Feb-22	7	SB-215-(19-24.5) :G215 2:1-1 (SO_4^{2-})	1,321	6.92	57
					SB-215-(19-24.5) :G215 2:1-2 (SO_4^{2-})	1,302	6.94	103
					Average Concentration (mg/L)	**1,311**	**6.93**	**80**
		1:1 Soil:Water Ratio	31-Jan-22	0				
			7-Feb-22	7	SB-215-(19-24.5) :G215 1:1-1 (SO_4^{2-})	1,727	6.89	85
					SB-215-(19-24.5) :G215 1:1-2 (SO_4^{2-})	860	6.91	91
					Average Concentration (mg/L)	**1,294**	**6.90**	**88**
		1:5 Soil:Water Ratio	31-Jan-22	0				
			7-Feb-22	7	SB-215-(19-24.5) :G215 1:5-1 (SO_4^{2-})	1,326	6.92	29
					SB-215-(19-24.5) :G215 1:5-2 (SO_4^{2-})	1,516	6.87	15
					Average Concentration (mg/L)	**1,421**	**6.90**	**22**
		1:10 Soil:Water Ratio	31-Jan-22	0				
			7-Feb-22	7	SB-215-(19-24.5) :G215 1:10-1 (SO_4^{2-})	1,570	6.87	23
					SB-215-(19-24.5) :G215 1:10-2 (SO_4^{2-})	1,551	6.85	30
					Average Concentration (mg/L)	**1,560**	**6.86**	**27**
		1:20 Soil:Water Ratio	31-Jan-22	0				
			7-Feb-22	7	SB-215-(19-24.5) :G215 1:20-1 (SO_4^{2-})	1,511	6.83	32
					SB-215-(19-24.5) :G215 1:20-2 (SO_4^{2-})	1,588	6.84	79
					Average Concentration (mg/L)	**1,550**	**6.84**	**56**

Notes:
mg/L - milligrams per liter
mV - millivolts
SU - Standard Units
ORP - oxidation/reduction potential

Table 4 - Batch Attenuation Testing Results
Coffeen GMF RP - Boric Acid Amendment

Groundwater Sample ID	Geologic Material Sample ID	Treatment	Date	Day	Replicate	Dissolved Boron	pH	ORP
						mg/L	SU	mV
G215	--	Groundwater Only Control	25-Jan-22	0	G215-1a (B)	4.6	6.88	90
					G215-2a (B)	4.7	6.85	72
					Average Concentration (mg/L)	**4.7**	**6.87**	**81**
			7-Feb-22	7	G215-1 (B)	5.3	6.9	57
					G215-2 (B)	5.4	7.03	13
					Average Concentration (mg/L)	**5.4**	**6.97**	**35**
	G215 SB-215 Geologic Material	2:1 Soil:Water Ratio	31-Jan-22	0				
			7-Feb-22	7	SB-215-(19-24.5) :G215 2:1-1 (B)	3.4	6.91	9
					SB-215-(19-24.5) :G215 2:1-2 (B)	3.4	7.05	11
					Average Concentration (mg/L)	**3.4**	**6.98**	**10**
		1:1 Soil:Water Ratio	31-Jan-22	0				
			7-Feb-22	7	SB-215-(19-24.5) :G215 1:1-1 (B)	4.3	6.98	15
					SB-215-(19-24.5) :G215 1:1-2 (B)	4.3	7.06	31
					Average Concentration (mg/L)	**4.3**	**7.02**	**23**
		1:5 Soil:Water Ratio	31-Jan-22	0				
			7-Feb-22	7	SB-215-(19-24.5) :G215 1:5-1 (B)	5.0	6.96	49
					SB-215-(19-24.5) :G215 1:5-2 (B)	5.2	7.00	19
					Average Concentration (mg/L)	**5.1**	**6.98**	**34**
		1:10 Soil:Water Ratio	31-Jan-22	0				
			7-Feb-22	7	SB-215-(19-24.5) :G215 1:10-1 (B)	5.5	6.95	20
					SB-215-(19-24.5) :G215 1:10-2 (B)	5.3	6.95	29
					Average Concentration (mg/L)	**5.4**	**6.95**	**25**
		1:20 Soil:Water Ratio	31-Jan-22	0				
			7-Feb-22	7	SB-215-(19-24.5) :G215 1:20-1 (B)	5.6	6.93	174
					SB-215-(19-24.5) :G215 1:20-2 (B)	5.5	6.84	102
					Average Concentration (mg/L)	**5.5**	**6.89**	**138**

