Luminant

Kincaid Generation, LLC
1500 Eastport Plaza Dr.
Collinsville, IL 62234

July 28, 2022

Illinois Environmental Protection Agency
DWPC – Permits MC #15
Attn: Part 845 Coal Combustion Residual Rule Submittal
1021 North Grand Avenue East
P.O. Box 19276
Springfield, IL 62794-9276

Re: Kincaid Power Plant Ash Pond; IEPA ID # W0218140002-01

Dear Mr. LeCrone:

In accordance with 35 I.A.C. § 845.200, Kincaid Generation, LLC is submitting a construction permit application for the Kincaid Power Plant Ash Pond (IEPA ID # W0218140002-01). One hardcopy is provided with this submittal.

The permit application was prepared in accordance with 35 I.A.C. § 845.220 (a) and (d). This submittal includes the completed permit forms as required by § 845.210.

Sincerely,

Cynthia Vodopivec
SVP-Environmental Health and Safety

Enclosures

Form CCR 1

Illinois Environmental Protection Agency

CCR Surface Impoundment Permit Application

Form CCR 1 – General Provisions

Bureau of Water ID Number:
W0218140002
CCR Permit Number:
N/A
Facility Name:
Kincaid Power Plant

For IEPA Use Only

SECTION 1: FACILITY, OPERATOR, AND OWNER INFORMATION (35 Ill. Adm. Code 845.210(b))

Facility, Operator, and Owner Information

1.1	Facility Name		
	Kincaid Generation, LLC - Kincaid Power Plant		
1.2	Illinois EPA CCR Permit Number (if applicable)		
	Initial Permit		
1.3	Facility Contact Information		
	Name (first and last) Phil Morris	Title Senior Director - Environmental	Phone Number 618-343-7794
	Email address phil.morris@vistracorp.com		
1.4	Facility Mailing Address		
	Street or P.O. box 1500 Eastport Plaza Dr		
	City or town Collinsville	State IL	Zip Code 62234
1.5	Facility Location		
	Street, route number, or other specific identifier 4 miles west of Kincaid on IL RT 104		
	County name Christian	County code (if known)	
	City or town Kincaid	State IL	Zip Code 62540
1.6	Name of Owner/Operator		
	Kincaid Generation, LLC		

Facility, Operator, and Owner Info				
1.7	Owner/Operator Contact Information			
	Name (first and last) Phil Morris	Title Senior Director - Environmental	Phone Number 618-343-7794	
	Email address phil.morris@vistracorp.com			
1.8	Owner/Operator Mailing Address			
	Street or P.O. box 1500 Eastport Plaza Dr			
	City or town Collinsville	State IL	Zip Code 62234	

SECTION 2: LEGAL DESCRIPTION (35 Ill. Adm. Code 845.210(c))

Legal Description	
2.1	Legal Description of the facility boundary
	See Attachment A.

SECTION 3: PUBLICLY ACCESSIBLE INTERNET SITE REQUIREMENTS (35 Ill. Adm. Code 845.810)

Internet Site				
3.1	Web Address(es) to publicly accessible internet site(s) (CCR website)			
	www.luminant.com/ccr			
3.2	Is/are the website(s) titled "Illinois CCR Rule Compliance Data and Information"			
	☑	Yes	☐	No

SECTION 4: IMPOUNDMENT IDENTIFICATION

Impoundment Identification			
4.1	List all the impoundment identification numbers for your facility and check the corresponding box to indicate that you have attached a written description for each impoundment.		
	W0218140002-01 (see Attachment A)	☑	Attached written description
		☐	Attached written description
		☐	Attached written description
		☐	Attached written description
		☐	Attached written description
		☐	Attached written description

☐	Attached written description
☐	Attached written description
☐	Attached written description
☐	Attached written description

SECTION 5: CHECKLIST AND CERTIFICATION STATEMENT

Checklist and Certification Statement

5.1 In Column 1 below, mark the sections of Form 1 that you have completed and are submitting with your application. For each section, specify in Column 2 any attachments that you are enclosing.

Column 1		Column 2	
Section 1: Facility, Operator, and Owner Information	☑	w/attachments	☐
Section 2: Legal Description	☑	w/attachments	☑
Section 3: Publicly Accessible Internet Site Requirement	☑	w/attachments	☐
Section 4: Impoundment Identification	☑	w/attachments	☑

5.2 **Certification Statement**

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Name (print or type first and last name) of Owner/Operator	Official Title
Cynthia Vodopivec	SVP - Environmental
Signature	**Date Signed**
Cynthia E Vodopivec	7-18-2022

Form 2CC	Illinois Environmental Protection Agency CCR Surface Impoundment Permit Application Form CCR 2CC – Closure Construction

Bureau of Water ID Number: W0218140002 **CCR Permit Number:** N/A **Facility Name:** Kincaid Power Plant	For IEPA Use Only

SECTION 1: DESIGN AND CONSTRUCTION PLANS (35 Ill. Adm. Code 845.220)

Design and Construction Plans (Construction History)

1.1	CCR surface impoundment name.	Ash Pond
1.2	Identification number of the CCR surface impoundment (if one has been assigned by the Agency).	N/A
1.3	Describe the boundaries of the CCR surface impoundment (35 Ill. Adm. Code 845.210 (c)).	Attachment A
1.4	State the purpose for which the CCR surface impoundment is being used.	Attachment C
1.5	How long has the CCR surface impoundment been in operation?	Attachment C
1.6	List the types of CCR that have been placed in the CCR surface impoundment.	Attachment D

Design and Construction Plans (Continued)

1.7	List the name of the watershed within which the CCR surface impoundment is located.
	Attachment F
1.8	What is the size in acres of the watershed within which the CCR surface impoundment is located?
	Attachment C
1.9	Check the corresponding boxes to indicate that you have attached the following:
	☑ A description of the physical and engineering properties of the foundation and abutment materials on which the CCR surface impoundment is constructed.
	☑ A statement of the type, size, range, and physical and engineering properties of the materials used in constructing each zone or stage of the CCR surface impoundment.
	☑ A statement of the method of site preparation and construction of each zone of the CCR surface impoundment.
	☑ A statement of the approximate dates of construction of each successive stage of construction of the CCR surface impoundment.
	☑ Drawings satisfying the requirements of 35 Ill. Adm. Code 845.220(a)(1)(F).
	☑ A description of the type, purpose, and location of existing instrumentation.
	☑ Area capacity curves for the CCR impoundment.
	☑ A description of each spillway and diversion design features and capacities and provide the calculations used in their determination.
	☑ The construction specifications and provisions for surveillance, maintenance, and repair of the CCR surface impoundment.
1.10.1	Is there any record or knowledge of structural instability of the CCR surface impoundment?
	☐ Yes ☑ No
1.10.2	If you answered yes to Item 1.10.1, provide detailed explanation of the structural instability.

SECTION 2: NARRATIVE DESCRIPTION OF THE FACILITY (35 Ill. Adm. Code 845.220)					
Narrative Description	2.1	List the types of CCR expected in the CCR surface impoundments.			
		Attachment D			
	2.2	Have you attached a chemical analysis of each type of expected CCR?			
		☑	Yes		
	2.3	Estimate of the maximum capacity of the surface impoundment in gallons or cubic yards.			
		Attachment C			
	2.4	The rate at which CCR and non-CCR waste streams currently enter the CCR impoundment in gallons per day and dry tons.			
		Attachment C	GPD	Attachment C	dTn
	2.5	Estimate length of time the CCR surface impoundment will receive CCR and non-CCR waste streams.			
		Attachment C			
	2.6	Have you attached an on-site transportation plan that includes all existing and planned roads in the facility that will be used during the operation of the CCR surface impoundment?			
		☑	Yes		

SECTION 3: MAPS (35 Ill. Adm. Code 845.220)			
Maps	3.1	Check the corresponding boxes to indicate that you have attached the following maps:	
		☑	A site location map on the most recent United Sates Geological Survey (USGS) quadrangle of the area from the 7 ½ minute series (topographic) or on another map whose scale clearly shows the information required in 35 Ill. Adm. Code 845.220(a)(3).
		☑	Site plans maps satisfying the requirements of 35 Ill. Adm. Code 845.220(a)(4).

SECTION 4: ATTACHMENTS			
Attachments	4.1	Check the corresponding boxes to indicate that you have attached the following:	
		☑	A narrative description of the proposed construction of, or modification to, a CCR surface impoundment and any projected changes in the volume or nature of the CCR or non-CCR waste streams.
		☑	Plans and specifications fully describing the design, nature, function, and interrelationship of each individual component of the facility.
		☑	The signature and seal of a qualified professional engineer.
		☑	Certification that the owner or operator of the CCR surface impoundment completed the public notification and public meetings required under 35 Ill. Adm. Code 845.240.

Attachments (Continued)		✓	A summary of the issues raised by the public during the public notification and public meetings.
		✓	A summary of any revisions, determinations, or other considerations made in response to those issues raised by the public during the public notification and public meetings.
		✓	A list of interested persons in attendance who would like to be added to the Agency's listserv for the facility.
		✓	Certification that all contractors, subcontractors, and installers utilized to construct, install, modify, or close a CCR surface impoundment are participants in a training program that is approved by and registered with the U.S. Department of Labor's Employment and Training Administration and that includes instruction in erosion control and environmental remediation.
		✓	Certification that all contractors, subcontractors, and installers utilized to construct, install, modify, or close a CCR surface impoundment are participants in a training program that is approved by and registered with the U.S. Department of Labor's Employment and Training Administration and that includes instruction in the operation of heavy equipment and excavation.
SECTION 5: GROUNDWATER MONITORING PROGRAM			
Groundwater Monitoring	5.1	Indicate that you have attached the following components of a new groundwater monitoring program or any modifications to an existing groundwater monitoring program by checking the corresponding boxes:	
		✓	A hydrogeologic site investigation meeting the requirements of 35 Ill. Adm. Code 845.620, if applicable.
		✓	Design and construction plans of a groundwater monitoring system meeting the requirements of 35 Ill. Adm. Code 845.630.
		✓	A proposed groundwater sampling and analysis program that includes selection of the statistical procedures to be used for evaluating groundwater monitoring data as required by 35 Ill. Adm. Code 845.640 and 845.650.
SECTION 6: CLOSURE (35 Ill. Adm. Code 845.220(d))			
Closure	6.1	What is the closure prioritization category under 35 Ill. Adm. Code 845.700(g), if applicable?	
		Attachment I	
	6.2	Indicate that you have attached the following by checking the corresponding boxes:	
		✓	The final closure plan, as specified in 35 Ill. Adm. Code 845.720(b), which includes the closure alternatives analysis required by 35 Ill. Adm. Code 845.710.
		✓	Proposed schedule to complete closure.
		✓	Post-closure care plan as specified in 35 Ill. Adm. Code 845.780(d).
SECTION 7: GROUNDWATER MODELING (35 Ill. Adm. Code 845.220(d)(3))			
Groundwater	7.1	Indicate that you have attached the following by checking the corresponding boxes:	
		✓	The results of groundwater contaminant transport modeling and calculations showing how the closure will achieve compliance with the applicable groundwater standards.
		✓	All modeling inputs and assumptions.
		✓	Description of the fate and transport of contaminants with the selected corrective action over time.

		☑	Capture zone modeling, if applicable.
		☑	Any necessary licenses and software needed to review and access both the model and the data contained within the model.

CONSTRUCTION PERMIT APPLICATION KINCAID POWER PLANT ASH POND (IEPA ID W0218140002-01) Kincaid, Illinois

Luminant

Kincaid Generation, L.L.C.

IEPA Part 845 Kincaid Ash Pond Construction Permit Application
Project No. 132803

Revision A
7/28/2022

CONSTRUCTION PERMIT APPLICATION KINCAID POWER PLANT ASH POND (IEPA ID W0218140002-01) Kincaid, Illinois

prepared for

Kincaid Generation, L.L.C.
IEPA Part 845 Kincaid Ash Pond Construction Permit Application
Kincaid, Illinois

Project No. 132803

Revision A
7/28/2022

prepared by

Burns & McDonnell Engineering Company, Inc.
St. Louis, Missouri

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LIST OF ABBREVIATIONS

Abbreviation	**Term/Phrase/Name**
Burns & McDonnell	Burns & McDonnell Engineering Company, Inc.
CCR	Coal Combustion Residual
C.F.R.	Code of Federal Regulations
CY	Cubic yard
FEMA	Federal Emergency Management Area
gpd	Gallons per day
HARGIS	Historic and Architectural Resources Geographic Information System
IEPA	Illinois Environmental Protection Agency
IDNR	Illinois Department of Natural Resources
ILCS	Illinois Complied Statutes
KAP	Kincaid Ash pond
KPP	Kincaid Power Plant
L.L.C.	Limited Liability Company
MWac	Megawatts AC
MWdc	Megawatts DC
PV	Photovoltaic
NID	National Inventory of Dams
NPDES	National Pollutant Discharge Elimination System
USFWS	U.S. Fish and Wildlife Service
USGS	United States Geological Survey
WWTP	Wastewater treatment plant

1.0 INTRODUCTION

Kincaid Generation, L.L.C. is the operator of the coal-fired Kincaid Power Plant (KPP) located in Christian County near Kincaid, Illinois. One Coal Combustion Residuals (CCR) surface impoundment, the Kincaid Ash Pond (KAP) is present at the KPP. The identification number assigned to the KAP by the Illinois Environmental Protection Agency (IEPA) is W0218140002-01. The National Inventory of Dams (NID) number assigned to the KAP by the Illinois Department of Natural Resources (IDNR) is IL50706.

This construction permit application was developed in accordance with 35 Ill. Admin. Code 845, Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments (Part 845).

This initial construction permit application is for the Ash Pond.

1.1 Legal Description

Section 845.210(c): All permit applications must contain a legal description of the facility boundary and a description of the boundaries of all units included in the facility.

The legal description of the facility is provided in **Attachment A**.

1.2 Previous Assessments

Section 845.210(d): Previous Assessments, Investigations Plans, and Programs

The KAP is currently active and receiving CCR. The KAP was initially regulated by 40 C.F.R. Part 257, herein referred to as the CCR Rule (United Stated Environmental Protection Agency, 2015) and subsequently regulated by Part 845. Multiple initial and periodic assessments, investigations and programs were previously completed for the KAP to satisfy the requirements of both the CCR Rule and Part 845; some of which are referred to within this report.

Section 845.210(d)(1): The Agency may approve the use of any hydrogeologic site investigation or characterization, groundwater monitoring well or system, or groundwater monitoring plan, bearing the seal and signature of an Illinois Licensed Professional Geologist or Licensed Professional Engineer, completed before April 21, 2021, to satisfy the requirements of this Part.

The hydrogeologic site investigation and characterization, groundwater monitoring well system, and groundwater monitoring plan conducted or constructed for the KAP are provided in **Attachment B**.

2.0 CONSTRUCTION PERMIT

Information required to satisfy Part 845 surface impoundment construction permit application requirements is presented below.

2.1 History of Construction

<u>Section 845.220(a)(1)</u>: Design and Construction Plans (Construction History)

The History of Construction report for the KAP and subsequent update letter are provided in **Attachment C**. The History of Construction originally developed in accordance with CCR Rule Part 257.73(c) is included along with a letter providing updates to the History of Construction in accordance with Section 845.230(a)(1).

2.2 Narrative Description of Facility

<u>Section 845.220(a)(2)</u>: Narrative Description of the Facility. The permit application must contain a written description of the facility with supporting documentation describing the procedures and plans that will be used at the facility to comply with the requirements of this Part. The descriptions must include, but are not limited to, the following information:

The Facility Narrative Description details are described in the following sections.

<u>Section 845.220(a)(2)(A)</u>: The types of CCR expected in the CCR surface impoundment, including a chemical analysis of each type of expected CCR;

The types of CCR expected in the KAP and analysis of the chemical constituents found within the CCR in the KAP is provided in **Attachment D.**

<u>Section 845.220(a)(2)(B)</u>: An estimate of the maximum capacity of each surface impoundment in gallons or cubic yards;

The KAP currently contains approximately 2,949,000 cubic yards (CY) of CCR. Approximately 180,000 CY (135,000 tons) of additional bottom ash will be generated between the end of 2021 and the time CCR generation ceases at the KPP in July 2027, resulting in a maximum CCR capacity of approximately 3,129,000 CY.

<u>Section 845.220(a)(2)(C)</u>: The rate at which CCR and non-CCR waste streams currently enter the CCR surface impoundment in gallons per day and dry tons;

CCR, sluice water, and miscellaneous KPP process water streams are currently discharged to the KAP at a rate of approximately 22 million gallons per day (gpd). The KAP receives approximately 63 tons of CCR (dry basis) per day. Non-CCR waste streams currently discharged to the KAP include West Area Runoff Basin stormwater discharges. These discharges occur periodically at rates ranging from approximately 1.0 to 4.08 million gpd.

Section 845.220(a)(2)(D): *The estimated length of time the CCR surface impoundment will receive CCR and non-CCR waste streams; and*

The KAP currently receives CCR discharges and West Area Runoff Basin discharges. CCR discharges will cease when the plant is retired in July 2027. The non-CCR West Area Runoff Basin discharges will cease when KAP closure is completed prior to October 2028.

Section 845.220(a)(2)(E): *An on-site transportation plan that includes all existing and planned roads in the facility that will be used during the operation of the CCR surface impoundment.*

The KAP is currently receiving CCR as the KPP is an active facility. The CCR is sluiced to the KAP from the plant. Existing roads are present and used for on and off-site transportation of CCR. Site access roads exist at the KPP and will be used, as necessary, to support closure construction for the KAP. An On-site Transportation Plan was developed as required by Section 845.220(a)(2)(E) and is provided for the KAP in **Attachment E**. The Transportation Plan includes all on-site access roads and the surrounding roadways.

2.3 Site Maps

Section 845.220(a)(3): *Site Location Map. All permit applications must contain a site location map on the most recent United States Geological Survey (USGS) quadrangle of the area from the 7½ minute series (topographic), or on another map whose scale clearly shows the following information:*

A. The facility boundaries and all adjacent property, extending at least 1000 meters (3280 feet) beyond the boundary of the facility;
B. All surface waters;
C. The prevailing wind direction;
D. The limits of all 100-year floodplains;
E. All-natural areas designated as a Dedicated Illinois Nature Preserve under the Illinois Natural Areas Preservation Act [525 ILCS 30];
F. All historic and archaeological sites designated by the National Historic Preservation Act (16 USC 470 et seq.) and the Illinois Historic Sites Advisory Council Act [20 ILCS 3410]; and

G. *All areas identified as critical habitat under the Endangered Species Act of 1973 (16 USC 1531 et seq.) and the Illinois Endangered Species Protection Act [520 ILCS 10].*

A Site Location Map showing the information required for the KAP in Section 845.220(a)(3) is provided in **Attachment F**. The Site Location Map consists of the most recent USGS topographic map (2013) which contains the facility and at least 1,000 meters of the surrounding area. Information included on the Site Location Map meets the requirements for a Flood Hazard Map, Topographic Vicinity Map, Designated Nature Map, Designated Historic and Archeological Site Map, and Identified Critical Habitat Map.

The data in the Site Location Map was obtained by performing a comprehensive search of the Illinois Department of Natural Resources (IDNR) natural heritage database (Illinois Department of Natural Resources, n.d.) for natural and protected areas within 1,000 meters of the KAP. None of the natural areas of preserves fall within 1,000 meters of the KAP.

The IDNR natural heritage database also includes a list of Endangered Species by County (Illinois Department of Natural Resources, 2021) located within Christian County and adjacent Sangamon County. The Kirtland's Snake (Clonophis kirtlandii) is a threatened/endangered species of nonvenomous snake that has an identified habitat approximately 940 meters north of the existing ash pond, opposite of Sangchris Lake. A review of the U.S. Fish and Wildlife Service (USFWS) Threatened & Endangered Species Active Critical Habitat Report (U.S. Fish & Wildlife Service, n.d.) did not identify any critical habitats located within 1,000 meters of the KAP. The Indiana Bat is considered endangered, and the Northern Long-Eared Bat is considered threatened. The KPP is located within the habitat range of both of these species; however, because no tree clearing is anticipated to occur during KAP closure activities, no impacts to these species are anticipated.

A search of the IDNR Historic and Architectural Resources Geographic Information System (HARGIS database (Illinois Department of Natural Resources, n.d.) for historical sites identified no sites within 1,000 meters of the Site.

The 100-year flood plain limits were obtained from the Federal Emergency Management Area (FEMA) Flood Map Service Center (Federal Emergency Management Agency, n.d.). Portions of the KPP site are within the 100-year flood plain of the Illinois River, although the KAP itself is located outside of the 100-year floodplain limits.

<u>Section 845.220(a)(4):</u> Site Plan Map. The application must contain maps, including cross-sectional maps of the site boundaries, showing the location of the facility. The following information must be shown:

A. The entire facility, including any proposed and all existing CCR surface impoundment locations;
B. The boundaries, both above and below ground level, of the facility and all CCR surface impoundments or landfills containing CCR included in the facility;
C. All existing and proposed groundwater monitoring wells; and
D. All main service corridors, transportation routes, and access roads to the facility.

The Site Plan Map showing the information required in Section 845.220(a)(4) is provided for the KAP in **Attachment E**.

2.4 Narrative Description of Proposed Construction

<u>Section 845.220(a)(5)</u>: A narrative description of the proposed construction of, or modification to, a CCR surface impoundment and any projected changes in the volume or nature of the CCR or non-CCR waste streams.

The KAP will be closed in place by consolidating the CCR into a reduced footprint and covering the consolidated CCR with a final cover compliant with 40 C.F.R. § 257.102(d)(3) and Section 845.750(c). The remainder of the KAP footprint will be closed by removing all of the CCR and placing it within the consolidated footprint. The KAP is an unlined CCR surface impoundment; however, the impoundment is underlain by lean clay overlying hard glacial till (lean sandy clay) and closure of the KAP will include constructing a final cover system that ties into existing, low permeability subsoils; existing, low permeability perimeter berm soils; or low permeability fill soils; thereby encapsulating CCR within the KAP on the top, bottom, and sides.

Closure of the KAP will occur in two phases, with the KPP operating during the initial phase. During the initial phase, a temporary operating pool, approximately 9.4-acres in size, will be constructed in the southeastern corner of the KAP using sheet pile or other vertical hydraulic barrier system. Ponded and subsurface free waters generated during KAP closure activities will be transferred to the temporary operating pool. The KAP currently operates as a closed-loop impoundment, whereby water is recirculated from the KAP back to the KPP for bottom ash sluicing. In addition to bottom ash sluice water, stormwater from the West Area Runoff Basin is also discharged to the KAP; however, the West Area Runoff Basin discharge can also be routed to the onsite wastewater treatment plant (WWTP) for treatment and subsequent discharge via National Pollutant Discharge Elimination System (NPDES) Outfall B01.

The temporary operating pool is sized to accommodate continued bottom ash and West Area Runoff Basin discharges, including storm surges. Under normal circumstances, the West Area Runoff Basin discharge will be routed to the WWTP, providing the capacity needed for the KAP temporary operating pool to receive free liquids removed from CCR generated during closure activities. However, in the event of a WWTP upset or large storm event, West Area Runoff Basin discharges can still be routed to the KAP temporary operating pool. This arrangement will also allow bottom ash sluice water recirculation to continue while free liquids are removed from CCR within the remainder of the KAP and CCR from the northern portion of the KAP is removed and consolidated with CCR in the southern portion of KAP. No other changes in waste streams are expected to occur during closure of the KAP.

Under certain circumstances (e.g., periods of high CCR unwaters/dewaters production), it may be necessary to transfer water from the KAP temporary operating pool to the WWTP for treatment and discharge via Outfall B01. Modifications to the existing WWTP may also be required to meet NPDES discharge permit requirements. Final NPDES discharge requirements will be established, and WWTP modification needs will be determined based on the results of a pending antidegradation study.

The KPP will be retired prior to the start of the second phase of KAP closure. Near the end of this phase, free liquids will be removed from the temporary operating pool and the pool will be filled in with CCR. The hydraulic barrier system used to create the temporary operating pool will not be removed but will be closed in place beneath the final cover system. Final CCR grading, general fill placement and grading, and cover system construction will be completed during the second phase of closure.

Closure with a final cover system will include unwatering the KAP by removing impounded water, abandoning and grouting the existing impoundment outflow structures, regrading existing CCR within the KAP, and constructing a final cover system including a geomembrane, geotextile, cover soil, topsoil, and vegetation. A post-closure stormwater management system consisting of riprap-lined letdown channels and perimeter ditches will direct the majority of non-contact stormwater to the northern portion of the KAP, where all CCR will be removed, and to Sangchris Lake. Positive drainage will be established in the northern portion of the KAP by placing and grading approximately 52,300 cubic yards (CY) of imported general fill. These drainage improvements will direct stormwater to the north, through the former KAP containment berm, and into a natural drainage that leads to Sangchris Lake. The natural drainage will be armored with riprap to prevent erosion. In the southeast corner of the KAP, a culvert will be constructed to convey stormwater from perimeter ditches to the Sangchris Lake channel that runs parallel to the southern boundary of the KAP.

The northern portion of the KAP will be decontaminated by removing all CCR and subsoils with visual presence of CCR. Decontamination of areas outside of the northern portion of the KAP will not be required because there have been no releases of CCR from the northern portion of the. All structures and conveyances used to manage CCR will be placed beneath the final cover system of the KAP, decontaminated, or removed and transported to a licensed landfill for disposal.

During the closure process, off-site CCR beneficial use opportunities will continue to be assessed. CCR consolidation and closure in place in combination with offsite beneficial use may result in a smaller onsite CCR footprint, for the purposes of final cover system design, and a reduced construction schedule.

As part of the closure effort, if closure in place is approved, a new photovoltaic (PV) solar power facility will be installed on top of the closed KAP. The PV facility will have a rated power of approximately 29 megawatts AC (MWac) and an installed power of approximately 34 megawatts DC (MWdc). Interconnection of the solar facility will occur at the existing Kincaid substation.

Additional information on the proposed construction and modification to the KAP is included within the Closure Plan provided in **Attachment G**.

2.5 Plans and Specifications

<u>Section 845.220(a)(6)</u>: *Plans and specifications fully describing the design, nature, function, and interrelationship of each individual component of the facility.*

Permit-level design plans are included within the Closure Plan provided for the KAP in **Attachment G** and were prepared in accordance with Section 845.220(a)(6). The permit-level design plans are consistent with the narrative description provided in Section 2.4.

2.6 Groundwater Monitoring Program

<u>Section 845.220(a)(7)</u>: *A new groundwater monitoring program or any modification to an existing groundwater monitoring program that includes but is not limited to the following information:*

The Groundwater Monitoring Program details are described within this section and the referenced attachments.

<u>Section 845.220(a)(7)(A)</u>: *A hydrogeologic site investigation meeting the requirements of Section 845.620, if applicable;*

Hydrogeologic site investigations for KAP are provided in **Attachment B**.

Section 845.220(a)(7)(B): Design and construction plans of a groundwater monitoring system meeting the requirements of Section 845.630; and

Design and construction plans for a groundwater monitoring system as required by Section 845.630 are provided in **Attachment B**.

Section 845.220(a)(7)(C): A proposed groundwater sampling and analysis program that includes selection of the statistical procedures to be used for evaluating groundwater monitoring data (see Sections 845.640 and 845.650).

A groundwater sampling and analysis program that meets the requirements of Section 845.640 and 845.650 is provided in **Attachment B**.

2.7 Certification

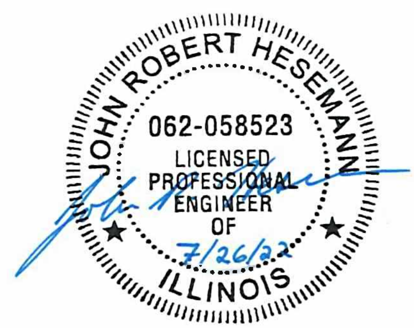
<u>Section 845.220(a)(8):</u> The signature and seal of a qualified professional engineer.

I, John R. Hesemann, being a Registered Professional Engineer in good standing in the State of Illinois, do hereby certify, to the best of my knowledge, information, and belief, that the information contained in this construction permit application has been prepared in accordance with the accepted practice of engineering.

John R. Hesemann
Printed Name

7/26/2022
Signature   Date

062.058523   IL   11/30/2023
Registration Number   State   Expiration Date



Affix Seal

2.8 Public Meeting Information

<u>Section 845.220(a)(9):</u> *Certification that the owner or operator of the CCR surface impoundment completed the public notification and public meetings required under Section 845.240, a summary of the issues raised by the public, a summary of any revisions, determinations, or other considerations made in response to those issues, and a list of interested persons in attendance who would like to be added to the Agency's listserv for the facility.*

Certification that the public notification and public meetings have been completed as required by Section 845.240 is provided as **Attachment H**.

2.9 Corrective Action Construction

<u>Section 845.220(c):</u> *Corrective Action Construction. In addition to the requirements in subsection (a), all construction permit applications that include any corrective action performed under Subpart F must also contain the following information and documents:*

The need for corrective action construction has not been determined for the KAP. Closure of the KAP will further mitigate future groundwater impacts by acting as source control, based on the Groundwater Model Report prepared by Ramboll and included in **Attachment B**. Therefore, corrective action construction will not be performed as part of KAP closure.

2.10 Closure Construction

<u>Section 845.220(d):</u> *Closure Construction. In addition to the requirements in subsection (a), all construction permit applications for closure of the CCR surface impoundment under Subpart G must contain the following information and documents:*

The Closure Construction details are described in the following sections.

<u>Section 845.220(d)(1):</u> *Closure prioritization category, if applicable (see Section 845.700(g));*

A CCR Surface Impoundment Category Designation and Justification letter was submitted to IEPA on May 19, 2021. The KAP was designated as a Category 5 CCR surface impoundment – an existing surface impoundment with exceedances of the groundwater protection standards specified in Section 845.600. This letter is provided in **Attachment I**.

<u>Section 845.220(d)(2):</u> *Final closure plan (see Section 845.720(b)), including the closure alternatives analysis required by Section 845.710;*

The Final Closure Plan as required by Section 845.720(b) and the Alternatives Analysis as required by Section 845.210 are provided in **Attachment G**.

<u>*Section 845.220(d)(3):*</u> *Groundwater modeling, including:*

A. The results of groundwater contaminant transport modeling and calculations showing how the closure will achieve compliance with the applicable groundwater standards;

B. All modeling inputs and assumptions;

C. Description of the fate and transport of contaminants, with the selected closure over time;

D. Capture zone modeling, if applicable; and

E. Any necessary licenses and software needed to review and access both the model and the data contained within the model.

Groundwater modeling as required by Section 845.220(d)(3) is provided in **Attachment B**.

<u>*Section 845.220(d)(4)*</u>*: Proposed schedule to complete closure; and*

The proposed schedule to completed closure is included within the Final Closure Plan, provided in **Attachment G.**

<u>*Section 845.220(d)(5)*</u>*: Post-closure care plan specified in Section 845.780(d), if applicable.*

The Post Closure Care Plan required by Section 845.220(d)(5) is provided in **Attachment J**.

3.0 ADDITIONAL INFORMATION

Certification that Kincaid Generation L.L.C. will utilize contractors, subcontractors, and installers who are participants in an approved training program, in accordance with 415 Illinois Complied Statutes (ILCS) 5/22.59(b)(4), is provided in **Attachment K**.

4.0 REFERENCES

Federal Emergency Management Agency. (n.d.). *FEMA Flood Map Service Center: Welcome!* Retrieved October 6, 2021, from https://msc.fema.gov/portal/home

Illinois Department of Natural Resources. (2021, September). *Illinois Threatened and Endangered Species by County*. Retrieved October 5, 2021, from https://www2.illinois.gov/sites/naturalheritage/DataResearch/Documents/ETCountyList_sept2021.pdf

Illinois Department of Natural Resources. (n.d.). *IDNR Historic Preservation Devision HARGIS*. Retrieved October 5, 2021, from https://www2.illinois.gov/dnrhistoric/Preserve/Pages/HARGIS.aspx

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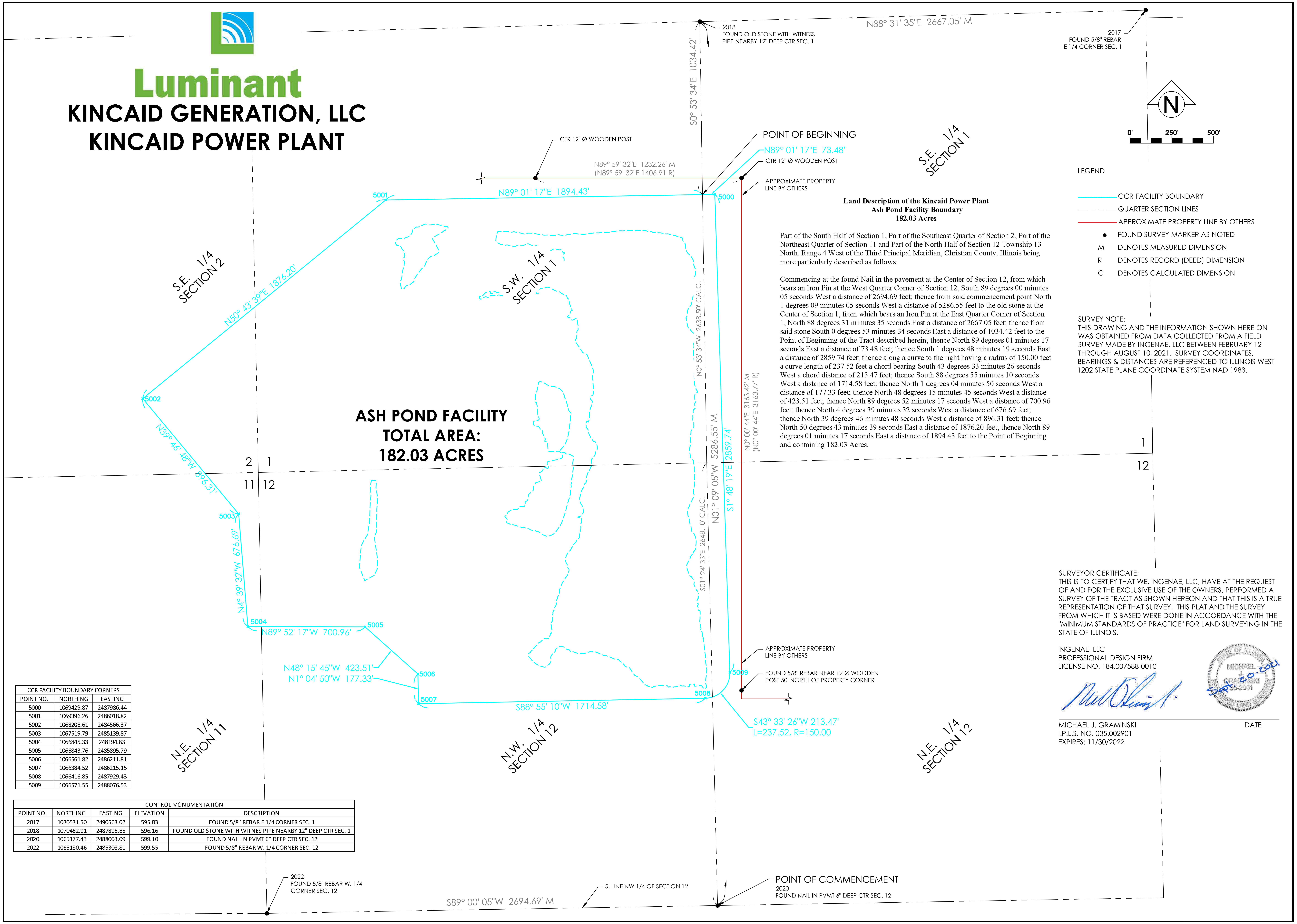
U.S. Fish & Wildlife Service. (n.d.). *USFWS Threatened & Endangered Species Active Critical Habitat Report*. Retrieved 6 2021, October, from https://ecos.fws.gov/ecp/report/table/critical-habitat.html

United Stated Environmental Protection Agency. (2015). *"40 CFR Parts 257 and 261, Hazardous and Solid Waste Management System, Disposal of Coal Combustion Residuals from Electric Utilities, Final Rule, 2015.*

ATTACHMENT A: LEGAL DESCRIPTION
845.210(c)



Land Description of the Kincaid Power Plant
Ash Pond Facility Boundary
182.03 Acres

Part of the South Half of Section 1, Part of the Southeast Quarter of Section 2, Part of the Northeast Quarter of Section 11 and Part of the North Half of Section 12 Township 13 North, Range 4 West of the Third Principal Meridian, Christian County, Illinois being more particularly described as follows:

Commencing at the found Nail in the pavement at the Center of Section 12, from which bears an Iron Pin at the West Quarter Corner of Section 12, South 89 degrees 00 minutes 05 seconds West a distance of 2694.69 feet; thence from said commencement point North 1 degrees 09 minutes 05 seconds West a distance of 5286.55 feet to the old stone at the Center of Section 1, from which bears an Iron Pin at the East Quarter Corner of Section 1, North 88 degrees 31 minutes 35 seconds East a distance of 2667.05 feet; thence from said stone South 0 degrees 53 minutes 34 seconds East a distance of 1034.42 feet to the Point of Beginning of the Tract described herein; thence North 89 degrees 01 minutes 17 seconds East a distance of 73.48 feet; thence South 1 degrees 48 minutes 19 seconds East a distance of 2859.74 feet; thence along a curve to the right having a radius of 150.00 feet a curve length of 237.52 feet a chord bearing South 43 degrees 33 minutes 26 seconds West a chord distance of 213.47 feet; thence South 88 degrees 55 minutes 10 seconds West a distance of 1714.58 feet; thence North 1 degrees 04 minutes 50 seconds West a distance of 177.33 feet; thence North 48 degrees 15 minutes 45 seconds West a distance of 423.51 feet; thence North 89 degrees 52 minutes 17 seconds West a distance of 700.96 feet; thence North 4 degrees 39 minutes 32 seconds West a distance of 676.69 feet; thence North 39 degrees 46 minutes 48 seconds West a distance of 896.31 feet; thence North 50 degrees 43 minutes 39 seconds East a distance of 1876.20 feet; thence North 89 degrees 01 minutes 17 seconds East a distance of 1894.43 feet to the Point of Beginning and containing 182.03 Acres.

LEGEND

- CCR FACILITY BOUNDARY
- QUARTER SECTION LINES
- APPROXIMATE PROPERTY LINE BY OTHERS
- ● FOUND SURVEY MARKER AS NOTED
- M DENOTES MEASURED DIMENSION
- R DENOTES RECORD (DEED) DIMENSION
- C DENOTES CALCULATED DIMENSION

SURVEY NOTE:
THIS DRAWING AND THE INFORMATION SHOWN HERE ON WAS OBTAINED FROM DATA COLLECTED FROM A FIELD SURVEY MADE BY INGENAE, LLC BETWEEN FEBRUARY 12 THROUGH AUGUST 10, 2021. SURVEY COORDINATES, BEARINGS & DISTANCES ARE REFERENCED TO ILLINOIS WEST 1202 STATE PLANE COORDINATE SYSTEM NAD 1983.

SURVEYOR CERTIFICATE:
THIS IS TO CERTIFY THAT WE, INGENAE, LLC, HAVE AT THE REQUEST OF AND FOR THE EXCLUSIVE USE OF THE OWNERS, PERFORMED A SURVEY OF THE TRACT AS SHOWN HEREON AND THAT THIS IS A TRUE REPRESENTATION OF THAT SURVEY. THIS PLAT AND THE SURVEY FROM WHICH IT IS BASED WERE DONE IN ACCORDANCE WITH THE "MINIMUM STANDARDS OF PRACTICE" FOR LAND SURVEYING IN THE STATE OF ILLINOIS.

INGENAE, LLC
PROFESSIONAL DESIGN FIRM
LICENSE NO. 184.007588-0010

MICHAEL J. GRAMINSKI — DATE: Sept 20 2021
I.P.L.S. NO. 035.002901
EXPIRES: 11/30/2022

CCR FACILITY BOUNDARY CORNERS		
POINT NO.	NORTHING	EASTING
5000	1069429.87	2487986.44
5001	1069396.26	2486018.82
5002	1068208.61	2484566.37
5003	1067519.79	2485139.87
5004	1066845.33	248194.83
5005	1066843.76	2485895.79
5006	1066561.82	2486211.81
5007	1066384.52	2486215.15
5008	1066416.85	2487929.43
5009	1066571.55	2488076.53

CONTROL MONUMENTATION				
POINT NO.	NORTHING	EASTING	ELEVATION	DESCRIPTION
2017	1070531.50	2490563.02	595.83	FOUND 5/8" REBAR E 1/4 CORNER SEC. 1
2018	1070462.91	2487896.85	596.16	FOUND OLD STONE WITH WITNES PIPE NEARBY 12" DEEP CTR SEC. 1
2020	1065177.43	2488003.09	599.10	FOUND NAIL IN PVMT 6" DEEP CTR SEC. 12
2022	1065130.46	2485308.81	599.55	FOUND 5/8" REBAR W. 1/4 CORNER SEC. 12

IngenAE
502 Earth City Plaza, Suite 120
Earth City, MO 63045
www.ingenae.com

Submissions / Revisions:	Date:
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2	
3	
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10	
11	
12	
13	

Luminant

Project Name & Location:

KINCAID
POWER PLANT
199 ILLINOIS ROUTE 104
KINCAID, IL 62540

Drawing Name:
CCR FACILITY BOUNDARY EXHIBIT

Date: 9/21/2021	Project No.
Type: SITE	Drawing No. 1
Drawn By: CB	
Approved By: MG	
Scale: AS NOTED	

Luminant
KINCAID GENERATION, LLC
KINCAID POWER PLANT

LEGEND

- CCR FACILITY BOUNDARY
- QUARTER SECTION LINES
- APPROXIMATE PROPERTY LINE BY OTHERS
- ● FOUND SURVEY MARKER AS NOTED
- M DENOTES MEASURED DIMENSION
- R DENOTES RECORD (DEED) DIMENSION
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SURVEY NOTE:
THIS DRAWING AND THE INFORMATION SHOWN HERE ON WAS OBTAINED FROM DATA COLLECTED FROM A FIELD SURVEY MADE BY INGENAE, LLC BETWEEN FEBRUARY 12 THROUGH AUGUST 10, 2021. SURVEY COORDINATES, BEARINGS & DISTANCES ARE REFERENCED TO ILLINOIS WEST 1202 STATE PLANE COORDINATE SYSTEM NAD 1983.

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Submissions / Revisions:	Date:
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Luminant

Project Name & Location:

KINCAID
POWER PLANT

199 ILLINOIS ROUTE 104
KINCAID, IL 62540

Drawing Name:
AERIAL PHOTOGRAPHY

Date: 9/21/2021	Project No.
Type: SITE	Drawing No. 2
Drawn By: CB	
Approved By: MG	
Scale: AS NOTED	

ATTACHMENT B: GROUNDWATER INFORMATION
845.210(d)(1), 845.220(a)(7)(A-C), 845.220(c)(2), AND 845.220(d)(3)

Intended for
Kincaid Generation, LLC

Date
July 28, 2022

Project No.
1940101010-006

GROUNDWATER MODELING REPORT

ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

GROUNDWATER MODELING REPORT
KINCAID POWER PLANT ASH POND

Project Name	**Kincaid Power Plant Ash Pond**
Project No.	**1940101010-006**
Recipient	**Kincaid Generation, LLC**
Document Type	**Groundwater Modeling Report**
Revision	**FINAL**
Date	**July 28, 2022**

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CONTENTS

TABLES (IN TEXT)

TABLES (ATTACHED)

FIGURES (IN TEXT)

FIGURES (ATTACHED)

APPENDICES

ACRONYMS AND ABBREVIATIONS

§	Section
35 I.A.C.	Title 35 of the Illinois Administrative Code
AP	Ash Pond
BCU	bedrock confining unit
Cabeno	Cabeno Field Services
CBR	closure by removal
CIP	closure in place
CCR	coal combustion residuals
cm/s	centimeters per second
CSM	conceptual site model
ft/d	feet/foot per day
Geosyntec	Geosyntec Consultants, Inc.
GMP	Groundwater Monitoring Plan
GMR	Groundwater Modeling Report
Golder	Golder Associates USA Inc.
GWPS	Groundwater Protection Standard
HCR	Hydrogeologic Site Characterization Report
HELP	Hydrologic Evaluation of Landfill Performance
ID	identification
IEPA	Illinois Environmental Protection Agency
Kd	soil adsorption coefficient
K_d	linear partition coefficients
K_{dF}	Frendlich partition coefficients
Kh/Kv	vertical anisotropy
KPP	Kincaid Power Plant
L/kg	liters per kilogram
LCU	lower confining unit
mg/L	milligrams per liter
mL/g	milliliters per gram
MNA	monitored natural attenuation
NAVD88	North American Vertical Datum of 1988

No.	number
Part 845	35 I.A.C. § 845: Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments
PMP	potential migration pathway
R2	correlation coefficient
Ramboll	Ramboll Americas Engineering Solutions, Inc.
TDS	total dissolved solids
TVD	total-variation-diminishing
UA	uppermost aquifer
USCU	upper semi-confining unit
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 Kincaid Power Plant (KPP), operated by Kincaid Generation, LLC, 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 Ash Pond (AP; Vistra identification [ID] number [No.] 141, IEPA ID No. W0218140002-01).

The AP coal combustion residuals (CCR) unit is located between two lobes of Sangchris Lake, which was formed in 1964 by damming Clear Creek, a tributary to the south fork of the Sangamon River. Sangchris Lake was created to provide a source of cooling water for the KPP. The western lobe of Sangchris Lake forms part of the western and the northern border of the AP and is connected to an intake flume for the KPP on the western edge of the AP. A discharge flume from the KPP forms the southern border of the AP and is connected to the eastern lobe of Sangchris Lake. The KPP property is surrounded by the lobes of Sangchris Lake and Sangchris Lake State Park to the north and east, and a combination of undeveloped land and surface support facilities associated with the former Peabody Coal Company #10 mine to the south and west.

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

- **CCR**: Saturated CCR, consisting primarily of bottom ash, and boiler slag.
- **Upper Semi-Confining Unit (USCU)**: Low-permeability clay with some silt and minor sand, silt layers, and occasional discontinuous sand lenses. Includes the lithologic layers identified as the Cahokia Formation. Sand lenses with higher permeability within the USCU have a higher probability of contaminant transport and these materials are referred to as the potential migration pathways (PMP).
- **Uppermost Aquifer (UA)**: Thin (generally less than 4 feet), moderate permeability sand, silty sand, and clayey sand and gravel units, which include the clays and silts of the Upper Cahokia Formation, where saturated, and the thin, moderate permeability sands and gravels of the Lower Cahokia Formation, which, at some locations, also includes the interface with the Vandalia Till.
- **Lower Confining Unit (LCU):** Underlying the aquifer unit is dense grey clay till; this till is easily distinguished during investigation by difficult drilling and/or refusal and is apparent on boring logs. The till was encountered at elevations ranging from approximately 570 to 583.5 feet (referenced to North American Vertical Datum of 1988 [NAVD88]. The LCU is comprised of low permeability silt and clay with minor sand, silt layers, and occasional discontinuous sand lenses (more frequently near the top of the unit). Includes the lithologic layers identified as the Vandalia Till.

- **Bedrock Confining Unit (BCU):** The water-bearing layer referred to as the BCU is composed of interbedded shale and limestone of the Pennsylvanian Age Bond Formation that underlie the Vandalia Till, and underlies the entire AP.

Groundwater flow in the UA is to the northwest toward Sangchris Lake. Groundwater elevations are primarily controlled by the surface water levels in the lobes of Sangchris Lake and the water level within the AP. An apparent groundwater divide trending southwest to northeast has been observed beneath the AP.

A review and summary of data collected from 2015 through 2021 for parameters with groundwater protection standards (GWPS) listed in 35 I.A.C. § 845.600 is provided in the HCR (Ramboll, 2021a). Groundwater concentrations presented in HCR Table 4-1 and summarized in the History of Potential Exceedances (Ramboll, 2021b) are considered potential exceedances because the methodology used to determine them is proposed in the Groundwater Monitoring Plan (GMP; Ramboll, 2021c) and has not been reviewed or approved by IEPA at the time of this submittal. The following constituents with potential exceedances of the GWPS listed in 35 I.A.C. § 845.600 were identified: boron, sulfate, and total dissolved solids (TDS) (Ramboll, 2021b).

Statistically significant correlations between boron concentrations and concentrations of other parameters identified as potential exceedances of the GWPS indicate boron is an acceptable surrogate for sulfate and TDS in the groundwater model. It was assumed that boron would not significantly sorb or chemically react with aquifer solids (soil adsorption coefficient [Kd] was set to 0 milliliters per gram [mL/g]) which is a conservative estimate for predicting contaminant transport times. Boron, sulfate, and TDS transport is likely to be affected by both chemical and physical attenuation mechanisms (*i.e.,* adsorption and/or precipitation reactions as well as dilution and dispersion).

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

- Scenario 1: CIP (CCR removal from the north and west areas of the AP, consolidation to the central and southeast portions of the AP, and construction of a cover system over the remaining CCR); and,
- Scenario 2: CBR (CCR removal from the AP)

Scenario 1 (CIP) was predicted to reduce both total flux in and out of the Fill Unit (CCR) by greater than 99% when simulated post-construction heads in the groundwater monitoring wells are predicted to stabilize.

Prior to the simulation of these scenarios, a dewatering simulation was included for the removal of free liquids from the AP prior to the implementation of the two scenarios. Predictive simulations of closure conservatively indicate groundwater in the UA will achieve the GWPS in site monitoring wells for Scenarios 1 and 2 in 17 and 16.5 years after implementation of the closure scenarios, respectively. From a modeling perspective, the difference between the predicted time to reach the GWPS for boron (2 mg/L) in Scenario 1 (17 years) versus Scenario 2 (16.5 years) is negligible. In other words, both scenarios are predicted to reach the GWPS after approximately 17 years, the simulated difference between these two scenarios is not significant.

Results of groundwater fate and transport modeling estimate that groundwater will attain the GWPS for all constituents identified as potential exceedances of the GWPS within 17 years of closure implementation for both Scenarios. In both scenarios residual boron exceedances from the calibrated model remain in close proximity to the ash pond and/or calibrated extent of exceedances as the plumes recede.

1. INTRODUCTION

1.1 Overview

In accordance with requirements of Part 845 (IEPA, 2021), Ramboll has prepared this GMR on behalf of KPP, operated by Kincaid Generation, LLC. This report will apply specifically to the CCR Unit referred to as the AP (**Figure 1-1**). The KPP operates as a coal-fired power plant and has a single CCR management unit, the AP (**Figure 1-2**), a 172-acre, unlined surface impoundment used to manage CCR and non-CCR waste streams at the KPP with a total storage capacity of approximately 3,560 acre-feet. This GMR presents and evaluates the results of predictive groundwater modeling simulations for two scenarios:

- Scenario 1: CIP (CCR removal from the north and west areas of the AP, consolidation to the central and southeast portions of the AP, and construction of a cover system over the remaining CCR)
- Scenario 2: CBR (CCR removal from the AP)

1.2 Site Location and Background

The KPP is located in the southwest quarter of Section 1, and the northeast quarter of Section 12, Township 13 North, Range 4 West, along West Route 104, Christian County, Illinois and approximately four miles west of the Village of Kincaid. The AP is located between two lobes of Sangchris Lake (**Figure 1-1**), which was formed in 1964 by damming Clear Creek, a tributary to the south fork of the Sangamon River. Sangchris Lake was created to provide a source of cooling water for the KPP. The western lobe of Sangchris Lake forms part of the western and northern border of the AP and is connected to an intake flume for the KPP on the western edge of the AP. A discharge flume from the KPP forms the southern border of the AP and is connected to the eastern lobe of Sangchris Lake. The KPP property is surrounded by the lobes of Sangchris Lake and Sangchris Lake State Park to the north and east, and a combination of undeveloped land and surface support facilities associated with the former Peabody Coal Company #10 mine to the south and west.

1.3 Site History and Unit Description

Construction of the AP began in 1964 and it was commissioned for use in 1967. The AP primarily contains bottom ash and boiler slag, and other minor materials, including water and wastewater treatment solids, excavation spoils, and dredge spoils. The discharge for the AP is located at the southeast corner of the unit. The approximate dates of construction of each successive stage of the AP are summarized in **Table A** on the following page (AECOM, 2016).

Table A. History of Construction

Date	Event
1964-1965	Construction of AP
1967	AP was put into service
1978-1980	Installation of AP recycle water intake structures and associated piping
Mid-1980's	Erosion repair along north embankment adjacent to Sangchris Lake
2006	Replacement of emergency outlet piping
2009-2010	Tree removal, grading, and vegetation re-established along the north and east embankment
2010	Riprap placement along the northwest AP embankment adjacent to Sangchris Lake

2. SITE GEOLOGY AND HYDROGEOLOGY

AP hydrogeologic and groundwater quality data was presented in the HCR (Ramboll, 2021a) and used to establish a conceptual site model (CSM) for this GMR, and is summarized below. There are three principal types of unlithified materials present overlying bedrock at the KPP, consisting of the following in descending order:

- Fill, the constructed AP consists of fill (predominantly coal ash within the AP, but also including constructed berms and railroad embankments around the AP).
- Clays and silts of the Cahokia Formation, interbedded with thin sand lenses, most of which are laterally discontinuous, but a thin bed of sand was observed at the bottom of the Cahokia Formation in the majority of soil borings advanced near the AP. This sand unit comprises the UA. The Cahokia materials extend to depths of less than 44 feet.
- Clay and silt with varying amounts of sand and gravel of the Vandalia Till, which extend to depths of up to 52 feet.

Bedrock beneath the AP consists of the Pennsylvanian-age Bond Formation, comprised mainly of limestone with lesser amounts of shale and sandstone.

Prior to 2021, there were 12 monitoring wells (MW-1 through MW-12) around the AP for monitoring groundwater. Nineteen additional monitoring wells (MW-7S, MW-8S, MW-11S, MW-12S, MW-12D, MW-20S, MW-20, MW-22, MW-23, MW-24, MW-25, MW-26, MW-27, MW-28, MW-29, MW-30, MW-31, MW-32, and MW-31S) were installed in 2021 around the perimeter of the AP to meet the requirements of Part 845. Construction details for monitoring wells and piezometers are provided in **Table 2-1** and depicted in **Figure 2-1**. Boring logs, monitoring well and piezometer construction forms are provided in Appendix B of the HCR.

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

- **CCR**: Saturated CCR, consisting primarily of bottom ash, and boiler slag.
- **USCU**: Low-permeability clay with some silt and minor sand, silt layers, and occasional discontinuous sand lenses. Includes the lithologic layers identified as the Cahokia Formation. Sand lenses with higher permeability within the USCU have a higher probability of contaminant transport and these materials are referred to as the PMP.
- **UA**: Thin (generally less than 4 feet), moderate permeability sand, silty sand, and clayey sand and gravel units, which include the clays and silts of the Upper Cahokia Formation, where saturated, and the thin, moderate permeability sands and gravels of the Lower Cahokia Formation, which, at some locations, also includes the interface with the Vandalia Till.
- **LCU:** Underlying the aquifer unit is dense grey clay till; this till is easily distinguished during investigation by difficult drilling and/or refusal and is apparent on boring logs. The till was encountered at elevations ranging from approximately 570 to 583.5 feet NAVD88. The LCU is comprised of low permeability silt and clay with minor sand, silt layers, and occasional discontinuous sand lenses (more frequently near the top of the unit). Includes the lithologic layers identified as the Vandalia Till.

- **BCU:** The water-bearing layer referred to as the BCU is composed of interbedded shale and limestone of the Pennsylvanian Age Bond Formation that underlie the Vandalia Till, and underlies the entire AP.

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

- Due to the downgradient location and proximity of Sangchris Lake to the AP, Sangchris Lake is likely to be hydraulically connected to the UA beneath the AP. Flow of groundwater from the KPP to Sangchris Lake through the UA is the primary pathway for contaminant migration.
- The elevations of water within the AP are greater than groundwater elevations in the surrounding areas, and, depending on the hydraulic connection between the AP and the surrounding aquifer, water may flow radially from the AP toward the lobes of Sangchris Lake.
- Horizontal groundwater flow in the USCU in the area of the AP is toward the north and northwest toward the western lobe of Sangchris Lake. There also appears to be a component of groundwater flow to the south and east toward the discharge flume that flows to the eastern lobe of Sangchris Lake, as evidenced by groundwater elevations on the southern side of the AP. These two components of groundwater flow suggest a groundwater divide beneath the AP.
- The groundwater divide beneath the AP is further supported by horizontal groundwater flow in the UA, which is to the northwest and southeast toward the western and eastern lobes of Sangchris Lake, respectively.
- Groundwater elevations are primarily controlled by the surface water level in Sangchris Lake, and the water level within the AP. Typically, groundwater from the AP flows from east to west and discharges to Sangchris Lake.
- Vertical gradients calculated between the bedrock and UA are generally upward, consistent with previous vertical gradient calculations (HCR, Ramboll, 2021a).

3. GROUNDWATER QUALITY

Groundwater at the AP does not meet the definition of Class I - Potable Resource Groundwater (35 I.A.C. § 620.210), based on the following criteria provided in the HCR:

- Site investigations have determined that water bearing lenses contain more than 12 percent fines and are less than five feet in thickness (Cabeno Field Services [Cabeno], 2013),
- Sustained groundwater yield from a 12-inch borehole of less than 150-gallons per day from a thickness of 15-feet or less.
- Field (horizontal) hydraulic conductivity tests and laboratory (vertical) hydraulic conductivity tests from wells screened within the UA resulted in an overall (geometric mean) of 5.07×10^{-5} centimeters per second (cm/s) and 1.07×10^{-7} cm/s, respectively (see Table 2-1 and Table 3-4 in the HCR; Ramboll, 2021a).

As set forth in 35 I.A.C. § 620.220, any geologic material with a hydraulic conductivity of less than 1×10^{-4} cm/s, and which does not meet the provisions of 35 I.A.C. § 620.210 (Class I), 35 I.A.C. § 620.230 (Class III), or 35 I.A.C. § 620.240 (Class IV), meets the definition of Class II: General Resource Groundwater. Based on the detailed geologic information provided for the unlithified materials and bedrock encountered at the AP and the hydrogeologic data, the groundwater in the UA can be classified as Class II: General Resource Groundwater. This is supported by results of the hydrogeologic study completed in 2013 (Cabeno, 2013), which concluded that the AP does not meet most criteria of Class I groundwater and the data collected supported a Class II groundwater classification.

Groundwater quality investigations were completed at the AP starting in 2010. In 2021, additional wells were installed to comply with Part 845 requirements, specifically to reduce the lateral spacing between monitoring points and to further characterize the PMPs. Wells were sampled for the parameters listed in 35 I.A.C. § 845.600. A review and summary of data collected from 2015 through 2021 for parameters with GWPSs listed in 35 I.A.C. § 845.600 is provided in the HCR (Ramboll, 2021a).

Concentration results presented in the HCR were compared directly to 35 I.A.C. § 845.600 GWPSs to determine potential exceedances. The results are considered potential exceedances because the results were compared directly to the standard and did not include an evaluation of background groundwater quality or utilize the statistical methodologies proposed in the GMP (Ramboll, 2021c) attached to the operating permit application.

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

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

- Boron – determined at monitoring wells MW-7S, MW-12, and MW-28
- Sulfate – determined at monitoring wells MW-28 and MW-32
- TDS – determined at monitoring well MW-28

4. GROUNDWATER MODEL

4.1 Overview

Data collected at the site from the 2021 field investigation were used to develop a groundwater model for the AP. The MODFLOW and MT3DMS models were then used to evaluate two closure scenarios, including CCR consolidation and CIP using information provided in the CCR Surface Impoundment Final Closure Plan (Burns & McDonnell, 2022), and CBR scenarios. The results of the CIP and CBR closure scenarios are summarized and evaluated in this GMR. Associated model files are included as **Appendix A**.

4.2 Conceptual Site Model

The HCR (Ramboll, 2021a) is the foundation of the site setting and CSM that describes groundwater flow at the site. The AP overlies the recharge area for the underlying transmissive geologic media, which are composed of moderate permeability sand, silty sand, and clayey sand and gravel units, which include the clays and silts of the Upper Cahokia Formation, where saturated, and the thin, moderate permeability sands and gravels of the Lower Cahokia Formation, which, at some locations, also includes the interface with the Vandalia Till deposits (*i.e.*, the UA). Groundwater enters the model domain vertically via recharge. The groundwater from the UA flows into the forks of Sangchris Lake.

Boron was selected for transport modeling. Boron is commonly used as an indicator parameter for contaminant transport modeling for CCR because: (i) it is commonly present in coal ash leachate; (ii) it is mobile and typically not very reactive but conservative (*i.e.*, low rates of sorption or degradation) in groundwater; and (iii) it is less likely than other constituents to be present in background groundwater from natural or other anthropogenic sources. The only significant source of boron is the AP. Mass (boron) is added to groundwater via vertical recharge through CCR, and horizontal groundwater flow through CCR where it is in contact with the water table. Mass flows with groundwater toward Sangchris Lake. The primary transport pathway is the UA as indicated by groundwater observations. The USCU is also a PMP, although the sands in this unit are discontinuous which limit migration potential.

4.3 Model Approach

4.3.1 Potential Groundwater Exceedances

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

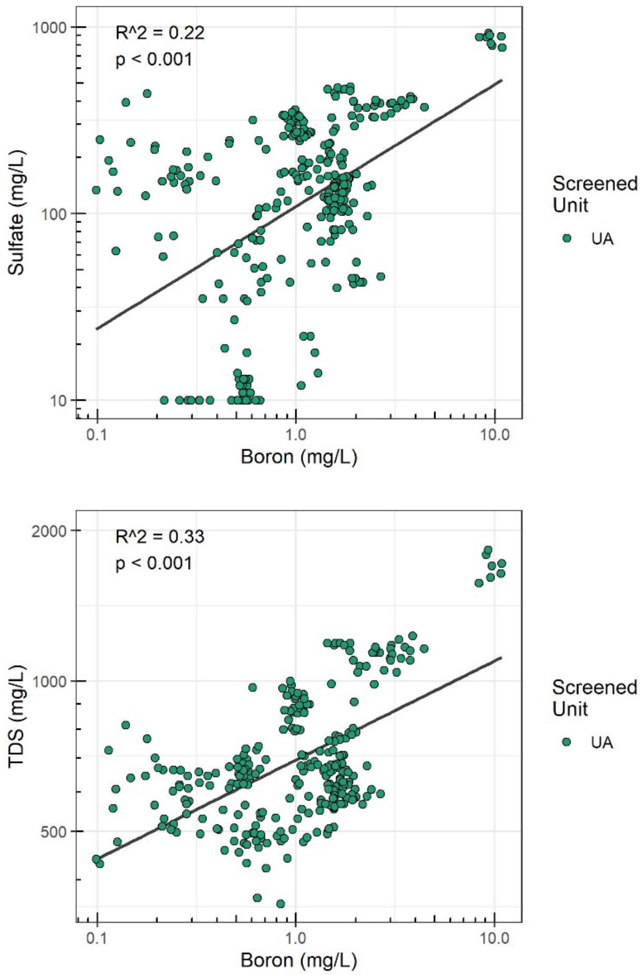

Figure A. Boron Correlation with Sulfate and TDS in UA Wells

4.3.2 Summary of Modeling Activities

A three-dimensional groundwater flow and transport model was calibrated to represent the conceptual flow system described above. Initial modeling was performed for a sufficient period (27.5 years) to allow modeled boron concentrations in the primary transport layer (*i.e.,* UA) to achieve steady concentrations. The model was calibrated to match the mean groundwater elevation and median concentration observed at individual monitoring wells. Prediction simulations were then performed to evaluate the effects of CBR and CIP closure scenarios on groundwater quality for a period of 30 years following corrective action measures, which include dewatering of the AP for 1 year, consolidation of CCR and cover system construction or removal of CCR. The calibration and prediction model timelines are illustrated in **Figure 4-1**.

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

- Groundwater flow was modeled in three dimensions using MODFLOW 2005
- Contaminant transport was modeled in three dimensions using MT3DMS
- Percolation (recharge) after removal at the AP was modeled using the results of the Hydrologic Evaluation of Landfill Performance (HELP) model.

Modeling steps are a summarized below:

- A steady state model was created in MODFLOW 2005 and used to simulate the general groundwater flow conditions at the site. The model was calibrated to match mean groundwater elevations observed between 2015 to 2021.
- A transient flow model based off of the calibrated steady state model was used to simulate groundwater flow and transport for 27.5 years using MODFLOW 2005 and MT3DMS to simulate boron entering the system through time and allow concentrations to match currently observed concentrations of boron in groundwater (**Table 4-1**).
- Prediction simulations began with a 1-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 1-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 boron 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 United States Geological Survey (USGS) (McDonald and Harbaugh, 1988). MODFLOW is thoroughly documented, widely used by consultants, government agencies and researchers, and is consistently accepted in regulatory and litigation proceedings. MODFLOW uses a finite difference approximation to solve a three-dimensional head distribution in a transient, multi-layer, heterogeneous, anisotropic, variable-gradient, variable-thickness, confined or unconfined flow system—given user-supplied inputs of hydraulic conductivity, aquifer/layer thickness, recharge, wells, and boundary conditions. The program also calculates water balance at wells, rivers, and drains.

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

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

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

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

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

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

5.2 Flow and Transport Model Setup

The modeled area was approximately 6,520 feet by 7,780 feet. The north, west, and south edges of the model are bounded by the forks of Sangchris Lake. The eastern edge of the model is selected to maintain sufficient distance from the AP to reduce boundary interference with model calculations, while not extending too far past the extent of available calibration data. The middle of the AP is an approximate topographic high and surface water divide in the model. The model grid and boundary conditions are displayed in **Figure 5-1 through Figure 5-4**.

Evaluation of monitoring well data has not identified statistically significant seasonal trends in groundwater quality which could affect model applicability for prediction of boron transport. The MODFLOW model was calibrated to mean groundwater elevation collected from June 2015 to September 2021 presented in **Table 5-1**. MT3DMS was run on the calibrated flow model and model-simulated concentrations were calibrated to the median observed boron concentration values at the monitoring wells calculated from boron concentrations results from March to July 2021 presented in **Table 5-2**. Multiple iterations of MODFLOW and MT3DMS calibration were performed to achieve an acceptable match to observed flow and transport data. The calibrated flow and transport models were used in predictive modeling to evaluate the CBR closure scenario by removing saturated ash cells and CIP closure scenario by removing ash cells from the northern part and capping ash cells in the southern part as demonstrated in the closure plan. The HELP model is used to estimate recharge values to simulate changes proposed in the closure scenarios.

5.2.1 Grid and Boundary Conditions

A five-layer, 326 x 389 node grid was established with 20 foot grid spacing (**Figure 5-1**). Boundary conditions are illustrated in **Figure 5-2 through Figure 5-4**. The north, south and west edges of the model are bounded by Sangchris Lake. To simulate the lake, a constant head (Dirichlet) boundary was imposed on layer 3. For water in the AP, a constant head boundary was also used. Constant concentration boundary conditions were imposed in layer 1 and a small wedge in northwest of layer 2 upgradient of MW-28. The observed boron concentrations at well MW-28 are two times greater than observed concentrations in other monitoring wells and the porewater samples collected from within the AP (**Table 5-2**). These elevated concentrations in MW-28 suggests that materials with higher concentrations than bottom ash may have been deposited in that area in the past. The historical survey map of 1966 (Appendix A in Ramboll, 2021) shows lower surface elevation extending into the AP footprint from the lake. This low area would have been filled during construction of the AP berm and have been interpreted to contain CCR material with higher boron concentrations than the rest of the AP to match observed elevated concentrations at MW-28.

5.2.2 Flow Model Input Values and Sensitivity

Flow model input values and sensitivity analyses results are presented in **Table 5-3** and described below.

The flow model calibration targets (*i.e.*, mean groundwater elevations from June 2015 to September 2021 and target well locations) are summarized in **Table 5-1**. Groundwater elevations measured at wells MW1, MW-2, MW-9, and MW-10 were not included as flow model calibration targets because they were on the other side of the lake channels and were outside the immediate vicinity of the AP.

Sensitivity analysis was conducted by changing input values and observing changes in the sum of squared residuals. Horizontal and vertical conductivities were varied between one-tenth- and ten-times calibrated values. Recharge terms were varied between one-half and two times calibrated values. When the calibrated model was tested, the sum of squared residuals was 81.1. Sensitivity test results were categorized into negligible, low, moderate, moderately high, and high sensitivity based on the change in the sum of squared residuals as summarized in the notes in **Table 5-3**.

5.2.2.1 Model Layers

Model layer elevations were generated through spatial interpolation of boring log data in Surfer software, with the use of pilot points as needed to maintain consistency with the conceptual site model for each of the five distinct water-bearing units described in **Section 2**. The bottom elevation of the LCU in layer 5 was generated by kriging with pilot points. Its thickness in the model is 50 feet. The contacts between the overlying layers were approximated from hydrostratigraphic unit thicknesses presented in the HCR (Ramboll, 2021a), including the bottom of the fill (ash) layer. The approximate base of ash surface was developed from information presented in the HCR (Ramboll, 2021a). The resulting surfaces were imported as layers into the model to represent the distribution and change in thickness of each water-bearing unit across the model domain.

5.2.2.2 Hydraulic Conductivity

Hydraulic conductivity values and sensitivity results are summarized in **Table 5-3**. When available, these values were derived from field or laboratory measured values reported in the HCR (Ramboll, 2021a). No horizontal anisotropy was assumed. Vertical anisotropy (presented as Kh/Kv in **Table 5-3**) was applied to conductivity zones to simulate preferential flow in the horizontal direction in these materials. Permeability tests discussed in the HCR (Ramboll, 2021a) indicate vertical conductivity values that are generally lower than horizontal.

The spatial distribution of the hydraulic conductivity zones (**Figure 5-5 through Figure 5-9**) in each layer simulates the distribution of hydrostratigraphic units as reported in the HCR (Ramboll, 2021a). The limits of the fill unit hydraulic conductivity zone (zone 1) in the model reflect the limits of the ash fill as presented in the HCR (Ramboll, 2021a). The distribution of other hydraulic conductivity zones was determined through analysis of each of the five distinct water-bearing unit layer surfaces. The USCU and UA are both exhibiting presence of each other's lenses which makes them relatively heterogenous, especially along the western and northern AP boundaries where historical survey map of 1966 (Appendix A in Ramboll, 2021) shows a lower topographic surface elevation extending into the AP footprint from the lake. Based on boring logs and measured hydraulic conductivities, zones of different hydraulic conductivity were defined to improve the flow calibration (**Figure 5-5 and Figure 5-8**).

The model displayed moderately high sensitivity to changes in horizontal conductivity in zones 1 (CCR), 2 (USCU) and 3 (UA), where the model was moderately sensitive to horizontal conductivity in the remaining zones. The model was highly sensitive to changes in vertical conductivity in zones 1 (CCR), 2 (USCU) and 3 (UA), while the model exhibited a low sensitivity in the remaining zones.

5.2.2.3 Recharge

Recharge rates were determined through calibration and spatial distribution of recharge zones were based on the location and type of material present at land surface (**Figure 5-10**). Four different zones were created to simulate recharge in the model area. The recharge occurring through the AP area was split into four different values. The recharge zone of 1.314 (inches per year [in/yr]) corresponds to approximate limits of ash based on the 1995 topographic map, which also matches with the current area of open water. The recharge zone 8.76 (in/yr) corresponds to the approximate extent of CCR present on a 1971 aerial image. The northern zone of 4.38 (in/yr) recharge zone approximates the extent of ash present on a 1983 aerial image and the same recharge rate was used in areas that have been disturbed along the western portion of the pond and south of the pond where the plant is present. The recharge zone of 0.22 (in/yr) represents ambient recharge through the USCU at the land surface and portions of the berms around the AP. In the model, zones with the same recharge rates that are divided by the implementation boundary of CBR and CIP were given different zone numbers for the purpose of calibration runs and closure scenarios setup (i.e. zone 3, 5 and zone 4, 7 and 8)

The model had a high sensitivity to changes in recharge in zones with high recharge rates (zones 4, 7 and 8). The model varied from moderately high to negligible sensitivity to changes in recharge in the remaining zones.

5.2.2.4 Storage and Specific Yield

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

5.2.2.5 Constant Head Boundary

Constant head boundary conditions were used for the lake and water impoundment in the AP area (**Figure 5-4**). Based on digital elevation model (DEM), constant head for the lake is set to 584.35 feet and 603.48 feet for the impoundment inside the AP domain. The flow calibration model had moderately high sensitivity to changes in constant head values.

5.2.3 Transport Model Input Values and Sensitivity

MT3DMS input values are listed in **Table 5-4** and described below. Sensitivity of the transport model is summarized in **Table 5-5**.

The model was calibrated to groundwater boron concentration ranges at each well as measured from June 2015 to September 2021. The transport model calibration targets are summarized in **Table 5-2**.

Sensitivity analysis was conducted by changing input values and observing percent change in boron concentration at each well from the calibrated model boron concentration. Effective porosity was varied by decreasing and increasing calibrated model values by 0.05. Storage values were multiplied and divided by a factor of 10, and specific yield by a factor of 2.

5.2.3.1 Initial Concentrations

No initial concentrations were placed in the calibration model. The flow model was run as transient and concentration was added to the model through constant concentration cells starting at the same time as flow simulation. Modeling was performed for a sufficient period (27.5 years, **Figure 4-1**) to allow modeled concentrations to match currently observed concentrations of boron in groundwater.

5.2.3.2 Source Concentrations

Two concentration sources in the form of constant concentration boundary cells were simulated in fill unit layer 1 and one small wedge of fill in layer 2 upgradient of MW-28 for calibration as discussed in **Section 5.2.1**. The locations of the boundary cells are illustrated in **Figures 5-2 and 5-3** and input values are summarized in **Table 5-4**. Water that comes into contact with CCR in the northern and eastern portions of the AP (constant concentration zones 31, 401 and 402) were given a concentration of 3.1 mg/L. Water that comes into contact with CCR in the western and southern portion of the AP (constant concentration zones 351 and 352) was given a concentration of 3.5. The observed boron concentrations at well MW-28 are two times greater than observed concentrations in other monitoring wells and the porewater samples collected from within the AP (**Table 5-2**). These elevated concentrations in MW-28 suggest that materials with higher concentrations than bottom ash may have been deposited in that area in the past. The historical survey map of 1966 (Appendix A in Ramboll, 2021) shows a lower topographic surface elevation extending into the AP footprint from the lake. This low area would have been filled during construction of the AP berm and has been interpreted to contain fill/CCR material with higher boron concentrations than the rest of the AP to match observed elevated concentrations at MW-28. All sources were simulated by assigning constant concentration cells placed in layer 1 and layer 2 to simulate saturated ash conditions. From the model perspective, this means that when the simulated water level is above the base of these cells, water that passes through the cell will take on the assigned concentration. All source concentrations were calibrated to the boron concentration data collected in from 2015 to 2021.

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

5.2.3.3 Effective Porosity

Effective porosity for each modeled hydrostratigraphic unit were calibrated in the model and derived from literature values, 0.21 for silt and clay, 0.25 for sand, silt and gravel and 0.1 for clay from Morris and Johnson (1967) and Heath (1983) and presented in **Table 5-4**.

The model had a negligible to high sensitivity to changes in porosity values, not including monitoring location where the calibration concentration was 0.0 mg/L (i.e., MW-8S) (**Table 5-5**). The greatest sensitivity for porosity was high for the low porosity sensitivity test at monitoring locations MW-8, MW-20 and MW-20S. Computed concentrations is these locations are very small (1.2E-3 to 2.3E-3 mg/L) and are prone to numerical errors and therefore their high sensitivity can be considered over-predicted.

5.2.3.4 Storage and Specific Yield Sensitivity

The model had negligible sensitivity to changes in storage and specific yield values (**Table 5-5**).

5.2.3.5 Dispersivity

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

Dispersivity values were applied to the entire model domain and determined during calibration. Longitudinal dispersivity was set at 5 feet. The transverse and vertical dispersivity were set at 1/10 and 1/100 of longitudinal dispersivity. These input values were determined during model calibration. With an approximate travel distance of 50 feet for groundwater from the source to the receiving body of water, the model is not expected to be sensitive to dispersivity inputs and the sensitivity of the model to dispersivity was not tested.

5.2.3.6 Retardation

It was assumed that boron would not significantly sorb or chemically react with aquifer solids (distribution coefficient [Kd] was set to 0 mL/g) which is a conservative estimate for estimating contaminant transport times. Boron, sulfate, and TDS transport is likely to be affected by both chemical and physical attenuation mechanisms (i.e., adsorption and/or precipitation reactions as well as dilution and dispersion). Batch adsorption testing was conducted to generate site specific partition coefficient results for boron and sulfate (Golder, 2022, **Appendix B**) for locations MW-12S and MW-28. Results of the testing are summarized below:

- Boron: Calculated linear partition coefficient (K_D) values for MW-12S and MW-28 were 0.05 and 1.81 liters per kilogram (L/kg), respectively. Langmuir partition coefficient (K_L) values were 1.4×10^6 and -1.5×10^4 L/kg, respectively. Freundlich partition coefficients (K_F) values were 112 and 27.5 L/kg, respectively. For comparison, in Strenge and Peterson (1989) the partition coefficients for boron range from 0.19 to 1.3 L/kg, depending on pH conditions and the amount of sorbent (*i.e.*, clay, organic matter, and iron and aluminum oxyhydroxide) present.

- Sulfate: Calculated K_D values for MW-12S and MW-28 were 0.23 and 15.5 L/kg, respectively. K_L values were 454 and -750 L/kg, respectively. K_F values were 1.87 and 0.13 L/kg, respectively. In Strenge and Peterson (1989), partition coefficients for sulfate are 0.0 L/kg, regardless of pH conditions and the amount of sorbent present.

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

5.3 Flow and Transport Model Assumptions and Limitations

Simplifying assumptions were made while developing this model:

- Leading up to 2022, the groundwater flow system can be simulated as steady state.
- Natural recharge is constant over the long term.
- No fluctuations are assumed for the lake stage.
- Hydraulic conductivity is consistent within hydrostratigraphic zones
- The approximate base of ash surface was developed from information presented in the HCR (Ramboll, 2021a).
- Observed concentrations in groundwater exhibit no long-term trend.
- Source concentrations are assumed to remain constant over time.
- Boron is not adsorbed and does not decay, and mixing and dispersion are the only attenuation mechanisms.

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

5.4 Calibration Flow and Transport Model Results

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

Flow model calibration results are presented in **Figure 5-11 through Figure 5-18**. The mass balance error for the flow model was -0.02 percent and the ratio of the residual standard deviation to the range was 8.0 percent; these values are within the targets for these criteria of 1 percent and 10 percent, respectively. Another flow model calibration goal is that residuals are evenly distributed such that there is no bias affecting modeled flow. The observed heads are plotted versus the simulated heads in **Figure 5-16**. The near-linear relationship between observed and simulated values indicates that the model adequately represents the calibration dataset. The residual mean was -0.08 feet and absolute residual mean was 1.31 feet; in general the simulated residuals were evenly distributed above and below the observed values as presented in **Figure 5-17**.

The range of observed boron concentrations in 2021 for transport calibration locations are summarized in **Table 5-2**. The goals of the transport model calibration were to have predicted concentrations fall within the range of observed concentrations, and/or have predicted concentrations above and below the GWPS for boron (2 mg/L) match observed concentrations above or below the standard at each well. One or both of these goals were achieved at all but 8 of the transport calibration location wells, including MW-5, MW-7, MW-12S, MW-23, MW-24, MW-27, MW-29, and MW-31S (**Figure 5-18**). Deviations from the observed ranges are discussed below.

- Simulated concentration at UA well MW-23 (0.72 mg/L) was slightly less than the observed minimum of 0.93. The median observed boron concentration at MW-23 is equal to the GWPS of 2.0 mg/L, so the simulated concentration below 2.0 mg/L was not far off the calibration goals. This is the only calibration location to not meet both goals where simulated concentration was lower than observed.
- Co-located wells are challenging to simulate accurately unless very detailed vertical discretization is being implemented in the model, which will cost performance and run time issues. Well MW-12S in the USCU did not meet the calibration goals because the simulated concentration (2.65 mg/L) is slightly above the observed maximum concentration of 2.63 mg/L and is also above the median observed concentration of 1.51 mg/L. The elevated concentrations in this well are acceptable because accurate calibration to UA well MW-12 (one of the UA wells with the highest observed boron concentrations) was a greater priority for calibration than wells MW-12S and MW-12D, which are nested in lower permeability materials at the same location. The model simulates MW-12 very accurately, which results in over simulation of concentrations at MW-12S and MW-12D. Over simulation of concentrations in these wells is also more conservative given the objectives of the modeling to estimate time to reach the GWPS (*i.e.,* there is more boron mass to be removed in the modeled system leading to longer predicted timelines to reach the GWPS).
- Similarly, the model simulates higher concentrations of boron (2.12 mg/L) at UA well MW-7 because the model was calibrated to simulate elevated boron concentrations observed in USCU well MW-7S at the same location. To be conservative, the model was calibrated to meet the goals at the nested well with higher observed concentrations.
- Wells MW-5 and MW-31S have simulated concentrations that are greater than observed and greater than the GWPS of 2.0 mg/L along the northern berm of the AP. These wells are in close proximity to the modeled source areas. Other wells along this berm met the calibration goals; over simulation in these wells makes the model more conservative.
- Similarly, wells MW-24, MW-27, and MW-29 have simulated concentrations that are greater than observed and greater than the GWPS of 2.0 mg/L along the eastern and southern berm. These wells are in close proximity to the source areas and other wells located on either side of these locations met the calibration goals. Over simulation of boron concentration in these wells makes the model more conservative.

The remaining calibration locations had predicted concentrations that fall within the range of observed concentrations and/or have predicted concentrations above and below the GWPS for boron (2.0 mg/L) that match observed concentrations above or below the standard at each well. MW-28, located downgradient of the CCR unit, where the highest concentrations downgradient of the CCR unit were observed, was also calibrated near the median concentration of the observed values from June 2015 to September 2021. Similarly, MW-12 was calibrated near the median concentration of observed values. The calibration result for wells MW-28 and MW-12 indicate the transport calibration model was able to simulate the highest observed concentrations downgradient of the AP in the UA.

The simulated extents of boron concentrations greater than the GWPS (2.0 mg/L) are presented by layer in **Figures 5-19 to 5-22**. Boron exceedances are in close proximity to the limits of the

Ash Pond with the exception of areas to the west, where the plume is simulated as present beneath Sangchris Lake.

6. SIMULATION OF CLOSURE SCENARIOS

6.1 Overview and Prediction Model Development

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

- Define ash fill material removal and consolidation areas based on designs provided in the CCR Surface Impoundment Final Closure Plan (Burns & McDonnell, 2022).
- A 1-year dewatering period to remove free liquids was simulated in MODFLOW 2005 and MT3DMS where heads were reduced within the CCR unit using constant heads and concentrations were removed from CCR removal areas.
- In the two closure scenarios, HELP-calculated average annual percolation rates were developed from a 30-year HELP model run. This 30-year HELP-calculated percolation rate remained constant over duration of the closure scenario prediction model runs following CBR.
- Changes in recharge resulting from dewatering (assumed decrease calibration model recharge rates by 90 percent) and ash fill removal/ ash consolidation areas (recharge rates are based on HELP-calculated average annual percolation rates) have an instantaneous effect on recharge and percolation through surface materials.
- Boron source concentrations were assumed to remain constant as a function of time following the end of the calibration simulation in the ash consolidation area. Boron concentration in the ash fill removal areas was assumed to be 0 mg/L following construction to simulate removal of ash.
- The start of each closure prediction simulation was initiated at the end of the calibration model period of 27.5 years plus 1 year to complete dewatering and closure. The prediction modeling timeline for each scenario is illustrated in **Figure 4-1**.
- Ash fill removal areas were assumed to be graded following placement of soil backfill based on the design drawings provided in the CCR Surface Impoundment Final Closure Plan (Burns & McDonnell, 2022).
- Apply drain cells (drain input parameters approximated designs provided in CCR Surface Impoundment Final Closure Plan) to simulate storm water management within CCR removal areas following closure.
- All saturated ash (constant concentration cells) in the transport calibration model were removed instantaneously in all prediction models following ash fill removal/final soil backfill grading. Local fill materials assumed to be sourced from surrounding USCU materials (clay) replaced ash fill in areas of removal.
- Local fill materials applied to the prediction models have similar hydraulic properties as the USCU materials used in the transport calibration models.

6.2 HELP Model Setup and Results

HELP (Version 4.0; Tolaymat and Krause, 2020) was used to estimate percolation through the AP areas for two ash fill removal scenarios. HELP input and output files are included electronically and attached to this report.

HELP input data and results are provided in **Table 5-6**. All scenarios were modeled for a period of 30 years. Climatic inputs were synthetically generated using default equations developed for Springfield, Illinois (the closest weather station included in the HELP database). Precipitation, temperature, and solar radiation was simulated based on the latitude of the Ash Pond. Thickness of soil backfill and soil runoff input parameters were developed for the ash fill removal scenarios using data provided the CCR Surface Impoundment Final Closure Plan (Burns & McDonnell, 2022).

HELP model results (**Table 5-6**) indicated 5.83 inches of percolation per year for the Ash Pond closure by removal and backfill area, 5.82 inches of percolation per year for the Ash Pond closure in place removal and backfill area, and 0.0041 inches of percolation per year for the Ash Pond closure in place consolidation and cover system area. The differences in HELP model runs for each area included the following parameters: area, soil backfill thickness, and soil runoff slope length; all other HELP model input parameters were the same for each simulated area.

Two additional HELP model simulations were completed to support the *Proposed Alternative Final Protective Layer Equivalency Demonstration*, (Geosyntec, 2022) which is an appendix to the Construction Permit Application to which this report is also attached. Results of these two HELP simulations were not incorporated in the MODFLOW simulations for closure. Simulation inputs and output results are presented in **Appendix C**.

6.3 Simulation of Closure Scenarios

The calibrated model was used to evaluate the effectiveness of the two closure scenarios by decreasing recharge to simulate dewatering of the ash fill prior to removal, applying drains to simulate stormwater management, and changing recharge rates to simulate ash fill removal areas at the AP. Removal of leachate inputs from the ash removal areas (source control) was simulated by deactivation constant concentration cell.

Each prediction scenario was started after the 1-year dewatering simulation to remove free liquids from the AP (27.5 years calibration plus 1 year of dewatering). The prediction model input values are summarized in **Table 6-2** and changes to the recharge zones for ash removal and consolidation areas and placement of drain for stormwater management for each closure scenario are illustrated in **Figures 6-1 and 6-2**. The two closure scenarios are discussed in this report based on predicted changes in boron concentrations as described below.

6.3.1 Closure Scenario 1 (CIP) Predicted Boron Concentrations

The design for Scenario 1: CIP includes CCR removal from the north and west areas of the AP, consolidation to the central and southeast portions of the AP, and construction of a cover system over the remaining CCR.

Predicted concentrations start to decline within approximately 2 years (**Figure 6-3**). These declines occur as recharge is reduced from dewatering. As a result of dewatering, downward percolation of solute mass from the AP is reduced, which decreases the boron concentration entering the model domain. The southern part of the AP was capped with a cover system which further reduces recharge and decreases the amount of boron mass entering the model domain. At all downgradient wells in the UA and USCU, concentrations in Scenario 1: CIP were predicted to decrease rapidly following initial dewatering and completion of closure construction (**Figure 6-3**).

At well MW-23, the model indicates concentrations will continue to increase for a brief period of time following closure construction before concentrations decrease. MW-28 shows the highest concentration and it falls below the GWPS for boron approximately 17 years after closure construction, at which time concentrations in all wells are predicted to be below the GWPS. Boron is predicted to decrease below the GWPS in all wells approximately 17 years after implementation of CIP.

Residual boron concentrations at approximately 17 years are presented in **Figures 6-4 through 6-7**. Note that boron is not present in layer 5 of the calibrated or prediction models so there are no figures of boron concentrations in model layer 5. By year 17, the residual boron plume has significantly receded when compared to the calibrated model plume (**Figures 5-19 to 5-22**).

Evaluations of post-construction water flux through the consolidated and covered Fill Unit (CCR) were completed using data obtained from the Scenario 1 (CIP) prediction model when simulated post-construction heads in the groundwater monitoring wells are predicted to stabilize (once heads stabilized in the model, the post-construction movement of water in and out of the Fill Unit [CCR] were compared to pre-construction conditions). The pre-construction (calibration model) and post-construction Scenario 1 (CIP) prediction model simulated water flux values are summarized in **Appendix D** and discussed below. Data export files used for flux evaluations are found along with model files in **Appendix A**.

Scenario 1 (CIP) was predicted to reduce both total flux in and out of the Fill Unit (CCR) by greater than 99% when simulated post-construction heads in the groundwater monitoring wells are predicted to stabilize (approximate hydraulic steady state) as illustrated in **Figure 6-8**. **Figure 6-9** is a plot showing the changes in flux reduction (shown as negative percentage) over time, starting from implementation of Scenario 1 (CIP) through approximate hydraulic steady state conditions. Following implementation of Scenario 1 (CIP), influx to the CCR unit decreases rapidly as illustrated in **Figure 6-9**. Concurrently, outflux from the CCR unit decreases rapidly and after approximately 21.5 years decreases by over 99%. The reduction of outflux of at least 99% is maintained as heads approach hydraulic stabilization (**Figure 6-9**).

Further, the base of consolidated CCR was compared to the simulated steady-state groundwater elevations and results indicate up to 10 feet of separation will be present between the base of CCR and groundwater (**Figure 6-10**).

6.3.2 Closure Scenario 2 (CBR) Predicted Boron Concentrations

The design for Scenario 2: CBR includes removal of all CCR. Predicted concentrations start to decline rapidly following closure (**Figure 6-11**). These declines occur as recharge is reduced from dewatering and constant concentration cells are removed to simulate removal of CCR. The decrease of concentration in the CBR scenario is slightly faster than the CIP scenario because in the CBR scenario all the fill material is being removed from the site. However, the decline in concentration in wells located north of the AP is almost identical with the CIP scenario, where ash is removed for consolidation. Following CBR, boron concentrations are no longer entering the model domain from recharge or from saturated ash cells (constant concentration cells). A very similar pattern of concentration decrease is observed in MW-23, where concentration starts to increase initially but then declines. The simulated increase of concentration at MW-23 is slightly less in the CBR scenario due to the absence of the consolidation and cover system which has lower recharge rates in the CIP scenario. MW-28 with the highest concentration falls below the GWPS for boron approximately 16.5 years after closure. Boron is also predicted to decrease below the GWPS in all wells approximately 16.5 years after implementation of CBR.

Residual boron concentrations after approximately 16.5 years are presented in **Figures 6-12 through 6-15**. Note that boron is not present in layer 5 of the calibrated or prediction models, so there are no figures of boron concentrations in model layer 5. By year 16.5 the residual boron plume has significantly receded when compared to the calibrated model plume (**Figures 5-19 to 5-22**). When compared to CIP (**Figures 6-4 to 6-7**) the residual boron plumes show similar distribution of boron greater than 2 mg/L. Differences are present in layers 2, 3, and 4 of the CIP scenario, where boron is present within the footprint of the AP near the area of CCR consolidation due to the lower infiltration rates beneath the cover system. In both scenarios residual boron exceedances remain in close proximity to the ash pond and/or calibrated extent of exceedances as the plumes recede.

From a modeling perspective, the difference between the predicted time to reach the GWPS for boron (2 mg/L) in Scenario 1 (17 years) versus Scenario 2 (16.5 years) is negligible. In other words, both scenarios are predicted to reach the GWPS after approximately 17 years.

7. CONCLUSIONS

This GMR has been prepared to evaluate how proposed closure scenarios will achieve compliance with the applicable groundwater standards at the KPP. Data collected from the 2021 field investigation were used to develop a groundwater model for the AP. Statistically significant correlations between boron concentrations and concentrations of other parameters identified as potential exceedances of the GWPS indicate boron is an acceptable surrogate for sulfate and TDS in the groundwater model. It was assumed that boron would not significantly sorb or chemically react with aquifer solids (soil adsorption coefficient [Kd] was set to 0 milliliters per gram [mL/g]) which is a conservative estimate for predicting contaminant transport times. 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). MODFLOW and MT3DMS models were then used to evaluate two closure scenarios:

- Scenario 1: CIP (CCR removal from the north and west areas of the AP, consolidation to the central and southeast portions of the AP, and construction of a cover system over the remaining CCR); and,
- Scenario 2: CBR (CCR removal from the AP)

Scenario 1 (CIP) was predicted to reduce both total flux in and out of the Fill Unit (CCR) by greater than 99% when simulated post-construction heads in the groundwater monitoring wells are predicted to stabilize.

Prior to the simulation of these scenarios, a dewatering simulation was included for the removal of free liquids from the AP prior to the implementation of the two scenarios. Predictive simulations of closure conservatively indicate groundwater in the UA will achieve the GWPS in site monitoring wells for Scenarios 1 and 2 in 17 and 16.5 years after implementation of the closure scenarios, respectively. From a modeling perspective, the difference between the predicted time to reach the GWPS for boron (2 mg/L) in Scenario 1 (17 years) versus Scenario 2 (16.5 years) is negligible. In other words, both scenarios are predicted to reach the GWPS after approximately 17 years, the simulated difference between these two scenarios is not significant.

Results of groundwater fate and transport modeling estimate that groundwater will attain the GWPS for all constituents identified as potential exceedances of the GWPS within 17 years of closure implementation for both Scenarios. In both scenarios residual boron exceedances from the calibrated model remain in close proximity to the ash pond and/or calibrated extent of exceedances as the plumes recede.