Notes:
mg/L - milligrams per liter
mV - millivolts
SU - Standard Units
ORP - oxidation/reduction potential

Table 5 - Partition Coefficient Results
Coffeen GMF RP

Analyte	Amendment	Isotherm	Variable	Value
Boron	Boric Acid	Linear	R^2	0.518
			K_D (L/kg)	-8.45
		Langmuir	R^2	0.47
			q_m (mg/g)	0.000
			K_L (L/kg)	-1.87E+05
		Freundlich	R^2	--
			1/n	--
			K_F (L/kg)	--
Sulfate	Sodium Sulfate	Linear	R^2	0.0
			K_D (L/kg)	0.10
		Langmuir	R^2	0.66
			q_m (mg/g)	-0.028
			K_L (L/kg)	-8.94E+02
		Freundlich	R^2	--
			1/n	--
			K_F (L/kg)	--

Notes:

The Freundlich isotherm was not calculated for boron or sulfate because the data were not conducive to log transformation

K_D - linear partition coefficient

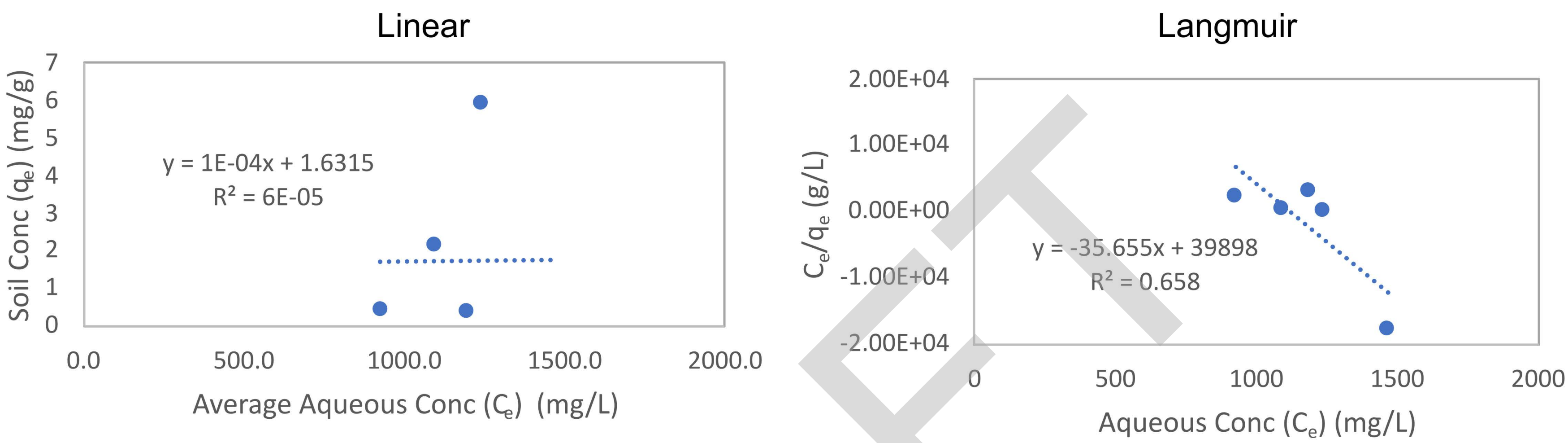
K_L - Langmuir partition coefficient

K_F - Freundlich partition coefficient

q_m - inverse of the slope of the linearized Langmuir isotherm

n - non-linearity constant of the Freundlich isotherm

APPENDIX A
BATCH TESTING ISOTHERM PLOTS



Notes:

The Freundlich isotherm was not calculated because the data were not conducive to log transformation.