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TABLES

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

Well Number	HSU	Date Constructed	Top of PVC Elevation (ft)	Measuring Point Elevation (ft)	Measuring Point Description	Ground Elevation (ft)	Screen Top Depth (ft BGS)	Screen Bottom Depth (ft BGS)	Screen Top Elevation (ft)	Screen Bottom Elevation (ft)	Well Depth (ft BGS)	Bottom of Boring Elevation (ft)	Screen Length (ft)	Screen Diameter (inches)	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)
MW-1	UA	04/20/2010	604.71	604.71	Top of PVC	602.60	15.00	25.00	587.60	577.60	25.00	568.10	10	2	39.592051	-89.490283
MW-2	UA	04/21/2010	601.10	601.10	Top of PVC	598.88	10.00	20.00	588.90	578.90	20.00	541.40	10	2	39.590698	-89.488916
MW-3	UA	04/15/2010	601.46	601.46	Top of PVC	599.24	14.00	24.00	585.20	575.20	24.00	552.70	10	2	39.594458	-89.487173
MW-4	UA	04/14/2010	600.88	600.88	Top of PVC	598.46	12.00	22.00	586.50	576.50	22.00	560.50	10	2	39.600751	-89.487354
MW-5	UA	04/22/2010	619.44	619.44	Top of PVC	617.77	30.00	40.00	587.80	577.80	40.00	541.80	10	2	39.601296	-89.490402
MW-6	UA	04/16/2010	600.46	600.46	Top of PVC	598.44	10.00	20.00	588.40	578.40	20.00	572.90	10	2	39.598638	-89.498944
MW-7	UA	04/16/2010	597.75	597.75	Top of PVC	596.00	10.00	20.00	586.00	576.00	20.00	569.50	10	2	39.597637	-89.498959
MW-7S	USCU	02/02/2021	597.64	597.64	Top of PVC	595.59	6.00	11.00	589.59	584.59	11.00	580.59	5	2	39.59766	-89.498978
MW-8	UA	04/13/2010	603.14	603.14	Top of PVC	601.14	12.00	22.00	589.10	579.10	22.00	563.10	10	2	39.594399	-89.496829
MW-8S	USCU	02/02/2021	603.30	603.30	Top of PVC	600.57	4.00	7.00	596.57	593.57	7.00	580.57	3	2	39.594381	-89.496822
MW-9	UA	04/19/2010	599.39	599.39	Top of PVC	597.63	10.00	20.00	587.60	577.60	20.00	573.10	10	2	39.595204	-89.500968
MW-10	UA	04/19/2010	600.11	600.11	Top of PVC	598.22	10.00	20.00	588.20	578.20	20.00	575.20	10	2	39.590652	-89.503745
MW-11	UA	06/17/2015	601.81	601.81	Top of PVC	599.27	11.00	21.00	588.30	578.30	21.00	578.30	10	2	39.593104	-89.491115
MW-11S	USCU	01/26/2021	601.76	601.76	Top of PVC	599.43	4.00	8.00	595.43	591.43	8.00	591.43	4	2	39.593122	-89.491102
MW-12	UA	07/23/2015	591.40	591.40	Top of PVC	589.04	15.00	25.00	573.90	563.90	25.00	563.90	10	2	39.600208	-89.496381
MW-12S	USCU	01/27/2021	591.10	591.10	Top of PVC	588.62	5.00	9.00	583.62	579.62	9.00	579.12	4	2	39.600208	-89.496412
MW-12D	BCU	01/26/2021	590.96	590.96	Top of PVC	589.08	50.00	55.00	539.08	534.08	55.00	489.08	5	2	39.600194	-89.496418
MW-20	UA	01/26/2021	600.77	600.77	Top of PVC	598.52	14.00	24.00	584.52	574.52	24.00	547.52	10	2	39.598653	-89.48728
MW-20S	USCU	01/26/2021	600.64	600.64	Top of PVC	598.43	4.00	10.00	594.43	588.43	10.00	588.43	6	2	39.598665	-89.487279
MW-22	UA	02/03/2021	601.77	601.77	Top of PVC	599.51	15.00	19.00	584.51	580.51	19.00	579.51	4	2	39.593235	-89.487638
MW-23	UA	02/02/2021	610.32	610.32	Top of PVC	608.05	23.00	28.00	585.05	580.05	28.00	558.05	5	2	39.593293	-89.489352
MW-24	UA	02/02/2021	615.48	615.48	Top of PVC	613.01	27.00	32.00	586.01	581.01	32.00	581.01	5	2	39.593271	-89.493267
MW-25	USCU	02/02/2021	607.20	607.20	Top of PVC	604.60	9.00	14.00	595.60	590.60	14.00	579.60	5	2	39.594397	-89.495062

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Well Number	HSU	Date Constructed	Top of PVC Elevation (ft)	Measuring Point Elevation (ft)	Measuring Point Description	Ground Elevation (ft)	Screen Top Depth (ft BGS)	Screen Bottom Depth (ft BGS)	Screen Top Elevation (ft)	Screen Bottom Elevation (ft)	Well Depth (ft BGS)	Bottom of Boring Elevation (ft)	Screen Length (ft)	Screen Diameter (inches)	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)
MW-26	UA	02/02/2021	596.16	596.16	Top of PVC	593.33	7.00	12.00	586.33	581.33	12.00	573.33	5	2	39.595584	-89.497582
MW-27	USCU	02/02/2021	600.05	600.05	Top of PVC	597.35	10.00	15.00	587.35	582.35	15.00	577.35	5	2	39.596694	-89.497927
MW-28	UA	02/02/2021	601.40	601.40	Top of PVC	598.33	12.00	22.00	586.33	576.33	22.00	573.33	10	2	39.599258	-89.497962
MW-29	UA	02/01/2021	599.94	599.94	Top of PVC	596.86	14.00	19.00	582.86	577.86	19.00	576.86	5	2	39.599691	-89.497249
MW-30	UA	02/03/2021	618.47	618.47	Top of PVC	616.00	35.00	40.00	581.00	576.00	40.00	571.00	5	2	39.601262	-89.493996
MW-31	UA	02/03/2021	617.34	617.34	Top of PVC	615.02	35.00	40.00	580.02	575.02	40.00	565.02	5	2	39.601301	-89.491702
MW-31S	USCU	02/03/2021	617.54	617.54	Top of PVC	615.13	25.00	30.00	590.13	585.13	30.00	585.13	5	2	39.601303	-89.491681
MW-32	UA	02/03/2021	619.49	619.49	Top of PVC	617.20	32.00	37.00	585.20	580.20	37.00	577.20	5	2	39.601279	-89.488643
PZ-4C	UA	03/30/2016	600.57	600.57	Top of PVC	597.89	15.50	20.50	582.39	577.39	20.50	577.39	5	2	39.596398	-89.487207
XPW01	CCR	02/01/2021	627.84	627.84	Top of PVC	625.48	22.00	32.00	603.48	593.48	32.00	593.48	10	2	39.594417	-89.493104
XPW02	CCR	01/26/2021	620.19	620.19	Top of PVC	617.91	13.00	23.00	604.91	594.91	23.00	595.91	10	2	39.597918	-89.49687
XPW03	CCR	01/26/2021	616.08	616.08	Top of PVC	616.08	10.00	20.00	606.08	596.08	20.00	596.08	10	2	39.599588	-89.495765
XPW04	CCR	01/26/2021	606.53	606.53	Top of PVC	604.57	13.00	23.00	591.57	581.57	23.00	580.57	10	2	39.600737	-89.492276
XSG-01	CCR	--	--	608.43	Staff gauge	--	--	--	--	--	--	--	--	--	39.593401	-89.48768
SG-02	SW	--	--	564.80	Staff gauge	--	--	--	--	--	--	--	--	--	39.593106	-89.498155

Notes:
All elevation data are presented relative to the North American Vertical Datum 1988 (NAVD88), GEOID 12A
-- = data not available
BCU = bedrock confining unit
BGS = below ground surface
CCR = Coal Combustion Residual
ft = foot or feet
HSU = Hydrostratigraphic Unit
PVC = polyvinyl chloride
SW = surface water
UA = uppermost aquifer
USCU = upper semi-confining unit

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TABLE 5-1. FLOW MODEL CALIBRATION TARGETS

GROUNDWATER MODELING REPORT

KINCAID POWER PLANT

ASH POND

KINCAID, ILLINOIS

Well Name	Easting	Northing	HSU	Flow Targets							
				Number of Samples	median GWL[1] (feet)	mean GWL[1] (feet)	std dev GWL[1] (feet)	min GWL[1] (feet)	max GWL[1] (feet)	Earliest Sample Date	Latest Sample Date
MW-1	2487193	1065989	UA	33	589.6	589.0	2.7	587.6	604.7	06/16/2015	09/01/2021
MW-2	2487582	1065499	UA	33	594.6	594.9	1.5	592.4	601.1	06/16/2015	09/01/2021
MW-4	2487995	1069164	UA	30	593.4	593.4	1.1	590.8	597.1	12/14/2015	09/01/2021
MW-5	2487135	1069356	UA	32	593.8	594.1	4.6	590.6	619.4	06/16/2015	09/01/2021
MW-6	2484735	1068370	UA	33	592.2	592.0	2.3	588.2	600.5	06/16/2015	09/01/2021
MW-7	2484734	1068005	UA	35	589.2	589.5	3.1	586.6	597.8	06/17/2015	09/01/2021
MW-7S	2484728.09	1068011.16	USCU	11	587.3	587.2	0.2	587.1	587.9	02/23/2021	08/11/2021
MW-8	2485342	1066831	UA	34	594.7	595.5	2.0	593.2	603.1	06/17/2015	09/01/2021
MW-8S	2485344.57	1066821.52	USCU	8	594.9	595.0	1.0	593.9	597.5	02/23/2021	06/10/2021
MW-9	2484174	1067115	UA	27	590.2	590.7	3.7	583.2	596.8	12/14/2015	09/01/2021
MW-10	2483403	1065451	UA	27	588.2	588.7	2.0	585.0	592.3	12/14/2015	09/01/2021
MW-11	2486956	1066371	UA	30	590.2	590.2	0.3	589.9	591.7	12/14/2015	09/01/2021
MW-12	2485452.88	1068944.67	UA	30	585.1	584.1	0.6	583.2	586.6	12/14/2015	09/01/2021
MW-12S	2485444.27	1068944.79	USCU	11	585.4	584.8	0.6	584.8	587.2	02/23/2021	08/11/2021
MW-12D	2485442.58	1068939.69	LCU	11	586.2	584.6	0.9	584.6	587.2	02/23/2021	08/11/2021
MW-20	2488021.74	1068397.57	UA	11	595.1	594.8	1.2	594.2	598.9	02/23/2021	08/10/2021
MW-20S	2488021.76	1068402.07	USCU	11	595.0	594.8	1.2	594.2	599.1	02/23/2021	08/10/2021
MW-22	2487935.62	1066423.38	UA	11	595.7	596.1	0.7	594.9	597.5	02/23/2021	08/10/2021
MW-23	2487452.37	1066440.78	UA	11	594.0	594.2	0.6	593.5	595.9	02/23/2021	08/10/2021
MW-24	2486349.15	1066424.59	UA	10	593.4	592.2	1.1	590.5	594.4	02/23/2021	07/22/2021
MW-25	2485840.34	1066830.95	USCU	11	601.2	601.4	5.0	584.0	602.1	02/23/2021	08/11/2021
MW-26	2485127.12	1067258.09	UA	11	589.0	588.9	2.2	585.0	592.5	02/23/2021	08/10/2021
MW-27	2485026.71	1067661.72	USCU	11	586.1	586.1	3.2	583.4	594.4	02/23/2021	08/11/2021
MW-28	2485010.02	1068595.29	UA	11	595.4	595.4	1.0	593.5	597.6	02/23/2021	08/11/2021

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TABLE 5-1. FLOW MODEL CALIBRATION TARGETS

GROUNDWATER MODELING REPORT

KINCAID POWER PLANT

ASH POND

KINCAID, ILLINOIS

Well Name	Easting	Northing	HSU	Flow Targets							
				Number of Samples	median GWL[1] (feet)	mean GWL[1] (feet)	std dev GWL[1] (feet)	min GWL[1] (feet)	max GWL[1] (feet)	Earliest Sample Date	Latest Sample Date
MW-29	2485209.8	1068754.64	UA	11	595.7	595.7	0.6	594.9	597.1	02/23/2021	08/11/2021
MW-30	2486122	1069336	UA	11	594.0	594.0	0.6	593.4	595.7	02/23/2021	08/10/2021
MW-31	2486768.38	1069352.71	UA	11	587.9	587.7	2.0	586.7	594.2	02/23/2021	08/10/2021
MW-31S	2486774.19	1069353.41	USCU	11	590.9	591.2	1.5	588.3	592.8	02/23/2021	08/10/2021
MW-32	2487630	1069354	UA	11	596.9	596.9	0.7	596.1	598.7	02/23/2021	08/10/2021
XPW01	2486392.09	1066842.23	CCR	11	603.4	603.5	0.1	603.1	603.5	02/23/2021	08/11/2021
XPW02	2485321.31	1068109.66	CCR	11	603.8	603.8	0.1	603.5	603.9	02/23/2021	08/11/2021
XPW03	2485628.19	1068720.21	CCR	11	601.0	601.0	0.2	600.8	601.6	02/23/2021	08/11/2021
XPW04	2486608.19	1069145.99	CCR	11	603.2	603.4	0.2	602.8	603.4	02/23/2021	08/10/2021

[O: PR 05/05/22; C: EGP 5/6/22]

Notes:

[1] Groundwater Elevation
std dev = standard deviation from the mean
min = minimum
max = maximum

HSU: Hydrostratigraphic Unit
CCR = coal combustion residual
USCU = upper semi-confining unit
UA = uppermost aquifer
LCU = lower confining unit

TABLE 5-2. TRANSPORT MODEL CALIBRATION TARGETS

GROUNDWATER MODELING REPORT

KINCAID POWER PLANT

ASH POND

KINCAID, ILLINOIS

				Transport Targets							
Well Name	**Easting**	**Northing**	**HSU**	**Number of Samples**	**median Boron (mg/L)**	**mean Boron (mg/L)**	**std dev Boron (mg/L)**	**min Boron (mg/L)**	**max Boron (mg/L)**	**Earliest Sample Date**	**Latest Sample Date**
MW-3	2488063	1066873	UA	20	1.62	1.68	0.28	1.02	2.40	06/03/2015	08/10/2021
MW-4	2487995	1069164	UA	17	0.57	0.57	0.12	0.34	0.84	06/03/2015	06/09/2021
MW-5	2487135	1069356	UA	24	0.55	0.55	0.04	0.47	0.66	06/04/2015	09/01/2021
MW-6	2484735	1068370	UA	24	1.06	1.11	0.33	0.63	1.91	06/04/2015	09/01/2021
MW-7	2484734	1068005	UA	24	0.26	0.28	0.14	0.10	0.65	06/04/2015	09/01/2021
MW-7S	2484728.09	1068011.16	USCU	8	4.03	4.33	0.75	3.56	5.51	02/24/2021	08/11/2021
MW-8	2485342	1066831	UA	24	1.01	1.03	0.13	0.86	1.51	06/04/2015	09/01/2021
MW-8S	2485344.57	1066821.52	USCU	4	1.04	0.98	0.14	0.74	1.10	02/24/2021	05/21/2021
MW-9	2484174	1067115	UA	13	0.10	0.10	0.03	0.06	0.18	06/04/2015	06/10/2021
MW-11	2486956	1066371	UA	23	1.65	1.65	0.21	1.34	2.28	12/15/2015	09/01/2021
MW-12	2485452.88	1068944.67	UA	23	2.78	2.87	0.65	1.95	4.42	12/15/2015	09/01/2021
MW-12S	2485444.27	1068944.79	USCU	8	1.51	1.60	0.52	0.86	2.63	02/25/2021	08/11/2021
MW-12D	2485442.58	1068939.69	LCU	8	0.84	0.86	0.10	0.71	1.08	02/25/2021	08/11/2021
MW-20	2488021.74	1068397.57	UA	8	0.45	0.46	0.06	0.34	0.56	02/26/2021	08/10/2021
MW-20S	2488021.76	1068402.07	USCU	8	1.29	1.24	0.50	0.06	1.89	02/26/2021	08/10/2021
MW-22	2487935.62	1066423.38	UA	4	1.46	1.48	0.04	1.44	1.55	02/26/2021	05/18/2021
MW-23	2487452.37	1066440.78	UA	8	2.00	1.96	0.45	0.93	2.67	02/26/2021	08/10/2021
MW-24	2486349.15	1066424.59	UA	--	--	--	--	--	--	--	--
MW-25	2485840.34	1066830.95	USCU	5	1.08	1.09	0.04	1.04	1.14	02/25/2021	08/11/2021
MW-26	2485127.12	1067258.09	UA	4	1.10	1.15	0.10	1.07	1.32	02/25/2021	05/21/2021
MW-27	2485026.71	1067661.72	USCU	8	1.23	1.19	0.24	0.77	1.50	02/24/2021	08/11/2021
MW-28	2485010.02	1068595.29	UA	8	9.49	9.64	0.80	8.35	10.90	02/24/2021	08/11/2021
MW-29	2485209.8	1068754.64	UA	8	1.66	1.72	0.14	1.57	2.01	02/25/2021	08/11/2021
MW-30	2486122	1069336	UA	8	1.19	1.22	0.16	1.06	1.60	02/25/2021	08/10/2021
MW-31	2486768.38	1069352.71	UA	8	0.29	0.29	0.04	0.22	0.37	02/24/2021	08/10/2021

TABLE 5-2. TRANSPORT MODEL CALIBRATION TARGETS

GROUNDWATER MODELING REPORT

KINCAID POWER PLANT

ASH POND

KINCAID, ILLINOIS

				Transport Targets							
Well Name	**Easting**	**Northing**	**HSU**	**Number of Samples**	**median Boron (mg/L)**	**mean Boron (mg/L)**	**std dev Boron (mg/L)**	**min Boron (mg/L)**	**max Boron (mg/L)**	**Earliest Sample Date**	**Latest Sample Date**
MW-31S	2486774.19	1069353.41	USCU	8	0.05	0.05	0.00	0.04	0.06	02/24/2021	08/11/2021
MW-32	2487630	1069354	UA	8	1.65	1.67	0.14	1.44	1.88	02/25/2021	08/10/2021
PZ-4C	1067576.48	2488048.39	UA	8	1.56	1.57	0.17	1.34	1.93	02/25/2021	08/11/2021
XPW01*	2486392.09	1066842.23	CCR	8	1.46	1.40	0.15	1.18	1.58	03/01/2021	08/11/2021
XPW02*	2485321.31	1068109.66	CCR	8	3.73	3.78	0.39	3.11	4.23	03/01/2021	08/11/2021
XPW03*	2485628.19	1068720.21	CCR	8	2.89	3.06	0.46	2.69	4.21	03/02/2021	08/11/2021
XPW04*	2486608.19	1069145.99	CCR	8	1.54	1.68	0.30	1.26	2.28	03/02/2021	08/10/2021

[O: PR 05/05/22; C: EGP 5/6/22]

Notes:

mg/L = milligrams per liter
std dev = standard deviation from the mean
min = minimum
max = maximum
* Porewater samples used for boundary condition estimate and not as target

HSU = Hydrostratigraphic Unit
CCR = coal combustion residuals
USCU = upper semi-confining unit
UA = uppermost aquifer
LCU = lower confining unit

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TABLE 5-3. FLOW MODEL INPUT AND SENSITIVITY ANALYSIS RESULTS

GROUNDWATER MODELING REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Zone	Hydrostratigraphic Unit	Materials	ft/d	cm/s	Kh/Kv	Value Source	Sensitivity[1]
Horizontal Hydraulic Conductivity			**Calibration Model**				
1	CCR	Bottom Ash and boiler slag	243	8.57E-02	NA	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	High
2	USCU	Clay with silt and sand lenses	0.45	1.59E-04	NA	Calibrated - Conductivity Value to Allow Groundwater Flow from UD to Riverand Drain Boundary Conditions	High
3	UA	Sand, silty sand, and clayey sand and gravel	0.5	1.76E-04	NA	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	High
4	LCU	Clay till	4.79	1.69E-03	NA	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	High
5	CL	Clay lens	0.05	1.76E-05	NA	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	High
6	SGL	Sand and gravel lens	25	8.82E-03	NA	Calibrated - Within Range of Field Test Results (Ramboll, 2021a)	Moderately High
Vertical Hydraulic Conductivity[2]			**Calibration Model**				
1	CCR	Bottom Ash and boiler slag	1.20E+01	4.23E-03	20	Calibrated - Within Range Laboratory Test Results and near Geomean of Laboratory Test Results (Ramboll, 2021a)	High
2	USCU	Clay with silt and sand lenses	4.50E-02	1.59E-05	10	Calibrated - Conductivity Value to Allow Groundwater Flow from UD to Riverand Drain Boundary Conditions	High
3	UA	Sand, silty sand, and clayey sand and gravel	5.00E-02	1.76E-05	10	Calibrated - Within Range Laboratory Test Results and near Geomean of Laboratory Test Results (Ramboll, 2021a)	High
4	LCU	Clay till	4.79E-01	1.69E-04	10	Calibrated - Within Range Laboratory Test Results and near Geomean of Laboratory Test Results (Ramboll, 2021a)	High
5	CL	Clay lens	5.00E-03	1.76E-06	10	Calibrated - Within Range Laboratory Test Results and near Geomean of Laboratory Test Results (Ramboll, 2021a)	High
6	SGL	Sand and gravel lens	2.50E+00	8.82E-04	10	Calibrated - Within Range Laboratory Test Results and near Geomean of Laboratory Test Results (Ramboll, 2021a)	Moderately High
Zone	**Hydrostratigraphic Unit**	**Materials**	**ft/d**	**in/yr**	**Kh/Kv**	**Value Source**	**Sensitivity[1]**
Recharge			**Calibration Model**				
1	USCU	Clay with silt and sand lenses	5.00E-05	0.22	NA	Calibrated	Low
2	CCR	Bottom Ash and boiler slag	1.00E-03	4.38	NA	Calibrated	Negligible
3, 5	CCR - 1971/1983 area	Bottom Ash and boiler slag	2.00E-03	8.76	NA	Calibrated	Moderate
6	USCU - developed area	Clay with silt and sand lenses	1.00E-03	4.38	NA	Calibrated	Moderately High
4, 7, 8	CCR - 1995 area	Bottom Ash and boiler slag	3.00E-04	1.31	NA	Calibrated	High
Storage							
1	CCR	Bottom Ash and boiler slag	*Not used in steady-state calibration model*				
2	USCU	Clay with silt and sand lenses					
3	UA	Sand, silty sand, and clayey sand and gravel					
4	LCU	Clay till					

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TABLE 5-3. FLOW MODEL INPUT AND SENSITIVITY ANALYSIS RESULTS
GROUNDWATER MODELING REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Zone	Hydrostratigraphic Unit	Materials		Value Source	Sensitivity[1]
Constant Head					
	Relative Location	**Head (feet)**			
5 (Lake)	Northwest and southern model boundary	*584.35*	---	---	High
4, 6, 7 (Pond)	Inside the Ash Pond domain	603.48			High

[O: PR 5/08/22; C: EGP 5/6/22]

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] For sensitivity analysis vertical conductivities maintained the same anisotropy.
RMSE = root of the mean squared error
--- = not tested
cm/s = centimeters per second
ft/d = feet per day
ft^2/day = feet squared per day
in/yr = inches per year
Kh/Kv = anisotropy ratio
NA = not applicable

Hydrostratigraphic Unit
CCR = coal combustion residuals
USCU = upper semi-confining unit
UA = uppermost aquifer

TABLE 5-4. TRANSPORT MODEL INPUT VALUES (CALIBRATION)
GROUNDWATER MODELING REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Zone	Hydrostratigraphic Unit	Materials	Calibration Model				
			Boron Concentration (mg/L)			Value Source	Sensitivity
Initial Concentration							
Entire Domain	NA	NA	0			NA	- - -
Source Concentration (Constant Concentration Cells)							
			pre-1983	**post 1983**			
351, 352	CCR	Bottom Ash and boiler slog	3.5	--		Boron concentration data from XWP01, XWP02, XWP03 and XWP04 - calibrated	- - -
31, 401, 402	CCR	Bottom Ash and boiler slog	--	3.1		Boron concentration data from XWP01, XWP02, XWP03 and XWP04 - calibrated	- - -
11	USCU	Other high concentration ash materials	14	14		Calibrated to meet MW-28 observed concentration	
Storage, Specific Yield and Effective Porosity			**Calibration Model**				
Zone	**Hydrostratigraphic Unit**	**Materials**	**Storage**	**Specific Yield**	**Effective Porosity**	**Value Source**	**Sensitivity**
1	CCR	Bottom Ash and boiler slog	0.003	0.15	0.15	Calibrated	see Table 5-5
2	USCU	Clay with silt and sand lenses	0.003	0.21	0.21	Calibrated	see Table 5-5
3	UA	Sand, silty sand, and clayey sand and gravel	0.003	0.25	0.25	Calibrated	see Table 5-5
4	LCU	Clay till	0.003	0.1	0.1	Calibrated	see Table 5-5
Dispersivity							
Applicable Region	**Hydrostratigraphic Unit**	**Materials**	**Longitudinal (feet)**	**Transverse (feet)**	**Vertical (feet)**	**Value Source**	**Sensitivity**
Entire Domain	NA	NA	5	0.5	0.05	calibrated	- - -

[O: PR 5/4/22; C: EGP 5/6/22]

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

Hydrostratigraphic Unit
CCR = coal combustion residuals
USCU = upper semi-confining unit
UA = uppermost aquifer

TABLE 5-5. TRANSPORT MODEL INPUT SENSITIVITY (CALIBRATION)
GROUNDWATER MODELING REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

			Storage and Specific Yield				Effective Porosity			
Well ID	HSU	Calibration on Boron Concentration (mg/L)	Boron Concentration (mg/L)	Sensitivity [1]	Boron Concentration (mg/L)	Sensitivity [1]	Boron Concentration (mg/L)	Sensitivity [1]	Boron Concentration (mg/L)	Sensitivity [1]
MW-3	UA	0.20	0.20	Negligible	0.20	Negligible	0.20	Low	0.19	Low
MW-4	UA	0.05	0.05	Negligible	0.05	Negligible	0.13	High	0.02	Moderately High
MW-5	UA	2.72	2.72	Negligible	2.72	Negligible	2.77	Low	2.63	Low
MW-6	UA	1.71	1.71	Negligible	1.71	Negligible	1.71	Negligible	1.70	Negligible
MW-7	UA	2.12	2.12	Negligible	2.12	Negligible	2.14	Negligible	2.09	Low
MW-7S	USCU	2.12	2.12	Negligible	2.12	Negligible	2.14	Negligible	2.09	Low
MW-8	UA	2.3E-03	2.3E-03	Negligible	2.3E-03	Negligible	5.2E-03	High	7.7E-04	Moderately High
MW-11	UA	1.90	1.90	Negligible	1.90	Negligible	1.90	Negligible	1.90	Negligible
MW-12	UA	2.72	2.72	Negligible	2.72	Negligible	2.89	Low	2.55	Low
MW-12S	USCU	2.65	2.65	Negligible	2.65	Negligible	2.75	Low	2.36	Low
MW-12D	LCU	1.78	1.78	Negligible	1.78	Negligible	2.48	Moderate	1.28	Moderate
MW-20	UA	1.2E-03	1.2E-03	Negligible	1.2E-03	Negligible	5.5E-03	High	3.0E-04	Moderately High
MW-20S	USCU	1.5E-03	1.5E-03	Negligible	1.5E-03	Negligible	6.9E-03	High	3.8E-04	Moderately High
MW-22	UA	1.39	1.39	Negligible	1.39	Negligible	1.39	Negligible	1.39	Negligible
MW-23	UA	0.72	0.72	Negligible	0.72	Negligible	0.72	Negligible	0.72	Negligible
MW-24	UA	3.45	3.45	Negligible	3.45	Negligible	3.45	Negligible	3.45	Negligible
MW-25	USCU	0.52	0.52	Negligible	0.52	Negligible	0.59	Moderate	0.43	Moderate
MW-26	UA	1.19	1.19	Negligible	1.19	Negligible	1.24	Low	1.11	Low
MW-27	USCU	3.11	3.11	Negligible	3.11	Negligible	3.12	Negligible	3.10	Negligible
MW-28	UA	9.06	9.06	Negligible	9.06	Negligible	9.06	Negligible	9.06	Negligible
MW-29	UA	2.38	2.38	Negligible	2.38	Negligible	2.39	Negligible	2.38	Negligible
MW-30	UA	1.89	1.89	Negligible	1.89	Negligible	1.90	Negligible	1.88	Negligible
MW-31	UA	1.71	1.71	Negligible	1.71	Negligible	1.71	Negligible	1.70	Negligible
MW-31S	USCU	2.42	2.42	Negligible	2.42	Negligible	2.42	Negligible	2.42	Negligible
MW-32	UA	1.15	1.15	Negligible	1.15	Negligible	1.15	Negligible	1.14	Negligible
PZ-4C	UA	0.52	0.52	Negligible	0.52	Negligible	0.59	Moderate	0.41	Moderate
			S*0.1 Sy*0.5[2]		S*10 Sy*2[2]		Porosity-0.05		Porosity+0.05	

Notes:

[O: PR 5/09/22; C: EGP 5/11/22]

[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 steady state flow and transient transport
ID = identification
mg/L = milligrams per liter
S = storativity
Sy = specific yield
Disp = dispersivity

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

Closure Scenario - Area Description	CBR - Removal Area	CIP - Removal Area	CIP - Consolidation and Cover System Area	Notes
Input Parameter				
Climate-General				
City	Kincaid, IL	Kincaid, IL	Kincaid, IL	Nearby city to the Site within HELP database
Latitude	39.59	39.59	39.59	Site latitude
Evaporative Zone Depth	18	18	18	Estimated based on geographic location (Illinois) and uppermost soil type (Tolaymat, T. and Krause, M, 2020)
Maximum Leaf Area Index	4.5	4.5	4.5	Maximum for geographic location (Illinois) (Tolaymat, T. and Krause, M, 2020)
Growing Season Period, Average Wind Speed, and Quarterly Relative Humidity	Springfield, IL	Springfield, IL	Springfield, IL	Nearby city to the Kincaid Ash Pond within HELP database
Number of Years for Synthetic Data Generation	30	30	30	
Temperature, Evapotranspiration, and Precipitation	Precipitation, temperature, and solar radiation was simulated based on HELP V4 weather simulation for: Lat/Long: 39.59/-89.50	Precipitation, temperature, and solar radiation was simulated based on HELP V4 weather simulation for: Lat/Long: 39.59/-89.50	Precipitation, temperature, and solar radiation was simulated based on HELP V4 weather simulation for: Lat/Long: 39.59/-89.50	
Soils-General				
% where runoff possible	100	100	100	
Area (acres)	172	88	84	CBR - Removal Area based on HCR (Ramboll, 2021); CIP - Consolidation and Cover System Area based on construction drawing for Kincaid Ash Pond; CIP -Removal Area equals the difference
Specify Initial Moisture Content	No	No	No	
Surface Water/Snow	Model Calculated	Model Calculated	Model Calculated	
Soils-Layers				
1	Unsaturated Backfill Material (HELP Final Cover Soil [topmost layer])	Unsaturated Backfill Material (HELP Final Cover Soil [topmost layer])	Vegetative Soil Layer (HELP Final Cover Soil [topmost layer])	Layer details for CBR and CIP areas based on grading plans, construction drawings, and cover system design for Kincaid Ash Pond
2	Protective Soil Layer (HELP Vertical Percolation Layer)	Protective Soil Layer (HELP Vertical Percolation Layer)	Protective Soil Layer (HELP Vertical Percolation Layer)	
3	--	--	Geotextile Liner (HELP Drainage Net)	
4	--	--	Geomembrane Liner	
5	--	--	Unsaturated CCR Material (HELP Waste)	
6	--	--	Unsaturated Material (HELP Vertical Percolation Layer)	
Soil Parameters--Layer 1, Unsaturated Backfill Material (HELP Final Cover Soil [topmost layer]) or Vegetative Soil Layer (HELP Final Cover Soil [topmost layer])				
Type	1	1	1	Vertical Percolation Layer (Cover Soil)
Thickness (in)	30	30	6	For CBR and CIP removal areas, layer 1 thickness is the average thickness of unsaturated backfill material placed after removal
Texture	12	12	12	defaults used
Description	Silty Clay Loam	Silty Clay Loam	Silty Clay Loam	
Saturated Hydraulic Conductivity (cm/s)	4.20E-05	4.20E-05	4.20E-05	defaults used

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

Closure Scenario - Area Description	CBR - Removal Area	CIP - Removal Area	CIP - Consolidation and Cover System Area	Notes
Soil Parameters--Layer 2, Protective Soil Layer (HELP Vertical Percolation Layer)				
Type	1	1	1	Vertical Percolation Layer
Thickness (in)	72	72	18	design thickness
Texture	43	43	43	Custom layer, adjusted for site specific hydraulic conductivity
Description	Silty Clay	Silty Clay	Sandy Silty Clay	
Saturated Hydraulic Conductivity (cm/s)	1.20E-07	1.20E-07	1.00E-05	Design vertical hydraulic conductivity for backfill
Soil Parameters--Layer 3, Geotextile Liner (HELP Drainage Net)				
Type	--	--	2	Geotextile Protective Layer
Thickness (in)	--	--	0.11	design thickness
Texture	--	--	123	custom layer
Description	--	--	10 oz Nonwoven Geotextile	
Saturated Hydraulic Conductivity (cm/s)	--	--	3.00E-01	custom design hydraulic conductivity
Soil Parameters--Layer 4, Geomembrane Liner				
Type	--	--	4	Flexible Membrane Liner
Thickness (in)	--	--	0.04	design thickness
Texture	--	--	36	defaults used
Description	--	--	Geomembrane	
Saturated Hydraulic Conductivity (cm/s)			4.00E -13	defaults used
Soil Parameters--Layer 5, Unsaturated CCR Material (HELP Waste)				
Type	--	--	1	Vertical Percolation Layer (Waste)
Thickness (in)	--	--	372	Estimated unsaturated CCR thickness within CIP Consolidation and Cover System Area
Texture	--	--	83	Custom layer, adjusted for site specific hydraulic conductivity
Description	--	--	Electric Plant Coal Bottom Ash	
Saturated Hydraulic Conductivity (cm/s)	--	--	1.40E-03	calibrated flow model vertical hydraulic conductivity for CCR
Soil Parameters--Layer 6, Unsaturated Material (HELP Vertical Percolation Layer)				
Type	--	--	1	Vertical Percolation Layer
Thickness (in)	--	--	84	Estimated unsaturated Silty Clay thickness within CIP Consolidation and Cover System Area
Texture	--	--	44	Custom layer, adjusted for site specific hydraulic conductivity
Description	--	--	Silty Clay	
Saturated Hydraulic Conductivity (cm/s)	--	--	1.20E-07	calibrated flow model vertical hydraulic conductivity for Silty Clay
Soils--Runoff				
Runoff Curve Number	85.7	85.9	87.2	HELP-computed curve number
Slope	0.5%	0.5%	2.5%	Estimated average from construction design drawings for Kincaid Ash Pond
Length (ft)	3000	2300	800	estimated maximum flow path
Texture	10	10	10	uppermost layer texture
Vegetation	fair	fair	fair	fair indicating fair stand of grass on surface of soil backfill

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

Closure Scenario - Area Description	CBR - Removal Area	CIP - Removal Area	CIP - Consolidation and Cover System Area	Notes
Execution Parameters				
Years	30	30	30	
Report Daily	No	No	No	
Report Monthly	No	No	No	
Report Annual	Yes	Yes	Yes	
Output Parameter				
Percolation Rate (in/yr)	**5.83**	**5.82**	**0.0041**	

[O: EGP 4/25/22 C: JJW 5/11/22]

Notes:
% = percent
cm/s = centimeters per second
ft = feet
HELP = Hydrologic Evaluation of Landfill Performance
in = inches
in/yr = inches per year
Lat/Long = latitude/longitude
CBR = closure by removal
CIP = closure in place
HCR = Hydrogeologic Site Characterization Report

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

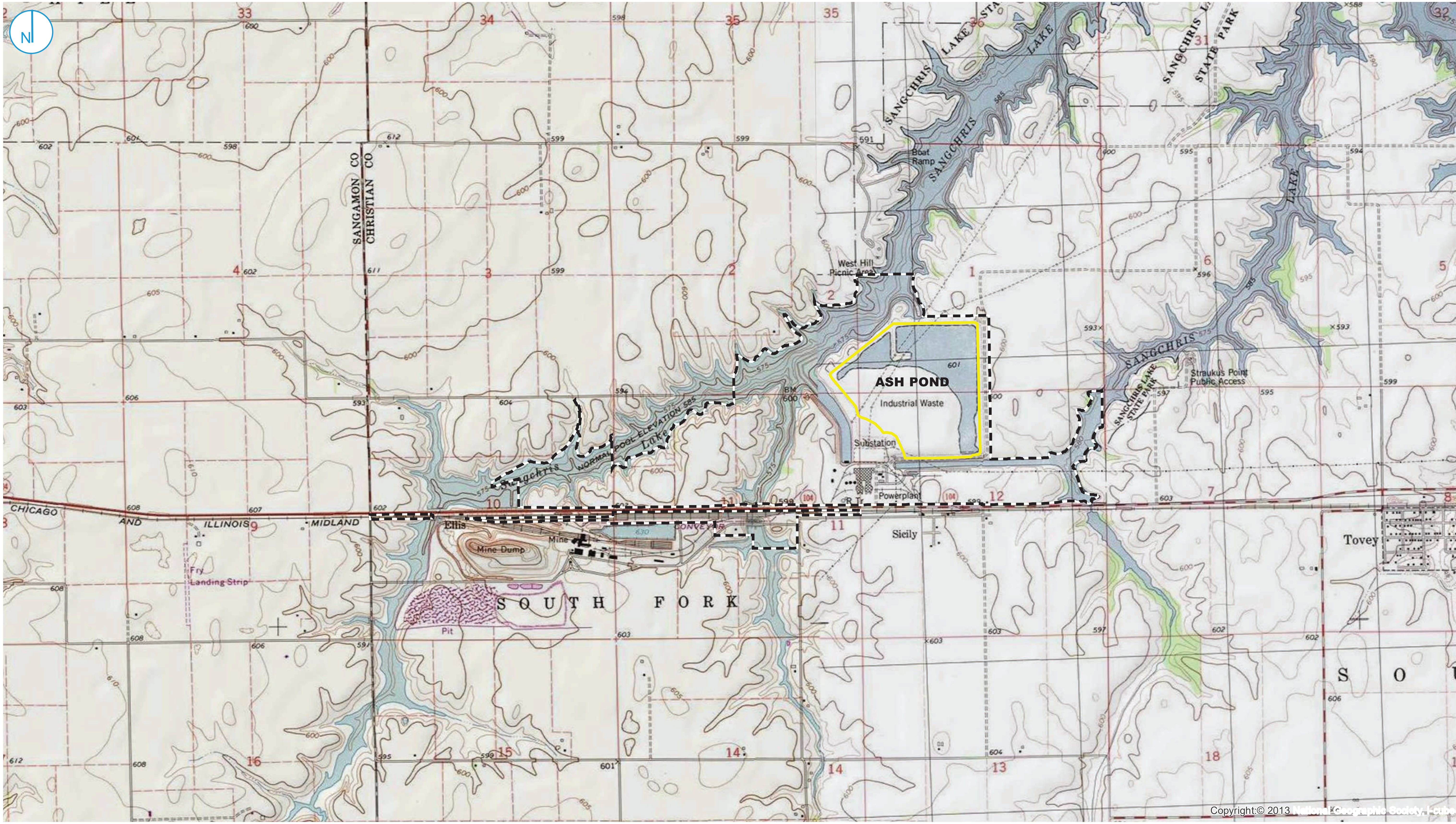
TABLE 6-2. PREDICTION MODEL INPUT VALUES
GROUNDWATER MODELING REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Hydrostratigraphic Unit/Recharge Area	Notes	Recharge Zone	Recharge (ft/day)	Recharge (inches/yr)	Stormwater Drain Stage	Constant Concentration Layer	Constant Concentration (mg/L)
Scenario 1: CIP							
Removal Area North	CCR	2, 4, 5, 7	1.3E-03	5.82	585	--	--
Removal Area South	CCR	3, 8	6.26E-08	4.10E-03	585	1	3.1, 3.5[1]
Scenario 2: CBR							
Removal Area North	CCR	2, 4, 5, 7	1.3E-03	5.82	585	--	--
Removal Area South	CCR	3, 8	1.3E-03	5.82	585	--	--

[O: PR 05/09/22; C: EGP 5/10/22]

Notes:
[1] See **Figure 5-2**
- - = not included
CCR = coal combustion residuals
ft/day = feet per day
inches/yr = inches per year
mg/L = milligrams per liter

FIGURES



PART 845 REGULATED UNIT FACILITY BOUNDARY

PROPERTY BOUNDARY

0 1,000 2,000 Feet

Y:\Mapping\Projects\22\2285\MXD\Model_Figures\Kincaid\Figure 1-1_Site Location Map.mxd

PROJECT: 169000XXXX | DATED: 5/10/2022 | DESIGNER: galarmmc

SITE LOCATION MAP

FIGURE 1-1

GROUNDWATER MODELING REPORT
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

RAMBOLL

PART 845 REGULATED UNIT (SUBJECT UNIT)
CLOSURE IN PLACE BOUNDARY
PROPERTY BOUNDARY

0 250 500 Feet

SITE MAP

GROUNDWATER MODELING REPORT
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

FIGURE 1-2

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

RAMBOLL

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

0 250 500 Feet

MONITORING WELL LOCATION MAP

GROUNDWATER MODELING REPORT
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

FIGURE 2-1

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

RAMBOLL

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

0 250 500 Feet

NOTES
1. PARENTHESES INDICATES WELL NOT USED FOR CONTOURING

POTENTIOMETRIC SURFACE MAP
FEBRUARY 23, 2021

GROUNDWATER MODELING REPORT
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

FIGURE 2-2

RAMBOLL AMERICAS ENGINEERING SOLUTIONS, INC.

RAMBOLL

Y:\Mapping\Projects\22\2285\MXD\Model_Figures\Kincaid\Figure 2-2_Pot Surface 20210223.mxd

PROJECT: 169000XXXX | DATED: 5/10/2022 | DESIGNER: galarmmc

Y:\Mapping\Projects\22\2285\MXD\Model_Figures\Kincaid\Figure 2-3_Pot Surface 20210405.mxd

PROJECT: 169000XXXX | DATED: 5/10/2022 | DESIGNER: galarmmc

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

0 250 500 Feet

NOTES
1. PARENTHESES INDICATES WELL NOT USED FOR CONTOURING

POTENTIOMETRIC SURFACE MAP
APRIL 5, 2021

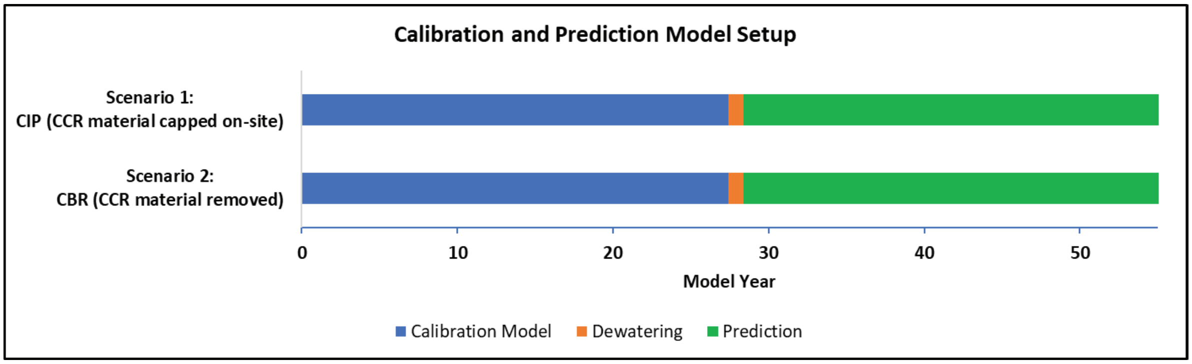
GROUNDWATER MODELING REPORT
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

FIGURE 2-3

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

RAMBOLL

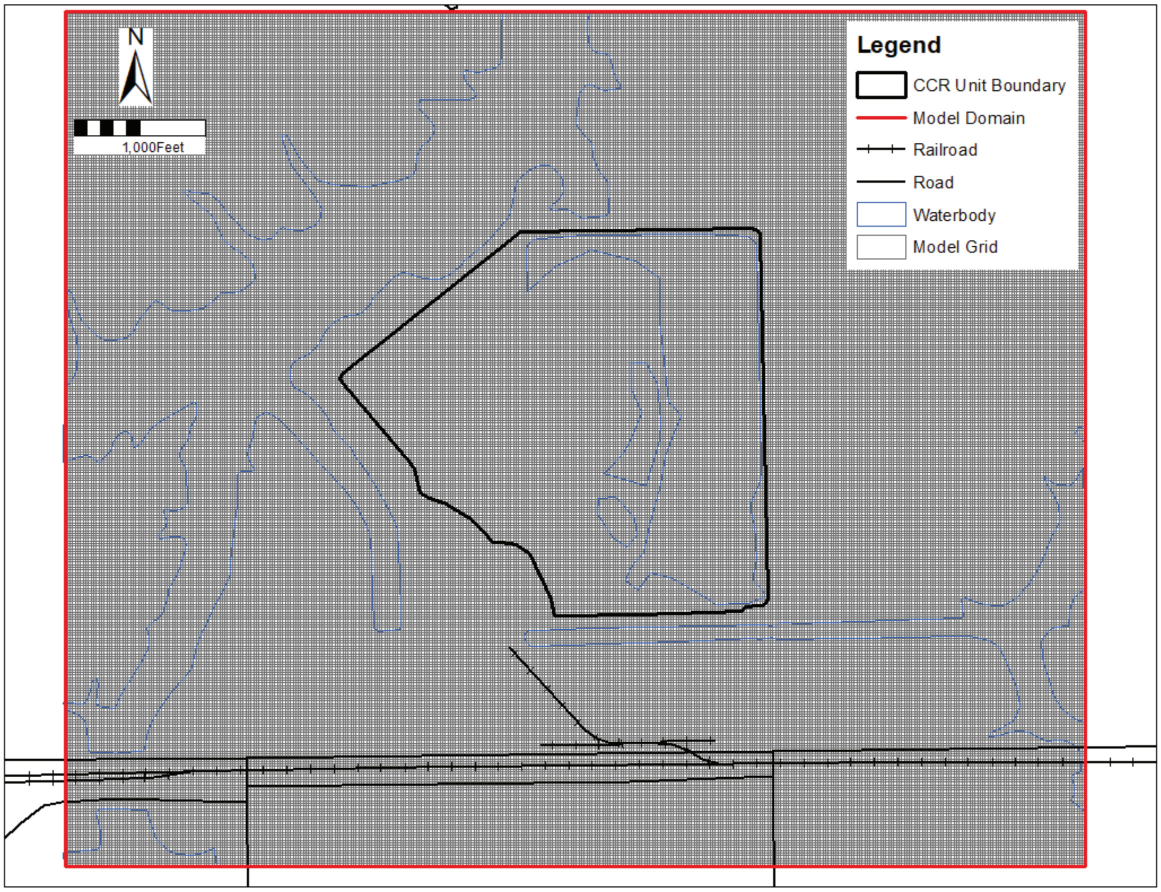
FIGURE 4-1



CALIBRATION AND PREDICTIVE TIMELINE

GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

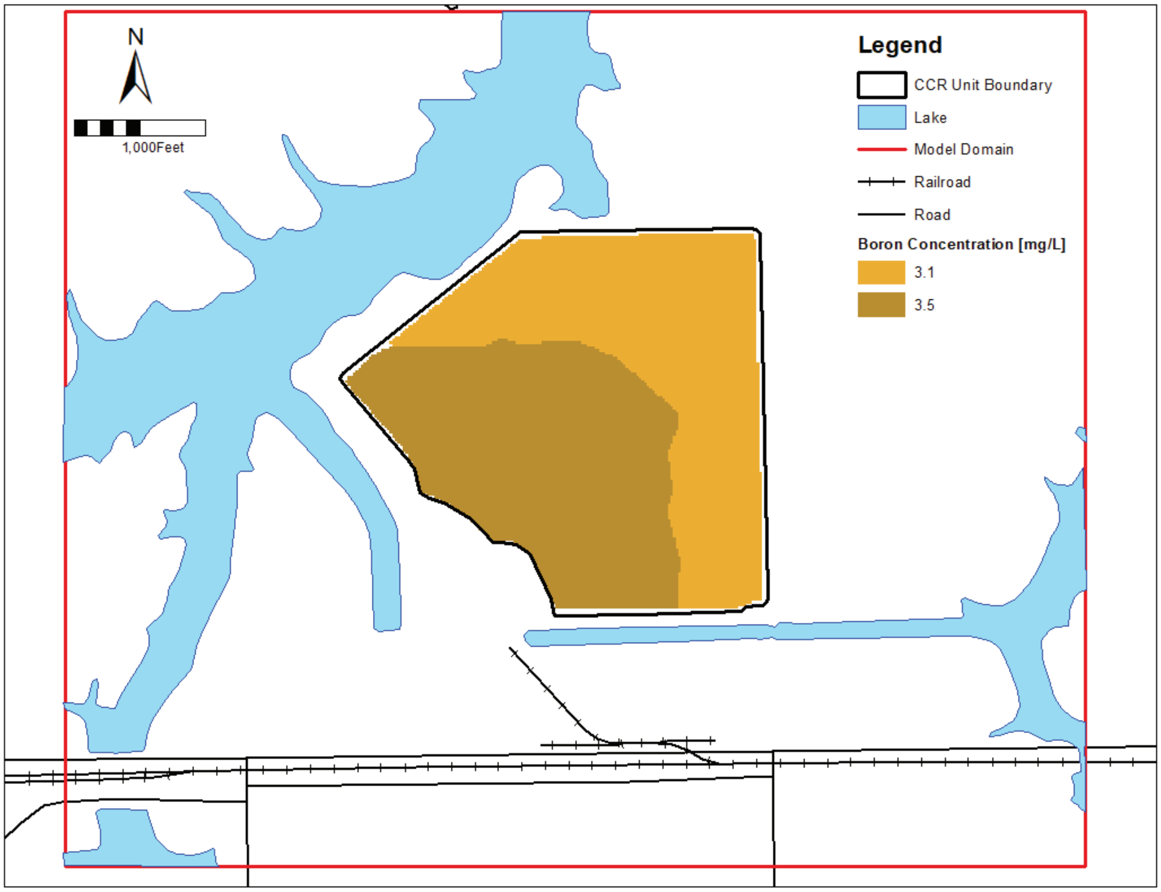
RAMBOLL



MODEL GRID FOR LAYERS 1 THROUGH 5

GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

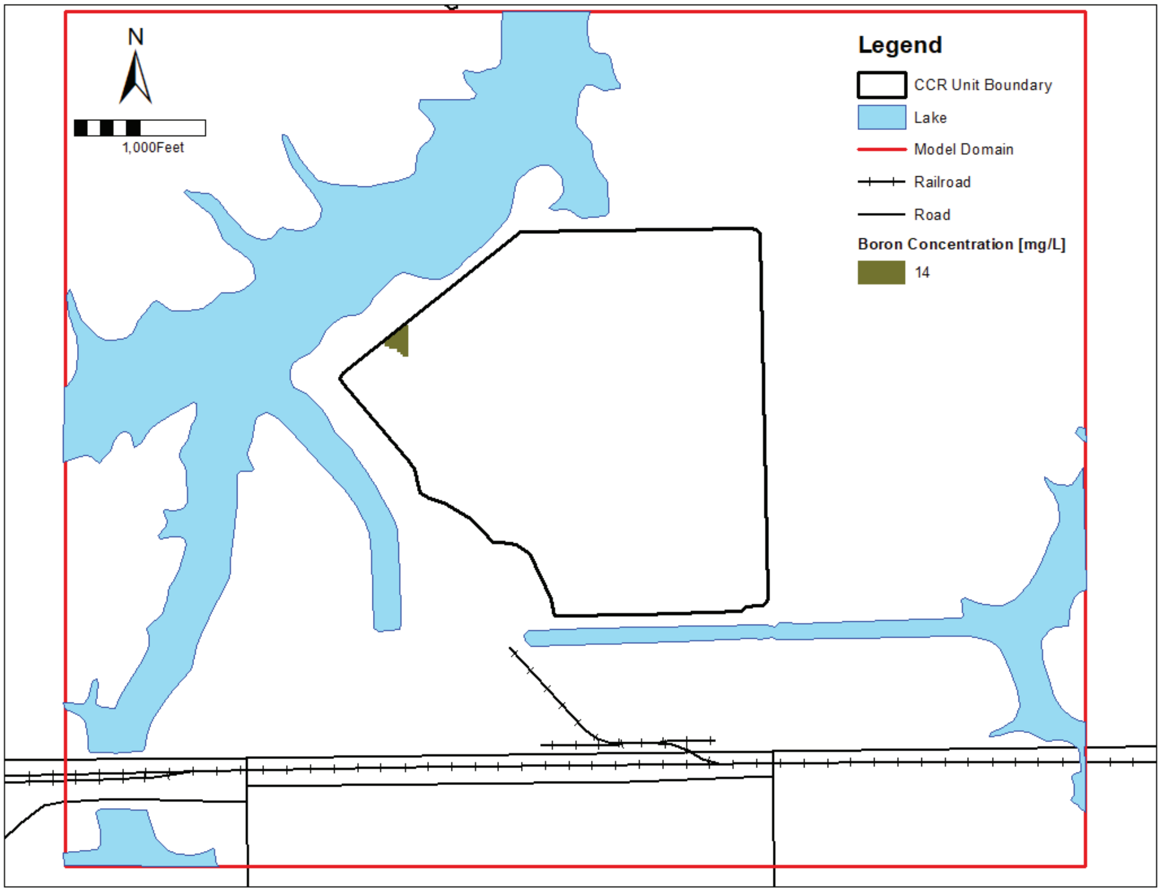
RAMBOLL



BOUNDARY CONDITIONS FOR LAYER 1

GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

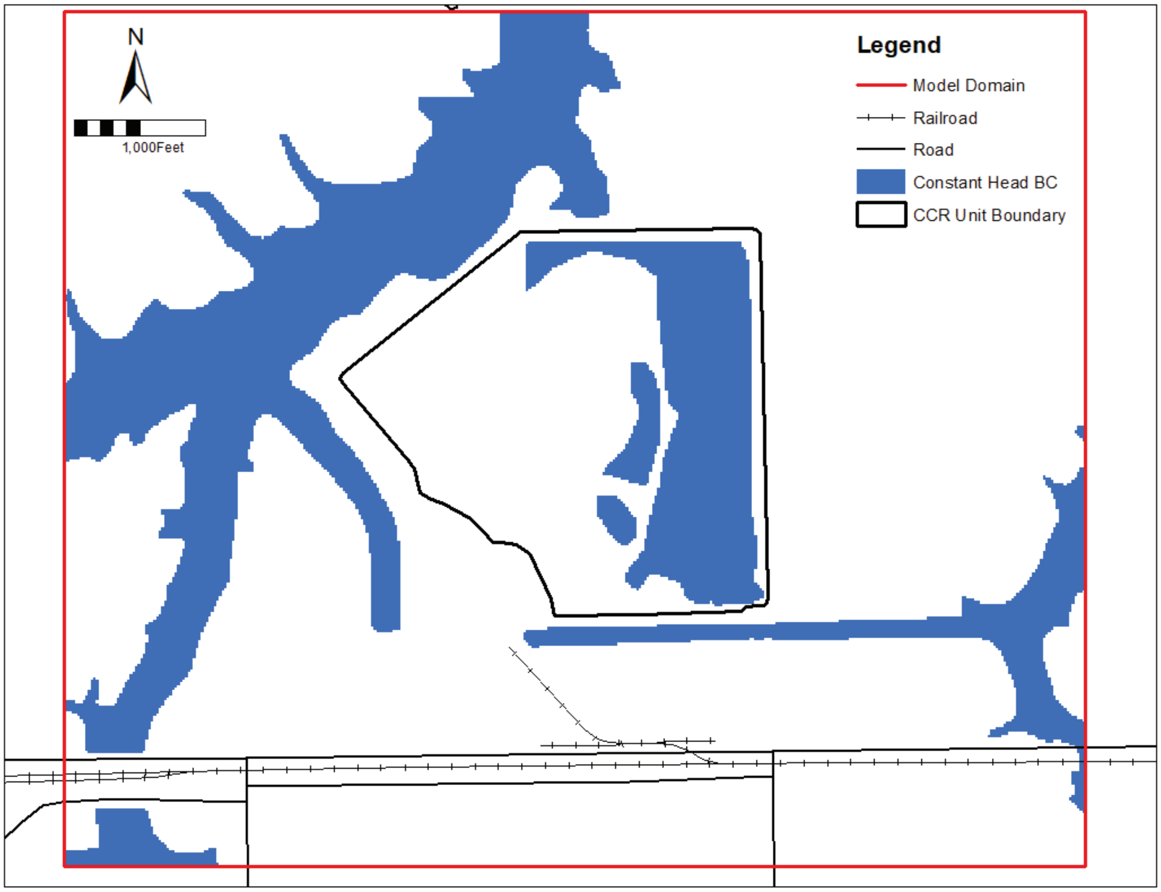
RAMBOLL



BOUNDARY CONDITIONS FOR LAYER 2

GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

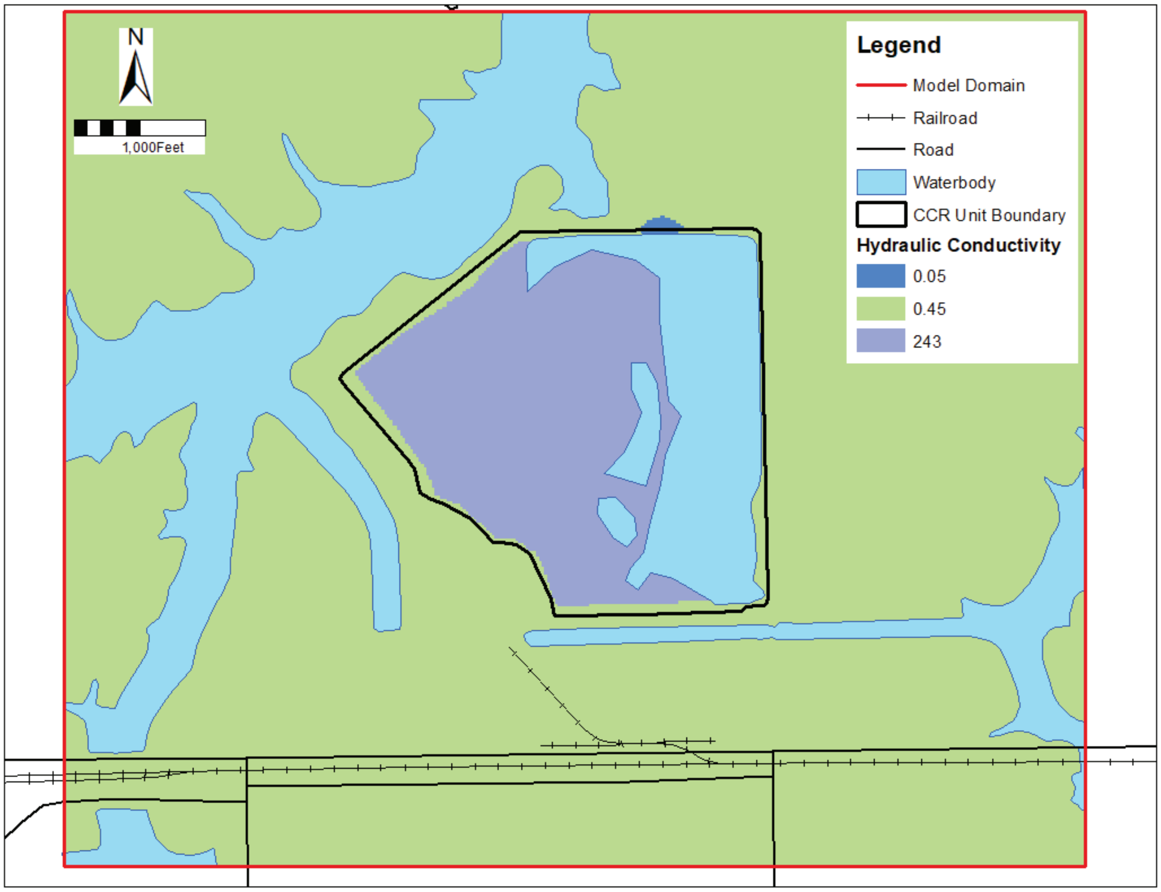
RAMBOLL



BOUNDARY CONDITIONS FOR LAYER 3

GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

RAMBOLL

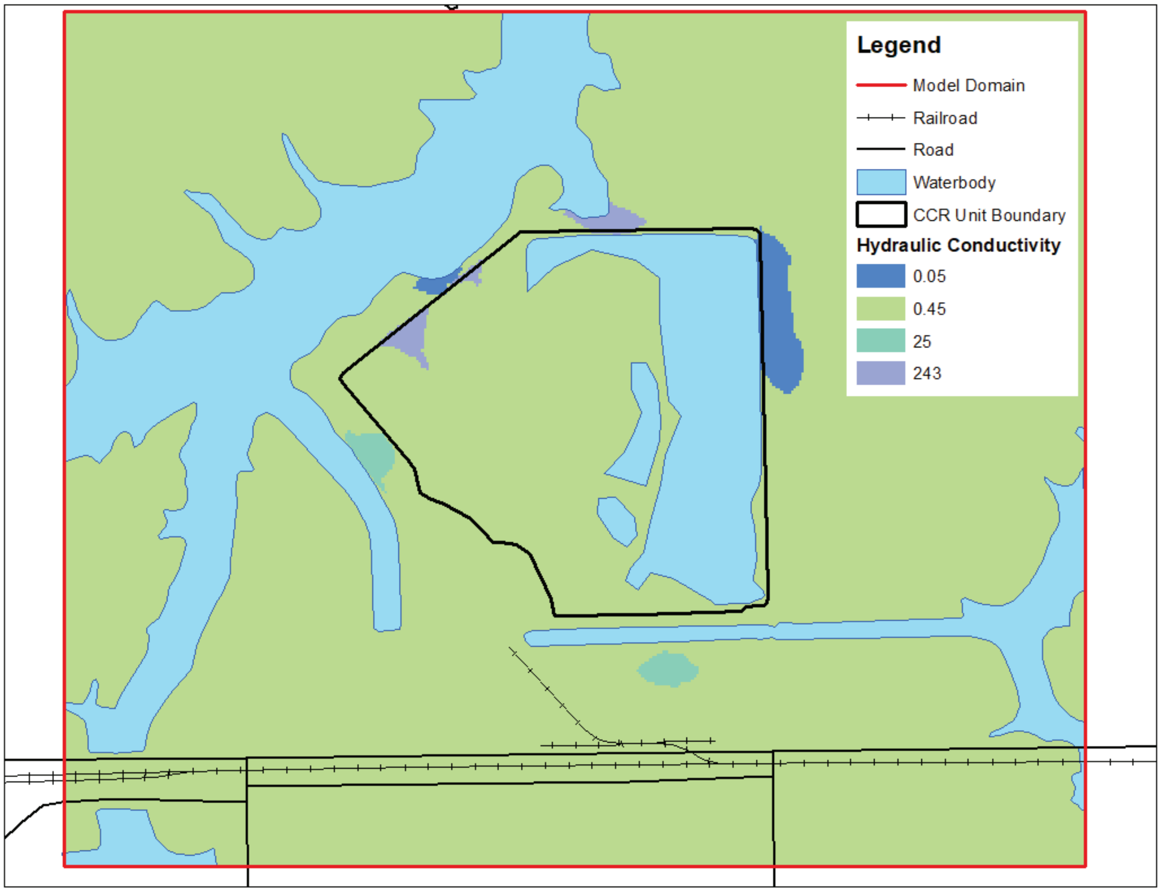


DISTRIBUTION OF HYDRAULIC CONDUCTIVITY ZONES (ft/d) FOR LAYER 1

GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

RAMBOLL

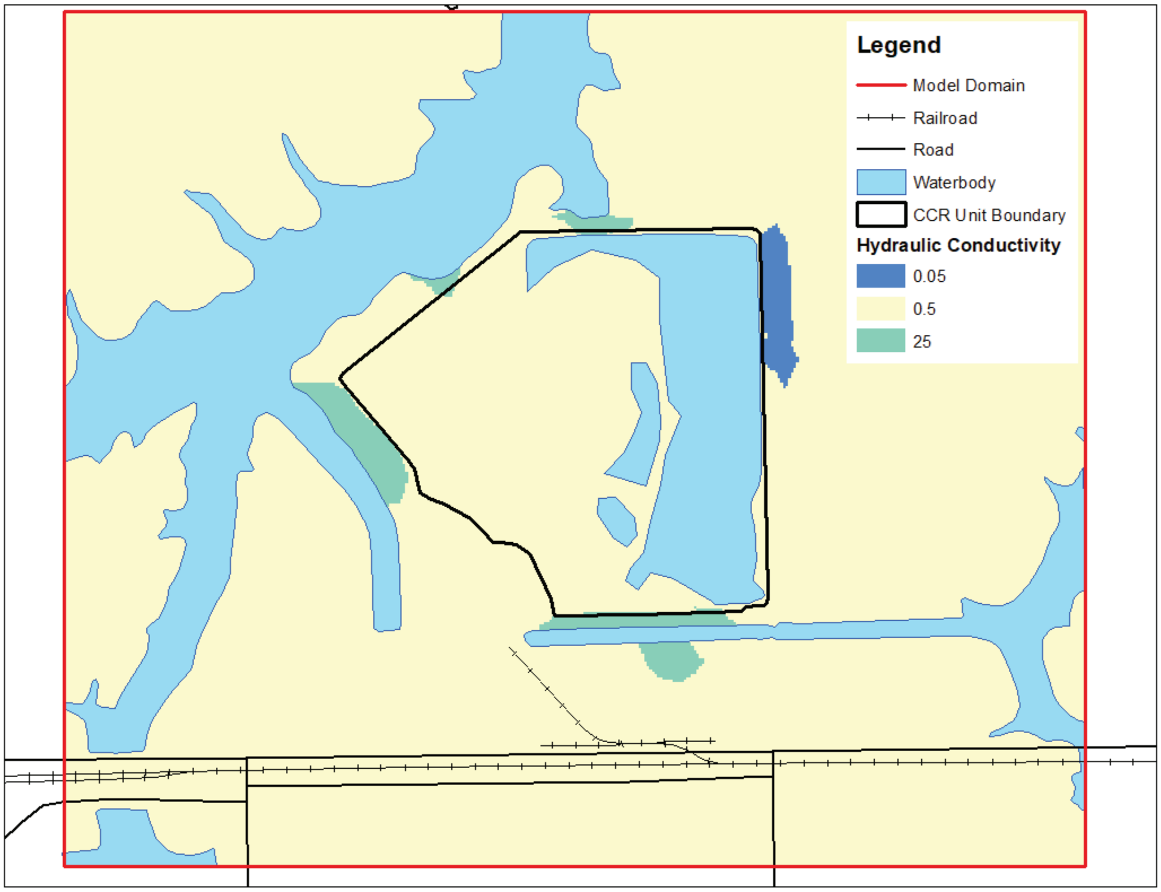
FIGURE 5-6



DISTRIBUTION OF HYDRAULIC CONDUCTIVITY ZONES (ft/d) FOR LAYER 2

GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

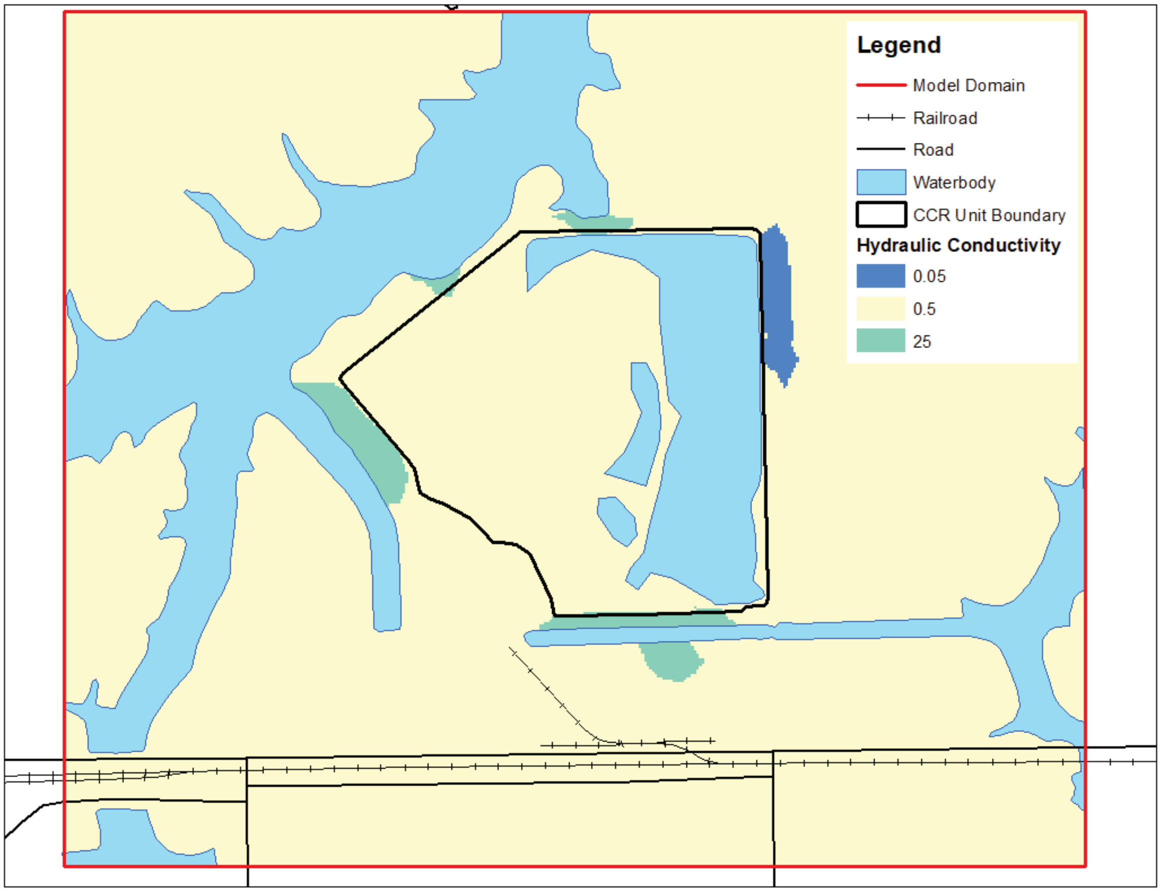
RAMBOLL



DISTRIBUTION OF HYDRAULIC CONDUCTIVITY ZONES (ft/d) FOR LAYER 3

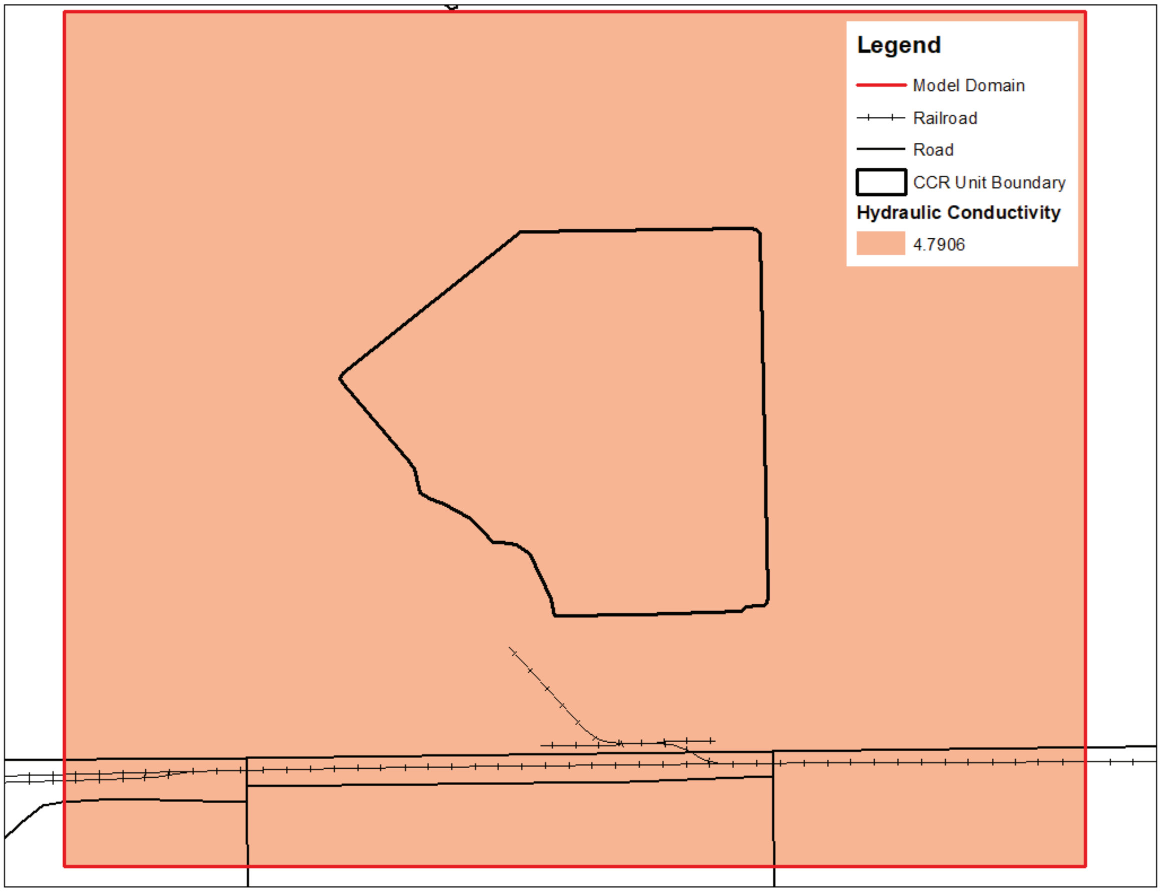
GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

RAMBOLL



DISTRIBUTION OF HYDRAULIC CONDUCTIVITY ZONES (ft/d) FOR LAYER 4

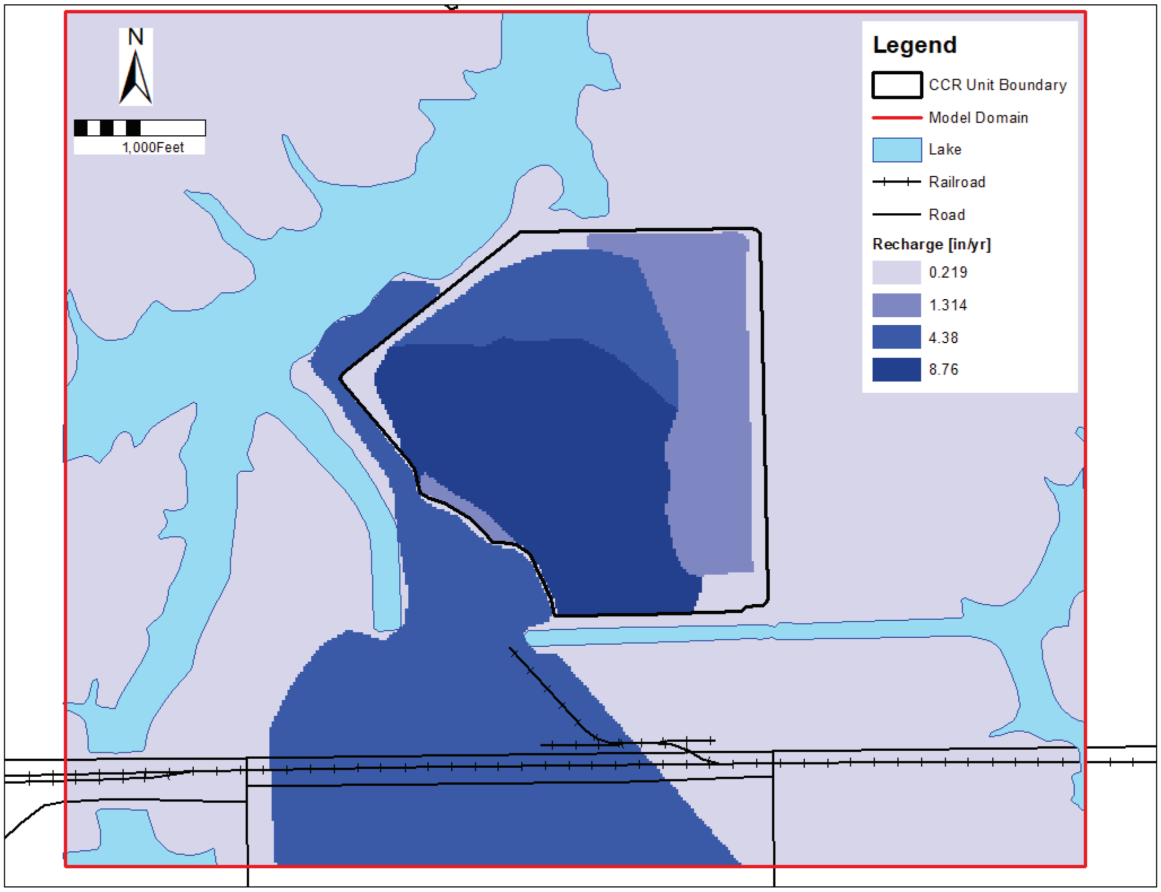
GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS



DISTRIBUTION OF HYDRAULIC CONDUCTIVITY ZONES (ft/d) FOR LAYER 5

GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

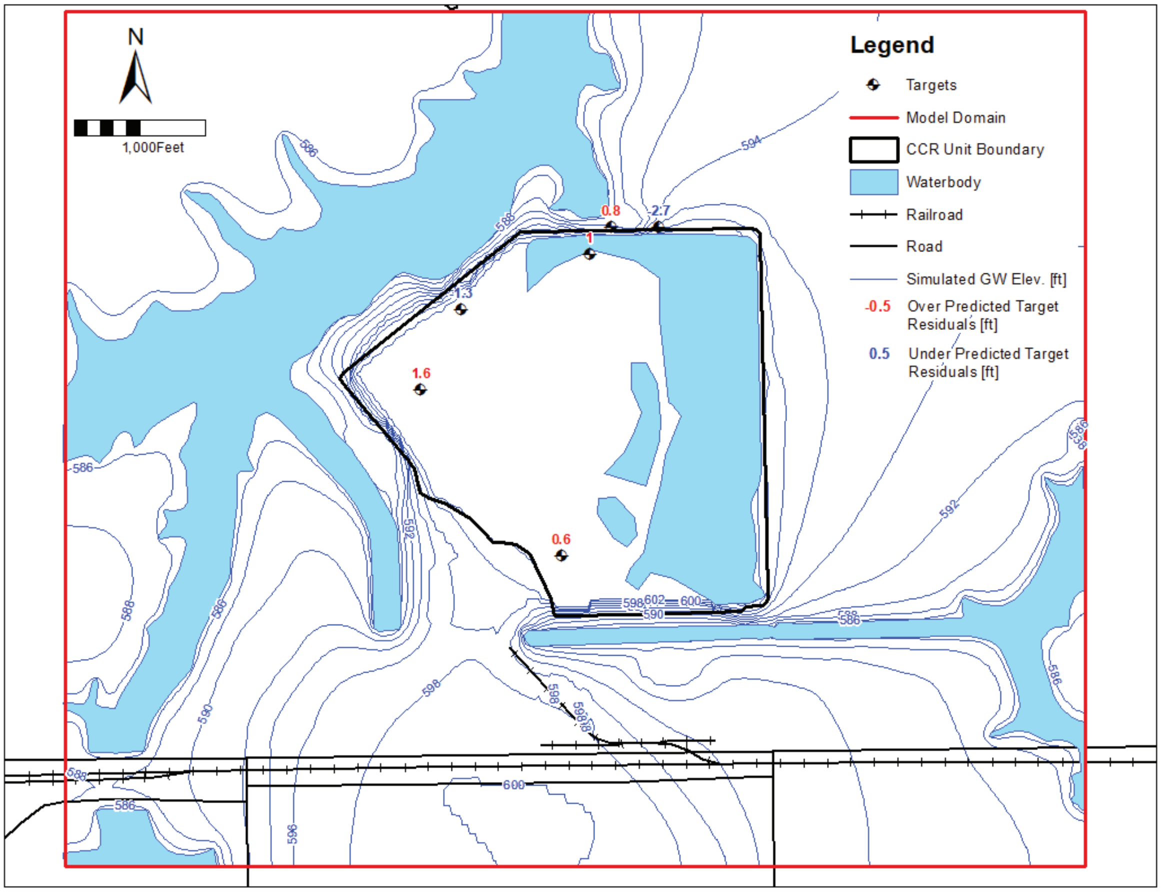
RAMBOLL



DISTRIBUTION OF RECHARGE ZONES (in/yr)

GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

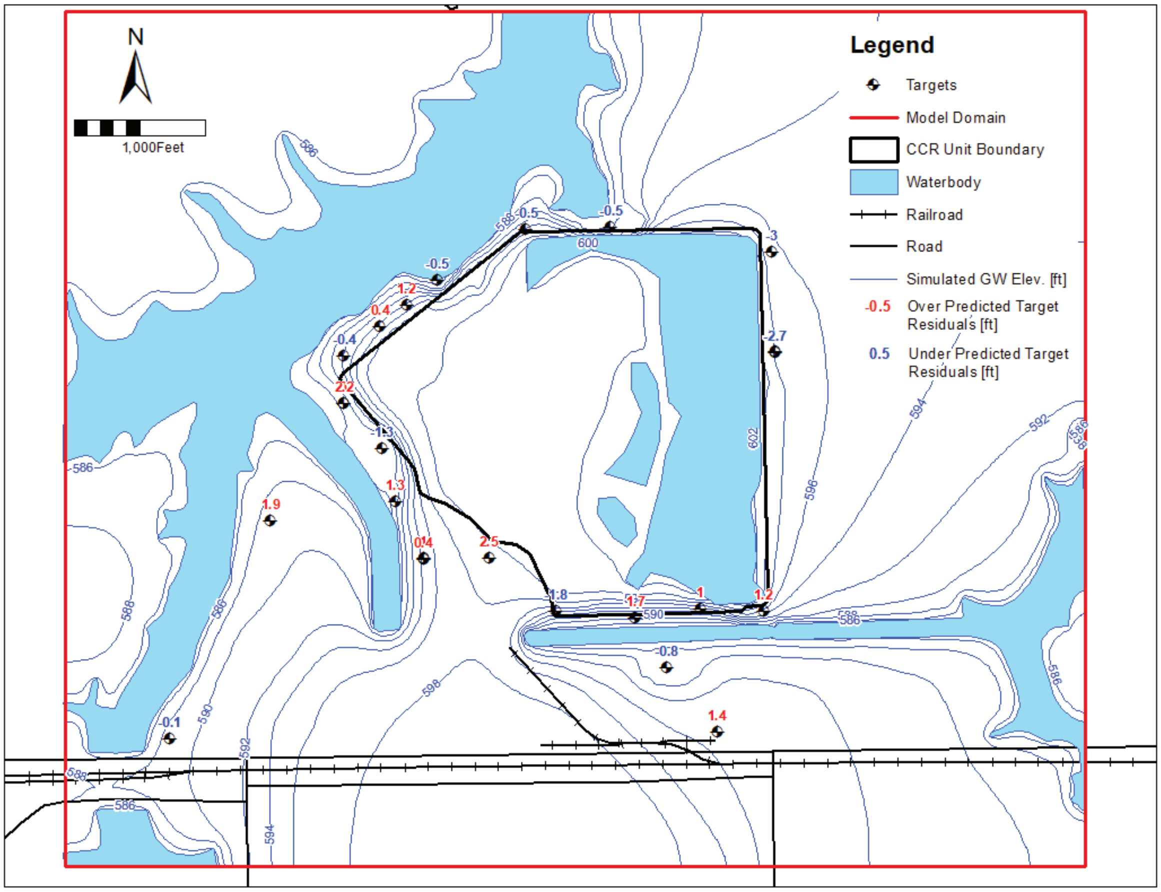
RAMBOLL



OBSERVED VERSUS SIMULATED GROUNDWATER ELEVATIONS LAYER 1

GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

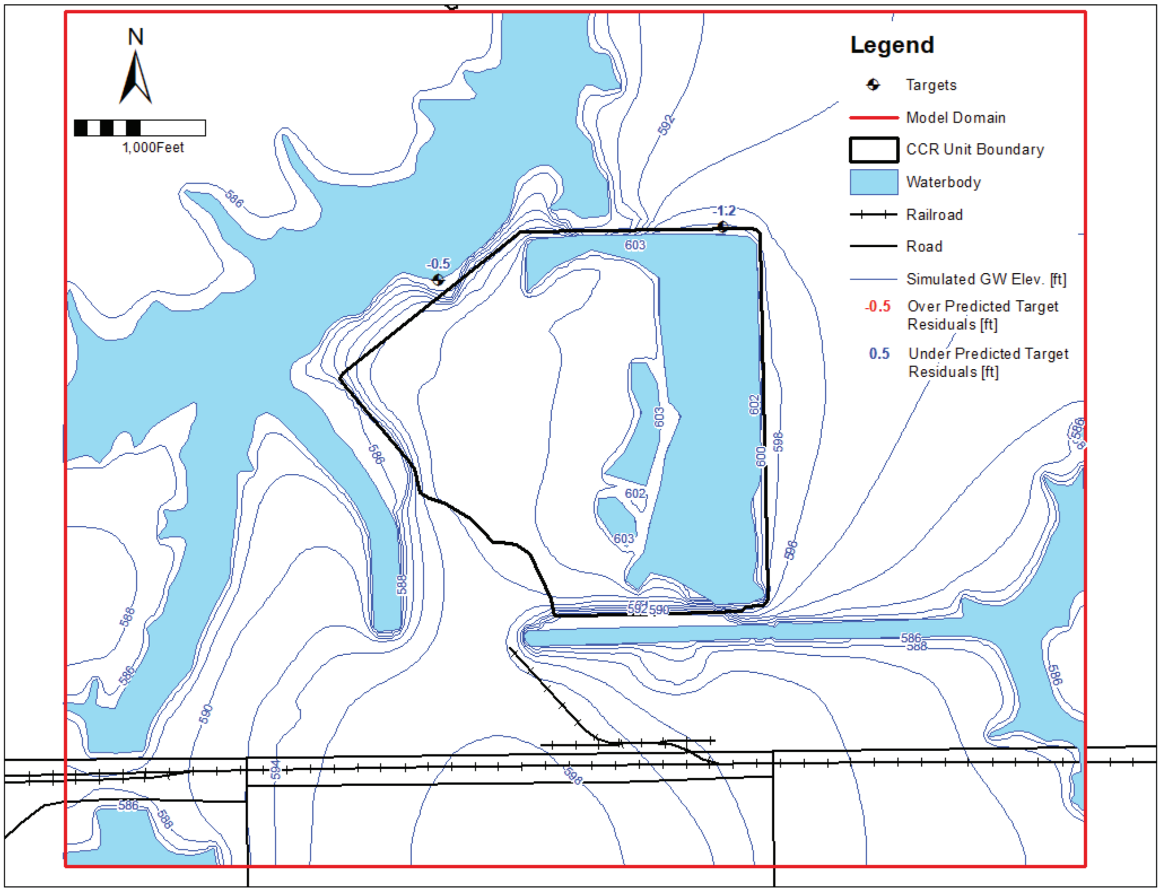
RAMBOLL



OBSERVED VERSUS SIMULATED GROUNDWATER ELEVATIONS LAYER 2

GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

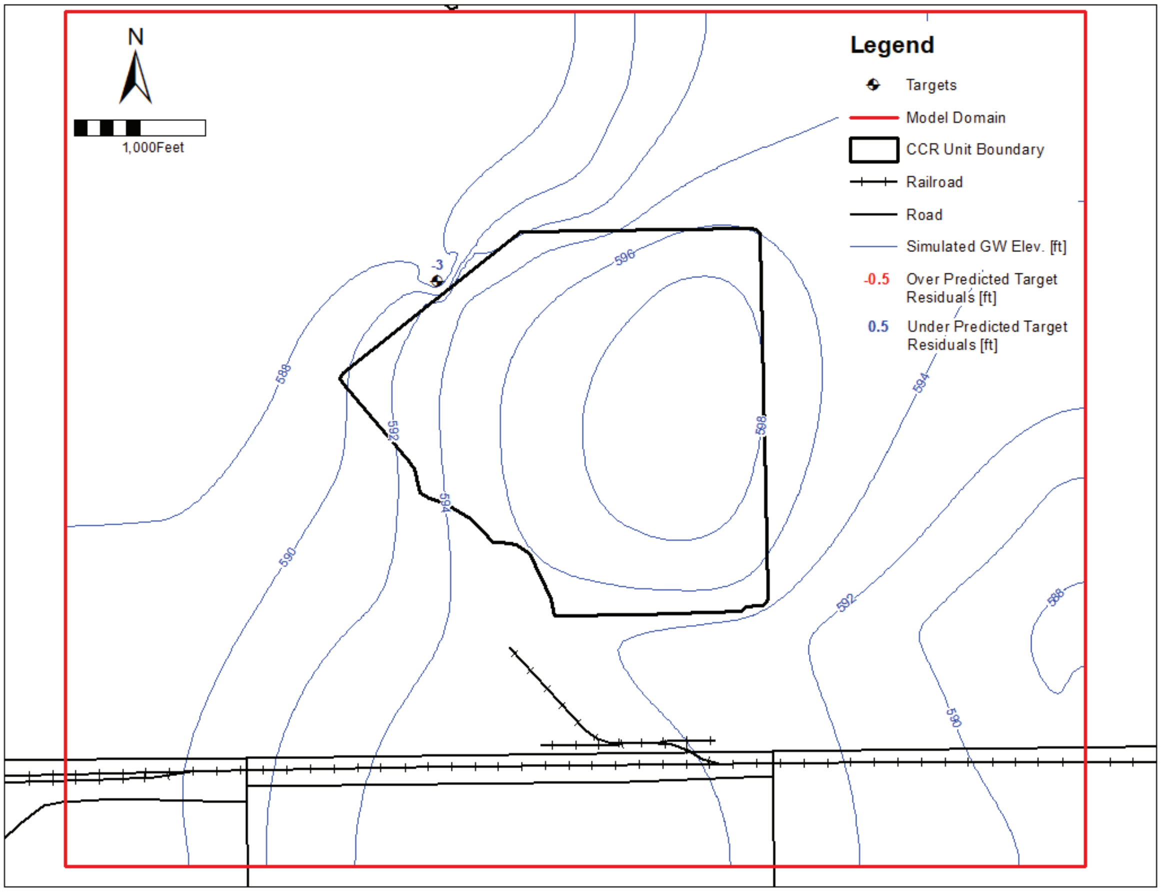
RAMBOLL



OBSERVED VERSUS SIMULATED GROUNDWATER ELEVATIONS LAYER 3

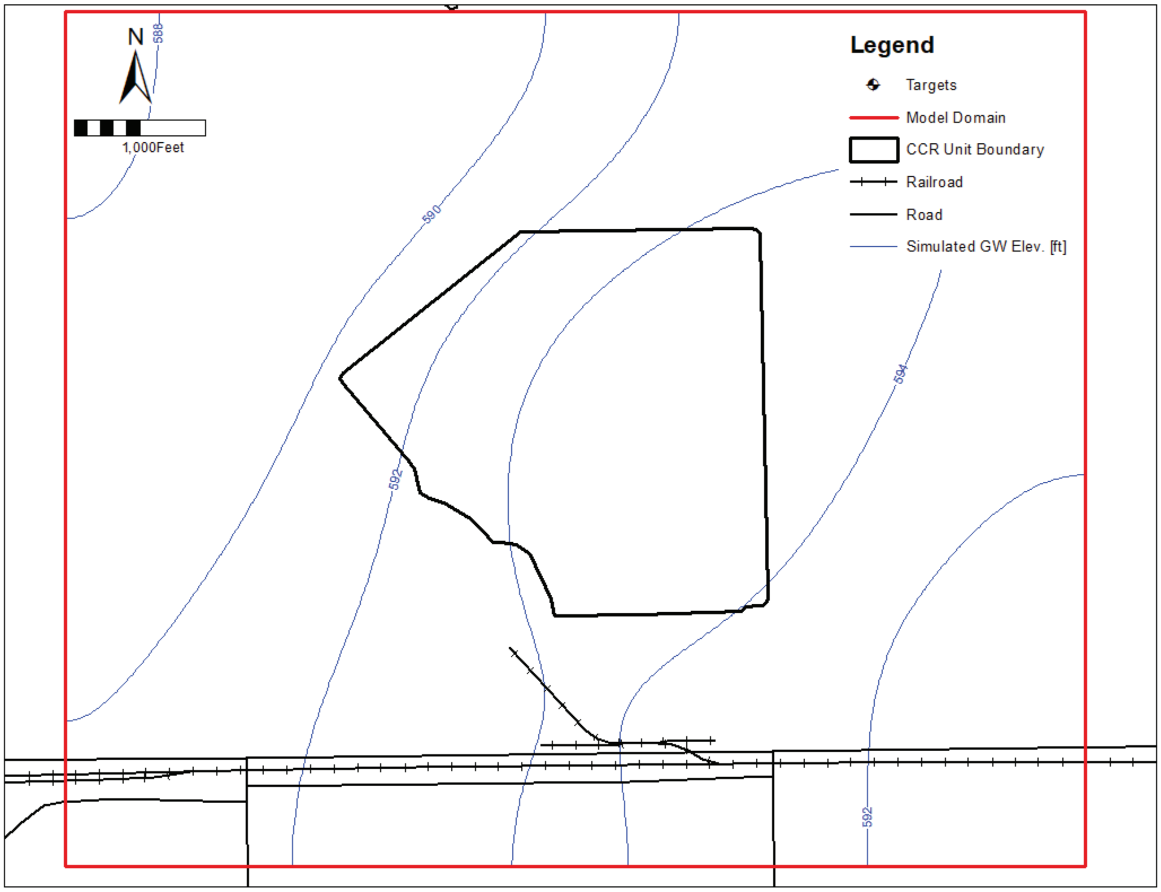
GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

RAMBOLL



OBSERVED VERSUS SIMULATED GROUNDWATER ELEVATIONS LAYER 4

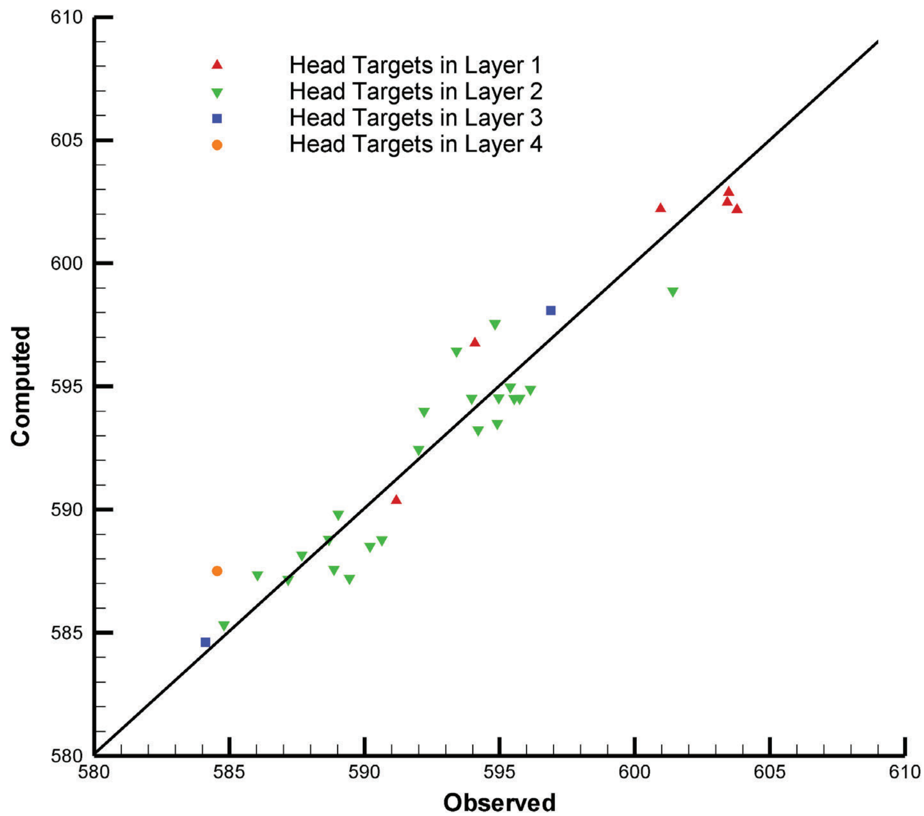
GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS



OBSERVED VERSUS SIMULATED GROUNDWATER ELEVATIONS LAYER 5

GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

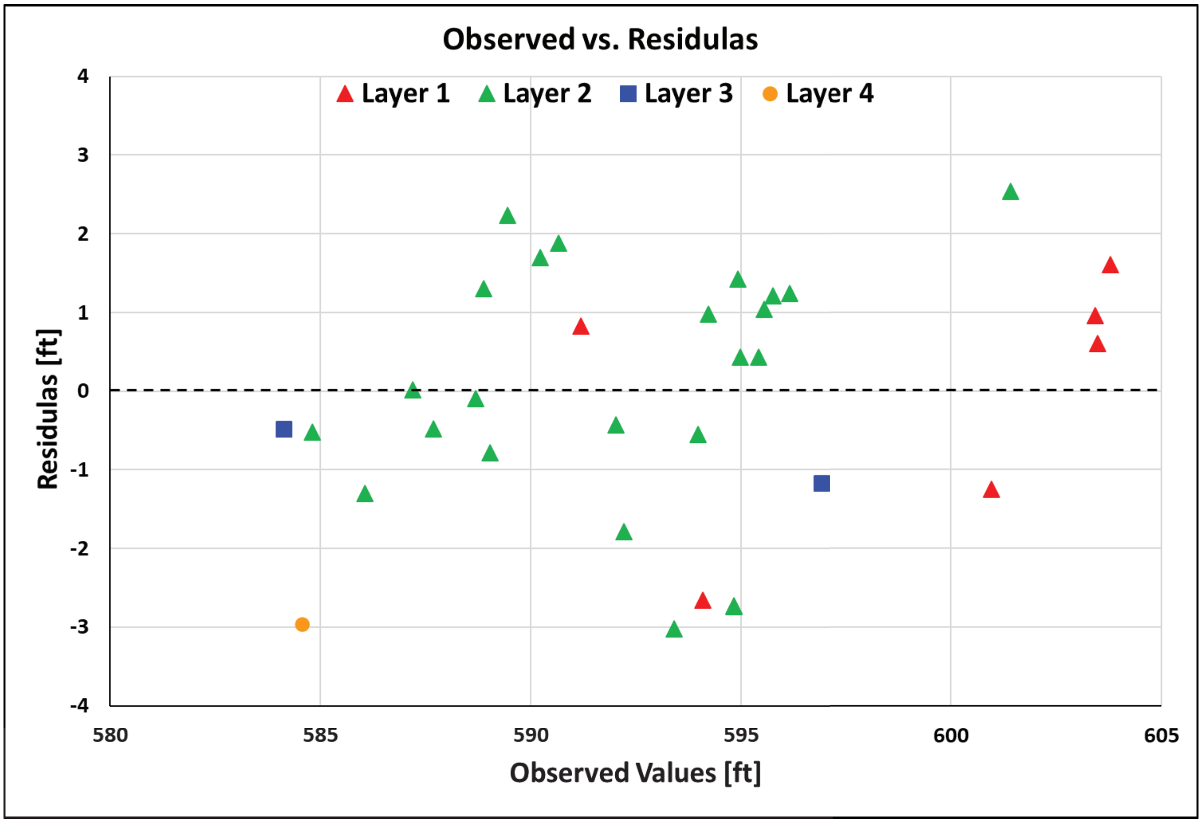
RAMBOLL



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

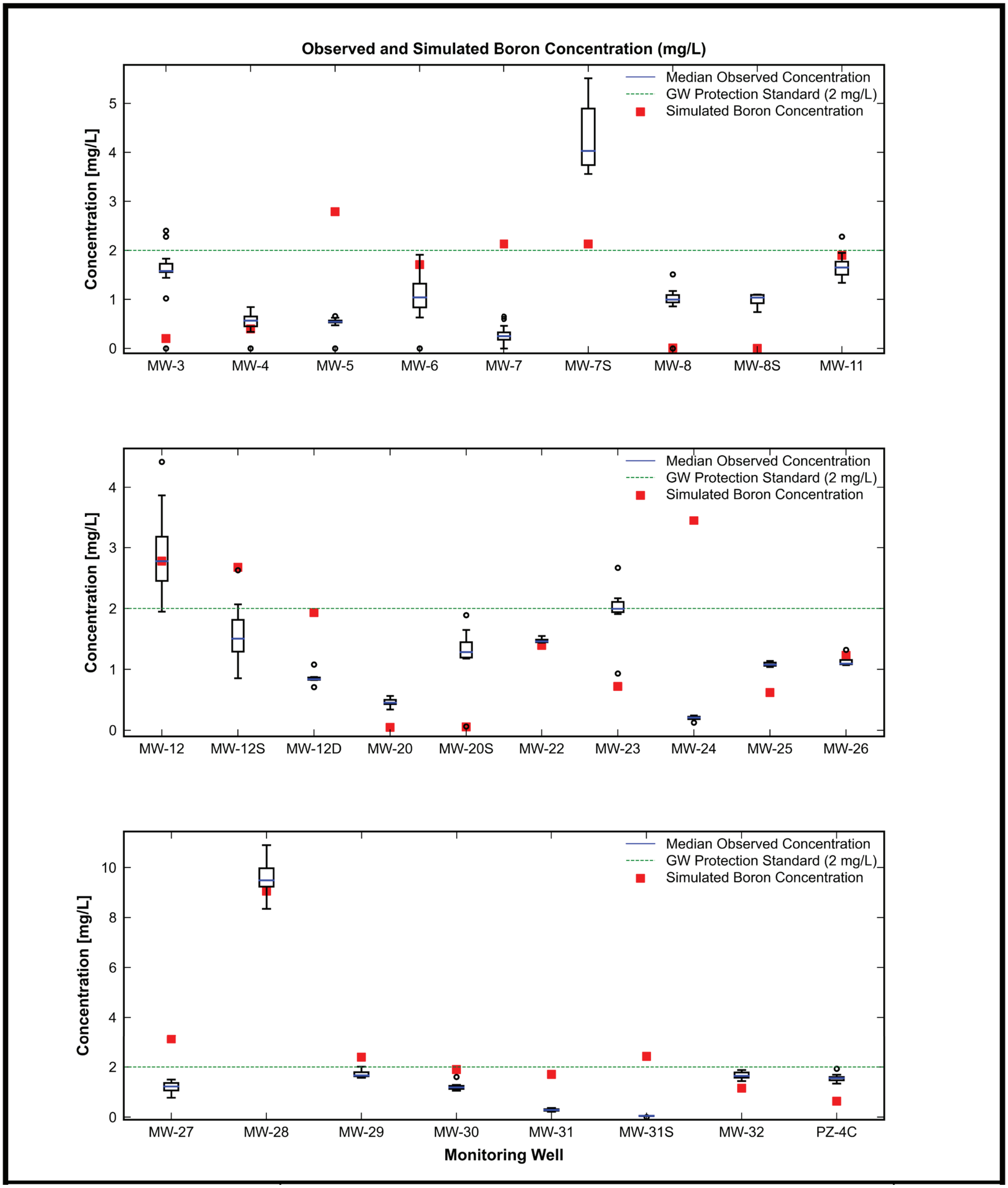
GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

RAMBOLL



SIMULATED GROUNDWATER LEVEL RESIDUAL FROM THE CALIBRATED MODEL

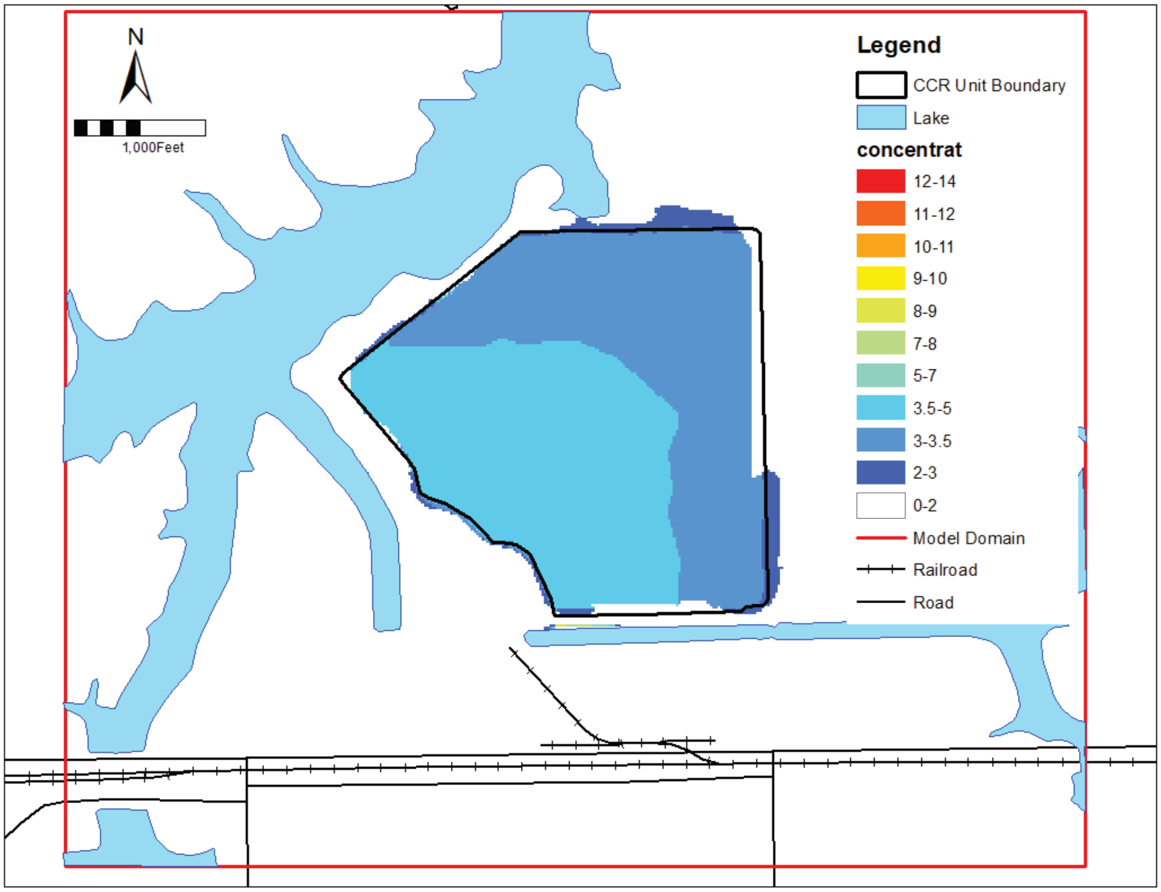
GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS



OBSERVED AND SIMULATED BORON CONCENTRATIONS (mg/L)

GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

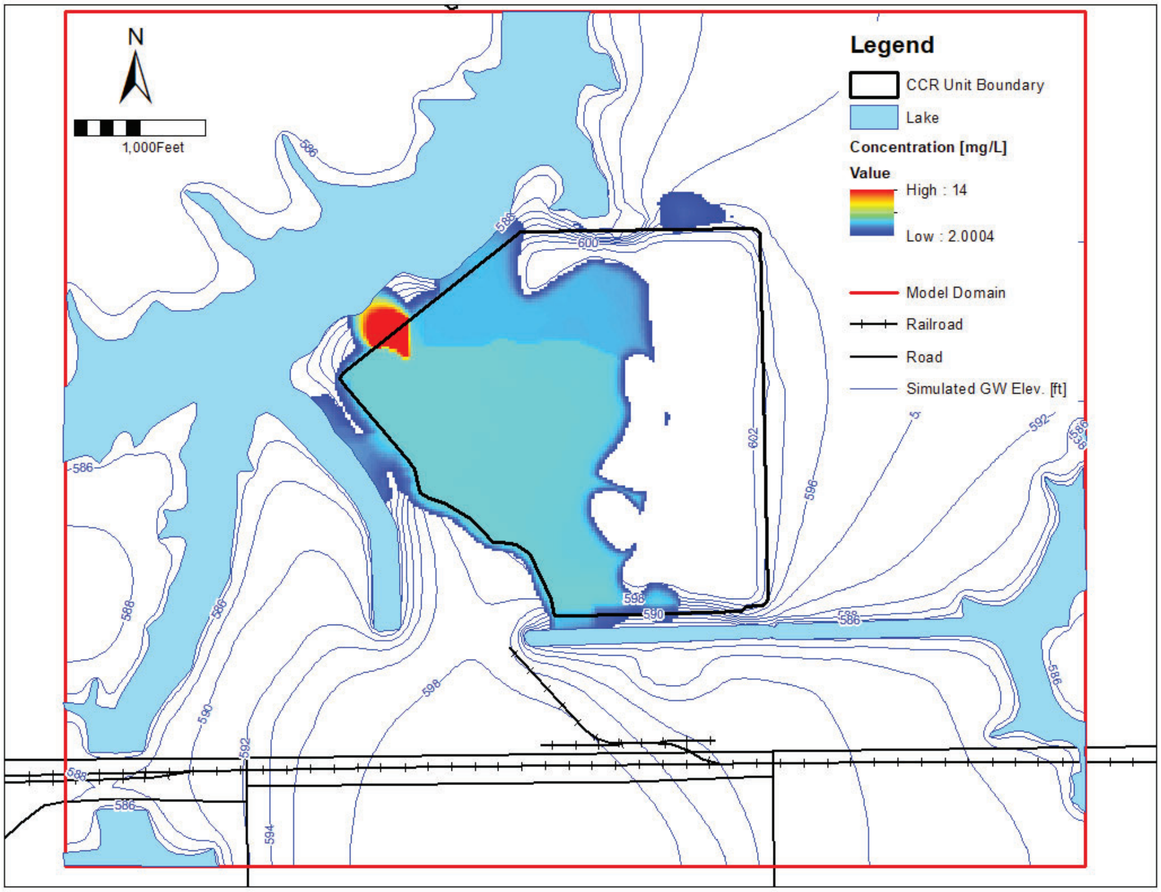
RAMBOLL



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

GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

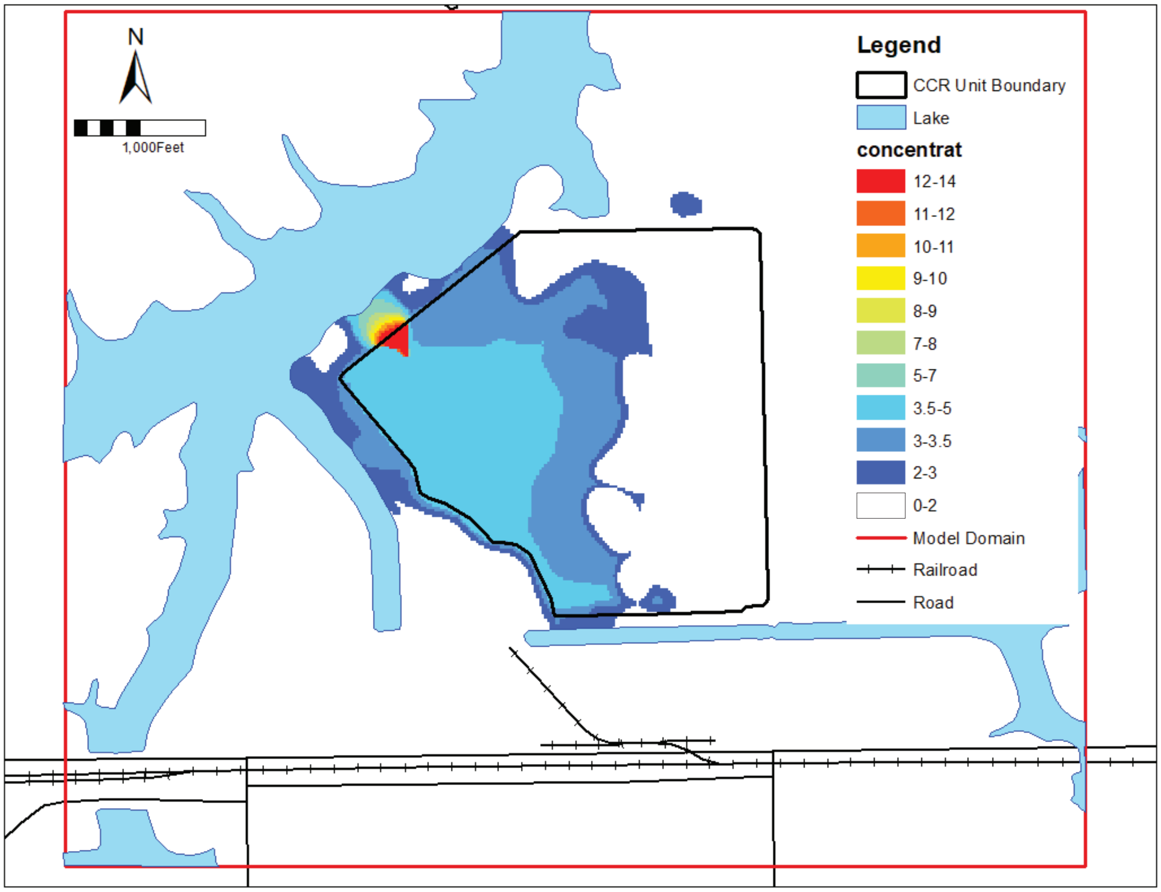
RAMBOLL



DISTRIBUTION OF BORON CONCENTRATION (mg/L) IN THE CALIBRATED MODEL LAYER 2

GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

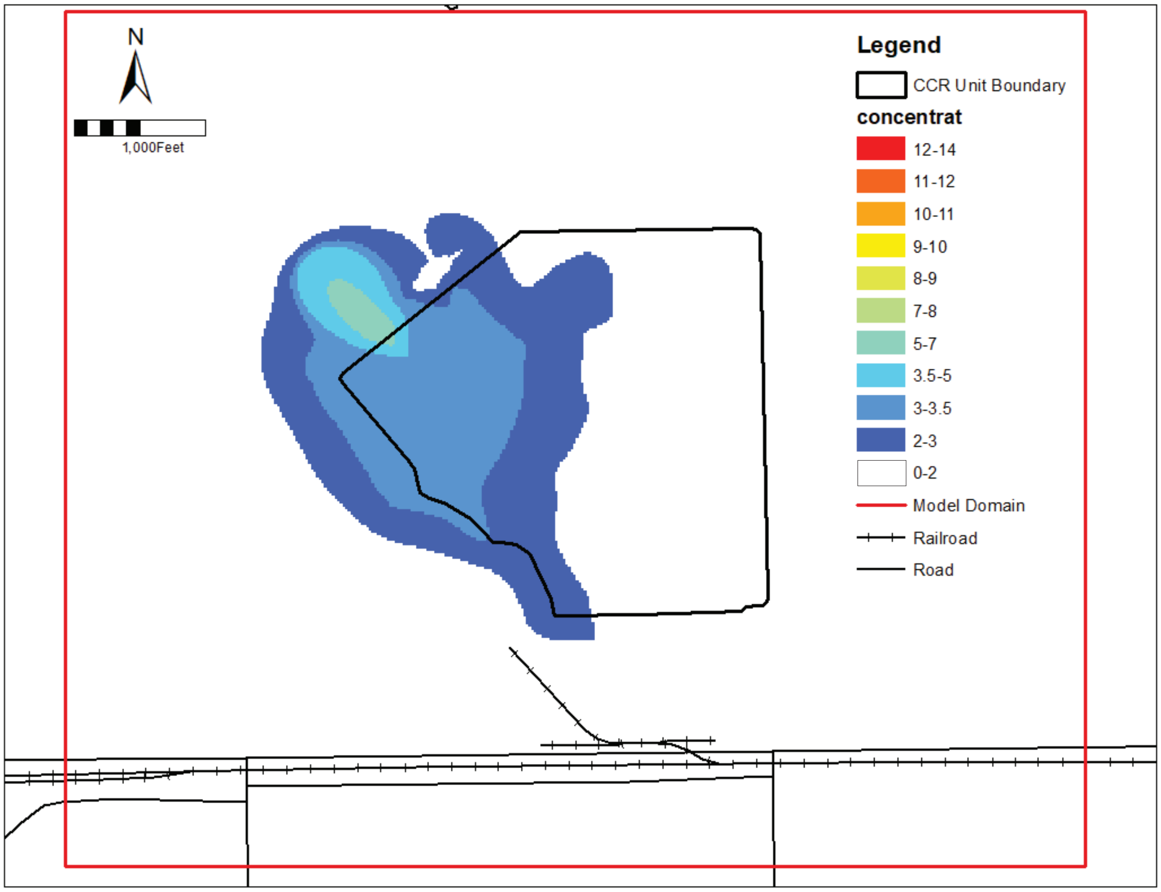
RAMBOLL



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

GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

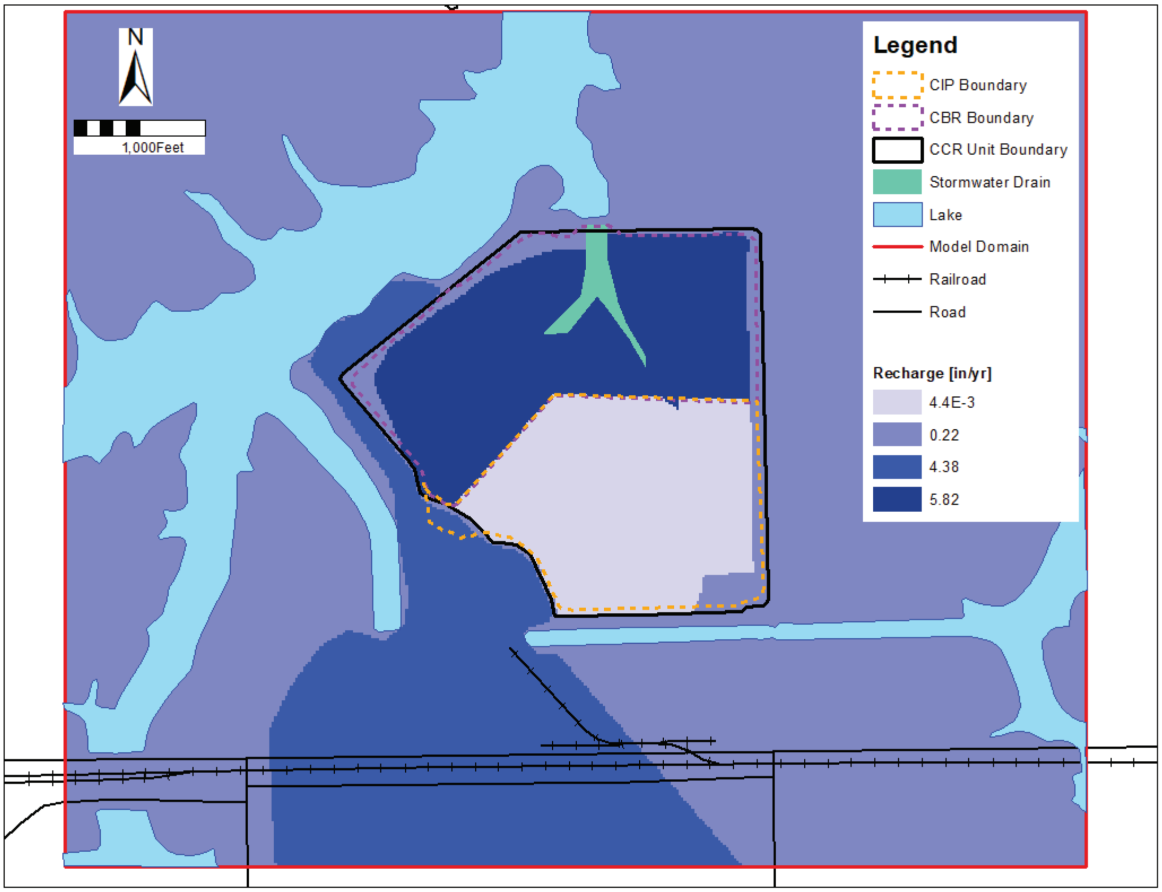
RAMBOLL



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

GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

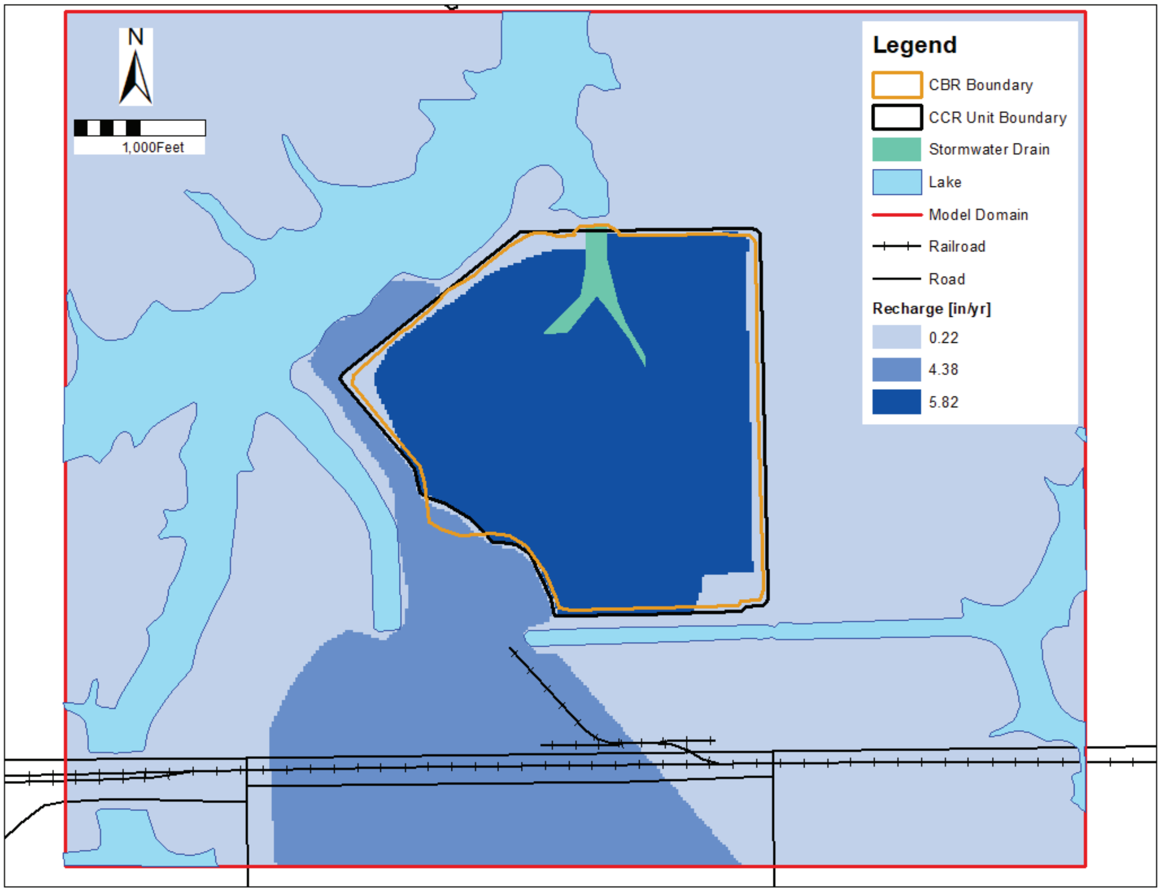
RAMBOLL



CIP RECHARGE DISTRIBUTION AND STORMWATER DRAIN

GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

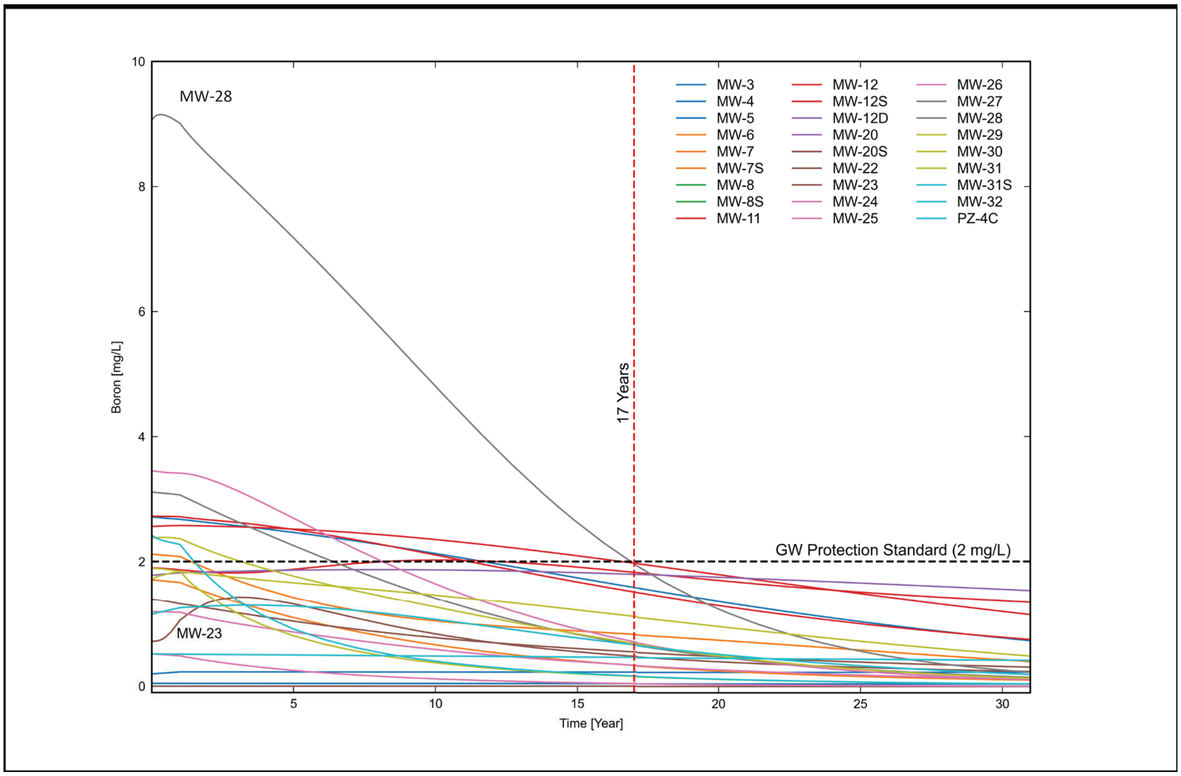
RAMBOLL



CBR RECHARGE DISTRIBUTION AND STORMWATER DRAIN

GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

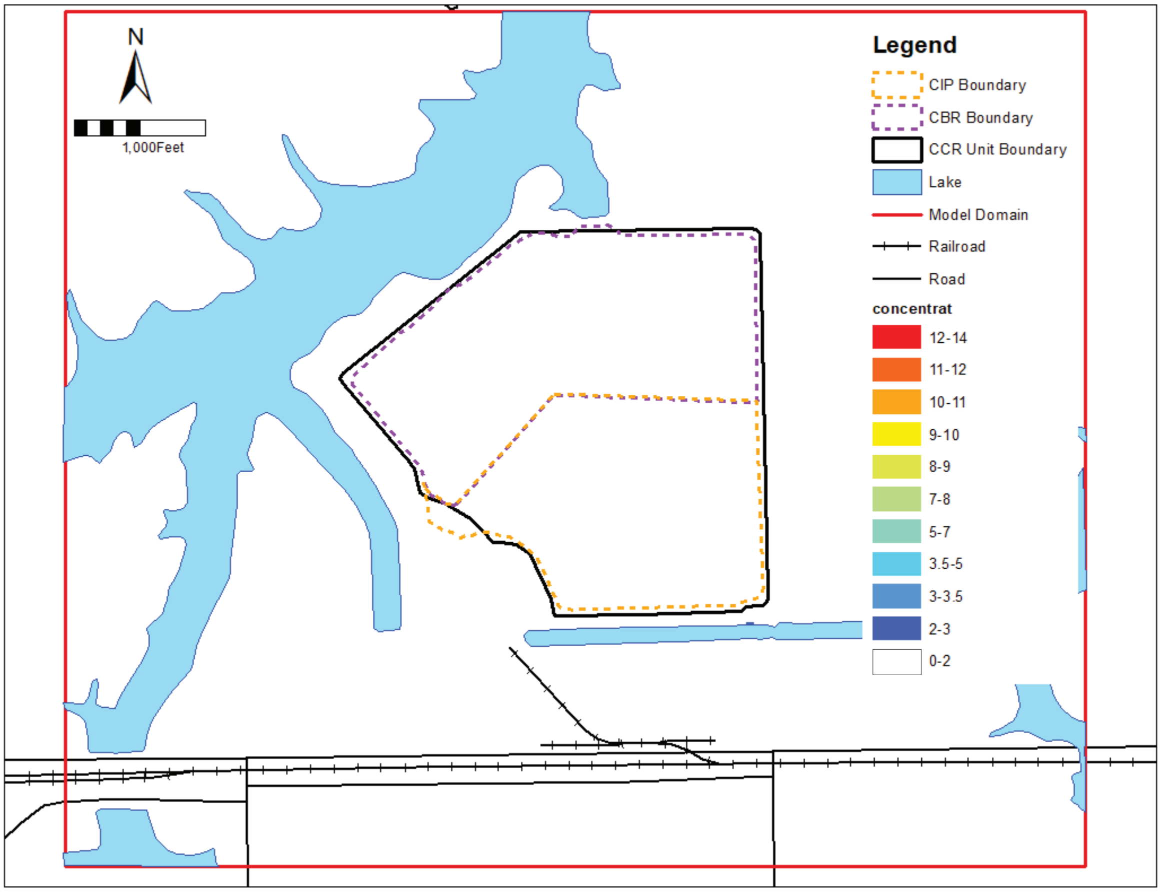
RAMBOLL



CIP (SCENARIO 1) - MODEL PREDICTED BORON CONCENTRATION

GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

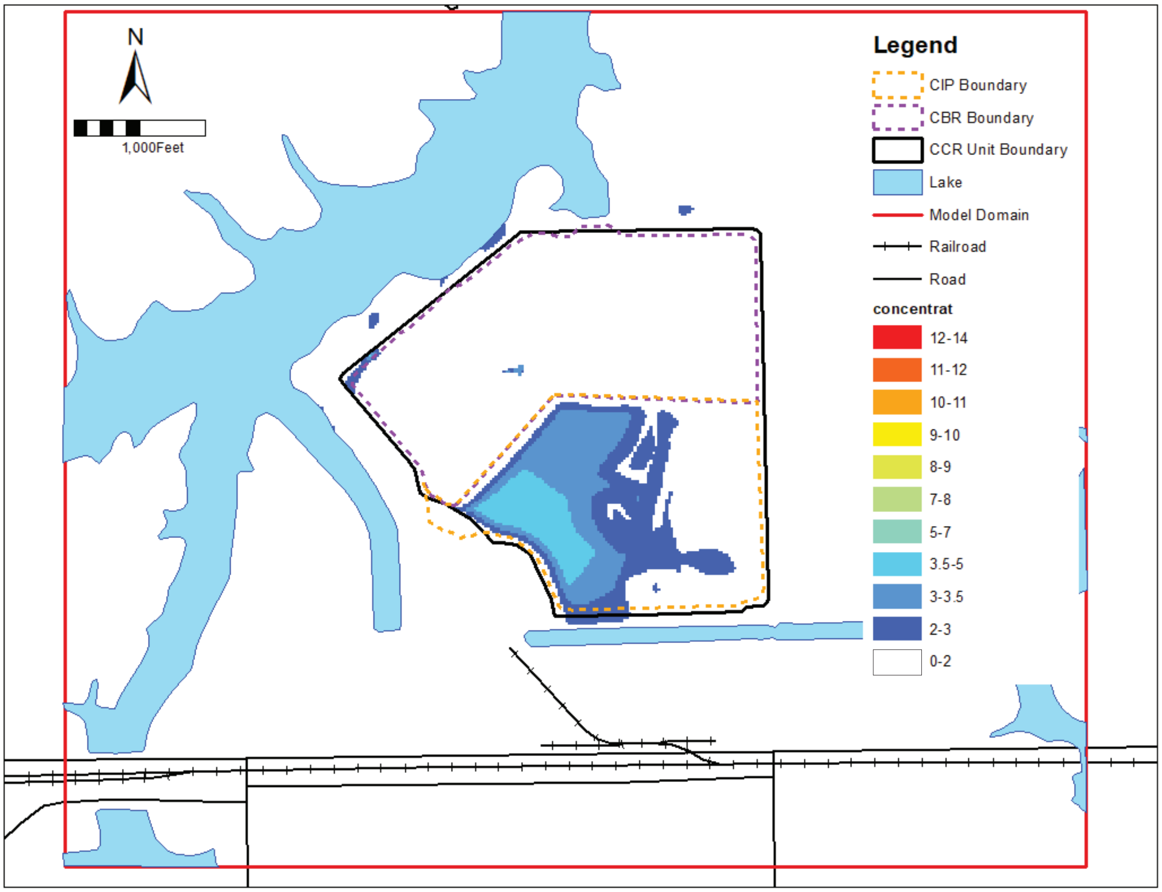
RAMBOLL



DISTRIBUTION OF BORON CONCENTRATION (mg/L) IN CIP SCENARIO LAYER 1 (17 YEARS)

GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

RAMBOLL

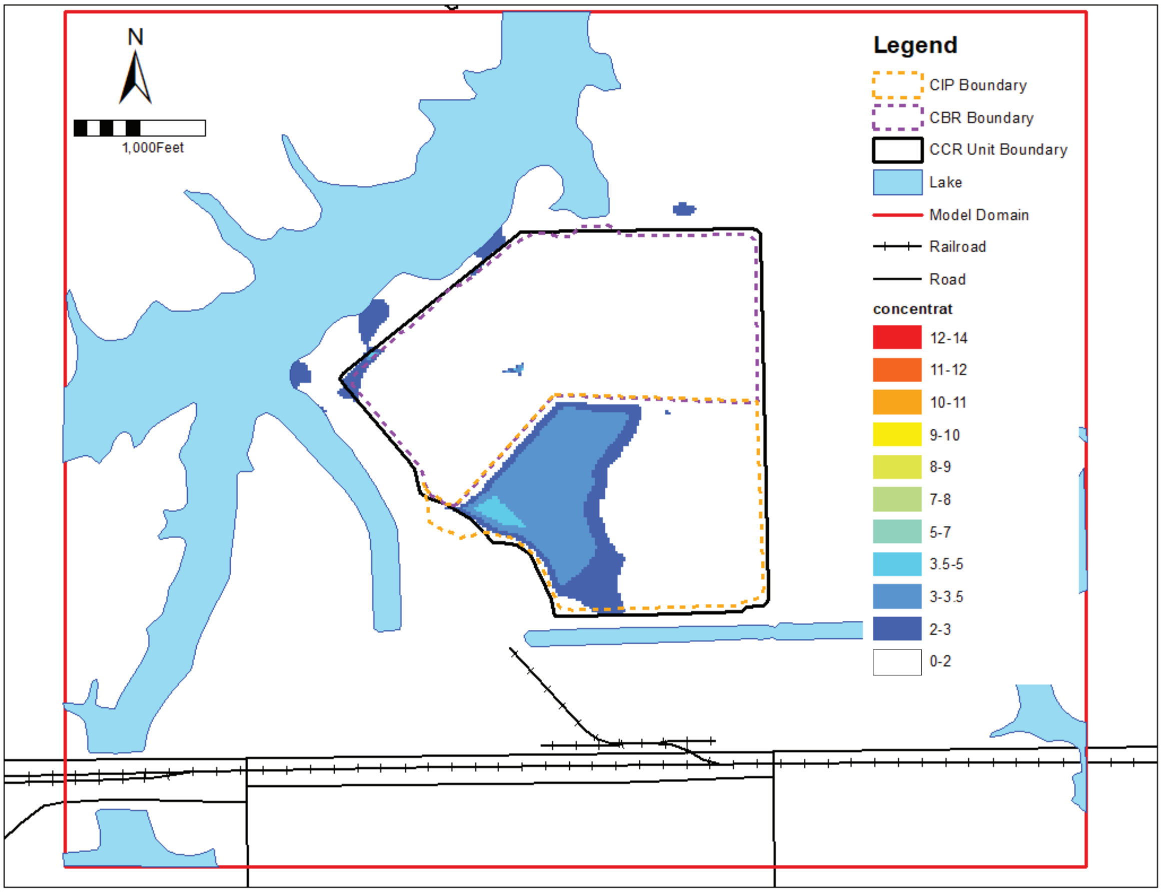


DISTRIBUTION OF BORON CONCENTRATION (mg/L) IN CIP SCENARIO LAYER 2 (17 YEARS)

GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

RAMBOLL

FIGURE 6-6

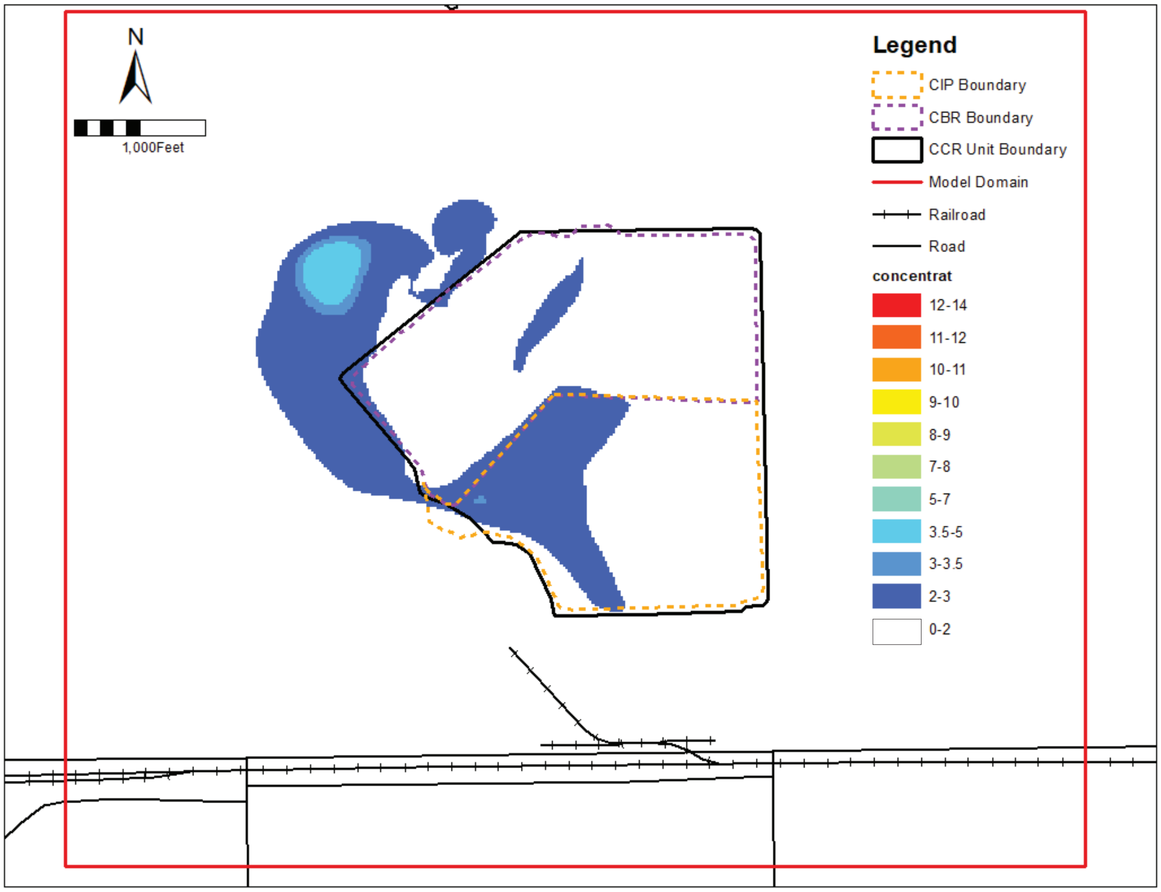


DISTRIBUTION OF BORON CONCENTRATION (mg/L) IN CIP SCENARIO LAYER 3 (17 YEARS)

GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

RAMBOLL

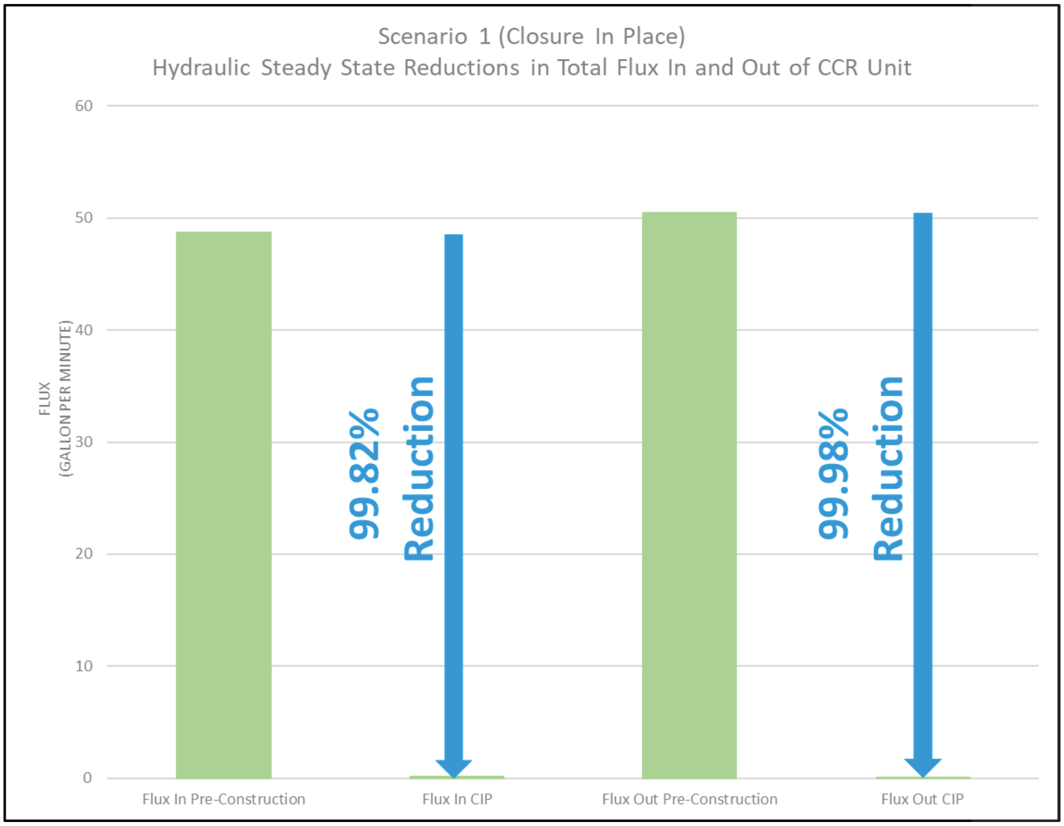
FIGURE 6-7



DISTRIBUTION OF BORON CONCENTRATION (mg/L) IN CIP SCENARIO LAYER 4 (17 YEARS)

GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

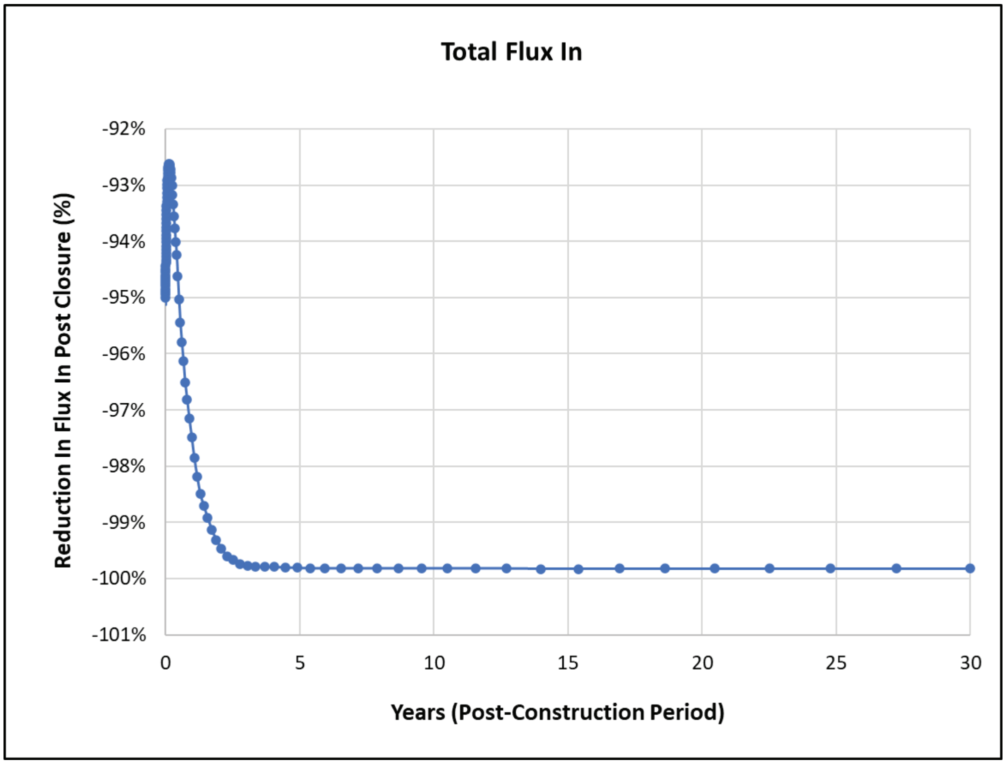
RAMBOLL

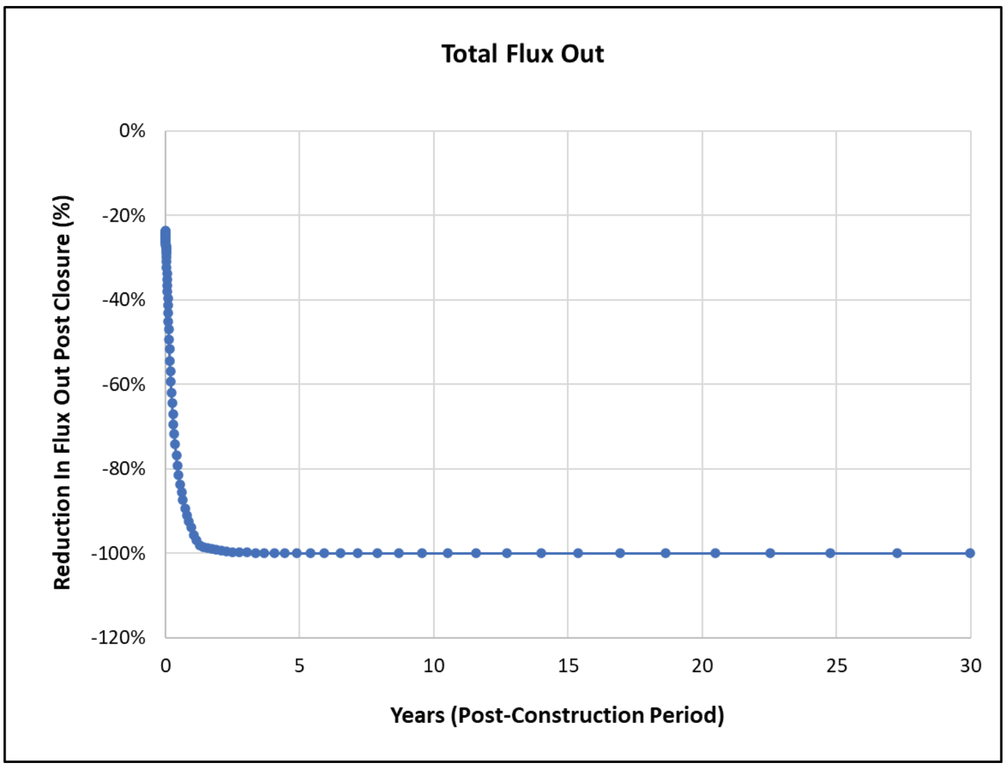


SCENARIO 1 (CIP) –
HYDRAULIC STEADY STATE REDUCTIONS IN TOTAL FLUX IN AND OUT OF CCR UNIT

GROUNDWATER MODELING REPORT
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

RAMBOLL

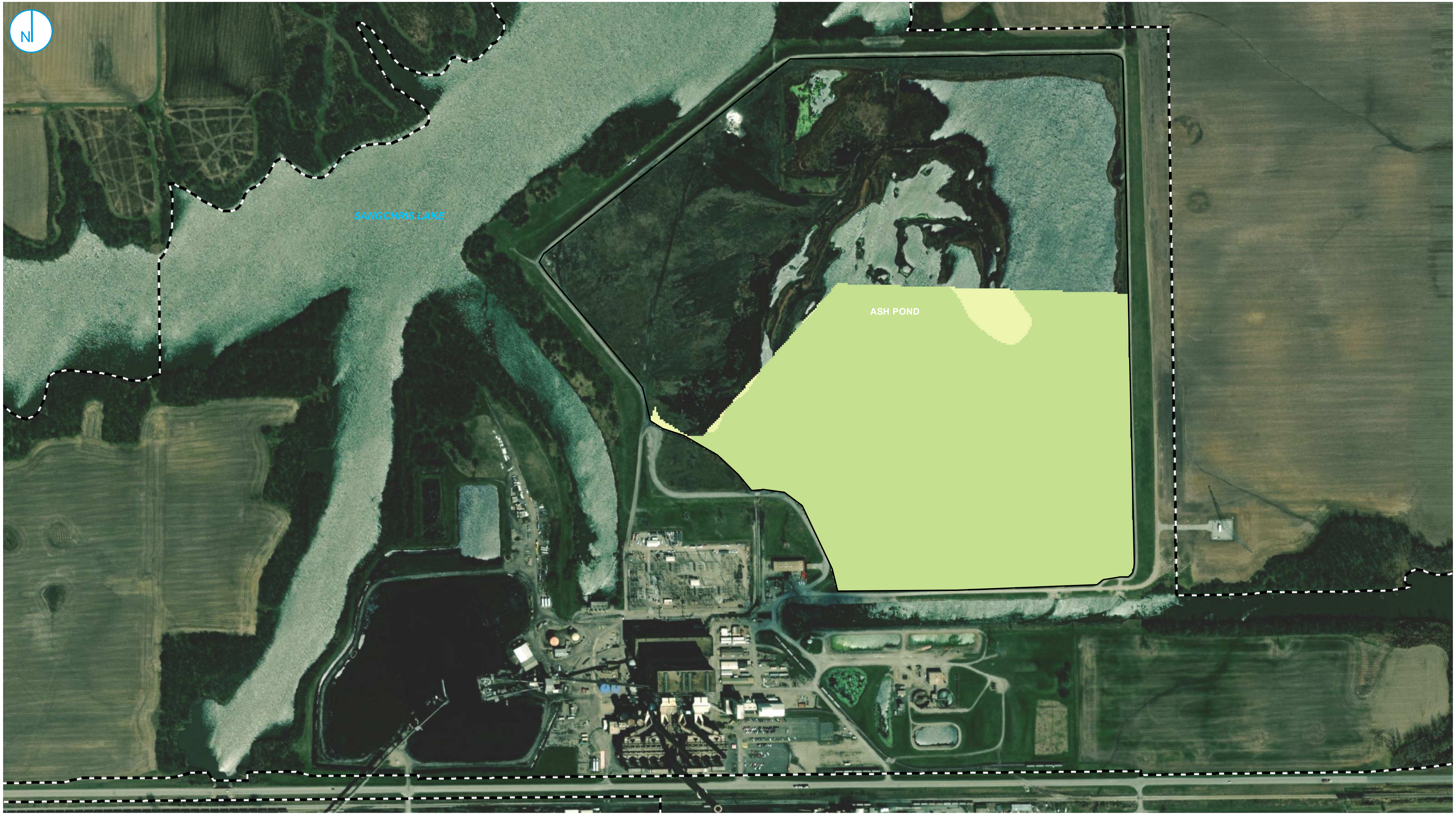




SCENARIO 1 (CIP) –
REDUCTIONS IN TOTAL FLUX IN AND OUT OF CCR UNIT

GROUNDWATER MODELING REPORT
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

RAMBOLL



SITE FEATURE

PROPERTY BOUNDARY

DIFFERENCE BETWEEN BOTTOM OF CCR AND SIMULATED GROUNDWATER SURFACE* (FEET, POSITIVE VALUES INDICATE SEPARATION)

0 - 5

5.1 - 10

0 250 500 Feet

*GROUNDWATER SURFACE BASED ON SIMULATED CLOSURE IN PLACE SCENARIO AT HYDRAULIC STABILIZATION.

SIMULATED CLOSURE IN PLACE GROUNDWATER SEPARATION

KINCAID POWER PLANT
KINCAID, ILLINOIS

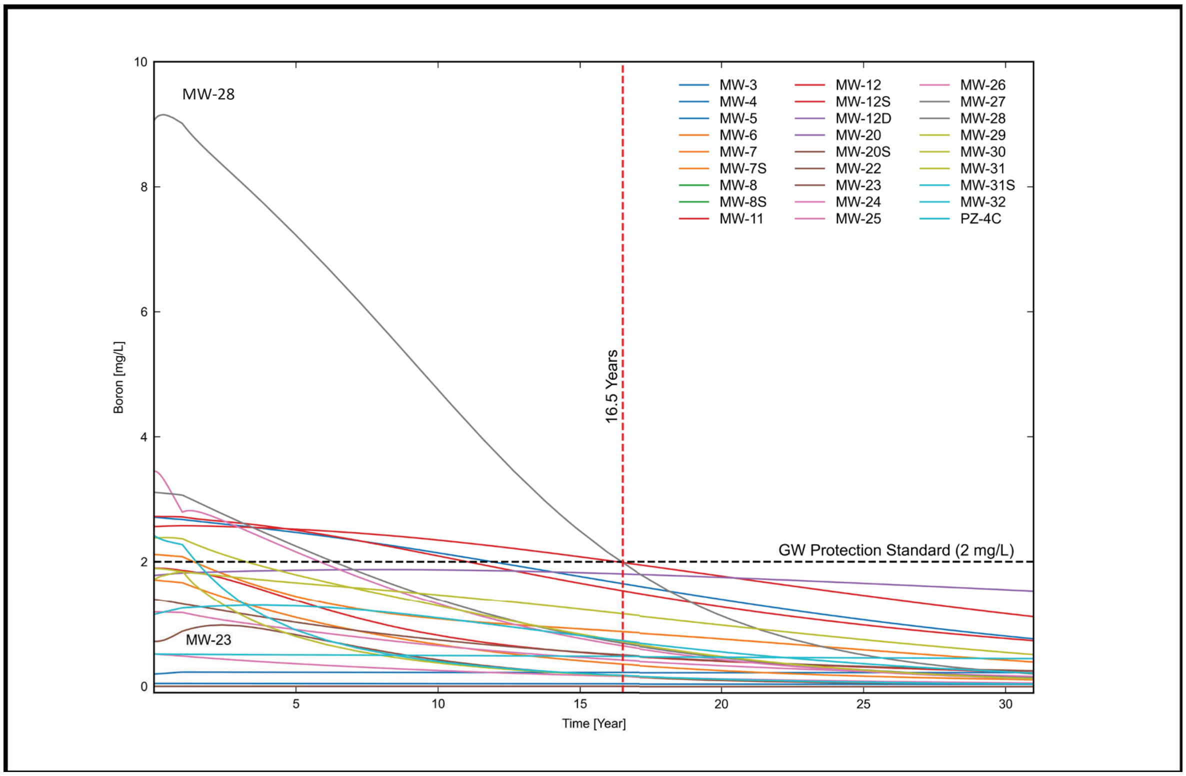
FIGURE 6-10

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

RAMBOLL

Y:\Mapping\Projects\22\2285\MXD\IntersectingGW_2022\KIN BOA Saturation CIP.mxd

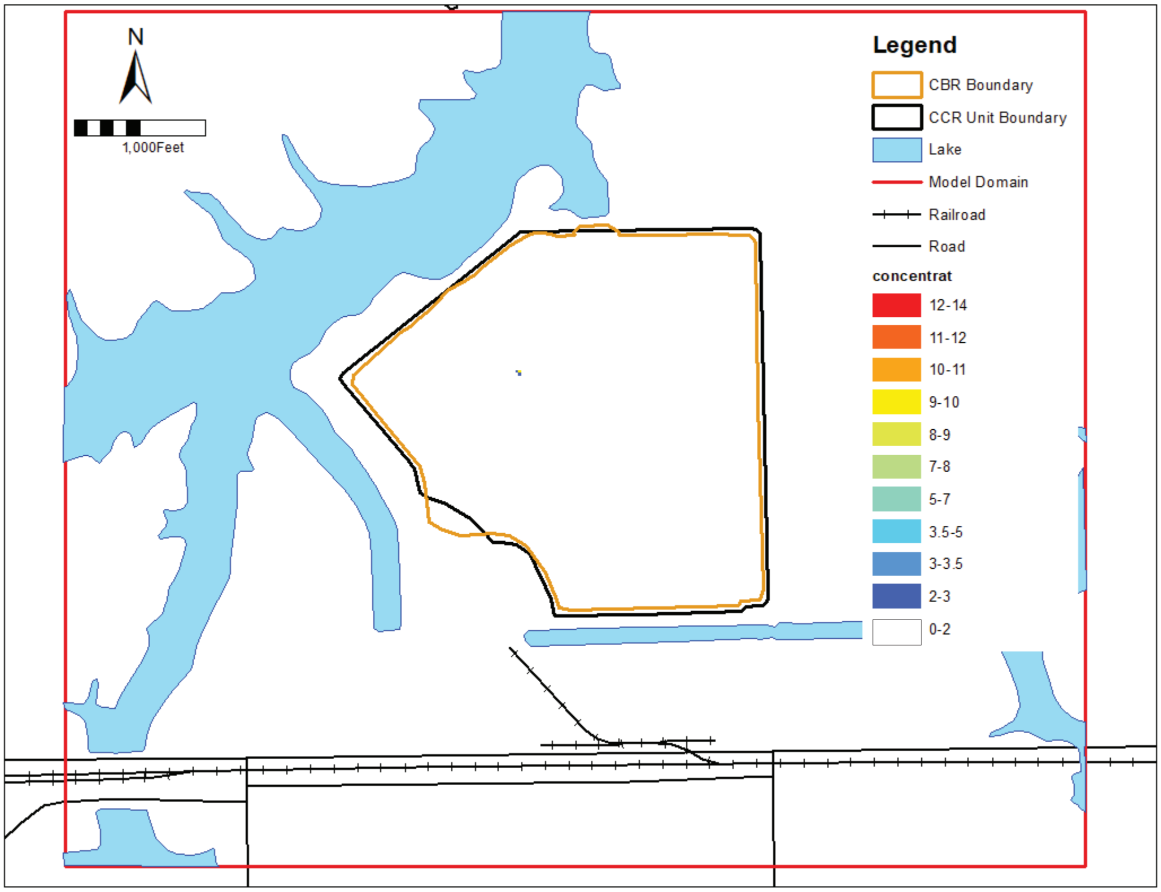
PROJECT: 169000XXXX | DATED: 7/14/2022 | DESIGNER: galarnmc



CBR (SCENARIO 2) - MODEL PREDICTED BORON CONCENTRATION

GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

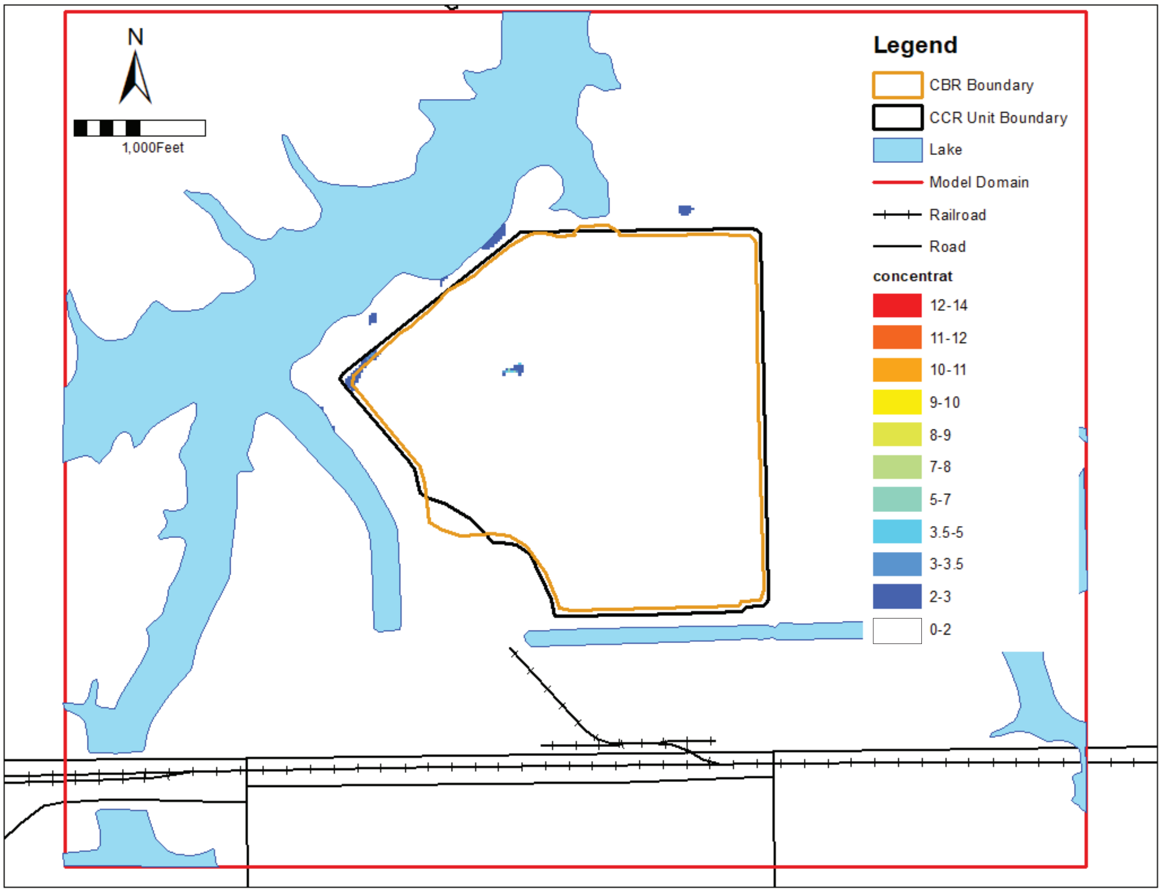
RAMBOLL



DISTRIBUTION OF BORON CONCENTRATION (mg/L) IN CBR SCENARIO LAYER 1 (17 YEARS)

GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

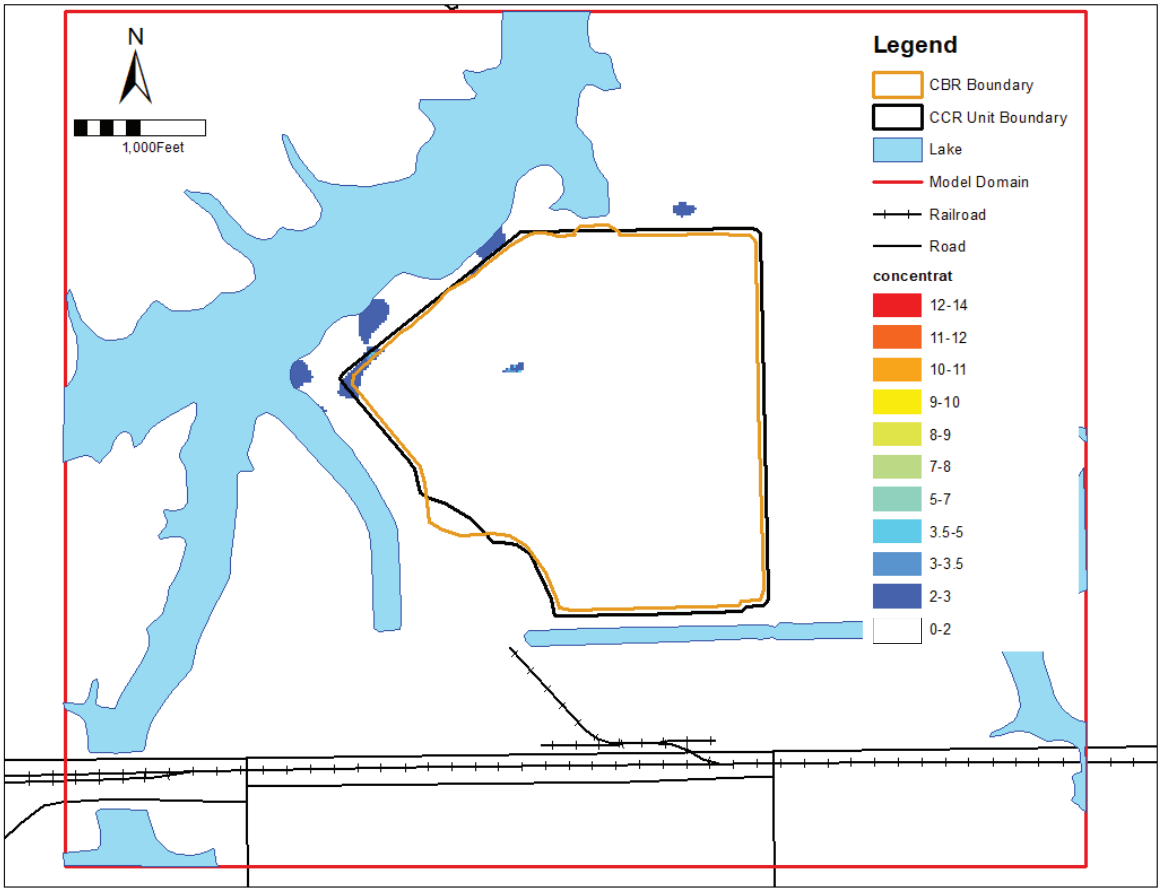
RAMBOLL



DISTRIBUTION OF BORON CONCENTRATION (mg/L) IN CBR SCENARIO LAYER 2 (17 YEARS)

GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

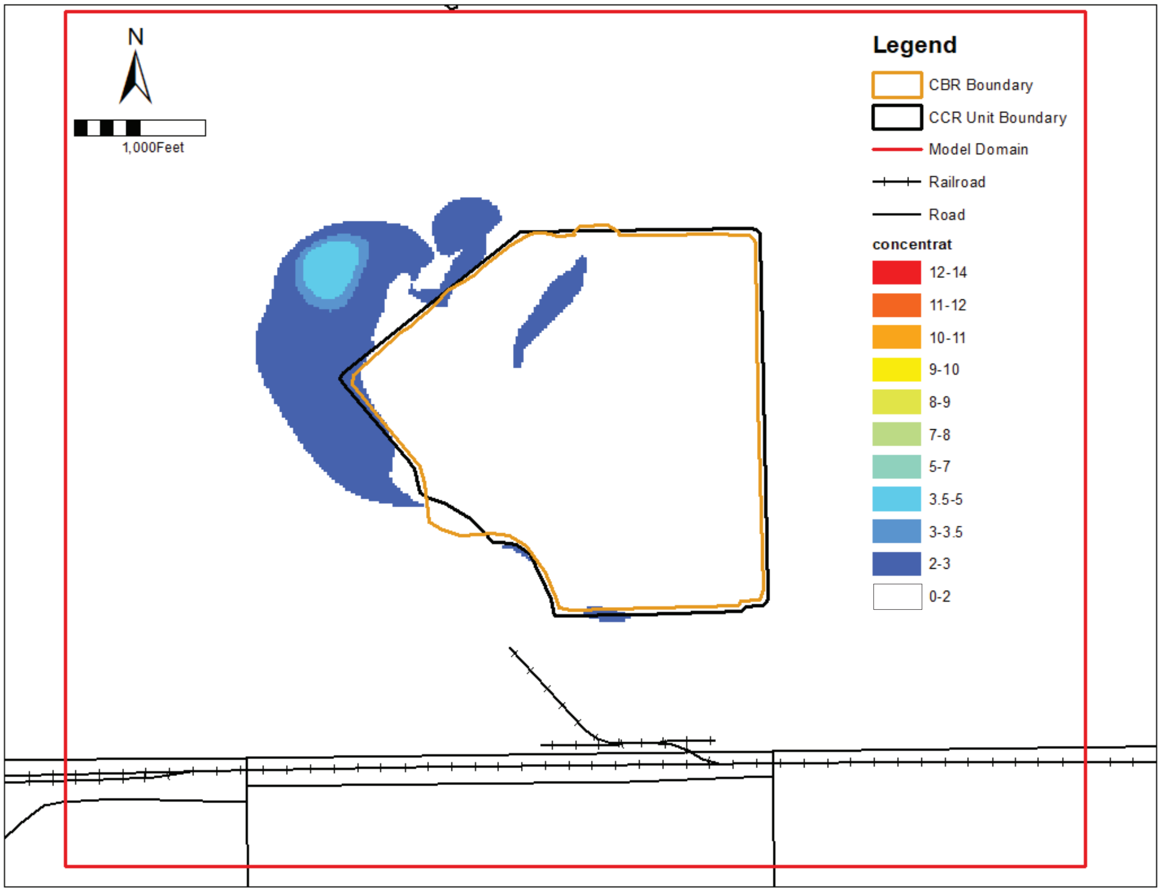
RAMBOLL



DISTRIBUTION OF BORON CONCENTRATION (mg/L) IN CBR SCENARIO LAYER 3 (17 YEARS)

GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

RAMBOLL



DISTRIBUTION OF BORON CONCENTRATION (mg/L) IN CBR SCENARIO LAYER 4 (17 YEARS)

GROUNDWATER MODELING REPORT
KINCAID CCR ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

RAMBOLL

APPENDICES

APPENDIX A
MODFLOW, MT3DMS, HELP MODEL, AND FLUX EVALUATION DATA EXPORT FILES (ELECTRONIC ONLY)

APPENDIX B
EVALUATION OF PARTITION COEFFICIENT RESULTS (GOLDER, 2022)

TECHNICAL MEMORANDUM

DATE March 30, 2022 **Project No.** 21454831

TO David Mitchell, Stu Cravens, Vic Modeer
Kincaid Generation, LLC

CC Brian Henning - Ramboll

FROM Golder Associates USA Inc. **EMAIL** **Jeffrey_Ingram@golder.com**

EVALUATION OF PARTITION COEFFICIENT RESULTS, KINCAID POWER PLANT ASH POND (CCR UNIT 141), KINCAID POWER PLANT, CHRISTIAN COUNTY, ILLINOIS

1.0 INTRODUCTION

Kincaid Generation, LLC (KG) operates the Kincaid Power Plant (KPP) located in Christian County, Illinois. The Ash Pond (AP or Site), Illinois Environmental Protection Agency [IEPA] ID No. W0218140002 - 01 is a 178-acre unlined surface impoundment used to manage coal combustion residuals (CCRs) at the KPP. The AP is regulated under Part 845 *"Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments"* (State CCR Rule or Part 845) which was promulgated by the Illinois Pollution Control Board (IPCB) on April 21, 2021. WSP Golder (Golder) is assisting KG with Part 845 compliance at the Site.

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

2.0 OVERVIEW

In August 2021, Golder conducted a field investigation at the KPP which included the completion of eight (8) soil/rock borings ranging in depth from 20 to 40 feet below ground surface (ft bgs). As a part of that investigation, soil and groundwater samples were submitted to SiREM laboratories (Guelph, ON) for batch solid/liquid partitioning testing. A summary of the soil samples used for the batch testing is provided in Table 1.

Table 1: Batch Attenuation Testing Data Summary

Groundwater Sample ID	Soil Sample ID	Soil: Water Ratio
MW-12S	K-SB-02 (10.0-14.7 ft bgs)	2:1
		1:1

Groundwater Sample ID	Soil Sample ID	Soil: Water Ratio
		1:5
		1:10
		1:20
MW-28	K-SB-02 (14.7-17.5 ft bgs)	2:1
		1:1
		1:5
		1:10
		1:20

Notes:

1) ft bgs – Feet below ground surface

Site-specific partitioning coefficients were determined for constituents of interest (COIs) boron and sulfate, which were identified based on statistical evaluation of potential groundwater exceedances calculated at the Site (Burns and McDonnell 2021). Two groundwater samples (MW-12S and MW-28) and two soil samples (K-SB-02 (10.0-14.7) and K-SB-02 (14.7-17.5)) were used for batch attenuation testing at various ratios (Table 1). For each treatment, 0.1 L of groundwater was brought in contact with an amount of soil (0.003 to 0.17 kg, depending on the ratio) over a seven-day period. Each contact water/soil microcosm was amended (spiked) with meta-arsenite, boric acid, lithium chloride, and sodium sulfate to a target concentration of arsenic, boron, lithium, and sulfate, respectively (Table 2). Arsenic and lithium are not currently COIs at the Site and, therefore, were not evaluated as part of this report. However, arsenic and lithium may be revisited in the future, thus meta-arsenite and lithium chloride were included as additional amendments. After the seven-day contact period, COI concentrations were analyzed in the contact water. The control samples (i.e., groundwater samples MW-12S and MW-28) were only analyzed at the initiation of testing. The oxidation/reduction potential (redox) and pH were measured for each batch test at the beginning and end of the contact period and in the control samples.

Table 2: Microcosm amendment and target concentration for COIs

COI	Groundwater Sample	Amendment	Target Concentration (mg/L)
Arsenic	MW-12S	67.45 µL of a 2 g/L As(III) solution	0.04
	MW-28	68.67 of a 2 g/L As(III) solution	
Boron	MW-12S	17.78 mL of a 10 g/L H_3BO_3 solution	16.8
	MW-28	9.61 mL of a 10 g/L H_3BO_3 solution	
Lithium	MW-12S	2.42 mL of a 1 g/L LiCl solution	0.2

	MW-28	2.39 mL of a 1 g/L LiCl solution	
Sulfate	MW-12S	51.56 mL of a 100 g/L Na_2SO_4 solution	1,748
	MW-28	27.56 mL of a 100 g/L Na_2SO_4 solution	

Notes:

1) g/L – grams per liter
2) mL – milliliter
3) µg/L – micrograms per liter
4) mg/L – miligrams per liter
5) As(III) – arsenite
6) H_3BO_3 – boric acid
7) LiCl – lithium chloride
8) Na_2SO_4 – sodium sulfate

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

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

Where

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

q_e = concentration of the adsorbate in soil

C_e = aqueous concentration of the adsorbate

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

n = non-linearity constant

3.0 SUMMARY OF RESULTS

Figures that show the linear, Langmuir, and Freundlich isotherms for the two COIs are provided in Appendix A. The partition coefficient values for MW-12S and MW-28 are presented in Tables 5 and 6, respectively. The results of the batch adsorption testing can be summarized as follows:

- **Boron**: Calculated K_D values for MW-12S and MW-28 were 0.05 and 1.81 L/kg, respectively, K_L values -1.4E+6 and -1.5E+4 L/kg, respectively, and K_F values 112 and 27.5 L/kg, respectively. For comparison, in Strenge and Peterson (1989), partition coefficients for boron range from 0.19 to 1.3 L/kg, depending on pH conditions and the amount of sorbent (i.e. clay, organic matter, and iron and aluminum oxyhydroxide) present.
- **Sulfate**: Calculated K_D values for MW-12S and MW-28 were 0.23 and 15.5 L/kg, respectively, K_L values -454 and -750 L/kg, respectively, and K_F values 1.87 and 0.13 L/kg, respectively. In Strenge and Peterson (1989), partition coefficients for sulfate are 0.0 L/kg, regardless of pH conditions and the amount of sorbent present.

- **pH and Redox**: Generally, after the seven-day contact time, the pH of each contact water was consistent with the pH of the control samples (6.94 for MW-12S and 6.90 for MW-28, respectively), ranging from 6.93 to 6.97 across the batch tests. The redox values of the control samples after the seven-day contact time were -54 mV and 116 mV for MW-12S and MW-28, respectively. The redox value of contact water ranged from -131 to +236 mV across treatments.

4.0 REFERENCES

Burns and McDonnell, 2021. Initial Operating Permit Kincaid Power Plant Ash Pond.

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

5.0 CLOSING

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

Golder Associates USA Inc.

Jeffrey Ingram
Senior Consultant, Geologist

Pat Behling
Practice Leader

CK/JSI/PJB

Attachments Appendix A – Partition Coefficient Graphs

Table 3: Batch Attenuation Testing Results, MW-12S

Geologic Material Sample ID	Treatment	Date	Day	Replicate	Dissolved Boron	Dissolved Sulfate	pH	ORP
					mg/L	mg/L	SU	mV
	Groundwater Only Control	2/10/2022	0	MW-12S-1a	17	1,700	6.96	13
				MW-12S-2a	18	1,513	6.95	8
				Average Concentration (mg/L)	17	1,606	6.96	11
		2/17/2022	7	MW-12S-1	16	964	6.94	-59
				MW-12S-2	17	1,059	6.94	-48
				Average Concentration (mg/L)	16	1,012	6.94	-54
MW-12S K-SB-02 (10.0-14.7)	2:1 Soil:Water Ratio	2/10/2022	0					
		2/17/2022	7	K-SB-02-(10.0-14.7) :MW-12S 2:1-1	8.9	878	6.94	-110
				K-SB-02-(10.0-14.7) :MW-12S 2:1-2	8.0	921	6.92	-127
				Average Concentration (mg/L)	8.4	899	6.93	-119
	1:1 Soil:Water Ratio	2/10/2022	0					
		2/17/2022	7	K-SB-02-(10.0-14.7) :MW-12S 1:1-1	12	1,137	6.92	-131
				K-SB-02-(10.0-14.7) :MW-12S 1:1-2	12	1,284	7.01	--
				Average Concentration (mg/L)	12	1,211	6.97	-131
	1:5 Soil:Water Ratio	2/10/2022	0					
		2/17/2022	7	K-SB-02-(10.0-14.7) :MW-12S 1:5-1	16	1,268	6.95	-4
				K-SB-02-(10.0-14.7) :MW-12S 1:5-2	15	1,568	6.94	16
				Average Concentration (mg/L)	16	1,418	6.95	6
	1:10 Soil:Water Ratio	2/10/2022	0					
		2/17/2022	7	K-SB-02-(10.0-14.7) :MW-12S 1:10-1	16	1,216	6.93	53
				K-SB-02-(10.0-14.7) :MW-12S 1:10-2	17	1,527	6.95	22
				Average Concentration (mg/L)	17	1,372	6.94	38
	1:20 Soil:Water Ratio	2/10/2022	0					
		2/17/2022	7	K-SB-02-(10.0-14.7) :MW-12S 1:20-1	19	981	6.96	42
				K-SB-02-(10.0-14.7) :MW-12S 1:20-2	18	1,381	6.95	53
				Average Concentration (mg/L)	19	1,181	6.96	48

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

Table 4: Batch Attenuation Testing Results, MW-28

Geologic Material Sample ID	Treatment	Date	Day	Replicate	Dissolved Boron	Dissolved Sulfate	pH	ORP
					mg/L	mg/L	SU	mV
	Groundwater Only Control	2/10/2022	0	MW-28-1a	18	1,515	6.92	-3
				MW-28-2a	17	1,582	6.93	3
				Average Concentration (mg/L)	18	1,549	6.93	0
		2/17/2022	7	MW-28-1	16	1,397	6.88	183
				MW-28-2	17	624	6.91	48
				Average Concentration (mg/L)	17	1,010	6.90	116
MW-12S K-SB-02 (14.7-17.5)	2:1 Soil:Water Ratio	2/10/2022	0					
		2/17/2022	7	K-SB-02-(14.7-17.5):MW-28 2:1-1	8.5	546	6.94	239
				K-SB-02-(14.7-17.5):MW-28 2:1-2	9.2	<1.4	6.92	232
				Average Concentration (mg/L)	8.8	546	6.93	236
	1:1 Soil:Water Ratio	2/10/2022	0					
		2/17/2022	7	K-SB-02-(14.7-17.5):MW-28 1:1-1	12	761	6.96	139
				K-SB-02-(14.7-17.5):MW-28 1:1-2	12	1,026	6.95	89
				Average Concentration (mg/L)	12	893	6.96	114
	1:5 Soil:Water Ratio	2/10/2022	0					
		2/17/2022	7	K-SB-02-(14.7-17.5):MW-28 1:5-1	17	1,023	6.99	106
				K-SB-02-(14.7-17.5):MW-28 1:5-2	16	999	6.95	107
				Average Concentration (mg/L)	16	1,011	6.97	107
	1:10 Soil:Water Ratio	2/10/2022	0					
		2/17/2022	7	K-SB-02-(14.7-17.5):MW-28 1:10-1	16	1,182	6.94	70
				K-SB-02-(14.7-17.5):MW-28 1:10-2	16	949	6.95	79
				Average Concentration (mg/L)	16	1,066	6.95	75
	1:20 Soil:Water Ratio	2/10/2022	0					
		2/17/2022	7	K-SB-02-(14.7-17.5):MW-28 1:20-1	17	1,112	6.94	73
				K-SB-02-(14.7-17.5):MW-28 1:20-2	17	915	6.93	41
				Average Concentration (mg/L)	17	1,013	6.94	57

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

Table 5: Partition Coefficient Results, MW-12S

Analyte	Isotherm	Variable	With Soil Mass
Boron	Raw Data R^2		0.01
	Linear K_D (L/kg)		0.05
	Langmuir	R^2	0.63
		q_m (mg/g)	0.007
		K_L (L/kg)	-1.43E+06
	Freundlich	R^2	0.01
		1/n	0.049
		K_F (L/kg)	111.65
Sulfate	Raw Data R^2		0.00
	Linear K_D (L/kg)		0.23
	Langmuir	R^2	0.08
		q_m (mg/g)	-0.883
		K_L (L/kg)	-4.54E+02
	Freundlich	R^2	0.08
		1/n	2.111
		K_F (L/kg)	1.87

Note(s):

K_D: linear partition coefficient

K_L: Langmuir partition coefficient

K_F: Freundlich partition coefficient

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

n: non-linearity constant

Table 6: Partition Coefficient Results, MW-28

Analyte	Isotherm	Variable	With Soil Mass
Boron	Raw Data R^2		0.41
	Linear K_D (L/kg)		1.81
	Langmuir	R^2	0.02
		q_m (mg/g)	-0.043
		K_L (L/kg)	-1.54E+04
	Freundlich	R^2	0.43
		1/n	1.495
		K_F (L/kg)	27.53
Sulfate	Raw Data R^2		0.26
	Linear K_D (L/kg)		15.50
	Langmuir	R^2	0.34
		q_m (mg/g)	-1.013
		K_L (L/kg)	-7.50E+02
	Freundlich	R^2	0.50
		1/n	3.198
		K_F (L/kg)	0.13

Note(s):

K_D: linear partition coefficient

K_L: Langmuir partition coefficient

K_F: Freundlich partition coefficient

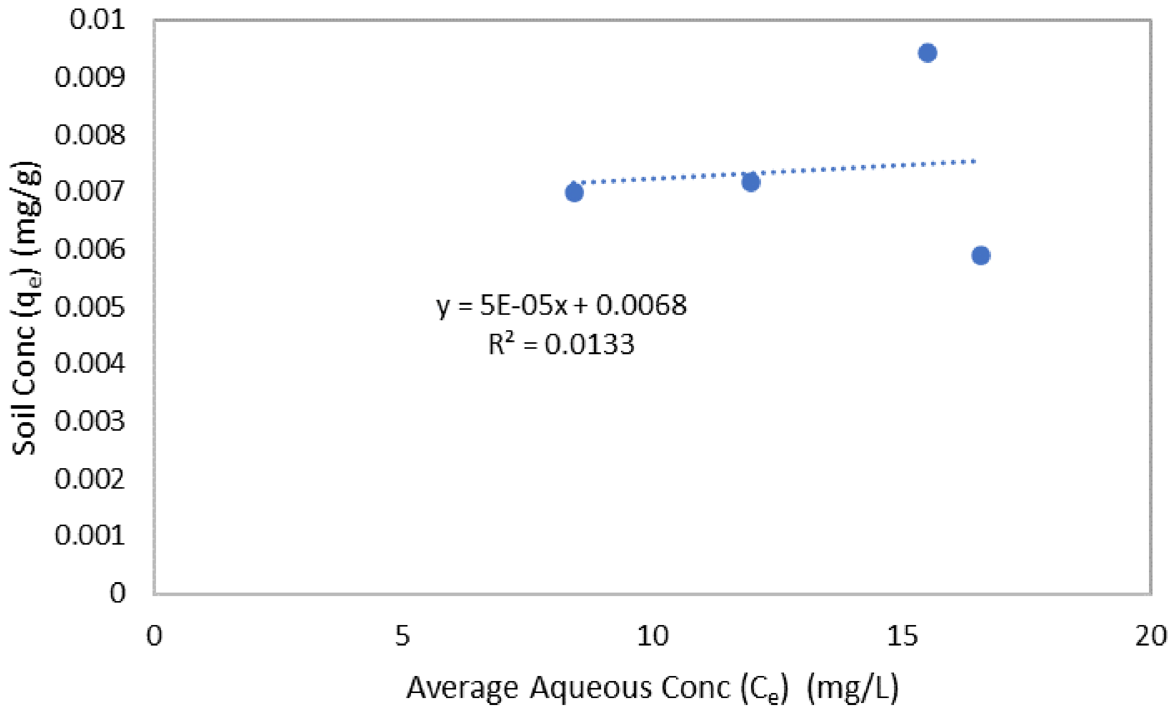
q_m: 1/slope in the linear expression of the isotherm

n: non-linearity constant

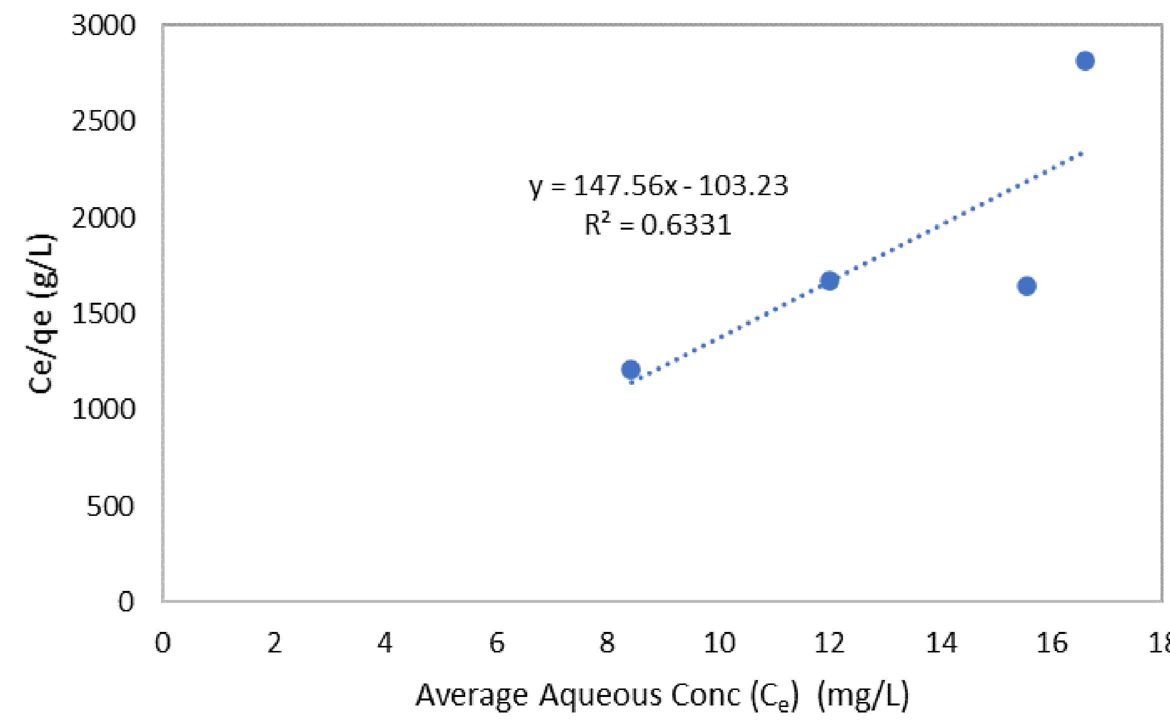
APPENDIX A

Partition Coefficient Graphs

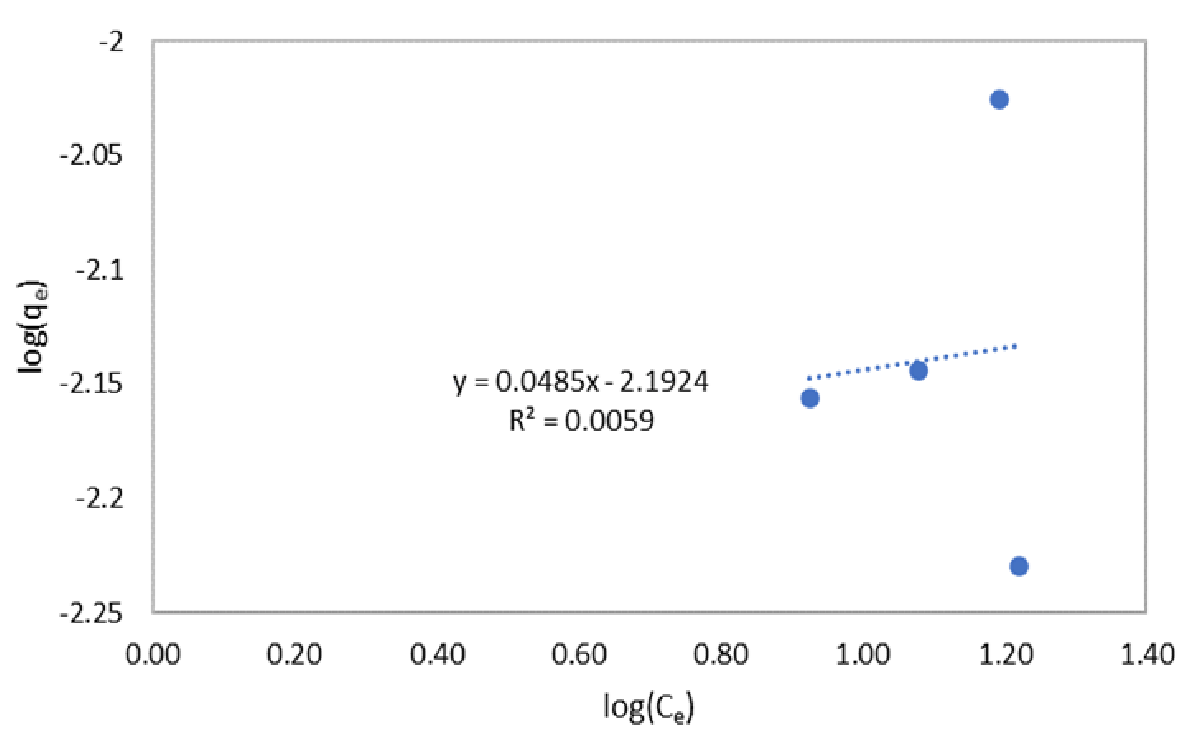
Linear



Langmuir



Freundlich



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

CLIENT
KINCAID GENERATION, LLC
KINCAID POWER PLANT ASH POND (CCR UNIT 141)

PROJECT
EVALUATION OF PARTITION COEFFICIENT RESULTS AP

CONSULTANT
WSP GOLDER

TITLE
MW-12S BORON PARTITION COEFFICIENTS

PROJECT NO.	PHASE	REV.	FIGURE
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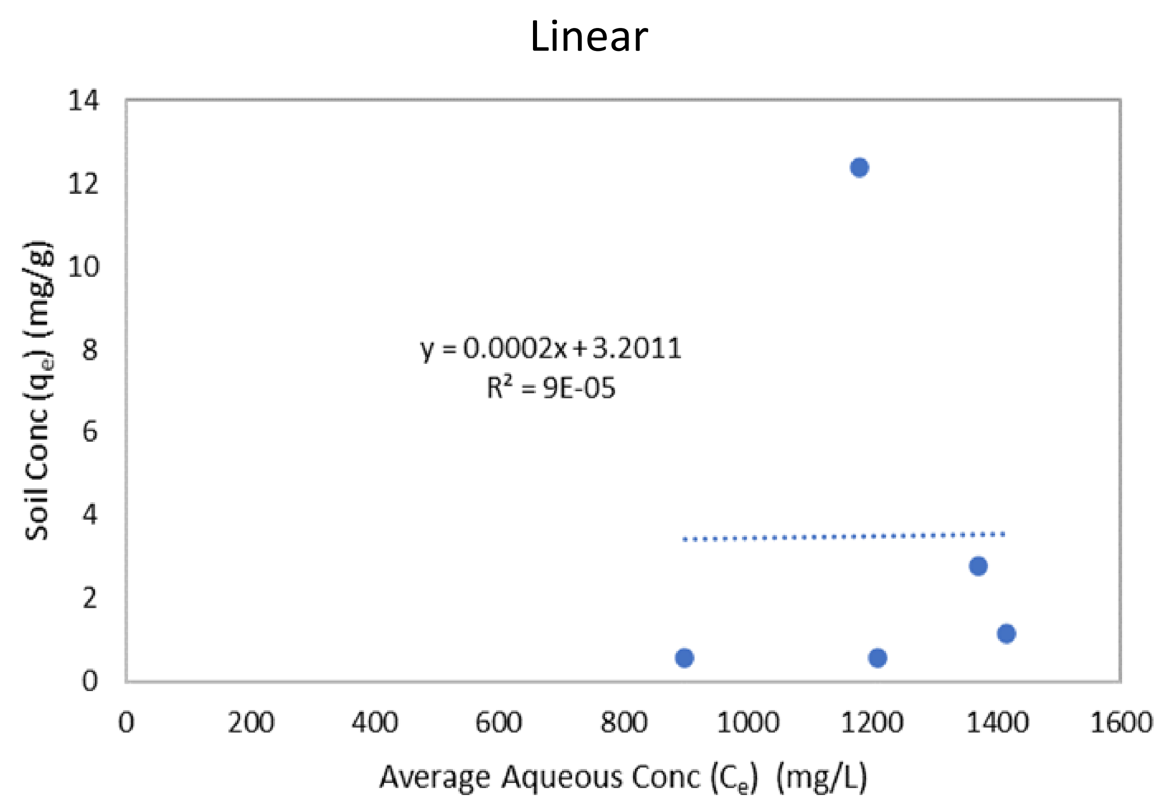

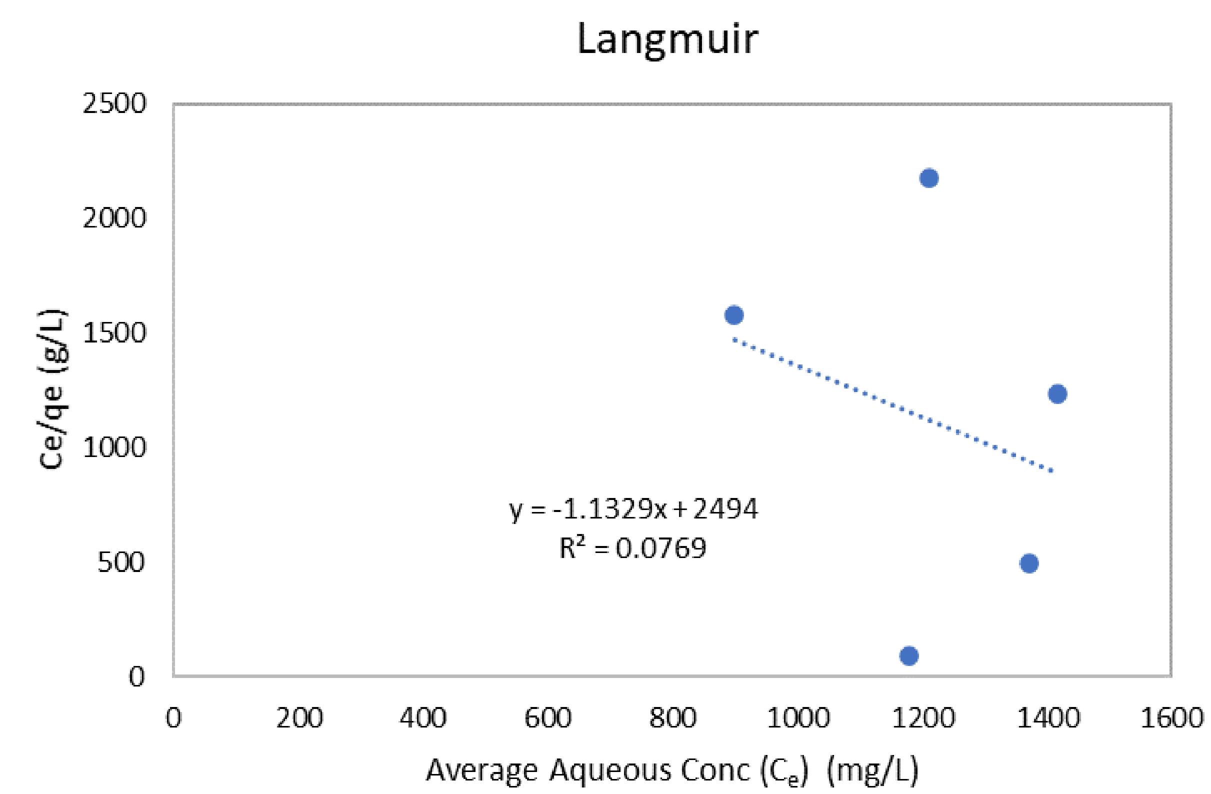

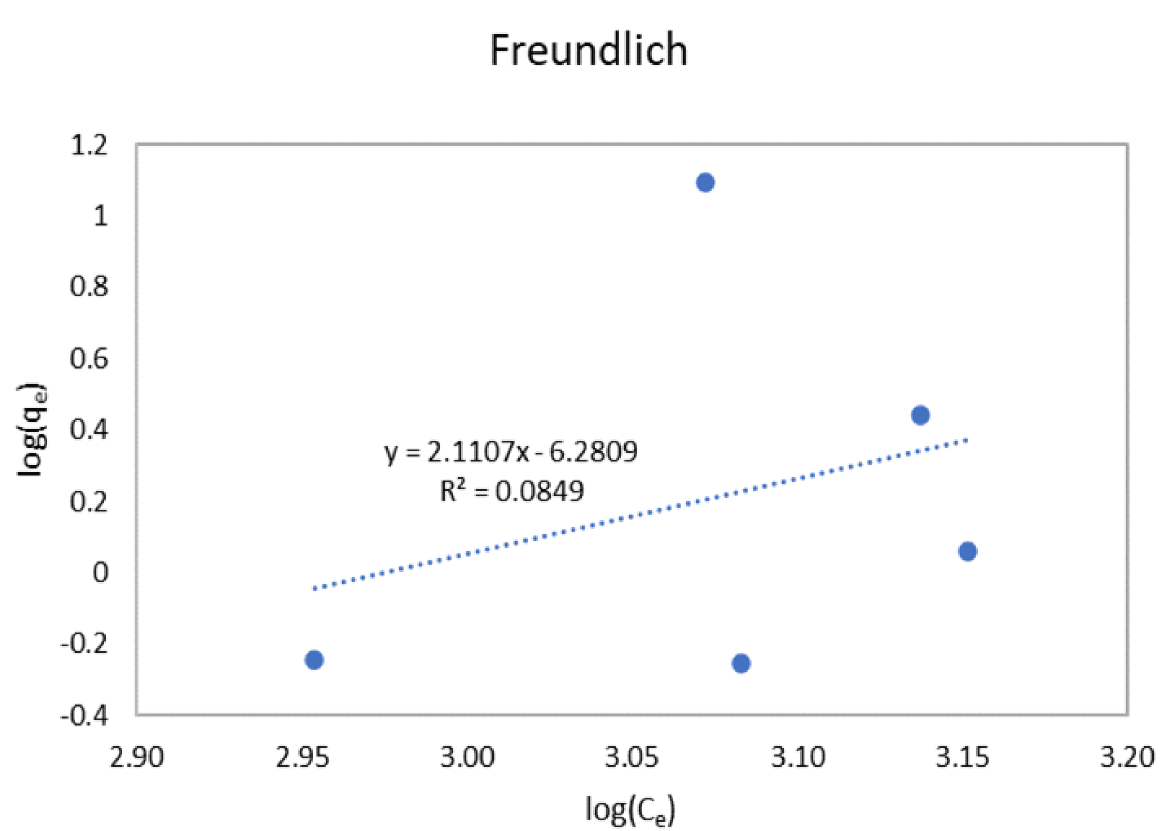

Note(s):
mg/L: milligrams per liter
mg/g: milligrams per gram
g/L: grams per liter
Ce: aqueous concentration of the adsorbate
qe: concentration of the adsorbate in soil

CLIENT
KINCAID GENERATION, LLC
KINCAID POWER PLANT ASH POND (CCR UNIT 141)

PROJECT
EVALUATION OF PARTITION COEFFICIENT RESULTS AP

CONSULTANT
WSP GOLDER

TITLE
MW-12S SULFATE PARTITION COEFFICIENTS

PROJECT NO.	PHASE	REV.	FIGURE
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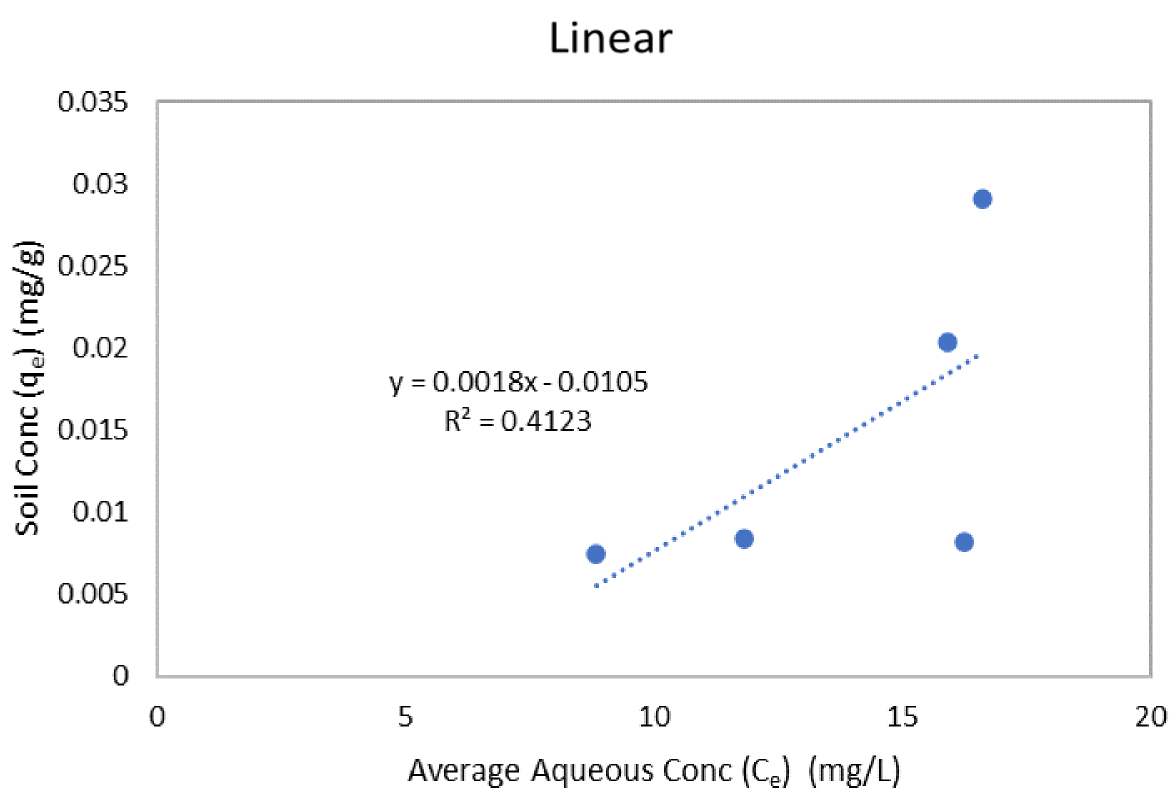

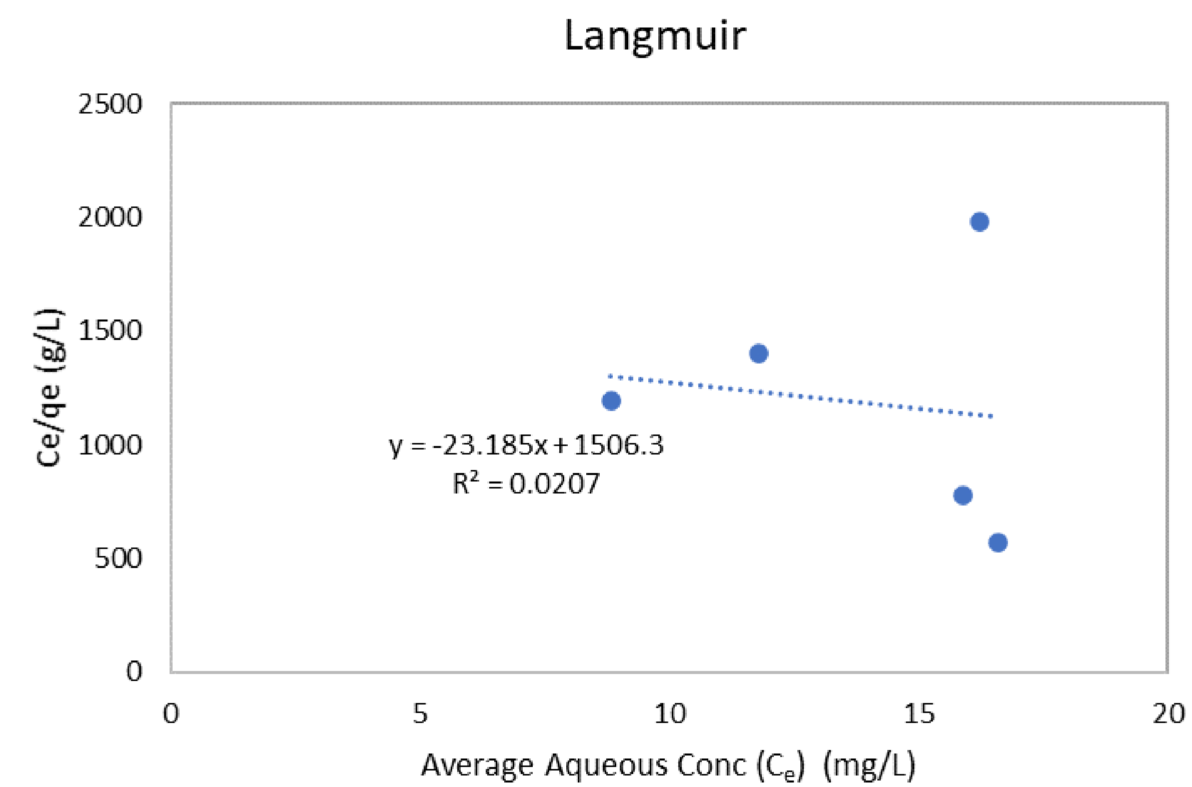

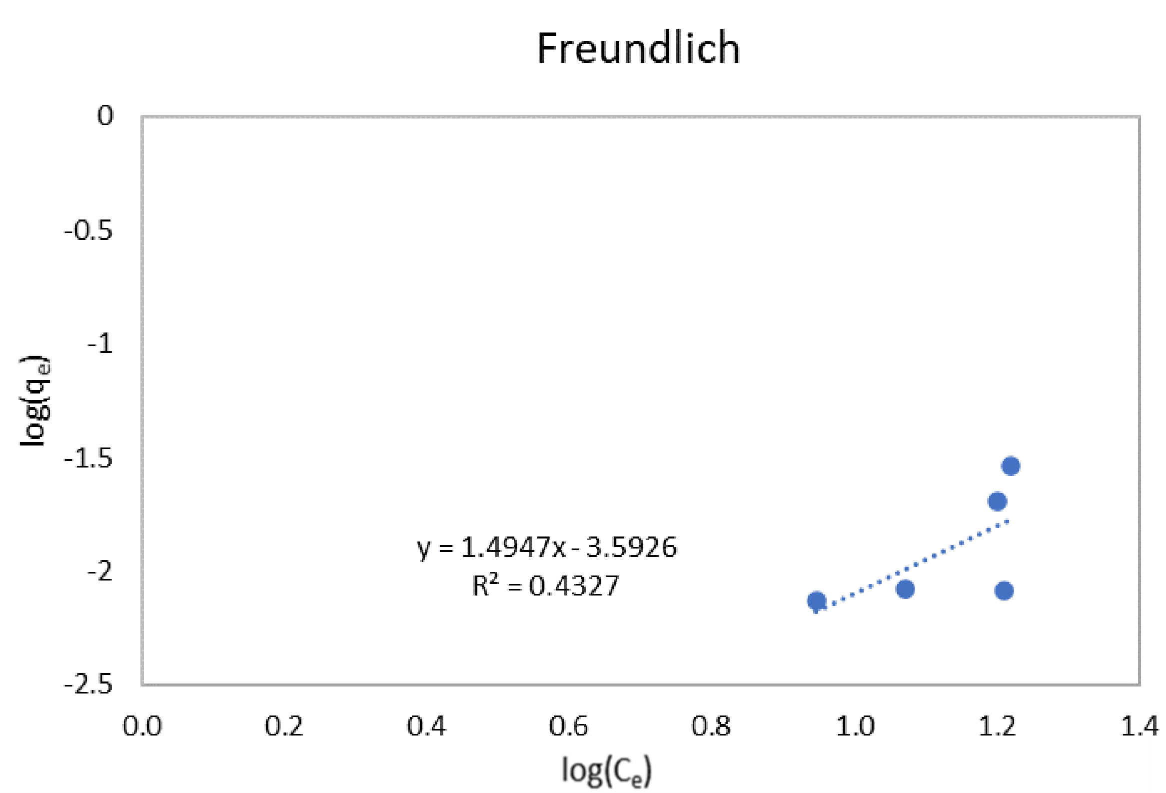

Note(s):
mg/L: milligrams per liter
mg/g: milligrams per gram
g/L: grams per liter
Ce: aqueous concentration of the adsorbate
qe: concentration of the adsorbate in soil

CLIENT
KINCAID GENERATION, LLC
KINCAID POWER PLANT ASH POND (CCR UNIT 141)

PROJECT
EVALUATION OF PARTITION COEFFICIENT RESULTS AP

CONSULTANT
WSP GOLDER

TITLE
MW-28 BORON PARTITION COEFFICIENTS

PROJECT NO.	PHASE	REV.	FIGURE
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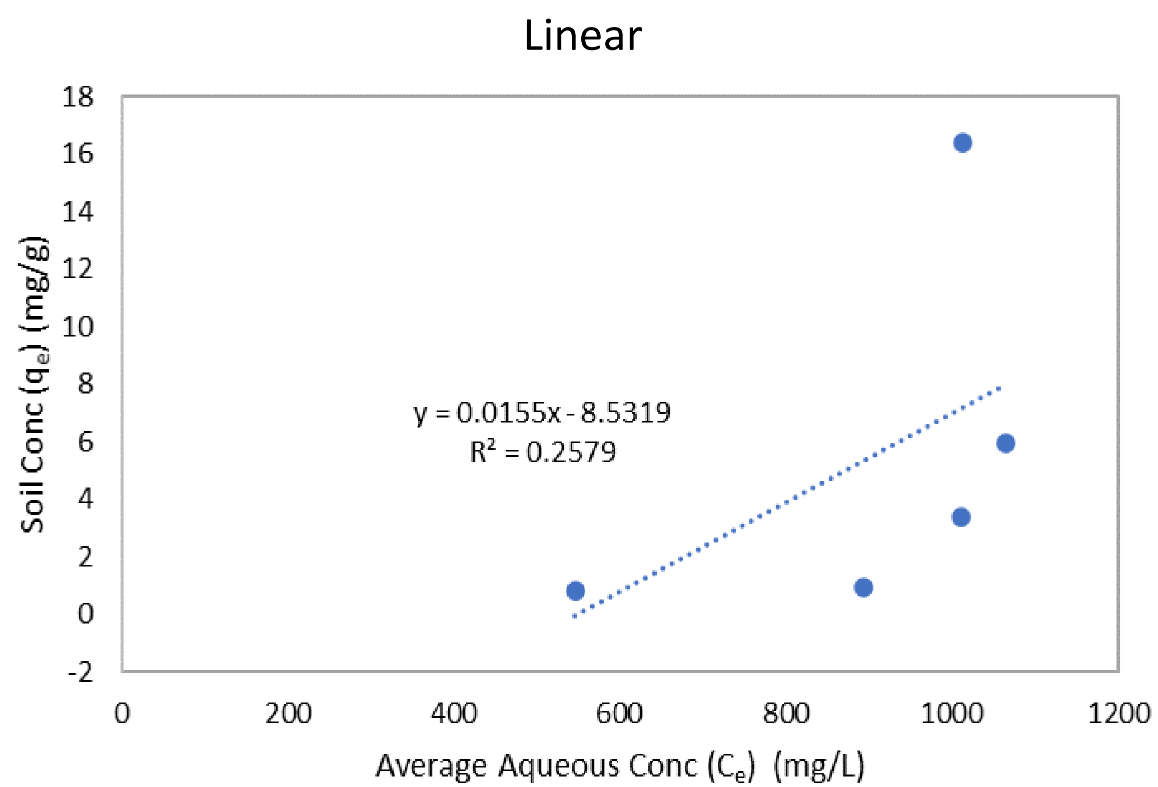

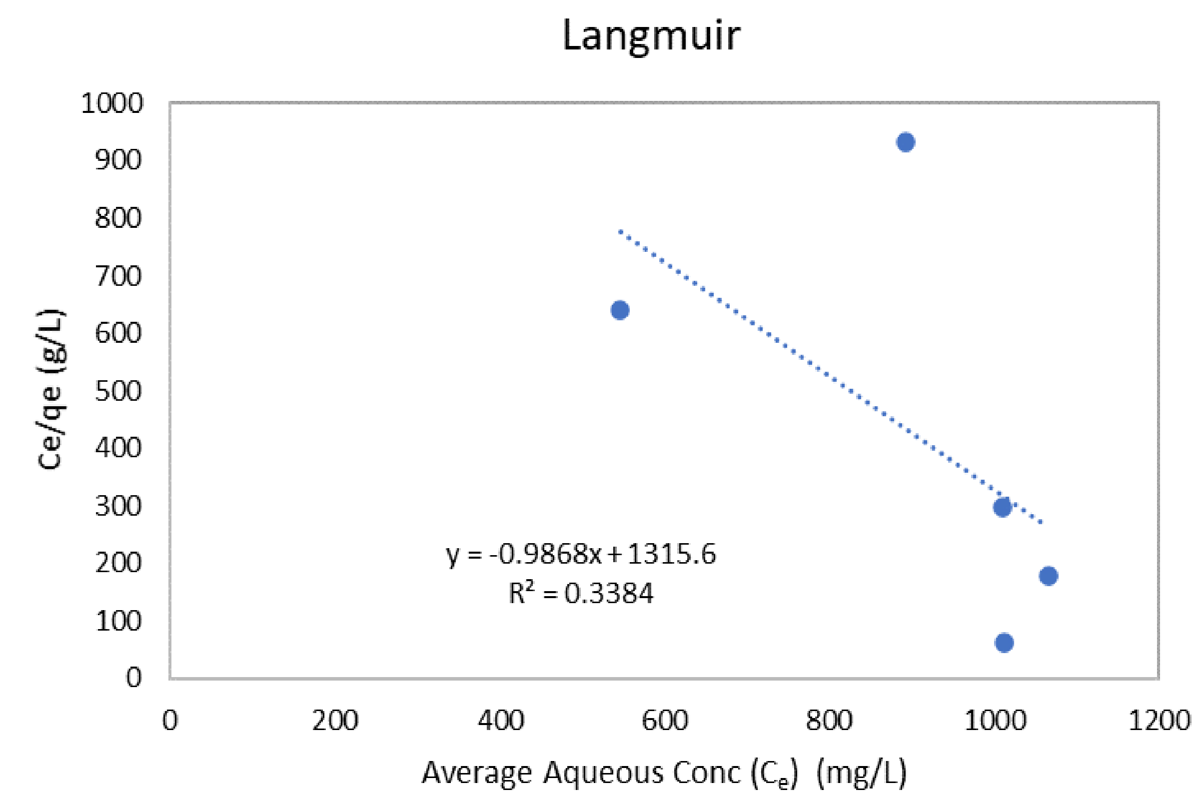

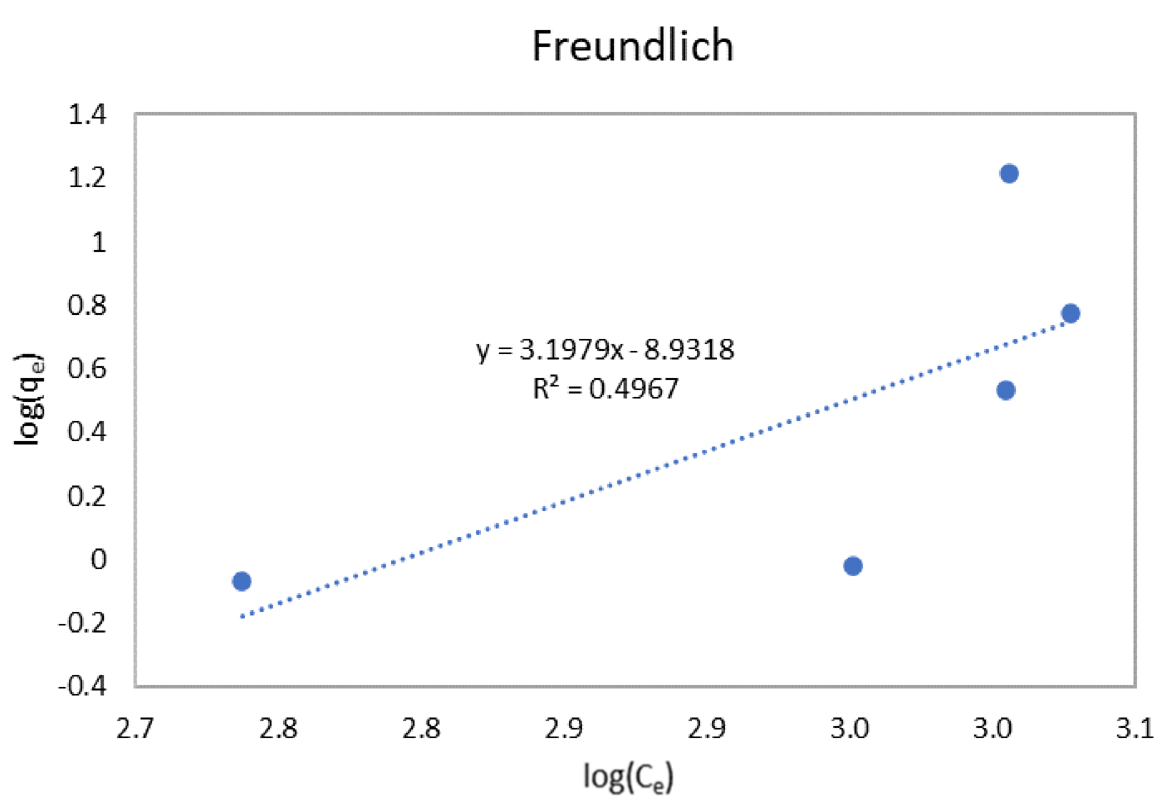

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mg/g: milligrams per gram
g/L: grams per liter
Ce: aqueous concentration of the adsorbate
qe: concentration of the adsorbate in soil

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PROJECT
EVALUATION OF PARTITION COEFFICIENT RESULTS AP

CONSULTANT
WSP GOLDER

TITLE
MW-28 SULFATE PARTITION COEFFICIENTS

PROJECT NO.	PHASE	REV.	FIGURE
21454831	0003	0	A-4

APPENDIX C
HELP MODEL OUTPUT FILES

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: KIN AP CBR **Simulated On:** 5/2/2022 12:26

Layer 1
Type 1 - Vertical Percolation Layer (Cover Soil)
SiCL - Silty Clay Loam
Material Texture Number 12

Thickness	=	30	inches
Porosity	=	0.471	vol/vol
Field Capacity	=	0.342	vol/vol
Wilting Point	=	0.21	vol/vol
Initial Soil Water Content	=	0.35	vol/vol
Effective Sat. Hyd. Conductivity	=	4.20E-05	cm/sec

Layer 2
Type 1 - Vertical Percolation Layer
Silty Clay
Material Texture Number 43

Thickness	=	72	inches
Porosity	=	0.479	vol/vol
Field Capacity	=	0.371	vol/vol
Wilting Point	=	0.251	vol/vol
Initial Soil Water Content	=	0.473	vol/vol
Effective Sat. Hyd. Conductivity	=	1.20E-07	cm/sec

Note: Initial moisture content of the layers and snow water were computed as nearly steady-state values by HELP.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	85.7	
Fraction of Area Allowing Runoff	=	100	%
Area projected on a horizontal plane	=	172	acres
Evaporative Zone Depth	=	18	inches
Initial Water in Evaporative Zone	=	5.946	inches
Upper Limit of Evaporative Storage	=	8.478	inches
Lower Limit of Evaporative Storage	=	3.78	inches
Initial Snow Water	=	0	inches
Initial Water in Layer Materials	=	44.555	inches

Total Initial Water	=	44.555	inches
Total Subsurface Inflow	=	0	inches/year

Note: SCS Runoff Curve Number was calculated by HELP.