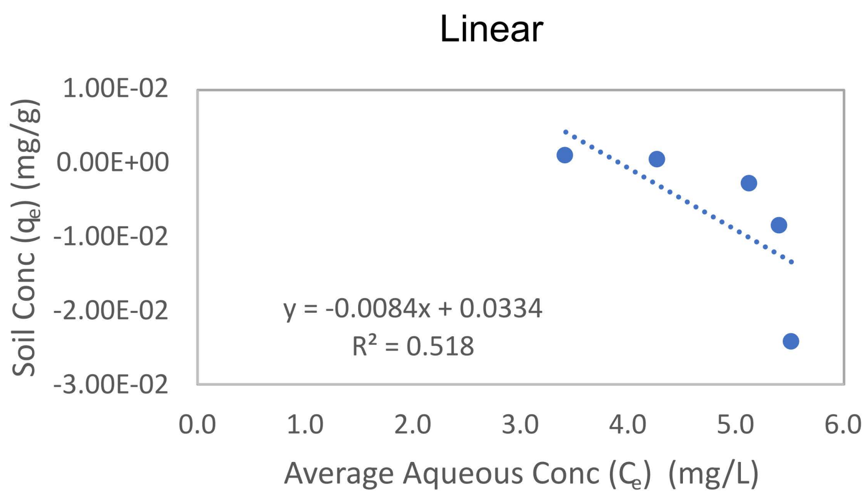
q_e - mass of constituent adsorbed to the solid phase
C_e - remaining aqueous constituent concentration
mg/L - milligrams per liter
mg/g - milligrams per gram
g/L - grams per liter

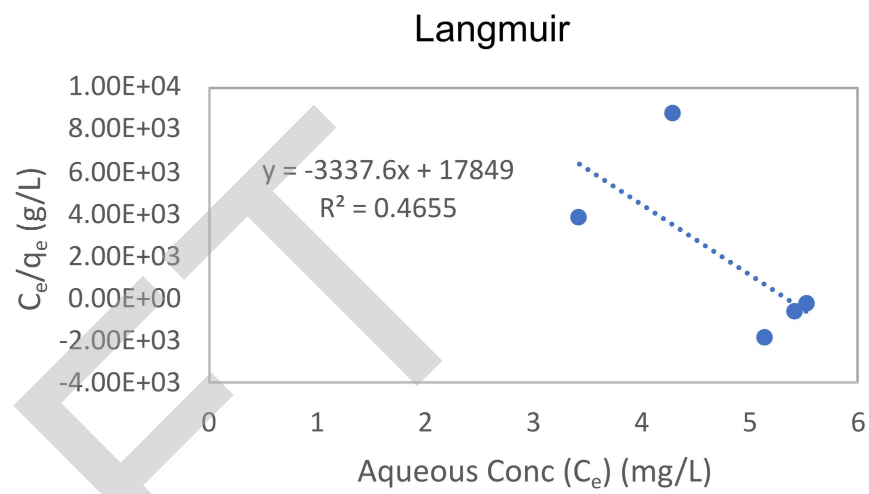
G215-SO_4 Sulfate Partitioning Coefficients
Coffeen Power Plant GMF RP
Coffeen, Illinois

Geosyntec consultants

Figure 1

Columbus, OH | May 2022





Notes:

The Freundlich isotherm was not calculated because the data were not conducive to log transformation.

q_e - mass of constituent adsorbed to the solid phase
C_e - remaining aqueous constituent concentration
mg/L - milligrams per liter
mg/g - milligrams per gram
g/L - grams per liter

G215-B Boron Partitioning Coefficients
Coffeen Power Plant GMF RP
Coffeen, Illinois

Geosyntec consultants

Columbus, OH | May 2022

Figure 2