Evapotranspiration and Weather Data

Station Latitude	=	39.59	Degrees
Maximum Leaf Area Index	=	4.5	
Start of Growing Season (Julian Date)	=	102	days
End of Growing Season (Julian Date)	=	292	days
Average Wind Speed	=	10	mph
Average 1st Quarter Relative Humidity	=	72	%
Average 2nd Quarter Relative Humidity	=	66	%
Average 3rd Quarter Relative Humidity	=	73	%
Average 4th Quarter Relative Humidity	=	65	%

Note: Evapotranspiration data was obtained for Kincaid, Illinois

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
2.696568	2.105836	2.602577	3.411672	4.852763	3.801581
3.335953	3.024381	2.885088	4.052491	3.627085	2.799647

Note: Precipitation was simulated based on HELP V4 weather simulation for:
Lat/Long: 39.591502215865/-89.496388435364

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
34.7	35.6	45.8	59.9	73	79.3
83.1	80.3	71.1	62	47.6	36.4

Note: Temperature was simulated based on HELP V4 weather simulation for:
Lat/Long: 39.591502215865/-89.496388435364
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 39.591502215865/-89.496388435364

Average Annual Totals Summary

Title: KIN AP CBR
Simulated on: 5/2/2022 12:27

	Average Annual Totals for Years 1 - 30*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	39.20	[3.42]	24,472,191.2	100.00
Runoff	3.101	[1.481]	1,936,416.9	7.91
Evapotranspiration	30.236	[3.334]	18,877,997.4	77.14
Subprofile1				
Percolation/leakage through Layer 2	5.834288	[1.888298]	3,642,696.1	14.89
Water storage				
Change in water storage	0.0242	[1.1169]	15,080.9	0.06

* Note: Average inches are converted to volume based on the user-specified area.

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: KIN AP CIP Rem **Simulated On:** 5/2/2022 12:49

Layer 1

Type 1 - Vertical Percolation Layer (Cover Soil)
SiCL - Silty Clay Loam
Material Texture Number 12

Thickness	=	30	inches
Porosity	=	0.471	vol/vol
Field Capacity	=	0.342	vol/vol
Wilting Point	=	0.21	vol/vol
Initial Soil Water Content	=	0.3511	vol/vol
Effective Sat. Hyd. Conductivity	=	4.20E-05	cm/sec

Layer 2

Type 1 - Vertical Percolation Layer
Silty Clay
Material Texture Number 43

Thickness	=	72	inches
Porosity	=	0.479	vol/vol
Field Capacity	=	0.371	vol/vol
Wilting Point	=	0.251	vol/vol
Initial Soil Water Content	=	0.4712	vol/vol
Effective Sat. Hyd. Conductivity	=	1.20E-07	cm/sec

Note: Initial moisture content of the layers and snow water were computed as nearly steady-state values by HELP.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	85.9	
Fraction of Area Allowing Runoff	=	100	%
Area projected on a horizontal plane	=	88	acres
Evaporative Zone Depth	=	18	inches
Initial Water in Evaporative Zone	=	5.947	inches
Upper Limit of Evaporative Storage	=	8.478	inches
Lower Limit of Evaporative Storage	=	3.78	inches
Initial Snow Water	=	0	inches
Initial Water in Layer Materials	=	44.455	inches

Total Initial Water	=	44.455	inches
Total Subsurface Inflow	=	0	inches/year

Note: SCS Runoff Curve Number was calculated by HELP.

Evapotranspiration and Weather Data

Station Latitude	=	39.59	Degrees
Maximum Leaf Area Index	=	4.5	
Start of Growing Season (Julian Date)	=	102	days
End of Growing Season (Julian Date)	=	292	days
Average Wind Speed	=	10	mph
Average 1st Quarter Relative Humidity	=	72	%
Average 2nd Quarter Relative Humidity	=	66	%
Average 3rd Quarter Relative Humidity	=	73	%
Average 4th Quarter Relative Humidity	=	65	%

Note: Evapotranspiration data was obtained for Kincaid, Illinois

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
2.696568	2.105836	2.602577	3.411672	4.852763	3.801581
3.335953	3.024381	2.885088	4.052491	3.627085	2.799647

Note: Precipitation was simulated based on HELP V4 weather simulation for:
Lat/Long: 39.591502215865/-89.496388435364

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
34.7	35.6	45.8	59.9	73	79.3
83.1	80.3	71.1	62	47.6	36.4

Note: Temperature was simulated based on HELP V4 weather simulation for:
Lat/Long: 39.591502215865/-89.496388435364
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 39.591502215865/-89.496388435364

Average Annual Totals Summary

Title: KIN AP CIP Rem
Simulated on: 5/2/2022 12:50

	Average Annual Totals for Years 1 - 30*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	39.20	[3.42]	12,520,656.0	100.00
Runoff	3.130	[1.479]	999,968.8	7.99
Evapotranspiration	30.223	[3.318]	9,654,351.8	77.11
Subprofile1				
Percolation/leakage through Layer 2	5.815203	[1.893835]	1,857,608.5	14.84
Water storage				
Change in water storage	0.0273	[1.1202]	8,726.8	0.07

* Note: Average inches are converted to volume based on the user-specified area.

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: KIN AP CIP Cons **Simulated On:** 5/2/2022 13:27

Layer 1
Type 1 - Vertical Percolation Layer (Cover Soil)
SiCL - Silty Clay Loam
Material Texture Number 12

Thickness	=	6	inches
Porosity	=	0.471	vol/vol
Field Capacity	=	0.342	vol/vol
Wilting Point	=	0.21	vol/vol
Initial Soil Water Content	=	0.4116	vol/vol
Effective Sat. Hyd. Conductivity	=	4.20E-05	cm/sec

Layer 2
Type 1 - Vertical Percolation Layer
Sandy Silty Clay
Material Texture Number 43

Thickness	=	18	inches
Porosity	=	0.4	vol/vol
Field Capacity	=	0.35	vol/vol
Wilting Point	=	0.3	vol/vol
Initial Soil Water Content	=	0.4	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-05	cm/sec

Layer 3
Type 2 - Lateral Drainage Layer
10 oz Nonwoven Geotextile
Material Texture Number 123

Thickness	=	0.11	inches
Porosity	=	0.85	vol/vol
Field Capacity	=	0.01	vol/vol
Wilting Point	=	0.005	vol/vol
Initial Soil Water Content	=	0.85	vol/vol
Effective Sat. Hyd. Conductivity	=	3.00E-01	cm/sec
Slope	=	2.5	%
Drainage Length	=	800	ft

Layer 4

Type 4 - Flexible Membrane Liner
LDPE Membrane
Material Texture Number 36

Thickness	=	0.04	inches
Effective Sat. Hyd. Conductivity	=	4.00E-13	cm/sec
FML Pinhole Density	=	1	Holes/Acre
FML Installation Defects	=	1	Holes/Acre
FML Placement Quality	=	3	Good

Layer 5

Type 1 - Vertical Percolation Layer (Waste)
Electric Plant Coal Bottom Ash
Material Texture Number 83

Thickness	=	372	inches
Porosity	=	0.578	vol/vol
Field Capacity	=	0.076	vol/vol
Wilting Point	=	0.025	vol/vol
Initial Soil Water Content	=	0.0791	vol/vol
Effective Sat. Hyd. Conductivity	=	1.40E-03	cm/sec

Layer 6

Type 1 - Vertical Percolation Layer
Silty CLay
Material Texture Number 44

Thickness	=	84	inches
Porosity	=	0.479	vol/vol
Field Capacity	=	0.371	vol/vol
Wilting Point	=	0.251	vol/vol
Initial Soil Water Content	=	0.371	vol/vol
Effective Sat. Hyd. Conductivity	=	1.20E-07	cm/sec

Note: Initial moisture content of the layers and snow water were computed as nearly steady-state values by HELP.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	87.2	
Fraction of Area Allowing Runoff	=	100	%
Area projected on a horizontal plane	=	84	acres
Evaporative Zone Depth	=	18	inches
Initial Water in Evaporative Zone	=	7.27	inches
Upper Limit of Evaporative Storage	=	7.626	inches
Lower Limit of Evaporative Storage	=	4.86	inches
Initial Snow Water	=	0	inches

Initial Water in Layer Materials	=	70.336	inches
Total Initial Water	=	70.336	inches
Total Subsurface Inflow	=	0	inches/year

Note: SCS Runoff Curve Number was calculated by HELP.

Evapotranspiration and Weather Data

Station Latitude	=	39.59	Degrees
Maximum Leaf Area Index	=	4.5	
Start of Growing Season (Julian Date)	=	102	days
End of Growing Season (Julian Date)	=	292	days
Average Wind Speed	=	10	mph
Average 1st Quarter Relative Humidity	=	72	%
Average 2nd Quarter Relative Humidity	=	66	%
Average 3rd Quarter Relative Humidity	=	73	%
Average 4th Quarter Relative Humidity	=	65	%

Note: Evapotranspiration data was obtained for Kincaid, Illinois

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
2.696568	2.105836	2.602577	3.411672	4.852763	3.801581
3.335953	3.024381	2.885088	4.052491	3.627085	2.799647

Note: Precipitation was simulated based on HELP V4 weather simulation for:
Lat/Long: 39.591502215865/-89.496388435364

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
34.7	35.6	45.8	59.9	73	79.3
83.1	80.3	71.1	62	47.6	36.4

Note: Temperature was simulated based on HELP V4 weather simulation for:
Lat/Long: 39.591502215865/-89.496388435364
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 39.591502215865/-89.496388435364

Average Annual Totals Summary

Title: KIN AP CIP Cons
Simulated on: 5/2/2022 13:28

	Average Annual Totals for Years 1 - 30*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	39.20	[3.42]	11,951,535.3	100.00
Runoff	6.862	[2.069]	2,092,482.9	17.51
Evapotranspiration	29.792	[3.16]	9,084,143.3	76.01
Subprofile1				
Lateral drainage collected from Layer 3	1.6178	[0.1841]	493,301.7	4.13
Percolation/leakage through Layer 4	0.916182	[0.203854]	279,362.3	2.34
Average Head on Top of Layer 4	7.6738	[1.8164]	---	---
Subprofile2				
Percolation/leakage through Layer 6	0.004092	[0.002049]	1,247.6	0.01
Water storage				
Change in water storage	0.9195	[0.7973]	280,359.8	2.35

* Note: Average inches are converted to volume based on the user-specified area.

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: KIN AP Default **Simulated On:** 6/27/2022 17:07

Layer 1

Type 1 - Vertical Percolation Layer (Cover Soil)
SiCL - Silty Clay Loam
Material Texture Number 12

Thickness	=	6	inches
Porosity	=	0.471	vol/vol
Field Capacity	=	0.342	vol/vol
Wilting Point	=	0.21	vol/vol
Initial Soil Water Content	=	0.4116	vol/vol
Effective Sat. Hyd. Conductivity	=	4.20E-05	cm/sec

Layer 2

Type 1 - Vertical Percolation Layer
Sandy Silty Clay
Material Texture Number 43

Thickness	=	18	inches
Porosity	=	0.4	vol/vol
Field Capacity	=	0.35	vol/vol
Wilting Point	=	0.3	vol/vol
Initial Soil Water Content	=	0.4	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-05	cm/sec

Layer 3

Type 2 - Lateral Drainage Layer
10 oz Nonwoven Geotextile
Material Texture Number 123

Thickness	=	0.11	inches
Porosity	=	0.85	vol/vol
Field Capacity	=	0.01	vol/vol
Wilting Point	=	0.005	vol/vol
Initial Soil Water Content	=	0.85	vol/vol
Effective Sat. Hyd. Conductivity	=	3.00E-01	cm/sec
Slope	=	2.5	%
Drainage Length	=	800	ft

Layer 4

Type 4 - Flexible Membrane Liner
LDPE Membrane
Material Texture Number 36

Thickness	=	0.04	inches
Effective Sat. Hyd. Conductivity	=	4.00E-13	cm/sec
FML Pinhole Density	=	1	Holes/Acre
FML Installation Defects	=	1	Holes/Acre
FML Placement Quality	=	3	Good

Layer 5

Type 1 - Vertical Percolation Layer (Waste)
Electric Plant Coal Bottom Ash
Material Texture Number 83

Thickness	=	372	inches
Porosity	=	0.578	vol/vol
Field Capacity	=	0.076	vol/vol
Wilting Point	=	0.025	vol/vol
Initial Soil Water Content	=	0.0791	vol/vol
Effective Sat. Hyd. Conductivity	=	1.40E-03	cm/sec

Layer 6

Type 1 - Vertical Percolation Layer
Silty CLay
Material Texture Number 44

Thickness	=	84	inches
Porosity	=	0.479	vol/vol
Field Capacity	=	0.371	vol/vol
Wilting Point	=	0.251	vol/vol
Initial Soil Water Content	=	0.371	vol/vol
Effective Sat. Hyd. Conductivity	=	1.20E-07	cm/sec

Note: Initial moisture content of the layers and snow water were computed as nearly steady-state values by HELP.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	87.2	
Fraction of Area Allowing Runoff	=	100	%
Area projected on a horizontal plane	=	84	acres
Evaporative Zone Depth	=	18	inches
Initial Water in Evaporative Zone	=	7.27	inches
Upper Limit of Evaporative Storage	=	7.626	inches
Lower Limit of Evaporative Storage	=	4.86	inches
Initial Snow Water	=	0	inches

Initial Water in Layer Materials	=	70.336	inches
Total Initial Water	=	70.336	inches
Total Subsurface Inflow	=	0	inches/year

Note: SCS Runoff Curve Number was calculated by HELP.

Evapotranspiration and Weather Data

Station Latitude	=	39.59	Degrees
Maximum Leaf Area Index	=	4.5	
Start of Growing Season (Julian Date)	=	102	days
End of Growing Season (Julian Date)	=	292	days
Average Wind Speed	=	10	mph
Average 1st Quarter Relative Humidity	=	72	%
Average 2nd Quarter Relative Humidity	=	66	%
Average 3rd Quarter Relative Humidity	=	73	%
Average 4th Quarter Relative Humidity	=	65	%

Note: Evapotranspiration data was obtained for Kincaid, Illinois

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
2.696568	2.105836	2.602577	3.411672	4.852763	3.801581
3.335953	3.024381	2.885088	4.052491	3.627085	2.799647

Note: Precipitation was simulated based on HELP V4 weather simulation for:
Lat/Long: 39.591502215865/-89.496388435364

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
34.7	35.6	45.8	59.9	73	79.3
83.1	80.3	71.1	62	47.6	36.4

Note: Temperature was simulated based on HELP V4 weather simulation for:
Lat/Long: 39.591502215865/-89.496388435364
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 39.591502215865/-89.496388435364

Average Annual Totals Summary

Title: KIN AP Default
Simulated on: 6/27/2022 17:09

	Average Annual Totals for Years 1 - 30*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	39.20	[3.42]	11,951,535.3	100.00
Runoff	6.862	[2.069]	2,092,482.9	17.51
Evapotranspiration	29.792	[3.16]	9,084,143.3	76.01
Subprofile1				
Lateral drainage collected from Layer 3	1.6178	[0.1841]	493,301.7	4.13
Percolation/leakage through Layer 4	0.916182	[0.203854]	279,362.3	2.34
Average Head on Top of Layer 4	7.6738	[1.8164]	---	---
Subprofile2				
Percolation/leakage through Layer 6	0.004092	[0.002049]	1,247.6	0.01
Water storage				
Change in water storage	0.9195	[0.7973]	280,359.8	2.35

* Note: Average inches are converted to volume based on the user-specified area.

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: KIN AP Default Earth **Simulated On:** 6/27/2022 17:25

Layer 1
Type 1 - Vertical Percolation Layer (Cover Soil)
SiCL - Silty Clay Loam
Material Texture Number 12

Thickness	=	6	inches
Porosity	=	0.471	vol/vol
Field Capacity	=	0.342	vol/vol
Wilting Point	=	0.21	vol/vol
Initial Soil Water Content	=	0.4189	vol/vol
Effective Sat. Hyd. Conductivity	=	4.20E-05	cm/sec

Layer 2
Type 1 - Vertical Percolation Layer
Sandy Silty Clay
Material Texture Number 43

Thickness	=	18	inches
Porosity	=	0.4	vol/vol
Field Capacity	=	0.35	vol/vol
Wilting Point	=	0.3	vol/vol
Initial Soil Water Content	=	0.4	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-05	cm/sec

Layer 3
Type 3 - Barrier Soil Liner
Liner Soil (High)
Material Texture Number 16

Thickness	=	36	inches
Porosity	=	0.427	vol/vol
Field Capacity	=	0.418	vol/vol
Wilting Point	=	0.367	vol/vol
Initial Soil Water Content	=	0.427	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-07	cm/sec

Layer 4
Type 1 - Vertical Percolation Layer (Waste)
Electric Plant Coal Bottom Ash

Material Texture Number 83

Thickness	=	372	inches
Porosity	=	0.578	vol/vol
Field Capacity	=	0.076	vol/vol
Wilting Point	=	0.025	vol/vol
Initial Soil Water Content	=	0.0805	vol/vol
Effective Sat. Hyd. Conductivity	=	1.40E-03	cm/sec

Layer 5

Type 1 - Vertical Percolation Layer

Material Texture Number 44

Thickness	=	84	inches
Porosity	=	0.479	vol/vol
Field Capacity	=	0.371	vol/vol
Wilting Point	=	0.251	vol/vol
Initial Soil Water Content	=	0.371	vol/vol
Effective Sat. Hyd. Conductivity	=	1.20E-07	cm/sec

Note: Initial moisture content of the layers and snow water were computed as nearly steady-state values by HELP.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	87.2	
Fraction of Area Allowing Runoff	=	100	%
Area projected on a horizontal plane	=	84	acres
Evaporative Zone Depth	=	18	inches
Initial Water in Evaporative Zone	=	7.313	inches
Upper Limit of Evaporative Storage	=	7.626	inches
Lower Limit of Evaporative Storage	=	4.86	inches
Initial Snow Water	=	0	inches
Initial Water in Layer Materials	=	86.21	inches
Total Initial Water	=	86.21	inches
Total Subsurface Inflow	=	0	inches/year

Note: SCS Runoff Curve Number was calculated by HELP.

Evapotranspiration and Weather Data

Station Latitude	=	39.59	Degrees
Maximum Leaf Area Index	=	4.5	
Start of Growing Season (Julian Date)	=	102	days
End of Growing Season (Julian Date)	=	292	days

Average Wind Speed	=	10 mph
Average 1st Quarter Relative Humidity	=	72 %
Average 2nd Quarter Relative Humidity	=	66 %
Average 3rd Quarter Relative Humidity	=	73 %
Average 4th Quarter Relative Humidity	=	65 %

Note: Evapotranspiration data was obtained for Kincaid, Illinois

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
2.696568	2.105836	2.602577	3.411672	4.852763	3.801581
3.335953	3.024381	2.885088	4.052491	3.627085	2.799647

Note: Precipitation was simulated based on HELP V4 weather simulation for:
Lat/Long: 39.591502215865/-89.496388435364

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
34.7	35.6	45.8	59.9	73	79.3
83.1	80.3	71.1	62	47.6	36.4

Note: Temperature was simulated based on HELP V4 weather simulation for:
Lat/Long: 39.591502215865/-89.496388435364
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 39.591502215865/-89.496388435364

Average Annual Totals Summary

Title: KIN AP Default Earth
Simulated on: 6/27/2022 17:26

	Average Annual Totals for Years 1 - 30*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	39.20	[3.42]	11,951,535.3	100.00
Runoff	7.634	[2.161]	2,327,765.2	19.48
Evapotranspiration	30.089	[3.257]	9,174,727.9	76.77
Subprofile1				
Percolation/leakage through Layer 3	1.459570	[0.141864]	445,052.2	3.72
Average Head on Top of Layer 3	9.8664	[1.889]	---	---
Subprofile2				
Percolation/leakage through Layer 5	0.079172	[0.302718]	24,141.2	0.20
Water storage				
Change in water storage	1.3935	[0.7761]	424,900.9	3.56

* Note: Average inches are converted to volume based on the user-specified area.

APPENDIX D
FLUX EVALUATION DATA

APPENDIX D. FLUX EVALUATION DATA
GROUNDWATER MODELING REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Calibration Model					
Model	**Years (Model Period)**	**HSU**	**Total Flux In[1] (ft^3/d)**	**Total Flux In (gpm)**	
Calibration Model	27	Fill Unit (CCR)	9375.80	48.71	
Model	**Years (Model Period)**	**HSU**	**Total Flux Out[1] (ft^3/d)**	**Total Flux Out (gpm)**	
Calibration Model	27	Fill Unit (CCR)	-9707.65	-50.43	
Scenario 1: CIP (CIP includes CCR removal from the north and west areas of the AP, consolidation to the central and southeast portions of the AP, and construction of a cover system over the remaining CCR)					
Prediction Model	**Years (Post-Construction Period)**	**HSU**	**Total Flux In[1] (ft^3/d)**	**Total Flux In (gpm)**	**Reduction in Flux In Post Closure[2] (Percentage, %)**
CIP	22	Fill Unit (CCR)	16.45	0.09	99.82%
Prediction Model	**Years (Post-Construction Period)**	**HSU**	**Total Flux Out[1] (ft^3/d)**	**Total Flux Out (gpm)**	**Reduction in Flux Out Post Closure[2] (Percentage, %)**
CIP	22	Fill Unit (CCR)	-1.59	-0.01	-99.98%

[O: PR 07/05/22; C: JJW 7/06/22]

Notes:
1. Reduction in flux in as compared to flux in at the end of calibration model (model period of 27 years).
2. Total flux in and out source data provided in flux calculation data files included in Appendix A.

CCR = coal combustion residuals
CIP = closure in place
HSU = Hydrostratigraphic Unit
% = percentage
ft^3/d = cubic feet per day
gpm = gallons per minute

Intended for
Kincaid Generation, LLC

Date
October 25, 2021

Project No.
1940100806-007

GROUNDWATER MONITORING PLAN
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

Bright ideas. Sustainable change.

GROUNDWATER MONITORING PLAN
KINCAID POWER PLANT ASH POND

Project Name	**Kincaid Power Plant Ash Pond**
Project No.	**1940100806-007**
Recipient	**Kincaid Generation, LLC**
Document type	**Groundwater Monitoring Plan**
Revision	**FINAL**
Date	**October 25, 2021**
Prepared by	**Chase J. Christenson, PG**

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LICENSED PROFESSIONAL CERTIFICATIONS

35 I.A.C. § 845.630 Groundwater Monitoring Systems (PE)

I, Eric J. Tlachac, a qualified professional engineer in good standing in the State of Illinois, certify that the groundwater monitoring system described in this document (Groundwater Monitoring Plan, Kincaid Power Plant Ash Pond), has been designed and constructed to meet the requirements of 35 I.A.C. § *845.630. The monitoring system was developed based on information included in the Hydrogeologic Site Characterization Report (Ramboll 2021; included in the Operating Permit to which this Groundwater Monitoring Plan is attached).*

Eric J. Tlachac
Qualified Professional Engineer
062-063091
Illinois
Date: October 25, 2021

35 I.A.C. § 845.630 Groundwater Monitoring Systems (PG)

I, Brian G. Hennings, a qualified professional geologist in good standing in the State of Illinois, certify that the groundwater monitoring system described in this document (Groundwater Monitoring Plan, Kincaid Power Plant Ash Pond), has been designed and constructed to meet the requirements of 35 I.A.C. § *845.630. The monitoring system was developed based on information included in the Hydrogeologic Site Characterization Report (Ramboll 2021; included in the Operating Permit to which this Groundwater Monitoring Plan is attached).*

Brian G. Hennings
Professional Geologist
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Date: October 25, 2021

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ACRONYMS AND ABBREVIATIONS

35 I.A.C.	Title 35 of the Illinois Administrative Code
40 C.F.R.	Title 40 of the Code of Federal Regulations
AP	Kincaid Ash Pond
ASD	Alternate Source Demonstration
BCU	bedrock confining unit
bgs	below ground surface
CCR	coal combustion residuals
cm/s	centimeters per second
GMP	Groundwater Monitoring Plan
GWPS	Groundwater Protection Standard
HCR	Hydrogeologic Site Characterization Report
ID	identification
IEPA	Illinois Environmental Protection Agency
KPP	Kincaid Power Plant
LCU	lower confining unit
NAVD88	North American Vertical Datum of 1988
NID	National Inventory of Dams
No.	Number
NRT/OBG	Natural Resources Technology, Inc., an OBG Company
Part 845	Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments: Title 35 of the Illinois Administrative Code § 845
PMP	Potential Migration Pathway
QA/QC	quality assurance/quality control
Ramboll	Ramboll Americas Engineering Solutions, Inc.
RL	Reporting Limit
SI	Surface Impoundment
TDS	total dissolved solids
USCU	upper semi-confining unit
USEPA	United States Environmental Protection Agency

1. INTRODUCTION

1.1 Overview

In accordance with requirements of the Standards for the Disposal of Coal Combustion Residuals (CCR) in Surface Impoundments (SIs): Title 35 of the Illinois Administrative Code (35 I.A.C.) § 845 (Part 845) (Illinois Environmental Protection Agency [IEPA], April 15, 2021), Ramboll Americas Engineering Solutions, Inc. (Ramboll) has prepared this Groundwater Monitoring Plan (GMP) on behalf of Kincaid Power Plant (KPP) (**Figure 1-1**), operated by Kincaid Generation, LLC. This report will apply specifically to the CCR Unit referred to as the Kincaid Ash Pond (AP), Vistra identification (ID) number (No.) 141, IEPA ID No. W0218140002-01, and National Inventory of Dams (NID) No. IL50706. The AP is a 172-acre unlined CCR SI used to manage CCR and non-CCR waste streams at the KPP. This GMP includes Part 845 content requirements specific to 35 I.A.C. § 845.630 (Groundwater Monitoring System), 35 I.A.C. § 845.640 (Groundwater Sampling and Analysis), and 35 I.A.C. § 845.650 (Groundwater Monitoring Program) for the AP at the KPP.

A checklist which identifies the specific requirements of 35 I.A.C. § 845.630, 35 I.A.C. § 845.640, and 35 I.A.C. § 845.650 is included in **Table 1-1**. The table provides references to sections, tables, and figures included in this document to locate the information that meets specific requirements of 35 I.A.C. § 845.630, 35 I.A.C. § 845.640, and 35 I.A.C. § 845.650.

1.2 Site Location and Background

The KPP is located in the southwest quarter of Section 1, and the northeast quarter of Section 12, Township 13 North, Range 4 West, along West Route 104 Christian County, Illinois and approximately four miles west of the Village of Kincaid (see **Figure 1-1**). The KPP operates as a coal-fired power plant and consists of one CCR unit, the AP, with a total storage capacity of approximately 3,560 acre-feet.

The AP is located between two lobes of Sangchris Lake, which was formed in 1964 by damming Clear Creek, a tributary to the south fork of the Sangamon River (see **Figure 1-2**). Sangchris Lake was created to provide a source of cooling water for the KPP. The western lobe of Sangchris Lake forms part of the western and northern border of the AP and is connected to an intake flume for the KPP on the western edge of the AP. A discharge flume from the KPP forms the southern border of Kincaid Ash Pond and is connected to the eastern lobe of Sangchris Lake.

Construction of the AP began in 1964 and was commissioned for use in 1967. The AP primarily contains bottom ash and boiler slag, and other minor materials including water and wastewater treatment solids, excavation spoils, and dredge spoils. Discharge for the AP is located at the southeast corner of the unit.

1.3 Conceptual Model

Significant site investigation has been completed at the KPP to characterize the geology, hydrogeology, and groundwater quality. Based on extensive investigation and monitoring, the AP has been well characterized and detailed in the Hydrogeologic Site Characterization Report (HCR; included in the Operating Permit to which this Plan is attached). A site conceptual model has been developed and is discussed below.

The five distinct hydrostratigraphic units summarized below have been identified at the AP based on stratigraphic relationships and common hydrogeologic characteristics:

- **CCR**: Saturated CCR, consisting primarily of fly ash and boiler slag.
- **Upper Semi-Confining Unit (USCU)**: Low permeability clay with some silt and minor sand, silt layers, and occasional discontinuous sand lenses. Includes the lithologic layers identified as the Cahokia Formation. Sand lenses within the USCU with higher permeability within the USCU have a higher probability of contaminant transport and these materials are referred to as the potential migration pathways (PMPs).
- **Uppermost Aquifer**: Thin (generally less than 4 feet), moderate permeability sand, silty sand, and clayey sand and gravel units, which includes the unconfined clays and silts of the Upper Cahokia Formation, where saturated, and the thin, moderate permeability sands and gravels of the Lower Cahokia Formation, which, at some locations also includes the interface with the Vandalia Till.
- **Lower Confining Unit (LCU):** Underlying the aquifer unit is dense grey clay till; this till is easily distinguished during investigation by difficult drilling and/or refusal and is apparent on boring logs. The till was encountered at elevations ranging from approximately 570 to 583.5 feet NAVD88. The LCU is comprised of low permeability silt and clay with minor sand, silt layers, and occasional discontinuous sand lenses (more frequently near the top of the unit). Includes the lithologic layers identified as the Vandalia Till.
- **Bedrock (BCU)**: This unit is composed of interbedded shale and limestone of the Bond Formation that underlie the Vandalia Till, and underlies the entire AP.

The elevations of water within the AP are greater than the surrounding areas, and, depending on the hydraulic connection between the AP and the surrounding aquifer, water may flow radially from the AP toward the lobes of Sangchris Lake. The phreatic surface within the AP between February and August 2021 averaged 603.29 feet North American Vertical Datum of 1988 (NAVD88), with a range from 600.76 feet NAVD88 in XPW03 (in the northwest portion of the AP) to 607.38 feet NAVD88 in XSG-01 (in the southeast corner of the AP). Groundwater elevation contour maps for the 2021 sampling events are included in **Figure 1-3** and **Figure 1-4**.

The groundwater elevation in wells within the USCU (MW-7S, MW-8S, MW-12S, MW-20S, MW-25, MW-27, and MW-31S) averaged 591.34 feet NAVD88 between February and August 2021, with a range from 583.38 feet NAVD88 in MW-27 (west of the AP) to 602.14 feet NAVD88 in MW-25 (southwest of the AP). The groundwater elevation in wells within the PMP (MW-7S, MW-12S, MW-25, and MW-27) averaged 589.99 feet NAVD88 between February and August 2021, with a range from 583.38 feet NAVD88 in MW-27 (west of the AP) to 602.14 feet NAVD88 in MW-25 (southwest of the AP). Wells MW-12S and MW-27, located on the north side of the AP near the former drainage feature consistently recorded the lowest groundwater elevation, while MW-8S and MW-20S had relatively equal groundwater elevations, and the highest elevations were measured at MW-25, suggesting that the predominant horizontal groundwater flow in the USCU in the area of the AP is toward the north and northwest toward the western lobe of Sangchris Lake. There also appears to be a component of groundwater flow to the south and east toward the discharge flume that flows to the eastern lobe of Sangchris Lake (see **Figure 1-3** and **Figure 1-4**), as evidenced by groundwater elevations on the southern side of the AP. These two components of groundwater flow suggest a groundwater divide beneath the AP.

The groundwater elevation in wells screened in the uppermost aquifer (MW-1 through MW-12, MW-22 through MW-24, MW-26, MW-28 through MW-32, and PZ4C) averaged 592.68 feet NAVD88 between February and August 2021, with a range from 584.12 feet NAVD88 in MW-12 northwest of the AP to 598.69 feet NAVD88 in MW-32 in the northeast corner of the AP. As noted above, groundwater elevation contour maps suggest that there is a groundwater divide beneath the AP and horizontal groundwater flow in the uppermost aquifer is to the northwest and southeast toward the western and eastern lobes of Sangchris Lake, respectively (**Figure 1-3 and Figure 1-4**).

The groundwater elevation in LCU well MW-20 averaged 595.35 feet NAVD88 between February 2021 and August 2021, with a range from 594.18 to 598.93 feet NAVD88. The groundwater elevation in BCU well MW-12D averaged 586.23 feet NAVD88 between February and August 2021, with a range from 584.55 to 587.18 feet NAVD88 (**Figure 1-3 and Figure 1-4**).

In summary, groundwater elevations are primarily controlled by the surface water levels in Sangchris Lake and the water levels within the AP. There is an apparent groundwater divide beneath the AP with groundwater flow to the northwest towards the western lobe of Sangchris Lake and southeast toward the eastern lobe of Sangchris Lake.

Vertical hydraulic gradients were calculated using available groundwater elevation data from February to August 2021 at nested well locations within the USCU/PMPs, uppermost aquifer, LCU, and BCU. Vertical hydraulic gradients are presented in Table 3-2 of the HCR. The results of the vertical hydraulic gradient calculations for these hydrostratigraphic units are summarized below:

- BCU to uppermost aquifer:
  - Gradients calculated between MW-12D (BCU) and MW-12 (uppermost aquifer) were upward for all events.
- Uppermost aquifer to USCU/PMP:
  - Gradients between MW-12 (uppermost aquifer) and MW-12S (PMP) were downward for all events.
- Uppermost aquifer to USCU:
  - Gradients between MW-31 (uppermost aquifer) and MW-31S (USCU) were downward for seven events, and upward in the July 1, 2021 event.
  - Gradients between MW-8 (uppermost aquifer) and MW-8S (USCU) were variable, with upward gradient in three events (February through April 2021) and a downward gradient in two events (May and June 2021). Gradients were not calculated for the two events in July and one event in August because MW-8S was dry during those sampling events.
  - Gradients between MW-7 (uppermost aquifer) and MW-7S (USCU) were upward for seven events and downward in the June 2021 event.

These results are consistent with previous vertical gradient calculations (Natural Resource Technology, an OBG Company [NRT/OBG], 2017b).

Part 845 parameters were monitored in the uppermost aquifer monitoring wells at the AP as part of the AP Title 40 of the Code of Federal Regulations (40 C.F.R.) § 257 monitoring program beginning in 2015. These data were supplemented with installation and sampling of additional locations installed in 2021. The results indicate that the following parameters were detected at concentrations greater than the applicable 35 I.A.C. § 845.600 groundwater protection standards (GWPSs) and are considered potential exceedances:

- Arsenic, cobalt, lead, pH, sulfate, total dissolved solids (TDS), and radium 226 and 228 combined were detected in the USCU wells (not including PMP wells) downgradient of the AP.
- Arsenic, barium, beryllium, boron, chromium, cobalt, lead, lithium, pH, sulfate, thallium, TDS, and radium 226 and 228 combined were detected in PMP wells downgradient of the AP.
- Boron, chloride, cobalt, pH, sulfate, thallium, TDS were detected in the uppermost aquifer wells downgradient of the AP.
- Chloride and pH were detected in the BCU wells downgradient of the AP.

Concentration results for the above parameters were compared directly to 35 I.A.C. § 845.600 GWPS, without an evaluation of background concentrations. Evaluation of background groundwater quality has been completed as part of this GMP, and compliance with Part 845 will be determined following the first round of groundwater sampling. The first round of groundwater sampling for compliance will be completed the quarter following issuance of the Operating Permit and in accordance with this GMP.

2. GROUNDWATER MONITORING SYSTEMS

2.1 Existing Monitoring Well Network and Analysis

This GMP is being provided to propose a groundwater monitoring network and monitoring program specific to the AP that will comply with Part 845. The remaining discussion in this document will include only these networks and monitoring programs that are applicable and specific to the AP, specifically the 40 C.F.R. § 257 network and the proposed Part 845 monitoring network.

2.1.1 IEPA Monitoring Program

The current IEPA-required groundwater monitoring program associated with the AP consists of 12 groundwater monitoring wells used to monitor the uppermost aquifer, including four background monitoring wells (MW-1, MW-2, MW 9, and MW-10) and eight compliance monitoring wells (MW-3, MW-4, MW-5, MW-6, MW-7, MW-8, MW-11, and MW-12) in accordance with the GMP (Kincaid Generation, LLC, 2017). The boring logs, well construction forms, and other related monitoring well forms for the well network are included in Appendix C of the HCR (included in the Operating Permit to which this Plan is attached). The well locations are shown on **Figure 2-1**.

Groundwater samples are collected, analyzed and reported semi-annually for the parameters listed in 35 I.A.C. § 620.410 (Groundwater Quality Standards for Class I: Potable Resource Groundwater) with the exception of perchlorate, which is not required under the IEPA monitoring program GMP. The parameters analyzed for the IEPA Monitoring Program are listed in **Table A** below:

Table A. IEPA Groundwater Monitoring Program Parameters

Field Parameters			
Groundwater Elevation	pH	Specific conductivity	Temperature
General Chemistry Parameters			
Chloride (total)	Fluoride (total)	Nitrate (total)	TDS
Cyanide (total)	Nitrite (total)	Sulfate(total)	
Metals (total)			
Antimony	Cadmium	Lead	Silver
Arsenic	Chromium	Manganese	Thallium
Barium	Cobalt	Mercury	Vanadium
Beryllium	Copper	Nickel	Zinc
Boron	Iron	Selenium	Radium 226 and 228 combined

2.1.2 40 C.F.R. § 257 Monitoring

The 40 C.F.R. § 257 well network for the AP consists of eight monitoring wells installed nearby or adjacent to the AP within the unlithified uppermost aquifer. The AP 40 C.F.R. § 257 well network consists of two background monitoring wells (MW-1 and MW-2) and six compliance monitoring wells (MW-5, MW-6, MW-7, MW-8, MW-11, and MW-12). The boring logs, well construction forms, and other related monitoring well forms are available in the Operating Records as required by 40 C.F.R. § 257.91 for each monitored CCR Unit or CCR Multi-Unit, and are included in Appendix C of the HCR (included in the Operating Permit to which this Plan is attached). The well locations are shown on **Figure 2-1**.

Assessment monitoring in accordance with 40 C.F.R. § 257.95 was initiated on April 9, 2018. Details on the procedures and techniques used to fulfill the groundwater sampling and analysis program requirements are found in the Sampling and Analysis Plan for the AP (NRT/OBG, 2017a).

Groundwater samples are collected semi-annually and analyzed for the field and laboratory parameters from Appendix III and Appendix IV of 40 C.F.R. § 257, summarized in **Table B** below.

Table B. 40 C.F.R. § 257 Groundwater Monitoring Program Parameters

Field Parameters[1]			
Groundwater Elevation	pH		
Appendix III Parameters (Total, except TDS)			
Boron	Chloride	Sulfate	
Calcium	Fluoride	TDS	
Appendix IV Parameters (Total)			
Antimony	Cadmium	Lithium	Selenium
Arsenic	Chromium	Mercury	Thallium
Barium	Cobalt	Molybdenum	Radium 226 and 228 combined
Beryllium	Lead		

[1] Dissolved oxygen, temperature, specific conductance, oxidation/reduction potential, and turbidity are recorded during sample collection.

Results and analysis of groundwater sampling are reported annually by January 31 of the following year and made available on the CCR public website as required by 40 C.F.R. § 257.

2.1.3 Part 845 Well Installation and Monitoring

In 2021, 19 additional monitoring wells (MW-7S, MW-8S, MW-12S, MW-12D, MW-20S, MW-20, MW-22, MW-23, MW-24, MW-25, MW-26, MW-27, MW-28, MW-29, MW-30, MW-31, MW-32, and MW-31S) were installed along the perimeter of the AP to assess the vertical and horizontal lithology, stratigraphy, chemical properties, and physical properties of geologic layers to a minimum of 100 feet below ground surface (bgs) as specified in 35 I.A.C. § 845.620(b).

Prospective Part 845 monitoring wells were sampled for eight rounds between February and August 2021 and the results were used for selection of the AP Part 845 monitoring well network. Groundwater samples were collected and analyzed for 35 I.A.C. § 845.600 parameters as summarized in **Table C** below.

Table C. Part 845 Groundwater Monitoring Program Parameters

Field Parameters[1]			
Groundwater elevation	pH	Turbidity	
Metals (Total)			
Antimony	Boron	Cobalt	Molybdenum
Arsenic	Cadmium	Lead	Selenium
Barium	Calcium	Lithium	Thallium
Beryllium	Chromium	Mercury	
Inorganics (Total)			
Fluoride	Sulfate	Chloride	TDS
Other (Total)			
Radium 226 and 228 combined			

[1]Dissolved oxygen, temperature, specific conductance, and oxidation/reduction potential were recorded during sample collection.

Data and results from the Part 845 background monitoring were included in the water quality discussion included in the HCR (included in the Operating Permit to which this Plan is attached). The data collected from background locations during the Part 845 monitoring were used to evaluate and calculate background concentrations for the AP. The evaluation and discussion are included in **Section 3.2** of this report.

Data collected from the 40 C.F.R. § 257 monitoring network from 2015 to 2020, and from the Part 845 background monitoring were used for selection of the Part 845 monitoring well network proposed in **Section 2.2**.

2.2 Proposed Part 845 Monitoring Well Network

The groundwater monitoring network proposed in this plan will include five monitoring wells screened in the USCU (wells MW-7S[1], MW-8S, MW-20S[1], MW-27[1], and MW-31S), 16 monitoring wells screened in the uppermost aquifer (wells MW-01, MW-02, MW-03, MW-05, MW-06, MW-07, MW-08, MW-11, MW-12, MW-20, MW-23, MW-28, MW-30, MW-31, MW-32, and PZ-4C), and two water level only surface water staff gages (XSG-01 and SG-02). The proposed network is summarized in **Table D** below and displayed on **Figure 2-1**. Twenty-two wells (two background and 20 compliance) will be used to monitor groundwater concentrations within the hydrostratigraphic units.

The groundwater samples collected from the 21 wells will be used to monitor and evaluate groundwater quality and demonstrate compliance with the groundwater quality standards listed in 35 I.A.C. § 845.600(a). The proposed monitoring wells will yield groundwater samples that represent the quality of downgradient groundwater at the CCR boundary (as required in 35 I.A.C. § 845.630(a)(2)). Monitoring well depths and construction details are listed in **Table 2-1** and summarized in **Table D** below.

[1] Wells MW-7S, MW-20S, and MW-27 are screened in the upper semi-confining unit that have been identified to monitor the PMP.

Table D. Proposed Part 845 Monitoring Well Network

Well ID	Monitored Unit	Well Screen Interval (feet bgs)	Well Type [3]
MW-1	uppermost aquifer	15.0 - 25.0	Background
MW-2	uppermost aquifer	10.0 - 20.0	Background
MW-3	uppermost aquifer	14.0 - 24.0	Compliance
MW-5	uppermost aquifer	30.0 - 40.0	Compliance
MW-6	uppermost aquifer	10.0 - 20.0	Compliance
MW-7	uppermost aquifer	10.0 - 20.0	Compliance
MW-7S*	USCU	6.0 - 11.0	Compliance
MW-8	uppermost aquifer	12.0 - 22.0	Compliance
MW-8S	USCU	4.0 - 7.0	Compliance
MW-11	uppermost aquifer	11.0 - 21.0	Compliance
MW-12	uppermost aquifer	15.0 - 25.0	Compliance
MW-20	uppermost aquifer	14.0 - 24.0	Compliance
MW-20S*	USCU	4.0 - 10.0	Compliance
MW-23	uppermost aquifer	23.0 - 28.0	Compliance
MW-27*	USCU	10.0 - 15.0	Compliance
MW-28	uppermost aquifer	12.0 - 22.0	Compliance
MW-30	uppermost aquifer	35.0 - 40.0	Compliance
MW-31	uppermost aquifer	35.0 - 40.0	Compliance
MW-31S	USCU	25.0 - 30.0	Compliance
MW-32	uppermost aquifer	32.0 - 37.0	Compliance
PZ4C	uppermost aquifer	15.5 - 20.5	Compliance
XSG-01[1,2]	Ash/CCR	NA	WLO
SG-02[1,2]	uppermost aquifer	NA	WLO

[1] Surface water level measuring points.
[2] Location is temporary pending implementation of impoundment closure per an approved Construction Permit Application.
[3] Well type refers to the role of the well in the monitoring network.
* Well in the USCU that has been identified to monitor the PMP.
NA = Not Applicable
WLO = water level only

2.3 Well Abandonment

No wells are currently proposed for abandonment.

3. APPLICABLE GROUNDWATER QUALITY STANDARDS

3.1 Groundwater Classification

Groundwater at the AP does not meet the definition of Class I: Potable Resource Groundwater (35 I.A.C. § 620.210), based on the following criteria:

- Site investigations have determined that water bearing lenses contain more than 12 percent fines and are less than five feet in thickness (Cabeno Field Services [Cabeno], 2013),
- Sustained groundwater yield, from a 12-inch borehole, of less than 150-gallons per day from a thickness of 15-feet or less.
- Field (horizontal) hydraulic conductivity tests and laboratory (vertical) hydraulic conductivity tests from wells screened within the uppermost aquifer resulted in an overall (geometric mean) of 5.07 x 10^{-5} centimeters per second (cm/s) and 1.07 x 10^{-7} cm/s, respectively.

As set forth in 35 I.A.C. § 620.220, any geologic material with a hydraulic conductivity of less than 1×10^{-4} cm/s, and which does not meet the provisions of 35 I.A.C. § 620.210 (Class I), 35 I.A.C. § 620.230 (Class III), or 35 I.A.C. § 620.240 (Class IV), meets the definition of Class II: General Resource Groundwater. Based on the detailed geologic information provided for the unlithified materials and bedrock intercepted at the AP along with the hydrogeologic data, the groundwater in the uppermost aquifer can be classified as Class II groundwater: General Resource Groundwater. This is supported by results of the hydrogeologic study completed in 2013 (Cabeno, 2013), which concluded that the AP does not meet most criteria of Class I Groundwater and the data collected supported a Class II Groundwater Classification.

3.2 Statistical Evaluation of Background Groundwater Data

A Statistical Analysis Plan (**Appendix A**) has been developed to describe procedures that will be used to establish background conditions and implement compliance monitoring as necessary and required by 35 I.A.C. § 845.640 and 845.650. The Statistical Analysis Plan was prepared in accordance with the requirements of 35 I.A.C. § 845.640(f), with reference to the acceptable statistical procedures provided in United States Environmental Protection Agency's (USEPA) *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance* (*Unified Guidance,* March 2009), and is intended to provide a logical process and framework for conducting the statistical analysis of the data obtained during groundwater monitoring.

In accordance with 35 I.A.C. § 845.640(f)(1), the statistical method chosen for analysis of background groundwater quality was either the tolerance interval or the prediction interval procedure for each constituent listed in 35 I.A.C. § 845.600(a)(1) at this CCR unit per 35 I.A.C. § 845.640(f)(1)(C). A comparison of the statistical background concentrations and groundwater quality standards listed in 35 I.A.C. § 845.600(a)(1) and the resulting GWPSs are summarized in **Table 3-1**.

3.3 Applicable Groundwater Protection Standards

The applicable GWPS will be established in accordance with 35 I.A.C. § 845.600(a)(1) (greater of the background concentration or numerical limit specified in 35 I.A.C. § 845.600(a)(1)). The results of the statistical analysis of background groundwater data (**Table 3-1**) indicate that most background concentrations in the uppermost aquifer are below the groundwater quality standards listed in 35 I.A.C. § 845.600(a)(1). Therefore, for these parameters, the groundwater quality standards listed in 35 I.A.C. § 845.600(a)(1) will be applied to the results from the proposed groundwater monitoring network. The exception is for pH lower limit, where the background lower limit for pH is lower than the 35 I.A.C. § 845.600 standard. Therefore, the GWPS for pH lower limit will be the background measurement.

Under most circumstances, the GWPS will be compared to the lower confidence limit for the observed concentrations for each constituent in each compliance well. Exceptions are when there are high percentages (greater than 50 percent) of non-detects in compliance well data, for which a future mean (for 50 to 70 percent non-detects) or median (for greater than 70 percent non-detects) will be compared to the GWPS. Consistent with the *Unified Guidance*, the same general statistical method of confidence interval testing against a fixed GWPS is recommended in compliance and corrective action programs. Confidence intervals provide a flexible and statistically accurate method to test how a parameter estimated from a single sample compares to a fixed numerical limit. Confidence intervals explicitly account for variation and uncertainty in the sample data used to construct them.

Evaluation of the applicable standards will occur in conjunction with the analysis of groundwater quality results. Background calculations and the resulting concentrations may be updated as appropriate, in accordance with the Statistical Analysis Plan included in **Appendix A.**

4. GROUNDWATER MONITORING PLAN

The groundwater monitoring plan will monitor and evaluate groundwater quality to demonstrate compliance with the groundwater quality standards included in 40 C.F.R. § 257.94(e), 40 C.F.R. § 257.95(h), and 35 I.A.C. § 845.600(a)(1). The groundwater monitoring program will include sampling and analysis procedures that are consistent and that provide an accurate representation of groundwater quality at the background and compliance wells as required by 35 I.A.C. § 845.630. As discussed in **Section 2**, three monitoring networks specific to the AP exist, the IEPA-required monitoring program, the 40 C.F.R. § 257 network, and the proposed Part 845 network. These networks will continue to be monitored until USEPA approves Part 845. It is expected that upon USEPA approval of Part 845, the 40 C.F.R. § 257 network monitoring and reporting will be eliminated, and the proposed Part 845 monitoring and reporting included in this Plan will replace the IEPA monitoring and continue until requirements of Part 845 have been achieved.

4.1 Monitoring Networks and Parameters

4.1.1 IEPA Groundwater Monitoring

The existing IEPA-required monitoring program was discussed in detail in **Section 2.1.1.** Twelve groundwater monitoring wells used to monitor the uppermost aquifer, including four background monitoring wells (MW-1, MW-2, MW 9, and MW-10) and eight compliance monitoring wells (MW-3, MW-4, MW-5, MW-6, MW-7, MW-8, MW-11, and MW-12) are sampled on a semi-annual frequency for the parameters listed in 35 I.A.C. § 620.410 (Groundwater Quality Standards for Class I: Potable Resource Groundwater) with the exception of perchlorate, which is not required under the IEPA monitoring program GMP. Upon approval of this GMP through IEPA granting a Part 845 Operating Permit for the AP, this monitoring program will be superseded by the Part 845 Monitoring Program summarized below.

4.1.2 40 C.F.R. § 257 Groundwater Monitoring

The existing 40 C.F.R. § 257 monitoring program was discussed in detail in **Section 2.1.2**. Eight wells (two background and six compliance) are sampled for Appendix III and Appendix IV parameters on a semi-annual frequency. No changes are proposed to this monitoring network. Well locations and parameters will continue to be monitored and reported as required by 40 C.F.R. § 257 until USEPA approves Part 845.

4.1.3 Part 845 Groundwater Monitoring

The proposed Part 845 Monitoring Network will consist of two background monitoring wells (MW-1 and MW-2), 19 compliance monitoring wells (MW-3, MW-5, MW-6, MW-7, MW-7S, MW-8, MW-8S, MW-11, MW-12, MW-20, MW-20S, MW-23, MW-27, MW-28, MW-30, MW-31, MW-31S, MW-32, and PZ4C), and two temporary water level only surface water staff gages (XSG-01 and SG-02) to monitor potential impacts from the AP (**Figure 2-1**). These monitoring wells are screened within the USCU (MW-7S[2], MW-8S, MW-20S[2], MW-27[2], and MW-31S), and the uppermost aquifer (MW-01, MW-02, MW-03, MW-05, MW-06, MW-07, MW-08, MW-11, MW-12, MW-20, MW-23, MW-28, MW-30, MW-31, MW-32, and PZ-4C) along the perimeter of the AP.

[2] Wells MW-7S, MW-20S, and MW-27 are screened in the upper semi=confining unit that have been identified to monitor the PMP.

Groundwater samples will be collected and analyzed for the laboratory and field parameters in **Table E** below:

Table E. Part 845 Groundwater Monitoring Program Parameters

Field Parameters[1]			
Groundwater elevation	pH	Turbidity	
Metals (Total)			
Antimony	Boron	Cobalt	Molybdenum
Arsenic	Cadmium	Lead	Selenium
Barium	Calcium	Lithium	Thallium
Beryllium	Chromium	Mercury	
Inorganics (Total)			
Fluoride	Sulfate	Chloride	TDS
Other (Total)			
Radium 226 and 228 combined			

[1]Dissolved oxygen, temperature, specific conductance, and oxidation/reduction potential will be recorded during sample collection.

All parameters listed above were sampled a minimum of eight times by October 18, 2021 to establish background groundwater quality in accordance with 35 I.A.C. § 845.650 (b)(1)(A). Discussion of background groundwater quality is included in **Section 3.2**.

4.2 Sampling Schedule

Groundwater sampling for the Part 845 monitoring well network will initially be performed quarterly according to the following schedule:

Table F. Part 845 Sampling Schedule

Frequency	Duration
Monthly (groundwater elevations only)	Begins: the quarter following approval of this plan and issuance of the Operating Permit.
	Ends: Following the 30-year post closure care period and following IEPA approval of documentation that groundwater concentrations are below standards in 35 I.A.C. § 845.600 and concentrations exceeding background are not increasing and meet requirements in 35 I.A.C. § 845.780 (c)(2)(B)(i) and (ii).
Quarterly (groundwater quality)	Begins: the quarter following approval of this plan and issuance of the Operating Permit.
	Ends: Following the 30-year post closure care period and following IEPA approval of documentation that groundwater concentrations are below standards in 35 I.A.C. § 845.600 and concentrations exceeding background are not increasing and meet requirements in 35 I.A.C. § 845.780 (c)(2)(B)(i) and (ii), or upon IEPA approval of an alternate schedule as allowed by 35 I.A.C. § 845.650(b)(4).
Semi-annual (groundwater quality)	Begins: Following 5 years of quarterly groundwater monitoring and IEPA approval of a demonstration that groundwater concentrations are below standards in 35 I.A.C. § 845.600 and not exhibiting statistically-significant increasing trends, monitoring effectiveness is not compromised by a semi-annual schedule, and sufficient data has been collected to characterize groundwater.
	Ends: Following detection of a statistically-significant increasing trend in groundwater concentrations or an exceedance of the standards in 35 I.A.C. § 845.600 (quarterly monitoring shall be resumed in these circumstances), or following the 30-year post closure care period and following IEPA approval of documentation that groundwater concentrations are below standards in 35 I.A.C. § 845.600 and concentrations exceeding background are not increasing and meet requirements in 35 I.A.C. § 845.780 (c)(2)(B)(i) and (ii).

4.3 Groundwater Sample Collection

Groundwater sampling procedures have been developed and the collection of groundwater samples is being implemented to meet the requirements of 35 I.A.C. § 845.640. In addition to groundwater well samples, quality assurance samples will be collected as described **in Section 4.5** (**Table 4-1**).

4.4 Laboratory Analysis

Laboratory analysis will be performed consistent with the requirements of 35 I.A.C. § 845.640(j) by a state-certified laboratory using methods approved by IEPA and USEPA. Laboratory methods may be modified based on laboratory equipment availability or procedures, but the Reporting Limit (RL) for all parameters analyzed, regardless of method, will be lower than the applicable groundwater quality standard. RLs for the applicable parameters are summarized in **Table 4-2**. Concentrations lower than the RL will be reported as less than the RL.

4.5 Quality Assurance Program

Consistent with the requirements of 35 I.A.C. § 845.640(a)(5), the sampling and analysis program includes procedures and techniques for quality assurance/quality control (QA/QC). Additional quality assurance samples to be collected will include the following:

- Field duplicates will be collected at a frequency of one per group of ten or fewer investigative water samples.

- One equipment blank sample will be collected and analyzed for each day of sampling. If dedicated sampling equipment is used, then equipment blank samples will not be collected.
- The duplicate and equipment blank quality assurance samples will be supplemented by the laboratory QA/QC program, which typically includes:
  - Regular generation of instrument calibration curves to assure instrument reliability
  - Laboratory control samples and/or quality control check standards that have been spiked, and analyses to monitor the performance of the analytical method
  - Matrix spike/matrix spike duplicate analyses to determine percent recoveries and relative percent differences for each of the parameters detected
  - Analysis of replicate samples to check the precision of the instrumentation and/or methodology employed for all analytical methods
  - Analysis of method blanks to assure that the system is free of contamination

Water quality meters used to measure pH and turbidity will be calibrated according to manufacturer's specifications. At a minimum, it is recommended that calibration of pH occur daily prior to sampling and checked for accuracy at the end of each day. Unusual or suspect pH measurements during sampling events will be flagged, evaluated, and additional calibration may be performed throughout the sampling events. Turbidity meters will be checked daily, prior to and following sampling. Unusual measurements or erratic meter performance will be flagged and evaluated for overall effects on the data prior to reporting.

4.6 Groundwater Monitoring System Maintenance Plan

Consistent with the requirements of 35 I.A.C. § 845.630(e)(2), maintenance will be performed as needed to assure that the monitoring wells provide representative groundwater samples. Monitoring wells will be inspected during each groundwater sampling event; inspections will consist of the following:

- Visual inspection, clearing of vegetation, replacement of markers, and painting of protective casings as needed to assure that monitoring wells are clearly marked and accessible
- Visual inspection and repair or replacement of well aprons as needed to assure that they are intact, drain water away from the well, and have not heaved
- Visual inspection and repair or replacement of protective casings as needed to assure that they are undamaged, and that locks are present and functional
- Checks to assure that well caps are intact and vented, unless in flood-prone areas in which case caps will not be vented
- Annual measurement of monitoring well depths to determine the degree of siltation within the wells. Wells will be redeveloped as needed to remove siltation from the screened interval if it impedes flow of water into the well
- Checks to assure that wells are clear of internal obstructions, and flow freely

If maintenance of a monitoring well cannot address an identified deficiency, a replacement well will be installed.

4.7 Statistical Analysis

Statistical analysis will be consistent with procedures listed in 35 I.A.C. § 845.640(f). A Statistical Analysis Plan, provided in **Appendix A**, has been developed to summarize the statistical procedures that will be used to evaluate the groundwater results.

4.8 Data Reporting

Data reporting for the 40 C.F.R. § 257 monitoring well network will be consistent with recordkeeping, notification, and internet posting requirements described in 40 C.F.R. § 257.105 through 257.107.

Groundwater monitoring and analysis completed as part of the Part 845 monitoring under an approved monitoring program will be reported to IEPA within 60 days after completion of sampling and the data placed in the facility's operating record as required by 35 I.A.C. § 845.610(b)(3)(D). Within 14 days of posting to the operating record, information will be posted to the publicly accessible internet site "Illinois CCR Rule Compliance Data and Information" as required by 35 I.A.C. § 845.810(d). Information will also be submitted to IEPA annually by January 31 as required by 35 I.A.C. § 845.550, for data collected the preceding year. The report will include the status of the groundwater monitoring and any required corrective action plan for the AP in addition to other requirements detailed in 35 I.A.C. § 845.610(e).

4.9 Compliance with Applicable On-site Groundwater Protection Standards

In accordance with 35 I.A.C. § 845.600(a)(1), the groundwater protection standard at the waste boundary will be the higher of either the 35 I.A.C. § 845.600 standard or the concentration determined by background groundwater monitoring.

As provided in 35 I.A.C. § 845.780(c)(2), at the end of the 30-year post-closure care period, groundwater monitoring will continue to be conducted in post-closure care until the groundwater results show the concentrations are:

- Below the groundwater protection standards in 35 I.A.C. § 845.600; and
- Not increasing for those constituents over background, using the statistical procedures and performance standards in 35 I.A.C. § 845.640(f) and (g), provided that:
  - Concentrations have been reduced to the maximum extent feasible; and
  - Concentrations are protective of human health and the environment.

If one or more constituents are detected and confirmed by an immediate resample, to be greater than the GWPS in any sampling event, an Alternate Source Demonstration (ASD) will be evaluated as described in **Section 4.10**.

4.10 Alternate Source Demonstrations

As allowed in 35 I.A.C. § 845.650(e), following detection of an exceedance of the GWPS, an ASD will be evaluated and, if completed, submitted to IEPA within 60 days. The ASD will provide lines of evidence that a source other than the CCR SI caused the contamination and the CCR SI did not contribute to the contamination, or that the exceedance of the GWPS resulted from error in sampling, analysis, statistical evaluation, natural variation in groundwater quality, or a change in the potentiometric surface and groundwater flow direction.

The ASD will include information and analysis that supports the conclusions and a certification of accuracy by a qualified professional engineer. Once the ASD is approved by IEPA, the Part 845 groundwater monitoring will continue as defined in **Section 4.1.3**.

If an ASD is not completed and submitted, or IEPA does not approve the ASD, a notification of the exceedance will be provided to IEPA and placed in the operating record. Additional actions will also be completed as required by 35 I.A.C § 845.650(d)(1) through (3); including, initiation of an assessment of corrective measures under 35 I.A.C § 845.660. As allowed in 35 I.A.C § 845.650(e)(7) a petition for review of IEPA's non-concurrence under 35 I.A.C. § 105 may also be filed.

4.11 Assessment of Corrective Measures and Corrective Action

As described in 35 I.A.C. § 845.660, if the ASD summarized in **Section 4.10** has not been approved by IEPA, an assessment of corrective measures will be initiated within 90 days of the detection of a result exceeding 35 I.A.C. § 845.600 standards (*i.e.,* receipt of laboratory data). The assessment of corrective measures will include at least the following (35 I.A.C. § 845.660 (c)):

- The performance, reliability, ease of implementation, and potential impacts of appropriate potential remedies, including safety impacts, cross-media impacts, and control of exposure to any residual contamination;
- The time required to begin and complete the corrective action plan; and
- The institutional requirements, such as State or local permit requirements or other environmental or public health requirements that may substantially affect implementation of the corrective action plan.

Within one year of completing the assessment of corrective measures, a corrective action plan will be developed to identify the selected remedy in accordance with 35 I.A.C. § 845.670. If closure of the CCR Unit is required, a closure alternatives analysis will be completed as specified in 35 I.A.C. § 845.710. The analysis and selected alternative will be submitted to IEPA in a Closure Plan as specified by 35 I.A.C. § 845.720. Groundwater monitoring proposed in this Addendum will continue as specified until the post closure care period has expired and IEPA has approved termination of post-closure care.

5. REFERENCES

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United States Environmental Protection Agency (USEPA), 2015. *Title 40 of the Code of Federal Regulations, Part 257*.

TABLES

TABLE 1-1. PART 845 REQUIREMENTS CHECKLIST
GROUNDWATER MONITORING PLAN
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Part 845 Reference	Part 845 Components	Location of Information in GMP
845.630	**Groundwater Monitoring Systems**	
845.630(a)(2)	Potential contaminant pathways must be monitored.	Sections 1.3, 2.2 & 4.1.3
845.630(a) 845.630(b) 845.630(c)	At least two upgradient wells and four downgradient wells (min. 1 and 3, but requires additional documentation)	Sections 2.2 & 4.1.3 Table 2-1 Figure 2-1
845.630(a) 845.630(b) 845.630(c)	Downgradient Well Density	Figure 2-1
845.630(a)(2)	Downgradient wells at waste boundary	Figure 2-1
845.640	**Groundwater Sampling and Analysis Requirements**	
845.640(a)	Consistent sampling and analysis procedures	Section 4 Tables 4-1 & 4-2
845.640(b)	Methods are appropriate	Section 4 Tables 4-1 & 4-2
845.640(c)	Groundwater elevations must be measured in each well prior to purging, each time groundwater is sampled.	Section 4.3
845.640 (d)(e)(f)(g)(h)	Establishment of background and application of statistical methods	Sections 3 & 4.7 Appendix A
845.640(i)	Analyze total recoverable metals	Section 4.1.3
845.640(j)	Analyze groundwater samples using a certified laboratory	Section 4.4

TABLE 1-1. PART 845 REQUIREMENTS CHECKLIST
GROUNDWATER MONITORING PLAN
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Part 845 Reference	Part 845 Components	Location of Information in GMP
845.650	**Groundwater Monitoring Program**	
845.650(a)	Must include monitoring for all constituents with a groundwater protection standard in Section 845.600(a), calcium, and turbidity	Section 4.1.3
845.650(b)(c)	Groundwater Monitoring Frequency	Sections 4.1.3 & 4.2
845.650(d)(e)	Exceedances of the groundwater protection standard	Sections 4.9, 4.10 & 4.11
845.650(b)(2) 845.650(b)(3)	Staff gauge/ piezometer to monitor head in impoundment	Sections 2.2 & 4.1.3 Figure 2-1 (XSG-01)
NA	Staff gauge/ piezometer to monitor head of neighboring surface water body	Sections 2.2 & 4.1.3 Figure 2-1 (SG-02)

[O: CJC 08/11/21; C: LDC 8/17/21]

Notes:
GMP = Groundwater Monitoring Plan
NA = Not Applicable

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TABLE 2-1. MONITORING WELL LOCATIONS AND CONSTRUCTION DETAILS
GROUNDWATER MONITORING PLAN
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Well Number	Type	HSU	Date Constructed	Top of PVC Elevation (ft)	Measuring Point Elevation (ft)	Measuring Point Description	Ground Elevation (ft)	Screen Top Depth (ft BGS)	Screen Bottom Depth (ft BGS)	Screen Top Elevation (ft)	Screen Bottom Elevation (ft)	Well Depth (ft BGS)	Bottom of Boring Elevation (ft)	Screen Length (ft)	Screen Diameter (inches)	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)
MW-1	B	UA	04/20/2010	604.71	604.71	Top of PVC	602.60	15.00	25.00	587.60	577.60	25.00	568.10	10	2	39.592051	-89.490283
MW-2	B	UA	04/21/2010	601.10	601.10	Top of PVC	598.88	10.00	20.00	588.90	578.90	20.00	541.40	10	2	39.590698	-89.488916
MW-3	C	UA	04/15/2010	601.46	601.46	Top of PVC	599.24	14.00	24.00	585.20	575.20	24.00	552.70	10	2	39.594458	-89.487173
MW-5	C	UA	04/22/2010	619.44	619.44	Top of PVC	617.77	30.00	40.00	587.80	577.80	40.00	541.80	10	2	39.601296	-89.490402
MW-6	C	UA	04/16/2010	600.46	600.46	Top of PVC	598.44	10.00	20.00	588.40	578.40	20.00	572.90	10	2	39.598638	-89.498944
MW-7	C	UA	04/16/2010	597.75	597.75	Top of PVC	596.00	10.00	20.00	586.00	576.00	20.00	569.50	10	2	39.597637	-89.498959
MW-7S	C	USCU	02/02/2021	597.64	597.64	Top of PVC	595.59	6.00	11.00	589.59	584.59	11.00	580.59	5	2	39.59766	-89.498978
MW-8	C	UA	04/13/2010	603.14	603.14	Top of PVC	601.14	12.00	22.00	589.10	579.10	22.00	563.10	10	2	39.594399	-89.496829
MW-8S	C	USCU	02/02/2021	603.30	603.30	Top of PVC	600.57	4.00	7.00	596.57	593.57	7.00	580.57	3	2	39.594381	-89.496822
MW-11	C	UA	06/17/2015	601.81	601.81	Top of PVC	599.27	11.00	21.00	588.30	578.30	21.00	578.30	10	2	39.593104	-89.491115
MW-12	C	UA	07/23/2015	591.40	591.40	Top of PVC	589.04	15.00	25.00	573.90	563.90	25.00	563.90	10	2	39.600208	-89.496381
MW-20	C	UA	01/26/2021	600.77	600.77	Top of PVC	598.52	14.00	24.00	584.52	574.52	24.00	547.52	10	2	39.598653	-89.48728
MW-20S	C	USCU	01/26/2021	600.64	600.64	Top of PVC	598.43	4.00	10.00	594.43	588.43	10.00	588.43	6	2	39.598665	-89.487279
MW-23	C	UA	02/02/2021	610.32	610.32	Top of PVC	608.05	23.00	28.00	585.05	580.05	28.00	558.05	5	2	39.593293	-89.489352
MW-27	C	USCU	02/02/2021	600.05	600.05	Top of PVC	597.35	10.00	15.00	587.35	582.35	15.00	577.35	5	2	39.596694	-89.497927
MW-28	C	UA	02/02/2021	601.40	601.40	Top of PVC	598.33	12.00	22.00	586.33	576.33	22.00	573.33	10	2	39.599258	-89.497962
MW-30	C	UA	02/03/2021	618.47	618.47	Top of PVC	616.00	35.00	40.00	581.00	576.00	40.00	571.00	5	2	39.601262	-89.493996
MW-31	C	UA	02/03/2021	617.34	617.34	Top of PVC	615.02	35.00	40.00	580.02	575.02	40.00	565.02	5	2	39.601301	-89.491702
MW-31S	C	USCU	02/03/2021	617.54	617.54	Top of PVC	615.13	25.00	30.00	590.13	585.13	30.00	585.13	5	2	39.601303	-89.491681
MW-32	C	UA	02/03/2021	619.49	619.49	Top of PVC	617.20	32.00	37.00	585.20	580.20	37.00	577.20	5	2	39.601279	-89.488643
PZ-4C	C	UA	03/30/2016	600.57	600.57	Top of PVC	597.89	15.50	20.50	582.39	577.39	20.50	577.39	5	2	39.596398	-89.487207
XSG-01	WLO	CCR	--	--	608.43	Staff gauge	--	--	--	--	--	--	--	--	--	39.593401	-89.48768
SG-02	WLO	SW	--	--	564.80	Staff gauge	--	--	--	--	--	--	--	--	--	39.593106	-89.498155

TABLE 2-1. MONITORING WELL LOCATIONS AND CONSTRUCTION DETAILS
GROUNDWATER MONITORING PLAN
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Well Number	Type	HSU	Date Constructed	Top of PVC Elevation (ft)	Measuring Point Elevation (ft)	Measuring Point Description	Ground Elevation (ft)	Screen Top Depth (ft BGS)	Screen Bottom Depth (ft BGS)	Screen Top Elevation (ft)	Screen Bottom Elevation (ft)	Well Depth (ft BGS)	Bottom of Boring Elevation (ft)	Screen Length (ft)	Screen Diameter (inches)	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)

Notes:
All elevation data are presented relative to the North American Vertical Datum 1988 (NAVD88), GEOID 12A
Type refers to the role of the well in the monitoring network: background (B), compliance (C), or water level measurements only (WLO)
WLO wells are temporary pending implementation of impoundment closure per an approved Construction Permit application
-- = data not available
BGS = below ground surface
CCR = Coal Combustion Residual
ft = foot or feet
HSU = Hydrostratigraphic Unit
PVC = polyvinyl chloride
SW = surface water
UA = uppermost aquifer
USCU = upper semi-confining unit

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TABLE 3-1. BACKGROUND GROUNDWATER QUALITY AND STANDARDS
GROUNDWATER MONITORING PLAN
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Parameter	Background Concentration	845 Limit	Groundwater Protection Standard	Unit
Antimony, total	0.001	0.006	0.006	mg/L
Arsenic, total	0.0048	0.010	0.010	mg/L
Barium, total	0.15	2.0	2.0	mg/L
Beryllium, total	0.001	0.004	0.004	mg/L
Boron, total	0.296	2	2	mg/L
Cadmium, total	0.001	0.005	0.005	mg/L
Chloride, total	18	200	200	mg/L
Chromium, total	0.0095	0.1	0.1	mg/L
Cobalt, total	0.0039	0.006	0.006	mg/L
Fluoride, total	0.51	4.0	4.0	mg/L
Lead, total	0.0051	0.0075	0.0075	mg/L
Lithium, total	0.012	0.04	0.04	mg/L
Mercury, total	0.0002	0.002	0.002	mg/L
Molybdenum, total	0.0062	0.1	0.1	mg/L
pH (field)	7.6 / 5.6	9.0 / 6.5	9.0 / 5.6	SU
Radium 226 and 228 combined	1	5	5	pCi/L
Selenium, total	0.0018	0.05	0.05	mg/L
Sulfate, total	151	400	400	mg/L
Thallium, total	0.002	0.002	0.002	mg/L
Total Dissolved Solids	494	1200	1200	mg/L

Notes:
For pH, the values presented are the upper / lower limits
GWPS for calcium and turbidity do not apply per 35 I.A.C. § 845.600(b)
mg/L = milligrams per liter
SU = standard units
pCi/L = picocuries per liter

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TABLE 4-1. SAMPLING AND ANALYSIS SUMMARY
GROUNDWATER MONITORING PLAN
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Parameter	Analytical Method [1]	Number of Samples	Field Duplicates [2]	Field Blanks [3]	Equipment Blanks [3]	MS/MSD [4]	Total	Container Type	Minimum Volume [5]	Preservation (Cool to 4 °C for all samples)	Sample Hold Time from Collection Date
Metals											
Metals [6]	6020, Li - EPA 200.7	22	3	0	0	2	27	plastic	600 mL	HNO_3 to pH<2	6 months
Mercury	7470A or 6020	22	3	0	0	2	27	plastic	400 mL	HNO_3 to pH<2	28 days
Inorganic Parameters											
Fluoride	9214 or EPA 300	22	3	0	0	2	27	plastic	300 mL	Cool to 4 °C	28 days
Chloride	9251 or EPA 300	22	3	0	0	2	27	plastic	100 mL	Cool to 4 °C	28 days
Sulfate	9036 or EPA 300	22	3	0	0	2	27	plastic	50 mL	Cool to 4 °C	28 days
Total Dissolved Solids	SM 2540 C	22	3	0	0	2	27	plastic	200 mL	Cool to 4 °C	7 days
Radium											
Radium 226	9315 or EPA 903	22	0	0	0	0	22	plastic	1000 mL	HNO_3 to pH<2	6 months
Radium 228	9320 or EPA 904	22	0	0	0	0	22	plastic	1000 mL	HNO_3 to pH<2	6 months
Field Parameters											
pH	SM 4500-H+ B	22	NA	NA	NA	NA	22	flow-through cell	NA	none	immediately
Dissolved Oxygen [8]	SM 4500-O/405.1	22	NA	NA	NA	NA	22	flow-through cell	NA	none	immediately
Temperature [8]	SM 2550	22	NA	NA	NA	NA	22	flow-through cell	NA	none	immediately
Oxidation/Reduction Potential [8]	SM 2580 B	22	NA	NA	NA	NA	22	flow-through cell	NA	none	immediately
Specific Conductance [8]	SM 2510 B	22	NA	NA	NA	NA	22	flow-through cell	NA	none	immediately
Turbidity [7]	SM 2130 B	22	NA	NA	NA	NA	22	flow-through cell or hand-held turbidity meter	NA	none	immediately

[O: CJC 08/11/21; C: LDC 8/17/21]

Notes:
[1] Analytical method numbers are from SW-846 unless otherwise indicated. Analytical methods may be updated with more recent versions as appropriate.
[2] Field duplicates will be collected at a frequency of one per group of 10 or fewer investigative water samples. Field duplicates will not be collected for radium analysis.
[3] Field blanks will be collected at the discretion of the project manager; Equipment blanks will be collected at a rate of 1 per sampling event if non-dedicated equipment is used.
[4] Matrix Spike/Matrix Spike Duplicate (MS/MSD) samples will be collected at a frequency of one per group of 20 or fewer investigative water samples per CCR unit/multi-unit. Additional volume to be determined by laboratory.
[5] Sample volume is estimated and will be determined by the laboratory.
[6] Metals = antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chromium, cobalt, lead, lithium, molybdenum, selenium, thallium. Metals may be analyzed via ICP/ ICP-MS USEPA methods 6010 or 6020 depending on laboratory instrument availability
[7] If turbidity exceeds 10 NTUs, a duplicate sample filtered through a .45 micron filter may be collected for metals analysis in addition to the unfiltered sample. Both samples would be submitted for analysis.
[8] Parameter collected for quality assurance and quality control for field sampling purposes only; not required to be collected or reported under Part 845; collection of parameter may be discontinued without notification.
< = less than
°C = degrees Celsius
HNO_3 = nitric acid
mL = milliliter
NA = not applicable
NTU = nephelometric turbidity unit

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TABLE 4-2. DETECTION AND REPORTING LIMITS FOR PART 845 PARAMETERS
GROUNDWATER MONITORING PLAN
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Constituent	CAS	Unit	Analytical Methods [1]	USEPA MCL [2]	35 I.A.C. § 845.600	RL [4, 5]	MDL [5]
Metals							
Antimony	7440-36-0	mg/L	6020	0.006	0.006	0.003	0.00036
Arsenic	7440-38-2	mg/L	6020	0.01	0.01	0.001	0.00013
Barium	7440-39-3	mg/L	6020	2	2	0.001	0.00028
Beryllium	7440-41-7	mg/L	6020	0.004	0.004	0.001	0.000017
Boron	7440-42-8	mg/L	6020	NS	2	0.01	0.0023
Cadmium	7440-43-9	mg/L	6020	0.005	0.005	0.001	0.000042
Calcium	7440-70-2	mg/L	6020	NS	NS	0.15	0.15
Chromium	7440-47-3	mg/L	6020	0.1	0.1	0.004	0.00027
Cobalt	7440-48-4	mg/L	6020	0.006	0.006	0.002	0.000017
Lead	7439-92-1	mg/L	6020	0.015	0.0075	0.001	0.000025
Lithium	7439-93-2	mg/L	6020 or EPA 200.7	0.04	0.04	0.02	0.0001
Mercury	7439-97-6	mg/L	6020 or 7470A	0.002	0.002	0.0002	0.000078
Molybdenum	7439-98-7	mg/L	6020	0.1	0.1	0.001	0.000063
Selenium	7782-49-2	mg/L	6020	0.05	0.05	0.001	0.00032
Thallium	7440-28-0	mg/L	6020	0.002	0.002	0.001	0.000062
Inorganics							
Fluoride	7681	mg/L	9214 or EPA 300	4	4	0.25	0.065
Chloride	16887-00-6	mg/L	9251 or EPA 300	250 [3]	200	1	0.15
Sulfate	18785-72-3	mg/L	9036 or EPA 300	250 [3]	400	1	0.24
Total Dissolved Solids	10052	mg/L	SM 2540C	500 [3]	1200	17	--
Other							
Radium 226 and 228 Combined	7440-14-4	pCi/L	9315/9320 or EPA 903/904	5	5	-- [6]	-- [7]
Field							
pH	NA	SU	SM 4500-H+ B	NS	6.5-9.0	NA	NA
Oxidation/Reduction Potential	NA	mV	SM 2580 B	NS	NS	NA	NA
Dissolved Oxygen	NA	mg/L	SM 4500-O/405.1	NS	NS	NA	NA
Temperature	NA	^{o}C	SM 2550	NS	NS	NA	NA
Specific Conductivity	NA	μS/cm	SM 2510 B	NS	NS	NA	NA

TABLE 4-2. DETECTION AND REPORTING LIMITS FOR PART 845 PARAMETERS

GROUNDWATER MONITORING PLAN

KINCAID POWER PLANT

ASH POND

KINCAID, ILLINOIS

Constituent	CAS	Unit	Analytical Methods [1]	USEPA MCL [2]	35 I.A.C. § 845.600	RL [4, 5]	MDL [5]
Turbidity	NA	NTU	SM 2130 B	NS	NS	NA	NA

[O: CJC 08/11/21; C: LDC 08/17/21; U: LDC 09/16/21; C: EJT 09/19/21]

Notes:

[1] Analytical method numbers are from SW-846 unless otherwise indicated. Metals will be analyzed via Method 6020 or 6010 depending on laboratory equipment availability. Selected method will ensure reporting limits (RL) are below Title 35 of the Illinois Administrative Code (35 I.A.C.) § 845.600 groundwater protection standards.

[2] USEPA MCL = United States Environmental Protection Agency Maximum Contaminant Level.

[3] USEPA SMCL = United States Environmental Protection Agency Secondary Maximum Contaminant Level.

[4] RLs will be less than the 35 I.A.C. § 845.600 groundwater protection standards.

[5] RLs and method detection limits (MDLs) will vary depending on the laboratory performing the work.

[6] All radium results will be reported (values may be positive or negative) and will include uncertainty and the calculated MDC.

[7] Laboratories calculate a minimum detectable concentration (MDC) based on the sample.

^{o}C = degrees Celsius

µS/cm = microSiemens per centimeter

CAS = Chemical Abstract Number

MDL = Method detection limit as established by the laboratory

mg/L = milligrams per liter

mV = millivolts

NS = No standard

NTU = nephelometric turbidity unit

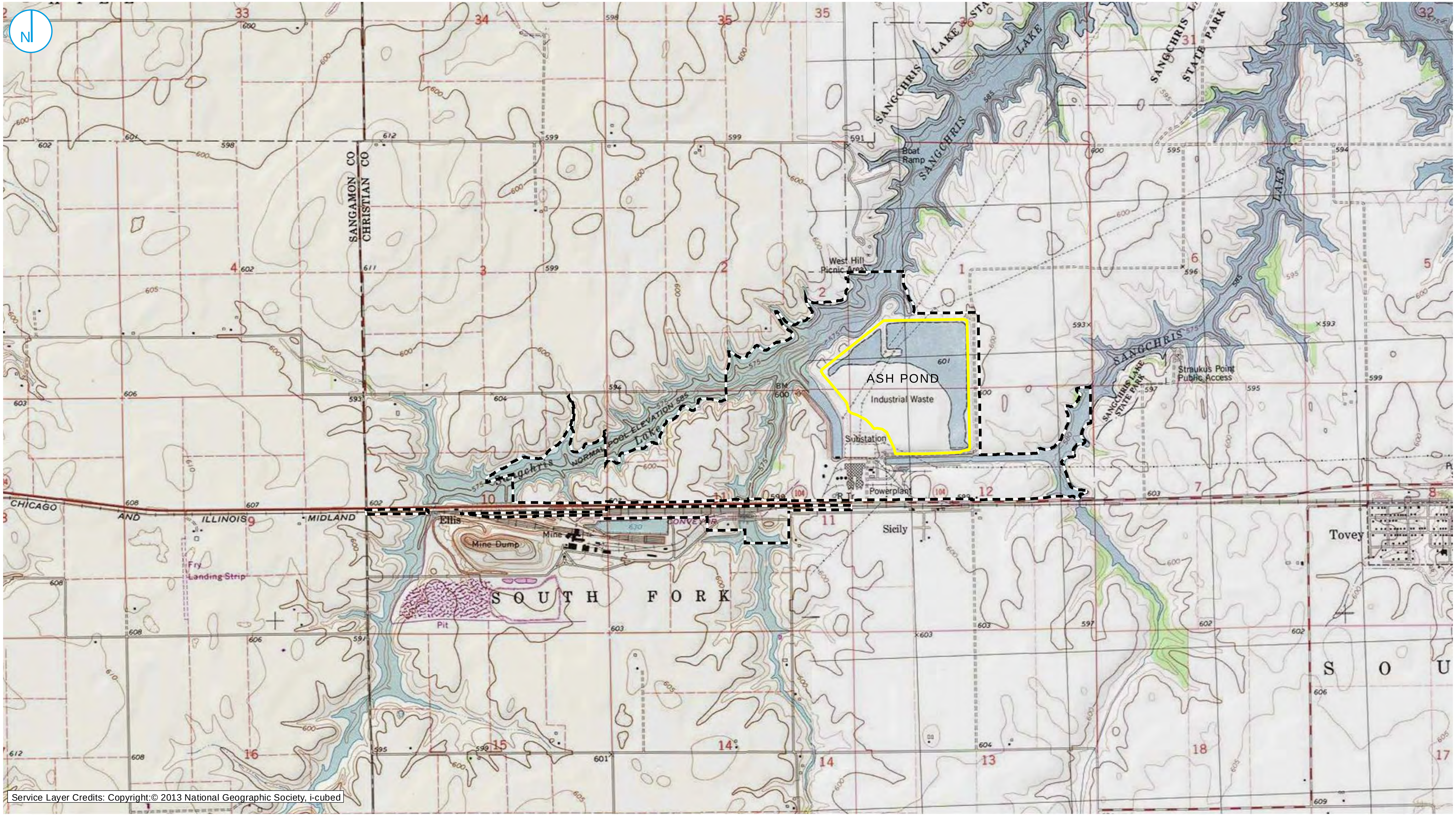
pCi/L = picoCuries per liter

RL = Reporting limit as established by the laboratory

SM = Standard Methods for the Examination of Water and Wastewater

SU = standard units

FIGURES



PART 845 REGULATED UNIT (SUBJECT UNIT)

PROPERTY BOUNDARY

0 1,000 2,000 Feet

SITE LOCATION MAP

GROUNDWATER MONITORING PLAN
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

FIGURE 1-1

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PROJECT: 169000XXXX | DATED: 8/5/2021 | DESIGNER: galarmc

Y:\Mapping\Projects\22\2285\MXD\845_Operating_Permit\Kincaid\GMP\Figure 1-1_Site Location Map.mxd

Y:\Mapping\Projects\22\2285\MXD\845_Operating_Permit\Kincaid\GMP\Figure 1-2_Site_Map.mxd

PROJECT: 169000XXXX | DATED: 8/5/2021 | DESIGNER: galarmmc

PART 845 REGULATED UNIT (SUBJECT UNIT)

PROPERTY BOUNDARY

0 250 500 Feet

SITE MAP

FIGURE 1-2

GROUNDWATER MONITORING PLAN
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

Y:\Mapping\Projects\22\2285\MXD\845_Operating_Permit\Kincaid\GMP\Figure 1-3_GWE_Contours_20210223.mxd

PROJECT: 169000XXXX | DATED: 10/1/2021 | DESIGNER: STOLZSD

BACKGROUND WELL
MONITORING WELL
SOURCE SAMPLE LOCATION
STAFF GAGE

GROUNDWATER ELEVATION CONTOUR (2-FT CONTOUR INTERVAL, NAVD88)
INFERRED GROUNDWATER ELEVATION CONTOUR
GROUNDWATER FLOW DIRECTION
PART 845 REGULATED UNIT (SUBJECT UNIT)
PROPERTY BOUNDARY

0 250 500 Feet

GROUNDWATER ELEVATION CONTOUR
FEBRUARY 23, 2021

GROUNDWATER MONITORING PLAN
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

FIGURE 1-3

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ELEVATIONS IN PARENTHESIS WERE NOT USED FOR CONTOURING.

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

- BACKGROUND WELL
- MONITORING WELL
- SOURCE SAMPLE LOCATION
- STAFF GAGE
- GROUNDWATER ELEVATION CONTOUR (2-FT CONTOUR INTERVAL, NAVD88)
- INFERRED GROUNDWATER ELEVATION CONTOUR
- GROUNDWATER FLOW DIRECTION
- PART 845 REGULATED UNIT (SUBJECT UNIT)
- PROPERTY BOUNDARY

0 250 500 Feet

GROUNDWATER ELEVATION CONTOUR
APRIL 5, 2021

GROUNDWATER MONITORING PLAN
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

FIGURE 1-4

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BACKGROUND WELL
COMPLIANCE WELL
STAFF GAGE
PART 845 REGULATED UNIT (SUBJECT UNIT)
PROPERTY BOUNDARY

0 250 500 Feet

PROPOSED PART 845 GROUNDWATER MONITORING WELL NETWORK

FIGURE 2-1

GROUNDWATER MONITORING PLAN
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

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APPENDIX A
STATISTICAL ANALYSIS PLAN

Prepared for
Kincaid Generation, LLC

Date
October 25, 2021

Project No.
1940100806-007

STATISTICAL ANALYSIS PLAN

ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

RAMBOLL Bright ideas. Sustainable change.

STATISTICAL ANALYSIS PLAN
KINCAID POWER PLANT ASH POND

Project Name	**Kincaid Power Plant Ash Pond**
Project No.	**1940100806-007**
Recipient	**Kincaid Generation, LLC**
Document Type	**Statistical Analysis Plan**
Version	**FINAL**
Date	**October 25, 2021**

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Brian G. Hennings, PG
Senior Managing Hydrogeologist

Eric J. Tlachac, PE
Senior Managing Engineer

Rachel A. Banoff, EIT
Project Statistician

LICENSED PROFESSIONAL CERTIFICATIONS

This certification is based on the description of the statistical methods selected to evaluate groundwater as presented in the following Statistical Analysis Plan; Kincaid Power Plant Ash Pond. The procedures described in the plan will be used to establish background conditions and implement compliance monitoring as necessary and required by 35 I.A.C. § 845.640 and 35 I.A.C. § 845.650. The Statistical Analysis Plan was prepared in accordance with the requirements of 35 I.A.C. § 845.640(f), with reference to the acceptable statistical procedures provided in the United States Environmental Protection Agency (USEPA)'s *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance* (*Unified Guidance,* March 2009), and is intended to provide a logical process and framework for conducting the statistical analysis of the data obtained during groundwater monitoring. In accordance with 35 I.A.C. § 845.640(f)(1), the statistical method chosen for analysis of background groundwater quality will be either the tolerance interval or the prediction interval procedure for each constituent listed in 35 I.A.C. § 845.600(a)(1) at this CCR unit per 35 I.A.C. § 845.640(f)(1)(C). Groundwater Protection Standards (GWPS) will be established in accordance with 35 I.A.C. § 845.600(a) (greater of the background concentration or numerical limit specified in 35 I.A.C. § 845.600(a)(1)). The GWPS will be compared to the lower confidence limit for the observed concentrations for each constituent in each compliance well. Consistent with the *Unified Guidance*, the same general statistical method of confidence interval testing against a fixed GWPS is recommended in compliance and corrective action programs. Confidence intervals provide a flexible and statistically accurate method to test how a parameter estimated from a single sample compares to a fixed numerical limit. Confidence intervals explicitly account for variation and uncertainty in the sample data used to construct them.

Description of the statistical methods chosen for analysis of groundwater monitoring data and application of these methods for determining exceedances of the GWPS identified in 35 I.A.C. § 845.600(a) is provided in this Statistical Analysis Plan.

35 I.A.C. § 845.640 Statistical Analysis (PE)

I, Eric J. Tlachac, a qualified professional engineer in good standing in the State of Illinois, certify that the statistical methods summarized above and described in this document (Statistical Analysis Plan; Kincaid Power Plant Ash Pond) are appropriate for evaluating the groundwater monitoring data collected as described in the attached document and are in substantial compliance with 35 I.A.C. § 845.640.

Eric J. Tlachac
Qualified Professional Engineer
062-063091
Illinois
Date: October 25, 2021

LICENSED PROFESSIONAL ENGINEER
ERIC J. TLACHAC
062-063091
STATE OF ILLINOIS

35 I.A.C. § 845.640 Statistical Analysis (PG)

I, Brian G. Hennings, a qualified professional geologist in good standing in the State of Illinois, certify that the statistical methods described in this document (Statistical Analysis Plan; Kincaid Power Plant Ash Pond) are appropriate for evaluating the groundwater monitoring data collected as described in the attached document and are in substantial compliance with 35 I.A.C. § *845.640.*

Brian G. Hennings
Professional Geologist
196.001482
Illinois
Date: October 25, 2021

35 I.A.C. § 845.640 Statistical Analysis

I, Rachel A. Banoff, a qualified professional, certify that the statistical methods described in this document (Statistical Analysis Plan; Kincaid Power Plant Ash Pond), are appropriate for evaluating the groundwater monitoring data collected as described in the attached document and are in substantial compliance with 35 I.A.C. § *845.640.*

Rachel A. Banoff, EIT
Project Statistician
Date: October 25, 2021

CONTENTS

TABLES (IN TEXT)

ACRONYMS AND ABBREVIATIONS

§	Section
35 I.A.C.	Title 35 of the Illinois Administrative Code
ANOVA	analysis of variance
CCR	coal combustion residuals
COC	constituents of concern
GWPS	groundwater protection standard
IEPA	Illinois Environmental Protection Agency
LCL	lower confidence limit
LTL	lower tolerance limit
MSE	mean squared error
P	probability
Part 845	Residuals in Surface Impoundments: Title 35 of the Illinois Administrative Code § 845
RCRA	Resource Conservation and Recovery Act
RL	reporting limit
ROS	regression on order statistics
SI	surface impoundment
SSI	statistically significant increase
SWFPR	site-wide false positive rate
Unified Guidance	*Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance* (USEPA, 2009)
UPL	upper prediction limit
USEPA	United States Environmental Protection Agency
UTL	upper tolerance limit

1. INTRODUCTION

In April 2021, the Illinois Environmental Protection Agency (IEPA) issued a final rule for the regulation and management of Coal Combustion Residuals (CCR) in surface impoundments (SIs) under the Standards for the Disposal of CCR in Surface Impoundments: Title 35 of the Illinois Administrative Code (35 I.A.C.) § 845 (Part 845). Facilities regulated under Part 845 are required to develop and sample a groundwater monitoring well network to evaluate whether impounded CCR materials are impacting downgradient groundwater quality. The groundwater quality evaluation must include selection and certification by a qualified professional engineer of the statistical procedures to be used. The procedures described in the evaluation will be used to establish background conditions and implement compliance and corrective action monitoring as necessary and required by 35 I.A.C. § 845.640 and 35 I.A.C. § 845.650. This Statistical Analysis Plan was prepared in accordance with the requirements of 35 I.A.C. § 845.640(f), with reference to the acceptable statistical procedures provided in United States Environmental Protection Agency's (USEPA's) *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance* (*Unified Guidance*) (March 2009).

This Statistical Analysis Plan does not include procedures for groundwater sample collection and analysis, as these activities are conducted in accordance with the Sampling and Analysis Plan prepared for each CCR unit in accordance with 35 I.A.C. § 845.640. This Statistical Analysis Plan will be used as the primary reference for evaluating groundwater quality during operation and post-closure care.

1.1 Statistical Analysis Objectives

This Statistical Analysis Plan is intended to provide a logical process and framework for conducting the statistical analyses of data obtained during groundwater monitoring conducted in accordance with the Sampling and Analysis Plan for each CCR unit. The Statistical Analysis Plan will enable a qualified professional engineer to certify that the selected statistical methods are appropriate for evaluating the groundwater monitoring data for the applicable CCR unit(s).

1.2 Statistical Analysis Plan Approach

The main sections of this Statistical Analysis Plan should be viewed as a "generic" outline of statistical methods utilized for each CCR unit and constituent required to be monitored. The statistical analysis of the groundwater monitoring data, however, will be conducted on an individual-constituent or well basis, and may involve the use of appropriate statistical procedures depending on multiple factors such as detection frequency and normality distributions.

The CCR Rule outlines two phases of groundwater monitoring:

- Background Monitoring in accordance with 35 I.A.C. § 845.650(b)(1)
- Compliance Monitoring in accordance with 35 I.A.C. § 845.650

Each phase of the groundwater monitoring program requires specific statistical procedures to accomplish the intended purpose. During the background monitoring phase, background groundwater quality will be established utilizing upgradient and background wells and downgradient groundwater quality data will be collected to facilitate statistics in subsequent phases. Compliance Monitoring is then initiated through the evaluation of the downgradient groundwater monitoring data for exceedances of the groundwater protection standard (GWPS) established by Part 845 (concentration specified in 35 I.A.C. § 845.600 or an IEPA-approved background concentration). The developed statistical analysis plan will be implemented for each monitoring phase and in accordance with the statistical procedures.

2. BACKGROUND MONITORING AND DATA PREPARATION

The background and compliance monitoring wells were sampled and analyzed for constituents, as listed in Part 845 (antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chloride, chromium, cobalt, fluoride, lead, lithium, mercury, molybdenum, pH, radium 226 and 228 combined, selenium, sulfate, thallium, total dissolved solids, and turbidity), during the baseline phase of the groundwater monitoring program.

The background monitoring well(s) were placed upgradient of the CCR unit, or at an alternative background location, where they are not affected by potential leakage from the CCR unit. Compliance monitoring wells were placed at the waste boundary of the CCR unit, along the same groundwater flow path. As 35 I.A.C. § 845.630(a) specifies, the location of these wells ensures that background accurately represents the quality of unaffected groundwater, while compliance wells accurately represent groundwater quality at the waste boundary and monitor all potential contaminant pathways.

As required by 35 I.A.C. § 845.650(a)(1), eight sampling events were completed within 180 days of April 21, 2021. As outlined, groundwater sampling procedures included sampling of the background and compliance wells using low-flow sampling methods, collection of one field quality control sample per event, and groundwater samples were not field filtered before laboratory analysis of total recoverable metals.

Following completion of the eight sampling events, background groundwater quality was established for Part 845 constituents. Groundwater monitoring will be conducted quarterly for at least the first five years. In accordance with 35 I.A.C. § 845.650(b)(4), after the first five years, a request to reduce the monitoring frequency to semiannual may be submitted to IEPA if all of the following can be demonstrated:

- Groundwater monitoring effectiveness will not be compromised by the reduced frequency
- Sufficient data has been collected to characterize groundwater
- Monitoring to date does not show any statistically significant increasing trends
- The concentrations of monitored constituents at the compliance monitoring wells are below the applicable GWPSs established in 35 I.A.C. § 845.600

The following subsections outline the statistical tests and procedures (methods) that will be utilized to evaluate data collected for each constituent in both background and compliance wells for Background and Compliance Monitoring. When necessary and contingent upon equivalent statistical power, an alternative test not included in this Statistical Analysis Plan may be chosen due to site-specific data requirements.

2.1 Sample Independence

Independence of sample results is a major assumption for most statistical analyses. To ensure physical independence of groundwater sampling results, the minimum time between sampling events must be longer than the time required for groundwater to move through the monitoring well. The sampling schedules for both the baseline and compliance monitoring periods are specified in 35 I.A.C. § 845.650(b) and may conflict with the statistical assumption of independence of sample results.

2.2 Non-Detect Data Processing

The reporting limit (RL) will be used as the lower level for the reporting of non-detected groundwater quality data. For all summary statistics (box plots, timeseries, etc.), the RL will be substituted for concentrations reported below the RL, including non-detects. With professional judgement, analytical results between the RL and the method detection limit, *i.e.,* estimated values, typically identified with a "J" flag, may be utilized if provided by the laboratory.

For all statistical test procedures:

- If the frequency of non-detect data are less than or equal to 15 percent, half of the RL will be substituted for these data
- If the non-detect frequency is between 15 percent and 50 percent, either the Kaplan-Meier or robust regression on order statistics (ROS) will be used to estimate the mean and standard deviation adjusted for the presence of left-censored values
- If the non-detect frequency is greater than 50 percent, a non-parametric test will be used
- If only one background result is detected that value will be used as the non-parametric upper prediction limit (UPL)

2.3 Testing for Normality

Many statistical analyses assume that sample data are normally distributed (parametric). However, environmental data are frequently not normally distributed (nonparametric). 35 I.A.C. § 845.640(g) requires the knowledge of the background data distribution for comparison to compliance results. The *Unified Guidance* document recommends the Shapiro-Wilk normality test for sample sizes of 50 or less, and the Shapiro-Francia normality test for sample sizes greater than 50.

When possible, transformation of datasets to achieve normal distributions is preferred.

2.4 Testing for Outliers

Part 845 constituents will be screened for the existence of outliers using a method described by the *Unified Guidance*. Outliers are extreme data points that may represent an anomaly or erroneous data point. To test for outliers, one or more of the following outlier tests will be utilized:

- Dixon's test, for well-constituent pairs with less than 25 samples, assumes normally distributed data.
- Rosner's test, for well-constituent pairs with more than 20 samples, assumes normally distributed data.
- Grubb's test for well-constituent pairs with seven or more samples, assumes normally distributed data.
- Time series, box-whisker plots, and probability plots provide visual tools to identify potential outliers, and evaluation of seasonal, spatial, or temporal variability for both normally and non-normally distributed data.

Data quality control, groundwater geochemistry, and sampling procedures will be evaluated as potential sources of error leading to an outlier result. The outlier tests cannot be used alone to determine whether a value is a true outlier that should be excluded from future statistical analysis. Corroborating evidence needed to exclude values includes a discrete data reporting or analytical error, or potential laboratory bias. Absent corroborating evidence, the flagged values are considered true, but extreme, values in the data set. Professional judgement will be used to exclude extreme outliers from further statistical analyses. Outliers will be retained in the database.

With professional judgement, a confirmatory sample may be collected to allow for the distinction between an outlier and a true representation of groundwater quality at the monitoring point. If re-sampling is conducted, this sample will be collected within 90 days following outlier identification. If the confirmatory sample indicates the original result as an outlier, it will be reported as such.

2.5 Trend Analysis

Statistical analyses supporting the lack of trend are a fundamental step to confirm the assumption that groundwater quality values are stationary or constant over time at a CCR unit. These analyses allow for evaluation of variation in the background and compliance data for each constituent over time. A statistically significant increasing trend in background data could indicate an existing release from the CCR unit or alternate source, requiring further investigation. In addition, statistically significant trending background data can result in increased standard deviation and, therefore, greater prediction or control limits. Consequently, the increased prediction or control limit will have less power or ability to identify a release from the CCR unit.

A linear regression, coupled with a t-test for slope significance at a 95 percent confidence level (0.05 significance level), may be used on datasets for each constituent with few non-detects and a normally distributed variance of the mean to evaluate time trends. The Theil-Sen trend line, coupled with the Mann-Kendall test for slope significance at a 95 percent confidence level (0.05 significance level), will be used for datasets with frequent non-detects or non-normal variance. Similarly, trend analyses could also be used on compliance data to evaluate a possible release from the CCR unit.

2.6 Spatial Variation

Spatial trends and/or variation between background wells could indicate an existing release from a CCR unit. If the spatial variability is not due to an existing release, intrawell comparisons in compliance wells may be used to account for spatial variability and monitor for a future release. However, the CCR unit being monitored was placed into service prior to the start of groundwater monitoring and it is unknown whether a previous release has occurred. Accordingly, intrawell comparisons in compliance wells cannot be used to determine the occurrence of a future release. Interwell comparisons between compliance wells and background wells will be used.

2.7 Temporal Variation

Time series plots can be used to identify temporal dependence. Potentially significant temporal components of variability can be identified by graphing single constituent data from multiple wells together on a time series plot. With temporal dependence, the time series plot as a pattern of parallel traces, in which the individual wells will tend to rise and fall together across the sequence of sampling dates. Time series plots can be helpful by plotting multiple constituents over time for the same well, or averaging values for each constituent across wells on each sampling event and then plotting the averages over time. In either case, the plots can signify whether the general concentration pattern over time is simultaneously observed for different constituents. If so, it may indicate that a group of constituents is highly correlated in groundwater or that the same artifacts of sampling and/or lab analysis impacted the results of several monitoring parameters.

Hydrologic factors such as drought, recharge patterns or regular (*e.g.,* seasonal) water table fluctuations may be responsible for the temporal variation. In these cases, it may be useful to test for the presence of a significant temporal effect by first constructing a parallel time series plot and then running a formal one-way analysis of variance (ANOVA) ($\alpha = 0.05$) for temporal effects. A one-way ANOVA for temporal effects considers multiple well data sets for individual sampling events or seasons as the relevant statistical factor. If event-specific analytical differences or seasonality appear to be an important temporal factor, the one-way ANOVA for temporal effects can be used to formally identify seasonality, parallel trends, or changes in lab performance that affect other temporal effects. The one-way ANOVA for temporal effects assumes that the data groups are normally distributed with constant variance. It is also assumed that for each of a series of background wells, measurements are collected at each well on sampling events or dates common to all the wells. Results of the ANOVA can also be used to create temporally stationary residuals, where the temporal effect has been 'subtracted from' the original measurements. These stationary residuals may be used to replace the original data in subsequent statistical testing.

If the data cannot be normalized, a similar test for a temporal or seasonal effect can be performed using the Kruskal-Wallis test ($\alpha = 0.05$). Each sampling event should be treated as a separate 'well,' while each well is treated as a separate 'sampling event.' In this case, no residuals can be computed since the Kruskal-Wallis test employs ranks of the data rather than the measurements themselves.

Where both spatial and temporal variation occur, two-way ANOVA can be considered where both well location and sampling event/season are treated as statistical factors. This procedure is described in Davis (1994).

2.8 Updating Background

Updating the background dataset periodically by adding recent results to an existing background dataset can improve the statistical power and accuracy of the statistical analysis, especially for non-parametric prediction intervals. The *Unified Guidance* recommends updating statistical limits (background) when at least four to eight new measurements (every 1 to 2 years under a quarterly monitoring program), are available for comparison to historical data. Professional judgement will be used to evaluate whether any background data appear to be affected by a release and need to be excluded from a background update. A t-test for equal means (if normal data distribution) or appropriate non-parametric test (if non-normal data distribution) such as a Mann-Whitney (or Wilcoxon) rank-sum or box-whisker plots, will be conducted to evaluate whether the two groups of background sample populations are statistically different prior to updating any background datasets. A 0.05 significance level will be utilized when evaluating the two populations, with the null hypothesis that they are equivalent. In addition, time series graphs or other trend evaluation statistics will be conducted on the new background dataset to verify the absence of a release or changing groundwater quality. If the tests indicate that there are no statistical differences between the two background populations, the new data will be combined with the existing dataset. If the two populations are found to be different, the data will be reviewed to evaluate the cause of the difference. If the differences appear to be caused by a release (if the new data are significantly higher, or lower for pH), then the previous background dataset may continue to be used. Furthermore, verified outliers will not be added to an existing background dataset. In accordance with the *Unified Guidance*, continual background updates will not be conducted due to the lack of sufficient samples for a statistical comparison.

3. COMPLIANCE MONITORING

Compliance monitoring is designed to monitor groundwater for evidence of a release by comparing Part 845 constituents in compliance wells to both background concentrations and the GWPS. Compliance Monitoring will begin the 1st quarter following approval of this Groundwater Monitoring Plan and issuance of the Operating Permit. The selected Compliance Monitoring statistical method used to compare compliance groundwater quality data for each constituent to the GWPS will provide for adequate statistical power, error levels and individual test false positive rates, and be appropriate for the distribution and detection frequency of the background dataset. Statistical power is the ability of a statistical test to detect a true exceedance.

In accordance with 35 I.A.C. § 845.610(b)(3)(D), compliance monitoring statistical analyses will be completed and submitted to IEPA within 60 days after completion of sampling.

3.1 GWPS Establishment and Exceedance Determination

In accordance with 35 I.A.C. § 845.600(a), the GWPS will be the constituent concentrations specified in 35 I.A.C. § 845.600(a)(1) except for when the background concentration is greater, or no concentration is specified (*i.e.,* for calcium and turbidity), in which case the GWPS will be the background concentration. The GWPS based on background concentration will be calculated using a parametric upper tolerance limit (UTL), a parametric UPL for a future mean, or a non-parametric UPL for a future median.

Statistical calculations that will be utilized in Compliance Monitoring procedures are summarized in **Table A** below and listed in **Sections 3.1.1** through **3.1.7**. Depending on the distribution of the data and the percentage of non-detects, it may be more appropriate to use a parametric model over a non-parametric model. As necessary, other techniques as mentioned in the *Unified Guidance* and/or new methods will be implemented.

Table A. Statistical Calculations Used in Compliance Monitoring Procedures

<table>
<tr><th colspan="8">Compliance Monitoring</th></tr>
<tr><th rowspan="2">Significant Trend?</th><th colspan="3">Background Data</th><th colspan="4">Compliance Data</th></tr>
<tr><th>Percent Non-Detects</th><th>Distribution</th><th>GWPS Determination</th><th>Percent Non-Detects</th><th>Distribution</th><th>Method to Determine Exceedance</th></tr>
<tr><td rowspan="7">No</td><td rowspan="4">0 ≤ 50</td><td rowspan="4">Normal</td><td rowspan="4">35 I.A.C § 845.600(a)(1) constituent concentration or The Upper Tolerance Limit</td><td>≤75</td><td>Normal</td><td>Parametric Lower Confidence Limit around a Normal Mean</td></tr>
<tr><td>≤75</td><td>Log-Normal</td><td>Parametric Lower Confidence Limit around a Lognormal Geometric Mean</td></tr>
<tr><td>NA</td><td>Non-Normal</td><td rowspan="2">Non-Parametric Lower Confidence Limit around a Median</td></tr>
<tr><td>>75</td><td>Unknown/ Cannot be determined</td></tr>
<tr><td>50 ≤ 70</td><td>Normal</td><td>The Upper Prediction Limit for a Future Mean</td><td>NA</td><td>NA</td><td>Future mean</td></tr>
<tr><td>>70</td><td>Non-Normal</td><td>Upper Prediction Limit for a Future Median</td><td>NA</td><td>NA</td><td>Future median</td></tr>
<tr><td>100</td><td>Non-Normal</td><td>Double Quantification Rule</td><td>NA</td><td>NA</td><td>Individual Retesting Values</td></tr>
<tr><td rowspan="2">Yes</td><td>0 ≤ 50</td><td>Normal</td><td>UCL of Confidence Band around Linear Regression</td><td>≤75</td><td>Residuals after subtracting trend are normal, equal variance</td><td>Lower Limit from Confidence Band around Linear Regression</td></tr>
<tr><td>50 ≤ 100</td><td>Non-Normal</td><td>UCL of Confidence Band around Thiel-Sen trend line</td><td>≤75</td><td>Residuals not normal</td><td>Lower Limit from Confidence Band around Thiel-Sen</td></tr>
</table>

3.1.1 The Upper Tolerance Limit

The UTL will be used to calculate the GWPS when pooled background data are normally distributed, with a non-detect frequency of 50 percent or less. When non-detect frequency is 15 percent or less, half the RL will be substituted for non-detects. The *Unified Guidance* recommends 95 percent confidence level and 95 percent coverage (95/95 tolerance interval).

- When non-detect frequency is 15 percent or less, half the RL will be substituted for non-detects (simple substitution), and the normal mean and standard deviation will be calculated.

- The Kaplan-Meier or the ROS method will be used when the detection frequency is between 15 percent and 50 percent. The Kaplan-Meier method assesses the linearity of a censored probability plot to determine whether the background sample can be approximately normalized. If so, then the Kaplan-Meier method will be used to compute estimates of the mean and standard deviation adjusted for the presence of left-censored values. The Kaplan-Meier or ROS estimate of the mean and standard deviation will be substituted for the sample mean and standard deviation.
- If background normality cannot be achieved, non-parametric UTLs will not be calculated until a minimum of 60 background samples have been collected (to achieve 95 percent coverage).

The parametric UTL on a future mean will be calculated from the background dataset as follows:

$$UTL = \overline{x} + \kappa\,(n, \gamma, \alpha - 1) \cdot s$$

$\overline{x}$ = background sample mean

s = background sample standard deviation

$\kappa\,(n, \gamma, \alpha - 1)$ = one-sided normal tolerance factor based on the chosen coverage (γ) and confidence level (α -1) and the size of the background dataset (n). Values are tabulated in Table 17-3 in Appendix D of the *Unified Guidance*. If exact values are not provided, then κ values can be estimated by linear interpolation.

If the UTL is constructed on the logarithms of original observations to achieve normality, where $\overline{y}$ and s_y are the log-mean and log-standard deviation, the limit will be exponentiated for back-transformation to the concentration scale as follows:

$$UTL = \exp\left[\overline{y} + \kappa\,(n, \gamma, \alpha - 1) \cdot s_y\right]$$

$\overline{y}$ = background sample log-mean

s_y = background sample log-standard deviation

When the GWPS is based on the 35 I.A.C. § 845.600(a)(1) constituent concentrations or a UTL derived from the background dataset, an exceedance in compliance wells relative to the GWPS will be evaluated using confidence intervals. A confidence interval defines the upper and lower bound of the true mean of a constituent concentration in groundwater within a specified confidence range.

- Non-detects in compliance data will be handled similarly to upgradient analyses, with half the RL substituted for non-detects when the frequency is 15 percent or less.
- The Kaplan-Meier, or the ROS method, will be used when the detection frequency is between 15 percent and 50 percent to compute estimates of the mean and standard deviation adjusted for the presence of left-censored values. These estimates will then be substituted for the sample mean and standard deviation.

Once the GWPS is established for background data using the UTL, either parametric or non-parametric confidence intervals will be computed for each constituent in compliance wells to identify GWPS exceedances.

3.1.2 Parametric Confidence Intervals around a Mean

If compliance data are approximately normal, one-sided parametric confidence intervals around a sample mean will be constructed for each constituent and well pair. The lower confidence limit (LCL) will be calculated as:

$$LCL_{1-\alpha} = \overline{x} - t_{1-\alpha,n-1} \cdot \frac{s}{\sqrt{n}}$$

$\overline{x}$ = compliance sample mean

s = compliance sample standard deviation

n = compliance sample size

$t_{1-\alpha,n-1}$ = obtained from a Student's t-table with (n–1) degrees of freedom (Table 16-1 in Appendix D of the *Unified Guidance*)

The chosen t value will aim to achieve both a low false-positive rate, and high statistical power. Minimum ɑ values are tabulated in Table 22-2 of Appendix D of the *Unified Guidance*. The selected minimum ɑ value, from which the t value will be derived, will have at least 80 percent power (1-β = 0.8) when the underlying mean concentration is twice the GWPS.

If compliance data are distributed lognormally, the LCL will be computed around the lognormal geometric mean as:

$$LCL_{1-\alpha} = \exp\left(\overline{y} - t_{1-\alpha,n-1} \cdot \frac{s_y}{\sqrt{n}}\right)$$

$\overline{y}$ = compliance sample log-mean

s_y = compliance sample log-standard deviation

3.1.3 Non-Parametric Confidence Intervals around a Median

Non-parametric confidence intervals around the median will be computed if the compliance data contain greater than 50 percent non-detects or are not normally distributed. The mathematical algorithm used to construct non-parametric confidence intervals is based on the probability (*P*) that any randomly selected measurement in a sample of n concentration measurements will be less than an unknown *P* x 100th percentile of interest (where *P* is between 0 and 1). Then the probability that the measurement will exceed the *P* x 100th percentile is (1–*P*). The number of sample values falling below the *P* x 100th percentile out of a set of n should follow a binomial distribution with parameters n and success probability *P*, where 'success' is defined as the event that a sample measurement is below the *P* x 100th percentile. The probability that the interval formed by a given pair of order statistics will contain the percentile of interest will then be determined by a cumulative binomial distribution *Bin(x;n,p)*, representing the probability of *x* or fewer successes occurring in *n* trials with success probability p. *P* will be set to 0.50 for an interval around the median.

The sample size n will be ordered from least to greatest. Given *P* = 0.50, candidate interval endpoints will be chosen by ordered data values with ranks close to the product of (n+1) x 0.50. If the result of (n+1) x 0.50 is a fraction (for even-numbered sample sizes), the rank values immediately above and below will be selected as possible candidate endpoints. If the result of (n+1) x 0.50 is an integer (for odd-numbered sample sizes), one will be added to and subtracted from the result to get the upper and lower candidate endpoints. The ranks of the endpoints will be denoted L* and U*. For a one-sided LCL, the confidence level associated with endpoint L* will be computed as:

$$1 - \alpha = Bin(L^* - 1; n, 0.50) = \sum_{x=L^*}^{n} \binom{n}{x} \left(\frac{1}{2}\right)^n$$

If the candidate endpoint(s) do not achieve the desired confidence level, new candidate endpoints (L*–1) and (U*+1) and achieved confidence levels will be calculated. If one candidate endpoint equals the data minimum or maximum, only the rank of the other endpoint will be changed. Achievable confidence levels are tabulated using these equations in Table 21-11 in Appendix D of the *Unified Guidance*.

Both parametric and non-parametric confidence limits will then be compared to the GWPS. The CCR unit is considered to be in compliance if the LCL is equal to or lower than the GWPS for all detected constituents at all compliance monitoring wells. A GWPS exceedance is determined if the LCL exceeds the GWPS.

3.1.4 The Upper Prediction Limit for a Future Mean

The parametric UPL for a future mean will be used to calculate the GWPS if the pooled background data contain 50 to 70 percent non-detects and normality can be achieved. The Kaplan-Meier or ROS methods will be used to estimate the mean and standard deviation. The non-parametric UPL for a future median will be calculated as the GWPS if background samples cannot be normalized or contain greater than 70 percent non-detects. The parametric UPL for a future mean will be calculated from the background dataset at follows:

$$UPL_{1-\alpha} = \overline{x} + \kappa s$$

$\overline{x}$ = background sample mean

s = background standard deviation

κ = multiplier based on the order (p) of the future mean to be predicted, the number of compliance wells to be tested (w), the background sample size (n) the number (c) of constituents of concern (COCs), the "1-of-m" retesting scheme, and the evaluation schedule (annual, semi-annual, quarterly). Values are tabulated in 19-5 to 19-9 in Appendix D of the *Unified Guidance*.

The mean of order p will be computed for each well and compared against the UPL. For any compliance point mean that exceeds the limit, p additional resamples may be collected at that well for a 1-of-2 retesting scheme. Resample means will then be compared to the UPL. A GWPS exceedance has been deemed to occur at a compliance well when the initial mean and all resample means exceed the UPL.

3.1.5 The Non-Parametric Upper Prediction Limit for a Future Median

The non-parametric UPL for a future median will be used to calculate the GWPS if the pooled background data contain greater than 70 percent non-detects and normality cannot be achieved. Non-parametric methods assume that the data does not have an underlying distribution. To calculate the non-parametric UPL on a future value, the target per-constituent false positive rate (a_{const}) will be determined as follows:

$$\alpha_{const} = 1 - (1 - \alpha)^{1/c}$$

α = the site-wide false positive rate (SWFPR) of 0.10 recommended by the *Unified Guidance*

c = the number of monitoring constituents

The number of yearly statistical evaluation (nE) will be multiplied by the number of compliance wells (w) to determine the look-up table entry, w*. The background sample size (n) and w* will be used to select an achievable per-constituent false positive rate value in Table 19-24 of Appendix D in the *Unified Guidance*. The chosen achievable per-constituent false positive rate value will determine the type of non-parametric prediction limit (maximum or 2nd highest value in background) and a retesting scheme for a future median. The background data will be sorted in ascending order, and the upper prediction limit will be set to the appropriate order statistic previously determined by the achievable per-constituent false positive rate value in Table 19-24. If all constituent measurements in a background sample are non-detect, the Double Quantification rule will be used. The use of the Double Quantification rule in Compliance Monitoring will only be applicable if the RL is above the 35 I.A.C. § 845.600(a)(1) constituent concentration or a constituent concentration is not specified in § 845.600(a)(1). This scenario is highly unlikely. The constituent will also be removed from calculations identifying the target false positive rate.

Two initial measurements per compliance well will be collected. If both do not exceed the upper prediction limit, a third initial measurement will not be collected since the median of order 3 will also not exceed the limit. If both exceed the prediction limit, a third initial measurement will not be collected since the median will also exceed the limit. If one initial measurement is above and one below the limit, a third initial observation may be collected to determine the position of the median relative to the UPL. Up to three resamples will be collected in order to assess the resample median. In all cases, if two or more of the compliance point observations are non-detect, the median will be set equal to the RL. The median value for each compliance well will be compared to the UPL. For the 1-of-2 retesting scheme, if any compliance point median exceeds the limit, up to three additional resamples will may be collected from that well. The resample median will be computed and compared to the UPL. A GWPS exceedance has been deemed to occur at a compliance well when either the initial median, or both the initial median and resample median exceed the UPL.

If the concentrations of detected constituents are below the established GWPS, Compliance Monitoring will continue.

3.1.6 Parametric Linear Regression and Confidence Band

If the t-test detects a significant trend in the parametric linear regression line using either background or compliance data for a particular constituent, confidence bands accounting for trends will be constructed to account for the trend-induced variation. If this is not accounted for, a wider confidence interval will inevitably be calculated for a given confidence level and sample size (n). A wider confidence interval will result in less statistical power, or ability to demonstrate an exceedance or return to compliance. When a linear trend line has been estimated, a series of confidence intervals is estimated at each point along the trend. This creates a simultaneous confidence band that follows the trend line. As the underlying population mean increases or decreases, the confidence band does also to reflect this change at that point in time.

Linear regression will be used when background or compliance data are approximately normally distributed, with a constant sample variance around the mean, and the frequency of non-detects is low. The linear regression of concentration against sampling date (time) will be computed as follows:

$$\hat{b} = \sum_{i=1}^{n} (t_i - \bar{t}) \cdot x_i / (n-1) \cdot s_t^2$$

x_i = i^{th} concentration value and

t_i = i^{th} sampling date

$\bar{t}$ = sampling mean date

s_t^2 = variance of the sampling dates

This estimate leads to the following regression equation:

$$\hat{x} = \bar{x} + \hat{b} \cdot (\mathrm{t} - \bar{t})$$

$\bar{x}$ = mean concentration level

$\hat{x}$ = estimated mean concentration at time t

The regression residuals will also be computed at each sampling event to ensure uniformity and lack of significant skewness. Regression residuals will be computed at each sampling event as follows:

$$r_i = x_i - \hat{x}_i$$

The estimated variance around the regression line, or mean squared error (MSE) will be computed as follows:

$$s_e^2 = \frac{1}{n-2} \sum_{i=1}^{n} r_i^2$$

The confidence intervals around a linear regression trend line given confidence level (1-ɑ) and a point in time (t_0), will be computed as follows:

$$LCL_{1-\alpha} = \hat{x}_0 - \sqrt{2s_e^2 \cdot F_{1-2\alpha,2,\mathrm{n}-1} \cdot \left[\frac{1}{n} + \frac{(t_0 - \bar{t})^2}{(n-1) \cdot s_t^2}\right]}$$

$$UCL_{1-\alpha} = \hat{x}_0 - \sqrt{2s_e^2 \cdot F_{1-2\alpha,2,\mathrm{n}-2} \cdot \left[\frac{1}{n} + \frac{(t_0 - \bar{t})^2}{(n-1) \cdot s_t^2}\right]}$$

$\hat{x}_0$ = estimated mean concentration from the regression equation at time t_0

$F_{1-2\alpha,2,\mathrm{n}-2}$ = upper $(1\text{-}2\alpha)^{th}$ percentage point from an F-distribution with 2 and (n-2) degrees of freedom

For background data, the UCL around the linear regression line will be used as the GWPS for the trending constituent. For compliance data, confidence bands around the linear regression line will be compared to the GWPS. The CCR unit is considered to be in compliance if the LCL is equal to or lower than the GWPS for all detected constituents at all compliance wells. A GWPS exceedance is determined when the LCL based on the trend line first exceeds the GWPS.

3.1.7 Non-Parametric Thiel-Sen Trend Line and Confidence Band

If the Mann-Kendall test detects a significant trend in the non-parametric Thiel-Sen line using either background or compliance data for a particular constituent, confidence bands accounting for trends will be constructed to account for the trend-induced variation. The Thiel-Sen trend line will be used as a non-parametric alternative to linear regression when trend residuals cannot be normalized or if there are a higher percentage of non-detects in either background or compliance data. The Thiel-Sen trend line estimates the median concentration over time by combining the median pairwise slope with the median concentration value and the median sample date. To compute the Thiel-Sen line, the data will first be ordered by sampling event x1, x2, xn. All possible distinct pairs of measurements (x_i, x_j) for j > i will be considered and the simple pairwise slope estimate will be computed for each pair as follows:

$$m_{ij} = (x_j - x_i)/(j - i)$$

With a sample size of n, there will be a total of N = n(n-1)/2 pairwise estimates (m_{ij}). If a given observation is a non-detect, half the RL will be substituted. The N pairwise slope estimates (m_{ij}) will be ordered from least to greatest (renamed m(1), m(2),..m(N)). The Thiel-Sen estimate of slope (Q) will be calculated as the median value of the list depending on whether N is even or odd as follows:

$$Q = \begin{cases} m_{([N+1]/2)} \; if\ N\ is\ odd \\ (m_{(N/2)} + m_{([N+2]/2)})/2 \; if\ N\ is\ even \end{cases}$$

The sample concentration magnitude will be ordered from least to greatest, x(1), x(2), to x(n) and the median concentration will be calculated as follows:

$$\tilde{x} = \begin{cases} x_{([n+1]/2)} \; if\ n\ is\ odd \\ (x_{(n/2)} + x_{([n+2]/2)})/2 \; if\ n\ is\ even \end{cases}$$

The median sampling date ($\tilde{t}$) with ordered times (t(1), t(2), to t(n)) will also be determined in this way. The Thiel-Sen trend line will then be computed for an estimate at any time (t) of the expected median concentration (x) as follows:

$$x = \tilde{x} + Q \cdot (\mathrm{t} - \tilde{t}) = (\tilde{x} - Q \cdot \tilde{t}) + Q \cdot \mathrm{t}$$

To construct a confidence band around the Thiel-Sen line, sample pairs (ti, xi) will be formed with a sample date (ti) and the concentration measurement from that date (xi). Bootstrap samples (B) will be formed by repeatedly sampling n pairs at random with replacement from the original sample pairs. This will be repeated 500 times. For each bootstrap sample, a Thiel-Sen trend line will be constructed using the equation above. A series of equally spaced time points (tj) will be identified along the range of sampling dates represented in the original sample, j =1 to m. The Thiel-Sen trend line associated with each bootstrap replicate will be used to compute an estimated concentration ($\hat{x}_j^B$). An LCL will be constructed for the lower α^{th} percentile $\hat{x}_j^{[\alpha]}$ from the distribution of estimated concentrations at each time point (tj). For a UCL, compute the upper $(1-\alpha)^{th}$ percentile, $\hat{x}_j^{[1-\alpha]}$ at each time point (tj).

For background data, the UCL around the Thiel-Sen trend line will be used as the GWPS for the trending constituent. For compliance data, confidence bands around the Thiel-Sen trend line will be compared to the GWPS. The CCR unit is considered to be in compliance if the LCL is equal to or lower than the GWPS for all detected constituents at all compliance wells. A GWPS exceedance is confirmed when the LCL based on the trend line first exceeds the GWPS.

3.2 Determination of Statistically Significant Increases over Background

In accordance with 35 I.A.C. §§ 845.610(b)(3)(B) and 845.640(h), individual monitoring event concentrations for each constituent detected in the compliance monitoring wells during compliance monitoring sampling events will be compared to the background concentration as determined by the methods described above. An exceedance of the background concentration for any constituent measured at any compliance monitoring well, or constituent detection if not detected in the background samples, constitutes a Statistically Significant Increase (SSI). An exception to this method is pH, where two-sided (upper and lower) tolerance limits are established from the distribution of the background groundwater quality data. An exceedance of either the UTL or lower tolerance limit (LTL) would constitute an SSI for pH.

4. REFERENCES

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United States Environmental Protection Agency (USEPA), 2009. *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities: Unified Guidance*. EPA 530-R-09-007. March 2009.

Intended for
Kincaid Generation, LLC

Date
October 25, 2021

Project No.
1940100806-007

HYDROGEOLOGIC SITE CHARACTERIZATION REPORT

ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT ASH POND

Project Name	**Kincaid Power Plant Ash Pond**
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APPENDICES

ACRONYMS AND ABBREVIATIONS

°F	degrees Fahrenheit
§	Section
35 I.A.C.	Title 35 of the Illinois Administrative Code
40 C.F.R.	Title 40 of the Code of Federal Regulations
AP	Kincaid Ash Pond
BCU	bedrock confining unit
bgs	below ground surface
CEC	Civil & Environmental Consultants, Inc.
CCR	coal combustion residuals
cm/s	centimeters per second
CPT	cone penetrometer test
ESRI	Environmental Systems Research Institute
ft/day	feet per day
ft/ft	feet per feet
g	horizontal acceleration
GMP	Groundwater Monitoring Plan
GWPS	Groundwater Protection Standard
HCR	Hydrogeologic Site Characterization Report
HUC	Hydrologic Unit Code
ID	identification
IDNR	Illinois Department of Natural Resources
IEPA	Illinois Environmental Protection Agency
ILWATER	Illinois Water and Related Wells
ISAS	Illinois State Archaeological Survey
ISGS	Illinois State Geological Survey
ISWS	Illinois State Water Survey
KPP	Kincaid Power Plant
LCU	lower confining unit
mg/L	milligrams per liter
msl	above mean sea level
NAVD88	North American Vertical Datum of 1988
NID	National Inventory of Dams
No.	Number
NRT/OBG	Natural Resource Technology, Inc., an OBG Company
Part 845	Residuals in Surface Impoundments: Title 35 of the Illinois Administrative Code § 845
pCi/L	picocuries per liter
pcf	Pound per cubic foot
PMP	Potential Migration Pathway
Ramboll	Ramboll Americas Engineering Solutions, Inc.
SI	Surface Impoundment
SSURGO	Soil Survey Geographic
SU	standard unit

TDS	total dissolved solids
USCS	Unified Soil Classification System
USCU	upper semi-confining unit
USFWS	United States Fish and Wildfire Service
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
Vandalia Till	Vandalia Till Member of the Glasford Formation

EXECUTIVE SUMMARY

This Hydrogeologic Site Characterization Report (HCR) for the Kincaid Ash Pond (AP) expands upon the hydrogeology and groundwater quality data presented in previous hydrogeologic investigation reports prepared for the AP (Civil & Environmental Consultants, Inc. [CEC], 2010; Cabeno Field Services, 2013). This report has been assembled to satisfy the information and analysis requirements of Title 35 of the Illinois Administrative Code (35 I.A.C.) Section (§) 845.620 as summarized in **Table ES-1**. The conceptual site model includes hydrogeologic and groundwater quality data specific to the AP, which has been collected between 2010 and 2021. The AP is part of the Kincaid Power Plant (KPP) which is located approximately four miles west of the Village of Kincaid in Christian County, Illinois.

The KPP operates as a coal-fired power plant and has a single coal combustion residuals (CCR) management unit, the AP (Vistra Identification [ID] Number [No.] 141, Illinois Environmental Protection Agency [IEPA] ID No. W0218140002-01, and National Inventory of Dams [NID] No. IL50706. The Kincaid Ash Pond is a 172-acre, unlined surface impoundment (SI) used to manage CCR and non-CCR waste streams at the KPP. Its total storage capacity is approximately 3,560 acre-feet.

The AP is located between two lobes of Sangchris Lake (**Figure 1-1**), which was formed in 1964 by damming Clear Creek, a tributary to the south fork of the Sangamon River. Sangchris Lake was created to provide a source of cooling water for the KPP. The western lobe of Sangchris Lake forms part of the western and the northern border of the AP and is connected to an intake flume for the KPP on the western edge of the AP. A discharge flume from the KPP forms the southern border of Kincaid Ash Pond and is connected to the eastern lobe of Sangchris Lake. The KPP property is surrounded by the lobes of Sangchris Lake and Sangchris Lake State Park to the north and east, and a combination of undeveloped land and surface support facilities associated with the former Peabody Coal Company #10 mine to the south and west.

In addition to the CCR, there are two principal types of unlithified material present above the bedrock in the vicinity of the AP. Underlying the constructed AP are the silts and clays of the Cahokia Formation and sandy, compact till of the Vandalia Till Member of the Glasford Formation (Vandalia Till). The Cahokia Formation contains thin layers of interbedded sand, most of which are laterally discontinuous, but a thin bed of sand was observed at the bottom of the Cahokia Formation in the majority of soil borings advanced near the AP. This sand unit comprises the uppermost aquifer. Bedrock beneath the AP consists of the Pennsylvanian-age Bond Formation, comprised mainly of limestone with lesser amounts of shale and sandstone. Flow of groundwater from the KPP to Sangchris Lake through the uppermost aquifer is the primary pathway for contaminant migration.

The unlithified materials were categorized into four hydrostratigraphic units in this report presented below in descending order:

- **CCR**: Saturated CCR, consisting primarily of bottom ash, and boiler slag.
- **Upper Semi-Confining Unit (USCU)**: Low-permeability clay with some silt and minor sand, silt layers, and occasional discontinuous sand lenses. Includes the lithologic layers identified as the Cahokia Formation. Sand lenses with higher permeability within the USCU have a

higher probability of contaminant transport and these materials are referred to as the potential migration pathways (PMP).

- **Uppermost Aquifer**: Thin (generally less than 4 feet), moderate permeability sand, silty sand, and clayey sand and gravel units, which include the clays and silts of the Upper Cahokia Formation, where saturated, and the thin, moderate permeability sands and gravels of the Lower Cahokia Formation, which, at some locations, also includes the interface with the Vandalia Till.
- **Lower Confining Unit (LCU):** Underlying the aquifer unit is dense grey clay till; this till is easily distinguished during investigation by difficult drilling and/or refusal and is apparent on boring logs. The till was encountered at elevations ranging from approximately 570 to 583.5 feet NAVD88. The LCU is comprised of low permeability silt and clay with minor sand, silt layers, and occasional discontinuous sand lenses (more frequently near the top of the unit). Includes the lithologic layers identified as the Vandalia Till.

The water-bearing layer referred to as the bedrock confining unit (BCU) is composed of interbedded shale and limestone of the Pennsylvanian Age Bond Formation that underlie the Vandalia Till, and underlies the entire AP.

Groundwater flow in the uppermost aquifer is to the northwest toward Sangchris Lake. Groundwater elevations are primarily controlled by the surface water levels in the lobes of Sangchris Lake and the water level within the AP. An apparent groundwater divide trending southwest to northeast has been observed beneath the AP.

Part 845 parameters were monitored in the uppermost aquifer monitoring wells at the AP as part of the Title 40 of the Code of Federal Regulations (40 C.F.R.) § 257 and IEPA groundwater monitoring programs between 2015 and 2021. These data were supplemented with installation and sampling of additional locations installed in 2021. The results indicate the following parameters were detected at concentrations greater than the applicable 35 I.A.C. § 845.600 groundwater protection standards (GWPSs) and are considered potential exceedances:

- Arsenic, cobalt, lead, pH, sulfate, total dissolved solids (TDS), and radium 226 and 228 combined were detected in the USCU wells (not including potential migration pathway [PMP] wells) downgradient of the AP.
- Arsenic, barium, beryllium, boron, chromium, cobalt, lead, lithium, pH, sulfate, thallium, TDS, and radium 226 and 228 combined were detected in PMP wells downgradient of the AP.
- Boron, chloride, cobalt, pH, sulfate, thallium, TDS were detected in the uppermost aquifer wells downgradient of the AP.
- Chloride and pH were detected in the bedrock wells downgradient of the AP.

Groundwater monitoring results were compared to the applicable 35 I.A.C. § 845.600 GWPSs to determine potential exceedances. Potential exceedances include results reported during the background groundwater monitoring or prior period that are greater than the GWPS. 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 the statistical methodologies proposed in the groundwater monitoring plan (GMP) provided in the Operating Permit application. Exceedances will be determined following IEPA approval of the GMP.

TABLE ES-1. PART 845 REQUIREMENTS CHECKLIST

HYDROGEOLOGIC SITE CHARACTERIZATION REPORT

KINCAID POWER PLANT

ASH POND

KINCAID, ILLINOIS

Part 845 Reference	**Individual Part 845 Components Reviewed for Completeness**	**Location of Information in HCR**
845.620(b)	**The hydrogeologic site characterization shall include but not be limited to the following:**	--
845.620(b)(1)	Geologic well logs/boring logs;	Table 3-1 Figure 3-1 Appendix C
845.620(b)(2)	Climatic aspects of the site, including seasonal and temporal fluctuations in groundwater flow;	Sections 3.2.4 & 3.3.1 Figures 3-3, 3-4 & 3-5
845.620(b)(3)	Identification of nearby surface water bodies and drinking water intakes;	Sections 3.3.2 & 5.2 Appendix B
845.620(b)(4)	Identification of nearby pumping wells and associated uses of the groundwater;	Section 5.1 Appendix B
845.620(b)(5)	Identification of nearby dedicated nature preserves;	Section 5.3 Appendix B
845.620(b)(6)	Geologic setting;	Section 2.4 & 2.5 Figures 2-2 through 2-4
845.620(b)(7)	Structural characteristics;	Section 2.4.3 Figure 2-4
845.620(b)(8)	Geologic cross-sections;	Figures 2-7 through 2-11
845.620(b)(9)	Soil characteristics;	Section 2.3 Figure 2-2 Tables 2-1 & 2-4
845.620(b)(10)	Identification of confining layers;	Section 3.2.1

TABLE ES-1. PART 845 REQUIREMENTS CHECKLIST
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Part 845 Reference	Individual Part 845 Components Reviewed for Completeness	Location of Information in HCR
845.620(b)(11)	Identification of potential migration pathways;	Sections 3.2.1 & 3.2.3
845.620(b)(12)	Groundwater quality data;	Section 4.2 Table 4-1 & 4.2
845.620(b)(13)	Vertical and horizontal extent of the geologic layers to a minimum depth of 100 feet below land surface, including lithology and stratigraphy;	Section 2.5 Figures 2-7 through 2-11 Appendix C
845.620(b)(14)	A map displaying any known underground mines beneath a CCR surface impoundment;	Section 2.4.5 Appendix B
845.620(b)(15)	Chemical and physical properties of the geologic layers to a minimum depth of 100 feet below land surface;	Sections 2.5 & 3.2 Tables 2-1, 2-2, 2-4 Appendix D
845.620(b)(16)	Hydraulic characteristics of the geologic layers identified as migration pathways and geologic layers that limit migration, including:	Sections 3.2.4.1, 3.2.5, & 3.2.6 Tables 3-2 to 3-4 Appendices D & E
845.620(b)(16)(A)	water table depth;	Section 3.2.4 Figures 3-3 to 3-5 Appendix F
845.620(b)(16)(B)	hydraulic conductivities;	Section 3.2.5 Tables 2-1 and 3-3 Appendices D & E
845.620(b)(16)(C)	effective and total porosities;	Section 2.5.1 Table 2-1
845.620(b)(16)(D)	direction and velocity of groundwater flow; and	Sections 3.2.4 & 3.2.6 Tables 3-2 & 3-4 Figures 3-3 through 3-5 Appendix E

TABLE ES-1. PART 845 REQUIREMENTS CHECKLIST
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Part 845 Reference	Individual Part 845 Components Reviewed for Completeness	Location of Information in HCR
845.620(b)(16)(E)	map of the potentiometric surface;	Figures 3-3 through 3-5
845.620(b)(17)	Groundwater classification pursuant to 35 I.A.C. § 620; and	Section 3.2.7

Notes: [O: LDC 06/15/21, U: LDC 08/19/21; C: EJT 08/19/21; U: LDC 09/14/21; C: EJT 09/16/21]

-- = reference to main regulation
35 I.A.C. § 620 = Title 35 of the Illinois Administrative Code, Part 620
HCR = Hydrogeologic Site Characterization Report

1. INTRODUCTION

1.1 Overview

In accordance with requirements of the Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments: 35 I.A.C. § 845 (Part 845) (IEPA, 2021), Ramboll Americas Engineering Solutions, Inc. (Ramboll) has prepared this HCR on behalf of KPP, operated by Kincaid Generation, LLC, to provide content required by 35 I.A.C. § 845.620(b) (Hydrogeologic Site Characterization) for the CCR Unit referred to as the AP (see **Figure 1-1**).

1.2 Part 845 Description

CCR is commonly referred to as coal ash, and CCR SIs are commonly referred to as coal ash ponds. Part 845 contains comprehensive rules for the design, construction, operation, corrective action, closure, and post closure care of these SIs. This rule includes GWPSs applicable at the waste boundary at each CCR SI and requires each owner or operator to monitor groundwater. IEPA's rule includes a permitting program as well as all federal standards for CCR SIs promulgated by the United States Environmental Protection Agency (USEPA). In addition, the rules include procedures for public participation, closure alternatives analyses, closure prioritization, and provides access to records via public website. The rules also include financial assurance requirements for CCR SIs.

A checklist summarizing the specific requirements of 35 I.A.C. § 845.620 is included in **Table ES-1**. The table provides references to sections, tables, and figures included in this document to locate the information that meets specific requirements of 35 I.A.C. § 845.620.

1.3 Previous Investigations and Reports

Numerous hydrogeologic investigations have been performed concerning the AP. The information presented in this HCR includes data collected in support of the monitoring well network established for development of the GMP and supplements comprehensive data collection and evaluations from prior hydrogeologic investigation reports (recent to oldest), including, but not limited to, the following:

- ***Ramboll, November 18, 2020. Illinois Administrative Code Part 845 Data Gap Analysis and Work Plan, Kincaid Ash Pond – CCR Unit 141***.
  A technical memorandum prepared to assess the AP for the minimum criteria outlined in Part 845. Includes a data gap analysis and work plan designed to resolve identified data gaps, categorized by desktop evaluations and a hydrogeologic field evaluation.
- ***Burns & McDonnell Engineering Company, Inc., September 28, 2020. CCR Surface Impoundment Demonstration for a Site-Specific Alternative to Initiation of Closure Deadline, Revision 0 – Kincaid Power Station, Project No. 122702***.
  Provides a demonstration that the requirements of 40 C.F.R. § 257.103(f)(2) are satisfied for the site-specific alternative closure deadline for the initiation of closure. The request is for authorization to receive CCR and non-CCR waste streams after April 11, 2021, and grant the alternative deadline of October 17, 2028, by which to complete closure of the impoundment.
- ***Natural Resource Technology, An OBG Company (NRT/OBG), October 17, 2017. Sampling and Analysis Plan, Kincaid Ash Pond – CCR Unit ID 141, Kincaid Power Station, Kincaid, Illinois.***

A sampling and analysis plan to document the procedures and techniques used to fulfill the groundwater sampling and analysis requirements of 40 C.F.R. § 257.93 for the AP.

- ***NRT/OBG, October 17, 2017. Hydrogeologic Monitoring Plan, Kincaid Ash Pond – CCR Unit ID 141, Kincaid Power Station, Kincaid, Illinois.***
  An assessment of the monitoring well network at the AP to provide background information in support of the groundwater monitoring system established to comply with 40 C.F.R. § 257.91. Included a review of the placement and number of monitoring wells with respect to individual and contiguous CCR units as well as potential locations for new monitoring wells.
- ***Kincaid Generation, LLC, August 8, 2017. Groundwater Monitoring Plan (GMP) for Kincaid Power Station Ash Impoundment, Revision 2.***
  The second revision to the 2010 groundwater monitoring plan for the AP.
- ***AECOM, October 2016. History of Construction, USEPA Final CCR Rule, 40 CFR § 257.73(c), Kincaid Power Station, Kincaid, Illinois.***
  A history of construction for the AP at the KPP which included review of construction drawings, geotechnical investigations, operation and maintenance information, and AECOM's site experience.
- ***AECOM, January 14, 2016. 30% Design Data Report for Dynegy Kincaid Power Station, Ash Pond CCR Unit.***
  A geotechnical program consisting of installation of auger borings, cone penetrometer test (CPT) soundings, open standpipe piezometers, and vibratory wire piezometers to obtain information for compliance with requirements of the federal CCR rule.
- ***Cabeno Field Services, January 10, 2013. Groundwater Reclassification and Manganese Discussion Report, Ash Impoundment, Kincaid Power Station.***
  An evaluation to determine if shallow groundwater in the vicinity of the AP met IEPA Class I or Class II standards. Included a summary of slug testing at monitoring wells, a pump test at one well, and a discussion of naturally occurring manganese concentrations.
- ***Dominion Electric Environmental Services, October 2010. Groundwater Monitoring Plan (GMP) for the Kincaid Power Station Ash (Slag) Impoundment.***
  Plan to sample and analyze groundwater at the Kincaid Ash Pond. Included a description of the uppermost aquifer, groundwater monitoring system, including monitoring well construction and development, and groundwater sample collection, handling, and analysis procedures.
- ***CEC, June 22, 2010. Hydrogeologic Assessment Report, Kincaid Power Station, Ash Impoundment.***
  A hydrogeologic site investigation requested by the IEPA to characterize the shallow geologic materials, identify nearby locations with potable water supplies, and evaluate the potential for groundwater impacts from the impoundment.

A GMP meeting the requirements of Part 845 is being prepared for the AP in conjunction with this HCR.

1.4 Site Location and Description

The KPP is located in the southwest quarter of Section 1, and the northeast quarter of Section 12, Township 13 North, Range 4 West, along West Route 104, Christian County, Illinois and approximately four miles west of the Village of Kincaid. The AP is located between two lobes of

Sangchris Lake (**Figure 1-1**), which was formed in 1964 by damming Clear Creek, a tributary to the south fork of the Sangamon River. Sangchris Lake was created to provide a source of cooling water for the KPP. The western lobe of Sangchris Lake forms part of the western and northern border of the AP and is connected to an intake flume for the KPP on the western edge of the AP. A discharge flume from the KPP forms the southern border of Kincaid Ash Pond and is connected to the eastern lobe of Sangchris Lake. The KPP property is surrounded by the lobes of Sangchris Lake and Sangchris Lake State Park to the north and east, and a combination of undeveloped land and surface support facilities associated with the former Peabody Coal Company #10 mine to the south and west.

The KPP operates as a coal-fired power plant and has a single CCR management unit, the AP (**Figure 1-2**), a 172-acre, unlined SI used to manage CCR and non-CCR waste streams at the KPP with a total storage capacity of approximately 3,560 acre-feet.

1.5 Site History and Unit Description

Construction of the AP began in 1964 and it was commissioned for use in 1967. The AP primarily contains bottom ash and boiler slag, and other minor materials, including water and wastewater treatment solids, excavation spoils, and dredge spoils. The discharge for the AP is located at the southeast corner of the unit. The approximate dates of construction of each successive stage of the AP are summarized in **Table A** below (AECOM, 2016b).

Table A. History of Construction

Date	Event
1964-1965	Construction of Ash Pond
1967	Ash Pond was put into service
1978-1980	Installation of Ash Pond recycle water intake structures and associated piping
Mid-1980's	Erosion repair along north embankment adjacent to Sangchris Lake
2006	Replacement of emergency outlet piping
2009-2010	Tree removal, grading, and vegetation re-established along the north and east embankment
2010	Riprap placement along the northwest Ash Pond embankment adjacent to Sangchris Lake

2. REGIONAL AND SITE GEOLOGY

2.1 Topography

The AP and surrounding areas are relatively flat at an elevation of approximately 600 feet North American Vertical Datum of 1988 (NAVD88). Sangchris Lake constitutes the lowest topographic feature in the area at approximately 585 feet NAVD88 (see **Figure 1-1**).

A Plat of Survey Map (1966) shows the KPP intake flume at an elevation of 555 feet above mean sea level (msl) and the discharge flume at an elevation of 565 feet msl (**Appendix A**). In the northcentral portion of the site, a former drainage feature is present with the lowest mapped elevation of this feature at approximately 580 feet. The feature extends generally in a north-south direction and formerly connected with the western lobe of Sangchris Lake.

A topographic field survey from 2021 (IngenAE, 2021) measured an average surface water elevation within the AP of 602.36 feet NAVD88. The embankments surrounding the AP extend upward to an elevation of approximately 616 feet NAVD88 northwest of the AP, 615 feet NAVD88 northeast of the AP, 619 feet NAVD88 southwest of the AP, 624 feet NAVD88 south of the AP, and 606 feet NAVD88 southeast of the AP. Site surface topography is shown on **Figure 2-1**.

2.2 Regional Geomorphology

The KPP is located within Christian County, which has an area of 716 square miles, of which 709 square miles is land and 6.3 square miles is water. The county is bounded on the north by the Sangamon River. The south fork of the Sangamon River runs through the center of Christian County. The majority of the county lies within the Sangamon Drainage Basin, which has an area of 5,418 square miles. The Sangamon River is a tributary to the Illinois River.

The AP is located in the Springfield Plain, which is in the Till Plains Section of the Central Lowland Physiographic Province. The Springfield Plain is distinguished mainly by its flatness and by shallow entrenchment of drainage. The southern boundary is drawn along a line of which the drift thins and bedrock topography becomes a controlling factor; the western boundary follows the edge of the Illinoian drift. The greater part of the district is a flat till plain. The moraines are low and broad. Drainage systems are well developed. The Illinoian drift is moderately thick and is underlain by older drift, except in areas where the bedrock is close to the surface. Along the southeast side of the Illinois Valley, there is a belt of thick loess (Leighton et al., 1948).

The Herrin Coal Seam was historically mined in the area and occurs at a depth of approximately 300 to 380 feet below ground surface (bgs) in the vicinity of the AP. Mining activities are discussed in detail in Section 2.4.5.

2.3 Soils

Surficial soils at the AP and vicinity are shown on **Figure 2-2**, based on the soil survey data for Christian County available in the Soil Survey Geographic database (SSURGO) by the United States Department of Agriculture Natural Resources Conservation Service provided by the Environmental Systems Research Institute (ESRI) web-hosted layer. Surficial soils within the extents of the AP are classified as Mine dumps. Surficial soils in the vicinity of the AP consist of Assumption silt loam (5 to 10 percent slopes, eroded), Ipava silt loam (0 to 2 percent slopes), Denny silt loam (0 to 2 percent slopes, Loess, poorly drained), Virden silty clay loam (0 to 2 percent slopes, Loess, poorly drained), Orthents (loamy, undulating), and Osco silt loam (2 to 5 percent slopes). Additional information sourced from SSURGO describing surficial soils listed above at the AP and vicinity is available in **Appendix B**.

2.4 Regional Geology

2.4.1 Regional Unlithified Geology

The AP is located in the Illinois Valley where the general sequence of unlithified Quaternary deposits consists of poorly sorted sand, silt, and clay of the Cahokia Formation. The Upper Cahokia Formation consists of overbank silts and clays, while the coarser-textured Lower Cahokia Formation is mainly sandy channel and lateral accretion deposits. The Cahokia Formation is present along all Illinois streams, although locally absent where active stream erosion is occurring (Willman and Frye, 1970).

The Cahokia Formation is predominantly a silty deposit because much of it is derived from erosion of loess and till. Loess was still accumulating in the region when some of the alluvium was deposited. Although lenses of sand and gravel are locally common in the alluvium, these lenses generally have a relatively high silt content. The degree of sorting varies but is generally poor. A major part of the alluvium consists of materials transported down the valley and deposited in the floodplains during intervals of flooding, but it also includes sediments deposited directly by tributary streams. The latter sediments commonly consist of lenses of relatively coarse material interbedded with floodplain silts. The thickness varies greatly, but 10 to 20 feet is common along many valleys and 50 to 75 feet is found along major valleys (ISGS, 2021d). Where present, the Cahokia Formation deposits at the AP are comprised of silts and clays interbedded with thin sand lenses near Sangchris Lake and extend to depths of approximately 40 feet (NRT/OBG, 2017a).

Underlying the Cahokia Formation is the Vandalia Till Member of the Glasford Formation. The Vandalia Till is the lowermost and oldest unlithified geologic material in the region. The Vandalia Till is a relatively sandy, gray, compact till (*i.e.,* diamicton deposits), commonly 25 to 50 feet thick, but it is probably much thicker in some of the deep valleys. Its extent has not been determined, but it probably is the surface till throughout most of the area of Illinoian drift in southeastern Illinois (ISGS, 2021d). The Vandalia Till deposits at the AP are comprised of dense clay and silt with varying amounts of sand and gravel, and extend to depths of approximately 50 feet (NRT/OBG, 2017a).

Although not shown on available ISGS survey data which is mapped on a regional scale, the silts and clays of the Cahokia Formation have been identified adjacent to the former Clear Creek and underlying the constructed AP, in addition to the Vandalia Till. The regional surficial geologic deposits in the vicinity of the Site, as surveyed by ISGS, are shown on **Figure 2-3**.

2.4.2 Regional Bedrock Geology

Underlying the unlithified materials of the Vandalia Till is the Pennsylvanian-age Bond Formation consisting of a sequence of lithified marine sediments comprised mainly of limestone interbedded with lesser amounts of shale and sandstone. The top of bedrock surface in the vicinity of the site is approximately 550 feet msl (CEC, 2010).

2.4.3 Structure

The major geological structure features around Illinois are shown on **Figure 2-4**. The KPP is located within a relatively stable region within the central portion of the Illinois Basin. The AP on the southern end of the Kincaid Anticline that is prominent on a structure map of the top of the Mississippian Karnak Limestone Member. The Anticline is about 11 miles long and plunges S15E. Closure is mapped in the northern part of the fold; vertical relief is about 80 feet on both flanks. The fold is relatively flat topped and has equal dips on both flanks.

The Kincaid Anticline also is referenced in Nelson's (1995) structural features of Illinois. The anticline is more irregular in outline and lower in relief on the coal than it is on the Karnak Limestone. A normal fault, the Sicily Fault, offsets the Herrin Coal along the west flank of the Kincaid Anticline. The fault is parallel to the fold axis and is downthrown toward the crest of the anticline.

The upward loss of structural relief suggests that the Kincaid Anticline, like many anticlines in central Illinois, may have developed during late Mississippian to early Pennsylvanian time. The Edinburg West and Kincaid Consolidated Oil Field are situated on or close to the crest of the Kincaid Anticline.

2.4.4 Seismic Setting

A review of the available data from the United States Geological Survey (USGS), ISGS, and other available structural information was completed by Haley & Aldrich, Inc., (2018) for the Location Restriction Demonstration to address the requirements of 40 C.F.R. § 257.62 (Fault Areas). The review found that the nearest known mapped fault is the Sicily Fault referenced above, which is located approximately 2 miles east of the AP. The timeframe of the most recent activity on the Sicily Fault is unknown. There are no known active faults or fault damage zones that have had displacement in Holocene time reported or indicated within 200 feet of the AP (see **Figure 2-4**).

35 I.A.C. § 845.330 requires that existing and new CCR SIs and lateral expansions of existing SIs must not be located in seismic impact areas, unless owners or operators demonstrate that the SI is designed to resist the maximum horizontal acceleration (g) in lithified earth material. This requirement is identical to that in 40 C.F.R. § 257.63. The definition of a seismic impact zone is "areas having a 2 percent or greater probability that the maximum expected horizontal acceleration, expressed as a percentage of the earth's gravitation pull, will exceed 0.10 g in 50 years." Although the AP is located within a seismic impact zone, it satisfies the demonstration requirements of 35 I.A.C. § 845.330. The AECOM report titled CCR Certification Report: Initial Structural Stability Assessment, Initial Safety Factor Assessment, and Initial Flow Design Control System Plan for the Kincaid Ash Pond at Kincaid Power Station", dated October 2016, includes engineering analysis, calculations, and findings that support the requirements of 40 C.F.R. § 257.63 (Haley & Aldrich, Inc., 2018), and, by extension, 35 I.A.C. § 845.330.

2.4.5 Mining Activities

Most of the areas immediately beneath and surrounding the facility have been mined underground by the Peabody Coal Company. Based on the directory of coal mines for Christian County, underground coal mines are located directly beneath most of the AP and throughout much of the region surrounding the KPP. The main power plant area and the southernmost edge of the AP are not underlain by a coal mine. The coal mined is referred to as the Herrin Seam and occurs at a depth of approximately 300 to 380 feet bgs in the vicinity of the AP. These mines, identified as #8 and #10, are both abandoned underground shaft mines. Geological problems reported during mining activities included slips, sandstone rolls, and roof falls and failures. The #8 mine was active from 1914 to 1954. The mining method used was Room and Pillar Panel and the coal seam at this location ranged from 7 to 8 feet in thickness. The #10 mine operated from 1951 to 1994. Mine #10 used the Blind Room and Pillar mining method and the coal seam at this location had a maximum thickness of 13 feet (ISGS, 2019; ISGS, 2021b; ISGS, 2021c). The nearest coal mines to the AP are shown in **Figure B-1** of **Appendix B**.

In 2013, minor subsidence of the embankment crest was observed along portions of the southwestern embankment of the AP. The subsidence was believed to have been caused by historical underground mining operations from the 1950s to 1990s. Gravel and soil fill was placed in the settlement areas to restore the embankment crest elevation (AECOM, 2016b).

Karst topography or physiographic features, such as sinkholes, vertical shafts, sinking streams, caves, large springs, or blind valleys, do not exist at the KPP and karst features are not common in Christian County. Data reviews indicate that the KPP is in an area of low landslide incidence; there has not been a landslide occurrence at or near the AP (Haley & Aldrich, Inc., 2018).

2.5 Site Geology

A field investigation was performed in 2021 to collect additional data for the discussion of vertical and horizontal lithology, stratigraphy, chemical properties, and physical properties of geologic layers to a minimum of 100 feet bgs as specified in 35 I.A.C. § 845.620(b). Field investigation locations are shown on **Figure 2-5**.

2.5.1 Site-Specific Unlithified Geology

The three principal types of unlithified materials present above the bedrock in the vicinity of the AP consist of the following in descending order:

- Fill, predominantly coal ash (bottom ash and slag) within the AP, but also including constructed berms and railroad embankments near the AP.
- Clays and silts of the Cahokia Formation, interbedded with thin sand lenses near Sangchris Lake, which extend to depths of less than 44 feet.
- Clay and silt with varying amounts of sand and gravel of the Vandalia Till, which extend to depths of up to 52 feet.

Soil boring logs and well construction logs are provided in **Appendix C**.

2.5.1.1 Fill and CCR

CCR within the AP is comprised predominantly of bottom ash. Ash is present within the AP at a thickness of up to 30 feet as measured in XPW01 (**Appendix C**). The AP overlies the Cahokia Formation, and the bottom of the ash was observed at a depth of 22 feet bgs, and elevation of 582.57 feet NAVD88, in the northern portion of the AP at XPW04. The bottom of ash elevation (**Figure 2-6)** was determined during the location restriction evaluation required by 40 C.F.R. § 257.60 and was compared to the historic topography (**Appendix A**). The base of ash elevation is consistent with the historic topography, *i.e.,* the bottom of the AP is the historic ground surface at the time the containment berms were constructed.

Eight samples were obtained from the ash within borings XPW01 through XPW04 (**Figure 2-5**) for geotechnical testing. Soil classifications using the Unified Soil Classification System (USCS) indicated poorly graded sand (SP) in XPW01 and XPW04, poorly graded sand/silty sand (SP-SM) in XPW02, and well graded sand, fine to coarse sand/silty sand (SW-SM) in XPW03. Geotechnical testing results are summarized in **Table 2-1**, and the geotechnical laboratory report is included in **Appendix D**. Geotechnical results from XPW01 through XPW04 indicated the following:

- The average moisture content was 23.3 percent and ranged from 11.8 to 36.4 percent.
- The average total porosity (calculated) was 54 percent and ranged from 46 to 64 percent.
- The average dry density was 80.7 pounds per cubic foot (pcf) and ranged from 62.7 to 93.9 pcf.
- The average specific gravity was 2.796 and ranged from 2.770 to 2.838.
- The distribution of particle sizes was 0 to 1.6 percent gravel, 91.4 to 98.4 percent sand, and 1.3 to 8.4 percent fines (silt and clay).
- The geometric mean vertical hydraulic conductivity was 1.4×10^{-3} centimeters per second (cm/s) and ranged from 3.5×10^{-4} to 4.3×10^{-3} cm/s.

Solids samples from XPW01 through XPW04 were also submitted to an analytical laboratory for chemical analysis. The results of the soil sample chemical analysis are summarized in **Table 2-2**.

Leachate wells were installed in XPW01 through XPW04 and porewater samples were collected for chemical analysis. The results of the porewater sample chemical analysis are summarized in **Table 2-3**.

2.5.1.2 Cahokia Formation

The Cahokia Formation was observed at boring locations MW-1 through MW-12, MW-8S, MW-12D, MW-12S, MW-20, MW-20S, MW-22 through MW-32, and MW-31S (**Appendix C**) and consists of predominantly clay and silt with some clayey sand and sandy clay intervals. Its color was described as pale brown, light yellowish brown, gray, brown, grayish brown, and dark yellowish brown. The thickness of the Cahokia Formation was observed to be up to 40 feet at MW-30 (**Figures 2-7 through 2-11**).

Three samples were collected from the Upper Cahokia Formation for geotechnical testing within borings MW-12D (5-7 feet bgs and 11.5-12 feet bgs) and MW-23 (15-17 feet bgs). USCS soil classifications indicated lean clay (CL) and clayey sand (SC). Boring locations are shown on **Figure 2-5**. The geotechnical testing results are summarized in **Table 2-1** and the geotechnical laboratory report is included in **Appendix D**. Geotechnical testing results from the Upper Cahokia Formation indicated the following:

- The average moisture content was 21.7 percent and ranged from 18.2 to 28.4 percent.
- The average total porosity (calculated) was 44 percent and ranged from 42 to 45 percent.
- The average dry density was 95.0 pcf and ranged from 92.7 to 97.8 pcf.
- The average specific gravity was 2.697 and ranged from 2.682 to 2.705.
- The distribution of particle sizes was 0 to 4.9 percent gravel, 2.5 to 49.8 percent sand, and 45.3 to 97.5 percent fines (silt and clay).

- The geometric mean vertical hydraulic conductivity was 1.2 x 10^{-7} cm/s and ranged from 7.2 x 10^{-8} to 3.2 x 10^{-7} cm/s.

Three samples were collected from the Lower Cahokia Formation for geotechnical testing within borings MW-12D (20.5-22.5 feet bgs), MW-20 (15-17 feet bgs), and MW-23 (25-27 feet bgs). USCS soil classifications indicated lean clay (CL) and clayey sand (SC). Boring locations are shown on **Figure 2-5**. The geotechnical testing results are summarized in **Table 2-1** and geotechnical laboratory report is included in **Appendix D**. Geotechnical testing results from the Lower Cahokia Formation indicated the following:

- The average moisture content was 16.2 percent and ranged from 14 to 18.9 percent.
- The average total porosity (calculated) was 35 percent and ranged from 34 to 36 percent.
- The average dry density was 109.0 pcf and ranged from 106.9 to 112.3 pcf.
- The average specific gravity was 2.701 and ranged from 2.672 to 2.731.
- The distribution of particle sizes was 0 to 6 percent gravel, 29.9 to 46.4 percent sand, and 47.6 to 69.5 percent fines (silt and clay).
- The geometric mean vertical hydraulic conductivity was 1.1 x 10^{-7} cm/s and ranged from 5.9 x 10^{-8} to 2.0 x 10^{-7} cm/s.

Soil samples collected from the Upper and Lower Cahokia Formation were also submitted to an analytical laboratory for chemical analysis. The results of this chemical analysis are summarized in **Table 2-4**.

2.5.1.3 Vandalia Till

The Vandalia Till was observed at boring locations MW-1 through MW-6, MW-8 through MW-10, MW-12, KIN-B001 through KIN-B012, MW-12D, MW-20, MW-20S, MW-23, MW-25, MW-26, MW-28, MW-30, MW-31, and MW-32 (**Appendix C**) and consists predominantly of dense clay and silt with varying amounts of sand and gravel. The lowermost portion may contain weathered limestone cobbles within a few feet of the top of bedrock. Field compressive strength readings on the Vandalia Till were 4.5 tons per square foot. The Vandalia Till is easily identified by difficult drilling and/or refusal and is apparent on boring logs.

Its color was variously described in the boring logs as brown and gray, brownish gray, light brown, and greenish gray and brown. The average thickness of the Vandalia Till observed in the soil borings was 7.5 feet with maximum thicknesses of 37.5 feet. The till was encountered at elevations ranging from approximately 570 to 583.5 feet NAVD88 (**Figures 2-7 through 2-11**).

Samples collected from the Vandalia Till were submitted to an analytical laboratory for chemical analysis, but were not submitted for geotechnical testing due to poor recovery. Boring locations are shown on **Figure 2-5**. The chemical analysis results are summarized in **Table 2-4**.

2.5.2 Site-Specific Bedrock Geology

Bedrock underlying the AP is the Pennsylvanian Age Bond Formation, which consists mainly of limestone with lesser amounts of shale and sandstone. Bedrock was encountered in borings MW-2, MW-5, B-12, KIN-B005, KIN-B010, MW-12D, and MW-20 (**Appendix C**). The elevation of the top of bedrock is highest at MW-20 (548.02 feet NAVD88) beneath the eastern portion of the AP and declines in elevation to the west toward MW-12D (540.68 feet NAVD88) and to the south toward KIN-B005 (520 feet) (**Figures 2-7 through 2-11**). The top of bedrock was described as limestone overlaying shale in borings advanced to bedrock.

No bedrock samples were collected for geotechnical testing or chemical analysis. Boring locations are shown on **Figure 2-5**.

3. REGIONAL AND LOCAL HYDROGEOLOGY

3.1 Regional Hydrogeology

Potable groundwater resources in Christian County range from poor to good. Extensive testing, however, is commonly required to locate suitable sources of groundwater in the valley flats. Domestic and farm supplies are generally obtainable throughout Christian County except for an area south and west of Pana and in the western part of the county where the drift is thin. In this area, water is obtained locally from large diameter dug wells in the drift or from wells drilled into the bedrock. The Pennsylvanian bedrock below the drift is composed principally of shale. Locally, sandstone lenses are present and may yield small water supplies. Wells drilled into the bedrock are generally limited to a depth of 200 to 250 feet or less below land surface, as water quality diminishes at greater depths (Selkregg and Kempton, 1958).

3.2 Site Hydrogeology

In 2010, 10 groundwater monitoring wells (MW-1 through MW-10) were installed at the KPP within and around the AP to evaluate potential impacts from the AP. In 2015, a groundwater monitoring program was initiated at these locations to meet the requirements of 40 C.F.R. § 257. In 2021, additional wells were installed to supplement the existing well network and provide information to meet the requirements of Part 845. A summary of monitoring well locations and construction details are included in **Table 3-1** and depicted on **Figure 3-1**.

3.2.1 Hydrostratigraphic Units

Five distinct water-bearing layers have been identified at the AP based on stratigraphic relationships and common hydrogeologic characteristics, which are summarized below and discussed in subsequent sections.

- **CCR**: Saturated CCR, consisting primarily of bottom ash, and boiler slag.
- **USCU**: Low-permeability clay with some silt and minor sand, silt layers, and occasional discontinuous sand lenses. Includes the lithologic layers identified as the Cahokia Formation. Sand lenses with higher permeability within the USCU have a higher probability of contaminant transport and these materials are referred to as the PMPs.
- **Uppermost Aquifer**: Thin (generally less than 4 feet), moderate permeability sand, silty sand, and clayey sand and gravel units, which include the clays and silts of the Upper Cahokia Formation, where saturated, and the thin, moderate permeability sands and gravels of the Lower Cahokia Formation, which, at some locations, also includes the interface with the Vandalia Till.
- **LCU:** Underlying the aquifer unit is dense grey clay till; this till is easily distinguished during investigation by difficult drilling and/or refusal and is apparent on boring logs. The till was encountered at elevations ranging from approximately 570 to 583.5 feet NAVD88. The LCU is comprised of low permeability silt and clay with minor sand, silt layers, and occasional discontinuous sand lenses (more frequently near the top of the unit). Includes the lithologic layers identified as the Vandalia Till.
- **BCU**: This unit is composed of interbedded shale and limestone of the Pennsylvanian Age Bond Formation that underlie the Vandalia Till, and underlies the entire AP.

3.2.2 Uppermost Aquifer

Underlying the USCU is a sandy unit which is considered the uppermost aquifer in the area. The lithologic description of the uppermost aquifer ranges from well graded sand to sandy clay, but in most locations, it is described as silty or clayey sand. Based on interpreted groundwater elevations, the top of the uppermost aquifer appears to decline in elevation to the northwest toward Sangchris Lake (**Figure 3-2**). Below the AP the uppermost aquifer was encountered at an elevation ranging from 577.1 to 582.2 feet NAVD88. This unit occurs directly above the Vandalia Till.

Although there may be other lenses of coarser grained material within the USCU, there is no evidence that they are laterally continuous across the Site. The determination that the sand unit is the uppermost aquifer is supported by a well search performed in the vicinity of the Site. Many of the nearby potable wells indicate the presence of this aquifer at a similar elevation to what was encountered at the Site. Potable well construction logs also identify this unit as the primary source of groundwater (**Appendix B**).

3.2.3 Potential Migration Pathway

The USCU, the Cahokia Formation, has been characterized with information collected from monitoring wells screened within both clay and silt and discontinuous sand lenses encountered during geologic investigations. The general discussion for the USCU, included below, includes all monitoring wells in this unit, but further subdivides the discussion to characterize PMPs based on information from wells screened within these materials. PMPs were interpreted using the lithologic composition and hydrogeologic properties (hydraulic conductivity and hydraulic position with respect to the unit) of the materials. In addition to the physical properties, the analytical results from baseline groundwater monitoring performed in wells screened in the USCU were used to identify PMPs. Monitoring wells are classified as follows:

- USCU monitoring locations: MW-7S, MW-8S, MW-11S, MW-12S, MW-20S, MW-25, MW-27, and MW-31S
- Interpreted PMP monitoring locations: MW-7S, MW-12S, MW-25, and MW27

3.2.4 Water Table Elevation and Groundwater Flow

The elevations of water within the AP (as observed in XPW-01 through XPW-04 and XSG-01) are greater than groundwater elevations in the surrounding areas, and, depending on the hydraulic connection between the AP and the surrounding aquifer, water may flow radially from the AP toward the lobes of Sangchris Lake. The phreatic surface within the AP between February and August 2021 averaged 603.29 feet NAVD88, ranging from 600.76 feet NAVD88 in XPW03 (in the northwest portion of the AP) to 607.38 feet NAVD88 in XSG-01 (in the southeast corner of the AP) (see **Figures 3-3 through 3-5**).

The groundwater elevation in wells within the USCU (MW-7S, MW-8S, MW-11S, MW-12S, MW-20S, MW-25, MW-27, and MW-31S) averaged 591.34 feet NAVD88 between February and August 2021, with a range from 583.38 feet NAVD88 in MW-27 (west of the AP) to 602.14 feet NAVD88 in MW-25 (southwest of the AP). The groundwater elevation in wells within the PMP (MW-7S, MW-12S, MW-25, and MW-27) averaged 589.99 feet NAVD88 between February and August 2021, with a range from 583.38 feet NAVD88 in MW-27 (west of the AP) to 602.14 feet NAVD88 in MW-25 (southwest of the AP). USCU well MW-11S was dry during all events with the exception of the May 2021 event. Wells MW-12S and MW-27, located on the north side of the AP near the former drainage feature, consistently recorded the lowest groundwater elevation, while MW-8S and MW-20S had relatively equal groundwater elevations, and the highest elevations were measured at MW-25, suggesting that the predominant horizontal groundwater flow in the USCU in the area of the AP is toward the north and northwest toward the western lobe of Sangchris Lake. There also appears to be a component of groundwater flow to the south and east toward the discharge flume that flows to the eastern lobe of Sangchris Lake (see **Figures 3-3 through 3-5**), as evidenced by groundwater elevations on the southern side of the AP being consistently below the screen interval of MW-11S (591-595 feet NAVD88); this monitoring well was consistently dry during 2021 groundwater monitoring. These two components of groundwater flow suggest a groundwater divide beneath the AP.

The groundwater elevation in wells screened in the uppermost aquifer (MW-1 through MW-12, MW-20, MW-22 through MW-24, MW-26, MW-28 through MW-32, and PZ4C) averaged 592.82 feet NAVD88 between February and August 2021, with a range from 584.12 feet NAVD88 in MW-12 northwest of the AP to 598.93 feet NAVD88 in MW-20 east of the AP. As noted above, groundwater elevation contour maps suggest that there is a groundwater divide beneath the AP and horizontal groundwater flow in the uppermost aquifer is to the northwest and southeast toward the lobes of Sangchris Lake (see **Figures 3-3 through 3-5**).

The groundwater elevation in BCU well MW-12D averaged 586.23 feet NAVD88 between February and August 2021, with a range from 584.55 to 587.18 feet NAVD88 (see **Figures 3-3 through 3-5**).

3.2.4.1 Vertical Hydraulic Gradient

Vertical hydraulic gradients were calculated using available groundwater elevation data from February to August 2021 at nested well locations within the USCU/PMPs, uppermost aquifer, and BCU. Vertical hydraulic gradients are presented in **Table 3-2.** The results of the vertical hydraulic gradient calculations for these hydrostratigraphic units are summarized below:

- BCU to uppermost aquifer:
  - Gradients calculated between MW-12D (BCU) and MW-12 (uppermost aquifer) were upward for all events.
- Uppermost aquifer to USCU/PMP:
  - Gradients between MW-12 (uppermost aquifer) and MW-12S (PMP) were downward for all events.
- Uppermost aquifer to USCU:
  - Gradients between MW-31 (uppermost aquifer) and MW-31S (USCU) were downward for seven events, and upward in the July 1, 2021 event.
  - Gradients between MW-8 (uppermost aquifer) and MW-8S (USCU) were variable, with upward gradient in three events (February through April 2021) and a downward gradient in two events (May and June 2021). Gradients were not calculated for the two events in July and one event in August because MW-8S was dry during those sampling events.
  - Gradients between MW-7 (uppermost aquifer) and MW-7S (USCU) were upward for seven events and downward in the June 2021 event.

These results are consistent with previous vertical gradient calculations (NRT/OBG, 2017a).

3.2.4.2 Impact of Sangchris Lake on Groundwater Flow

Groundwater elevations are primarily controlled by the level in Sangchris Lake, and the water level within the AP. There is an apparent groundwater divide beneath the AP with groundwater flow to the northwest and southeast toward the western and eastern lobes of Sangchris Lake, respectively (**Figures 3-3** through **3-5** and **Appendix E).**

3.2.5 Hydraulic Conductivity

3.2.5.1 Field Hydraulic Conductivity

Results of field hydraulic conductivity tests conducted in 2021 in the CCR (XPW01 through XPW04) ranged from 2.09 x 10^{-2} to 2.64 x 10^{-1} cm/s, with a geometric mean of 8.57 x 10^{-2} cm/s.

Results of field hydraulic conductivity tests performed in 2021 in wells screened in the USCU (MW-12S, MW-25, MW-27, and MW-20S) ranged from 1.56 x 10^{-5} to 1.22 x 10^{-4} cm/s, with an overall geometric mean of 5.04 x 10^{-5} cm/s. Tests were not completed for all wells in the USCU, of the wells evaluated, two were screened in sandier zones of the USCU and the resulting geometric mean hydraulic conductivity for the unit is likely overestimated.

Field hydraulic conductivity tests performed in 2021 in wells screened within the uppermost aquifer (MW-20, MW-22, MW-23, MW-26, MW-28, MW-29, MW-30, MW-31, MW-32, and PZ-4C) ranged from 1.29 x 10^{-6} to 5.35 x 10^{-4} cm/s, with an overall geometric mean hydraulic conductivity of 4.14 x 10^{-5} cm/s. The geometric mean likely underestimates the hydraulic conductivity of the unit because it includes locations where sandier material was not present (MW-20, MW-32, and PZ-4C).

Field hydraulic conductivity tests were performed in BCU well MW-12D resulting in hydraulic conductivity of this unit is 1.69 x 10^{-3} cm/s. Well MW-12D was screened within the top 5 feet of the bedrock and the resulting hydraulic conductivity likely represents the weathered bedrock surface.

Field hydraulic conductivity test results are summarized on **Table 3-3** and the field hydraulic conductivity test data is included in **Appendix F**.

3.2.5.2 Laboratory Hydraulic Conductivity

Falling head permeability tests (ASTM D5084 Method F) were performed in the laboratory on samples collected during the 2021 investigations. Sample locations are shown on **Figure 2-5**. The geotechnical laboratory report is provided in **Appendix D**. The results are summarized in **Table 2-1** and discussed below.

- Eight samples were collected from ash borings XPW01 through XPW04. Laboratory falling head permeability test results in the ash indicated a geometric mean of 1.4 x 10^{-3} cm/s.
- Three USCU samples were collected from borings MW-12D and MW-23. Laboratory falling head permeability test results in the USCU indicated a geometric mean vertical hydraulic conductivity of 1.2 x 10^{-7} cm/s. No laboratory vertical hydraulic conductivity tests were performed on samples from the PMP wells.

- Three uppermost aquifer samples were collected from borings MW-12D, MW-20, and MW-23. Test results indicated a geometric mean of 1.1 x 10^{-7} cm/s.
- Laboratory hydraulic conductivity tests were not performed in the BCU.

3.2.6 Horizontal Groundwater Gradients and Groundwater Flow Velocity

Horizontal gradient and groundwater velocities for the uppermost aquifer were calculated based upon groundwater elevation measurements from February to August 2021 between MW-5 and MW-31, MW-6 and MW-12, and MW-8 and MW-26 (**Table 3-4**). Horizontal gradient between MW-5 and MW-31 averaged 0.015 feet per foot (ft/ft), between MW-6 and MW-12 it averaged 0.008 ft/ft, and between MW-8 and MW-26 it averaged 0.015 ft/ft. Average groundwater flow velocity in the uppermost aquifer between MW-5 and MW-31 was calculated to be 0.004 feet per day (ft/day), between MW-6 and MW-12 was calculated to be 0.002 ft/day, and between MW-8 and MW-26 was calculated to be 0.001 ft/day.

The horizontal gradient and groundwater velocities for the USCU/PMP was determined at wells MW-25 and MW-27 (**Table 3-4**). The horizontal gradient for the USCU/PMP averaged 0.010 ft/ft. Average groundwater flow velocity in the USCU/PMP was 0.010 ft/day as determined by the interpolated groundwater elevation contours from February to August 2021.

Horizontal hydraulic gradients and groundwater flow velocity calculations are summarized in **Table 3-4**. Groundwater flow velocity in the LCU could not be determined because there are no wells screened within the LCU well. Similarly, groundwater flow velocity in the BCU could not be determined because there is only one bedrock well (MW-12D).

3.2.7 Groundwater Classification

Groundwater at the AP does not meet the definition of Class I - Potable Resource Groundwater (35 I.A.C. § 620.210), based on the following criteria:

- Site investigations have determined that water bearing lenses contain more than 12 percent fines (see **Table 2-1**) and are less than five feet in thickness (Cabeno, 2013),
- Sustained groundwater yield, from a 12-inch borehole, of less than 150-gallons per day from a thickness of 15-feet or less.
- Field (horizontal) hydraulic conductivity tests and laboratory (vertical) hydraulic conductivity tests from wells screened within the uppermost aquifer resulted in an overall (geometric mean) of 5.07 x 10^{-5} cm/s and 1.07 x 10^{-7} cm/s, respectively (see **Table 2-1** and **Table 3-4**).

As set forth in 35 I.A.C. § 620.220, any geologic material with a hydraulic conductivity of less than 1 x 10^{-4} cm/s, and which does not meet the provisions of 35 I.A.C. § 620.210 (Class I), 35 I.A.C. § 620.230 (Class III), or 35 I.A.C. § 620.240 (Class IV), meets the definition of Class II: General Resource Groundwater. Based on the detailed geologic information provided for the unlithified materials and bedrock encountered at the AP and the hydrogeologic data, the groundwater in the uppermost aquifer can be classified as Class II groundwater: General Resource Groundwater. This is supported by results of the hydrogeologic study completed in 2013 (Cabeno, 2013), which concluded that the AP does not meet most criteria of Class I Groundwater and the data collected supported a Class II Groundwater Classification.

3.3 Surface Water Hydrology

3.3.1 Climate

Average climatic data was obtained from the Illinois State Water Survey (ISWS) records between 1981 and 2010 from Springfield, Illinois, located approximately 18 miles northwest of the AP. The data indicates that precipitation averages 37.43 inches per year. Monthly precipitation is greatest in April through August. On average, 20.9 inches of precipitation occur as snowfall.

As shown in **Table B** below, ISWS temperature records show average maximum daily temperatures for 1989 to 2010 ranging from above 70 degrees Fahrenheit (°F) May through September and minimum average daily temperatures that are below freezing December through February.

Table B. Average Monthly Temperature Extremes and Precipitation for Springfield, Illinois

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Annual
Max Temperature (°F)	34.8	39.9	52.1	64.6	74.8	83.1	86.2	84.9	78.9	66.4	52.3	38.3	63.1
Min Temperature (°F)	18.7	22.6	32.2	42.4	52.6	61.9	65.4	63.6	54.6	43.8	33.9	22.5	43.0
Precipitation (inches)	1.82	1.81	2.63	3.51	4.24	4.46	3.94	3.24	2.90	3.15	3.21	2.52	37.43
https://www.isws.illinois.edu/statecli/newnormals/normals.USW00093822.txt													

3.3.2 Surface Waters

The predominant surface water body in the region is Sangchris Lake. Sangchris Lake is located directly adjacent to the AP. Bordering the northwest perimeter of the AP, Sangchris Lake has a normal pool elevation of about 585 feet NAVD88 (see **Figure 1-1**). The surface water elevation of Sangchris Lake was measured on May 21 and June 9, 2021 and was 585.62 and 585.20 feet NAVD88, respectively. Surface water elevations in Sangchris Lake are not expected to fluctuate in the vicinity of the KPP as a result of the lake being controlled by a dam to provide cooling water for the KPP. The phreatic surface within the AP between February and August 2021 averaged 603.28 feet NAVD88, ranging from 600.76 feet NAVD88 in XPW03 (in the northwest portion of the AP) to 607.38 feet NAVD88 in XSG-01 (in the southeast corner of the AP). There is an apparent groundwater divide beneath the AP with groundwater flow to the northwest and southeast towards the western and eastern lobes of Sangchris Lake, respectively.

Other surface waters in the vicinity include various freshwater emergent wetlands on the property to the northwest, freshwater forested/shrub wetland to the west, a small riverine to the southeast, and several freshwater ponds directly south of the AP.

4. GROUNDWATER QUALITY

4.1 Summary of Groundwater Monitoring Activities

4.1.1 IEPA Monitoring Program

The current IEPA-required groundwater monitoring program associated with the AP consists of 12 groundwater monitoring wells used to monitor the uppermost aquifer, including four background monitoring wells (MW-1, MW-2, MW-9, and MW-10) and eight wells downgradient of the AP (MW-3 through MW-8, MW-11, and MW-12) in accordance with the Groundwater Monitoring Plan (GMP; Kincaid Generation, LLC, 2017). The boring logs, well construction forms, and other related monitoring well forms for the well network are included in **Appendix C** of this HCR. The well locations are shown on **Figure 3-1**.

Groundwater samples are collected semi-annually and analyzed for the parameters listed in 35 I.A.C. § 620.410 (Groundwater Quality Standards for Class I: Potable Resource Groundwater) with the exception of perchlorate, which is not required under the GMP. The parameters analyzed for the IEPA Monitoring Program are listed in **Table C** below.

Table C. IEPA Groundwater Monitoring Parameters at Kincaid Ash Pond

Water Pollution Control Board Permit Monitored Groundwater Parameters			
Field Parameters			
Groundwater Elevation	pH	Specific conductivity	Temperature
General Chemistry Parameters			
Chloride (total)	Fluoride (total)	Nitrate (total)	Total Dissolved Solids
Cyanide (total)	Nitrite (total)	Sulfate(total)	
Metals (total)			
Antimony	Cadmium	Lead	Silver
Arsenic	Chromium	Manganese	Thallium
Barium	Cobalt	Mercury	Vanadium
Beryllium	Copper	Nickel	Zinc
Boron	Iron	Selenium	Radium 226 and 228 combined

4.1.2 40 C.F.R. § 257 Program Monitoring and Well Network

In 2015, additional well installation and groundwater sampling was initiated to meet the requirements of 40 C.F.R. § 257. The 40 C.F.R. § 257 monitoring well network consists of eight groundwater monitoring wells screened in the uppermost aquifer, including two background monitoring wells (MW-1 and MW-2) and six compliance wells (MW-5 through MW-8, MW-11, and MW-12). The boring logs, well construction forms, and other related monitoring well forms for the well network are included in **Appendix C** of this HCR. The well locations are shown on **Figure 3-1**.

Assessment monitoring in accordance with 40 C.F.R. § 257.95 was initiated on April 9, 2018. Details of the procedures and techniques used to fulfill the groundwater sampling and analysis program requirements are found in the Sampling and Analysis Plan for the AP. Results are discussed in **Section 4.2**.

Groundwater samples are collected semi-annually and analyzed for the field and laboratory parameters from Appendix III and Appendix IV of 40 C.F.R. § 257, summarized in **Table D** below.

Table D. 40 C.F.R. § 257 Groundwater Monitoring Program Parameters

Field Parameters[1]			
Groundwater Elevation	pH		
Appendix III Parameters (Total, except TDS)			
Boron	Chloride	Sulfate	
Calcium	Fluoride	TDS	
Appendix IV Parameters (Total)			
Antimony	Cadmium	Lithium	Selenium
Arsenic	Chromium	Mercury	Thallium
Barium	Cobalt	Molybdenum	Radium 226 and 228 combined
Beryllium	Lead		

[1] Dissolved oxygen, temperature, specific conductance, oxidation/reduction potential, and turbidity are recorded during sample collection.

4.1.3 Part 845 Well Installation and Monitoring

In 2021, 19 additional monitoring wells (MW-7S, MW-8S, MW-11S, MW-12S, MW-12D, MW-20S, MW-20, MW-22, MW-23, MW-24, MW-25, MW-26, MW-27, MW-28, MW-29, MW-30, MW-31, MW-32, and MW-31S) were installed along the perimeter of the AP to assess the vertical and horizontal lithology, stratigraphy, chemical properties, and physical properties of geologic layers to a minimum of 100 feet bgs as specified in 35 I.A.C. § 845.620(b). Additionally, four leachate monitoring wells (XPW01, XPW02, XPW03, and XPW04) were installed within the AP unit to characterize CCR materials and leachate. These locations and samples were discussed in Section 2.5.1.1. The boring logs, well construction forms, and other related monitoring well forms for the well network are included in **Appendix C** of this HCR. The well locations are shown on **Figure 3-1**.

Prospective monitoring wells were sampled for eight rounds between February and August 2021 and the results were used to develop this HCR and assess well locations for inclusion in the AP Part 845 monitoring well network.

Groundwater samples were analyzed for 35 I.A.C. § 845.600 parameters summarized in **Table E** below. Part 845 groundwater monitoring results are included below in **Section 4.2**. A summary of groundwater analytical data is presented in **Table 4-1**.

Table E. Part 845 Groundwater Monitoring Program Parameters

Field Parameters[1]			
Groundwater elevation	pH	Turbidity	
Metals (Total)			
Antimony	Boron	Cobalt	Molybdenum
Arsenic	Cadmium	Lead	Selenium
Barium	Calcium	Lithium	Thallium
Beryllium	Chromium	Mercury	
Inorganics (Total)			
Fluoride	Sulfate	Chloride	TDS
Other (Total)			
Radium 226 and 228 combined			

[1]Dissolved oxygen, temperature, specific conductance, and oxidation/reduction potential were recorded during sample collection.

4.2 Groundwater Monitoring Results and Analysis

Groundwater data collected from the 40 C.F.R. § 257 network monitoring wells between 2015 and 2021 were supplemented with sampling of additional locations in 2021 and evaluated with respect to the standards included in 35 I.A.C. § 845.600(a)(1). This data set was selected because it includes parameters (total metals) consistent with the parameter list in 35 I.A.C. § 845.600(a)(1). Based on this data set, there were no consistent and/or significant concentrations of antimony, cadmium, mercury, molybdenum, selenium, and fluoride greater than the GWPSs. Results indicate that the parameters discussed in the following sections were detected at concentrations greater than the applicable 35 I.A.C. § 845.600(a)(1) standards and are considered potential exceedances[1]. A summary of groundwater analytical data is provided in **Table 4-1**. Groundwater elevations and field parameters are included in **Table 4-2**.

4.2.1 Arsenic

- Arsenic was detected at concentrations greater than the GWPS (0.01 milligrams per liter [mg/L]) in downgradient USCU well MW-31S (two events in June and July 2021). Arsenic concentrations in the USCU ranged from 0.002 to 0.020 mg/L, with a median concentration of 0.006 mg/L.
- Arsenic was detected at concentrations greater than the GWPS in downgradient PMP wells MW-7S (four events in February, June, July, and August 2021), MW-12S (two events in June and July 2021), and MW-27 (four events in February, June, and July 2021). Arsenic concentrations in PMP wells MW-7S, MW-12S, and MW-27 ranged from 0.003 to 0.175 mg/L, with a median of 0.008 mg/L.

[1] Potential exceedances include results reported during the eight rounds of baseline groundwater monitoring that are greater than the applicable 35 I.A.C. § 845.600(a)(1) standards. The results are considered potential exceedances because they were compared directly to the standard and did not include an evaluation of background groundwater quality or apply the statistical methodologies proposed in the Groundwater Monitoring Plan (GMP). For simplicity, "GWPS" will be used hereafter in discussing potential exceedances. Exceedances will be determined following IEPA approval of the GMP.

- Arsenic was detected at concentrations greater than the GWPS in uppermost aquifer wells during groundwater monitoring events between 2015 and 2021.
- Arsenic was not detected at concentrations greater than the GWPS in BCU wells during groundwater monitoring events in 2021.

4.2.2 Barium

- Barium was not detected at concentrations greater than the GWPS (2.0 mg/L) in USCU wells during groundwater monitoring events in 2021.
- Barium was detected at a concentration greater than the GWPS in downgradient PMP well MW-27 (one event in June 2021). Barium concentrations in MW-27 ranged from 0.092 to 2.660 mg/L, with a median concentration of 0.181 mg/L.
- Barium was not detected at concentrations greater than the GWPS in uppermost aquifer wells during groundwater monitoring events between 2015 and 2021.
- Barium was not detected at concentrations greater than the GWPS in BCU wells during groundwater monitoring events in 2021. While not detected at concentrations greater than the GWPS, barium concentrations in BCU well MW-12D were consistently greater than concentrations observed from samples at wells in other units (ranging from 1.26 to 1.90 mg/L).

4.2.3 Beryllium

- Beryllium was not detected at concentrations greater than the GWPS (0.004 mg/L) in USCU wells during groundwater monitoring events in 2021.
- Beryllium was detected in concentrations greater than the GWPS in downgradient PMP well MW-27 (two events in February and June 2021). Beryllium concentrations in MW-27 ranged from non-detect (at a reporting limit of 0.001 mg/L) to 0.010 mg/L, with a median concentration of 0.001 mg/L. The reporting limit for the May 2021 sample from PMP well MW-7S was 0.005 mg/L, higher than the GWPS, but beryllium was not detected in that sample.
- Beryllium was not detected at concentrations greater than the GWPS in uppermost aquifer wells during groundwater monitoring events between 2015 and 2021.
- Beryllium was not detected at concentrations greater than the GWPS in BCU wells during groundwater monitoring events in 2021.

4.2.4 Boron

- Boron was not detected at concentrations greater than the GWPS (2 mg/L) in USCU wells during groundwater monitoring events in 2021.
- Boron was detected at concentrations greater than the GWPS in downgradient PMP wells MW-7S (eight events between February and August 2021) and MW-12S (two events in June and July 2021). Boron concentrations in PMP well MW-7S ranged from 3.56 to 5.51 mg/L, with a median concentration of 4.030 mg/L. Boron concentrations in PMP well MW-12S ranged from 0.856 mg/L to 2.630 mg/L with a median concentration of 1.505 mg/L.
- Boron was detected at concentrations greater than the GWPS in five downgradient uppermost aquifer wells: MW-3 (two events in April and July 2021), MW-11 (one event in November

2018), MW-12 (20 events between 2015 and 2021), MW-23 (four events in February, May, June, and July 2021), and MW-28 (eight events between February and August 2021). Boron concentrations in uppermost aquifer wells ranged from 0.0488 to 10.90 mg/L, with a median concentration of 0.918 mg/L.

- Boron was not detected at concentrations greater than the GWPS in BCU wells during groundwater monitoring events in 2021.

4.2.5 Chloride

- Chloride was not detected at concentrations greater than the GWPS (200 mg/L) in USCU wells or PMP wells during groundwater monitoring events in 2021.
- Chloride was detected at concentrations greater than the GWPS in uppermost aquifer well MW-10 (one event in November 2017). Chloride concentrations in uppermost aquifer well MW-10 ranged from 1.0 to 245 mg/L, with a median concentration of 22.0 mg/L.
- Chloride was detected at concentrations greater than the GWPS in downgradient BCU well MW-12D (six events in February, March, May, July, and August 2021). Chloride concentrations in MW-12D ranged from 195 to 216 mg/L, with a median concentration of 209 mg/L.

4.2.6 Chromium

- Chromium was not detected at concentrations greater than the GWPS (0.1 mg/L) in USCU wells during groundwater monitoring events in 2021.
- Chromium was detected at concentrations greater than the GWPS in downgradient PMP well MW-27 (two events in February and June 2021). Chromium concentrations in PMP well MW-27 ranged from 0.0015 to 0.351 mg/L, with a median concentration of 0.0015 mg/L.
- Chromium was not detected at concentrations greater than the GWPS in uppermost aquifer wells during groundwater monitoring events between 2015 and 2021.
- Chromium was not detected at concentrations greater than the GWPS in BCU wells during groundwater monitoring events in 2021.

4.2.7 Cobalt

- Cobalt was detected at concentrations greater than the GWPS (0.006 mg/L) in downgradient USCU well MW-31S (two events in June and July 2021). Cobalt concentrations in USCU well MW-31S ranged from 0.003 to 0.018 mg/L, with a median concentration of 0.005 mg/L.
- Cobalt was detected at concentrations greater than the GWPS in downgradient PMP wells MW-7S (one event in July 2021) and MW-27 (five events in February, March, June, and July 2021). Cobalt concentrations in PMP wells MW-7S and MW-27 ranged from 0.001 to 0.139 mg/L, with a median concentration of 0.003 mg/L.
- Cobalt was detected at concentrations greater than the GWPS in uppermost aquifer well MW-26 (one event in March 2021). Cobalt concentrations in uppermost aquifer well MW-26 ranged from 0.003 to 0.007 mg/L, with a median concentration of 0.0043 mg/L.
- Cobalt was not detected at concentrations greater than the GWPS in BCU wells during groundwater monitoring events in 2021.

4.2.8 Lead

- Lead was detected at concentrations greater than the GWPS (0.0075 mg/L) in downgradient USCU well MW-31S (two events in June and July 2021). Lead concentrations in USCU well MW-31S ranged from non-detect (at a reporting limit of 0.001 mg/L) to 0.029 mg/L, with a median concentration of 0.003 mg/L.
- Lead was detected at concentrations greater than the GWPS in downgradient PMP wells MW-7S (one event in July 2021) and MW-27 (three events in February, June, and July 2021). Lead concentrations in PMP wells MW-7S and MW-27 ranged from non-detect (at a reporting limit of 0.001 mg/L) to 0.254 mg/L, with a median concentration of 0.003 mg/L.
- Lead was not detected at concentrations greater than the GWPS in uppermost aquifer wells during groundwater monitoring events between 2015 and 2021.
- Lead was not detected at concentrations greater than the GWPS in BCU wells during groundwater monitoring events in 2021.

4.2.9 Lithium

- Lithium was not detected at concentrations greater than the GWPS (0.04 mg/L) in USCU wells during groundwater monitoring events in 2021.
- Lithium was detected at concentrations greater than the GWPS in downgradient PMP well MW-27 (two events in February and June 2021). Lithium concentrations in PMP well MW-27 ranged from non-detect (at a reporting limit of 0.003 mg/L) to 0.178 mg/L, with a median concentration of 0.0071 mg/L.
- Lithium was not detected at concentrations greater than the GWPS in uppermost aquifer wells during groundwater monitoring events between 2015 and 2021.
- Lithium was not detected at concentrations greater than the GWPS in BCU wells during groundwater monitoring events in 2021.

4.2.10 pH

- Measurements of pH were detected at less than the lower limit GWPS for pH (6.5 standard units [SU]) at USCU wells MW-31S (four events in April, May, June, and July 2021) and MW-8S (one event in May 2021). The upper limit standard for pH is 9.0 SU. Measurements of pH at USCU wells MW-31S and MW-8S ranged from 6.30 to 6.80 SU, with a median measurement of 6.55 SU.
- Measurements of pH were detected at less than the lower limit GWPS in PMP wells MW-7S (one event in April 2021), MW-12S (four events in April, June, and July 2021), MW-27 (one event in April 2021), MW-20S, (two events in April and June 2021), and MW-25 (two events in April and May 2021). Measurements of pH at PMP wells MW-7S, MW-12S, MW-27, MW-20S, and MW-25 ranged from 6.20 to 7.00 SU, with a median measurement of 6.57 SU.
- Measurements of pH were detected at less than the lower limit GWPS in uppermost aquifer wells MW-1 (nine events between 2015 and 2021), MW-10 (three events between 2015 and 2021), MW-12 (one event in March 2021), MW-23 (two events in June and July 2021), MW-24 (three events in March, April, and May 2021), MW-26 (two events in April and May 2021), MW-28 (one event in April 2021), MW-29 (one event in April 2021), MW-3 (one event in April 2021), MW-30 (five events in April, May, June, and July 2021), MW-31 (two events in April

and June 2021), MW-32 (seven events in March, April, May, June, July, and August 2021), MW-4 (one event in April 2021), MW-5 (one event in June 2021), MW-6 (one events in June 2021), MW-8 (one event in June 2021), and PZ-4C (two events in April and May 2021). Measurements of pH at uppermost aquifer wells MW-1, MW-10, MW-12, MW-23, MW-24, MW-26, MW-28, MW-29, MW-3, MW-30, MW-31, MW-32, MW-4, MW-5, MW-6, MW-8, and PZ-4C ranged from 6.00 to 7.60 SU, with a median measurement of 6.7 SU.

- Measurements of pH were detected at greater than the upper limit GWPS in BCU well MW-12D (one event in July 2021). Measurements of pH in BCU well MW-12D ranged from 6.70 to 9.9 SU, with a median measurement of 7.2 SU.

4.2.11 Sulfate

- Sulfate was detected at concentrations greater than the GWPS (400 mg/L) in downgradient USCU well MW-8S (four events in February, March, April, and May 2021). Sulfate concentrations within USCU well MW-8S ranged from 427 to 609 mg/L, with a median concentration of 576 mg/L.
- Sulfate was detected at concentrations greater than the GWPS in downgradient PMP well MW-7S (six events in February, March, June, July, and August 2021). Sulfate concentrations in PMP well MW-7S ranged from 343 to 577 mg/L, with a median concentration of 450 mg/L.
- Sulfate was detected at concentrations greater than the GWPS in uppermost aquifer wells MW-7 (one event in December 2015), MW-10 (nine events between 2015 and 2020), MW-12 (four events between 2017 and 2020), MW-28 (eight events between February and August 2021), and MW-32 (eight events between February and August 2021). Sulfate concentrations in uppermost aquifer wells MW-6, MW-7, MW-10, MW-12, MW-28, and MW-32, ranged from 10.0 to 929 mg/L, with a median concentration of 139 mg/L.
- Sulfate was not detected at concentrations greater than the GWPS in BCU wells during groundwater monitoring events in 2021.

4.2.12 Thallium

- Thallium was not detected at concentrations greater than the GWPS (0.002 mg/L) in USCU wells during groundwater monitoring events in 2021.
- Thallium was detected at concentrations greater than the GWPS in downgradient PMP well MW-27 (one event in June 2021). Thallium concentrations in PMP well MW-27 ranged from non-detect (at a reporting limit at the GWPS of 0.002 mg/L) to 0.0022 mg/L.
- Thallium was detected at concentrations greater than the GWPS in downgradient uppermost aquifer wells MW-3 (one event in July 2021) and MW-5 (one event in June 2021). Thallium concentrations in uppermost aquifer wells MW-3 and MW-5 ranged from non-detect (at reporting limit of 0.002 mg/L) to 0.0022 mg/L.
- Thallium was not detected at concentrations greater than the GWPS in BCU wells during groundwater monitoring events in 2021.

4.2.13 Total Dissolved Solids

- TDS was detected at concentrations greater than the GWPS (1,200 mg/L) in downgradient USCU well MW-8S (two events in April and May 2021). TDS concentrations in USCU well MW-8S ranged from 1,150 to 1,320 mg/L, with a median concentration of 1,200 mg/L.

- TDS was detected at concentrations greater than the GWPS in PMP well MW-7S (two events in July and August 2021) during groundwater monitoring events in 2021.
- TDS was detected at concentrations greater than the GWPS in uppermost aquifer wells MW-10 (three events between 2015 and 2018), MW-12 (two events in May and November 2018), and MW-28 (seven events between February and August 2021). TDS concentrations in uppermost aquifer wells MW-10, MW-12, and MW-28 ranged from 224 to 1,830 mg/L, with a median concentration of 620 mg/L.
- TDS was not detected at concentrations greater than the GWPS in BCU wells during groundwater monitoring events in 2021.

4.2.14 Radium 226 and 228 Combined

- Radium 226 and 228 combined was detected at concentrations greater than the GWPS (5 picocuries per liter [pCi/L]) in downgradient USCU well MW-31S (one event in June 2021). Radium 226 and 228 combined concentrations in USCU well MW-31S ranged from 0.340 to 5.29 pCi/L, with a median concentration of 2.8 pCi/L.
- Radium 226 and 228 combined was detected at concentrations greater than the GWPS in downgradient PMP well MW-27 (two events in June and July 2021). Radium 226 and 228 combined concentrations in PMP well MW-27 ranged from 0.318 to 9.25 pCi/L, with a median concentration of 0.897 pCi/L.
- Radium 226 and 228 combined was not detected at concentrations greater than GWPS in uppermost aquifer wells during groundwater monitoring events between 2015 and 2021.
- Radium 226 and 228 combined was not detected at concentrations greater than the GWPS in BCU wells during groundwater monitoring events in 2021.

5. EVALUATION OF POTENTIAL RECEPTORS

5.1 Water Well Survey

A potable water well inventory was completed in 2021 utilizing federal and state databases to assess nearby pumping wells, drinking water receptors, and other uses of water in the vicinity of the AP. The following sources of information were queried to identify well locations, drinking water receptors, and other uses of water within 1,000 meters of the AP boundary:

- ISGS Illinois Water and Related Wells (ILWATER) Map[1]

A search of the ILWATER Map identified nine wells located within 1,000-meters of the KPP. These included two dry wells, one Municipal Water Supply for the Sangchris State park, two farm/domestic wells, one water well for commercial Operation commonwealth, one coal test well, one engineering test, and one test hole. Two (120210003900 and 120212289800) of the nine wells are located downgradient of the AP. The water well potential receptors of the AP are detailed in **Figure B-2** of **Appendix B**.

5.2 Surface Water

A comprehensive search was performed utilizing the United States Fish and Wildlife Service (USFWS) Wetlands Mapper[2] and the USGS National Map[3] for surface water bodies within 1,000 meters of the AP.

As indicated on the USFWS Wetlands Mapper and USGS National Map, 21 surface water features were identified within a 1,000-meter radius of the AP, nine of which are located downgradient of the AP. The predominant surface water body in the region is Sangchris Lake (Hydrologic Unit Code [HUC] 07130007). Sangchris Lake is located directly adjacent to and down-gradient from the AP. Bordering the north perimeter of the AP, Sangchris Lake has a normal pool elevation of about 585 feet NAVD88 (see **Figure 1-1**). The surface water elevation of Sangchris Lake was measured on May 21 and June 9, 2021 and was 585.62 and 585.20 feet NAVD88, respectively. Surface water elevations in Sangchris Lake are not expected to fluctuate in the vicinity of the KPP as a result of the lake being controlled by a dam to provide cooling water for the KPP.

Additional surface water features in the vicinity of the AP include nine freshwater ponds located northwest and southwest; Clear Creek located northwest and southeast; six freshwater emergent wetlands located to the north, northwest, and southwest; three freshwater forested/shrub wetlands located east and southeast; and a small riverine located southeast. A map of wetlands and surface waters in the vicinity of the AP is presented in **Figure B-3** of **Appendix B**.

The USGS National Map places the AP within the Sangchris Lake-Clear Creek Watershed (HUC 071300070402). The HUC watershed location is presented in **Figure B-3** of **Appendix B**.

Based on groundwater elevation contour maps (see **Figures 3-2 and 3-4**), under normal conditions, groundwater predominantly flows to the northwest, towards Sangchris Lake. Due to

[1] ISGS ILWATER Map:
https://prairieresearch.maps.arcgis.com/apps/webappviewer/index.html?id=e06b64ae0c814ef3a4e43a191cb57f87
[2] USFWS Wetlands Mapper: https://www.fws.gov/wetlands/data/mapper.html
[3] USGS National Map: https://apps.nationalmap.gov/viewer/

the downgradient location and proximity of Sangchris Lake to the AP, the Sangchris Lake is likely to be hydraulically connected to the uppermost aquifer beneath the AP.

5.3 Nature Preserves, Historic Sites, Endangered/Threatened Species

A search of the Illinois Department of Natural Resources (IDNR) Natural Heritage Database[4] for natural areas and protected areas within 1,000 meters of the AP was performed. No natural areas were identified within 1,000 meters of the AP. The AP is located within the Abraham Lincoln National Heritage Area, a 17-million-acre Category III Natural Historic Site (see **Figure B-4 in Appendix B**).

The IDNR Natural Heritage Database Threatened and Endangered Species by County[5] lists two endangered and three threatened species in Christian County. Listed threatened species include the Kirtland's Snake, American Orpine, and Franklin's Ground Squirrel, and listed endangered species include the Upland Sandpiper and the Loggerhead Shrike.

Additionally, a search of the IDNR Historic Preservation Division[6] database for historic sites in the vicinity of the Site yielded no results within 1,000 meters of the AP. The Illinois State Archaeological Survey (ISAS)[7] databases that do not require credentials to access were also searched and yielded no results within 1,000 meters of the AP.

[4] IDNR Natural Heritage Database: https://www2.illinois.gov/dnr/conservation/NaturalHeritage/Pages/NaturalHeritageDatabase.aspx
[5] Illinois Threatened and Endangered Species by County: https://www2.illinois.gov/dnr/ESPB/Documents/ET_by_County.pdf
[6] IDNR Historic Preservation Division: https://www2.illinois.gov/dnrhistoric/Pages/default.aspx
[7] ISAS: https://www.isas.illinois.edu/

6. CONCLUSIONS

Based on extensive site investigation and monitoring, the AP has been characterized and a detailed site conceptual model has been developed. Results of these hydrogeologic studies were reintroduced in this HCR and updated to include geologic, hydrogeologic, and groundwater quality data collected with a focus on the AP (Part 845 regulated CCR Unit and subject of this HCR).

The data were summarized and evaluated for changes in groundwater conditions since 2015; available groundwater quality data for the Ash Pond was compared to the Part 845 Standards.

The results of the hydrogeologic and groundwater quality evaluation are:

- There are three principal types of unlithified materials above the bedrock in the vicinity of the Ash Pond, these include the following in descending order:
  - Fill (predominantly coal ash within the AP, but also including constructed berms and railroad embankments around the AP).
  - Cahokia Formation (clays and silts interbedded with thin sand lenses near Sangchris Lake); Vandalia Till (clay and silt with varying amounts of sand and gravel).
  - Bedrock underlying the AP is the Bond Formation, which consists mainly of limestone with lesser amounts of shale and sandstone.
- Five distinct water bearing layers have been identified at the Ash Pond based on stratigraphic relationships and common hydrogeologic characteristics, these include the following in descending order:
  - CCR: saturated CCR, consisting primarily of fly ash and boiler slag.
  - USCU: low permeability clay with some silt and minor sand, silt layers, and occasional discontinuous sand lenses of the Cahokia Formation, as well as high-permeability sand lenses that have been identified as the PMPs.
  - Uppermost Aquifer: thin, generally less than 4 feet, moderate permeability sand, silty sand, and clayey sand and gravel units which includes the unconfined clays and silts of the Upper Cahokia Formation, where saturated, and the thin, moderate permeability sands and gravels of the Lower Cahokia Formation, which at some locations also includes the interface with the Vandalia Till.
  - LCU: low permeability silt and clay with minor sand, silt layers, and occasional discontinuous sand lenses of the Vandalia Till.
  - BCU: composed of interbedded shale and limestone of the Bond Formation.
- The elevations of water within the AP are greater than the surrounding areas and depending on the hydraulic connection between the AP and the surrounding aquifer water may flow radially from the AP toward the lobes of Sangchris Lake.
- Groundwater flow in the uppermost aquifer is to the northwest toward Sangchris Lake. Groundwater elevations are primarily controlled by the surface water level in Sangchris Lake, and the water level within the AP. Typically, groundwater from the AP flows from east to west

and discharges to Sangchris Lake, although there is an apparent groundwater divide located beneath the AP.

- As determined by the detailed geologic information provided for the Ash Pond geology, and the hydrogeologic and groundwater quality data, groundwater within the uppermost aquifer at the Ash Pond is classified as Class II: General Resource Groundwater.
- Potential exceedances of 35 I.A.C. § 845.600 GWPSs were detected in monitoring wells downgradient of the AP in the various hydrostratigraphic units as follows:
  - Arsenic, cobalt, lead, pH, sulfate, TDS, and radium 226 and 228 combined were detected in the USCU wells (not including PMP wells) downgradient of the AP.
  - Arsenic, barium, beryllium, boron, chromium, cobalt, lead, lithium, pH, sulfate, thallium, TDS, and radium 226 and 228 combined were detected in PMP wells downgradient of the AP.
  - Boron, chloride, cobalt, pH, sulfate, thallium, TDS were detected in the uppermost aquifer wells downgradient of the AP.
  - Chloride and pH were detected in the BCU wells downgradient of the AP.

This HCR satisfies Part 845 content requirements specific to 35 I.A.C. Part 845.620(b) (Hydrogeologic Site Characterization) for the AP at the KPP.

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TABLES

TABLE 2-1. GEOTECHNICAL RESULTS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Sample ID	Field Location ID	Top of Sample (ft bgs)	Bottom of Sample (ft bgs)	Moisture Content (%)	Dry Density (pcf)	Specific Gravity	Calculated Porosity [1] (%)	Vertical Hydraulic Conductivity (cm/s)	LL	PL	PI	Laboratory USCS	Gravel (%)	Sand (%)	Fines (%)
CCR															
XPW01 (8.5-9)	XPW01	8.5	9	19.4	74.8	2.790	57%	7.2E-04	12	14	NP	SP	0	97.4	2.6
XPW01 (20.5-21)	XPW01	20.5	21	26.8	79.2	2.838	55%	3.5E-04	17	15	2	SP	0	96.3	3.7
XPW02 (8.5-9)	XPW02	8.5	9	11.8	62.7	2.787	64%	4.0E-03	4	9	NP	SP-SM	0	94.1	5.9
XPW02 (21-21.5)	XPW02	21	21.5	13.9	93.9	2.799	46%	1.9E-03	8	11	NP	SP-SM	0	94.5	5.5
XPW03 (8-8.5)	XPW03	8	8.5	27.4	86.9	2.805	50%	4.3E-03	14	13	1	SW-SM	0.2	91.4	8.4
XPW03 (18-18.5)	XPW03	18	18.5	36.4	89.3	2.770	48%	3.5E-03	5	10	NP	SP	1.6	97.1	1.3
XPW04 (10.5-11)	XPW04	10.5	11	18.3	77.4	2.786	55%	9.2E-04	3	6	NP	SP	0.2	98.4	1.4
XPW04 (21-21.5)	XPW04	21	21.5	32.3	81.3	2.795	53%	5.5E-04	15	16	NP	SP	0	97.3	2.7
Upper Cahokia Formation															
MW-12D (5-7)	MW-12D	5	7	18.6	97.8	2.682	42%	3.2E-07	22	13	9	SC	4.9	49.8	45.3
MW-12D (11.5-12)	MW-12D	11.5	12	18.2	94.5	2.704	44%	7.2E-08	22	12	10	CL	1.1	34.7	64.2
MW-23 (15-17)	MW-23	15	17	28.4	92.7	2.705	45%	7.4E-08	43	17	26	CL	0	2.5	97.5
Lower Cahokia Formation															
MW-12D (20.5-22.5)	MW-12D	20.5	22.5	14.0	106.9	2.672	36%	2.0E-07	22	13	9	SC	6	46.4	47.6
MW-20 (15-17)	MW-20	15	17	18.9	107.7	2.701	36%	1.2E-07	32	14	18	CL	0.6	29.9	69.5
MW-23 (25-27)	MW-23	25	27	15.6	112.3	2.731	34%	5.9E-08	32	14	18	CL	0	41.6	58.4

[O: SSW 04/30/21; U: CJC 08/11/21; C: LDC 08/17/21; U: LDC 09/13/21; C: EJT 09/19/21]

Notes:
[1] Porosity calculated as relationship of bulk density (p_b) to particle density (p_d) ($n = 100[1- (p_b/p_d)]$)
bgs = below ground surface
CCR = coal combustion residuals
cm/s = centimeters per second
ft = foot/feet
LL = Liquid limit
NP = Non-Plastic
pcf = pounds per cubic foot
PI = Plasticity Index
PL = Plastic Limit
% = percent

USCS = Unified Soil Classification System
CL = Lean Clay
SC = Clayey Sand
SP = Poorly Graded Sand
SP-SM = Poorly Graded Sand with Silt
SW-SM = Well Graded Sand with Silt

RAMBOLL

TABLE 2-2. ASH ANALYTICAL RESULTS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Sample Location	Sample Depth (ft BGS)	Sample Date	Antimony (mg/kg)	Arsenic (mg/kg)	Barium (mg/kg)	Beryllium (mg/kg)	Boron (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Cobalt (mg/kg)	Lead (mg/kg)	Lithium (mg/kg)	Mercury (mg/kg)	Molybdenum (mg/kg)	Selenium (mg/kg)	Thallium (mg/kg)
XPW01	6-8	02/01/2021	1.12	1.84	83.8	2.31	107	<0.19	37.7	5.18	3.99	10.7	<0.011	3.35	<0.96	0.19
XPW01	16-18	02/01/2021	<0.73	0.63	34.4	0.74	30.1	<0.19	11.5	2.16	0.68	4.43	<0.012	1.55	<0.93	0.28
XPW01	26-28	02/01/2021	<0.77	1.4	22.7	0.53	21.7	<0.19	7.79	1.4	1.09	2.57	<0.012	1.52	<0.96	<0.19
XPW02	6-8	01/26/2021	0.84	1.36	60.6	1.49	77	0.19	23.4	3.9	5.84	6.75	<0.01	2.08	<0.93	<0.19
XPW02	16-18	01/26/2021	<0.8	2.26	57.7	1.39	69.1	0.26	21.3	4.54	5.68	6.02	<0.012	3.03	<0.96	0.31
XPW03	6-8	01/26/2021	<0.77	1.48	1580	1.23	82.4	0.25	20.6	6.39	4.32	11.1	<0.01	2.09	<0.93	<0.19
XPW03	16-18	01/26/2021	<0.75	1.31	470	2.59	106	<0.19	56.7	7.33	4.32	13.4	<0.01	3.07	<0.94	<0.19
XPW04	5-7	01/26/2021	<1.92	0.45	164	2.09	84.9	<0.2	48.8	5.44	1.93	10.3	<0.011	2.2	<0.98	<0.2
XPW04	20-20.5	01/26/2021	1.05	0.5	112	1.48	60.2	<0.19	23.9	3.81	1.54	7.28	<0.011	1.46	<0.93	<0.19

Notes:
< = concentration is less than the concentration shown, which corresponds to the reporting limit for the method.
BGS = below ground surface
ft = feet
mg/kg = milligrams per kilogram

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TABLE 2-3. POREWATER ANALYTICAL RESULTS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Sample Location	Sample Date	Antimony, total (mg/L)	Arsenic, total (mg/L)	Barium, total (mg/L)	Beryllium, total (mg/L)	Boron, total (mg/L)	Cadmium, total (mg/L)	Calcium, total (mg/L)	Chloride, total (mg/L)	Chromium, total (mg/L)	Cobalt, total (mg/L)	Fluoride, total (mg/L)	Lead, total (mg/L)	Lithium, total (mg/L)	Mercury, total (mg/L)	Molybdenum, total (mg/L)	pH (field) (SU)	Radium 226 and 228 combined (pCi/L)	Selenium, total (mg/L)	Sulfate, total (mg/L)	Thallium, total (mg/L)
XPW01	03/01/2021	<0.001	0.0019	0.056	<0.001	1.5	<0.001	76.8	29	<0.0015	<0.001	0.84	<0.001	0.0159	<0.0002	0.0154	7.5	0.239	0.0037	353	<0.002
XPW01	03/18/2021	<0.001	0.0036	0.0702	<0.001	1.58	<0.001	78.2	25	0.0065	0.0015	0.8	0.0017	0.0197	<0.0002	0.0161	7.3	1.06	0.0198	280	<0.002
XPW01	04/07/2021	<0.001	0.0013	0.0565	<0.001	1.53	<0.001	70.5	29	<0.0015	<0.001	0.73	<0.001	0.0179	<0.0002	0.0142	6.9	0.335	0.0178	295	<0.002
XPW01	05/21/2021	<0.001	0.0013	0.0557	<0.001	1.53	<0.001	89.9	28	<0.0015	<0.001	0.63	<0.001	0.0171	<0.0002	0.0147	7.0	0.141	0.0238	312	<0.002
XPW01	06/10/2021	<0.001	0.001	0.0475	<0.001	1.18	<0.001	80.1	29	<0.0015	<0.001	0.71	<0.001	0.0145	<0.0002	0.0131	7.3	0.729	0.0092	215	<0.002
XPW01	07/02/2021	<0.001	0.0012	0.0521	<0.001	1.2	<0.001	66.1	28	<0.0015	<0.001	0.64	<0.001	0.0124	<0.0002	0.0121	7.3	0.862	0.0042	202	<0.002
XPW01	07/22/2021	<0.001	0.0019	0.0487	<0.001	1.41	<0.001	64.8	29	<0.0015	<0.001	0.62	<0.001	0.0142	<0.0002	0.0147	7.3	0.263	0.0016	237	<0.002
XPW01	08/11/2021	<0.001	0.0013	0.0442	<0.001	1.3	<0.001	60.8	29	<0.0015	<0.001	0.61	<0.001	0.0111	<0.0002	0.0161	7.5	0	<0.001	267	<0.002
XPW02	03/01/2021	<0.001	0.0116	0.0638	<0.001	3.74	<0.001	160	6	0.0046	<0.001	0.45	0.0027	0.0529	<0.0002	0.0446	7.0	0.915	<0.001	437	<0.002
XPW02	03/18/2021	<0.001	0.0091	0.0567	<0.001	4.22	<0.001	169	4	<0.0015	<0.001	0.37	<0.001	0.0573	<0.0002	0.0429	6.7	0.625	<0.001	465	<0.002
XPW02	04/07/2021	<0.001	0.0148	0.0817	<0.001	4.22	<0.001	165	4	0.0075	0.001	0.37	0.004	0.057	<0.0002	0.0445	6.1	1.21	<0.001	435	<0.002
XPW02	05/21/2021	<0.001	0.0073	0.0742	<0.001	3.49	<0.001	145	3	<0.0015	<0.001	0.32	<0.001	0.041	<0.0002	0.0358	6.5	0.675	0.001	314	<0.002
XPW02	06/10/2021	<0.001	0.006	0.0657	<0.001	3.72	<0.001	158	3	<0.0015	<0.001	0.35	<0.001	0.0515	<0.0002	0.0364	6.4	0.532	<0.001	359	<0.002
XPW02	07/02/2021	<0.001	0.0087	0.0675	<0.001	4.23	<0.001	145	3	<0.0015	<0.001	0.33	<0.001	0.0556	<0.0002	0.0349	6.6	0.188	<0.001	359	<0.002
XPW02	07/22/2021	<0.001	0.006	0.0473	<0.001	3.11	<0.001	142	13	<0.0015	<0.001	0.31	<0.001	0.0437	<0.0002	0.0318	6.6	0.433	<0.001	330	<0.002
XPW02	08/11/2021	<0.001	0.0076	0.0579	<0.001	3.52	<0.001	138	3	<0.0015	<0.001	0.31	<0.001	0.0505	<0.0002	0.0364	6.7	0.318	<0.001	353	<0.002
XPW03	03/02/2021	<0.001	0.0037	0.0481	<0.001	2.92	<0.001	180	5	<0.0015	<0.001	0.69	<0.001	0.0299	<0.0002	0.0494	7.1	0.121	<0.001	937	<0.002
XPW03	03/18/2021	<0.001	0.0165	0.0894	<0.001	2.69	<0.001	154	4	0.0036	<0.001	0.62	<0.001	0.0304	<0.0002	0.0434	6.8	0.64	0.0043	745	<0.002
XPW03	04/07/2021	<0.001	0.0172	0.0823	<0.001	4.21	<0.001	153	4	0.0037	<0.001	0.78	<0.001	0.0308	<0.0002	0.0559	6.6	0.013	0.0088	1110	<0.002
XPW03	05/20/2021	<0.001	0.0025	0.0329	<0.001	2.81	<0.001	150	3	<0.0015	<0.001	0.58	<0.001	0.0256	<0.0002	0.0346	6.7	0.178	0.0028	715	<0.002
XPW03	06/10/2021	<0.001	0.0024	0.0356	<0.001	3.11	<0.001	140	4	<0.0015	<0.001	0.68	<0.001	0.0301	<0.0002	0.0383	6.7	0.0626	0.0023	751	<0.002
XPW03	07/01/2021	<0.001	0.005	0.0503	<0.001	3.1	<0.001	128	3	<0.0015	<0.001	0.65	<0.001	0.0272	<0.0002	0.0386	6.8	0.979	<0.001	537	<0.002
XPW03	07/22/2021	<0.001	0.0039	0.0389	<0.001	2.77	<0.001	156	3	<0.0015	<0.001	0.56	<0.001	0.0283	<0.0002	0.0441	6.8	0.11	<0.001	642	<0.002
XPW03	08/11/2021	<0.001	0.0027	0.0373	<0.001	2.85	<0.001	161	3	<0.0015	<0.001	0.51	<0.001	0.0271	<0.0002	0.0353	6.9	0.287	<0.001	684	<0.002

TABLE 2-3. POREWATER ANALYTICAL RESULTS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Sample Location	Sample Date	Antimony, total (mg/L)	Arsenic, total (mg/L)	Barium, total (mg/L)	Beryllium, total (mg/L)	Boron, total (mg/L)	Cadmium, total (mg/L)	Calcium, total (mg/L)	Chloride, total (mg/L)	Chromium, total (mg/L)	Cobalt, total (mg/L)	Fluoride, total (mg/L)	Lead, total (mg/L)	Lithium, total (mg/L)	Mercury, total (mg/L)	Molybdenum, total (mg/L)	pH (field) (SU)	Radium 226 and 228 combined (pCi/L)	Selenium, total (mg/L)	Sulfate, total (mg/L)	Thallium, total (mg/L)
XPW04	03/02/2021	<0.001	<0.001	0.13	<0.001	1.5	<0.001	68.4	18	<0.0015	<0.001	0.46	<0.001	0.0315	<0.0002	0.0065	7.1	1.01	<0.001	51	<0.002
XPW04	03/18/2021	<0.001	<0.001	0.133	<0.001	1.54	<0.001	62.2	14	<0.0015	<0.001	0.5	<0.001	0.0289	<0.0002	0.0064	6.7	0.131	<0.001	44	<0.002
XPW04	04/07/2021	<0.001	0.0012	0.0946	<0.001	2.28	<0.001	63.7	15	<0.0015	<0.001	0.42	<0.001	0.0282	<0.0002	0.0088	6.3	0.235	<0.001	51	<0.002
XPW04	05/20/2021	<0.001	0.0022	0.0719	<0.001	1.26	<0.001	51.8	7	<0.0015	<0.001	0.42	<0.001	0.019	<0.0002	0.0068	6.7	1.07	<0.001	78	<0.002
XPW04	06/09/2021	<0.001	0.0034	0.0803	<0.001	1.5	<0.001	63	9	<0.0015	<0.001	0.5	<0.001	0.021	<0.0002	0.0099	6.6	0.337	<0.001	88	<0.002
XPW04	07/01/2021	<0.001	0.0048	0.0951	<0.001	1.87	<0.001	61.1	10	<0.0015	<0.001	0.49	<0.001	0.0217	<0.0002	0.0135	6.9	1.25	<0.001	87	<0.002
XPW04	07/22/2021	<0.001	0.0038	0.0718	<0.001	1.54	<0.001	65	10	<0.0015	<0.001	0.46	<0.001	0.0204	<0.0002	0.0107	6.7	0.248	<0.001	85	<0.002
XPW04	08/10/2021	<0.001	0.0018	0.0681	<0.001	1.94	<0.001	69.7	12	<0.0015	<0.001	0.48	<0.001	0.0212	<0.0002	0.0107	6.9	1.12	<0.001	104	0.0031

Notes:
Field readings are reported with as many significant figures as provided by analytical laboratory.
< = concentration is less than the concentration shown, which corresponds to the reporting limit for the method.
mg/L = milligrams per liter
pCi/L = picocuries per liter
SU = standard units

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TABLE 2-4. SOIL ANALYTICAL RESULTS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Sample Location	Geologic Unit	Sample Depth (ft BGS)	Sample Date	Antimony (mg/kg)	Arsenic (mg/kg)	Barium (mg/kg)	Beryllium (mg/kg)	Boron (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Cobalt (mg/kg)	Lead (mg/kg)	Lithium (mg/kg)	Mercury (mg/kg)	Molybdenum (mg/kg)	Selenium (mg/kg)	Thallium (mg/kg)
MW-12D	Upper Cahokia Formation	3-5	01/26/2021	<0.37	8.46	127	0.59	9.36	<0.19	18	9.25	25.5	11.7	0.476	0.52	<0.94	<0.19
MW-12D	Upper Cahokia Formation	10.8-12.8	01/26/2021	<0.39	4.97	50	<0.29	7.02	<0.2	7.94	3.05	8.75	5.19	<0.012	0.58	<0.98	<0.2
MW-12D	Lower Cahokia Formation	33-35	01/26/2021	0.73	24.4	84.4	0.58	11.8	0.61	17.8	10	14.3	7.36	0.028	3.83	1.06	0.37
MW-12D	Bedrock	49-51	01/26/2021	<0.38	2.6	49.2	0.37	5.86	0.36	10.4	2.2	2.49	3.32	<0.01	<0.2	<1	<0.2
MW-20	Upper Cahokia Formation	13-15	01/26/2021	<0.73	8.21	98.6	0.82	<4.63	<0.19	21.7	7.42	13	13.4	0.014	0.35	<0.93	<0.19
MW-20	Lower Cahokia Formation	43-45	01/26/2021	<0.38	6.17	75.4	0.45	8.4	<0.18	14.8	7.16	9.57	15.6	0.014	1.71	<0.91	0.2
MW-23	Upper Cahokia Formation	13-15	02/02/2021	<0.37	6.36	204	0.94	6.19	<0.19	23.6	9.21	14.2	11.7	0.029	<0.19	<0.96	0.25
MW-23	Lower Cahokia Formation	25-27	02/02/2021	<0.39	6.42	74.5	0.59	9.61	<0.19	17.8	8.18	10.7	15.2	0.014	1.1	<0.93	<0.19

Notes:
< = concentration is less than the concentration shown, which corresponds to the reporting limit for the method.
BGS = below ground surface
ft = foot or feet
mg/kg = milligrams per kilogram

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TABLE 3-1. MONITORING WELL LOCATIONS AND CONSTRUCTION DETAILS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Well Number	HSU	Date Constructed	Top of PVC Elevation (ft)	Measuring Point Elevation (ft)	Measuring Point Description	Ground Elevation (ft)	Screen Top Depth (ft BGS)	Screen Bottom Depth (ft BGS)	Screen Top Elevation (ft)	Screen Bottom Elevation (ft)	Well Depth (ft BGS)	Bottom of Boring Elevation (ft)	Screen Length (ft)	Screen Diameter (inches)	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)
MW-1	UA	04/20/2010	604.71	604.71	Top of PVC	602.60	15.00	25.00	587.60	577.60	25.00	568.10	10	2	39.592051	-89.490283
MW-2	UA	04/21/2010	601.10	601.10	Top of PVC	598.88	10.00	20.00	588.90	578.90	20.00	541.40	10	2	39.590698	-89.488916
MW-3	UA	04/15/2010	601.46	601.46	Top of PVC	599.24	14.00	24.00	585.20	575.20	24.00	552.70	10	2	39.594458	-89.487173
MW-4	UA	04/14/2010	600.88	600.88	Top of PVC	598.46	12.00	22.00	586.50	576.50	22.00	560.50	10	2	39.600751	-89.487354
MW-5	UA	04/22/2010	619.44	619.44	Top of PVC	617.77	30.00	40.00	587.80	577.80	40.00	541.80	10	2	39.601296	-89.490402
MW-6	UA	04/16/2010	600.46	600.46	Top of PVC	598.44	10.00	20.00	588.40	578.40	20.00	572.90	10	2	39.598638	-89.498944
MW-7	UA	04/16/2010	597.75	597.75	Top of PVC	596.00	10.00	20.00	586.00	576.00	20.00	569.50	10	2	39.597637	-89.498959
MW-7S	USCU	02/02/2021	597.64	597.64	Top of PVC	595.59	6.00	11.00	589.59	584.59	11.00	580.59	5	2	39.59766	-89.498978
MW-8	UA	04/13/2010	603.14	603.14	Top of PVC	601.14	12.00	22.00	589.10	579.10	22.00	563.10	10	2	39.594399	-89.496829
MW-8S	USCU	02/02/2021	603.30	603.30	Top of PVC	600.57	4.00	7.00	596.57	593.57	7.00	580.57	3	2	39.594381	-89.496822
MW-9	UA	04/19/2010	599.39	599.39	Top of PVC	597.63	10.00	20.00	587.60	577.60	20.00	573.10	10	2	39.595204	-89.500968
MW-10	UA	04/19/2010	600.11	600.11	Top of PVC	598.22	10.00	20.00	588.20	578.20	20.00	575.20	10	2	39.590652	-89.503745
MW-11	UA	06/17/2015	601.81	601.81	Top of PVC	599.27	11.00	21.00	588.30	578.30	21.00	578.30	10	2	39.593104	-89.491115
MW-11S	USCU	01/26/2021	601.76	601.76	Top of PVC	599.43	4.00	8.00	595.43	591.43	8.00	591.43	4	2	39.593122	-89.491102
MW-12	UA	07/23/2015	591.40	591.40	Top of PVC	589.04	15.00	25.00	573.90	563.90	25.00	563.90	10	2	39.600208	-89.496381
MW-12S	USCU	01/27/2021	591.10	591.10	Top of PVC	588.62	5.00	9.00	583.62	579.62	9.00	579.12	4	2	39.600208	-89.496412
MW-12D	BCU	01/26/2021	590.96	590.96	Top of PVC	589.08	50.00	55.00	539.08	534.08	55.00	489.08	5	2	39.600194	-89.496418
MW-20	UA	01/26/2021	600.77	600.77	Top of PVC	598.52	14.00	24.00	584.52	574.52	24.00	547.52	10	2	39.598653	-89.48728
MW-20S	USCU	01/26/2021	600.64	600.64	Top of PVC	598.43	4.00	10.00	594.43	588.43	10.00	588.43	6	2	39.598665	-89.487279
MW-22	UA	02/03/2021	601.77	601.77	Top of PVC	599.51	15.00	19.00	584.51	580.51	19.00	579.51	4	2	39.593235	-89.487638
MW-23	UA	02/02/2021	610.32	610.32	Top of PVC	608.05	23.00	28.00	585.05	580.05	28.00	558.05	5	2	39.593293	-89.489352
MW-24	UA	02/02/2021	615.48	615.48	Top of PVC	613.01	27.00	32.00	586.01	581.01	32.00	581.01	5	2	39.593271	-89.493267
MW-25	USCU	02/02/2021	607.20	607.20	Top of PVC	604.60	9.00	14.00	595.60	590.60	14.00	579.60	5	2	39.594397	-89.495062

TABLE 3-1. MONITORING WELL LOCATIONS AND CONSTRUCTION DETAILS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Well Number	HSU	Date Constructed	Top of PVC Elevation (ft)	Measuring Point Elevation (ft)	Measuring Point Description	Ground Elevation (ft)	Screen Top Depth (ft BGS)	Screen Bottom Depth (ft BGS)	Screen Top Elevation (ft)	Screen Bottom Elevation (ft)	Well Depth (ft BGS)	Bottom of Boring Elevation (ft)	Screen Length (ft)	Screen Diameter (inches)	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)
MW-26	UA	02/02/2021	596.16	596.16	Top of PVC	593.33	7.00	12.00	586.33	581.33	12.00	573.33	5	2	39.595584	-89.497582
MW-27	USCU	02/02/2021	600.05	600.05	Top of PVC	597.35	10.00	15.00	587.35	582.35	15.00	577.35	5	2	39.596694	-89.497927
MW-28	UA	02/02/2021	601.40	601.40	Top of PVC	598.33	12.00	22.00	586.33	576.33	22.00	573.33	10	2	39.599258	-89.497962
MW-29	UA	02/01/2021	599.94	599.94	Top of PVC	596.86	14.00	19.00	582.86	577.86	19.00	576.86	5	2	39.599691	-89.497249
MW-30	UA	02/03/2021	618.47	618.47	Top of PVC	616.00	35.00	40.00	581.00	576.00	40.00	571.00	5	2	39.601262	-89.493996
MW-31	UA	02/03/2021	617.34	617.34	Top of PVC	615.02	35.00	40.00	580.02	575.02	40.00	565.02	5	2	39.601301	-89.491702
MW-31S	USCU	02/03/2021	617.54	617.54	Top of PVC	615.13	25.00	30.00	590.13	585.13	30.00	585.13	5	2	39.601303	-89.491681
MW-32	UA	02/03/2021	619.49	619.49	Top of PVC	617.20	32.00	37.00	585.20	580.20	37.00	577.20	5	2	39.601279	-89.488643
PZ-4C	UA	03/30/2016	600.57	600.57	Top of PVC	597.89	15.50	20.50	582.39	577.39	20.50	577.39	5	2	39.596398	-89.487207
XPW01	CCR	02/01/2021	627.84	627.84	Top of PVC	625.48	22.00	32.00	603.48	593.48	32.00	593.48	10	2	39.594417	-89.493104
XPW02	CCR	01/26/2021	620.19	620.19	Top of PVC	617.91	13.00	23.00	604.91	594.91	23.00	595.91	10	2	39.597918	-89.49687
XPW03	CCR	01/26/2021	616.08	616.08	Top of PVC	616.08	10.00	20.00	606.08	596.08	20.00	596.08	10	2	39.599588	-89.495765
XPW04	CCR	01/26/2021	606.53	606.53	Top of PVC	604.57	13.00	23.00	591.57	581.57	23.00	580.57	10	2	39.600737	-89.492276
XSG-01	CCR	--	--	608.43	Staff gauge	--	--	--	--	--	--	--	--	--	39.593401	-89.48768
SG-02	SW	--	--	564.80	Staff gauge	--	--	--	--	--	--	--	--	--	39.593106	-89.498155

Notes:
All elevation data are presented relative to the North American Vertical Datum 1988 (NAVD88), GEOID 12A
-- = data not available
BCU = bedrock confining unit
BGS = below ground surface
CCR = Coal Combustion Residual
ft = foot or feet
HSU = Hydrostratigraphic Unit
PVC = polyvinyl chloride
SW = surface water
UA = uppermost aquifer
USCU = upper semi-confining unit

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TABLE 3-2. VERTICAL HYDRAULIC GRADIENTS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Date	MW-12 Groundwater Elevation (ft NAVD88)	MW-12D Groundwater Elevation (ft NAVD88)	Head Change (ft)	Distance Change [1] (ft)	Vertical Hydraulic Gradient [2] (dh/dl)	
	UA	BCU				
2/23/2021	584.12	584.55	-0.43	32.46	-0.013	up
3/15/2021	584.70	585.36	-0.66	32.46	-0.020	up
4/5/2021	585.10	586.23	-1.13	32.46	-0.035	up
5/20/2021	586.59	587.18	-0.59	32.46	-0.018	up
6/10/2021	585.02	586.55	-1.53	32.46	-0.047	up
7/01/2021-7/02/2021	585.41	586.71	-1.30	32.46	-0.040	up
7/22/2021-7/23/2021	584.98	586.58	-1.60	32.46	-0.049	up
8/10/2021-8/11/2021	585.05	586.71	-1.66	32.46	-0.051	up
			Middle of screen elevation MW-12			569.0
			Middle of screen elevation MW-12D			536.6

Date	MW-12S Groundwater Elevation (ft NAVD88)	MW-12 Groundwater Elevation (ft NAVD88)	Head Change (ft)	Distance Change [1] (ft)	Vertical Hydraulic Gradient [2] (dh/dl)	
	PMP	UA				
2/23/2021	584.81	584.12	0.69	12.58	0.055	down
3/15/2021	585.43	584.70	0.73	12.58	0.058	down
4/5/2021	585.53	585.10	0.43	12.58	0.034	down
5/20/2021	587.19	586.59	0.60	12.58	0.048	down
6/10/2021	585.27	585.02	0.25	12.58	0.020	down
7/01/2021-7/02/2021	585.60	585.41	0.19	12.58	0.015	down
7/22/2021-7/23/2021	585.12	584.98	0.14	12.58	0.011	down
8/10/2021-8/11/2021	585.31	585.05	0.26	12.58	0.021	down
			Middle of screen elevation MW-12S			581.6
			Middle of screen elevation MW-12			569.0

TABLE 3-2. VERTICAL HYDRAULIC GRADIENTS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Date	MW-31S Groundwater Elevation (ft NAVD88)	MW-31 Groundwater Elevation (ft NAVD88)	Head Change (ft)	Distance Change [1] (ft)	Vertical Hydraulic Gradient [2] (dh/dl)	
	USCU	UA				
2/23/2021	591.18	587.68	3.50	10.11	0.346	down
3/15/2021	591.83	587.96	3.87	10.11	0.383	down
4/5/2021	590.92	587.86	3.06	10.11	0.303	down
5/20/2021	592.83	588.63	4.20	10.11	0.415	down
6/09/2021-6/10/2021	588.77	586.66	2.11	11.25	0.188	down
7/1/2021	588.55	594.19	-5.64	11.03	-0.511	up
7/22/2021-7/23/2021	588.55	586.69	1.86	11.03	0.169	down
8/10/2021	588.30	587.49	0.81	10.78	0.075	down
			Middle of screen elevation MW-31S			587.6
			Middle of screen elevation MW-31			577.5

Date	MW-8S Groundwater Elevation (ft NAVD88)	MW-8 Groundwater Elevation (ft NAVD88)	Head Change (ft)	Distance Change [1] (ft)	Vertical Hydraulic Gradient [2] (dh/dl)	
	USCU	UA				
2/23/2021	594.97	595.54	-0.57	10.83	-0.053	up
3/15/2021	594.85	595.97	-1.12	10.71	-0.105	up
4/5/2021	594.45	594.70	-0.25	10.31	-0.024	up
5/21/2021	597.46	597.33	0.13	10.93	0.012	down
6/10/2021	593.90	593.85	0.05	9.76	0.005	down
7/1/2021	--	598.50	--	--	--	--
7/22/2021	--	594.15	--	--	--	--
8/10/2021	--	596.10	--	--	--	--
			Middle of screen elevation MW-8S			595.1
			Middle of screen elevation MW-8			584.1

TABLE 3-2. VERTICAL HYDRAULIC GRADIENTS

HYDROGEOLOGIC SITE CHARACTERIZATION REPORT

KINCAID POWER PLANT

ASH POND

KINCAID, ILLINOIS

Date	MW-7S Groundwater Elevation (ft NAVD88)	MW-7 Groundwater Elevation (ft NAVD88)	Head Change (ft)	Distance Change [1] (ft)	Vertical Hydraulic Gradient [2] (dh/dl)	
	USCU	UA				
2/23/2021	587.18	589.45	-2.27	6.18	-0.367	up
3/15/2021	587.26	594.86	-7.60	6.26	-1.214	up
4/5/2021	587.12	588.64	-1.52	6.12	-0.248	up
5/21/2021	587.86	591.55	-3.69	6.86	-0.538	up
6/10/2021	587.44	586.86	0.58	6.44	0.090	down
7/01/2021-7/02/2021	587.34	592.54	-5.20	6.34	-0.820	up
7/22/2021-7/23/2021	587.33	587.73	-0.40	6.33	-0.063	up
8/10/2021-8/11/2021	587.73	595.40	-7.67	6.73	-1.140	up
			Middle of screen elevation MW-7S			587.1
			Middle of screen elevation MW-7			581.0

[O:SSW 06/09/21; U:LDC 08/18/21, C:CJC 08/18/21; U:LDC 09/13/21, C:EJT 09/15/21]

Notes:

[1] Distance change was calculated using the midpoint of the piezometer screen and water table surface. If the water table surface was above the top of the monitoring well screen, then distance change was calculated using the midpoint of both screens.

[2] Vertical gradients between ±0.0015 are considered flat, and typically have less than 0.02 foot difference in groundwater elevation between wells.

-- = data not available

BCU = bedrock confining unit

dh = head change

dl = distance change

ft = foot/feet

NAVD88 = North American Vertical Datum of 1988

PMP = potential migration pathway

UA = uppermost aquifer

USCU = upper semi-confining unit

TABLE 3-3. FIELD HYDRAULIC CONDUCTIVITIES
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Well ID	Gradient Position	Bottom of Screen Elevation (ft NAVD88)	Screen Length [1] (ft)	Field Identified Screened Material (USCS)	Slug Type	Analysis Method	Number of Field Tests	Test Analyzed [2]	Hydraulic Conductivity (cm/s)	Minimum Hydraulic Conductivity (cm/s)	Maximum Hydraulic Conductivity (cm/s)	Hydraulic Conductivity Geometric Mean (cm/s)
USCU												
MW-12S*	D	579.62	5	CL	Solid	Kansas Geological Survey	4	FH-1	3.30E-05	1.56E-05	1.22E-04	5.04E-05
MW-25*	D	590.60	5	SW-SM/CL	Solid	Kansas Geological Survey	4	FH-1	1.03E-04			
MW-27*	D	582.35	5	CL/SC/ML	Solid	Bouwer-Rice	1	FH-1	1.56E-05			
MW-20S	U	588.43	6	ML/CL	Solid	Bouwer-Rice	4	FH-1	1.22E-04			
UA												
MW-20	U	574.52	10	ML/CL	Solid	Bouwer-Rice	1	FH-1	6.77E-06	1.29E-06	5.35E-04	4.14E-05
MW-22	D	580.51	4	SC/SP-SC	Solid	Bouwer-Rice	2	RH-1	3.80E-05			
MW-23	D	580.05	5	CL	Solid	Kansas Geological Survey	4	FH-1	5.35E-04			
MW-26	D	581.33	5	SC/ML	Solid	Bouwer-Rice	1	FH-1	1.29E-06			
MW-28	D	576.33	10	ML/SM	Solid	Bouwer-Rice	4	FH-1	1.34E-04			
MW-29	D	577.86	5	SW-SM	Solid	Cooper-Bredehoeft-Papadopulos	4	FH-1	1.18E-04			
MW-30	D	576.00	5	CL/ML/SM	Solid	Kansas Geological Survey	1	FH-1	7.07E-06			
MW-31	D	575.02	5	CL/ML/SC	Solid	Cooper-Bredehoeft-Papadopulos	2	FH-1	3.30E-05			
MW-32	D	580.20	5	CL/ML	Solid	Kansas Geological Survey	4	RH-1	4.61E-04			
PZ-4C	D	577.39	5	CL	Solid	Bouwer-Rice	2	FH-1	4.95E-05			
BCU												
MW-12D	D	534.08	5	BR	Solid	Kansas Geological Survey	4	FH-1	1.69E-03	1.69E-03	1.69E-03	1.69E-03
CCR												
XPW-01	NA	593.48	10	SW-SM	Solid	Springer-Gelhar	6	FH-1	2.64E-01	2.09E-02	2.64E-01	8.57E-02
XPW-02	NA	594.91	10	SW/SP	Solid	Springer-Gelhar	4	RH-1	2.09E-02			
XPW-03	NA	596.08	10	SW	Solid	Springer-Gelhar	4	RH-2	9.48E-02			
XPW-04	NA	581.57	10	SW	Solid	Springer-Gelhar	6	FH-1	1.03E-01			

[O: SSW 06/09/21; U:CJC 08/17/21; C: LDC 08/17/21; U: LDC 09/13/21; C: EJT 09/19/21]

Notes:
[1] All wells are constructed from 2 inch polyvinyl chloride (PVC) with 0.01 inch slotted screens.
[2] Test response data (elapsed time and corresponding changes in water levels) were plotted as normalized displacement to evaluate similarity among repeat test data within each well. A single test was selected for analysis at each well based on the quality of the test data (*i.e.,* smooth recovery curve) and coincidence of repeat test data.
* Well in the upper semi-confining unit that has been identified to monitor the potential migration pathway.
BCU = bedrock confining unit
CCR = coal combustion residuals
cm/s = centimeters per second
D = Downgradient
FH-1 = Falling Head 1 Test
ft = foot/feet
NAVD88 = North American Vertical Datum of 1988
RH-1 = Rising Head 1 Test
RH-2 = Rising Head 2 Test
U = Upgradient
UA = uppermost aquifer
USCU = upper semi-confining unit

USCS = Unified Soil Classification System
BR = Bedrock
CL = Lean Clay
ML = Silt
SC = Clayey Sand
SM = Silty Sand
SP = Poorly Graded Sand
SP-SC = Poorly Graded Sand with Clay
SW = Well Graded Sand with Gravel
SW-SM = Well Graded Sand with Silt

TABLE 3-4. HORIZONTAL HYDRAULIC GRADIENTS AND GROUNDWATER FLOW VELOCITIES
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

$V = K i \ / n_e$

V = Groundwater Velocity [1]
K = Hydraulic Conductivity [2]
i = hydraulic gradient
n_e = Effective Porosity [3]

North of CCR Unit (MW-5 to MW-31): Uppermost Aquifer

Distance between Wells (ft): 360
Hydraulic Conductivity (ft/day): 0.05
Effective Porosity (%): 18.3 Assumes: sand, silt, and clay

Date	MW-5 Groundwater Elevation (ft NAVD88)	MW-31 Groundwater Elevation (ft NAVD88)	Change in Elevation (ft)	Horizontal Gradient (ft/ft)	Velocity (ft/day)
2/23/2021	594.09	587.68	6.41	0.018	0.005
3/15/2021	594.36	587.96	6.40	0.018	0.005
4/5/2021	593.84	587.86	5.98	0.017	0.004
5/20/2021	594.57	588.63	5.94	0.017	0.004
6/9/2021	593.15	586.66	6.49	0.018	0.005
7/1/2021	593.94	594.19	-0.25	-0.001	0.000
7/22/2021	593.09	586.69	6.40	0.018	0.005
8/10/2021	594.66	587.49	7.17	0.020	0.005
			Average	0.015	0.004

Northwest of CCR Unit (MW-6 to MW-12): Uppermost Aquifer

Distance between Wells (ft): 905
Hydraulic Conductivity (ft/day): 0.04
Effective Porosity (%): 18.3 Assumes: sand, silt, and clay

Date	MW-6 Groundwater Elevation (ft NAVD88)	MW-12 Groundwater Elevation (ft NAVD88)	Change in Elevation (ft)	Horizontal Gradient (ft/ft)	Velocity (ft/day)
2/23/2021	592.01	584.12	7.89	0.009	0.002
3/15/2021	592.27	584.70	7.57	0.008	0.002
3/30/2021	594.96	585.65	9.31	0.010	0.002
4/5/2021	593.71	585.10	8.61	0.010	0.002
5/20/2021-5/21/2021	595.26	586.59	8.67	0.010	0.002
6/10/2021	591.58	585.02	6.56	0.007	0.002
7/1/2021	590.43	585.41	5.02	0.006	0.001
7/22/2021	591.82	584.98	6.84	0.008	0.002
8/10/2021	592.67	585.05	7.62	0.008	0.002
			Average	0.008	0.002

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TABLE 3-4. HORIZONTAL HYDRAULIC GRADIENTS AND GROUNDWATER FLOW VELOCITIES

HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Southwest of CCR Unit (MW-8 to MW-26): Uppermost Aquifer

Distance between Wells (ft): 485
Hydraulic Conductivity (ft/day): 0.01
Effective Porosity (%): 18.3 Assumes: sand, silt, and clay

Date	MW-8 Groundwater Elevation (ft NAVD88)	MW-26 Groundwater Elevation (ft NAVD88)	Change in Elevation (ft)	Horizontal Gradient (ft/ft)	Velocity (ft/day)
2/23/2021	595.54	588.87	6.67	0.014	0.001
3/15/2021	595.97	589.61	6.36	0.013	0.001
4/5/2021	594.70	591.21	3.49	0.007	0.001
5/21/2021	597.33	592.50	4.83	0.010	0.001
6/9/2021-6/10/2021	593.85	589.04	4.81	0.010	0.001
7/1/2021	598.50	586.18	12.32	0.025	0.002
7/22/2021	594.15	585.02	9.13	0.019	0.001
8/10/2021	596.10	586.14	9.96	0.021	0.002
			Average	0.015	0.001

Southwest of CCR Unit (MW-25 to MW-27): Upper Semi-Confining Unit/Potential Migration Pathway

Distance between Wells (ft): 1165
Hydraulic Conductivity (ft/day): 0.17
Effective Porosity (%): 17.5 Assumes: sand and clay

Date	MW-25 Groundwater Elevation (ft NAVD88)	MW-27 Groundwater Elevation (ft NAVD88)	Change in Elevation (ft)	Horizontal Gradient (ft/ft)	Velocity (ft/day)
2/23/2021	601.41	586.05	15.36	0.013	0.013
3/15/2021	601.60	587.14	14.46	0.012	0.012
4/5/2021	601.24	591.44	9.80	0.008	0.008
5/21/2021	602.14	594.44	7.70	0.007	0.006
6/9/2021-6/10/2021	583.98	583.38	0.60	0.001	0.000
7/1/2021-7/2/2021	601.23	585.55	15.68	0.013	0.013
7/22/2021-7/23/2021	600.36	584.70	15.66	0.013	0.013
8/11/2021	601.24	585.72	15.52	0.013	0.013
			Average	0.010	0.010

[O: SSW 06/09/21; U: LDC 08/18/21, C: EJT 08/18/21; U: CJC 10/01/21; C: SSW 10/01/21]

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TABLE 3-4. HORIZONTAL HYDRAULIC GRADIENTS AND GROUNDWATER FLOW VELOCITIES

HYDROGEOLOGIC SITE CHARACTERIZATION REPORT

KINCAID POWER PLANT

ASH POND

KINCAID, ILLINOIS

Notes:

[1] A negative groundwater velocity indicates a reversal of groundwater flow from normal conditions.

[2] Hydraulic conductivity values used above are average of the individual wells used in each velocity calculation as derived from slug tests completed in August 2015 and April 2021 by Ramboll.

[3] Effective porosity used in these calculations was derived from an average between estimated values of 0.20 for silt material, 0.267 for gravel, 0.07 for clay, and 0.28 for sand from Morris, D.A. and A.I. Johnson, 1967. *Summary of hydrologic and physical properties of rock and soil materials as analyzed by the Hydrologic Laboratory of the U.S. Geological Survey,* U.S. Geological Survey Water-Supply Paper 1839-D, 42p. and Heath, R.C., 1983. *Basic ground-water hydrology,* U.S. Geological Survey Water-Supply Paper 2220, 86p. Effective porosity may be as high as maximum total porosity (45%) calculated in Table 2-1.

% = percent

ft= foot/feet

ft/day = feet per day

ft/ft = feet per foot

NAVD88 = North American Vertical Datum of 1988

TABLE 4-1. GROUNDWATER ANALYTICAL RESULTS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Location	Sample Date	Antimony, total (mg/L)	Arsenic, total (mg/L)	Barium, total (mg/L)	Beryllium, total (mg/L)	Boron, total (mg/L)	Cadmium, total (mg/L)	Calcium, total (mg/L)	Chloride, total (mg/L)	Chromium, total (mg/L)	Cobalt, total (mg/L)	Fluoride, total (mg/L)	Lead, total (mg/L)	Lithium, total (mg/L)	Mercury, total (mg/L)	Molybdenum, total (mg/L)	pH (field) (SU)	Radium 226 and 228 combined (pCi/L)	Selenium, total (mg/L)	Sulfate, total (mg/L)	Thallium, total (mg/L)	Total Dissolved Solids (mg/L)
35 I.A.C. 845.600	Lower	0	0	0	0	0	0	--	0	0	0	0	0	0	0	0	6.5	0	0	0	0	0
	Upper	0.006	0.010	2.0	0.004	2	0.005	--	200	0.1	0.006	4.0	0.0075	0.04	0.002	0.1	9.0	5	0.05	400	0.002	1200
MW-1	06/03/2015	--	--	--	--	--	--	--	--	--	--	0.17	--	--	<0	--	--	--	--	--	--	--
MW-1	06/16/2015	<0.001	<0.025	0.0482	<0.0005	0.192	<0.002	--	10	<0.005	<0.005	0.16	<0.0075	--	<0.0002	--	6.8	--	<0.04	106	<0.001	358
MW-1	12/15/2015	<0.001	<0.001	0.0458	<0.001	0.255	<0.001	58.8	12	<0.001	<0.001	0.19	<0.001	0.0019	<0.0002	<0.001	6.6	0.47	<0.001	113	<0.001	314
MW-1	02/29/2016	<0.001	<0.001	0.0448	<0.001	0.203	<0.001	63.9	11	<0.001	<0.001	0.16	<0.001	0.0017	<0.0002	<0.001	6.6	0.537	<0.001	117	<0.001	292
MW-1	05/16/2016	<0.001	<0.001	0.0446	<0.001	0.229	<0.001	59.3	10	<0.001	<0.001	0.16	<0.001	0.0016	<0.0002	<0.001	6.9	0.34	<0.001	108	<0.001	336
MW-1	08/22/2016	<0.001	<0.001	0.0465	<0.001	0.269	<0.001	61.1	11	<0.001	<0.001	0.18	<0.001	0.0016	<0.0002	<0.001	6.8	1.03	<0.001	117	<0.001	358
MW-1	11/15/2016	<0.001	<0.001	0.0471	<0.001	0.271	<0.001	57.6	11	<0.001	<0.001	0.18	<0.001	0.0021	<0.0002	<0.001	7.0	0.16	<0.001	109	<0.001	390
MW-1	02/13/2017	<0.001	<0.001	0.0437	<0.001	0.228	<0.001	57.5	10	<0.001	<0.001	0.16	<0.001	0.0015	<0.0002	<0.001	6.8	0.58	<0.001	105	<0.001	326
MW-1	05/18/2017	<0.001	<0.001	0.0465	<0.001	0.256	<0.001	57	12	<0.001	<0.001	0.16	<0.001	0.0017	<0.0002	<0.001	6.7	0.41	<0.001	109	<0.001	370
MW-1	07/18/2017	<0.001	<0.001	0.0443	<0.001	0.273	<0.001	55.6	11	0.0018	<0.001	0.18	<0.001	0.002	<0.0002	<0.001	6.7	1.35	<0.001	101	<0.001	334
MW-1	11/06/2017	<0.001	<0.001	0.0487	<0.001	0.281	<0.001	60.3	11	<0.001	<0.001	0.18	<0.001	--	<0.0002	--	6.8	1.53	<0.001	104	<0.001	340
MW-1	05/31/2018	<0.001	<0.001	0.0444	<0.001	0.234	<0.001	59.1	12	0.0016	<0.001	0.19	<0.001	0.0017	<0.0002	<0.0015	6.5	1.72	<0.001	91	<0.002	356
MW-1	08/28/2018	--	<0.001	0.044	--	0.258	--	59.8	11	0.009	<0.001	0.18	<0.001	0.0026	--	0.0016	6.2	0.41	<0.001	94	--	374
MW-1	11/08/2018	<0.001	<0.001	0.0619	<0.001	0.352	<0.001	--	12	<0.0015	<0.001	0.19	<0.001	--	<0.0002	--	6.4	0.08	<0.001	95	<0.002	400
MW-1	02/14/2019	<0.001	<0.001	0.0498	<0.001	0.243	<0.001	66	10	<0.0015	<0.001	0.17	<0.001	0.0019	<0.0002	<0.0015	6.7	0.92	<0.001	92	<0.002	312
MW-1	05/14/2019	<0.001	<0.001	0.0451	<0.001	0.21	<0.001	--	11	<0.0015	<0.001	0.19	<0.001	--	<0.0002	--	6.4	0.26	<0.001	97	<0.002	364
MW-1	08/21/2019	--	<0.001	0.0489	--	0.29	--	60.2	10	<0.0015	<0.001	0.18	<0.001	<0.003	--	<0.0015	6.3	0.68	<0.001	80	--	334
MW-1	11/13/2019	<0.001	<0.001	0.0462	<0.001	0.278	<0.001	--	9	<0.0015	<0.001	0.19	<0.001	--	<0.0002	--	6.5	0.48	<0.001	101	<0.002	326
MW-1	02/11/2020	<0.001	<0.001	0.0466	<0.001	0.222	<0.001	59.6	8	<0.0015	<0.001	0.18	<0.001	<0.003	<0.0002	<0.0015	6.6	2.38	<0.001	92	<0.002	366
MW-1	05/12/2020	<0.001	<0.001	0.0464	<0.001	0.223	<0.001	--	8	<0.0015	<0.001	0.18	<0.001	--	<0.0002	--	6.6	1.3	<0.001	102	<0.002	350
MW-1	08/26/2020	<0.001	<0.001	0.0463	<0.001	0.252	--	57.5	7	<0.0015	<0.001	0.23	<0.001	<0.003	--	<0.0015	6.6	2.55	<0.001	93	--	300
MW-1	12/02/2020	<0.001	<0.001	0.0459	<0.001	0.28	<0.001	--	7	<0.0015	<0.001	0.2	<0.001	--	<0.0002	--	6.6	1.31	<0.001	97	<0.002	302

TABLE 4-1. GROUNDWATER ANALYTICAL RESULTS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Location	Sample Date	Antimony, total (mg/L)	Arsenic, total (mg/L)	Barium, total (mg/L)	Beryllium, total (mg/L)	Boron, total (mg/L)	Cadmium, total (mg/L)	Calcium, total (mg/L)	Chloride, total (mg/L)	Chromium, total (mg/L)	Cobalt, total (mg/L)	Fluoride, total (mg/L)	Lead, total (mg/L)	Lithium, total (mg/L)	Mercury, total (mg/L)	Molybdenum, total (mg/L)	pH (field) (SU)	Radium 226 and 228 combined (pCi/L)	Selenium, total (mg/L)	Sulfate, total (mg/L)	Thallium, total (mg/L)	Total Dissolved Solids (mg/L)
35 I.A.C. 845.600	Lower	0	0	0	0	0	0	--	0	0	0	0	0	0	0	0	6.5	0	0	0	0	0
	Upper	0.006	0.010	2.0	0.004	2	0.005	--	200	0.1	0.006	4.0	0.0075	0.04	0.002	0.1	9.0	5	0.05	400	0.002	1200
MW-1	02/24/2021	<0.001	<0.001	0.0475	<0.001	0.214	<0.001	57	7	<0.0015	<0.001	0.19	<0.001	<0.005	<0.0002	<0.0015	6.5	0.222	<0.001	93	<0.002	332
MW-1	03/15/2021	<0.001	<0.001	0.043	<0.001	0.195	<0.001	55.3	6	<0.0015	<0.001	0.18	<0.001	<0.003	<0.0002	<0.0015	6.5	0.38	<0.001	89	<0.002	330
MW-1	03/30/2021	<0.001	<0.001	0.0445	<0.001	0.204	<0.001	57.8	6	<0.0015	<0.001	0.18	<0.001	<0.003	<0.0002	<0.0015	6.5	0	<0.001	84	<0.002	298
MW-1	04/05/2021	<0.001	<0.001	0.0412	<0.001	0.204	<0.001	56.4	7	<0.0015	<0.001	0.19	<0.001	<0.003	<0.0002	<0.0015	6.0	0.0782	<0.001	84	<0.002	304
MW-1	05/19/2021	<0.001	<0.001	0.0413	<0.001	0.218	<0.001	57.8	7	<0.0015	<0.001	0.18	<0.001	<0.003	<0.0002	<0.0015	6.1	0.0767	<0.001	84	<0.002	310
MW-1	06/10/2021	<0.001	<0.001	0.0441	<0.001	0.217	<0.001	54.8	8	<0.0015	<0.001	0.21	<0.001	<0.003	<0.0002	<0.0015	6.2	0.416	<0.001	90	<0.002	306
MW-1	07/01/2021	<0.001	<0.001	0.0471	<0.001	0.226	<0.001	58.3	8	<0.0015	<0.001	0.2	<0.001	<0.003	<0.0002	<0.0015	6.2	0.54	<0.001	87	<0.002	306
MW-1	07/22/2021	<0.001	<0.001	0.0504	<0.001	0.296	<0.001	57.3	12	<0.0015	<0.001	0.2	<0.001	<0.003	<0.0002	<0.0015	6.3	0.265	<0.001	85	<0.002	302
MW-1	08/10/2021	<0.001	<0.001	0.0413	<0.001	0.266	<0.001	54.8	9	<0.0015	<0.001	0.19	<0.001	<0.003	<0.0002	<0.0015	6.3	0.521	<0.001	86	<0.002	308
MW-1	09/01/2021	<0.001	<0.001	0.0466	<0.001	0.301	<0.001	55.2	9	<0.0015	<0.001	0.19	<0.001	<0.003	<0.0002	<0.0015	6.5	0.456	<0.001	85	<0.002	302
MW-2	06/03/2015	--	--	--	--	--	--	--	--	--	--	0.49	--	--	<0	--	--	--	--	--	--	--
MW-2	06/16/2015	<0.001	<0.025	0.122	<0.0005	0.0608	<0.002	--	17	<0.005	<0.005	0.46	<0.0075	--	<0.0002	--	7.5	--	<0.04	150	<0.001	500
MW-2	12/15/2015	<0.001	0.0022	0.127	<0.001	0.11	<0.001	105	16	0.0025	0.0012	0.47	0.0014	0.0068	<0.0002	0.004	7.1	0.58	0.0048	171	<0.001	566
MW-2	02/29/2016	<0.001	<0.001	0.111	<0.001	0.0873	<0.001	104	17	<0.001	<0.001	0.43	<0.001	0.0063	<0.0002	0.0053	7.2	0.16	<0.001	143	<0.001	416
MW-2	05/16/2016	<0.001	0.0011	0.113	<0.001	0.0892	<0.001	101	15	<0.001	<0.001	0.45	<0.001	0.0056	<0.0002	0.0043	7.4	0.87	0.0016	159	<0.001	534
MW-2	08/22/2016	<0.001	<0.001	0.114	<0.001	0.0808	<0.001	97.3	14	<0.001	<0.001	0.47	<0.001	0.0055	<0.0002	0.0039	7.4	1.26	<0.001	169	<0.001	566
MW-2	11/15/2016	<0.001	0.0011	0.113	<0.001	0.102	<0.001	101	13	<0.001	<0.001	0.47	<0.001	0.0057	<0.0002	0.004	7.5	0.01	<0.001	161	<0.001	576
MW-2	02/13/2017	<0.001	<0.001	0.112	<0.001	0.101	<0.001	97.5	14	<0.001	<0.001	0.44	<0.001	0.0058	<0.0002	0.0043	7.2	0	<0.001	173	<0.001	520
MW-2	05/18/2017	<0.001	<0.001	0.112	<0.001	0.106	<0.001	104	14	<0.001	<0.001	0.43	<0.001	0.0051	<0.0002	0.0037	7.2	1.16	<0.001	178	<0.001	596
MW-2	07/18/2017	<0.001	0.0015	0.112	<0.001	0.111	<0.001	99.2	15	0.0019	<0.001	0.45	<0.001	0.0055	<0.0002	0.0042	7.3	1.72	<0.001	159	<0.001	512
MW-2	11/06/2017	<0.001	0.0015	0.114	<0.001	0.0848	<0.001	102	14	<0.001	<0.001	0.44	<0.001	--	<0.0002	--	7.1	0.62	<0.001	159	<0.001	506
MW-2	05/31/2018	<0.001	0.0058	0.163	<0.001	0.0787	<0.001	125	14	0.0139	0.0052	0.5	0.0067	0.016	<0.0002	0.0051	7.0	0.86	0.0026	142	<0.002	538

TABLE 4-1. GROUNDWATER ANALYTICAL RESULTS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Location	Sample Date	Antimony, total (mg/L)	Arsenic, total (mg/L)	Barium, total (mg/L)	Beryllium, total (mg/L)	Boron, total (mg/L)	Cadmium, total (mg/L)	Calcium, total (mg/L)	Chloride, total (mg/L)	Chromium, total (mg/L)	Cobalt, total (mg/L)	Fluoride, total (mg/L)	Lead, total (mg/L)	Lithium, total (mg/L)	Mercury, total (mg/L)	Molybdenum, total (mg/L)	pH (field) (SU)	Radium 226 and 228 combined (pCi/L)	Selenium, total (mg/L)	Sulfate, total (mg/L)	Thallium, total (mg/L)	Total Dissolved Solids (mg/L)
35 I.A.C. 845.600	Lower	0	0	0	0	0	0	--	0	0	0	0	0	0	0	0	6.5	0	0	0	0	0
	Upper	0.006	0.010	2.0	0.004	2	0.005	--	200	0.1	0.006	4.0	0.0075	0.04	0.002	0.1	9.0	5	0.05	400	0.002	1200
MW-2	08/28/2018	--	0.0013	0.103	--	0.0907	--	104	14	0.0023	<0.001	0.44	<0.001	0.0043	--	0.0033	6.8	0.42	0.0023	145	--	558
MW-2	11/08/2018	<0.001	0.0024	0.156	<0.001	0.152	<0.001	--	14	0.0017	<0.001	0.45	<0.001	--	<0.0002	--	6.9	0.22	0.0056	139	<0.002	556
MW-2	02/14/2019	<0.001	0.0015	0.116	<0.001	0.0701	<0.001	104	18	<0.0015	<0.001	0.55	<0.001	0.007	<0.0002	0.0058	7.4	0.24	<0.001	136	<0.002	442
MW-2	05/14/2019	<0.001	0.001	0.107	<0.001	0.058	<0.001	--	18	<0.0015	<0.001	0.55	<0.001	--	<0.0002	--	7.2	0.61	<0.001	132	<0.002	516
MW-2	08/20/2019	--	0.001	0.107	--	0.0667	--	94.2	16	<0.0015	<0.001	0.48	<0.001	0.0051	--	0.0046	7.1	0.94	<0.001	119	--	488
MW-2	11/13/2019	<0.001	0.0022	0.12	<0.001	0.0571	<0.001	--	17	0.0029	0.0011	0.53	0.0012	--	<0.0002	--	7.3	0.42	<0.001	132	<0.002	464
MW-2	02/11/2020	<0.001	0.0021	0.117	<0.001	0.0565	<0.001	94.9	18	<0.0015	<0.001	0.52	<0.001	0.007	<0.0002	0.005	7.3	0.99	<0.001	138	<0.002	508
MW-2	05/12/2020	<0.001	<0.001	0.107	<0.001	0.0488	<0.001	--	18	<0.0015	<0.001	0.52	<0.001	--	<0.0002	--	7.4	0	<0.001	153	<0.002	490
MW-2	08/26/2020	<0.001	<0.001	0.106	<0.001	0.0576	--	96.6	17	<0.0015	<0.001	0.55	<0.001	0.0051	--	0.0047	7.3	0.92	<0.001	139	--	442
MW-2	12/02/2020	<0.001	<0.001	0.103	<0.001	0.0714	<0.001	--	15	<0.0015	<0.001	0.48	<0.001	--	<0.0002	--	7.3	1.32	<0.001	139	<0.002	474
MW-2	02/24/2021	<0.001	0.0016	0.113	<0.001	0.0571	<0.001	96.7	15	<0.0015	<0.001	0.46	<0.001	<0.005	<0.0002	0.0038	7.2	0.0315	<0.001	138	<0.002	490
MW-2	03/15/2021	<0.001	0.0014	0.115	<0.001	0.069	<0.001	97.3	17	<0.0015	<0.001	0.44	<0.001	0.0052	<0.0002	0.0037	7.3	0.178	<0.001	146	<0.002	494
MW-2	03/30/2021	<0.001	0.0013	0.113	<0.001	0.0609	<0.001	96.2	16	<0.0015	<0.001	0.47	<0.001	0.005	<0.0002	0.0036	7.1	0.662	<0.001	129	<0.002	458
MW-2	04/05/2021	<0.001	0.0048	0.15	<0.001	0.0711	<0.001	111	18	0.0095	0.0039	0.44	0.0051	0.0116	<0.0002	0.0041	6.7	0.103	0.0018	137	<0.002	482
MW-2	05/19/2021	<0.001	<0.001	0.0937	<0.001	0.0698	<0.001	95.4	16	<0.0015	<0.001	0.43	<0.001	0.0035	<0.0002	0.0035	7.0	0.114	<0.001	145	<0.002	464
MW-2	06/10/2021	<0.001	0.001	0.11	<0.001	0.0552	<0.001	92	18	<0.0015	<0.001	0.51	<0.001	0.0044	<0.0002	0.004	7.0	0.665	<0.001	150	<0.002	456
MW-2	07/01/2021	<0.001	0.0014	0.116	<0.001	0.0582	<0.001	96.6	17	<0.0015	<0.001	0.48	<0.001	0.0042	<0.0002	0.0033	6.5	0.206	<0.001	151	<0.002	470
MW-2	07/22/2021	<0.001	0.0014	0.126	<0.001	0.0852	<0.001	96.6	16	<0.0015	<0.001	0.46	<0.001	0.0048	<0.0002	0.0036	6.6	0.554	<0.001	146	<0.002	480
MW-2	08/10/2021	<0.001	0.0017	0.126	<0.001	0.0791	<0.001	106	16	<0.0015	<0.001	0.45	<0.001	0.0061	<0.0002	0.0062	6.9	1.03	<0.001	144	<0.002	490
MW-2	09/01/2021	<0.001	0.0014	0.101	<0.001	0.128	<0.001	93.4	15	<0.0015	<0.001	0.42	<0.001	0.004	<0.0002	0.0034	7.0	0.725	<0.001	133	<0.002	476
MW-3	06/03/2015	--	--	--	--	--	--	--	--	--	--	0.22	--	--	<0	--	--	--	--	--	--	--
MW-3	06/16/2015	<0.001	<0.025	0.065	<0.0005	1.5	<0.002	--	30	<0.005	<0.005	0.23	<0.0075	--	<0.0002	--	7.1	--	<0.04	209	<0.001	680

TABLE 4-1. GROUNDWATER ANALYTICAL RESULTS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Location	Sample Date	Antimony, total (mg/L)	Arsenic, total (mg/L)	Barium, total (mg/L)	Beryllium, total (mg/L)	Boron, total (mg/L)	Cadmium, total (mg/L)	Calcium, total (mg/L)	Chloride, total (mg/L)	Chromium, total (mg/L)	Cobalt, total (mg/L)	Fluoride, total (mg/L)	Lead, total (mg/L)	Lithium, total (mg/L)	Mercury, total (mg/L)	Molybdenum, total (mg/L)	pH (field) (SU)	Radium 226 and 228 combined (pCi/L)	Selenium, total (mg/L)	Sulfate, total (mg/L)	Thallium, total (mg/L)	Total Dissolved Solids (mg/L)
35 I.A.C. 845.600	Lower	0	0	0	0	0	0	--	0	0	0	0	0	0	0	0	6.5	0	0	0	0	0
	Upper	0.006	0.010	2.0	0.004	2	0.005	--	200	0.1	0.006	4.0	0.0075	0.04	0.002	0.1	9.0	5	0.05	400	0.002	1200
MW-3	12/15/2015	<0.001	<0.001	0.0575	<0.001	1.68	<0.001	--	37	<0.001	<0.001	0.25	<0.001	--	<0.0002	--	7.0	--	<0.001	189	<0.001	686
MW-3	05/16/2016	<0.001	<0.001	0.0573	<0.001	1.44	<0.001	--	34	<0.001	<0.001	0.23	<0.001	--	<0.0002	--	7.1	--	<0.001	188	<0.001	672
MW-3	11/15/2016	<0.001	<0.001	0.0533	<0.001	1.66	<0.001	--	34	<0.001	<0.001	0.22	<0.001	--	<0.0002	--	7.3	--	<0.001	199	<0.001	708
MW-3	05/18/2017	<0.001	<0.001	0.0494	<0.001	1.71	<0.001	--	36	<0.001	<0.001	0.24	<0.001	--	<0.0002	--	6.7	--	<0.001	182	<0.001	684
MW-3	11/06/2017	<0.001	<0.001	0.0261	<0.001	1.02	<0.001	--	32	<0.001	<0.001	0.23	<0.001	--	<0.0002	--	7.1	0.04	<0.001	150	<0.001	618
MW-3	05/31/2018	<0.001	<0.001	0.0448	<0.001	1.67	<0.001	--	34	<0.0015	<0.001	0.26	<0.001	--	<0.0002	--	6.8	0.52	<0.001	152	<0.002	634
MW-3	11/08/2018	<0.001	<0.001	0.0461	<0.001	1.83	<0.001	--	32	<0.0015	<0.001	0.26	<0.001	--	<0.0002	--	7.0	0.52	<0.001	154	<0.002	656
MW-3	05/14/2019	<0.001	<0.001	0.0416	<0.001	1.57	<0.001	--	31	<0.0015	<0.001	0.27	<0.001	--	<0.0002	--	6.7	0.36	<0.001	122	<0.002	586
MW-3	11/13/2019	<0.001	<0.001	0.0466	<0.001	1.79	<0.001	--	26	<0.0015	<0.001	0.25	<0.001	--	<0.0002	--	6.8	0.73	<0.001	158	<0.002	584
MW-3	05/12/2020	<0.001	<0.001	0.0503	<0.001	1.73	<0.001	--	29	<0.0015	<0.001	0.25	<0.001	--	<0.0002	--	6.9	0.43	<0.001	156	<0.002	628
MW-3	12/02/2020	<0.001	<0.001	0.0453	<0.001	1.82	<0.001	--	29	<0.0015	<0.001	0.24	<0.001	--	<0.0002	--	6.8	0.4	<0.001	143	<0.002	582
MW-3	02/25/2021	<0.001	<0.001	0.0503	<0.001	1.58	<0.001	102	33	<0.0015	0.0014	0.25	<0.001	<0.005	<0.0002	<0.0015	6.8	0.195	<0.001	141	<0.002	610
MW-3	03/16/2021	<0.001	<0.001	0.0499	<0.001	1.58	<0.001	103	32	<0.0015	<0.001	0.24	<0.001	<0.003	<0.0002	<0.0015	6.7	0.387	<0.001	147	<0.002	616
MW-3	04/05/2021	<0.001	<0.001	0.0837	<0.001	2.4	<0.001	104	34	<0.0015	0.0012	0.25	<0.001	0.004	<0.0002	<0.0015	6.4	0.381	<0.001	142	<0.002	606
MW-3	05/18/2021	<0.001	<0.001	0.0479	<0.001	1.55	<0.001	104	31	<0.0015	<0.001	0.24	<0.001	<0.003	<0.0002	<0.0015	6.7	0.125	<0.001	145	<0.002	604
MW-3	06/09/2021	<0.001	<0.001	0.0513	<0.001	1.56	<0.001	98.7	32	<0.0015	<0.001	0.27	<0.001	<0.003	<0.0002	<0.0015	6.5	0.271	<0.001	141	<0.002	558
MW-3	07/01/2021	<0.001	<0.001	0.0491	<0.001	1.57	<0.001	101	31	<0.0015	<0.001	0.26	<0.001	<0.003	<0.0002	<0.0015	6.6	0.988	<0.001	138	0.0022	590
MW-3	07/22/2021	<0.001	<0.001	0.0626	<0.001	2.28	<0.001	102	32	<0.0015	<0.001	0.26	<0.001	<0.003	<0.0002	<0.0015	6.7	0.115	<0.001	139	<0.002	588
MW-3	08/10/2021	<0.001	<0.001	0.0471	<0.001	1.56	<0.001	98.3	32	<0.0015	<0.001	0.24	<0.001	<0.003	<0.0002	<0.0015	6.7	0	<0.001	139	<0.002	582
MW-4	06/03/2015	--	--	--	--	--	--	--	--	--	--	0.35	--	--	<0	--	--	--	--	--	--	--
MW-4	06/16/2015	<0.001	<0.025	0.172	<0.0005	0.339	<0.002	--	31	<0.005	<0.005	0.35	<0.0075	--	<0.0002	--	7.3	--	<0.04	35	<0.001	530
MW-4	12/15/2015	<0.001	<0.001	0.132	<0.001	0.627	<0.001	--	30	<0.001	<0.001	0.33	<0.001	--	<0.0002	--	6.9	--	<0.001	72	<0.001	514

TABLE 4-1. GROUNDWATER ANALYTICAL RESULTS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Location	Sample Date	Antimony, total (mg/L)	Arsenic, total (mg/L)	Barium, total (mg/L)	Beryllium, total (mg/L)	Boron, total (mg/L)	Cadmium, total (mg/L)	Calcium, total (mg/L)	Chloride, total (mg/L)	Chromium, total (mg/L)	Cobalt, total (mg/L)	Fluoride, total (mg/L)	Lead, total (mg/L)	Lithium, total (mg/L)	Mercury, total (mg/L)	Molybdenum, total (mg/L)	pH (field) (SU)	Radium 226 and 228 combined (pCi/L)	Selenium, total (mg/L)	Sulfate, total (mg/L)	Thallium, total (mg/L)	Total Dissolved Solids (mg/L)
35 I.A.C. 845.600	Lower	0	0	0	0	0	0	--	0	0	0	0	0	0	0	0	6.5	0	0	0	0	0
	Upper	0.006	0.010	2.0	0.004	2	0.005	--	200	0.1	0.006	4.0	0.0075	0.04	0.002	0.1	9.0	5	0.05	400	0.002	1200
MW-4	05/16/2016	<0.001	<0.001	0.121	<0.001	0.602	<0.001	--	28	<0.001	<0.001	0.31	<0.001	--	<0.0002	--	7.1	--	<0.001	74	<0.001	496
MW-4	11/15/2016	<0.001	<0.001	0.171	<0.001	0.43	<0.001	--	30	<0.001	<0.001	0.35	<0.001	--	<0.0002	--	7.3	--	<0.001	35	<0.001	552
MW-4	05/18/2017	<0.001	<0.001	0.121	<0.001	0.661	<0.001	--	29	<0.001	<0.001	0.31	<0.001	--	<0.0002	--	6.8	--	<0.001	72	<0.001	544
MW-4	11/06/2017	<0.001	<0.001	0.0697	<0.001	0.4	<0.001	--	28	0.0015	<0.001	0.31	<0.001	--	<0.0002	--	7.1	0.59	<0.001	62	<0.001	506
MW-4	05/31/2018	<0.001	<0.001	0.145	<0.001	0.563	<0.001	--	29	<0.0015	<0.001	0.33	<0.001	--	<0.0002	--	6.8	0.68	<0.001	58	<0.002	492
MW-4	11/08/2018	<0.001	<0.001	0.14	<0.001	0.679	<0.001	--	27	<0.0015	<0.001	0.32	<0.001	--	<0.0002	--	7.0	0	<0.001	52	<0.002	546
MW-4	05/14/2019	<0.001	<0.001	0.112	<0.001	0.618	<0.001	--	26	<0.0015	<0.001	0.33	<0.001	--	<0.0002	--	6.7	0.1	<0.001	51	<0.002	496
MW-4	11/13/2019	<0.001	<0.001	0.152	<0.001	0.438	<0.001	--	28	<0.0015	<0.001	0.38	<0.001	--	<0.0002	--	6.9	0.35	<0.001	19	<0.002	458
MW-4	05/12/2020	<0.001	<0.001	0.115	<0.001	0.668	<0.001	--	26	<0.0015	<0.001	0.33	<0.001	--	<0.0002	--	7.0	0.07	<0.001	43	<0.002	484
MW-4	12/02/2020	<0.001	<0.001	0.146	<0.001	0.565	<0.001	--	28	<0.0015	<0.001	0.38	<0.001	--	<0.0002	--	7.2	0.13	<0.001	18	<0.002	432
MW-4	02/25/2021	<0.001	<0.001	0.129	<0.001	0.55	<0.001	85.1	30	<0.0015	<0.001	0.34	<0.001	<0.005	<0.0002	<0.0015	6.9	0.487	<0.001	35	<0.002	474
MW-4	03/16/2021	<0.001	<0.001	0.122	<0.001	0.567	<0.001	91.2	29	<0.0015	<0.001	0.32	<0.001	0.0031	<0.0002	<0.0015	6.9	0.0762	<0.001	34	<0.002	470
MW-4	04/06/2021	<0.001	<0.001	0.133	<0.001	0.715	<0.001	94.6	27	<0.0015	<0.001	0.31	<0.001	0.0034	<0.0002	<0.0015	6.4	0.191	<0.001	45	<0.002	474
MW-4	05/19/2021	<0.001	<0.001	0.0965	<0.001	0.843	<0.001	93.6	26	<0.0015	<0.001	0.29	<0.001	<0.003	<0.0002	<0.0015	6.6	0.685	<0.001	57	<0.002	478
MW-4	06/09/2021	<0.001	<0.001	0.12	<0.001	0.49	<0.001	--	30	<0.0015	<0.001	0.38	<0.001	--	<0.0002	--	6.6	0.324	<0.001	27	<0.002	478
MW-5	06/04/2015	--	--	--	--	--	--	--	--	--	--	0.16	--	--	<0	--	--	--	--	--	--	--
MW-5	06/16/2015	<0.001	<0.025	0.15	<0.0005	0.544	<0.002	--	32	<0.005	<0.005	0.15	<0.0075	--	<0.0002	--	7.0	--	<0.04	<10	<0.001	695
MW-5	12/15/2015	<0.001	<0.001	0.141	<0.001	0.573	<0.001	137	41	<0.001	0.0013	0.17	<0.001	0.0029	<0.0002	<0.001	6.6	0.78	<0.001	<10	<0.001	620
MW-5	02/29/2016	<0.001	<0.001	0.143	<0.001	0.555	<0.001	148	39	<0.001	0.001	0.15	<0.001	0.003	<0.0002	<0.001	6.6	0.35	<0.001	<10	<0.001	564
MW-5	05/16/2016	<0.001	<0.001	0.141	<0.001	0.588	<0.001	133	38	<0.001	<0.001	0.15	<0.001	0.0029	<0.0002	<0.001	7.0	0.89	<0.001	11	<0.001	646
MW-5	08/22/2016	<0.001	<0.001	0.137	<0.001	0.54	<0.001	135	41	<0.001	<0.001	0.16	<0.001	0.0027	<0.0002	<0.001	7.2	1.11	<0.001	11	<0.001	660
MW-5	11/15/2016	<0.001	<0.001	0.139	<0.001	0.507	<0.001	133	41	<0.001	<0.001	0.15	<0.001	0.0027	<0.0002	<0.001	7.2	1.08	<0.001	<10	<0.001	698

TABLE 4-1. GROUNDWATER ANALYTICAL RESULTS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Location	Sample Date	Antimony, total (mg/L)	Arsenic, total (mg/L)	Barium, total (mg/L)	Beryllium, total (mg/L)	Boron, total (mg/L)	Cadmium, total (mg/L)	Calcium, total (mg/L)	Chloride, total (mg/L)	Chromium, total (mg/L)	Cobalt, total (mg/L)	Fluoride, total (mg/L)	Lead, total (mg/L)	Lithium, total (mg/L)	Mercury, total (mg/L)	Molybdenum, total (mg/L)	pH (field) (SU)	Radium 226 and 228 combined (pCi/L)	Selenium, total (mg/L)	Sulfate, total (mg/L)	Thallium, total (mg/L)	Total Dissolved Solids (mg/L)
35 I.A.C. 845.600	Lower	0	0	0	0	0	0	--	0	0	0	0	0	0	0	0	6.5	0	0	0	0	0
	Upper	0.006	0.010	2.0	0.004	2	0.005	--	200	0.1	0.006	4.0	0.0075	0.04	0.002	0.1	9.0	5	0.05	400	0.002	1200
MW-5	02/13/2017	<0.001	<0.001	0.14	<0.001	0.473	<0.001	130	39	<0.001	<0.001	0.15	<0.001	0.0029	<0.0002	<0.001	6.7	0.34	<0.001	<10	<0.001	624
MW-5	05/18/2017	<0.001	<0.001	0.145	<0.001	0.571	<0.001	136	43	<0.001	<0.001	0.18	<0.001	0.0031	<0.0002	<0.001	6.7	0.95	<0.001	10	<0.001	680
MW-5	07/18/2017	<0.001	<0.001	0.143	<0.001	0.574	<0.001	142	39	<0.001	<0.001	0.16	0.0013	0.0029	<0.0002	<0.001	6.8	2.41	<0.001	<10	<0.001	660
MW-5	11/06/2017	<0.001	<0.001	0.139	<0.001	0.515	<0.001	141	40	0.0023	<0.001	0.15	<0.001	--	<0.0002	--	7.1	0.63	<0.001	<10	<0.001	652
MW-5	05/31/2018	<0.001	<0.001	0.179	<0.001	0.657	<0.001	136	43	<0.0015	<0.001	0.18	<0.001	0.0033	<0.0002	<0.0015	6.7	0.61	<0.001	<10	<0.002	666
MW-5	08/28/2018	--	<0.001	0.132	--	0.567	--	135	41	<0.0015	<0.001	0.17	<0.001	0.0029	--	<0.0015	6.8	0.55	<0.001	12	--	696
MW-5	11/08/2018	<0.001	<0.001	0.146	<0.001	0.546	<0.001	--	42	<0.0015	<0.001	0.16	<0.001	--	<0.0002	--	6.9	0.37	<0.001	10	<0.002	712
MW-5	02/14/2019	<0.001	<0.001	0.156	<0.001	0.53	<0.001	147	42	<0.0015	<0.001	0.16	<0.001	0.0029	<0.0002	<0.0015	7.0	0.04	<0.001	12	<0.002	650
MW-5	05/14/2019	<0.001	<0.001	0.16	<0.001	0.536	<0.001	--	44	<0.0015	<0.001	0.18	<0.001	--	<0.0002	--	6.6	0.3	<0.001	12	<0.002	674
MW-5	08/21/2019	--	<0.001	0.15	--	0.547	--	150	41	<0.0015	<0.001	0.18	<0.001	<0.003	--	<0.0015	6.6	1.15	<0.001	<10	--	646
MW-5	11/14/2019	<0.001	<0.001	0.144	<0.001	0.521	<0.001	--	42	<0.0015	<0.001	0.16	<0.001	--	<0.0002	--	6.7	0.36	<0.001	12	<0.002	646
MW-5	02/11/2020	<0.001	<0.001	0.131	<0.001	0.542	<0.001	146	44	<0.0015	<0.001	0.18	<0.001	<0.003	<0.0002	<0.0015	6.7	0.85	<0.001	<10	<0.002	684
MW-5	05/12/2020	<0.001	<0.001	0.149	<0.001	0.581	<0.001	--	45	<0.0015	<0.001	0.17	<0.001	--	<0.0002	--	6.8	0.16	<0.001	13	<0.002	680
MW-5	08/26/2020	<0.001	<0.001	0.151	<0.001	0.507	--	146	45	<0.0015	<0.001	<0.2	<0.001	<0.003	--	<0.0015	6.7	0.94	<0.001	14	--	622
MW-5	12/02/2020	<0.001	0.0016	0.163	<0.001	0.543	<0.001	--	43	<0.0015	0.001	0.17	<0.001	--	<0.0002	--	6.7	0.22	<0.001	10	<0.002	622
MW-5	03/30/2021	<0.001	<0.001	0.154	<0.001	0.555	<0.001	150	43	<0.0015	<0.001	0.18	<0.001	<0.003	<0.0002	<0.0015	6.5	0	<0.001	13	<0.002	666
MW-5	06/09/2021	<0.001	<0.001	0.153	<0.001	0.543	<0.001	--	47	<0.0015	<0.001	0.19	<0.001	--	<0.0002	--	6.4	0.118	<0.001	13	0.0021	662
MW-5	09/01/2021	<0.001	0.0014	0.144	<0.001	0.625	<0.001	143	47	<0.0015	<0.001	0.16	<0.001	0.0031	<0.0002	<0.0015	6.6	0.0861	<0.001	<10	<0.002	652
MW-6	06/04/2015	--	--	--	--	--	--	--	--	--	--	0.19	--	--	<0	--	--	--	--	--	--	--
MW-6	06/16/2015	<0.001	<0.025	0.0306	<0.0005	1	<0.002	--	5	<0.005	<0.005	0.19	<0.0075	--	<0.0002	--	7.0	--	<0.04	161	<0.001	635
MW-6	12/15/2015	<0.001	<0.001	0.0316	<0.001	1.58	<0.001	113	7	<0.001	<0.001	0.18	<0.001	0.0012	<0.0002	<0.001	6.5	0.48	<0.001	287	<0.001	676
MW-6	02/29/2016	<0.001	<0.001	0.0274	<0.001	0.837	<0.001	101	5	<0.001	<0.001	0.17	<0.001	<0.001	<0.0002	<0.001	6.7	0.01	<0.001	164	<0.001	358

TABLE 4-1. GROUNDWATER ANALYTICAL RESULTS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Location	Sample Date	Antimony, total (mg/L)	Arsenic, total (mg/L)	Barium, total (mg/L)	Beryllium, total (mg/L)	Boron, total (mg/L)	Cadmium, total (mg/L)	Calcium, total (mg/L)	Chloride, total (mg/L)	Chromium, total (mg/L)	Cobalt, total (mg/L)	Fluoride, total (mg/L)	Lead, total (mg/L)	Lithium, total (mg/L)	Mercury, total (mg/L)	Molybdenum, total (mg/L)	pH (field) (SU)	Radium 226 and 228 combined (pCi/L)	Selenium, total (mg/L)	Sulfate, total (mg/L)	Thallium, total (mg/L)	Total Dissolved Solids (mg/L)
35 I.A.C. 845.600	Lower	0	0	0	0	0	0	--	0	0	0	0	0	0	0	0	6.5	0	0	0	0	0
	Upper	0.006	0.010	2.0	0.004	2	0.005	--	200	0.1	0.006	4.0	0.0075	0.04	0.002	0.1	9.0	5	0.05	400	0.002	1200
MW-6	05/16/2016	<0.001	<0.001	0.0298	<0.001	0.874	<0.001	98.6	5	<0.001	<0.001	0.19	<0.001	<0.001	<0.0002	<0.001	7.0	0.91	<0.001	167	<0.001	484
MW-6	08/22/2016	<0.001	<0.001	0.0368	<0.001	1.16	<0.001	116	<5	<0.001	<0.001	0.2	<0.001	0.0012	<0.0002	<0.001	6.5	1.08	<0.001	187	<0.001	588
MW-6	11/15/2016	<0.001	<0.001	0.0343	<0.001	1.54	<0.001	113	7	<0.001	<0.001	0.17	<0.001	0.0012	<0.0002	<0.001	6.8	0.29	<0.001	275	<0.001	726
MW-6	02/13/2017	<0.001	<0.001	0.0286	<0.001	1.04	<0.001	100	<5	<0.001	<0.001	0.16	<0.001	<0.001	<0.0002	<0.001	6.6	0.35	<0.001	246	<0.001	624
MW-6	05/18/2017	<0.001	<0.001	0.0292	<0.001	1.02	<0.001	96	<5	<0.001	<0.001	0.19	<0.001	<0.001	<0.0002	<0.001	6.6	0.27	<0.001	153	<0.001	530
MW-6	07/18/2017	<0.001	<0.001	0.0597	<0.001	1.48	<0.001	105	<5	<0.001	<0.001	0.17	<0.001	<0.001	<0.0002	<0.001	6.5	3.14	<0.001	238	<0.001	622
MW-6	11/06/2017	<0.001	<0.001	0.0412	<0.001	1.91	<0.001	139	11	<0.001	<0.001	0.16	<0.001	--	<0.0002	--	6.7	0.73	<0.001	335	<0.001	780
MW-6	05/31/2018	<0.001	<0.001	0.0322	<0.001	1.07	<0.001	93.6	<5	<0.0015	<0.001	0.19	<0.001	<0.0015	<0.0002	<0.0015	6.5	1.97	<0.001	195	<0.002	554
MW-6	08/28/2018	--	<0.001	0.0436	--	1.16	--	122	<5	0.0016	<0.001	0.22	<0.001	<0.0015	--	<0.0015	6.6	0.53	0.001	133	--	544
MW-6	11/08/2018	<0.001	<0.001	0.0372	<0.001	1.45	<0.001	--	<5	0.0019	<0.001	0.19	<0.001	--	<0.0002	--	6.8	0.22	0.0013	159	<0.002	620
MW-6	02/15/2019	<0.001	<0.001	0.0366	<0.001	0.649	<0.001	101	<5	<0.0015	<0.001	0.19	<0.001	<0.0015	<0.0002	<0.0015	6.7	0.37	<0.001	106	<0.002	464
MW-6	05/14/2019	<0.001	<0.001	0.035	<0.001	0.792	<0.001	--	<4	<0.0015	<0.001	0.22	<0.001	--	<0.0002	--	6.6	0.03	<0.001	107	<0.002	532
MW-6	08/21/2019	--	<0.001	0.0395	--	1.32	--	113	<5	<0.0015	<0.001	0.19	<0.001	<0.003	--	<0.0015	6.4	0.75	<0.001	153	--	550
MW-6	11/13/2019	<0.001	<0.001	0.0389	<0.001	0.804	<0.001	--	<4	<0.0015	<0.001	0.2	<0.001	--	<0.0002	--	6.6	0.13	<0.001	114	<0.002	490
MW-6	02/11/2020	<0.001	<0.001	0.0267	<0.001	0.632	<0.001	90.9	<5	<0.0015	<0.001	0.2	<0.001	<0.003	<0.0002	<0.0015	6.7	1.25	<0.001	97	<0.002	478
MW-6	05/12/2020	<0.001	<0.001	0.0331	<0.001	0.836	<0.001	--	<4	<0.0015	<0.001	0.2	<0.001	--	<0.0002	--	6.7	0.63	<0.001	131	<0.002	500
MW-6	08/26/2020	<0.001	<0.001	0.0425	<0.001	1.09	--	103	<5	<0.0015	<0.001	0.24	<0.001	<0.003	--	<0.0015	6.6	1.02	<0.001	157	--	476
MW-6	12/02/2020	<0.001	<0.001	0.0422	<0.001	1.46	<0.001	--	7	<0.0015	<0.001	0.18	<0.001	--	<0.0002	--	6.6	1.15	<0.001	237	<0.002	608
MW-6	03/30/2021	<0.001	<0.001	0.0293	<0.001	0.64	<0.001	75.6	<5	<0.0015	<0.001	0.21	<0.001	<0.003	<0.0002	<0.0015	6.6	0.0547	<0.001	98	<0.002	368
MW-6	06/10/2021	<0.001	<0.001	0.0357	<0.001	0.906	<0.001	--	3	<0.0015	<0.001	0.22	<0.001	--	<0.0002	--	6.4	0.0391	<0.001	117	<0.002	442
MW-6	09/01/2021	<0.001	<0.001	0.0405	<0.001	1.28	<0.001	93.5	4	<0.0015	<0.001	0.19	<0.001	<0.003	<0.0002	<0.0015	6.4	1.17	<0.001	173	<0.002	498
MW-7	06/04/2015	--	--	--	--	--	--	--	--	--	--	0.23	--	--	<0	--	--	--	--	--	--	--

TABLE 4-1. GROUNDWATER ANALYTICAL RESULTS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Location	Sample Date	Antimony, total (mg/L)	Arsenic, total (mg/L)	Barium, total (mg/L)	Beryllium, total (mg/L)	Boron, total (mg/L)	Cadmium, total (mg/L)	Calcium, total (mg/L)	Chloride, total (mg/L)	Chromium, total (mg/L)	Cobalt, total (mg/L)	Fluoride, total (mg/L)	Lead, total (mg/L)	Lithium, total (mg/L)	Mercury, total (mg/L)	Molybdenum, total (mg/L)	pH (field) (SU)	Radium 226 and 228 combined (pCi/L)	Selenium, total (mg/L)	Sulfate, total (mg/L)	Thallium, total (mg/L)	Total Dissolved Solids (mg/L)
35 I.A.C. 845.600	Lower	0	0	0	0	0	0	--	0	0	0	0	0	0	0	0	6.5	0	0	0	0	0
	Upper	0.006	0.010	2.0	0.004	2	0.005	--	200	0.1	0.006	4.0	0.0075	0.04	0.002	0.1	9.0	5	0.05	400	0.002	1200
MW-7	06/17/2015	<0.001	<0.025	0.068	<0.0005	0.29	<0.002	--	<5	<0.005	<0.005	0.24	<0.0075	--	<0.0002	--	7.5	--	<0.04	149	<0.001	575
MW-7	12/15/2015	<0.001	<0.001	0.0848	<0.001	0.178	<0.001	145	<5	<0.001	<0.001	0.25	<0.001	0.0034	<0.0002	0.0033	7.1	1.29	<0.001	439	<0.001	766
MW-7	02/29/2016	<0.001	<0.001	0.0515	<0.001	0.103	<0.001	107	<5	<0.001	<0.001	0.22	<0.001	0.0023	<0.0002	0.0033	7.3	0.32	<0.001	249	<0.001	430
MW-7	05/16/2016	<0.001	<0.001	0.0572	<0.001	0.251	<0.001	105	<5	<0.001	<0.001	0.24	<0.001	0.003	<0.0002	0.0027	7.3	0.99	<0.001	170	<0.001	498
MW-7	08/22/2016	<0.001	0.0011	0.0656	<0.001	0.287	<0.001	115	<5	<0.001	<0.001	0.27	<0.001	0.0048	<0.0002	0.0037	6.9	1.74	<0.001	177	<0.001	610
MW-7	11/15/2016	<0.001	0.0015	0.0629	<0.001	0.648	<0.001	128	<5	0.0024	<0.001	0.32	<0.001	0.004	<0.0002	0.0032	7.3	2.16	<0.001	247	<0.001	740
MW-7	02/13/2017	<0.001	<0.001	0.0656	<0.001	0.139	<0.001	149	<5	<0.001	<0.001	0.23	<0.001	0.0031	<0.0002	0.0021	7.1	0.81	<0.001	395	<0.001	816
MW-7	05/19/2017	<0.001	<0.001	0.0505	<0.001	0.235	<0.001	105	<5	<0.001	<0.001	0.26	<0.001	0.0033	<0.0002	0.0028	7.0	0.64	<0.001	158	<0.001	504
MW-7	07/18/2017	<0.001	<0.001	0.0516	<0.001	0.36	<0.001	120	<5	<0.001	<0.001	0.31	<0.001	0.0029	<0.0002	0.0033	7.1	1.76	<0.001	201	<0.001	646
MW-7	11/07/2017	<0.001	<0.001	0.0505	<0.001	0.462	<0.001	127	<5	<0.001	<0.001	0.32	<0.001	--	<0.0002	--	7.0	1.58	<0.001	247	<0.001	674
MW-7	06/01/2018	<0.001	<0.001	0.0363	<0.001	0.24	<0.001	112	<5	<0.0015	<0.001	0.32	<0.001	0.0026	<0.0002	0.0029	7.0	0.95	<0.001	172	<0.002	602
MW-7	08/28/2018	--	0.0013	0.0349	--	0.276	--	104	<5	0.0029	<0.001	0.33	<0.001	0.0046	--	0.0046	7.0	0.41	<0.001	143	--	578
MW-7	11/08/2018	<0.001	0.0012	0.0451	<0.001	0.195	<0.001	--	<5	<0.0015	<0.001	0.32	<0.001	--	<0.0002	--	7.3	0.52	<0.001	230	<0.002	702
MW-7	02/15/2019	<0.001	<0.001	0.0681	<0.001	0.114	<0.001	170	<5	<0.0015	<0.001	0.22	<0.001	0.0044	<0.0002	0.0023	7.2	0.38	<0.001	193	<0.002	726
MW-7	05/14/2019	<0.001	<0.001	0.065	<0.001	0.263	<0.001	--	<4	<0.0015	<0.001	0.22	<0.001	--	<0.0002	--	7.0	0.4	<0.001	160	<0.002	662
MW-7	08/21/2019	--	0.0017	0.0634	--	0.395	--	133	<5	<0.0015	0.0011	0.25	<0.001	0.0048	--	0.0033	6.7	0.41	<0.001	150	--	654
MW-7	11/13/2019	<0.001	0.0024	0.0569	<0.001	0.194	<0.001	--	<4	<0.0015	0.0013	0.29	<0.001	--	<0.0002	--	7.1	0.77	<0.001	220	<0.002	564
MW-7	02/11/2020	<0.001	<0.001	0.0473	<0.001	0.12	<0.001	110	<5	<0.0015	<0.001	0.21	<0.001	<0.003	<0.0002	0.0022	7.2	0.25	<0.001	168	<0.002	556
MW-7	05/12/2020	<0.001	<0.001	0.0469	<0.001	0.212	<0.001	--	<4	<0.0015	<0.001	0.22	<0.001	--	<0.0002	--	7.2	0.21	<0.001	149	<0.002	512
MW-7	08/26/2020	<0.001	<0.001	0.0437	<0.001	0.33	--	104	<5	<0.0015	<0.001	0.36	<0.001	<0.003	--	0.0029	7.1	1.66	<0.001	160	--	494
MW-7	12/02/2020	<0.001	<0.001	0.0535	<0.001	0.46	<0.001	--	4	<0.0015	<0.001	0.29	<0.001	--	<0.0002	--	7.0	0.25	<0.001	237	<0.002	610
MW-7	03/30/2021	<0.001	<0.001	0.0522	<0.001	0.126	<0.001	104	<5	<0.0015	<0.001	0.23	<0.001	<0.003	<0.0002	0.0026	7.1	0.109	<0.001	132	<0.002	476

TABLE 4-1. GROUNDWATER ANALYTICAL RESULTS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Location	Sample Date	Antimony, total (mg/L)	Arsenic, total (mg/L)	Barium, total (mg/L)	Beryllium, total (mg/L)	Boron, total (mg/L)	Cadmium, total (mg/L)	Calcium, total (mg/L)	Chloride, total (mg/L)	Chromium, total (mg/L)	Cobalt, total (mg/L)	Fluoride, total (mg/L)	Lead, total (mg/L)	Lithium, total (mg/L)	Mercury, total (mg/L)	Molybdenum, total (mg/L)	pH (field) (SU)	Radium 226 and 228 combined (pCi/L)	Selenium, total (mg/L)	Sulfate, total (mg/L)	Thallium, total (mg/L)	Total Dissolved Solids (mg/L)
35 I.A.C. 845.600	Lower	0	0	0	0	0	0	--	0	0	0	0	0	0	0	0	6.5	0	0	0	0	0
	Upper	0.006	0.010	2.0	0.004	2	0.005	--	200	0.1	0.006	4.0	0.0075	0.04	0.002	0.1	9.0	5	0.05	400	0.002	1200
MW-7	06/10/2021	<0.001	<0.001	0.0399	<0.001	0.281	<0.001	--	2	<0.0015	<0.001	0.27	<0.001	--	<0.0002	--	6.8	0.658	<0.001	135	<0.002	542
MW-7	09/01/2021	<0.001	0.0014	0.0909	<0.001	0.604	<0.001	198	3	<0.0015	0.0017	0.26	<0.001	0.0043	<0.0002	0.0031	6.6	1.83	<0.001	317	<0.002	970
MW-7S	02/24/2021	<0.001	0.0106	0.0461	<0.001	3.83	<0.001	183	12	<0.0015	0.0014	0.34	<0.001	<0.005	<0.0002	<0.0015	6.8	0.134	<0.001	432	<0.002	1130
MW-7S	03/16/2021	<0.001	0.0072	0.047	<0.001	3.8	<0.001	175	11	0.0032	0.0012	0.33	<0.001	<0.003	<0.0002	<0.0015	6.8	0.227	<0.001	429	<0.002	1080
MW-7S	04/06/2021	<0.001	0.003	0.0421	<0.001	3.57	<0.001	172	10	<0.0015	0.0012	0.34	<0.001	<0.003	<0.0002	<0.0015	6.2	0.149	<0.001	400	<0.002	1030
MW-7S	05/21/2021	<0.005	0.0059	0.0543	<0.005	3.56	<0.005	170	10	<0.0075	<0.005	0.34	<0.005	<0.015	<0.0002	<0.0075	6.5	0.161	<0.005	343	<0.01	1010
MW-7S	06/10/2021	<0.001	0.0141	0.0665	<0.001	4.23	<0.001	189	12	0.0045	0.002	0.35	0.003	<0.003	<0.0002	0.0017	6.8	1.12	<0.001	468	<0.002	--
MW-7S	07/02/2021	<0.001	0.0086	0.0402	<0.001	4.72	<0.001	204	11	<0.0015	0.0013	0.31	<0.001	<0.003	<0.0002	<0.0015	6.6	0.594	<0.001	563	<0.002	1160
MW-7S	07/23/2021	0.0016	0.175	0.203	<0.001	5.51	<0.001	210	11	0.0221	0.0064	0.31	0.0113	0.0076	<0.0002	0.0043	6.7	0.0936	<0.001	573	<0.002	1240
MW-7S	08/11/2021	<0.001	0.0261	0.071	<0.001	5.42	<0.001	224	11	0.0107	0.0027	0.29	0.0019	<0.003	<0.0002	0.0032	6.8	1.75	<0.001	577	<0.002	1270
MW-8	06/04/2015	--	--	--	--	--	--	--	--	--	--	0.2	--	--	<0	--	--	--	--	--	--	--
MW-8	06/17/2015	<0.001	<0.025	0.0366	<0.0005	0.935	<0.002	--	24	<0.005	<0.005	0.2	<0.0075	--	<0.0002	--	7.0	--	<0.04	319	<0.001	1000
MW-8	12/15/2015	<0.001	<0.001	0.0364	<0.001	0.965	<0.001	167	27	<0.001	0.002	0.22	<0.001	0.0019	<0.0002	<0.001	6.6	2.08	<0.001	316	<0.001	866
MW-8	02/29/2016	<0.001	<0.001	0.0329	<0.001	1.02	<0.001	180	25	<0.001	0.0013	0.19	<0.001	0.0019	<0.0002	<0.001	6.6	0.15	<0.001	336	<0.001	862
MW-8	05/16/2016	<0.001	<0.001	0.0328	<0.001	0.997	<0.001	162	24	<0.001	0.0014	0.2	<0.001	0.002	<0.0002	<0.001	6.8	0.7	<0.001	325	<0.001	932
MW-8	08/22/2016	<0.001	<0.001	0.0335	<0.001	0.954	<0.001	159	25	<0.001	0.0016	0.2	<0.001	0.0016	<0.0002	<0.001	6.5	2.11	<0.001	348	<0.001	952
MW-8	11/15/2016	<0.001	<0.001	0.0359	<0.001	1.51	<0.001	162	25	<0.001	0.0019	0.2	<0.001	0.0022	<0.0002	<0.001	7.0	0	<0.001	327	<0.001	986
MW-8	02/13/2017	<0.001	<0.001	0.0296	<0.001	0.9	<0.001	157	25	<0.001	0.0013	0.21	<0.001	0.002	<0.0002	<0.001	6.6	0.31	<0.001	324	<0.001	936
MW-8	05/19/2017	<0.001	<0.001	0.0322	<0.001	1.09	<0.001	159	26	<0.001	0.0013	0.2	<0.001	0.002	<0.0002	<0.001	6.6	0.66	<0.001	311	<0.001	940
MW-8	07/18/2017	<0.001	<0.001	0.0326	<0.001	1.17	<0.001	169	25	<0.001	0.0016	0.2	<0.001	0.0021	<0.0002	<0.001	6.8	2.32	<0.001	273	<0.001	898
MW-8	11/07/2017	<0.001	<0.001	0.0323	<0.001	1.09	<0.001	164	24	<0.001	0.0015	0.2	<0.001	--	<0.0002	--	6.9	0.71	<0.001	285	<0.001	872
MW-8	06/01/2018	<0.001	<0.001	0.0338	<0.001	1.14	<0.001	163	25	<0.0015	0.0014	0.22	<0.001	0.0022	<0.0002	<0.0015	6.6	0.14	<0.001	264	<0.002	898

TABLE 4-1. GROUNDWATER ANALYTICAL RESULTS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Location	Sample Date	Antimony, total (mg/L)	Arsenic, total (mg/L)	Barium, total (mg/L)	Beryllium, total (mg/L)	Boron, total (mg/L)	Cadmium, total (mg/L)	Calcium, total (mg/L)	Chloride, total (mg/L)	Chromium, total (mg/L)	Cobalt, total (mg/L)	Fluoride, total (mg/L)	Lead, total (mg/L)	Lithium, total (mg/L)	Mercury, total (mg/L)	Molybdenum, total (mg/L)	pH (field) (SU)	Radium 226 and 228 combined (pCi/L)	Selenium, total (mg/L)	Sulfate, total (mg/L)	Thallium, total (mg/L)	Total Dissolved Solids (mg/L)
35 I.A.C. 845.600	Lower	0	0	0	0	0	0	--	0	0	0	0	0	0	0	0	6.5	0	0	0	0	0
	Upper	0.006	0.010	2.0	0.004	2	0.005	--	200	0.1	0.006	4.0	0.0075	0.04	0.002	0.1	9.0	5	0.05	400	0.002	1200
MW-8	08/28/2018	--	<0.001	0.0303	--	1.05	--	157	25	<0.0015	0.0014	0.21	<0.001	0.002	--	<0.0015	6.6	0.39	<0.001	255	--	884
MW-8	11/08/2018	<0.001	<0.001	0.0338	<0.001	1.1	<0.001	--	24	<0.0015	0.0015	0.2	<0.001	--	<0.0002	--	6.9	0.3	<0.001	262	<0.002	922
MW-8	02/14/2019	<0.001	<0.001	0.0267	<0.001	1.02	<0.001	175	21	<0.0015	<0.001	0.23	<0.001	0.0032	<0.0002	<0.0015	6.9	0.2	<0.001	332	<0.002	946
MW-8	05/14/2019	<0.001	<0.001	0.0284	<0.001	0.971	<0.001	--	22	<0.0015	0.0013	0.25	<0.001	--	<0.0002	--	6.5	0.04	<0.001	281	<0.002	882
MW-8	08/21/2019	--	<0.001	0.033	--	1.1	--	166	19	<0.0015	0.0014	0.21	<0.001	<0.003	--	<0.0015	6.5	0.34	<0.001	258	--	864
MW-8	11/14/2019	<0.001	<0.001	0.0302	<0.001	1.04	<0.001	--	20	<0.0015	0.0014	0.23	<0.001	--	<0.0002	--	6.7	0.21	<0.001	332	<0.002	894
MW-8	02/11/2020	<0.001	<0.001	0.0222	<0.001	0.858	<0.001	168	17	<0.0015	<0.001	0.26	<0.001	<0.003	<0.0002	<0.0015	6.7	0.23	<0.001	337	<0.002	966
MW-8	05/12/2020	<0.001	<0.001	0.0246	<0.001	0.938	<0.001	--	16	<0.0015	0.001	0.26	<0.001	--	<0.0002	--	6.7	0.41	<0.001	305	<0.002	870
MW-8	08/26/2020	<0.001	<0.001	0.0306	<0.001	0.918	--	154	17	<0.0015	0.0013	0.21	<0.001	<0.003	--	<0.0015	6.7	0.6	<0.001	289	--	836
MW-8	12/02/2020	<0.001	<0.001	0.0315	<0.001	1.05	<0.001	--	18	<0.0015	0.0013	0.21	<0.001	--	<0.0002	--	6.6	0	<0.001	272	<0.002	798
MW-8	03/30/2021	<0.001	<0.001	0.0237	<0.001	0.865	<0.001	159	15	<0.0015	0.0013	0.26	<0.001	<0.003	<0.0002	<0.0015	6.6	0.217	<0.001	260	<0.002	800
MW-8	06/10/2021	<0.001	<0.001	0.0249	<0.001	0.958	<0.001	--	20	<0.0015	<0.001	0.25	<0.001	--	<0.0002	--	6.3	0	<0.001	261	<0.002	806
MW-8	09/01/2021	<0.001	<0.001	0.027	<0.001	0.986	<0.001	149	21	<0.0015	0.0013	0.21	<0.001	<0.003	<0.0002	<0.0015	6.5	0.604	<0.001	267	<0.002	794
MW-8S	02/24/2021	<0.001	0.002	0.103	<0.001	0.742	<0.001	194	16	<0.0015	0.0044	0.2	0.001	<0.005	<0.0002	0.0037	6.8	2.01	<0.001	427	<0.002	1190
MW-8S	03/17/2021	<0.001	0.0023	0.0848	<0.001	0.982	<0.001	184	12	0.0018	0.0028	0.33	0.0011	<0.003	<0.0002	0.0027	6.8	0.31	<0.001	586	<0.002	1150
MW-8S	04/06/2021	<0.001	0.0044	0.0657	<0.001	1.1	<0.001	182	11	<0.0015	0.003	0.19	<0.001	<0.003	<0.0002	0.0023	6.7	0.476	<0.001	609	<0.002	1210
MW-8S	05/21/2021	<0.001	0.0011	0.0688	<0.001	1.09	<0.001	241	11	<0.0015	0.001	0.19	<0.001	<0.003	<0.0002	<0.0015	6.4	0.269	<0.001	566	<0.002	1320
MW-9	06/04/2015	--	--	--	--	--	--	--	--	--	--	0.18	--	--	<0	--	--	--	--	--	--	--
MW-9	06/17/2015	<0.001	<0.025	0.0781	<0.0005	0.101	<0.002	--	<5	<0.005	<0.005	0.18	<0.0075	--	<0.0002	--	7.4	--	<0.04	48	<0.001	385
MW-9	12/14/2015	<0.001	<0.001	0.0598	<0.001	0.0605	<0.001	--	5	<0.001	<0.001	0.21	<0.001	--	<0.0002	--	7.0	--	0.0026	87	<0.001	334
MW-9	05/16/2016	<0.001	<0.001	0.0502	<0.001	0.0898	<0.001	--	<5	<0.001	<0.001	0.18	<0.001	--	<0.0002	--	7.2	--	<0.001	50	<0.001	258
MW-9	11/15/2016	<0.001	<0.001	0.0577	<0.001	0.102	<0.001	--	5	<0.001	<0.001	0.2	<0.001	--	<0.0002	--	7.5	--	0.0053	96	<0.001	416

TABLE 4-1. GROUNDWATER ANALYTICAL RESULTS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Location	Sample Date	Antimony, total (mg/L)	Arsenic, total (mg/L)	Barium, total (mg/L)	Beryllium, total (mg/L)	Boron, total (mg/L)	Cadmium, total (mg/L)	Calcium, total (mg/L)	Chloride, total (mg/L)	Chromium, total (mg/L)	Cobalt, total (mg/L)	Fluoride, total (mg/L)	Lead, total (mg/L)	Lithium, total (mg/L)	Mercury, total (mg/L)	Molybdenum, total (mg/L)	pH (field) (SU)	Radium 226 and 228 combined (pCi/L)	Selenium, total (mg/L)	Sulfate, total (mg/L)	Thallium, total (mg/L)	Total Dissolved Solids (mg/L)
35 I.A.C. 845.600	Lower	0	0	0	0	0	0	--	0	0	0	0	0	0	0	0	6.5	0	0	0	0	0
	Upper	0.006	0.010	2.0	0.004	2	0.005	--	200	0.1	0.006	4.0	0.0075	0.04	0.002	0.1	9.0	5	0.05	400	0.002	1200
MW-9	05/19/2017	<0.001	<0.001	0.0597	<0.001	0.078	<0.001	--	<5	<0.001	<0.001	0.19	<0.001	--	<0.0002	--	6.9	--	0.0017	62	<0.001	340
MW-9	11/07/2017	<0.001	<0.001	0.0601	<0.001	0.101	<0.001	--	10	0.0016	<0.001	0.18	<0.001	--	<0.0002	--	7.2	0.78	0.0071	139	<0.001	456
MW-9	06/01/2018	<0.001	<0.001	0.0548	<0.001	0.14	<0.001	--	11	<0.0015	<0.001	0.18	<0.001	--	<0.0002	--	6.9	1.58	0.0063	152	<0.002	466
MW-9	11/08/2018	<0.001	<0.001	0.0659	<0.001	0.182	<0.001	--	9	<0.0015	<0.001	0.17	<0.001	--	<0.0002	--	7.2	0.03	0.0036	137	<0.002	494
MW-9	05/14/2019	<0.001	<0.001	0.0583	<0.001	0.0766	<0.001	--	<4	<0.0015	<0.001	0.18	<0.001	--	<0.0002	--	7.0	0.05	<0.001	52	<0.002	324
MW-9	11/14/2019	<0.001	<0.001	0.0654	<0.001	0.113	<0.001	--	<4	<0.0015	<0.001	0.17	<0.001	--	<0.0002	--	7.0	0.22	0.0011	63	<0.002	292
MW-9	05/12/2020	<0.001	<0.001	0.055	<0.001	0.0676	<0.001	--	<4	<0.0015	<0.001	0.17	<0.001	--	<0.0002	--	7.1	0.04	<0.001	33	<0.002	266
MW-9	12/02/2020	<0.001	<0.001	0.0618	<0.001	0.101	<0.001	--	9	<0.0015	<0.001	0.16	<0.001	--	<0.0002	--	6.9	0.25	0.0036	121	<0.002	390
MW-9	06/10/2021	<0.001	<0.001	0.0529	<0.001	0.0918	<0.001	--	1	<0.0015	<0.001	0.2	<0.001	--	<0.0002	--	6.8	0.894	<0.001	33	<0.002	244
MW-10	06/04/2015	--	--	--	--	--	--	--	--	--	--	0.17	--	--	<0	--	--	--	--	--	--	--
MW-10	06/17/2015	<0.001	<0.025	0.0233	<0.0005	1.46	<0.002	--	14	<0.005	<0.005	0.16	<0.0075	--	<0.0002	--	6.7	--	<0.04	472	<0.001	1100
MW-10	12/14/2015	<0.001	<0.001	0.0328	<0.001	1.25	<0.001	--	74	<0.001	<0.001	0.17	<0.001	--	<0.0002	--	6.3	--	0.0207	527	<0.001	1140
MW-10	05/16/2016	<0.001	<0.001	0.0228	<0.001	1.57	<0.001	--	10	<0.001	<0.001	0.16	<0.001	--	<0.0002	--	6.8	--	0.0067	401	<0.001	902
MW-10	11/15/2016	<0.001	<0.001	0.0231	<0.001	1.27	<0.001	--	81	<0.001	<0.001	0.17	<0.001	--	<0.0002	--	7.6	--	0.0027	459	<0.001	1200
MW-10	05/19/2017	<0.001	<0.001	0.0204	<0.001	1.46	<0.001	--	<5	<0.001	<0.001	0.21	<0.001	--	<0.0002	--	6.5	--	0.012	313	<0.001	754
MW-10	11/07/2017	<0.001	<0.001	0.0343	<0.001	0.685	<0.001	--	245	<0.001	<0.001	0.13	<0.001	--	<0.0002	--	6.8	1.24	0.0048	492	<0.001	1430
MW-10	06/01/2018	<0.001	<0.001	0.0223	<0.001	1.18	<0.001	--	101	<0.0015	<0.001	0.16	<0.001	--	<0.0002	--	6.6	0.93	0.008	480	<0.002	1310
MW-10	11/08/2018	<0.001	<0.001	0.0328	<0.001	1.08	<0.001	--	181	<0.0015	<0.001	0.12	<0.001	--	<0.0002	--	6.8	0.07	0.0085	535	<0.002	1490
MW-10	05/14/2019	<0.001	<0.001	0.0201	<0.001	1.69	<0.001	--	5	<0.0015	<0.001	0.21	<0.001	--	<0.0002	--	6.4	0.11	0.0153	323	<0.002	834
MW-10	11/14/2019	<0.001	<0.001	0.0359	<0.001	1.45	<0.001	--	45	<0.0015	<0.001	0.18	<0.001	--	<0.0002	--	6.5	0.58	0.0089	411	<0.002	978
MW-10	05/12/2020	<0.001	<0.001	0.0238	<0.001	1.56	<0.001	--	<4	<0.0015	<0.001	0.2	<0.001	--	<0.0002	--	6.6	0.25	0.0189	310	<0.002	728
MW-10	12/02/2020	<0.001	<0.001	0.031	<0.001	1.04	<0.001	--	108	<0.0015	<0.001	0.16	<0.001	--	<0.0002	--	6.5	0.73	0.008	428	<0.002	1100

TABLE 4-1. GROUNDWATER ANALYTICAL RESULTS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Location	Sample Date	Antimony, total (mg/L)	Arsenic, total (mg/L)	Barium, total (mg/L)	Beryllium, total (mg/L)	Boron, total (mg/L)	Cadmium, total (mg/L)	Calcium, total (mg/L)	Chloride, total (mg/L)	Chromium, total (mg/L)	Cobalt, total (mg/L)	Fluoride, total (mg/L)	Lead, total (mg/L)	Lithium, total (mg/L)	Mercury, total (mg/L)	Molybdenum, total (mg/L)	pH (field) (SU)	Radium 226 and 228 combined (pCi/L)	Selenium, total (mg/L)	Sulfate, total (mg/L)	Thallium, total (mg/L)	Total Dissolved Solids (mg/L)
35 I.A.C. 845.600	Lower	0	0	0	0	0	0	--	0	0	0	0	0	0	0	0	6.5	0	0	0	0	0
	Upper	0.006	0.010	2.0	0.004	2	0.005	--	200	0.1	0.006	4.0	0.0075	0.04	0.002	0.1	9.0	5	0.05	400	0.002	1200
MW-10	06/10/2021	<0.001	<0.001	0.0257	<0.001	1.45	<0.001	--	11	<0.0015	<0.001	0.21	<0.001	--	<0.0002	--	6.1	1.14	0.0036	311	<0.002	758
MW-11	12/15/2015	<0.001	0.0028	0.157	<0.001	1.79	<0.001	130	45	<0.001	<0.001	0.53	<0.001	0.003	<0.0002	0.0026	6.9	0.18	<0.001	135	<0.001	660
MW-11	02/29/2016	<0.001	0.0028	0.147	<0.001	1.65	<0.001	135	45	<0.001	<0.001	0.42	<0.001	0.002	<0.0002	0.0026	6.9	0.64	0.0012	130	<0.001	624
MW-11	05/16/2016	<0.001	0.0013	0.139	<0.001	1.46	<0.001	125	41	<0.001	<0.001	0.46	<0.001	0.0021	<0.0002	0.0025	7.1	0.86	<0.001	130	<0.001	670
MW-11	08/22/2016	<0.001	0.0015	0.14	<0.001	1.75	<0.001	121	43	<0.001	<0.001	0.51	<0.001	0.0022	<0.0002	0.002	7.3	0.56	<0.001	130	<0.001	664
MW-11	11/15/2016	<0.001	0.0019	0.15	<0.001	1.67	<0.001	123	42	<0.001	<0.001	0.52	<0.001	0.0026	<0.0002	0.0025	7.4	1.54	<0.001	115	<0.001	678
MW-11	02/13/2017	<0.001	0.0012	0.136	<0.001	1.38	<0.001	117	42	<0.001	<0.001	0.44	<0.001	0.0019	<0.0002	0.0023	6.9	0.39	<0.001	123	<0.001	660
MW-11	05/18/2017	<0.001	<0.001	0.134	<0.001	1.61	<0.001	121	42	<0.001	<0.001	0.48	<0.001	0.0029	<0.0002	0.0023	7.0	1.02	0.0015	121	<0.001	670
MW-11	07/18/2017	<0.001	0.0016	0.136	<0.001	1.79	<0.001	133	42	<0.001	<0.001	0.5	<0.001	0.0025	<0.0002	0.0022	7.0	1.22	0.0021	106	<0.001	664
MW-11	11/06/2017	<0.001	0.0029	0.155	<0.001	1.95	<0.001	125	39	<0.001	<0.001	0.49	<0.001	--	<0.0002	--	7.0	1.2	<0.001	114	<0.001	646
MW-11	05/31/2018	<0.001	0.002	0.126	<0.001	1.52	<0.001	127	40	<0.0015	<0.001	0.52	<0.001	0.0021	<0.0002	0.0036	6.8	1.16	0.0011	102	<0.002	662
MW-11	08/28/2018	--	0.0017	0.126	--	1.73	--	114	41	0.0018	<0.001	0.54	<0.001	0.0032	--	0.0032	6.8	0.29	<0.001	103	--	658
MW-11	11/08/2018	<0.001	0.0023	0.142	<0.001	2.28	<0.001	--	41	<0.0015	<0.001	0.53	<0.001	--	<0.0002	--	6.9	0.61	<0.001	97	<0.002	676
MW-11	02/14/2019	<0.001	0.0081	0.138	<0.001	1.69	<0.001	131	38	<0.0015	0.0011	0.52	<0.001	0.0025	<0.0002	0.0025	7.1	0.81	<0.001	103	<0.002	616
MW-11	05/14/2019	<0.001	<0.001	0.118	<0.001	1.42	<0.001	--	38	<0.0015	<0.001	0.55	<0.001	--	<0.0002	--	6.8	0.06	0.0037	104	<0.002	646
MW-11	08/21/2019	--	0.0012	0.129	--	1.85	--	125	30	<0.0015	<0.001	0.49	<0.001	<0.003	--	0.0024	6.7	0.7	0.0027	88	--	628
MW-11	11/13/2019	<0.001	0.0015	0.16	<0.001	1.83	<0.001	--	33	<0.0015	<0.001	0.54	<0.001	--	<0.0002	--	6.8	0	<0.001	103	<0.002	620
MW-11	02/11/2020	<0.001	0.0011	0.113	<0.001	1.49	<0.001	121	34	<0.0015	<0.001	0.53	<0.001	<0.003	<0.0002	0.002	6.9	1.28	0.0016	95	<0.002	658
MW-11	05/12/2020	<0.001	<0.001	0.125	<0.001	1.49	<0.001	--	36	<0.0015	<0.001	0.55	<0.001	--	<0.0002	--	7.0	0	0.0025	112	<0.002	658
MW-11	08/26/2020	<0.001	0.0013	0.129	<0.001	1.55	--	120	35	<0.0015	<0.001	0.59	<0.001	<0.003	--	0.0021	6.9	1.08	0.0016	107	--	554
MW-11	12/02/2020	<0.001	<0.001	0.139	<0.001	1.73	<0.001	--	40	<0.0015	<0.001	0.54	<0.001	--	<0.0002	--	6.8	0.95	<0.001	106	<0.002	612
MW-11	03/30/2021	<0.001	0.0021	0.129	<0.001	1.34	<0.001	118	36	<0.0015	<0.001	0.51	<0.001	<0.003	<0.0002	0.0021	6.9	0.97	<0.001	96	<0.002	578

TABLE 4-1. GROUNDWATER ANALYTICAL RESULTS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Location	Sample Date	Antimony, total (mg/L)	Arsenic, total (mg/L)	Barium, total (mg/L)	Beryllium, total (mg/L)	Boron, total (mg/L)	Cadmium, total (mg/L)	Calcium, total (mg/L)	Chloride, total (mg/L)	Chromium, total (mg/L)	Cobalt, total (mg/L)	Fluoride, total (mg/L)	Lead, total (mg/L)	Lithium, total (mg/L)	Mercury, total (mg/L)	Molybdenum, total (mg/L)	pH (field) (SU)	Radium 226 and 228 combined (pCi/L)	Selenium, total (mg/L)	Sulfate, total (mg/L)	Thallium, total (mg/L)	Total Dissolved Solids (mg/L)
35 I.A.C. 845.600	Lower	0	0	0	0	0	0	--	0	0	0	0	0	0	0	0	6.5	0	0	0	0	0
	Upper	0.006	0.010	2.0	0.004	2	0.005	--	200	0.1	0.006	4.0	0.0075	0.04	0.002	0.1	9.0	5	0.05	400	0.002	1200
MW-11	06/09/2021	<0.001	0.0011	0.127	<0.001	1.53	<0.001	--	36	<0.0015	<0.001	0.53	<0.001	--	<0.0002	--	6.6	0.24	0.0013	108	<0.002	604
MW-11	09/01/2021	<0.001	0.0013	0.127	<0.001	1.56	<0.001	115	38	<0.0015	<0.001	0.48	<0.001	<0.003	<0.0002	0.0022	6.7	1.31	<0.001	110	<0.002	584
MW-12	12/15/2015	<0.001	<0.001	0.137	<0.001	2.1	<0.001	197	49	<0.001	<0.001	0.22	<0.001	0.0093	<0.0002	0.0013	6.9	0.13	<0.001	326	<0.001	1070
MW-12	02/29/2016	<0.001	<0.001	0.113	<0.001	2.64	<0.001	220	39	<0.001	<0.001	0.18	<0.001	0.0082	<0.0002	<0.001	6.8	0.19	<0.001	390	<0.001	1140
MW-12	05/16/2016	<0.001	<0.001	0.119	<0.001	2.48	<0.001	205	44	<0.001	<0.001	0.18	<0.001	0.0088	<0.0002	<0.001	7.0	1.12	<0.001	379	<0.001	1140
MW-12	08/22/2016	<0.001	<0.001	0.115	<0.001	2.53	<0.001	198	44	<0.001	<0.001	0.19	<0.001	0.0102	<0.0002	<0.001	7.2	1.51	<0.001	398	<0.001	1160
MW-12	11/15/2016	<0.001	<0.001	0.112	<0.001	2.43	<0.001	200	42	<0.001	<0.001	0.21	<0.001	0.0106	<0.0002	0.0011	7.2	0.56	<0.001	330	<0.001	1140
MW-12	02/13/2017	<0.001	<0.001	0.0941	<0.001	3.03	<0.001	199	41	<0.001	<0.001	0.17	<0.001	0.0088	<0.0002	<0.001	6.7	0	<0.001	390	<0.001	1180
MW-12	05/18/2017	<0.001	<0.001	0.106	<0.001	2.51	<0.001	199	33	<0.001	<0.001	0.18	<0.001	0.009	<0.0002	<0.001	6.7	0.64	<0.001	406	<0.001	1170
MW-12	07/18/2017	<0.001	<0.001	0.0953	<0.001	3.55	<0.001	235	39	<0.001	<0.001	0.18	<0.001	0.0097	<0.0002	<0.001	6.9	2.65	<0.001	383	<0.001	1170
MW-12	11/06/2017	<0.001	<0.001	0.101	<0.001	2.99	<0.001	212	38	<0.001	<0.001	0.18	<0.001	--	<0.0002	--	7.1	0.49	<0.001	388	<0.001	1110
MW-12	05/31/2018	<0.001	<0.001	0.0701	<0.001	3.87	<0.001	214	35	<0.0015	<0.001	0.16	<0.001	0.0085	<0.0002	<0.0015	6.6	1.44	<0.001	413	<0.002	1230
MW-12	08/28/2018	--	<0.001	0.0815	--	3	--	209	33	<0.0015	<0.001	0.18	<0.001	0.0097	--	<0.0015	6.7	1.05	<0.001	388	--	1160
MW-12	11/08/2018	<0.001	<0.001	0.0889	<0.001	3.3	<0.001	--	35	<0.0015	<0.001	0.18	<0.001	--	<0.0002	--	7.0	0.57	<0.001	381	<0.002	1210
MW-12	02/14/2019	<0.001	<0.001	0.0892	<0.001	3.06	<0.001	224	32	<0.0015	<0.001	0.19	<0.001	0.0095	<0.0002	<0.0015	6.9	0.4	<0.001	393	<0.002	1130
MW-12	05/14/2019	<0.001	<0.001	0.0772	<0.001	1.95	<0.001	--	20	<0.0015	<0.001	0.18	<0.001	--	<0.0002	--	6.5	0.28	<0.001	399	<0.002	1100
MW-12	08/20/2019	--	<0.001	0.0655	--	4.42	--	219	29	<0.0015	<0.001	0.18	<0.001	0.0087	--	<0.0015	6.4	1.02	<0.001	371	--	1160
MW-12	11/13/2019	<0.001	<0.001	0.0921	<0.001	3	<0.001	--	27	<0.0015	<0.001	0.18	<0.001	--	<0.0002	--	6.7	0.24	<0.001	345	<0.002	1100
MW-12	02/11/2020	<0.001	<0.001	0.056	<0.001	2.26	<0.001	197	22	<0.0015	<0.001	0.17	<0.001	0.0068	<0.0002	<0.0015	6.7	0.99	<0.001	370	<0.002	1070
MW-12	05/12/2020	<0.001	<0.001	0.0762	<0.001	2.05	<0.001	--	22	<0.0015	<0.001	0.21	<0.001	--	<0.0002	--	6.8	0	<0.001	368	<0.002	1040
MW-12	08/26/2020	<0.001	<0.001	0.0734	<0.001	3.76	--	211	31	<0.0015	<0.001	0.22	<0.001	0.0079	--	<0.0015	6.6	4.2	<0.001	424	--	1100
MW-12	12/02/2020	<0.001	<0.001	0.0708	<0.001	3.76	<0.001	--	32	<0.0015	<0.001	0.16	<0.001	--	<0.0002	--	6.7	0.28	<0.001	411	<0.002	1150

TABLE 4-1. GROUNDWATER ANALYTICAL RESULTS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Location	Sample Date	Antimony, total (mg/L)	Arsenic, total (mg/L)	Barium, total (mg/L)	Beryllium, total (mg/L)	Boron, total (mg/L)	Cadmium, total (mg/L)	Calcium, total (mg/L)	Chloride, total (mg/L)	Chromium, total (mg/L)	Cobalt, total (mg/L)	Fluoride, total (mg/L)	Lead, total (mg/L)	Lithium, total (mg/L)	Mercury, total (mg/L)	Molybdenum, total (mg/L)	pH (field) (SU)	Radium 226 and 228 combined (pCi/L)	Selenium, total (mg/L)	Sulfate, total (mg/L)	Thallium, total (mg/L)	Total Dissolved Solids (mg/L)
35 I.A.C. 845.600	Lower	0	0	0	0	0	0	--	0	0	0	0	0	0	0	0	6.5	0	0	0	0	0
	Upper	0.006	0.010	2.0	0.004	2	0.005	--	200	0.1	0.006	4.0	0.0075	0.04	0.002	0.1	9.0	5	0.05	400	0.002	1200
MW-12	03/30/2021	<0.001	0.0013	0.0848	<0.001	1.97	<0.001	181	17	<0.0015	<0.001	0.18	<0.001	0.0069	<0.0002	<0.0015	6.5	0.429	0.0019	295	<0.002	908
MW-12	06/10/2021	<0.001	<0.001	0.0884	<0.001	2.48	<0.001	--	34	<0.0015	<0.001	0.26	<0.001	--	<0.0002	--	6.6	0.447	<0.001	329	<0.002	985
MW-12	09/01/2021	<0.001	<0.001	0.0802	<0.001	2.78	<0.001	197	40	<0.0015	<0.001	0.22	<0.001	0.0096	<0.0002	<0.0015	6.7	1.97	<0.001	332	<0.002	1050
MW-12S	02/25/2021	<0.001	0.0029	0.0826	<0.001	0.856	<0.001	124	25	<0.0015	0.0016	0.15	<0.001	<0.005	<0.0002	0.004	6.8	1.65	<0.001	140	<0.002	598
MW-12S	03/16/2021	<0.001	0.0032	0.0942	<0.001	1.18	<0.001	145	15	<0.0015	0.0017	0.19	<0.001	<0.003	<0.0002	0.0035	6.8	0.339	<0.001	128	<0.002	648
MW-12S	04/06/2021	<0.001	0.0082	0.0729	<0.001	1.73	<0.001	169	7	<0.0015	0.0025	0.21	<0.001	<0.003	<0.0002	0.0037	6.2	0.518	<0.001	212	<0.002	814
MW-12S	05/20/2021	<0.001	0.0033	0.114	<0.001	1.43	<0.001	154	2	<0.0015	0.0012	0.19	<0.001	<0.003	<0.0002	0.0044	6.5	0.587	<0.001	118	<0.002	654
MW-12S	06/10/2021	<0.001	0.0113	0.0567	<0.001	2.07	<0.001	169	5	<0.0015	0.0021	0.26	<0.001	<0.003	<0.0002	0.0035	6.5	0.695	<0.001	243	<0.002	--
MW-12S	07/02/2021	<0.001	0.005	0.174	<0.001	1.33	<0.001	181	5	<0.0015	0.0012	0.21	<0.001	<0.003	<0.0002	0.007	6.4	0.565	<0.001	176	<0.002	730
MW-12S	07/23/2021	<0.001	0.0178	0.106	<0.001	2.63	<0.001	175	6	<0.0015	0.0023	0.27	<0.001	<0.003	<0.0002	0.0047	6.5	0.0467	<0.001	239	<0.002	884
MW-12S	08/11/2021	<0.001	0.0083	0.107	<0.001	1.58	<0.001	159	6	<0.0015	0.0012	0.24	<0.001	<0.003	<0.0002	0.0055	6.6	0.729	<0.001	223	<0.002	818
MW-12D	02/25/2021	<0.001	0.0012	1.26	<0.001	0.709	<0.001	55.6	210	<0.0015	<0.001	0.78	<0.001	0.0086	<0.0002	<0.0015	7.2	0.773	<0.001	<10	<0.002	606
MW-12D	03/16/2021	<0.001	0.002	1.61	<0.001	0.829	<0.001	66.4	209	0.0102	0.0021	0.33	0.0023	0.0123	<0.0002	<0.0015	7.3	3.12	<0.001	<10	<0.002	634
MW-12D	04/06/2021	<0.001	0.0013	1.52	<0.001	0.827	<0.001	62.1	195	0.0053	<0.001	0.73	0.0012	0.0112	<0.0002	<0.0015	6.7	1.3	<0.001	<10	<0.002	616
MW-12D	05/20/2021	<0.001	<0.001	1.52	<0.001	0.876	<0.001	61.2	210	0.0017	<0.001	0.72	<0.001	0.0105	<0.0002	<0.0015	7.2	1.84	<0.001	<10	<0.002	632
MW-12D	06/10/2021	<0.001	<0.001	1.47	<0.001	0.833	<0.001	62.5	199	<0.0015	<0.001	0.78	<0.001	0.0103	<0.0002	<0.0015	7.1	1.47	<0.001	<10	<0.002	--
MW-12D	07/02/2021	<0.001	<0.001	1.55	<0.001	0.839	<0.001	60.6	209	<0.0015	<0.001	0.75	<0.001	0.0101	<0.0002	<0.0015	9.9	2.23	<0.001	<10	<0.002	602
MW-12D	07/23/2021	<0.001	<0.001	1.9	<0.001	1.08	<0.001	61	216	<0.0015	<0.001	0.74	<0.001	0.0118	<0.0002	<0.0015	7.1	2.48	<0.001	<10	<0.002	614
MW-12D	08/11/2021	<0.001	<0.001	1.64	<0.001	0.863	<0.001	66	210	<0.0015	<0.001	0.71	<0.001	0.0095	<0.0002	<0.0015	7.2	2.12	<0.001	<10	<0.002	612
MW-20	02/26/2021	<0.001	<0.001	0.164	<0.001	0.34	<0.001	106	25	<0.0015	<0.001	0.42	<0.001	0.0233	<0.0002	0.0124	7.2	0.312	<0.001	134	<0.002	572
MW-20	03/16/2021	<0.001	<0.001	0.142	<0.001	0.4	<0.001	115	24	<0.0015	<0.001	0.4	<0.001	0.0201	<0.0002	0.0094	7.1	0.0709	<0.001	127	<0.002	594
MW-20	04/06/2021	<0.001	0.0011	0.122	<0.001	0.442	<0.001	112	26	<0.0015	<0.001	0.41	<0.001	0.0169	<0.0002	0.0064	6.5	0.0814	<0.001	130	<0.002	608

TABLE 4-1. GROUNDWATER ANALYTICAL RESULTS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Location	Sample Date	Antimony, total (mg/L)	Arsenic, total (mg/L)	Barium, total (mg/L)	Beryllium, total (mg/L)	Boron, total (mg/L)	Cadmium, total (mg/L)	Calcium, total (mg/L)	Chloride, total (mg/L)	Chromium, total (mg/L)	Cobalt, total (mg/L)	Fluoride, total (mg/L)	Lead, total (mg/L)	Lithium, total (mg/L)	Mercury, total (mg/L)	Molybdenum, total (mg/L)	pH (field) (SU)	Radium 226 and 228 combined (pCi/L)	Selenium, total (mg/L)	Sulfate, total (mg/L)	Thallium, total (mg/L)	Total Dissolved Solids (mg/L)
35 I.A.C. 845.600	Lower	0	0	0	0	0	0	--	0	0	0	0	0	0	0	0	6.5	0	0	0	0	0
	Upper	0.006	0.010	2.0	0.004	2	0.005	--	200	0.1	0.006	4.0	0.0075	0.04	0.002	0.1	9.0	5	0.05	400	0.002	1200
MW-20	05/18/2021	<0.001	0.0012	0.115	<0.001	0.463	<0.001	123	23	<0.0015	<0.001	0.38	<0.001	0.0142	<0.0002	0.0055	6.9	0.524	<0.001	134	<0.002	624
MW-20	06/09/2021	<0.001	0.0011	0.117	<0.001	0.44	<0.001	132	24	<0.0015	<0.001	0.41	<0.001	0.0118	<0.0002	0.0051	6.8	0.132	<0.001	141	<0.002	--
MW-20	07/01/2021	<0.001	0.0014	0.117	<0.001	0.503	<0.001	119	24	<0.0015	<0.001	0.39	<0.001	0.0122	<0.0002	0.0055	6.9	0.698	<0.001	137	<0.002	628
MW-20	07/22/2021	<0.001	0.0024	0.138	<0.001	0.564	<0.001	125	24	<0.0015	<0.001	0.39	<0.001	0.0134	<0.0002	0.006	6.9	0.459	<0.001	143	<0.002	610
MW-20	08/10/2021	<0.001	0.0023	0.119	<0.001	0.499	<0.001	127	26	<0.0015	<0.001	0.37	<0.001	0.01	<0.0002	0.0056	6.9	0.44	<0.001	147	<0.002	636
MW-20S	02/26/2021	<0.001	<0.001	0.038	<0.001	1.18	<0.001	158	24	<0.0015	<0.001	0.18	<0.001	<0.005	<0.0002	<0.0015	6.8	0.139	<0.001	243	<0.002	842
MW-20S	03/16/2021	<0.001	<0.001	0.0423	<0.001	1.2	<0.001	163	20	<0.0015	<0.001	0.17	<0.001	<0.003	<0.0002	<0.0015	6.9	0	<0.001	254	<0.002	846
MW-20S	04/06/2021	<0.001	<0.001	0.0373	<0.001	1.2	<0.001	162	21	<0.0015	<0.001	0.18	<0.001	<0.003	<0.0002	<0.0015	6.3	0.00643	<0.001	260	<0.002	878
MW-20S	05/19/2021	<0.001	<0.001	0.0407	<0.001	1.38	<0.001	174	21	<0.0015	<0.001	0.18	<0.001	<0.003	<0.0002	<0.0015	6.5	0.807	<0.001	297	<0.002	922
MW-20S	06/09/2021	<0.001	<0.001	0.0378	<0.001	1.37	<0.001	187	20	<0.0015	<0.001	0.2	<0.001	<0.003	<0.0002	<0.0015	6.4	0.308	<0.001	346	<0.002	--
MW-20S	07/01/2021	<0.001	<0.001	<0.001	<0.001	0.0611	<0.001	175	20	<0.0015	<0.001	0.2	<0.001	<0.003	<0.0002	<0.0015	6.5	0.582	<0.001	312	<0.002	936
MW-20S	07/22/2021	<0.001	<0.001	0.0442	<0.001	1.89	<0.001	187	20	<0.0015	<0.001	0.2	<0.001	<0.003	<0.0002	<0.0015	6.5	0.262	<0.001	392	<0.002	1020
MW-20S	08/10/2021	<0.001	<0.001	0.0492	<0.001	1.65	<0.001	201	22	<0.0015	<0.001	0.19	<0.001	<0.003	<0.0002	<0.0015	6.6	0.269	<0.001	383	<0.002	1020
MW-22	02/26/2021	<0.001	<0.001	0.0822	<0.001	1.55	<0.001	91.7	26	<0.0015	<0.001	0.36	<0.001	<0.005	<0.0002	0.0051	7.0	0.291	<0.001	104	<0.002	510
MW-22	03/17/2021	0.001	<0.001	0.0762	<0.001	1.45	<0.001	91.1	28	<0.0015	<0.001	0.36	<0.001	0.0036	<0.0002	0.0038	7.0	0.483	<0.001	123	<0.002	500
MW-22	04/07/2021	<0.001	<0.001	0.0726	<0.001	1.44	<0.001	91	28	<0.0015	<0.001	0.36	<0.001	<0.003	<0.0002	0.0034	6.5	0.151	<0.001	119	<0.002	494
MW-22	05/18/2021	<0.001	<0.001	0.0719	<0.001	1.47	<0.001	92.8	25	<0.0015	<0.001	0.34	<0.001	<0.003	<0.0002	0.0029	6.9	0.0665	<0.001	118	<0.002	506
MW-23	02/26/2021	<0.001	<0.001	0.159	<0.001	2.01	<0.001	109	33	<0.0015	0.001	0.34	<0.001	<0.005	<0.0002	0.0024	6.9	0.151	<0.001	55	<0.002	586
MW-23	03/18/2021	<0.001	<0.001	0.052	<0.001	0.932	<0.001	50.5	30	<0.0015	<0.001	0.36	<0.001	<0.003	<0.0002	<0.0015	6.7	0.194	<0.001	43	<0.002	582
MW-23	04/06/2021	<0.001	0.0013	0.107	<0.001	1.95	<0.001	107	31	<0.0015	0.0012	0.37	<0.001	<0.003	<0.0002	<0.0015	6.6	0.311	<0.001	42	<0.002	580
MW-23	05/19/2021	<0.001	<0.001	0.0987	<0.001	2.17	<0.001	116	30	<0.0015	0.001	0.33	<0.001	<0.003	<0.0002	<0.0015	6.6	1.15	<0.001	43	<0.002	566
MW-23	06/09/2021	<0.001	<0.001	0.101	<0.001	2.09	<0.001	120	31	<0.0015	<0.001	0.38	<0.001	<0.003	<0.0002	<0.0015	6.4	0.744	<0.001	43	<0.002	--

TABLE 4-1. GROUNDWATER ANALYTICAL RESULTS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Location	Sample Date	Antimony, total (mg/L)	Arsenic, total (mg/L)	Barium, total (mg/L)	Beryllium, total (mg/L)	Boron, total (mg/L)	Cadmium, total (mg/L)	Calcium, total (mg/L)	Chloride, total (mg/L)	Chromium, total (mg/L)	Cobalt, total (mg/L)	Fluoride, total (mg/L)	Lead, total (mg/L)	Lithium, total (mg/L)	Mercury, total (mg/L)	Molybdenum, total (mg/L)	pH (field) (SU)	Radium 226 and 228 combined (pCi/L)	Selenium, total (mg/L)	Sulfate, total (mg/L)	Thallium, total (mg/L)	Total Dissolved Solids (mg/L)
35 I.A.C. 845.600	Lower	0	0	0	0	0	0	--	0	0	0	0	0	0	0	0	6.5	0	0	0	0	0
	Upper	0.006	0.010	2.0	0.004	2	0.005	--	200	0.1	0.006	4.0	0.0075	0.04	0.002	0.1	9.0	5	0.05	400	0.002	1200
MW-23	07/01/2021	<0.001	0.001	0.0938	<0.001	1.98	<0.001	114	29	<0.0015	0.0011	0.36	<0.001	<0.003	<0.0002	<0.0015	6.5	0.502	<0.001	45	<0.002	608
MW-23	07/22/2021	<0.001	0.0016	0.122	<0.001	2.67	<0.001	114	30	<0.0015	0.0016	0.37	<0.001	<0.003	<0.0002	<0.0015	6.5	0.502	<0.001	46	<0.002	594
MW-23	08/10/2021	<0.001	0.0011	0.0913	<0.001	1.91	<0.001	102	30	<0.0015	0.0012	0.36	<0.001	<0.003	<0.0002	<0.0015	6.6	0.0477	<0.001	45	<0.002	592
MW-24	03/01/2021	<0.001	0.001	0.169	<0.001	0.124	<0.001	109	18	<0.0015	0.0018	0.23	<0.001	0.0066	<0.0002	0.0033	6.6	0.156	<0.001	63	<0.002	608
MW-24	03/18/2021	<0.001	<0.001	0.212	<0.001	0.214	<0.001	138	17	<0.0015	0.0012	0.22	<0.001	0.0045	<0.0002	0.0027	6.4	0.545	<0.001	59	<0.002	664
MW-24	04/07/2021	<0.001	<0.001	0.195	<0.001	0.242	<0.001	135	16	<0.0015	<0.001	0.26	<0.001	0.0051	<0.0002	0.0026	6.0	0.959	<0.001	76	<0.002	664
MW-24	05/19/2021	<0.001	<0.001	0.18	<0.001	0.203	<0.001	141	15	<0.0015	<0.001	0.26	<0.001	<0.003	<0.0002	0.0027	6.4	1.29	<0.001	75	<0.002	670
MW-25	02/25/2021	<0.001	0.0025	0.0668	<0.001	1.04	<0.001	72.9	8	0.003	0.0039	0.17	0.0012	0.0077	<0.0002	0.0022	6.7	0.113	<0.001	177	<0.002	448
MW-25	03/17/2021	<0.001	0.0049	0.0833	<0.001	1.08	<0.001	77.9	8	0.0059	0.0056	0.17	0.0028	0.0064	<0.0002	<0.0015	6.6	0.269	<0.001	177	<0.002	454
MW-25	04/07/2021	<0.001	0.0039	0.0548	<0.001	1.06	<0.001	75.2	8	0.0027	0.0045	0.17	0.0011	0.0037	<0.0002	<0.0015	6.2	0.186	<0.001	174	<0.002	436
MW-25	05/21/2021	<0.001	0.0062	0.0694	<0.001	1.11	<0.001	80.6	7	0.0052	0.0055	0.17	0.0021	0.0048	<0.0002	<0.0015	6.3	0.0383	<0.001	177	<0.002	450
MW-25	08/11/2021	<0.001	0.0068	0.0569	<0.001	1.14	<0.001	78.7	8	0.0027	0.0051	0.17	0.0016	<0.003	<0.0002	0.0018	6.5	0.157	<0.001	205	<0.002	440
MW-26	02/25/2021	<0.001	0.0014	0.103	<0.001	1.09	<0.001	125	19	0.0055	0.0026	0.21	0.0017	<0.005	<0.0002	0.0023	6.7	2.45	<0.001	179	<0.002	660
MW-26	03/17/2021	<0.001	0.0044	0.158	<0.001	1.1	<0.001	137	19	0.0138	0.0065	0.22	0.0061	0.0071	<0.0002	0.0022	6.7	0.522	<0.001	181	<0.002	708
MW-26	04/06/2021	<0.001	0.0027	0.0961	<0.001	1.07	<0.001	134	20	0.0045	0.0048	0.22	0.002	0.0031	<0.0002	<0.0015	6.4	0.251	<0.001	175	<0.002	712
MW-26	05/21/2021	<0.001	0.0022	0.0687	<0.001	1.32	<0.001	144	19	<0.0015	0.0038	0.21	<0.001	<0.003	<0.0002	<0.0015	6.4	0.914	<0.001	196	<0.002	724
MW-27	02/24/2021	<0.001	0.0649	0.926	0.0048	0.774	<0.001	162	18	0.155	0.0552	0.17	0.0777	0.088	0.00023	0.0086	7.0	0.318	<0.001	247	<0.002	344
MW-27	03/16/2021	<0.001	0.0067	0.19	<0.001	1.13	<0.001	156	15	0.0158	0.0074	0.72	0.0074	0.0092	<0.0002	0.0042	6.9	0.454	<0.001	313	<0.002	938
MW-27	04/06/2021	<0.001	0.0026	0.106	<0.001	1.18	<0.001	165	16	0.0034	0.0022	0.22	0.0018	<0.003	<0.0002	0.0023	6.4	0.355	<0.001	283	<0.002	962
MW-27	05/21/2021	<0.001	0.0054	0.0916	<0.001	1.34	<0.001	174	14	0.0024	0.0012	0.22	0.0012	<0.003	<0.0002	<0.0015	6.8	0.32	<0.001	232	<0.002	958
MW-27	06/10/2021	<0.001	0.14	2.66	0.0104	0.866	0.0017	377	17	0.351	0.139	0.25	0.254	0.178	0.00048	0.0278	6.7	9.25	<0.001	266	0.0022	--
MW-27	07/02/2021	0.001	0.0111	0.172	<0.001	1.45	<0.001	187	14	0.0096	0.0077	0.24	0.0044	0.0049	<0.0002	0.0048	6.7	1.34	<0.001	326	<0.002	1100

TABLE 4-1. GROUNDWATER ANALYTICAL RESULTS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Location	Sample Date	Antimony, total (mg/L)	Arsenic, total (mg/L)	Barium, total (mg/L)	Beryllium, total (mg/L)	Boron, total (mg/L)	Cadmium, total (mg/L)	Calcium, total (mg/L)	Chloride, total (mg/L)	Chromium, total (mg/L)	Cobalt, total (mg/L)	Fluoride, total (mg/L)	Lead, total (mg/L)	Lithium, total (mg/L)	Mercury, total (mg/L)	Molybdenum, total (mg/L)	pH (field) (SU)	Radium 226 and 228 combined (pCi/L)	Selenium, total (mg/L)	Sulfate, total (mg/L)	Thallium, total (mg/L)	Total Dissolved Solids (mg/L)
35 I.A.C. 845.600	Lower	0	0	0	0	0	0	--	0	0	0	0	0	0	0	0	6.5	0	0	0	0	0
	Upper	0.006	0.010	2.0	0.004	2	0.005	--	200	0.1	0.006	4.0	0.0075	0.04	0.002	0.1	9.0	5	0.05	400	0.002	1200
MW-27	07/23/2021	<0.001	0.0269	0.436	0.0021	1.5	<0.001	205	15	0.0721	0.0284	0.21	0.031	0.0377	<0.0002	0.0081	6.6	5.81	<0.001	346	<0.002	1080
MW-27	08/11/2021	<0.001	0.0054	0.143	<0.001	1.27	<0.001	168	16	0.0079	0.0044	0.2	0.0035	0.0046	<0.0002	0.0033	6.7	1.53	<0.001	336	<0.002	1050
MW-28	02/24/2021	<0.001	<0.001	0.0243	<0.001	9.09	<0.001	265	14	<0.0015	0.0011	0.13	<0.001	0.0066	<0.0002	<0.0015	6.9	0	<0.001	884	<0.002	1790
MW-28	03/16/2021	<0.001	<0.001	0.0234	<0.001	9.29	<0.001	264	13	<0.0015	<0.001	0.54	<0.001	0.0066	<0.0002	<0.0015	7.0	0.303	<0.001	929	<0.002	1830
MW-28	04/07/2021	<0.001	<0.001	0.0292	<0.001	10.8	<0.001	247	13	<0.0015	0.0015	0.13	<0.001	0.0076	<0.0002	<0.0015	6.3	0	<0.001	889	<0.002	1640
MW-28	05/18/2021	<0.001	<0.001	0.0209	<0.001	9.7	<0.001	256	12	<0.0015	<0.001	0.12	<0.001	0.0069	<0.0002	<0.0015	6.5	0.0913	<0.001	795	<0.002	1700
MW-28	06/10/2021	<0.001	<0.001	0.0196	<0.001	9.42	<0.001	261	14	<0.0015	<0.001	0.14	<0.001	0.0072	<0.0002	<0.0015	6.6	0.0444	<0.001	903	<0.002	--
MW-28	07/02/2021	<0.001	<0.001	0.0263	<0.001	9.56	<0.001	237	13	<0.0015	<0.001	0.13	<0.001	0.0061	<0.0002	<0.0015	6.7	0.327	<0.001	815	<0.002	1610
MW-28	07/23/2021	<0.001	<0.001	0.0241	<0.001	10.9	<0.001	244	12	<0.0015	<0.001	0.14	<0.001	0.0078	<0.0002	<0.0015	6.7	0.18	<0.001	774	<0.002	1720
MW-28	08/11/2021	<0.001	<0.001	0.0215	<0.001	8.35	<0.001	219	13	<0.0015	<0.001	0.12	<0.001	0.0057	<0.0002	<0.0015	6.8	0.172	<0.001	883	<0.002	1570
MW-29	02/25/2021	<0.001	<0.001	0.0913	<0.001	1.59	<0.001	144	50	<0.0015	<0.001	0.13	<0.001	0.0084	<0.0002	<0.0015	6.7	0.311	<0.001	148	<0.002	778
MW-29	03/16/2021	<0.001	<0.001	0.0885	<0.001	1.65	<0.001	149	47	<0.0015	<0.001	0.6	<0.001	0.009	<0.0002	<0.0015	6.9	1.32	<0.001	149	<0.002	774
MW-29	04/06/2021	<0.001	<0.001	0.0907	<0.001	1.78	<0.001	148	48	<0.0015	<0.001	0.13	<0.001	0.0091	<0.0002	<0.0015	6.2	0.182	<0.001	148	<0.002	768
MW-29	05/21/2021	<0.001	<0.001	0.0789	<0.001	1.66	<0.001	154	44	<0.0015	<0.001	0.12	<0.001	0.0083	<0.0002	<0.0015	6.6	0.194	<0.001	148	<0.002	764
MW-29	06/10/2021	<0.001	<0.001	0.0814	<0.001	1.66	<0.001	153	46	<0.0015	<0.001	0.13	<0.001	0.0087	<0.0002	<0.0015	6.6	0.499	<0.001	154	<0.002	--
MW-29	07/02/2021	<0.001	<0.001	0.0983	<0.001	1.85	<0.001	149	48	<0.0015	<0.001	0.12	<0.001	0.0088	<0.0002	<0.0015	6.6	0	<0.001	154	<0.002	788
MW-29	07/23/2021	<0.001	<0.001	0.0952	<0.001	2.01	<0.001	150	51	<0.0015	<0.001	0.12	<0.001	0.0106	<0.0002	<0.0015	6.7	0.835	<0.001	163	<0.002	790
MW-29	08/11/2021	<0.001	<0.001	0.0796	<0.001	1.57	<0.001	136	49	<0.0015	<0.001	0.11	<0.001	0.0078	<0.0002	<0.0015	6.7	0.749	<0.001	161	<0.002	756
MW-30	02/25/2021	<0.001	0.0014	0.17	<0.001	1.14	<0.001	129	52	0.0047	0.0026	0.2	<0.001	<0.005	<0.0002	0.0043	6.6	4.64	<0.001	85	<0.002	678
MW-30	03/17/2021	<0.001	0.002	0.162	<0.001	1.19	<0.001	137	53	0.0021	0.0025	0.25	<0.001	0.0042	<0.0002	0.0036	6.6	0.783	<0.001	54	<0.002	682
MW-30	04/07/2021	<0.001	0.0021	0.16	<0.001	1.6	<0.001	132	49	0.0024	0.0027	0.23	<0.001	0.0033	<0.0002	0.0026	6.2	1.14	<0.001	40	<0.002	682
MW-30	05/20/2021	<0.001	0.0023	0.135	<0.001	1.18	<0.001	136	54	<0.0015	0.0021	0.25	<0.001	<0.003	<0.0002	<0.0015	6.4	0.733	<0.001	22	<0.002	684

TABLE 4-1. GROUNDWATER ANALYTICAL RESULTS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Location	Sample Date	Antimony, total (mg/L)	Arsenic, total (mg/L)	Barium, total (mg/L)	Beryllium, total (mg/L)	Boron, total (mg/L)	Cadmium, total (mg/L)	Calcium, total (mg/L)	Chloride, total (mg/L)	Chromium, total (mg/L)	Cobalt, total (mg/L)	Fluoride, total (mg/L)	Lead, total (mg/L)	Lithium, total (mg/L)	Mercury, total (mg/L)	Molybdenum, total (mg/L)	pH (field) (SU)	Radium 226 and 228 combined (pCi/L)	Selenium, total (mg/L)	Sulfate, total (mg/L)	Thallium, total (mg/L)	Total Dissolved Solids (mg/L)
35 I.A.C. 845.600	Lower	0	0	0	0	0	0	--	0	0	0	0	0	0	0	0	6.5	0	0	0	0	0
	Upper	0.006	0.010	2.0	0.004	2	0.005	--	200	0.1	0.006	4.0	0.0075	0.04	0.002	0.1	9.0	5	0.05	400	0.002	1200
MW-30	06/09/2021	<0.001	0.0037	0.155	<0.001	1.09	<0.001	141	52	<0.0015	0.002	0.29	<0.001	<0.003	<0.0002	0.0019	6.4	0.692	<0.001	22	<0.002	--
MW-30	07/01/2021	<0.001	0.0044	0.173	<0.001	1.24	<0.001	133	51	<0.0015	0.003	0.29	<0.001	<0.003	<0.0002	0.0019	6.5	0.532	<0.001	18	<0.002	690
MW-30	07/22/2021	<0.001	0.0073	0.174	<0.001	1.29	<0.001	129	52	<0.0015	0.0023	0.28	<0.001	<0.003	<0.0002	<0.0015	6.4	0.757	<0.001	14	<0.002	680
MW-30	08/10/2021	<0.001	0.0048	0.155	<0.001	1.06	<0.001	122	52	<0.0015	0.0018	0.27	<0.001	<0.003	<0.0002	<0.0015	6.6	1.48	<0.001	12	<0.002	676
MW-31	02/24/2021	<0.001	0.0032	0.279	<0.001	0.217	<0.001	125	51	<0.0015	0.0013	0.2	<0.001	0.0057	<0.0002	0.0029	6.8	0.454	<0.001	<10	<0.002	530
MW-31	03/17/2021	<0.001	0.0032	0.263	<0.001	0.259	<0.001	138	51	<0.0015	<0.001	0.19	<0.001	0.0054	<0.0002	0.0023	6.7	1.87	<0.001	<10	<0.002	620
MW-31	04/07/2021	<0.001	0.0036	0.22	<0.001	0.369	<0.001	137	48	<0.0015	<0.001	0.18	<0.001	0.0063	<0.0002	0.0019	6.2	0.926	<0.001	<10	<0.002	618
MW-31	05/20/2021	<0.001	0.0026	0.218	<0.001	0.285	<0.001	143	47	<0.0015	<0.001	0.17	<0.001	0.0047	<0.0002	0.0022	6.5	1.3	<0.001	<10	<0.002	646
MW-31	06/09/2021	<0.001	0.0028	0.244	<0.001	0.296	<0.001	140	51	<0.0015	<0.001	0.19	<0.001	0.0052	<0.0002	0.0017	6.4	0.688	<0.001	<10	<0.002	--
MW-31	07/01/2021	<0.001	0.0028	0.263	<0.001	0.325	<0.001	142	50	<0.0015	<0.001	0.17	<0.001	0.0055	<0.0002	<0.0015	6.6	0.381	<0.001	<10	<0.002	658
MW-31	07/22/2021	<0.001	0.0031	0.269	<0.001	0.327	<0.001	136	50	<0.0015	<0.001	0.18	<0.001	0.0059	<0.0002	0.0019	6.5	2.27	<0.001	<10	<0.002	626
MW-31	08/10/2021	<0.001	0.0023	0.22	<0.001	0.259	<0.001	139	48	<0.0015	<0.001	0.16	<0.001	0.0049	<0.0002	<0.0015	6.6	0.902	<0.001	<10	<0.002	614
MW-31S	02/24/2021	<0.001	0.0021	0.233	<0.001	0.0539	<0.001	170	17	<0.0015	0.0034	0.21	<0.001	<0.005	<0.0002	0.004	6.6	0.34	<0.001	216	<0.002	872
MW-31S	03/17/2021	0.0012	0.0064	0.255	<0.001	0.0606	<0.001	184	15	0.007	0.0056	0.22	0.0037	0.0052	<0.0002	0.0036	6.7	1.25	<0.001	177	<0.002	896
MW-31S	04/06/2021	<0.001	0.0063	0.224	<0.001	0.0542	<0.001	181	16	0.0032	0.0038	0.23	0.0016	<0.003	<0.0002	0.0031	6.3	1.55	<0.001	160	<0.002	900
MW-31S	05/20/2021	<0.001	0.0083	0.213	<0.001	0.0493	<0.001	182	14	<0.0015	0.0037	0.24	<0.001	<0.003	<0.0002	0.0024	6.4	3.82	<0.001	119	<0.002	840
MW-31S	06/10/2021	0.0014	0.02	0.633	0.0012	0.0575	<0.001	235	21	0.0477	0.018	0.25	0.0294	0.0255	<0.0002	0.0061	6.4	5.29	<0.001	102	<0.002	--
MW-31S	07/01/2021	<0.001	0.0195	0.503	<0.001	0.059	<0.001	191	17	0.0381	0.0168	0.23	0.0169	0.0167	<0.0002	0.005	6.5	2.8	<0.001	78	<0.002	820
MW-31S	07/23/2021	<0.001	0.0096	0.304	<0.001	0.0527	<0.001	167	17	0.0145	0.0051	0.23	0.0046	0.0052	<0.0002	0.0053	6.8	4.19	<0.001	69	<0.002	770
MW-31S	08/10/2021	<0.001	0.0075	0.247	<0.001	0.0444	<0.001	149	16	0.0094	0.004	0.22	0.0029	0.0033	<0.0002	0.0049	6.6	--	<0.001	63	<0.002	762
MW-31S	08/11/2021	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2.84	--	--	--	--
MW-32	02/25/2021	<0.001	<0.001	0.104	<0.001	1.56	<0.001	172	14	<0.0015	0.0013	0.18	<0.001	<0.005	<0.0002	<0.0015	6.6	0.471	<0.001	443	<0.002	1180

TABLE 4-1. GROUNDWATER ANALYTICAL RESULTS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Location	Sample Date	Antimony, total (mg/L)	Arsenic, total (mg/L)	Barium, total (mg/L)	Beryllium, total (mg/L)	Boron, total (mg/L)	Cadmium, total (mg/L)	Calcium, total (mg/L)	Chloride, total (mg/L)	Chromium, total (mg/L)	Cobalt, total (mg/L)	Fluoride, total (mg/L)	Lead, total (mg/L)	Lithium, total (mg/L)	Mercury, total (mg/L)	Molybdenum, total (mg/L)	pH (field) (SU)	Radium 226 and 228 combined (pCi/L)	Selenium, total (mg/L)	Sulfate, total (mg/L)	Thallium, total (mg/L)	Total Dissolved Solids (mg/L)
35 I.A.C. 845.600	Lower	0	0	0	0	0	0	--	0	0	0	0	0	0	0	0	6.5	0	0	0	0	0
	Upper	0.006	0.010	2.0	0.004	2	0.005	--	200	0.1	0.006	4.0	0.0075	0.04	0.002	0.1	9.0	5	0.05	400	0.002	1200
MW-32	03/17/2021	<0.001	<0.001	0.0977	<0.001	1.58	<0.001	190	13	<0.0015	0.0011	0.16	<0.001	<0.003	<0.0002	<0.0015	6.4	0.239	<0.001	425	<0.002	1190
MW-32	04/07/2021	<0.001	<0.001	0.0905	<0.001	1.88	<0.001	193	14	<0.0015	0.001	0.18	<0.001	<0.003	<0.0002	<0.0015	6.0	0.338	<0.001	477	<0.002	1190
MW-32	05/19/2021	<0.001	<0.001	0.0795	<0.001	1.67	<0.001	193	13	<0.0015	<0.001	0.18	<0.001	<0.003	<0.0002	<0.0015	6.3	0.591	<0.001	462	<0.002	1190
MW-32	06/09/2021	<0.001	<0.001	0.0851	<0.001	1.62	<0.001	198	14	<0.0015	<0.001	0.19	<0.001	<0.003	<0.0002	<0.0015	6.2	0.285	<0.001	474	<0.002	--
MW-32	07/01/2021	<0.001	<0.001	0.0973	<0.001	1.75	<0.001	186	13	<0.0015	<0.001	0.18	<0.001	<0.003	<0.0002	<0.0015	6.4	0.149	<0.001	464	<0.002	1180
MW-32	07/22/2021	<0.001	<0.001	0.0882	<0.001	1.87	<0.001	192	13	<0.0015	<0.001	0.18	<0.001	<0.003	<0.0002	<0.0015	6.5	1.55	<0.001	454	<0.002	1150
MW-32	08/10/2021	<0.001	0.0013	0.0732	<0.001	1.44	<0.001	176	13	<0.0015	<0.001	0.18	<0.001	<0.003	<0.0002	<0.0015	6.5	0	<0.001	465	<0.002	1190
PZ-4C	02/25/2021	<0.001	<0.001	0.233	<0.001	1.34	<0.001	117	43	0.0016	<0.001	0.41	<0.001	0.0076	<0.0002	<0.0015	7.4	0.485	<0.001	71	<0.002	570
PZ-4C	03/16/2021	<0.001	<0.001	0.252	<0.001	1.49	<0.001	124	40	<0.0015	<0.001	0.41	<0.001	0.0076	<0.0002	<0.0015	7.0	2.02	<0.001	71	<0.002	564
PZ-4C	04/05/2021	<0.001	<0.001	0.25	<0.001	1.57	<0.001	118	39	<0.0015	<0.001	0.4	<0.001	0.007	<0.0002	<0.0015	6.4	0.328	<0.001	77	<0.002	560
PZ-4C	05/20/2021	<0.001	<0.001	0.258	<0.001	1.54	<0.001	123	36	<0.0015	<0.001	0.38	<0.001	0.0067	<0.0002	<0.0015	6.5	0.522	<0.001	82	<0.002	582
PZ-4C	06/10/2021	<0.001	0.0014	0.295	<0.001	1.57	<0.001	123	40	0.0023	<0.001	0.42	0.0013	0.0089	<0.0002	<0.0015	6.7	0.482	<0.001	82	<0.002	--
PZ-4C	07/02/2021	<0.001	0.0045	0.335	<0.001	1.69	<0.001	134	39	0.0104	0.0042	0.4	0.0059	0.0134	<0.0002	0.0018	6.7	2.04	<0.001	82	<0.002	568
PZ-4C	07/23/2021	<0.001	0.0026	0.341	<0.001	1.93	<0.001	119	39	0.0023	<0.001	0.41	0.0011	0.0095	<0.0002	<0.0015	6.7	1.46	<0.001	82	<0.002	578
PZ-4C	08/11/2021	<0.001	0.0039	0.302	<0.001	1.41	<0.001	121	39	0.0099	0.0036	0.39	0.0062	0.0137	<0.0002	<0.0015	6.8	1.93	<0.001	55	<0.002	568

Notes:
Detected at concentration greater than the GWPS
-- = data not available
GWPS = Groundwater Protection Standard
mg/L = milligrams per liter
pCi/L = picocuries per liter
SU = standard units
< = concentration is less than the concentration shown, which corresponds to the reporting limit for the method. Estimated concentrations below the reporting limit and associated qualifiers are not provided since they are not utilized in statistics to determine exceedances above Part 845 standards.
35 I.A.C. 845.600 = Residuals in Surface Impoundments: Title 35 of the Illinois Administrative Code § 845

TABLE 4-2. GROUNDWATER FIELD PARAMETERS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Sample Location	Sample Date	Dissolved Oxygen (mg/L)	Oxidation Reduction Potential (mV)	pH (field) (SU)	Specific Conductance (micromhos/cm)	Temperature (deg. C)	Turbidity (NTU)
MW-1	06/16/2015	--	--	6.8	447	--	--
MW-1	12/15/2015	<1	94	6.6	407	16.1	<1
MW-1	02/29/2016	<1	122	6.6	397	13.8	<1
MW-1	05/16/2016	<1	103	6.9	356	12.9	<1
MW-1	08/22/2016	<1	136	6.8	429	18.4	1
MW-1	11/15/2016	<1	51	7.0	397	15.6	<1
MW-1	02/13/2017	<1	115	6.8	409	14.8	<1
MW-1	05/18/2017	1.81	69	6.7	429	14.7	<1
MW-1	07/18/2017	<1	137	6.7	411	19.5	<1
MW-1	11/06/2017	0	263	6.8	478	16.2	4.5
MW-1	05/31/2018	<1	163	6.5	578	15.0	<1
MW-1	08/28/2018	<1	86	6.2	461	17.7	2.5
MW-1	11/08/2018	--	--	6.4	499	16.0	--
MW-1	02/14/2019	<1	100	6.7	526	11.8	<1
MW-1	05/14/2019	--	--	6.4	593	11.5	--
MW-1	08/21/2019	1.00	233	6.3	603	15.1	2.8
MW-1	11/13/2019	--	--	6.5	616	9.2	--
MW-1	02/11/2020	<1	128	6.6	566	12.8	1.8
MW-1	05/12/2020	--	--	6.6	501	11.9	--
MW-1	08/26/2020	1.00	109	6.6	482	16.3	1.7
MW-1	12/02/2020	--	--	6.6	487	15.6	--
MW-1	02/24/2021	0.46	219	6.5	562.5	9.8	0
MW-1	03/15/2021	0.18	182	6.5	511.4	11.5	0
MW-1	03/30/2021	<1	126	6.5	534	11.6	<1
MW-1	04/05/2021	0.30	204	6.0	475.4	12.8	0
MW-1	05/19/2021	0.41	214	6.1	538	12.4	<1
MW-1	06/10/2021	0.37	68	6.2	528	12.9	<1
MW-1	07/01/2021	0.44	81	6.2	572	13.9	<1
MW-1	07/22/2021	1.26	94	6.3	548	18.0	<1
MW-1	08/10/2021	0.92	106	6.3	513	19.1	<1
MW-1	09/01/2021	0.58	117	6.5	555	20.0	4.4
MW-10	06/17/2015	--	--	6.7	1038	--	--
MW-10	12/14/2015	--	--	6.3	1544	14.3	--
MW-10	05/16/2016	--	--	6.8	800	12.3	--
MW-10	11/15/2016	--	--	7.6	1260	--	--
MW-10	05/19/2017	--	--	6.5	776	12.8	--
MW-10	11/07/2017	--	--	6.8	1980	15.6	--
MW-10	06/01/2018	--	--	6.6	1530	15.7	--
MW-10	11/08/2018	--	--	6.8	2060	15.0	--
MW-10	05/14/2019	--	--	6.4	1150	11.9	--
MW-10	11/14/2019	--	--	6.5	1370	15.1	--
MW-10	05/12/2020	--	--	6.5	973	13.2	--
MW-10	12/02/2020	--	--	6.5	1370	14.5	--
MW-10	06/10/2021	--	--	6.1	1090	13.1	--

TABLE 4-2. GROUNDWATER FIELD PARAMETERS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Sample Location	Sample Date	Dissolved Oxygen (mg/L)	Oxidation Reduction Potential (mV)	pH (field) (SU)	Specific Conductance (micromhos/cm)	Temperature (deg. C)	Turbidity (NTU)
MW-11	12/15/2015	<1	55	6.9	812	17.1	8.3
MW-11	02/29/2016	6.74	121	6.9	779	16.0	5.9
MW-11	05/16/2016	<1	83	7.1	720	14.4	4.8
MW-11	08/22/2016	<1	0	7.3	821	21.2	3.4
MW-11	11/15/2016	6.65	-21	7.4	784	17.3	2.5
MW-11	02/13/2017	<1	101	6.9	813	16.4	2.9
MW-11	05/18/2017	<1	94	7.0	771	19.6	<1
MW-11	07/18/2017	<1	35	7.0	809	19.4	2.1
MW-11	11/06/2017	0	248	7.0	952	15.5	0
MW-11	05/31/2018	<1	77	6.8	1088	17.4	9.8
MW-11	08/28/2018	1.25	31	6.8	884	17.8	2.6
MW-11	11/08/2018	--	--	6.9	948	16.3	--
MW-11	02/14/2019	1.16	106	7.1	994	13.6	<1
MW-11	05/14/2019	--	--	6.8	1120	13.5	--
MW-11	08/21/2019	<1	147	6.7	1150	17.2	1.6
MW-11	11/13/2019	--	--	6.8	1180	16.1	--
MW-11	02/11/2020	<1	61	6.9	1080	13.0	2
MW-11	05/12/2020	--	--	7.0	979	13.1	--
MW-11	08/26/2020	1.00	63	6.9	967	16.8	2.1
MW-11	12/02/2020	--	--	6.8	977	14.9	--
MW-11	03/30/2021	1.61	109	6.9	1010	14.1	2.4
MW-11	06/09/2021	--	--	6.6	1070	14.7	--
MW-11	09/01/2021	0.44	72	6.7	1030	17.2	3.6
MW-12	12/15/2015	<1	40	6.9	1080	15.1	3.7
MW-12	02/29/2016	<1	18	6.8	1130	13.8	27
MW-12	05/16/2016	<1	-19	7.0	1030	13.1	17.6
MW-12	08/22/2016	<1	-77	7.2	1370	17.0	13.1
MW-12	11/15/2016	<1	-97	7.2	1080	14.9	3.5
MW-12	02/13/2017	<1	5	6.7	1300	14.5	18.5
MW-12	05/18/2017	<1	19	6.7	1120	15.7	9.3
MW-12	07/18/2017	<1	-81	6.9	1280	18.4	15.2
MW-12	11/06/2017	0	160	7.1	1450	15.7	6.9
MW-12	05/31/2018	<1	40	6.6	1648	14.3	9.7
MW-12	08/28/2018	<1	-53	6.7	1480	17.3	9.9
MW-12	11/08/2018	--	--	7.0	1610	15.4	--
MW-12	02/14/2019	<1	-34	6.9	1630	12.6	42.3
MW-12	05/14/2019	--	--	6.5	1580	11.8	--
MW-12	08/20/2019	<1	42	6.4	1750	16.2	1.4
MW-12	11/13/2019	--	--	6.7	1740	14.5	--
MW-12	02/11/2020	<1	-10	6.6	1520	12.4	24
MW-12	05/12/2020	--	--	6.8	1350	12.5	--
MW-12	08/26/2020	1.00	-28	6.6	1480	15.7	7.8
MW-12	12/02/2020	--	--	6.7	1500	14.8	--
MW-12	03/30/2021	<1	28	6.5	1410	11.8	5.3

TABLE 4-2. GROUNDWATER FIELD PARAMETERS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Sample Location	Sample Date	Dissolved Oxygen (mg/L)	Oxidation Reduction Potential (mV)	pH (field) (SU)	Specific Conductance (micromhos/cm)	Temperature (deg. C)	Turbidity (NTU)
MW-12	06/10/2021	--	--	6.6	1550	13.2	--
MW-12	09/01/2021	0.29	-64	6.7	1460	15.8	9.6
MW-12D	02/25/2021	0.16	12.4	7.2	1207	9.0	27.1
MW-12D	03/16/2021	0.13	-20.2	7.3	1134	13.4	0
MW-12D	04/06/2021	0.17	6	6.7	1160	14.0	114
MW-12D	05/20/2021	0.21	-99	7.2	1270	14.3	18
MW-12D	06/10/2021	0.44	-72	7.1	1210	14.7	9.3
MW-12D	07/02/2021	0.45	61	9.9	1330	14.8	8
MW-12D	07/23/2021	1.23	-74	7.1	1290	18.1	19
MW-12D	08/11/2021	1.06	-73	7.2	1090	17.8	7.9
MW-12S	02/25/2021	4.95	10.6	6.8	805.1	3.6	0
MW-12S	03/16/2021	3.00	27.3	6.8	926	8.0	0
MW-12S	04/06/2021	0.23	-24	6.2	1188	10.9	0
MW-12S	05/20/2021	0.46	-21	6.5	908	14.0	4.6
MW-12S	06/10/2021	0.78	145	6.5	1260	15.6	<1
MW-12S	07/02/2021	0.53	-20	6.4	1190	18.4	<1
MW-12S	07/23/2021	0.48	-107	6.5	1370	19.1	1
MW-12S	08/11/2021	0.62	-89	6.6	1040	20.0	7.9
MW-2	06/16/2015	--	--	7.5	684	--	--
MW-2	12/15/2015	<1	-5	7.1	635	14.7	65.4
MW-2	02/29/2016	2.23	78	7.2	571	12.7	10.8
MW-2	05/16/2016	<1	4	7.4	546	13.0	30.5
MW-2	08/22/2016	<1	34	7.4	680	18.8	4.5
MW-2	11/15/2016	<1	-49	7.5	614	14.6	9.8
MW-2	02/13/2017	2.09	143	7.2	658	13.8	1.9
MW-2	05/18/2017	2.86	62	7.2	690	14.7	<1
MW-2	07/18/2017	<1	-23	7.3	646	17.0	6
MW-2	11/06/2017	0	207	7.1	700	15.3	7.2
MW-2	05/31/2018	<1	44	7.0	843	15.0	23.2
MW-2	08/28/2018	2.41	-38	6.8	647	18.9	13.2
MW-2	11/08/2018	--	--	6.9	725	14.9	--
MW-2	02/14/2019	4.64	76	7.4	714	10.6	27.6
MW-2	05/14/2019	--	--	7.2	820	12.8	--
MW-2	08/20/2019	<1	2	7.1	820	15.0	5
MW-2	11/13/2019	--	--	7.3	846	11.6	--
MW-2	02/11/2020	4.82	103	7.3	785	11.4	9.1
MW-2	05/12/2020	--	--	7.4	714	12.0	--
MW-2	08/26/2020	1.00	77	7.3	717	16.0	6.9
MW-2	12/02/2020	--	--	7.3	717	14.2	--
MW-2	02/24/2021	1.80	38.9	7.2	837.4	10.5	61.5
MW-2	03/15/2021	0.76	15.6	7.3	762.2	11.0	211
MW-2	03/30/2021	<1	86	7.1	784	11.5	9.9
MW-2	04/05/2021	1.01	68.7	6.7	722.3	15.8	75.1
MW-2	05/19/2021	0.22	-73	7.0	778	12.6	10

TABLE 4-2. GROUNDWATER FIELD PARAMETERS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Sample Location	Sample Date	Dissolved Oxygen (mg/L)	Oxidation Reduction Potential (mV)	pH (field) (SU)	Specific Conductance (micromhos/cm)	Temperature (deg. C)	Turbidity (NTU)
MW-2	06/10/2021	0.40	-63	7.0	780	13.5	9.8
MW-2	07/01/2021	0.60	62	6.5	843	13.4	9.8
MW-2	07/22/2021	1.30	124	6.6	809	14.2	7.2
MW-2	08/10/2021	1.18	102	6.9	751	19.5	21
MW-2	09/01/2021	0.37	-41	7.0	726	15.8	25
MW-20	02/26/2021	2.97	173	7.2	1012	8.6	3.11
MW-20	03/16/2021	0.89	70.8	7.1	920.7	11.2	0
MW-20	04/06/2021	0.57	71.3	6.5	922.3	12.7	0
MW-20	05/18/2021	0.52	107	6.9	1430	14.6	9.4
MW-20	06/09/2021	0.72	-118	6.8	1060	18.1	8.6
MW-20	07/01/2021	0.57	-93	6.9	1040	17.1	7.5
MW-20	07/22/2021	1.26	-93	6.9	1100	22.4	8.7
MW-20	08/10/2021	1.05	-63	6.9	1010	21.0	9.9
MW-20S	02/26/2021	1.84	151	6.8	1336	8.4	0.79
MW-20S	03/16/2021	1.16	114	6.9	1292	9.1	0
MW-20S	04/06/2021	0.54	162	6.3	1300	11.2	0
MW-20S	05/19/2021	0.50	77	6.5	1400	14.8	9.8
MW-20S	06/09/2021	0.70	58	6.4	1480	14.7	7.3
MW-20S	07/01/2021	0.48	83	6.5	1530	16.8	3.8
MW-20S	07/22/2021	0.84	81	6.5	1570	18.8	1.3
MW-20S	08/10/2021	0.10	73	6.6	1360	19.9	5.1
MW-22	02/26/2021	2.62	177	7.0	881.7	9.7	41
MW-22	03/17/2021	1.41	80.3	7.0	851.5	10.2	261
MW-22	04/07/2021	0.59	133	6.5	423.9	14.1	0
MW-22	05/18/2021	0.35	-36	6.9	1170	12.7	8.8
MW-23	02/26/2021	1.38	182	6.9	1074	12.2	1.86
MW-23	03/18/2021	0.92	220	6.7	1058	11.9	14.7
MW-23	04/06/2021	1.02	104	6.6	1007	16.7	0
MW-23	05/19/2021	1.68	429	6.6	1030	15.3	9.7
MW-23	06/09/2021	1.12	141	6.4	1060	15.1	<1
MW-23	07/01/2021	0.73	112	6.5	1130	15.6	1.2
MW-23	07/22/2021	0.91	120	6.5	1080	16.3	1
MW-23	08/10/2021	0.89	106	6.6	998	19.1	<1
MW-24	03/01/2021	4.11	471	6.6	937	13.7	25.9
MW-24	03/18/2021	3.76	555	6.4	1088	12.8	246
MW-24	04/07/2021	3.98	487	6.0	1112	17.4	0
MW-24	05/19/2021	4.20	373	6.4	1110	18.0	7.6
MW-25	02/25/2021	3.33	118	6.7	732.5	10.5	973
MW-25	03/17/2021	1.21	29	6.6	645.3	11.4	0
MW-25	04/07/2021	1.10	69.3	6.2	662.2	14.7	146
MW-25	05/21/2021	0.40	-65	6.3	777	15.8	34
MW-25	08/11/2021	0.76	-98	6.5	679	19.7	36
MW-26	02/25/2021	2.36	11.8	6.7	1133	10.0	91.7
MW-26	03/17/2021	1.99	20	6.7	1095	8.8	47.2

TABLE 4-2. GROUNDWATER FIELD PARAMETERS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Sample Location	Sample Date	Dissolved Oxygen (mg/L)	Oxidation Reduction Potential (mV)	pH (field) (SU)	Specific Conductance (micromhos/cm)	Temperature (deg. C)	Turbidity (NTU)
MW-26	04/06/2021	0.25	-68.9	6.4	979	14.5	0
MW-26	05/21/2021	0.92	-110	6.4	1290	16.8	8.4
MW-27	02/24/2021	4.66	120	7.0	1035	11.6	66.7
MW-27	03/16/2021	3.71	115	6.9	1331	10.3	2370
MW-27	04/06/2021	0.86	18.6	6.4	1386	15.2	0
MW-27	05/21/2021	0.51	-180	6.8	1680	16.0	68
MW-27	06/10/2021	0.48	-145	6.6	1560	14.1	28
MW-27	07/02/2021	0.66	-83	6.7	1760	14.4	180
MW-27	07/23/2021	4.54	44	6.6	1710	14.9	620
MW-27	08/11/2021	2.96	-42	6.6	1420	15.8	150
MW-28	02/24/2021	0.45	89	6.9	2305	11.8	0
MW-28	03/16/2021	0.22	15.6	7.0	1484	11.8	0
MW-28	04/07/2021	0.41	65.2	6.3	2138	15.2	0
MW-28	05/18/2021	0.28	-59	6.5	2840	12.9	<1
MW-28	06/10/2021	0.76	-6	6.6	2200	15.3	<1
MW-28	07/02/2021	0.43	47	6.7	2360	14.3	<1
MW-28	07/23/2021	0.42	4	6.6	2230	14.9	1
MW-28	08/11/2021	1.39	-50	6.8	1910	20.5	2.7
MW-29	02/25/2021	0.15	106	6.7	1338	10.7	0
MW-29	03/16/2021	0.19	76.3	6.9	1224	12.2	0
MW-29	04/06/2021	0.22	103	6.2	1065	13.1	0
MW-29	05/21/2021	1.21	48	6.6	1400	15.9	1.5
MW-29	06/10/2021	0.51	29	6.6	1280	13.6	<1
MW-29	07/02/2021	0.48	28	6.6	1410	13.8	<1
MW-29	07/23/2021	0.47	47	6.7	1360	14.7	<1
MW-29	08/11/2021	0.60	-4	6.7	1160	16.2	<1
MW-3	06/16/2015	--	--	7.1	902	--	--
MW-3	12/15/2015	--	--	7.0	785	15.5	--
MW-3	05/16/2016	--	--	7.1	712	12.6	--
MW-3	11/15/2016	--	--	7.3	771	--	--
MW-3	05/18/2017	--	--	6.7	793	13.7	--
MW-3	11/06/2017	--	--	7.1	871	15.2	--
MW-3	05/31/2018	--	--	6.8	1035	15.4	--
MW-3	11/08/2018	--	--	7.0	860	14.3	--
MW-3	05/14/2019	--	--	6.7	1020	12.4	--
MW-3	11/13/2019	--	--	6.8	1110	13.8	--
MW-3	05/12/2020	--	--	6.9	936	12.3	--
MW-3	12/02/2020	--	--	6.8	924	14.5	--
MW-3	02/25/2021	0.34	78.3	6.8	1087	12.2	16.8
MW-3	03/16/2021	0.32	208	6.7	1010	11.4	0
MW-3	04/05/2021	0.29	146	6.4	954.4	12.7	0
MW-3	05/18/2021	0.86	46	6.7	1400	13.8	<1
MW-3	06/09/2021	0.32	54	6.5	1030	13.2	<1
MW-3	07/01/2021	0.53	99	6.6	1090	14.3	<1

TABLE 4-2. GROUNDWATER FIELD PARAMETERS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Sample Location	Sample Date	Dissolved Oxygen (mg/L)	Oxidation Reduction Potential (mV)	pH (field) (SU)	Specific Conductance (micromhos/cm)	Temperature (deg. C)	Turbidity (NTU)
MW-3	07/22/2021	0.77	89	6.7	1030	19.2	<1
MW-3	08/10/2021	0.77	91	6.7	947	20.3	<1
MW-30	02/25/2021	0.94	-31.6	6.6	1212	14.6	11.6
MW-30	03/17/2021	0.34	-33.5	6.6	889.5	12.8	47.8
MW-30	04/07/2021	1.59	28.9	6.2	1113	15.9	0
MW-30	05/20/2021	0.44	-68	6.4	1310	15.7	10
MW-30	06/09/2021	0.48	-90	6.4	1260	15.4	10
MW-30	07/01/2021	0.90	-77	6.5	1360	17.2	9.8
MW-30	07/22/2021	0.62	-79	6.4	1270	15.5	4.6
MW-30	08/10/2021	0.88	-79	6.6	1150	18.1	2.6
MW-31	02/24/2021	0.55	-42.1	6.8	1015	13.3	0
MW-31	03/17/2021	0.38	-30.5	6.7	1136	11.9	0
MW-31	04/07/2021	0.39	-9.9	6.2	968.6	14.9	0
MW-31	05/20/2021	0.80	-76	6.5	1200	15.1	8.5
MW-31	06/09/2021	0.83	-92	6.4	1160	15.9	10
MW-31	07/01/2021	0.69	-89	6.6	1240	15.9	9.8
MW-31	07/22/2021	0.87	-77	6.5	1170	15.7	10
MW-31	08/10/2021	0.80	-70	6.6	1090	18.1	1
MW-31S	02/24/2021	0.48	-60.5	6.6	1320	14.2	21.5
MW-31S	03/17/2021	0.89	-8.3	6.7	1384	10.4	67.7
MW-31S	04/06/2021	1.30	17.4	6.3	1147	18.7	0
MW-31S	05/20/2021	0.73	-102	6.4	1330	16.3	36
MW-31S	06/10/2021	3.25	-102	6.4	1360	17.0	37
MW-31S	07/01/2021	4.15	-48	6.5	1460	16.8	21
MW-31S	07/23/2021	5.66	-9	6.8	1420	15.9	320
MW-31S	08/10/2021	6.88	-122	6.6	1180	15.5	160
MW-32	02/25/2021	0.35	-50.4	6.6	1678	15.4	0
MW-32	03/17/2021	0.36	34.7	6.4	1641	13.4	0
MW-32	04/07/2021	0.53	63.8	6.0	1581	17.8	0
MW-32	05/19/2021	0.86	-40	6.3	1550	15.8	1
MW-32	06/09/2021	1.22	-7	6.2	1660	16.2	<1
MW-32	07/01/2021	1.30	51	6.4	1760	16.4	3.4
MW-32	07/22/2021	2.13	35	6.5	1690	19.9	1
MW-32	08/10/2021	0.93	20	6.5	1550	18.1	<1
MW-4	06/16/2015	--	--	7.3	727	--	--
MW-4	12/15/2015	--	--	6.9	654	15.7	--
MW-4	05/16/2016	--	--	7.1	593	12.6	--
MW-4	11/15/2016	--	--	7.3	646	--	--
MW-4	05/18/2017	--	--	6.8	693	13.7	--
MW-4	11/06/2017	--	--	7.1	775	15.9	--
MW-4	05/31/2018	--	--	6.8	904	15.2	--
MW-4	11/08/2018	--	--	7.0	769	15.3	--
MW-4	05/14/2019	--	--	6.7	921	12.9	--
MW-4	11/13/2019	--	--	6.9	969	14.2	--

TABLE 4-2. GROUNDWATER FIELD PARAMETERS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Sample Location	Sample Date	Dissolved Oxygen (mg/L)	Oxidation Reduction Potential (mV)	pH (field) (SU)	Specific Conductance (micromhos/cm)	Temperature (deg. C)	Turbidity (NTU)
MW-4	05/12/2020	--	--	7.0	793	12.4	--
MW-4	12/02/2020	--	--	7.2	787	14.6	--
MW-4	02/25/2021	0.11	-80.2	6.9	912.9	12.1	0
MW-4	03/16/2021	0.14	-36.1	6.9	864.4	11.7	0
MW-4	04/06/2021	0.19	-9.5	6.4	845.3	13.0	0
MW-4	05/19/2021	0.30	-139	6.6	876	13.4	<1
MW-4	06/09/2021	--	--	6.6	889	14.5	--
MW-5	06/16/2015	--	--	7.0	997	--	--
MW-5	12/15/2015	<1	76	6.6	858	14.6	9.4
MW-5	02/29/2016	<1	83	6.6	839	15.3	1.9
MW-5	05/16/2016	<1	71	7.0	770	14.3	<1
MW-5	08/22/2016	<1	30	7.2	920	16.4	1
MW-5	11/15/2016	1.16	-13	7.2	828	13.9	<1
MW-5	02/13/2017	<1	96	6.7	878	14.9	7.5
MW-5	05/18/2017	1.11	69	6.7	867	16.9	<1
MW-5	07/18/2017	<1	31	6.8	897	17.4	1
MW-5	11/06/2017	0	208	7.1	992	14.1	0
MW-5	05/31/2018	<1	74	6.7	1194	17.4	<1
MW-5	08/28/2018	<1	28	6.8	980	15.8	3.7
MW-5	11/08/2018	--	--	6.9	1070	13.6	--
MW-5	02/14/2019	1.90	40	7.0	1090	12.4	<1
MW-5	05/14/2019	--	--	6.6	1270	14.6	--
MW-5	08/21/2019	<1	132	6.6	1320	16.4	1.4
MW-5	11/14/2019	--	--	6.6	1340	12.5	--
MW-5	02/11/2020	<1	39	6.7	1250	13.3	1.3
MW-5	05/12/2020	--	--	6.8	1130	14.0	--
MW-5	08/26/2020	1.00	69	6.7	1100	16.3	2.1
MW-5	12/02/2020	--	--	6.7	1100	13.6	--
MW-5	03/30/2021	<1	130	6.5	1290	14.6	5.2
MW-5	06/09/2021	--	--	6.4	1270	15.4	--
MW-5	09/01/2021	2.43	42	6.6	1280	18.6	9.3
MW-6	06/16/2015	--	--	7.0	718	--	--
MW-6	12/15/2015	<1	169	6.5	722	14.8	3.3
MW-6	02/29/2016	4.91	136	6.7	573	13.6	3.6
MW-6	05/16/2016	3.05	165	7.0	540	12.3	2
MW-6	08/22/2016	<1	154	6.5	719	17.2	3.7
MW-6	11/15/2016	<1	62	6.8	732	15.2	5.8
MW-6	02/13/2017	4.65	170	6.6	675	14.0	2
MW-6	05/18/2017	3.63	53	6.6	590	13.9	<1
MW-6	07/18/2017	<1	103	6.5	703	17.4	2.5
MW-6	11/06/2017	0	218	6.7	914	16.0	0
MW-6	05/31/2018	6.74	168	6.5	842	14.1	<1
MW-6	08/28/2018	2.74	71	6.6	697	17.4	6.1
MW-6	11/08/2018	--	--	6.8	773	15.1	--

TABLE 4-2. GROUNDWATER FIELD PARAMETERS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Sample Location	Sample Date	Dissolved Oxygen (mg/L)	Oxidation Reduction Potential (mV)	pH (field) (SU)	Specific Conductance (micromhos/cm)	Temperature (deg. C)	Turbidity (NTU)
MW-6	02/15/2019	7.31	161	6.7	838	10.1	8.6
MW-6	05/14/2019	--	--	6.5	863	11.7	--
MW-6	08/21/2019	1.95	224	6.4	984	16.3	2.2
MW-6	11/13/2019	--	--	6.6	909	14.0	--
MW-6	02/11/2020	6.29	126	6.7	753	11.8	3
MW-6	05/12/2020	--	--	6.7	717	11.7	--
MW-6	08/26/2020	2.38	128	6.5	744	16.2	6.5
MW-6	12/02/2020	--	--	6.5	863	14.5	--
MW-6	03/30/2021	9.26	116	6.6	630	11.5	<1
MW-6	06/10/2021	--	--	6.4	727	13.1	--
MW-6	09/01/2021	0.28	78	6.4	841	19.1	7.3
MW-7	06/17/2015	--	--	7.5	692	--	--
MW-7	12/15/2015	3.87	142	7.1	772	14.1	<1
MW-7	02/29/2016	7.43	139	7.3	556	11.3	1.8
MW-7	05/16/2016	2.47	149	7.3	519	12.9	2
MW-7	08/22/2016	<1	1	6.9	707	17.6	<1
MW-7	11/15/2016	<1	-44	7.3	719	15.3	<1
MW-7	02/13/2017	<1	140	7.1	799	13.5	1.7
MW-7	05/19/2017	3.53	153	7.0	621	14.0	<1
MW-7	07/18/2017	<1	-91	7.1	720	16.4	<1
MW-7	11/07/2017	0	150	7.0	843	16.1	8
MW-7	06/01/2018	<1	103	7.0	803	15.7	<1
MW-7	08/28/2018	<1	-32	7.0	674	17.7	1.3
MW-7	11/08/2018	--	--	7.3	805	14.6	--
MW-7	02/15/2019	1.22	152	7.2	1160	6.6	<1
MW-7	05/14/2019	--	--	7.0	1030	11.5	--
MW-7	08/21/2019	<1	-112	6.7	1140	17.6	3.6
MW-7	11/13/2019	--	--	7.1	952	14.7	--
MW-7	02/11/2020	3.08	113	7.2	843	9.3	2.6
MW-7	05/12/2020	--	--	7.2	719	11.5	--
MW-7	08/26/2020	1.00	23	7.1	748	17.4	3.9
MW-7	12/02/2020	--	--	7.0	914	14.4	--
MW-7	03/30/2021	1.46	113	7.1	773	11.7	1.8
MW-7	06/10/2021	--	--	6.8	820	13.1	--
MW-7	09/01/2021	0.59	107	6.6	1550	20.5	15
MW-7S	02/24/2021	0.28	-28.8	6.8	1686	11.8	3.06
MW-7S	03/16/2021	0.27	-21.6	6.8	1536	11.0	0
MW-7S	04/06/2021	1.64	63	6.2	1418	14.9	0
MW-7S	05/21/2021	0.44	-111	6.5	1590	13.5	2.6
MW-7S	06/10/2021	4.30	-130	6.8	1620	14.4	790
MW-7S	07/02/2021	0.50	-84	6.6	1860	15.5	7.8
MW-7S	07/23/2021	4.64	-19	6.7	1820	17.4	190
MW-7S	08/11/2021	5.63	-62	6.8	1540	18.0	91
MW-8	06/17/2015	--	--	7.0	1085	--	--

TABLE 4-2. GROUNDWATER FIELD PARAMETERS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Sample Location	Sample Date	Dissolved Oxygen (mg/L)	Oxidation Reduction Potential (mV)	pH (field) (SU)	Specific Conductance (micromhos/cm)	Temperature (deg. C)	Turbidity (NTU)
MW-8	12/15/2015	<1	124	6.6	959	15.3	2
MW-8	02/29/2016	<1	220	6.6	932	14.4	1.3
MW-8	05/16/2016	<1	150	6.8	858	13.5	<1
MW-8	08/22/2016	<1	78	6.5	1040	15.4	<1
MW-8	11/15/2016	<1	42	7.0	951	14.4	<1
MW-8	02/13/2017	<1	154	6.6	1000	15.5	<1
MW-8	05/19/2017	1.95	138	6.6	935	14.9	<1
MW-8	07/18/2017	<1	50	6.8	978	16.8	<1
MW-8	11/07/2017	0	206	6.9	1120	15.3	2.5
MW-8	06/01/2018	<1	153	6.6	1280	16.2	<1
MW-8	08/28/2018	1.25	63	6.6	1030	16.5	1
MW-8	11/08/2018	--	--	6.9	1130	15.0	--
MW-8	02/14/2019	<1	100	6.9	1260	12.8	<1
MW-8	05/14/2019	--	--	6.5	1370	12.8	--
MW-8	08/21/2019	<1	74	6.5	1410	15.1	1.6
MW-8	11/14/2019	--	--	6.6	1420	14.6	--
MW-8	02/11/2020	<1	129	6.7	1380	13.3	1.6
MW-8	05/12/2020	--	--	6.7	1180	12.8	--
MW-8	08/26/2020	1.00	100	6.7	1160	15.1	1.7
MW-8	12/02/2020	--	--	6.6	1170	14.9	--
MW-8	03/30/2021	<1	103	6.6	1250	12.9	<1
MW-8	06/10/2021	--	--	6.3	1280	14.8	--
MW-8	09/01/2021	0.29	98	6.5	1160	15.0	4.8
MW-8S	02/24/2021	5.53	36.1	6.8	1696	9.3	25.2
MW-8S	03/17/2021	4.15	31.3	6.8	1393	8.1	260
MW-8S	04/06/2021	6.46	121	6.7	1661	26.3	0
MW-8S	05/21/2021	2.99	78	6.4	1950	18.9	19
MW-9	06/17/2015	--	--	7.4	463	--	--
MW-9	12/14/2015	--	--	7.0	617	13.9	--
MW-9	05/16/2016	--	--	7.2	304	12.0	--
MW-9	11/15/2016	--	--	7.5	452	--	--
MW-9	05/19/2017	--	--	6.9	435	12.3	--
MW-9	11/07/2017	--	--	7.2	607	14.8	--
MW-9	06/01/2018	--	--	6.9	489	14.0	--
MW-9	11/08/2018	--	--	7.2	618	15.0	--
MW-9	05/14/2019	--	--	7.0	526	11.6	--
MW-9	11/14/2019	--	--	7.0	549	15.1	--
MW-9	05/12/2020	--	--	7.1	419	11.5	--
MW-9	12/02/2020	--	--	6.9	582	14.3	--
MW-9	06/10/2021	--	--	6.8	434	12.5	--
PZ-4C	02/25/2021	5.66	113	7.4	1007	9.9	26.8
PZ-4C	03/16/2021	1.86	10	7.0	930.8	9.5	61.4
PZ-4C	04/05/2021	1.03	44.1	6.4	858.1	17.2	0
PZ-4C	05/20/2021	0.28	-57	6.5	1050	19.3	9

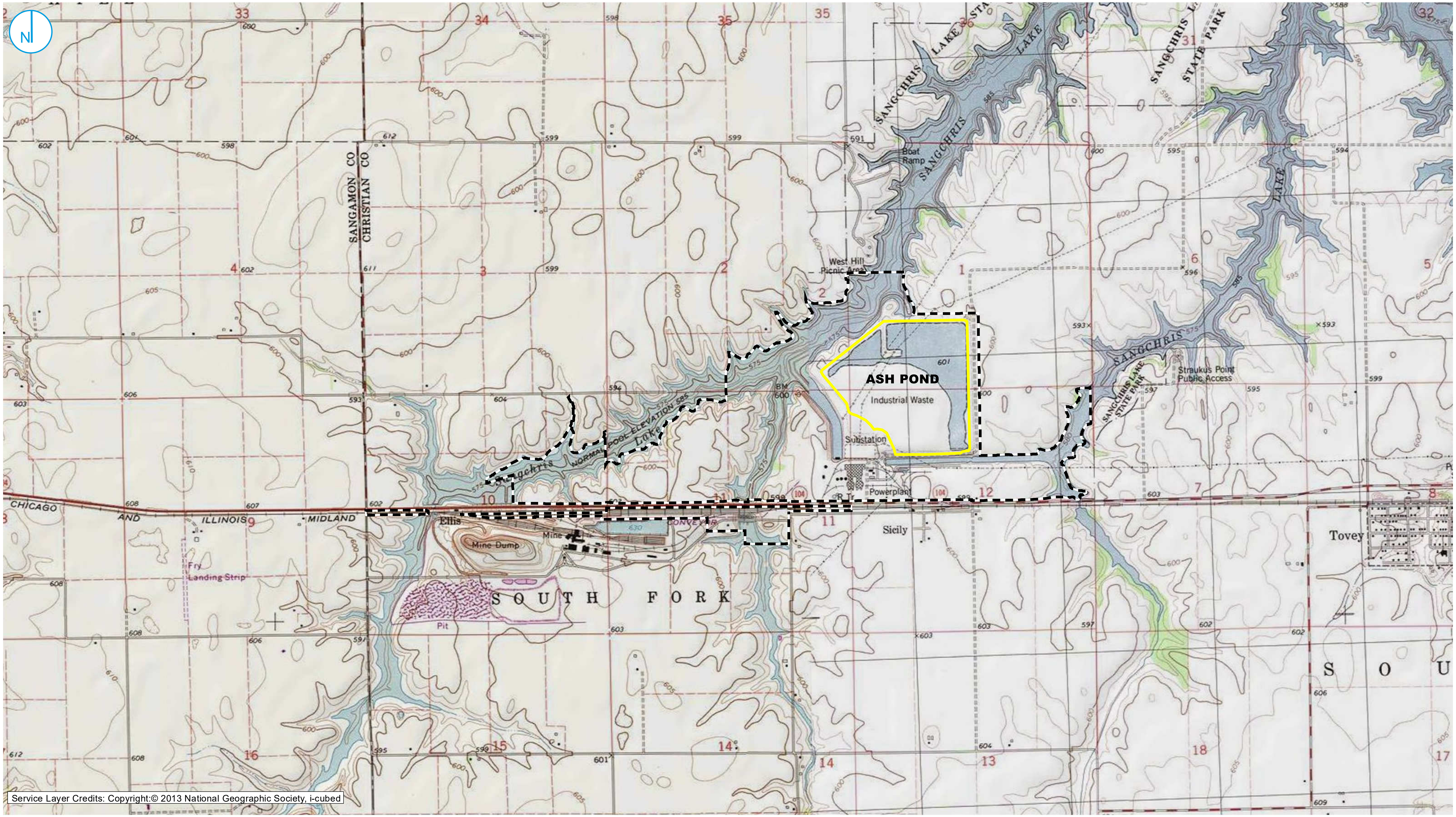
TABLE 4-2. GROUNDWATER FIELD PARAMETERS
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
KINCAID POWER PLANT
ASH POND
KINCAID, ILLINOIS

Sample Location	Sample Date	Dissolved Oxygen (mg/L)	Oxidation Reduction Potential (mV)	pH (field) (SU)	Specific Conductance (micromhos/cm)	Temperature (deg. C)	Turbidity (NTU)
PZ-4C	06/10/2021	0.34	-118	6.7	994	20.9	43
PZ-4C	07/02/2021	8.96	-3	6.7	964	15.4	650
PZ-4C	07/23/2021	0.41	-93	6.7	1060	16.7	25
PZ-4C	08/11/2021	0.45	-231	6.8	886	18.1	210

Notes:
Field readings are reported with as many significant figures as provided by analytical laboratory.
-- = data not available
cm = centimeter
deg. C = degrees Celsius
mg/L = milligrams per liter
mV = millivolts
NTU = nephelometric turbidity units
SU = standard units

generated 10/05/2021, 3:58:28 PM CDT

FIGURES



PART 845 REGULATED UNIT (SUBJECT UNIT)

PROPERTY BOUNDARY

0 1,000 2,000 Feet

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

PROJECT: 169000XXXX | DATED: 8/5/2021 | DESIGNER: galarnmc

SITE LOCATION MAP

FIGURE 1-1

HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

RAMBOLL

Y:\Mapping\Projects\22\2285\MXD\845_Operating_Permit\Kincaid\Figure 1-2_Site_Map.mxd

PROJECT: 169000XXXX | DATED: 8/5/2021 | DESIGNER: galarnmc

PART 845 REGULATED UNIT (SUBJECT UNIT)

PROPERTY BOUNDARY

0 250 500 Feet

SITE MAP

FIGURE 1-2

HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

RAMBOLL

Y:\Mapping\Projects\22\2285\MXD\845_Operating_Permit\Kincaid\Figure 2-1_Site Topographic Map.mxd

PROJECT: 169000XXXX | DATED: 8/16/2021 | DESIGNER: STOLZSD

PART 845 REGULATED UNIT (SUBJECT UNIT)
PROPERTY BOUNDARY
10 FOOT ELEVATION CONTOUR (NAVD88)
2 FOOT ELEVATION CONTOUR (NAVD88)

0 250 500 Feet

SOURCE:
INGENAE SURVEY, 2021

SITE TOPOGRAPHIC MAP

HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

FIGURE 2-1

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

MAP UNIT SYMBOL	MAP UNIT NAME
536	Dumps, mine
259C2	Assumption silt loam, 5 to 10 percent slopes, eroded
43A	Ipava silt loam, 0 to 2 percent slopes
45A	Denny silt loam, 0 to 2 percent slopes
50A	Virden silty clay loam, 0 to 2 percent slopes
802B	Orthents, loamy, undulating
86B	Osco silt loam, 2 to 5 percent slopes
W	Water

PART 845 REGULATED UNIT (SUBJECT UNIT)
PROPERTY BOUNDARY
NRCS SOIL SURVEY MAP UNIT BOUNDARY

0 250 500 Feet

SOURCE:
NATURAL RESOURCES CONSERVATION SERVICE (NRCS)

SOIL SURVEY MAP

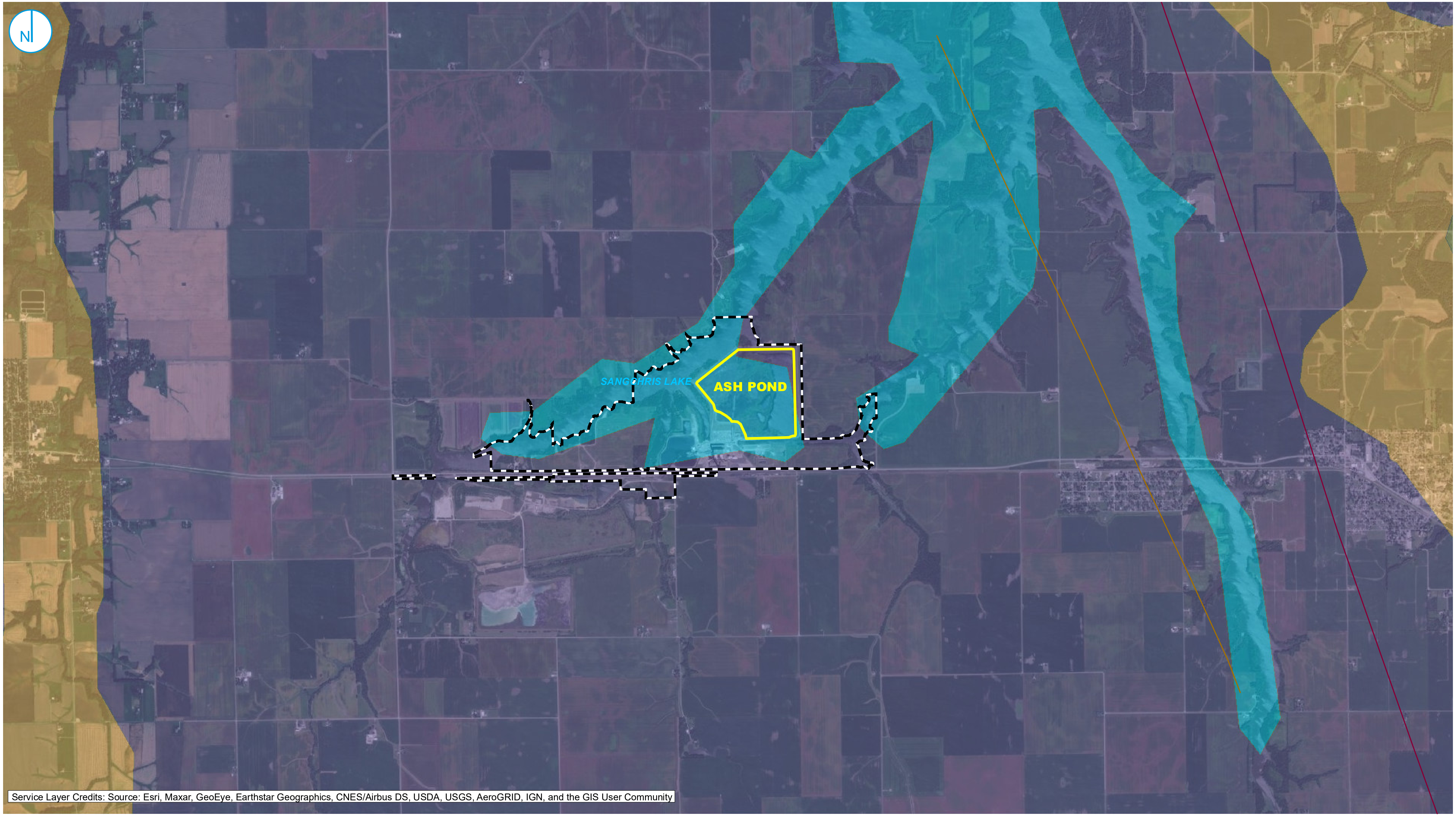
HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

FIGURE 2-2

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

Y:\Mapping\Projects\22\2285\MXD\845_Operating_Permit\Kincaid\Figure 2-2_Soil Survey.mxd

PROJECT: 169000XXXX | DATED: 8/5/2021 | DESIGNER: galarnmc



Y:\Mapping\Projects\22\2285\MXD\845_Operating_Permit\Kincaid\Figure 2-3_Surficial Geologic Deposits.mxd

PROJECT: 169000XXXX | DATED: 9/30/2021 | DESIGNER: STOLZSD

PART 845 REGULATED UNIT (SUBJECT UNIT)
PROPERTY BOUNDARY

CAHOKIA ALLUVIUM (INCLUDES ALLUVIAL FAN FACIES)
MACKINAW MEMBER
VANDALIA TILL MEMBER
WATER

0 1,500 3,000 Feet

SOURCE:
ILLINOIS STATE GEOLOGICAL SURVEY (ISGS)

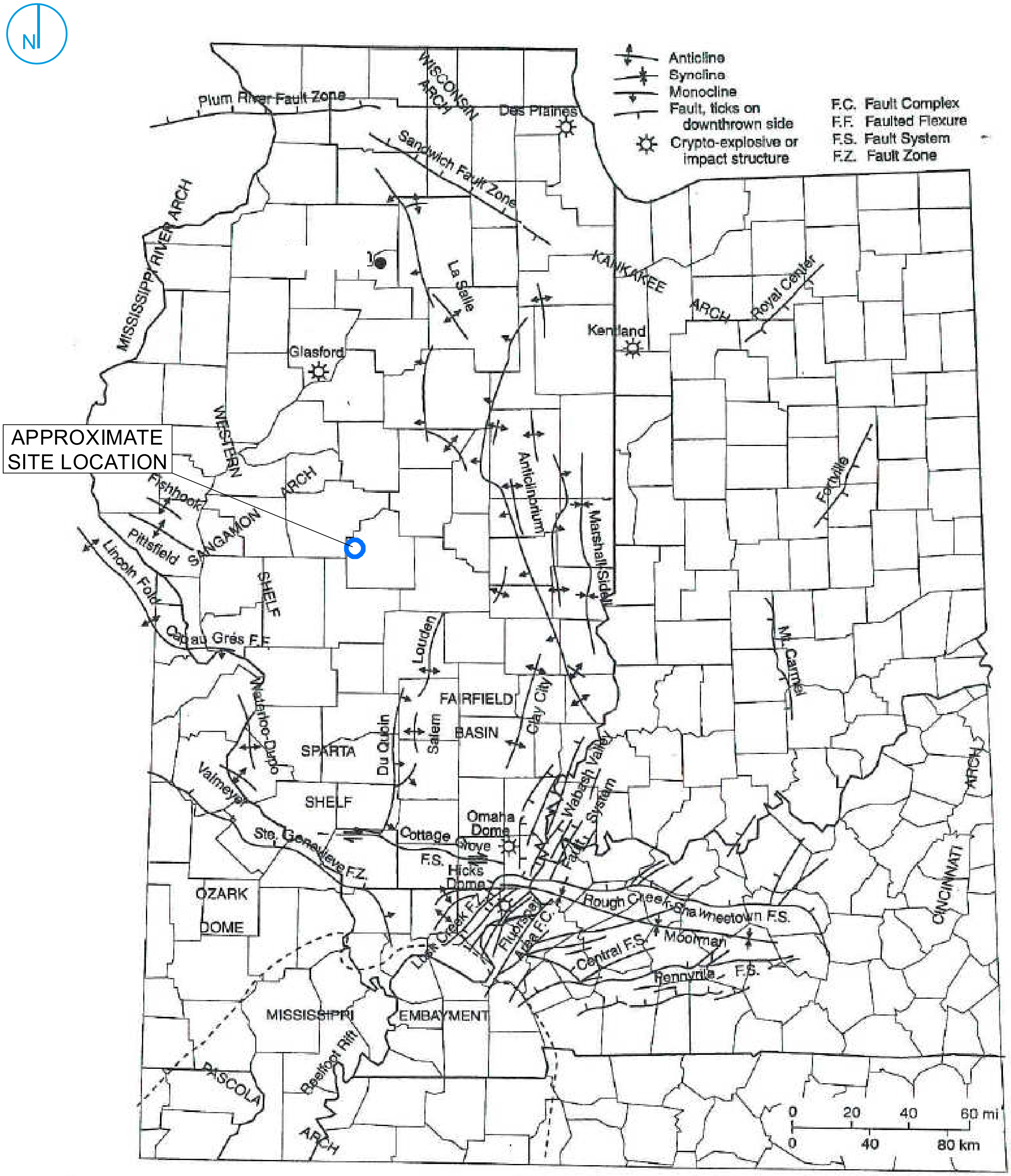
SURFICIAL GEOLOGIC DEPOSITS

HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

FIGURE 2-3

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

RAMBOLL



SOURCE NOTE: MODIFIED FROM "NELSON, W.J. 1995, STRUCTURAL FEATURES IN ILLINOIS, ILLINOIS STATE GEOLOGICAL SURVEY, BULLETIN 100, CHAMPAIGN, ILLINOIS."

Service Layer Credits:

PROJECT: 169000XXXX | DATED: 8/5/2021 | DESIGNER: galarnmc

MAJOR STRUCTURAL FEATURES OF ILLINOIS

FIGURE 2-4

RAMBOLL AMERICAS ENGINEERING SOLUTIONS, INC.

HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

Y:\Mapping\Projects\22\2285\MXD\845_Operating_Permit\Kincaid\Figure 2-5_Field Investigation Location Map.mxd

PROJECT: 169000XXXX | DATED: 10/5/2021 | DESIGNER: STOLZSD

MONITORING WELL
SOURCE SAMPLE LOCATION
SOIL BORING
PART 845 REGULATED UNIT (SUBJECT UNIT)
PROPERTY BOUNDARY

0 250 500 Feet

FIELD INVESTIGATION LOCATION MAP

HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

FIGURE 2-5

RAMBOLL AMERICAS ENGINEERING SOLUTIONS, INC.

RAMBOLL

NOTES: CONTOUR LINES ARE FROM HISTORIC SURVEY (SARGENT & LUNDY ENGINEERS, 1964)
Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Y:\Mapping\Projects\22\2285\MXD\845_Operating_Permit\Kincaid\Figure 2-6_Bottom of Ash.mxd

PROJECT: 169000XXXX | DATED: 9/30/2021 | DESIGNER: STOLZSD

5 FOOT HISTORIC ELEVATION CONTOUR
4 FOOT HISTORIC ELEVATION CONTOUR
PART 845 REGULATED UNIT (SUBJECT UNIT)
PROPERTY BOUNDARY

0 250 500 Feet

BOTTOM OF ASH

HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

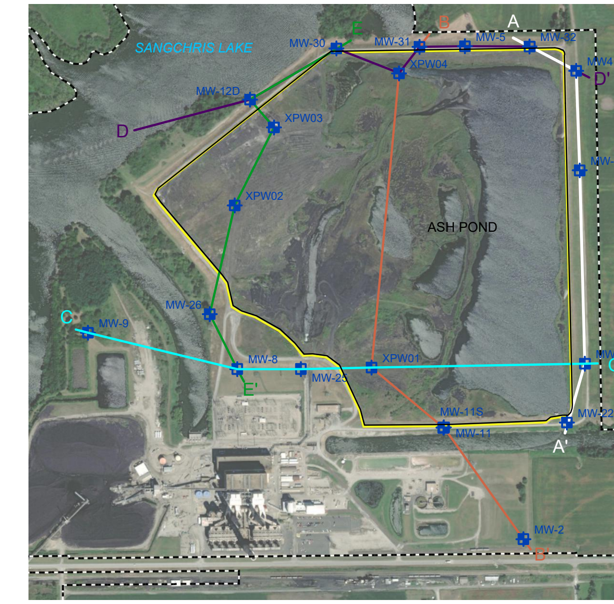
FIGURE 2-6

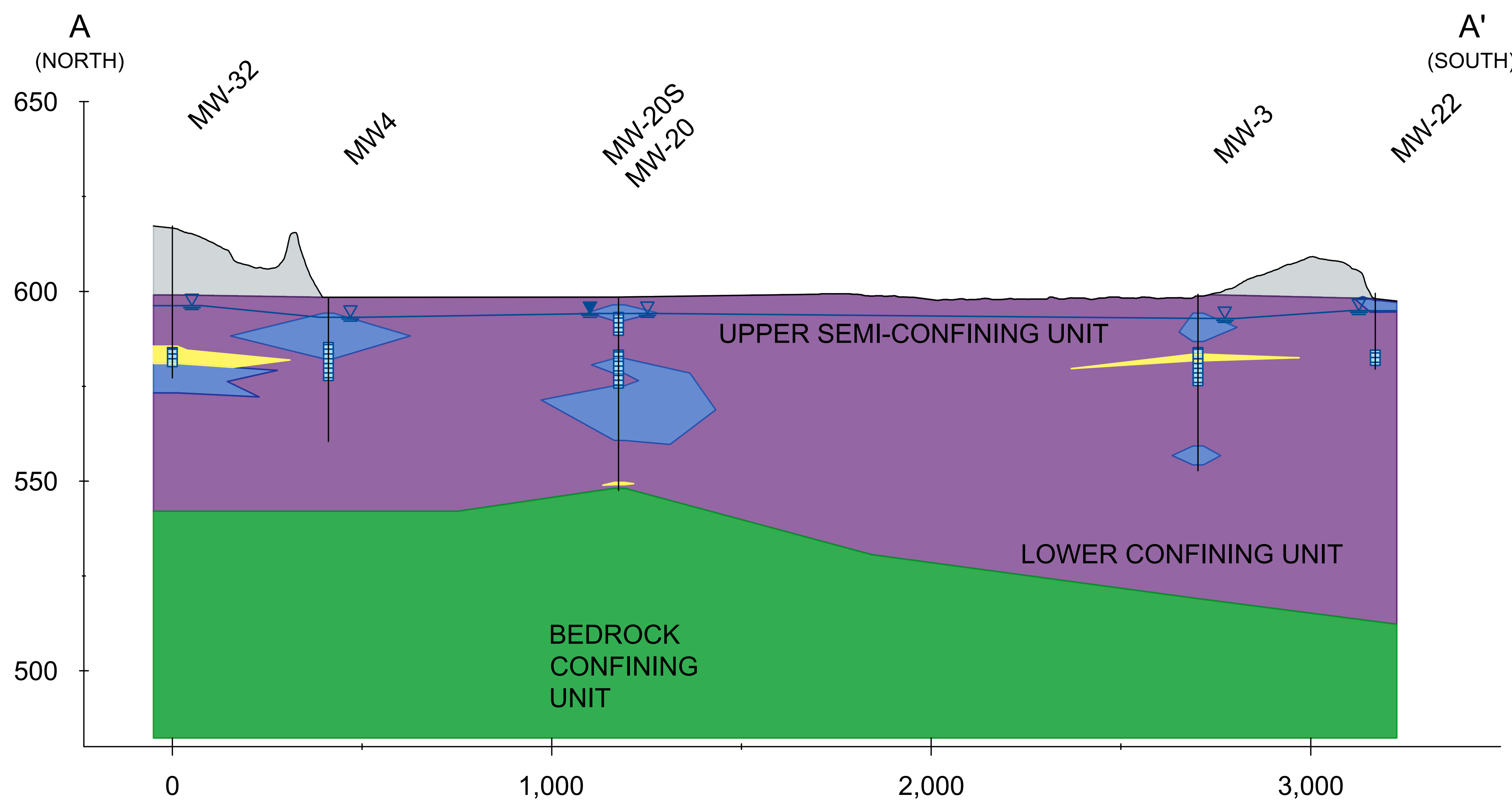
RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

RAMBOLL

NOTES

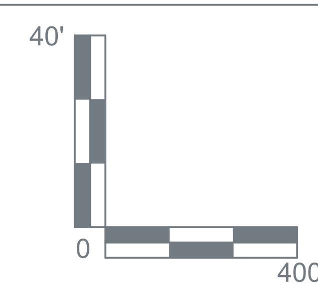
1. This profile was developed by interpolation between widely spaced boreholes. Only at the borehole location should it be considered as an approximately accurate representation and then only to the degree implied by the notes on the borehole logs.
2. Scale is approximate.
3. Vertical scale is exaggerated 10X.
4. Vertical Datum: NAVD88
5. Groundwater elevations measured on July 22-23, 2021.





LEGEND

- COAL COMBUSTION RESIDUALS, CCRs
- FILL
- CLAY (CL/CH)
- SILT (ML)
- SAND (SP/SM/SW)
- BEDROCK / WEATHERED BEDROCK (INTERBEDDED SHALE, LIMESTONE, SANDSTONE, V. LITTLE SS)
- WELL SCREEN INTERVAL
- UPPERMOST AQUIFER POTENTIOMETRIC SURFACE
- UPPER AQUIFER GROUNDWATER ELEVATION
- POREWATER ELEVATION
- BEDROCK GROUNDWATER / OTHER GROUNDWATER / SURFACE WATER ELEVATION(S)



GEOLOGIC CROSS SECTION A-A'

HYDROGEOLOGIC SITE CHARACTERIZATION REPORT ASH POND

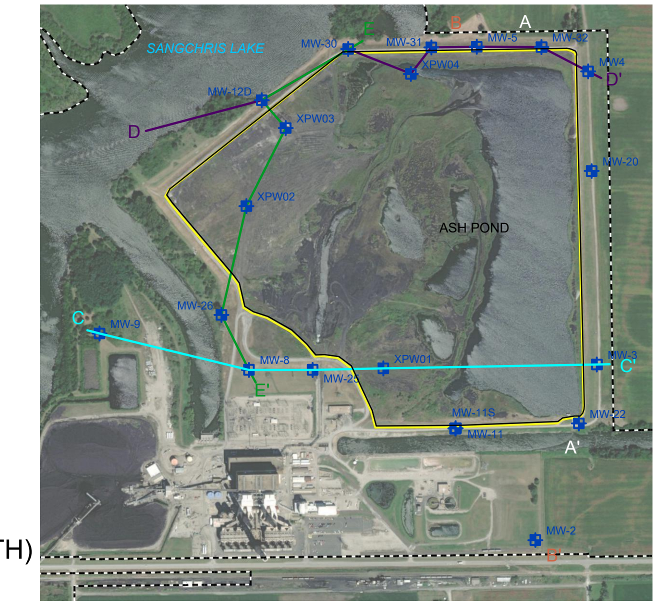
KINCAID POWER PLANT
KINCAID, ILLINOIS

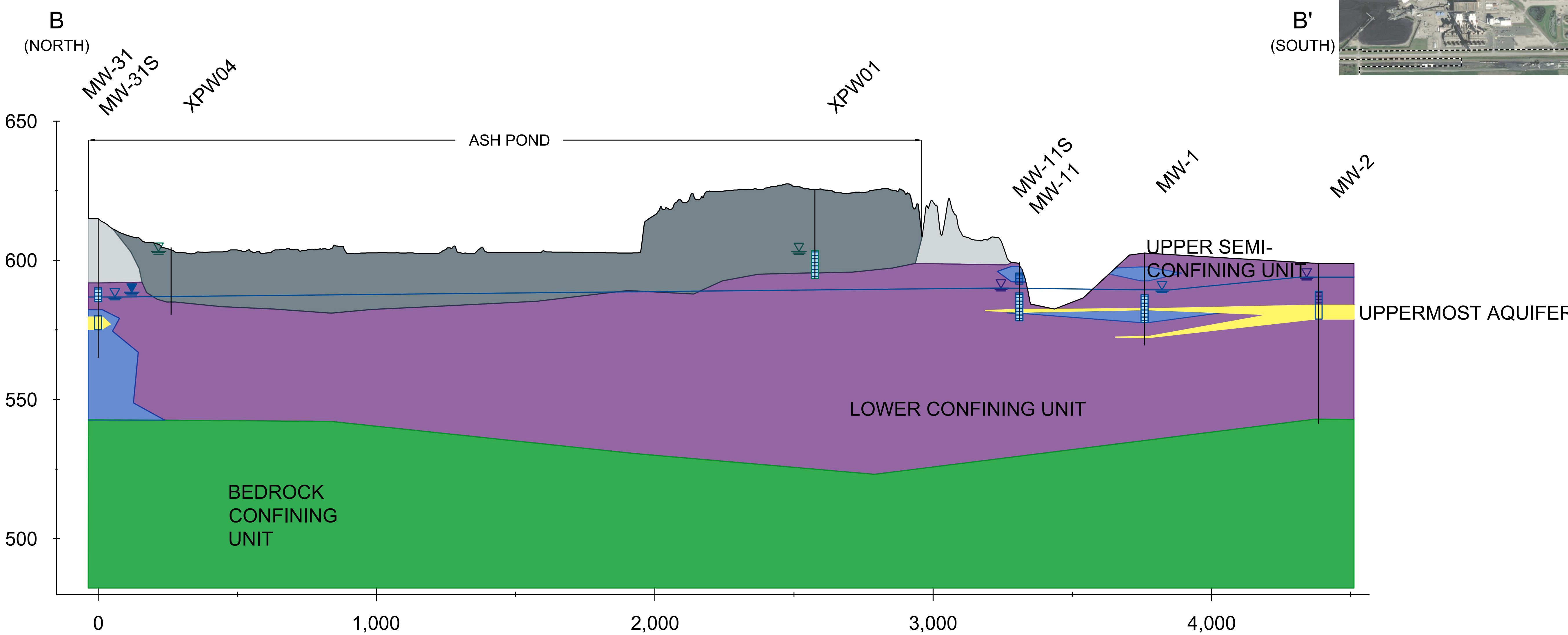
FIGURE 2-7

RAMBOLL AMERICAS ENGINEERING SOLUTIONS, INC.

RAMBOLL

NOTES
1. This profile was developed by interpolation between widely spaced boreholes. Only at the borehole location should it be considered as an approximately accurate representation and then only to the degree implied by the notes on the borehole logs.
2. Scale is approximate.
3. Vertical scale is exaggerated 10X.
4. Vertical Datum: NAVD88
5. Groundwater elevations measured on July 22-23, 2021.





LEGEND

- COAL COMBUSTION RESIDUALS, CCRs
- FILL
- CLAY (CL/CH)
- SILT (ML)
- SAND (SP/SM/SW)
- BEDROCK / WEATHERED BEDROCK (INTERBEDDED SHALE, LIMESTONE, SANDSTONE, V. LITTLE SS)
- WELL SCREEN INTERVAL
- UPPERMOST AQUIFER POTENTIOMETRIC SURFACE
- UPPER AQUIFER GROUNDWATER ELEVATION
- POREWATER ELEVATION
- BEDROCK GROUNDWATER / OTHER GROUNDWATER / SURFACE WATER ELEVATION(S)

40'
0
400'

GEOLOGIC CROSS SECTION B-B'

HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

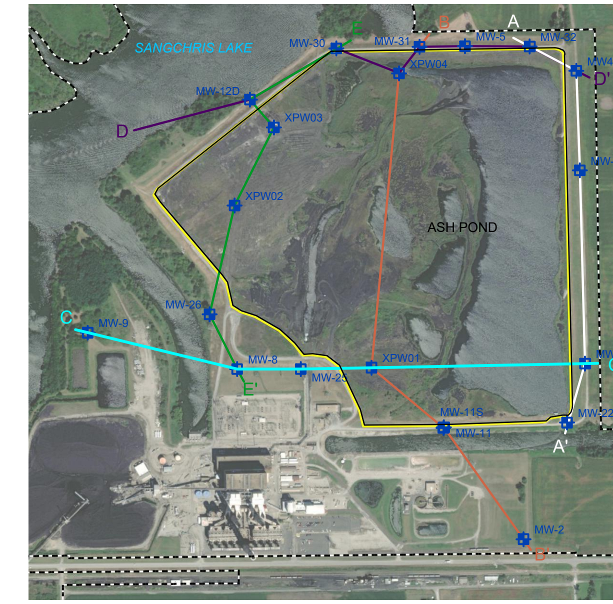
FIGURE 2-8

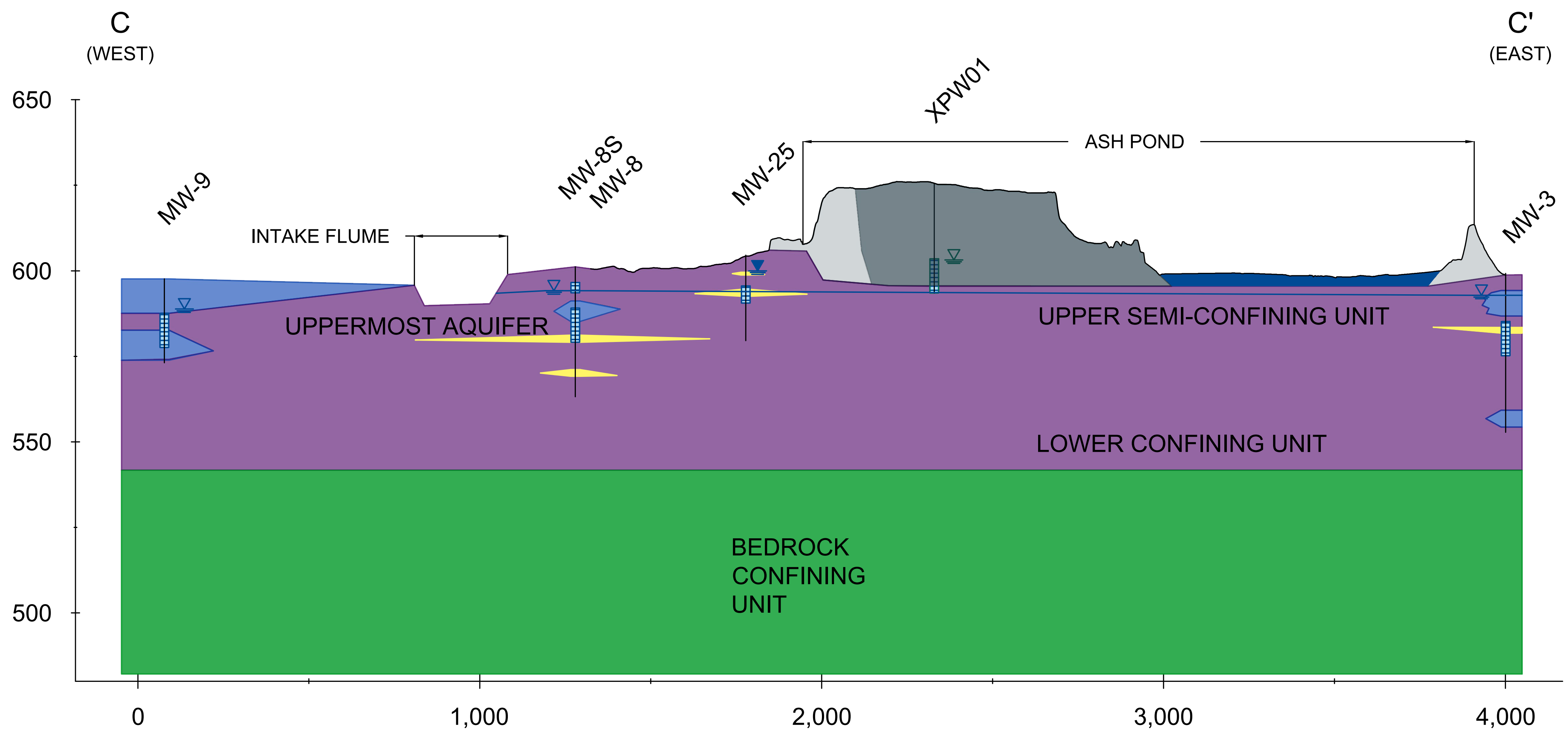
RAMBOLL AMERICAS ENGINEERING SOLUTIONS, INC.

RAMBOLL

NOTES

1. This profile was developed by interpolation between widely spaced boreholes. Only at the borehole location should it be considered as an approximately accurate representation and then only to the degree implied by the notes on the borehole logs.
2. Scale is approximate.
3. Vertical scale is exaggerated 10X.
4. Vertical Datum: NAVD88
5. Groundwater elevations measured on July 22-23, 2021.





LEGEND

- SURFACE WATER
- COAL COMBUSTION RESIDUALS, CCRs
- FILL
- CLAY (CL/CH)
- SILT (ML)
- SAND (SP/SM/SW)
- BEDROCK / WEATHERED BEDROCK (INTERBEDDED SHALE, LIMESTONE, SANDSTONE, V. LITTLE SS)
- WELL SCREEN INTERVAL
- UPPERMOST AQUIFER POTENTIOMETRIC SURFACE
- UPPER AQUIFER GROUNDWATER ELEVATION
- POREWATER ELEVATION
- BEDROCK GROUNDWATER / OTHER GROUNDWATER / SURFACE WATER ELEVATION(S)

40'
0
400'

GEOLOGIC CROSS SECTION C-C'

HYDROGEOLOGIC SITE CHARACTERIZATION REPORT ASH POND

KINCAID POWER PLANT
KINCAID, ILLINOIS

FIGURE 2-9

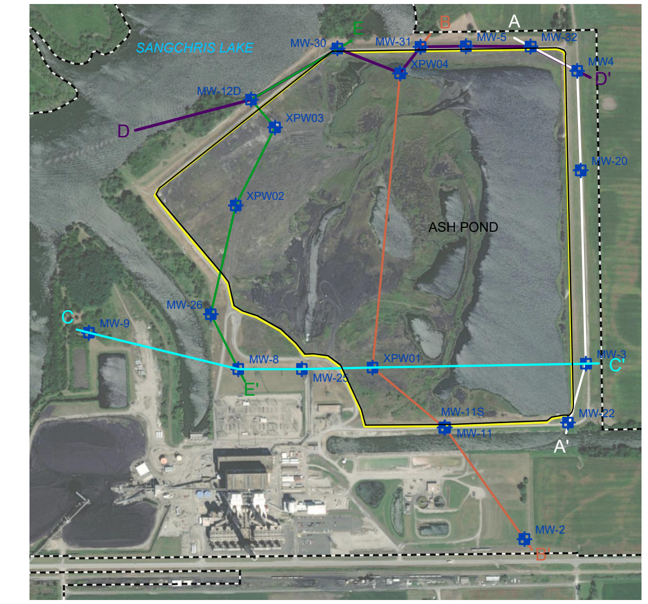
RAMBOLL AMERICAS ENGINEERING SOLUTIONS, INC.

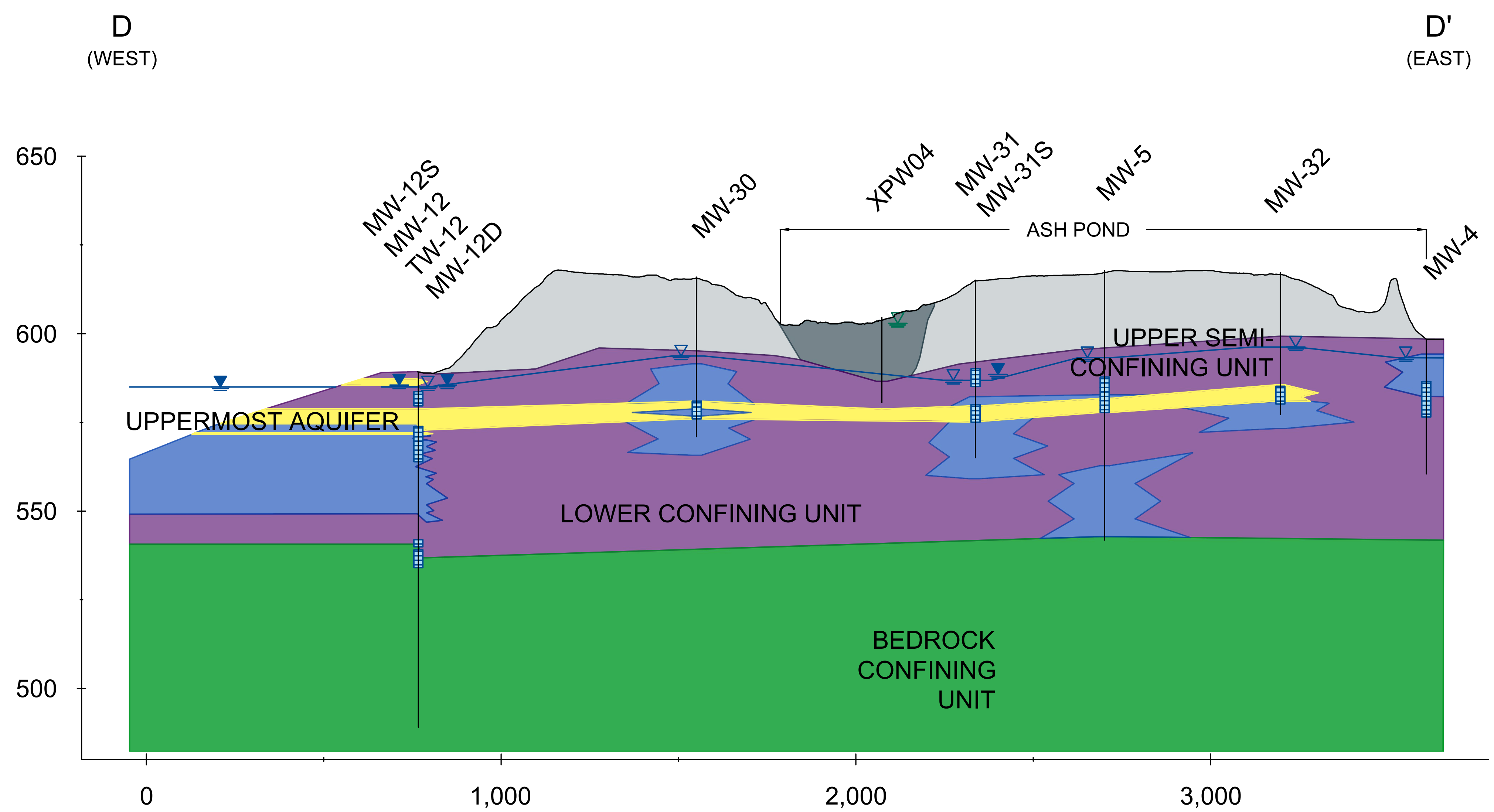
RAMBOLL

PROJECT: 1940... \...Documents\-CCR GW\Deliverables\Part 845 Operating Permits\Sites\Kincaid\Hydrogeo\Figures\EVS\working files\CAD\Cross Sections\Kincaid Cross Sections.dwg

NOTES

1. This profile was developed by interpolation between widely spaced boreholes. Only at the borehole location should it be considered as an approximately accurate representation and then only to the degree implied by the notes on the borehole logs.
2. Scale is approximate.
3. Vertical scale is exaggerated 10X.
4. Vertical Datum: NAVD88
5. Groundwater elevations measured on July 22-23, 2021.





LEGEND

- COAL COMBUSTION RESIDUALS, CCRs
- FILL
- CLAY (CL/CH)
- SILT (ML)
- SAND (SP/SM/SW)
- BEDROCK / WEATHERED BEDROCK (INTERBEDDED SHALE, LIMESTONE, SANDSTONE, V. LITTLE SS)
- WELL SCREEN INTERVAL
- UPPERMOST AQUIFER POTENTIOMETRIC SURFACE
- UPPER AQUIFER GROUNDWATER ELEVATION
- POREWATER ELEVATION
- BEDROCK GROUNDWATER / OTHER GROUNDWATER / SURFACE WATER ELEVATION(S)
- SURFACE WATER

40'
0
400'

GEOLOGIC CROSS SECTION D-D'

HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

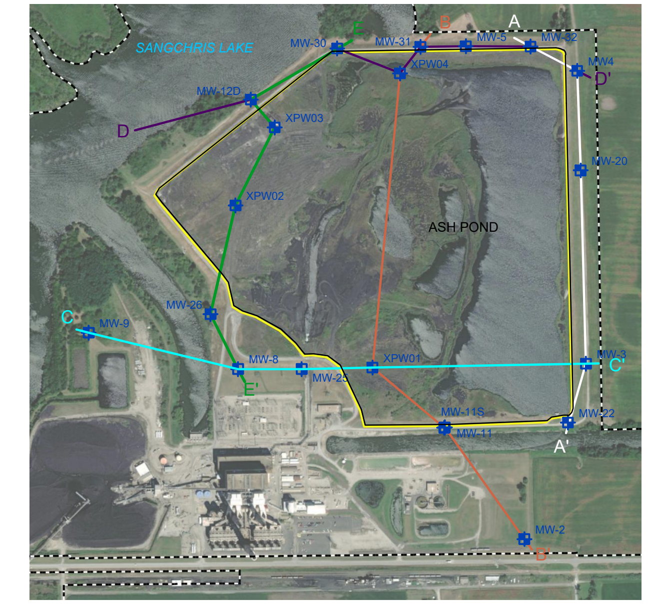
FIGURE 2-10

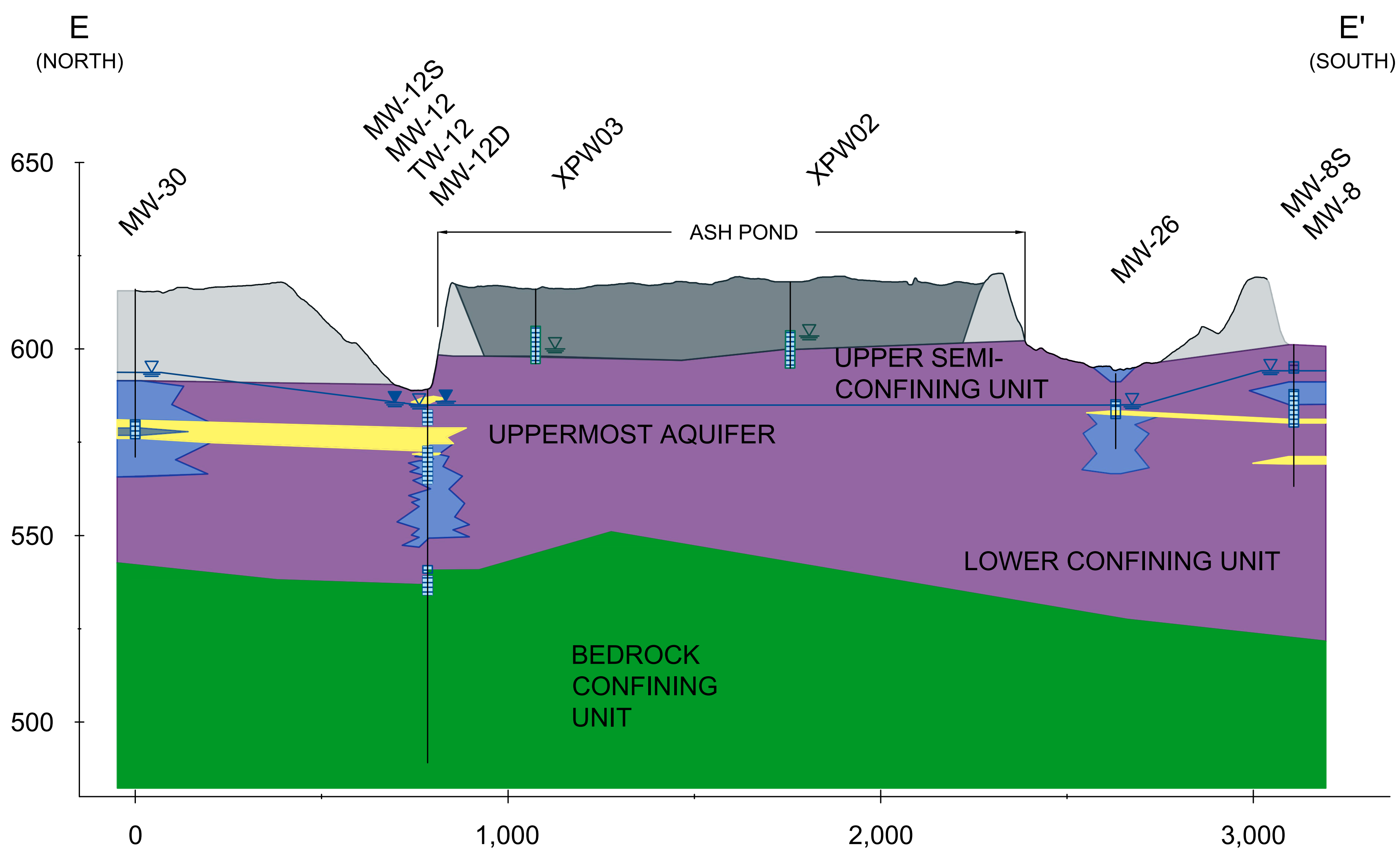
RAMBOLL AMERICAS ENGINEERING SOLUTIONS, INC.

RAMBOLL

NOTES

1. This profile was developed by interpolation between widely spaced boreholes. Only at the borehole location should it be considered as an approximately accurate representation and then only to the degree implied by the notes on the borehole logs.
2. Scale is approximate.
3. Vertical scale is exaggerated 10X.
4. Vertical Datum: NAVD88
5. Groundwater elevations measured on July 22-23, 2021.





LEGEND

- COAL COMBUSTION RESIDUALS, CCRs
- FILL
- CLAY (CL/CH)
- SILT (ML)
- SAND (SP/SM/SW)
- BEDROCK / WEATHERED BEDROCK (INTERBEDDED SHALE, LIMESTONE, SANDSTONE, V. LITTLE SS)
- WELL SCREEN INTERVAL
- UPPERMOST AQUIFER POTENTIOMETRIC SURFACE
- UPPER AQUIFER GROUNDWATER ELEVATION
- POREWATER ELEVATION
- BEDROCK GROUNDWATER / OTHER GROUNDWATER / SURFACE WATER ELEVATION(S)

40'
0
400'

GEOLOGIC CROSS SECTION E-E'

HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

FIGURE 2-11

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

RAMBOLL

BACKGROUND WELL
MONITORING WELL
SOURCE SAMPLE LOCATION
STAFF GAGE

PART 845 REGULATED UNIT (SUBJECT UNIT)
PROPERTY BOUNDARY

0 250 500 Feet

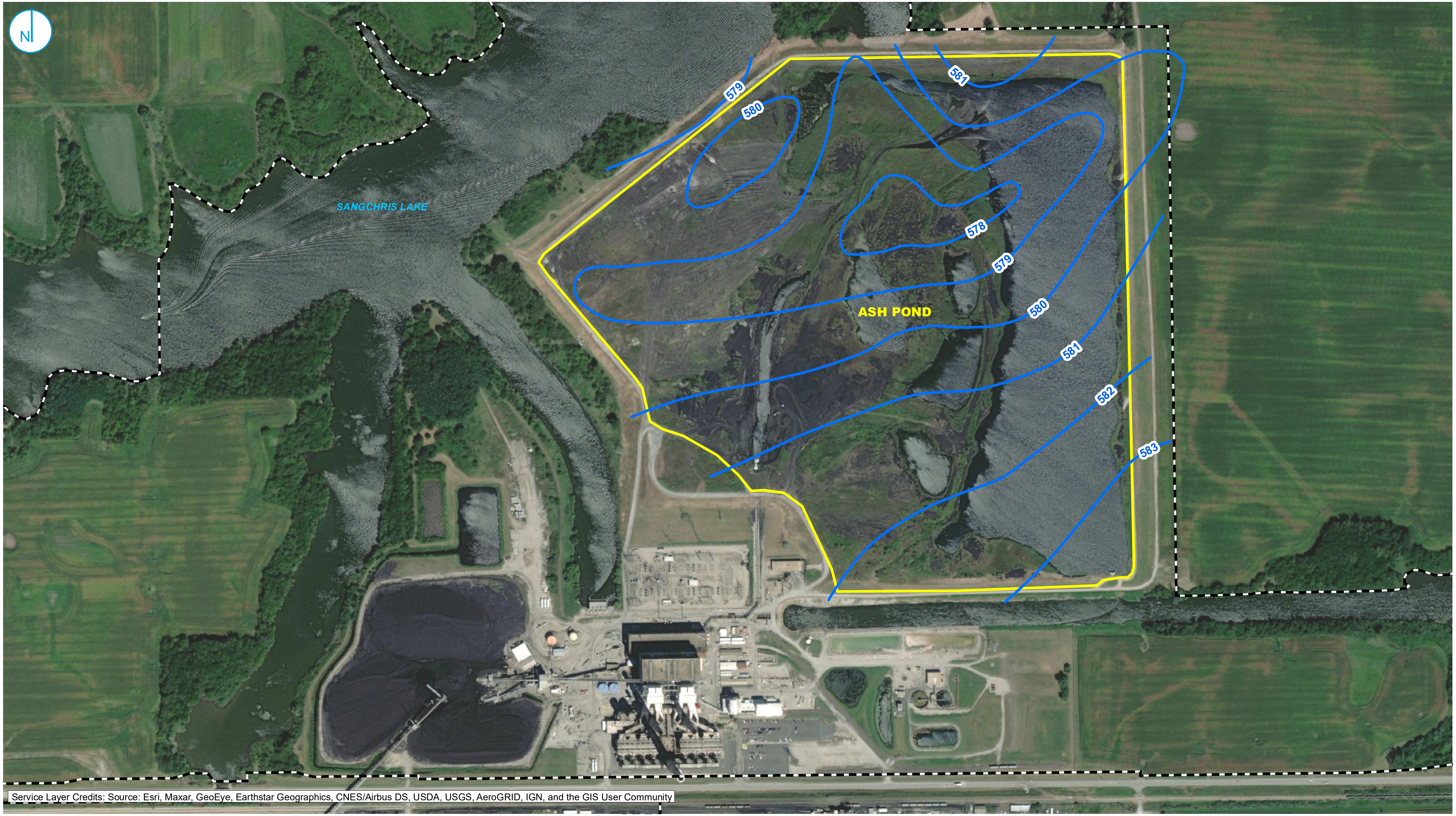
MONITORING WELL LOCATION MAP

HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

FIGURE 3-1

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

RAMBOLL



Y:\Mapping\Projects\22\2285\MXD\845_Operating_Permit\Kincaid\Figure 3-2_Top of Uppermost Aquifer.mxd
PROJECT: 169000XXXX | DATED: 8/18/2021 | DESIGNER: STOLZSD

INTERPRETED TOP OF UPPERMOST AQUIFER (95TH PERCENTILE GROUNDWATER ELEVATION CONTOURS)

PART 845 REGULATED UNIT (SUBJECT UNIT)

PROPERTY BOUNDARY

0 250 500 Feet

NOTE
TOP OF AQUIFER CONTOURS GENERATED IN 2018 (HALEY & ALDRICH, INC., 2018) FOR 40 C.F.R. § 257; CONTOURS HAVE NOT BEEN MODIFIED USING BORING DATA COLLECTED IN 2021, ALTHOUGH THE SEPARATION DISTANCE BETWEEN TOP OF UPPERMOST AQUIFER AND BASE OF ASH IS CONSISTENT.

TOP OF UPPERMOST AQUIFER

FIGURE 3-2

HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

RAMBOLL

BACKGROUND WELL
MONITORING WELL
SOURCE SAMPLE LOCATION
STAFF GAGE

GROUNDWATER ELEVATION CONTOUR (2-FT CONTOUR INTERVAL, NAVD88)
INFERRED GROUNDWATER ELEVATION CONTOUR
GROUNDWATER FLOW DIRECTION
PART 845 REGULATED UNIT (SUBJECT UNIT)
PROPERTY BOUNDARY

0 250 500 Feet

GROUNDWATER ELEVATION CONTOUR
FEBRUARY 23, 2021

HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

FIGURE 3-3

RAMBOLL AMERICAS ENGINEERING SOLUTIONS, INC.

RAMBOLL

Y:\Mapping\Projects\22\2285\MXD\845_Operating_Permit\Kincaid\Figure 3-4_GWE_Contours_20210315.mxd

PROJECT: 169000XXXX | DATED: 9/28/2021 | DESIGNER: STOLZSD

BACKGROUND WELL
MONITORING WELL
SOURCE SAMPLE LOCATION
STAFF GAGE

GROUNDWATER ELEVATION CONTOUR (2-FT CONTOUR INTERVAL, NAVD88)
INFERRED GROUNDWATER ELEVATION CONTOUR
GROUNDWATER FLOW DIRECTION
PART 845 REGULATED UNIT (SUBJECT UNIT)
PROPERTY BOUNDARY

0 250 500 Feet

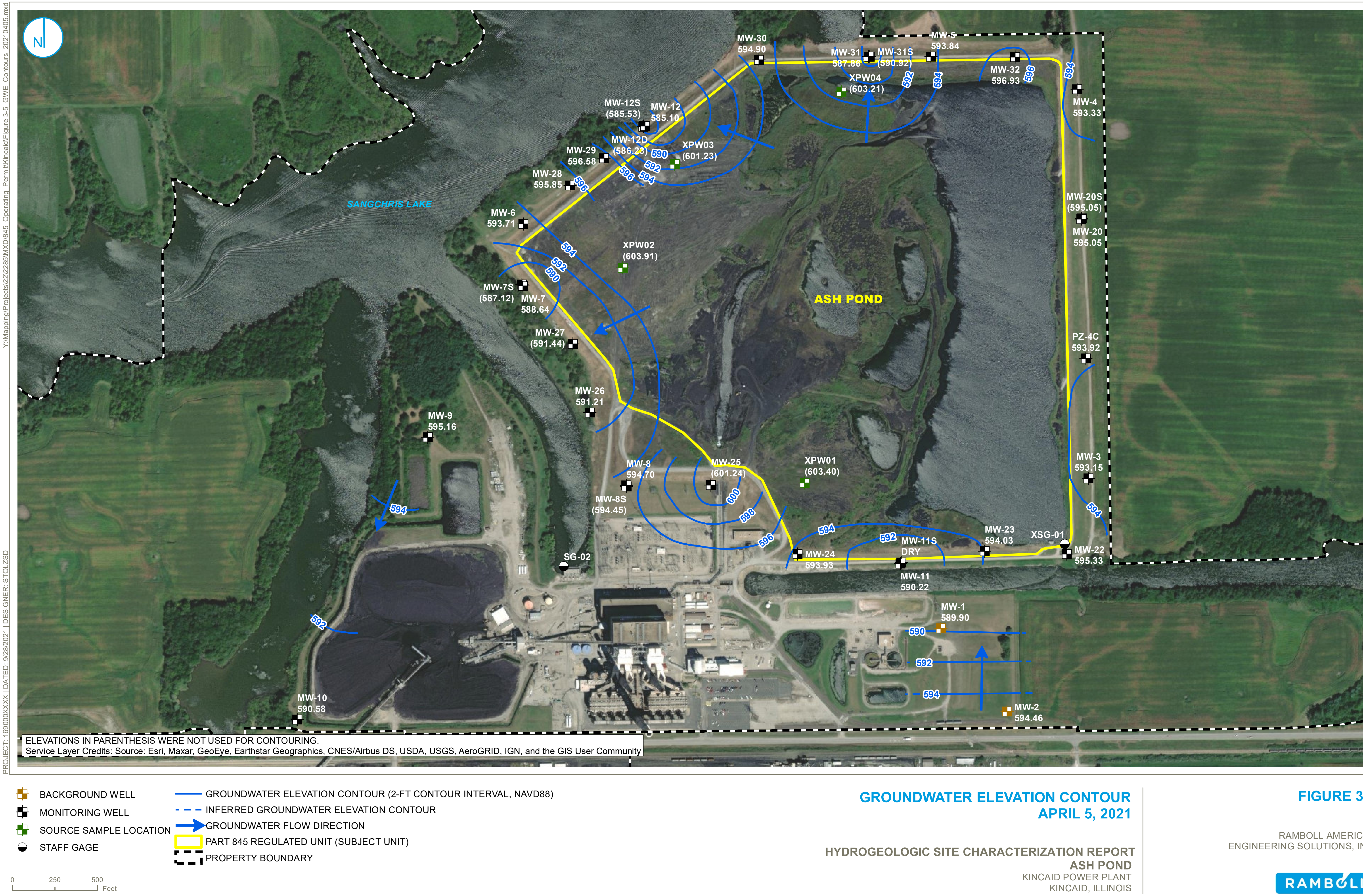
GROUNDWATER ELEVATION CONTOUR
MARCH 15, 2021

HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

FIGURE 3-4

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

RAMBOLL



GROUNDWATER ELEVATION CONTOUR
APRIL 5, 2021

HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

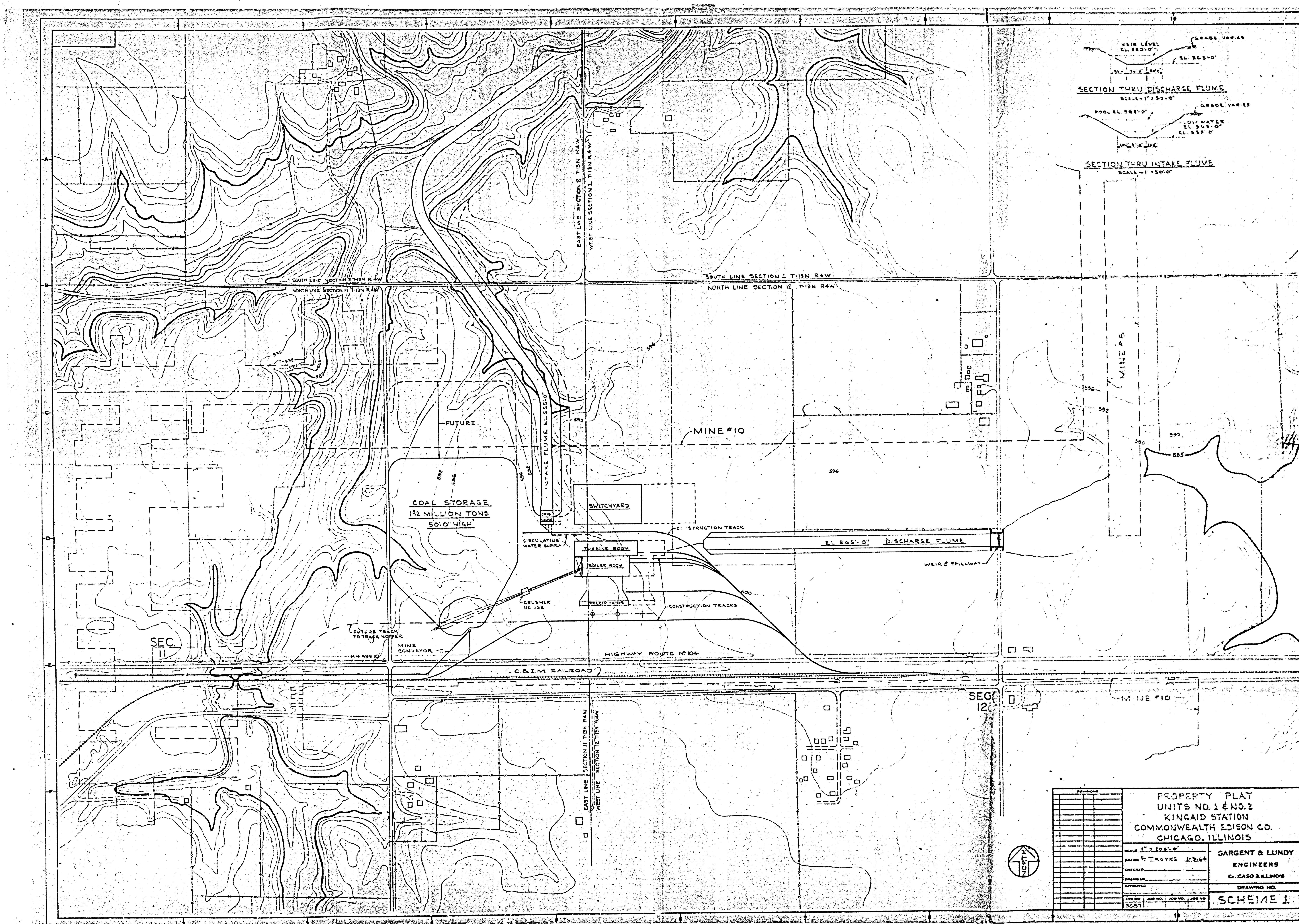
FIGURE 3-5

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

RAMBOLL

APPENDICES

APPENDIX A
HISTORIC PLAT OF SURVEY MAP (1966)


SECTION THRU DISCHARGE FLUME
SCALE - 1" = 50'-0"
GRADE VARIES
SECTION THRU INTAKE FLUME
SCALE - 1" = 50'-0"
GRADE VARIES
LOW WATER
SOUTH LINE SECTION 2 T-13N R4W
NORTH LINE SECTION 11 T-13N R4W
SOUTH LINE SECTION 1 T-13N R4W
NORTH LINE SECTION 12 T-13N R4W
EAST LINE SECTION 2 T-13N R4W
WEST LINE SECTION 1 T-13N R4W
INTAKE FLUME
MINE #10
MINE #8
FUTURE
COAL STORAGE
1¾ MILLION TONS
50'-0" HIGH
SWITCHYARD
CONSTRUCTION TRACK
DISCHARGE FLUME
WEIR & SPILLWAY
CIRCULATING WATER SUPPLY
TURBINE ROOM
BOILER ROOM
PRECIPITATOR
CRUSHER
CONSTRUCTION TRACKS
FUTURE TRACK TO TRACK HOPPER
MINE CONVEYOR
HIGHWAY ROUTE No 104
C. & I. M. RAILROAD
SEC. 11
SEC. 12
EAST LINE SECTION 11 T-13N R4W
WEST LINE SECTION 12 T-13N R4W
NORTH
REVISIONS
PROPERTY PLAT
UNITS NO. 1 & NO. 2
KINCAID STATION
COMMONWEALTH EDISON CO.
CHICAGO, ILLINOIS
SCALE 1" = 100'-0"
DRAWN
CHECKED
ENGINEER
APPROVED
JOB NO.
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
SCHEME 1

APPENDIX B
INFORMATION PERTINENT TO 35 I.A.C. § 845.220(A)(3)

SUMMARY OF POTENTIAL RECEPTORS WITHIN 1,000 METERS
DESKTOP STUDY
KINCAID POWER PLANT
ASH POND
KINCAID, IL

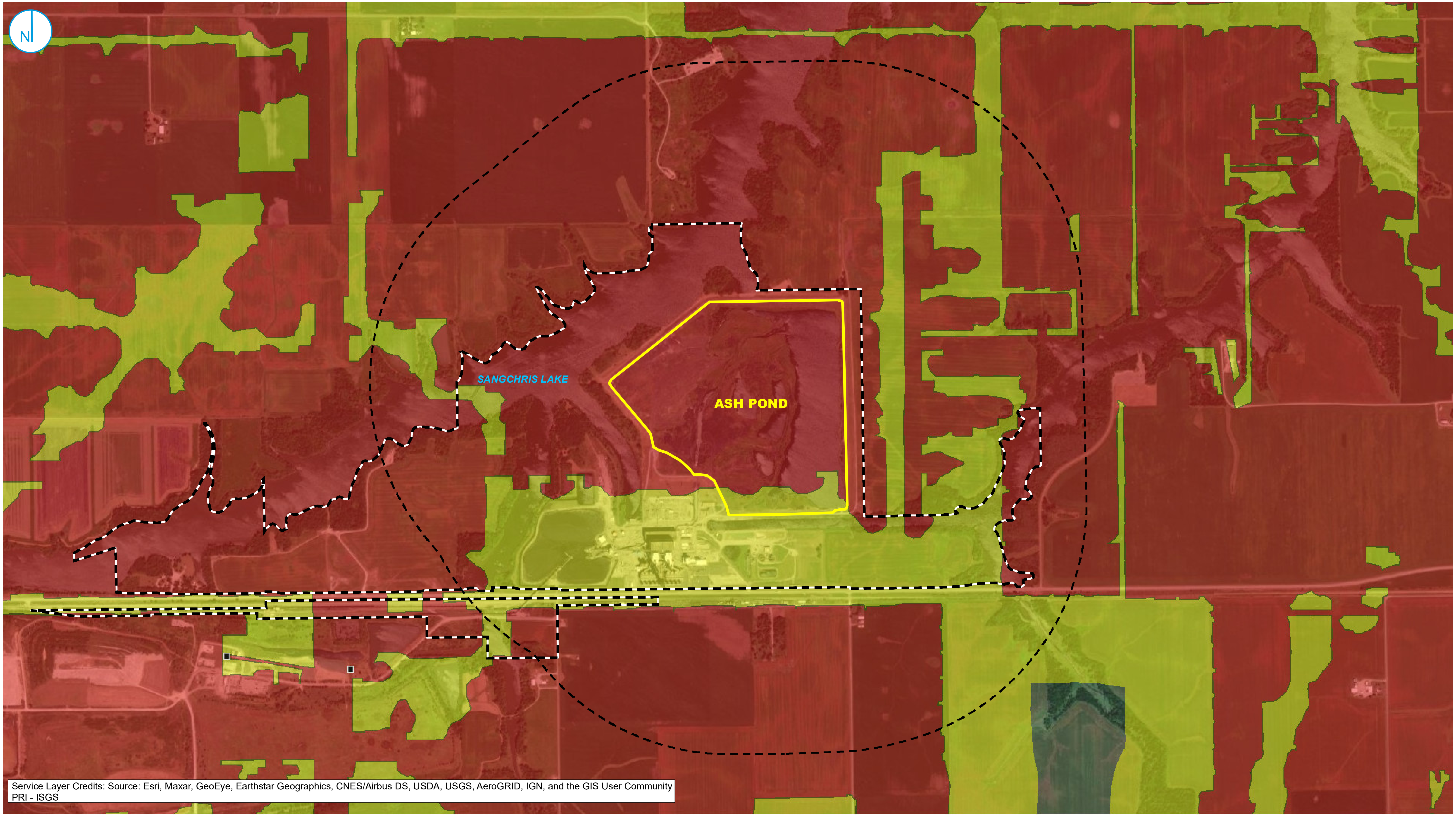
Category	Number of Receptors Identified Within 1,000 Meters	Number of Receptors Identified Downgradient of Unit	Notes
Wells	9	2	
Surface Water Features	21	9	
Historic Sites	1	1	
Natural Sites	-	---	
Threatened or Endangered Species	5	5	Data provided only at county level
Mines	2	---	Mines identified are located beneath unit
Oil Sites	2	2	Dry/ Plugged Units

[O: LTA 04/08/21; C: LDC 09/15/21]

Notes:
--- = none

RAMBOLL

MINING ACTIVITIES



Y:\Mapping\Projects\22\2285\MXD\845_Operating_Permit\Kincaid\Figure B-1_Active and Abandoned Coal Mines.mxd

PROJECT: 169000XXXX | DATED: 8/18/2021 | DESIGNER: STOLZSD

- COAL MINE SHAFT
- UNDERGROUND COAL MINE
- UNDERGROUND MINE BUFFER REGION
- PART 845 REGULATED UNIT (SUBJECT UNIT)
- 1000 METER UNIT BUFFER
- PROPERTY BOUNDARY

0 625 1,250 Feet

SOURCES:
ISGS - ILMINES

ACTIVE AND ABANDONED COAL MINES

HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

FIGURE B-1

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

RAMBOLL

MINES WITHIN 1,000 METERS
DESKTOP STUDY
KINCAID POWER PLANT
ASH POND
KINCAID, IL

Mine ID	Mine Name	Distance from Unit (meters)	Physical Orientation to Unit	Hydraulic Orientation to Unit	Range of Active Dates	Mine Type	Coal Unit Mined	Mine Depth Top (ft BGS)	Mine Depth Bottom (ft BGS)	Final Extent Map Available
0220	Peabody No. 8 Mine	244	Below and surrounding	Downgradient	1914-1954	Main Shaft/Air Shaft	Herrin	--	370	Yes
0693	Peabody No. 10 Mine	0	Below and surrounding	Upgradient	1951-1994	Main Slopt/Air Shaft	Herrin	300	380	Yes

[O: LTA 04/08/21; C: LDC 09/15/21]

WATER WELL SURVEY

Y:\Mapping\Projects\22\2285\MXD\845_Operating_Permit\Kincaid\Figure B-2_Drinking Water Intakes Pumps Other Water Uses.mxd

PROJECT: 169000XXXX | DATED: 8/18/2021 | DESIGNER: STOLZSD

DRY
ENGINEERING
MINE-RELATED
WATER
N/A

PART 845 REGULATED UNIT (SUBJECT UNIT)
1000 METER UNIT BUFFER
PROPERTY BOUNDARY

0 625 1,250 Feet

SOURCE:
IL WELLS

DRINKING WATER INTAKES, PUMPS, AND OTHER WATER USES

FIGURE B-2

HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

RAMBOLL

WELLS WITHIN 1,000 METERS
DESKTOP STUDY
KINCAID POWER PLANT
ASH POND
KINCAID, IL

Well Number	Date Constructed	Ground Elevation (ft NAVD88)	Screen Top Depth (FT BGS)	Screen Bottom Depth (ft BGS)	Screen Length (ft)	Screen Diameter (inches)	Well Depth (ft BGS)	Total Boring Depth (ft BGS)	Latitude (DD)	Longitude (DD)	Hydraulic Position Designation (B/Sd/U/D)	Notes
120210003900	12/31/1911	---	---	---	---	---	---	310	39.601681	-89.495745	D	coal test, Herrin Coal #6
120210052100	4/1/1956	590	---	---	---	---	---	1933	---	---	---	dry and abandoned
120210070900	12/1/1954	606	---	---	---	---	---	1914	---	---	---	dry and abandoned
120210245500	7/1/1964	---	---	---	---	---	25	28	39.59156	-89.479955	---	engineering test
120212289800	4/1/1975	---	11	47	36	36	47	47	39.605548	-89.492034	D	municipal water well
120212346200	3/4/1980	---	10	30	20	30	30	30	39.590652	-89.483559	---	water well, commercial
120212449100	11/1/1996	---	---	---	---	---	---	21	39.590657	-89.478728	---	test hole
120212464000	02/08/1996	---	12	35	23	36	50	50	39.547152	-89.447541	---	private water well
120212464200	2/14/1996	---	11	62	51	36	68	68	39.595172	-89.489659	---	private water well

[O: LTA 04/08/21; C: LDC 09/15/21]

Notes:
--- = no data
B = background
BGS = below ground surface
D = downgradient
DD = decimal degrees
ft = foot/feet
LCU = lower confining unit
Sd= Sidegradient
U = upgradient
NAVD88 = North American Vertical Datum of 1988, GEOID 12A

ILLINOIS STATE GEOLOGICAL SURVEY

Coal Test	Top	Bottom
surface	0	2
sand	2	15
sandstone	15	19
limestone	19	30
slate, blue	30	34
slate, black	34	40
limestone	40	55
slate, blue	55	107
slate, black	107	108
coal	108	110
slate, light	110	129
coal	129	130
limestone	130	135
sandstone	135	156
slate, sandy	156	232
slate, light	232	237
slate, blue	237	244
limestone	244	249
slate, blue	249	260
sandstone	260	267
limestone	267	269
slate, light	269	272
limestone	272	274
shale	274	278

Permit Date: **Permit #:**

COMPANY owner
FARM Whitecraft, Mrs.
DATE DRILLED January 1, 1912 **NO.** 8
ELEVATION 569GL **COUNTY NO.** 00039
LOCATION SW NW SW
LATITUDE 39.601681 **LONGITUDE** -89.495745
COUNTY Christian **API 120210003900** **1 - 13N - 4W**

sandstone	278	287
slate, black	287	289
limestone	289	298
slate, black	298	299
coal (6)	299	306
fireclay, very soft	306	310
Herrin Coal #6	299	306
Total Depth		**310**

Driller's Log filed

Owner Address: ,

Location source: Location from the driller

ILLINOIS STATE GEOLOGICAL SURVEY

	Top	Bottom
Ste Genevieve	834	
Rosiclare	856	900
Fredonia	900	1203
Osage	1203	1422
Keokuk	1422	1638
Chouteau	1638	1660
Kinderhook	1660	1735
Rockford	1735	1738
New Albany	1738	1848
Devonian	1848	1850
Silurian	1850	1933
Aux Vases	8908	817
Total Depth		1933

Dry and abandoned.

Plugged March 2, 1956.

Electric Log filed.
Drilling Time Log filed.
Survey Core Study filed.

Core # 3332 1844'- 1874'Silurian
1844'- 1874'Devonian
Sample set # 26587 110'- 1930'

Imaged Log viewing help: New users please read this.

GET FILE Induction Electric Log

Get Scout Check Ticket for this well.

Get Handwritten Scout Ticket for this well.

Get Scanned Documents for this well.

Get Scanned Drilling Time Log.

Permit Date March 23, 1956 **Permit #** 958 **Reference #** 803578

COMPANY Wirth, Edward Lee

FARM Bryant **NO.** 1

DATE DRILLED April 1, 1956 **COUNTY NO** 00521

AUTHORITY

ELEVATION 590' KB

LOCATION 275'N line, 321'W line of section

COUNTY **CHRISTIAN** **API#120210052100** **7-13N-3W**

	Top	Bottom

ILLINOIS STATE GEOLOGICAL SURVEY

	Top	Bottom
Pennsylvanian	71	743
Paint Creek	743	795
Renault	795	804
Aux Vases	804	824
Ste Genevieve	835	850
Rosiclare	850	882
Fredonia	882	1148
Osage	1148	1354
Keokuk	1354	1616
Chouteau	1616	1632
Kinderhook	1632	1760
New Albany	1760	1826
Silurian	1826	1914
Total Depth		1914

Dry and abandoned.

Plugged December 23, 1954.

Electric Log filed.
Drilling Time Log filed.
Survey Core Study filed.

Core # 3192 1828'- 1853'Silurian
Sample set # 25281 100'- 1915'

Imaged Log viewing help: New users please read this.

GET FILE Induction Electric Log

Get Scout Check Ticket for this well.

Get Handwritten Scout Ticket for this well.

Get Scanned Documents for this well.

Permit Date December 16, 1954 **Permit #** 288 **Reference #** 803638

COMPANY Heath, B. M. etal
FARM Kavanaugh Trust **NO.** 1
DATE DRILLED December 1, 1954 **COUNTY NO** 00709
AUTHORITY
ELEVATION 606' DF
LOCATION 330'S line, 990'W line of NE
COUNTY **CHRISTIAN** **API#120210070900** **2-13N-4W**

	Top	Bottom
Get Scanned Drilling Time Log.		

ILLINOIS STATE GEOLOGICAL SURVEY

Engineering Test	Top	Bottom
red-brown silty clay (medium)	0	7
gray-brown silty clay (stiff)	7	9
black silty clay loam (medium)	9	18
gray-brown silty clay till (hard)	18	22
brown silt (very dense)(medium)	22	24
gry-brn sty cl till (vy dns)anglr lyrs	24	28
Total Depth		**28**

Owner Address: ,
Location source: Location from the driller

Permit Date: **Permit #:**

COMPANY owner
FARM SBI 104
DATE DRILLED July 1, 1964 **NO.** 1
ELEVATION 587GL **COUNTY NO.** 02455
LOCATION SE NE
LATITUDE 39.59156 **LONGITUDE** -89.479955
COUNTY Christian **API 120210245500** **12 - 13N - 4W**

ILLINOIS STATE GEOLOGICAL SURVEY

Municipal Water Supply	Top	Bottom
SS#60180	0	0
top soil, black	0	2
yellow clay	2	15
yellow sand & gravel, little water	15	17
gray sandy clay	17	36
brown shale soft	36	42
brown clay	42	47
rock at	47	47
Total Depth		**47**

Casing: 6" 40# STEEL PIPE from -1' to 11'
36" CONCRETE PIPE from 11' to 46'
38" CONCRETE PIPE from 44' to 47'

Water from drift at 11' to 47'.
Static level 4' below casing top which is 1' above GL
Pumping level 23' when pumping at 5 gpm for 3 hours

Driller's Log filed
Sample set # 60180 (0' - 50') Received: February 10, 1976

Owner Address: ,
Add'l loc. info: FALSE
ST.of Ill. Dept.of Conser
Location source: Location from permit

Permit Date: October 29, 1974 **Permit #:** 34214

COMPANY owner
FARM SangChris State Park
DATE DRILLED April 1, 1975 **NO.** 1-1975
ELEVATION 0 **COUNTY NO.** 22898
LOCATION 2315'N line, 1390'W line of NW
LATITUDE 39.605548 **LONGITUDE** -89.492034
COUNTY **Christian** **API** **120212289800** **1 - 13N - 4W**

ILLINOIS STATE GEOLOGICAL SURVEY

Water Well for Commercial Operation	**Top**	**Bottom**
top soil	0	1
light gray clay	1	8
medium gray w/yellow	8	18
dark gray w/yellow	18	30
Total Depth		**30**

Casing: 6" PVC SCH 40 from -2' to 10'
30" CONCRETE from 10' to 30'

Water from clay at 16' to 18'.
Static level 3' below casing top which is 2' above GL

Remarks: sub pump set at 27'

Driller's Log filed

Sample set # 62948 (0' - 30') Received: April 14, 1980

Owner Address: Kincade, IL

Location source: Platbook verified

Permit Date: February 27, 1980 **Permit #:** 92795

COMPANY Erwin, James Ray

FARM Commonwealth Edison

DATE DRILLED March 4, 1980 **NO.** 1

ELEVATION 0 **COUNTY NO.** 23462

LOCATION SE SW NE

LATITUDE 39.590652 **LONGITUDE** -89.483559

COUNTY Christian **API 120212346200** **12 - 13N - 4W**

ILLINOIS STATE GEOLOGICAL SURVEY

Test Hole	Top	Bottom
C#C4911 (0-20.5')	0	0
Total Depth		**21**

Core #C 4911 (0' - 21') Received: November 1, 1996

Owner Address: ,
Add'l loc. info: FALSE
Paris District
Location source: Location from the driller

Permit Date: **Permit #:**

COMPANY owner
FARM SBI 104 test
DATE DRILLED **NO.** 2
ELEVATION 0 **COUNTY NO.** 24491
LOCATION SE SE NE
LATITUDE 39.590657 **LONGITUDE** -89.478728
COUNTY Christian **API** 120212449100 **12 - 13N - 4W**

ILLINOIS STATE GEOLOGICAL SURVEY

Private Water Well	Top	Bottom
clay	0	8
sandy clay	8	12
gravelly clay	12	17
gray gravelly clay	17	34
gray sandy gravel	34	35
gray gravelly clay	35	50
Total Depth		**50**

Casing: 6" PLASTIC from 0' to 10'
36" CONCRETE from 0' to 50'

Water from gravelly clay-sand at 12' to 35'.

Owner Address: R.R. #2 Box #148 Pawnee, IL

Location source: Location from permit

Permit Date: January 31, 1996 **Permit #:**

COMPANY Walters, Steven

FARM Braeuniger, Walter

DATE DRILLED February 8, 1996 **NO.**

ELEVATION 0 **COUNTY NO.** 24640

LOCATION SE SW NE

LATITUDE 39.547152 **LONGITUDE** -89.447541

COUNTY Christian **API 120212464000** **29 - 13N - 3W**

ILLINOIS STATE GEOLOGICAL SURVEY

Private Water Well	Top	Bottom
black dirt	0	2
brown clay	2	11
sandy brown clay	11	16
gray clay	16	22
sand	22	23
gray clay	23	30
sand	30	31
gray clay	31	62
soft sandstone	62	68
Total Depth		**68**

Casing: 6" PVC from -1' to 11'
36" CONCRETE from 11' to 68'

Water from clay-sandstone at 11' to 62'.

Owner Address: R.R. #2 Box #137 E Pawnee, IL

Location source: Location from permit

Permit Date: February 14, 1996 **Permit #:**

COMPANY Reynolds Well Drilling

FARM Terra International Inc.

DATE DRILLED February 14, 1996 **NO.**

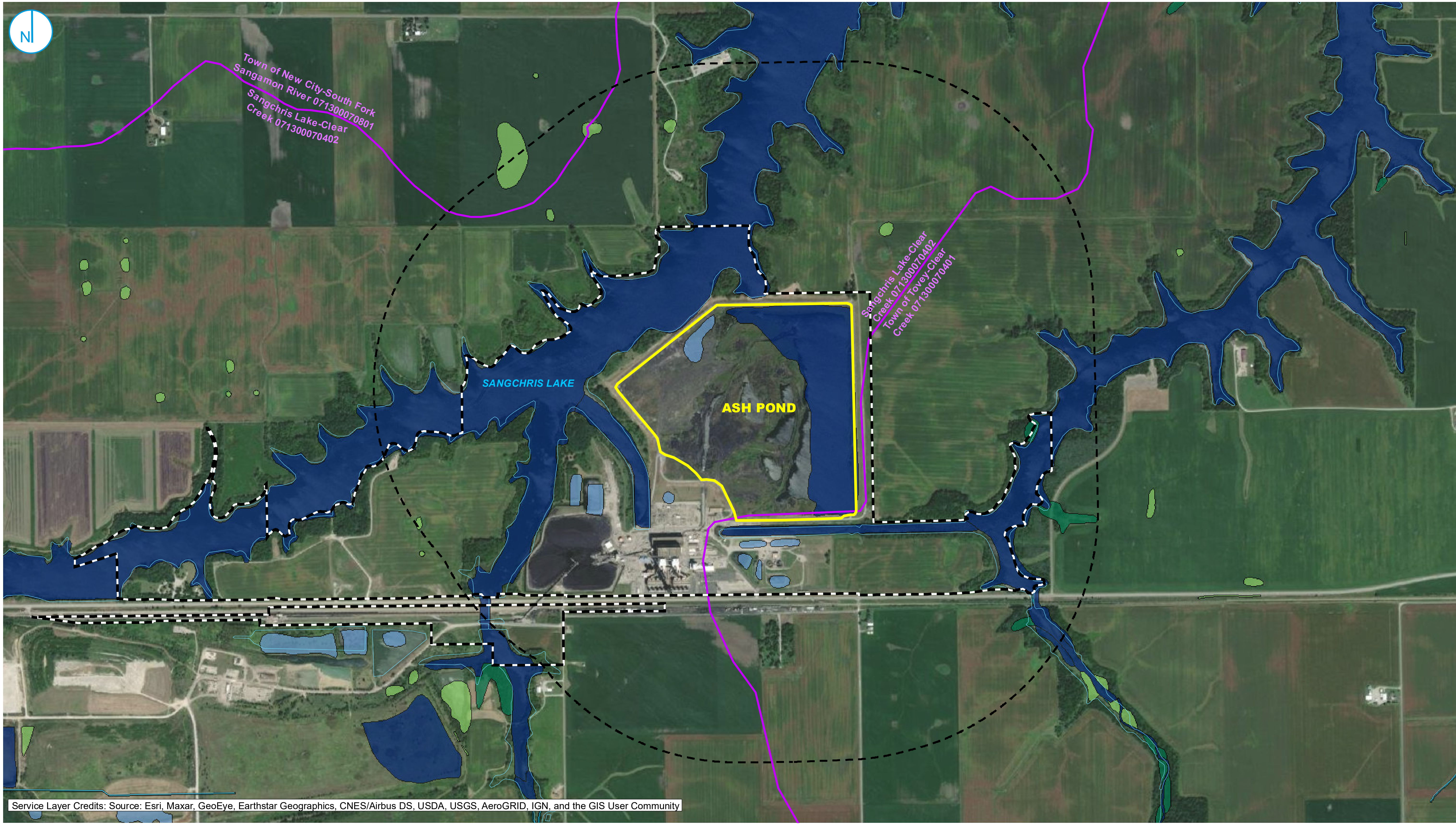
ELEVATION 0 **COUNTY NO.** 24642

LOCATION NE NW

LATITUDE 39.595172 **LONGITUDE** -89.489659

COUNTY Christian **API 120212464200** **12 - 13N - 4W**

SURFACE WATERS



Y:\Mapping\Projects\22\2285\MXD\845_Operating_Permit\Kincaid\Figure B-3_Surface Waterbodies.mxd

PROJECT: 169000XXXX | DATED: 8/18/2021 | DESIGNER: STOLZSD

SURFACE WATERBODY
WATERSHED BOUNDARY (HUC 12)
PART 845 REGULATED UNIT (SUBJECT UNIT)
1000 METER UNIT BUFFER
PROPERTY BOUNDARY

0 625 1,250 Feet

NATIONAL WETLANDS INVENTORY
FRESHWATER EMERGENT WETLAND
FRESHWATER FORESTED/SHRUB WETLAND
FRESHWATER POND
LAKE
OTHER
RIVERINE

SOURCES:
USGS, USFWS

SURFACE WATERBODIES

HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

FIGURE B-3

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

RAMBOLL

SURFACE WATER FEATURES WITHIN 1,000 METERS

DESKTOP STUDY

KINCAID POWER PLANT

ASH POND

KINCAID, IL

HUC	Surface Water ID	Distance from Unit (meters)	Physical Orientation to Unit	Hydraulic Orientation to Unit	Classification Code	Size (acres)
07130007	Lake (Sangchris Lake)	27	NW, SE	Downgradient	L1UBHh	300.4
--	Freshwater Pond 1	30	NW	Downgradient	PUBGh	2.60
--	Freshwater Pond 2	335	SW	Upgradient	PUBGx	1.40
--	Freshwater Pond 3	305	SW	Upgradient	PUBGx	2.10
--	Freshwater Pond 4	146	SW	Upgradient	PUBGx	0.45
--	Freshwater Pond 5	91	SW	Upgradient	PUBGx	0.65
--	Freshwater Pond 6	91	SW	Upgradient	PUBGx	0.83
--	Freshwater Pond 7	152	SW	Upgradient	PUBGx	0.63
--	Freshwater Pond 8	183	SW	Upgradient	PUBGx	0.42
--	Freshwater Pond 9	213	SW	Upgradient	PUBGx	0.86
--	Creek (Clear Creek)	229	NW, SE	Downgradient	--	--
--	Freshwater Emergent Wetland 1	914	NW	Downgradient	PEM1Af	6.59
--	Freshwater Emergent Wetland 2	701	NW	Downgradient	PEM1Af	0.36
--	Freshwater Emergent Wetland 3	853	NW	Downgradient	PEM1Af	0.98
--	Freshwater Emergent Wetland 4	731	N	Downgradient	PEM1C	0.57
--	Freshwater Emergent Wetland 5	320	N	Upgradient	PEM1Af	0.64
--	Freshwater Emergent Wetland 6	1067	SW	Upgradient	PEM1Af	0.26
--	Freshwater Forested/Shrub Wetland 1	716	E	Downgradient	PFO1A	1.00
--	Freshwater Forested/Shrub Wetland 2	762	SE	Downgradient	PFO1Ah	2.99
--	Freshwater Forested/Shrub Wetland 3	823	SE	Upgradient	PFO1Ah	0.82
--	Riverine	792	SE	Upgradient	R5UBH	0.07

[O: LTA 04/08/21; C: LDC 09/15/21]

Notes:
- -- = not applicable
- E = east
- HUC = Hydrologic Unit Code
- N = north
- NW = northwest
- SE = southeast
- SW = southwest
- W = west

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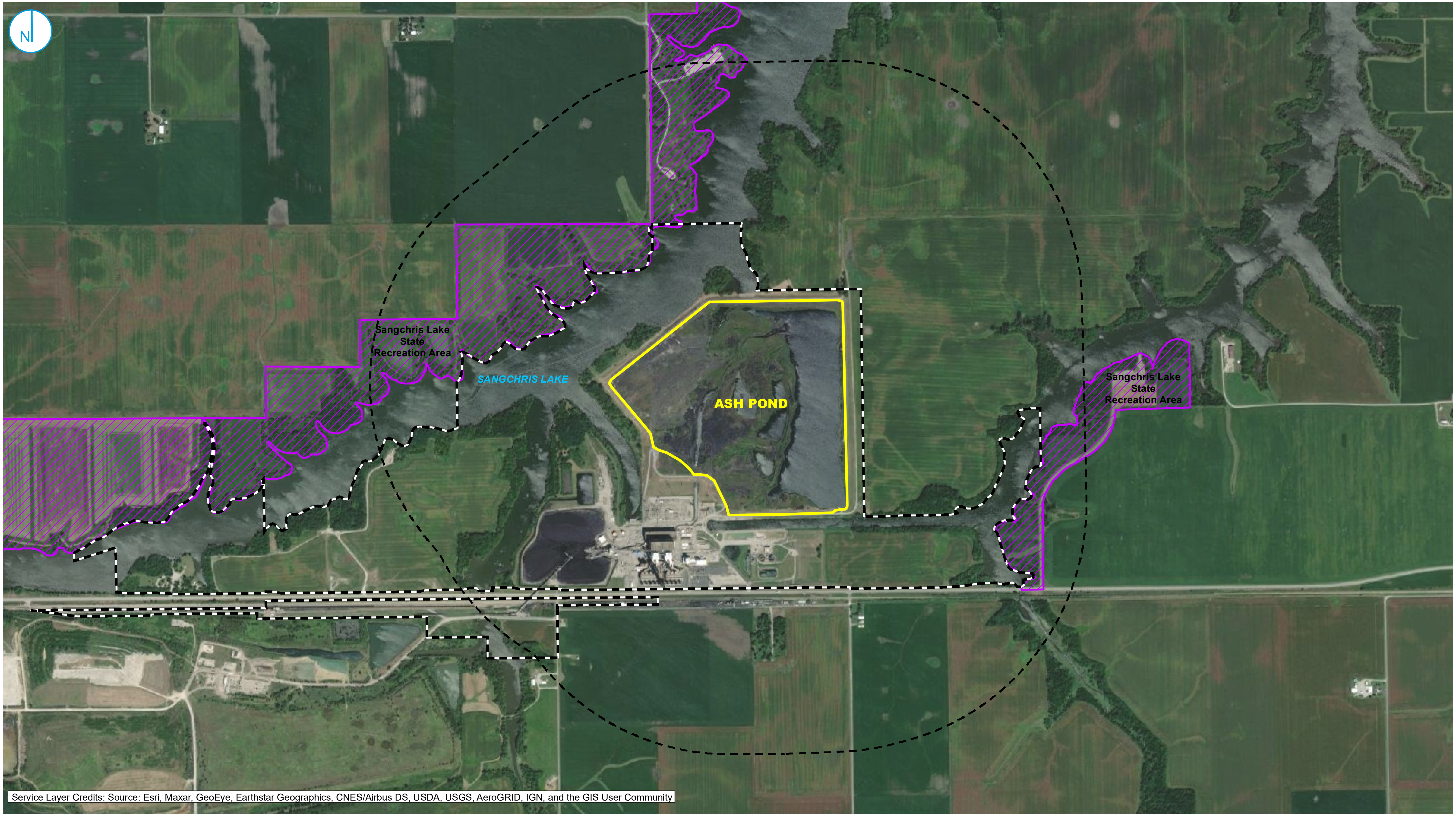
NATURE PRESERVES, HISTORIC SITES, ENDANGERED/THREATENED SPECIES



Y:\Mapping\Projects\22\2285\MXD\845_Operating_Permit\Kincaid\Figure B-4_Nature Preserves.mxd

PROJECT: 169000XXXX | DATED: 8/18/2021 | DESIGNER: STOLZSD

PROTECTED AREA
PART 845 REGULATED UNIT (SUBJECT UNIT)
1000 METER UNIT BUFFER
PROPERTY BOUNDARY

0 625 1,250 Feet

SOURCES:
USGS - PAD-US, USFWS

NATURE PRESERVES

HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

FIGURE B-4

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

RAMBOLL

NATURAL AND HISTORIC SITES WITHIN 1,000 METERS

DESKTOP STUDY

KINCAID POWER PLANT

ASH POND

KINCAID, IL

INAI/INPC Number	INAI/INPC Name	Category/Categories	Size (acres)	Distance from Unit (meters)	Orientation to Unit
--	Abraham Lincoln National Heritage Area	I, III	17,053,708	0	Within

[O: LTA 04/08/21; C: LDC 09/15/21]

Notes:
-- = not applicable
INAI = Illinois Natural Areas Inventory
INPC = Illinois Nature Preserves Commission
I = High quality natural community and natural community restorations
II = Specific suitable habitat for state-listed species or state-listed species relocations
III = State dedicated Nature Preserves, Land and Water Reserves, & Natural Heritage Landmarks
IV = Outstanding geological features
V = Not used at this time
VI = Unusual concentrations of flora or fauna and high quality streams

CHRISTIAN COUNTY THREATENED AND ENDANGERED SPECIES DESKTOP STUDY
KINCAID POWER PLANT
ASH POND
KINCAID, IL

Scientific Name	Common Name	Status	Number of Occurances	Last Observed
Bartramia longicauda	Upland Sandpiper	LE	1	1979-07-28
Clonophis kirtlandii	Kirtland's Snake	LT	4	2019-09-01
Hylotelephium telephioides	American Orpine	LT	1	1948-06-02
Lanius ludovicianus	Loggerhead Shrike	LE	1	2000-06-12
Poliocitellus franklinii	Franklin's Ground Squirrel	LT	1	2019-06-01

[O: LTA 04/08/21; C: LDC 09/15/21]

Notes:
-- = not provided/cannot be determined
LE = listed endangered
LT = listed threatened

OIL FIELDS

OIL FIELDS WITHIN 1,000 METERS
DESKTOP STUDY
KINCAID POWER PLANT
ASH POND
KINCAID, IL

ID Number	Oil Field Name	Distance from Unit (meters)	Physical Orientation to Unit	Hydraulic Orientation to Unit	Range of Active Dates	Field Type	Producing Unit	Top Depth of Producing Zone (ft BGS)	Bottom Depth of Producing Zone (ft BGS)	Notes
120210052100	Bryant	686	east	Downgradient	None Given	-	-	-	-	Dry and Abandoned, No Shows, Plugged
120210070900	Kavanaugh Trust	808	northwest	Downgradient	None GIven	-	-	-	-	Dry and Abandoned, No Shows, Plugged

[O: LTA 04/08/21; C: LDC 09/15/21]

Notes:
-- = not applicable
BGS = below ground surface

RAMBOLL

APPENDIX C
BORING AND WELL CONSTRUCTION LOGS

2021 Ramboll Soil Boring Logs

Y:\Mapping\Projects\22\2285\MXD\845_Operating_Permit\Kincaid\Figure 2-5_Field Investigation Location Map.mxd

PROJECT: 169000XXXX | DATED: 10/5/2021 | DESIGNER: STOLZSD

MONITORING WELL
SOURCE SAMPLE LOCATION
SOIL BORING
PART 845 REGULATED UNIT (SUBJECT UNIT)
PROPERTY BOUNDARY

0 250 500 Feet

FIELD INVESTIGATION LOCATION MAP

HYDROGEOLOGIC SITE CHARACTERIZATION REPORT
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

FIGURE C-1

RAMBOLL AMERICAS ENGINEERING SOLUTIONS, INC.

RAMBOLL

SOIL BORING LOG INFORMATION

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Kincaid Power Station		MW-11S

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Adam Jochimsen Cascade Drilling	1/26/2021	1/26/2021	Mini Sonic

Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
MW-11S	Feet (NAVD88)	599.43 Feet (NAVD88)	6.0 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,066,374.94 N, 2,486,959.86 E E/W (W circled)
1/4 of 1/4 of Section 12, T 13 N, R 4 W

Lat 39° 35' 35.214"
Long -89° 29' 27.9672"

Local Grid Location: Feet ☐N ☐S; Feet ☐E ☐W

Facility ID	County	State	Civil Town/City/ or Village
	Christian	IL	Kincaid

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 CS	60 60		0	0 - 8' **SILTY CLAY:** CL/ML, dark brown (10YR3/3), yellowish brown (10YR 5/6) mottling (5-10%), sand (0-10%), gravel (0-5%), hard to stiff, no dilatancy to slow dilatancy, medium to low toughness, dry to moist.	CL/ML									CS = Core Sample
			1						4.5					
			2–3	2.4' - 2.7' layer of silt brown (10YR 5/3), gravel (0-5%), dry.					3					
2 CS	36 26		5	5' brown (10YR 5/3), yellowish brown (10YR 5/6) mottling (15-25%), firm to stiff, slow dilatancy, moist.					1.5					
			7						1					
			8	8' End of Boring.										

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm	
(signed)	Ramboll 234 W. Florida Street, Milwaukee,WI 53204	Tel: (414) 837-3607 Fax: (414) 837-3608

RAMBOLL

SOIL BORING LOG INFORMATION

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Kincaid Power Station		MW-12D

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Dave Gordon Cascade Drilling	1/26/2021	1/26/2021	Mini Sonic

Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
MW-12D	Feet (NAVD88)	589.08 Feet (NAVD88)	6.0 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,068,939.69 N, 2,485,442.58 E E/W
1/4 of 1/4 of Section 1, T 13 N, R 4 W
Lat 39° 36' 0.6732"
Long -89° 29' 47.1048"
Local Grid Location: Feet ☐ N ☐ S; Feet ☐ E ☐ W

Facility ID	County	State	Civil Town/City/ or Village
	Christian	IL	Kincaid

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 CS	60 60		0 - 1.8	0 - 1.8' **LEAN CLAY:** CL, dark yellowish brown (10YR 4/6), roots (5-15%), silt (5-15%), sand (0-5%), no dilatancy, medium toughness, medium plasticity, wet.	CL									CS = Core Sample
			1.8 - 3.1	1.8 - 3.1' **POORLY-GRADED SAND:** SP, dark yellowish brown (10YR 4/6), silt (15-30%), clay (5-15%), gravel (0-5%), loose, moist.	SP									
			3.1 - 5	3.1 - 5' **LEAN CLAY:** CL, dark grayish brown (10YR 4/2), silt (15-30%), sand (0-5%), roots (0-5%), no dilatancy, low toughness, low plasticity.	CL									
2 SH	24 24		5 - 7	5 - 7' **CLAYEY SAND:** SC.	SC					18.6	22	9	45.3	SH = Shelby Tube
3 CS	36 36		7 - 7.5	7 - 7.5' **LEAN CLAY:** CL, dark grayish brown (10YR 4/2), silt (15-30%), sand (0-5%), roots (0-5%), no dilatancy, low toughness, low plasticity.	CL									
			7.5 - 10	7.5 - 10' **LEAN CLAY:** CL, brownish yellow (10YR 6/6), dark yellowish brown (10YR 4/6) mottling (5-15%), no dilatancy, low toughness, low to medium plasticity, moist.	CL									

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature [signature]

Firm Ramboll
234 W. Florida Street, Milwaukee, WI 53204
Tel: (414) 837-3607
Fax: (414) 837-3608

Boring Number MW-12D

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Soil Properties: Compressive Strength (tsf)	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
4 MC	24 24		10.5, 11.0, 11.5	10 - 12' **LEAN CLAY:** CL.	CL					18.2	22	10	64.2	MC = Modified California
5 CS	36 36		12.0, 12.5	12 - 12.8' **WELL-GRADED SAND WITH SILT:** SW, brownish yellow (10YR 6/6), subrounded to subangular sand, gravel (15-30%), clay (5-15%), wet.	SW									
			13.0, 13.5, 14.0	12.8 - 14.5' **SILTY SAND:** to **SANDY SILT:** SM, brownish yellow (10YR 6/6), fine subrounded sand, clay (15-30%), dense, wet.	SM									
6 CS	60 60		14.5, 15.0, 15.5, 16.0, 16.5, 17.0, 17.5, 18.0, 18.5, 19.0, 19.5	14.5 - 20' **SILT:** ML, grayish brown (10YR 5/2), clay (15-30%), sand (5-15%), gravel (0-5%), no dilatancy, high toughness, low plasticity, dry.	ML									
7 SH	24 7		20.0, 20.5, 21.0, 21.5	20 - 22' **CLAYEY SAND:** SC.	SC					14	22	9	47.6	
8 CS	156 156		22.0, 22.5, 23.0	22 - 39.8' **SILT:** ML, grayish brown (10YR 5/2), clay (15-30%), sand (5-15%), gravel (0-5%), no dilatancy, high toughness, low plasticity, dry.	ML									
			23.5, 24.0, 24.5	23.5' - 24' layer of silty clay, olive brown (2.5Y 4/3) mottling (5-15%), gray (10YR 5/1) mottling (0-5%), sand (5-15%), gravel (0-5%).										
			25.0, 25.5, 26.0, 26.5	25' - 26.5' layer of silty clay, olive brown (2.5Y 4/3) mottling (0-5%), gray (10YR 5/1) mottling (5-15%).										

Boring Number MW-12D

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Soil Properties: Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			27.0	22 - 39.8' **SILT:** ML, grayish brown (10YR 5/2), clay (15-30%), sand (5-15%), gravel (0-5%), no dilatancy, high toughness, low plasticity, dry. *(continued)*	ML									
			28.5	28.5' gray (10YR 5/1) mottling (15-30%), olive brown (2.5Y 4/3) mottling (5-15%), sand (15-30%).										
			31.0	31' - 33.5' layer of silty clay, gray (10YR 5/1), grayish brown (10YR 5/2) mottling (15-30%), olive brown (2.5Y 4/3) mottling (0-5%), dark yellowish brown (10YR 3/4) mottling (0-5%).										
			33.5	33.5' brown (10YR 4/3).										
			34.0	34' - 34.5' layer of silty clay, gray (10YR 5/1), grayish brown (10YR 5/2) mottling (15-30%), olive brown (2.5Y 4/3) mottling (0-5%), dark yellowish brown (10YR 3/4) mottling (0-5%).										
			34.5	34.5' dark gray (10YR 4/1).										
9 CS	36 36		35.0											
10 CS	120 98		38.0											
			40.0	39.9 - 47.3' **LEAN CLAY:** CL, very dark gray (10YR 3/1), gray (10YR 5/1) mottling (0-5%), sand (0-5%), gravel (0-5%), slow dilatancy, high toughness, high plasticity, moist, laminated black (10YR 2/1) (0-5%).	CL									

Depth scale: 27.0, 27.5, 28.0, 28.5, 29.0, 29.5, 30.0, 30.5, 31.0, 31.5, 32.0, 32.5, 33.0, 33.5, 34.0, 34.5, 35.0, 35.5, 36.0, 36.5, 37.0, 37.5, 38.0, 38.5, 39.0, 39.5, 40.0, 40.5, 41.0, 41.5, 42.0, 42.5, 43.0

Sample Number and Type	Sample Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			43.5–47.3	39.9 - 47.3' **LEAN CLAY:** CL, very dark gray (10YR 3/1), gray (10YR 5/1) mottling (0-5%), sand (0-5%), gravel (0-5%), slow dilatancy, high toughness, high plasticity, moist, laminated black (10YR 2/1) (0-5%). *(continued)*	CL									
11 CS	72 72		47.3–48.4	47.3 - 48.4' **WELL-GRADED GRAVEL:** GW, gray (10YR 5/1), sand (5-15%), dry.	GW									
12 CS	72 72		48.4–56.6	48.4 - 56.6' **LIMESTONE:** BDX (LS), bluish black (GLEY2 5PB 2.5/1), fossiliferous, light gray (GLEY1 N 7/1) in recrystallized fossils, calcite replacement in some fossils.	BDX (LS)									
			56.6–60.0	56.6 - 60.8' **SHALE:** BDX (SH), black (GLEY 1 2.5/N).	BDX (SH)									

Depth scale: 43.5, 44.0, 44.5, 45.0, 45.5, 46.0, 46.5, 47.0, 47.5, 48.0, 48.5, 49.0, 49.5, 50.0, 50.5, 51.0, 51.5, 52.0, 52.5, 53.0, 53.5, 54.0, 54.5, 55.0, 55.5, 56.0, 56.5, 57.0, 57.5, 58.0, 58.5, 59.0, 59.5, 60.0

Boring Number MW-12D

Sample Number and Type	Sample Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
13 CS	240 120		60.5	56.6 - 60.8' **SHALE:** BDX (SH), black (GLEY 1 2.5/N). *(continued)*	BDX (SH)									
			61.0 – 68.5	60.8 - 68.8' **LIMESTONE:** BDX (LS), bluish black (GLEY2 5PB 2.5/1), fossiliferous, light gray (GLEY1 N 7/1) in recrystallized fossils, calcite replacement in some fossils.	BDX (LS)									
			69.0 – 76.5	68.8 - 81' **SHALE:** BDX (SH), black (GLEY 1 2.5/N).	BDX (SH)									

Boring Number MW-12D

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
14 CS	120 71		77.0–81.0	68.8 - 81' **SHALE:** BDX (SH), black (GLEY 1 2.5/N). *(continued)*	BDX (SH)									
			81.0–83.0	81 - 83' **LIMESTONE:** BDX (LS), bluish black (GLEY2 5PB 2.5/1), fossiliferous, light gray (GLEY1 N 7/1) in recrystallized fossils, calcite replacement in some fossils.	BDX (LS)									
15 CS	120 120		83.0–93.0	83 - 100' **SHALE:** BDX (SH), greenish gray (GLEY 1 10Gy 5/1) to gray (GLEY1 N 5/N), dark gray (10YR 4/1) laminae (5-15%), white (10YR 8/1) laminae (0-5%).	BDX (SH)									

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Boring Number MW-12D

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Soil Properties: Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			93.5 – 100.0	83 - 100' **SHALE:** BDX (SH), greenish gray (GLEY 1 10Gy 5/1) to gray (GLEY1 N 5/N), dark gray (10YR 4/1) laminae (5-15%), white (10YR 8/1) laminae (0-5%). *(continued)* 97' dark gray (10YR 4/1).	BDX (SH)									
			100.0	100' End of Boring.										

RAMBOLL

SOIL BORING LOG INFORMATION

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Kincaid Power Station		MW-12S

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Dave Gordon Cascade Drilling	1/27/2021	1/27/2021	Mini Sonic

Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
MW-12S	Feet (NAVD88)	588.62 Feet (NAVD88)	6.0 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,068,944.79 N, 2,485,444.27 E E/W (W circled)
1/4 of 1/4 of Section 1, T 13 N, R 4 W

Lat 39° 36' 0.7236"
Long -89° 29' 47.0832"

Local Grid Location: Feet ☐N ☐S Feet ☐E ☐W

Facility ID	County	State	Civil Town/City/ or Village
	Christian	IL	Kincaid

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	Soil Properties: Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0 - 1.8	0 - 1.8' **LEAN CLAY:** CL, Blind drill to 9.5 feet below ground surface. See MW-12D boring log for detailed lithologies.	CL								
			1.8 - 3.1	1.8 - 3.1' **POORLY-GRADED SAND:** SP.	SP								
			3.1 - 5	3.1 - 5' **LEAN CLAY:** CL.	CL								
			5 - 7	5 - 7' **CLAYEY SAND:** SC.	SC								
			7 - 7.5	7 - 7.5' **LEAN CLAY:** CL.	CL								
			7.5 - 9.5	7.5 - 9.5' **LEAN CLAY:** CL.	CL								
			9.5	9.5' End of Boring.									

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature

Firm Ramboll
234 W. Florida Street, Milwaukee, WI 53204
Tel: (414) 837-3607
Fax: (414) 837-3608

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Kincaid Power Station		MW-20

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Adam Jochimsen Cascade Drilling	1/26/2021	1/26/2021	Mini Sonic

Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
MW-20	Feet (NAVD88)	598.52 Feet (NAVD88)	6.0 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,068,397.57 N, 2,488,021.74 E E/Ⓦ
1/4 of 1/4 of Section 1, T 13 N, R 4 W
Lat 39° 35' 55.122"
Long -89° 29' 14.208"
Local Grid Location: Feet ☐N ☐S, Feet ☐E ☐W

Facility ID	County	State	Civil Town/City/ or Village
	Christian	IL	Kincaid

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 CS	60 49		0–2	0 - 2' **FILL, LEAN CLAY:** CL, brown (10YR 5/3) to pale brown (10YR 6/3), silt (15-25%), roots (0-5%), sand (0-5%), gravel (0-5%), stiff, slow dilatancy, low toughness, medium plasticity, moist.	(FILL) CL				1.5					CS = Core Sample
			2–6.2	2 - 6.2' **CLAYEY SILT** ML/CL, very dark grayish brown (10YR 3/2), sand (0-5%), very stiff, slow dilatancy, medium toughness, low plasticity, moist.	ML/CL				2					
2 CS	60 44								3.5					
			6.2–15	6.2 - 15' **LEAN CLAY:** CL, pale brown (10YR 6/3) to brownish yellow (10YR 6/6), silt (15-25%), sand (0-5%), stiff to firm, slow dilatancy, low toughness, medium to high plasticity, moist.	CL				3.5					
									1.5					
3 CS	60 53								0.75					

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature]

Firm: Ramboll
234 W. Florida Street, Milwaukee,WI 53204
Tel: (414) 837-3607
Fax: (414) 837-3608

RAMBOLL

Boring Number MW-20

Sample Number and Type	Sample Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			13, 14	6.2 - 15' **LEAN CLAY:** CL, pale brown (10YR 6/3) to brownish yellow (10YR 6/6), silt (15-25%), sand (0-5%), stiff to firm, slow dilatancy, low toughness, medium to high plasticity, moist. *(continued)*	CL				0.75					
4 SH	24 24		15, 16	15 - 17' **LEAN CLAY:** CL.	CL				0.75	18.9	32	18	69.5	SH = Shelby Tube
5 CS	96 89		17, 18, 19, 20	17 - 20.2' **SILT:** ML, light yellowish brown (2.5Y 6/4), clay (15-25%), sand (5-10%), gravel (0-5%), hard, no dilatancy, medium toughness, low plasticity, dry.	ML				0.75 4.5					
			21, 22, 23	20.2 - 23.4' **SILTY CLAY:** CL/ML, gray (10YR 5/1), sand (0-5%), gravel (0-5%), very stiff to hard, no dilatancy, medium toughness, non-plastic, dry.	CL/ML				4.5 4.5					
6 CS	60 50		24, 25, 26	23.4 - 26.8' **CLAYEY SILT** ML/CL, gray (10YR 5/1), sand (0-5%), gravel (0-5%), very stiff to hard, no dilatancy, medium toughness, low plasticity, dry.	ML/CL				2.5					
7 CS	60 49		27, 28, 29, 30, 31, 32	26.8 - 37.8' **SILT:** ML, gray (10YR 5/1), sand (0-10%), gravel (0-5%), stiff, no dilatancy, medium toughness, non-plastic, dry.	ML									

RAMBOLL

Boring Number MW-20

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Soil Properties: Compressive Strength (tsf)	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
			33–37	26.8 - 37.8' **SILT:** ML, gray (10YR 5/1), sand (0-10%), gravel (0-5%), stiff, no dilatancy, medium toughness, non-plastic, dry. *(continued)*	ML									
8 CS	60 42		35											
			38	37.8 - 48.9' **LEAN CLAY:** CL, gray (10YR 5/1), silt (15-25%), sand (5-10%), gravel (0-5%), hard, no dilatancy, medium toughness, medium plasticity, dry to moist.	CL									
			39						4.5					
9 CS	60 55		40											
			41						4.5					
			43						4.5					
11 CS	60 54		45						4.5					Shelby Tube and Modified California samples attempted with refusal at 45 feet below ground surface.
			47						4.5					
			49	48.9 - 49.5' **WELL-GRADED SAND:** SW, grayish brown (10YR 5/2), subrounded to round, fine sand, loose, moist.	SW				4.5					
12 CS	12 12		50	49.5 - 50.5' **LEAN CLAY:** CL, gray (10YR 5/1), silt (15-25%), sand (5-10%), gravel (0-5%), hard, no dilatancy, medium toughness, medium plasticity, dry to moist.	CL				4.5					
			51	50.5 - 51' **LIMESTONE:** BDX (LS).	BDX (LS)									
				51' End of Boring.										

SOIL BORING LOG INFORMATION

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Kincaid Power Station		MW-20S

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Adam Jochimsen Cascade Drilling	1/26/2021	1/26/2021	Mini Sonic

Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
MW-20S	Feet (NAVD88)	598.43 Feet (NAVD88)	6.0 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,068,402.07 N, 2,488,021.76 E E/W
1/4 of 1/4 of Section 1, T 13 N, R 4 W
Lat 39° 35' 55.1688"
Long -89° 29' 14.2044"
Local Grid Location ☐ N ☐ S Feet ☐ E ☐ W Feet

Facility ID	County	State	Civil Town/City/ or Village
	Christian	IL	Kincaid

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0 - 2	0 - 2' **FILL, LEAN CLAY:** CL, Blind drill to 10 feet below ground surface. See MW-20 boring log for detailed lithologies.	(FILL) CL								
			2 - 6.2	2 - 6.2' **CLAYEY SILT** ML/CL.	ML/CL								
			6.2 - 10	6.2 - 10' **LEAN CLAY:** CL.	CL								
			10	10' End of Boring.									

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm	
[signature]	Ramboll 234 W. Florida Street, Milwaukee, WI 53204	Tel: (414) 837-3607 Fax: (414) 837-3608

SOIL BORING LOG INFORMATION

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Kincaid Power Station		MW-22

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Adam Jochimsen Cascade Drilling	2/3/2021	2/3/2021	Mini Sonic

Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
MW-22	Feet (NAVD88)	599.51 Feet (NAVD88)	6.0 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,066,423.38 N, 2,487,935.62 E E/W (W circled)
1/4 of 1/4 of Section 12, T 13 N, R 4 W
Lat 39° 35' 35.6208"
Long -89° 29' 15.4968"
Local Grid Location: Feet ☐ N ☐ S; Feet ☐ E ☐ W

Facility ID	County	State	Civil Town/City/ or Village
	Christian	IL	Kincaid

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 CS	60 43		0	0 - 0.7' **FILL, LEAN CLAY:** CL, light yellowish brown (10YR 6/4), silt (15-25%), gravel (0-5%), sand (0-5%), stiff , slow dilatancy, low toughness, medium plasticity, moist.	(FILL) CL									CS = Core Sample
			1	0.7 - 5' **CLAYEY SILT** ML/CL, dark brown (10YR 3/3), organic material (5-10%), sand (0-5%), very stiff, slow dilatancy, low toughness, low plasticity, moist.	ML/CL				2.5					
			3						3.5					
2 CS	60 59		5	5 - 16.7' **LEAN CLAY:** CL, yellowish brown (10YR 5/6) to gray (10YR 5/1), sand (0-5%), soft, slow dilatancy, low toughness, medium to high plasticity, moist.	CL				4					
			7						0.5					
			9						0.5					
3 CS	60 56		10											
			11						0.75					
			12											

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm	
[signature]	Ramboll 234 W. Florida Street, Milwaukee,WI 53204	Tel: (414) 837-3607 Fax: (414) 837-3608

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Boring Number MW-22

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Soil Properties: Compressive Strength (tsf)	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
4 CS	60 60		13–16	5 - 16.7' **LEAN CLAY:** CL, yellowish brown (10YR 5/6) to gray (10YR 5/1), sand (0-5%), soft, slow dilatancy, low toughness, medium to high plasticity, moist. *(continued)*	CL				1.75 1.75					
			17–20	16.7 - 20' **SANDY LEAN CLAY:** to **CLAYEY SAND:** s(CL), yellowish brown (10YR 5/4), hard, no dilatancy, medium toughness, low to medium plasticity, moist to dry. 17.2' - 17.4' layer of silty sand.	s(CL)				4.5 4.5					
			20	20' End of Boring.										

SOIL BORING LOG INFORMATION

Facility/Project Name	License/Permit/Monitoring Number	Boring Number	
Kincaid Power Station		MW-23	
Boring Drilled By: Name of crew chief (first, last) and Firm	**Date Drilling Started**	**Date Drilling Completed**	**Drilling Method**
Adam Jochimsen Cascade Drilling	2/2/2021	2/2/2021	Mini Sonic
Common Well Name	**Final Static Water Level**	**Surface Elevation**	**Borehole Diameter**
MW-23	Feet (NAVD88)	608.05 Feet (NAVD88)	6.0 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,066,440.78 N, 2,487,452.37 E E/Ⓦ
1/4 of 1/4 of Section 12, T 13 N, R 4 W

Lat 39° 35' 35.826"
Long -89° 29' 21.6672"

Local Grid Location: Feet ☐ N ☐ S; Feet ☐ E ☐ W

Facility ID	County	State	Civil Town/City/ or Village
	Christian	IL	Kincaid

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 CS	60 29		0	0 - 8.3' **FILL, LEAN CLAY:** CL, very dark grayish brown (10YR 3/2), silt (15-25%), sand (0-5%), gravel (0-5%), roots (0-5%), stiff, no dilatancy to slow dilatancy, low toughness, medium plasticity.	(FILL) CL									CS = Core Sample
			1						1.5					
			3						2.5					
2 CS	60 43		5						2.25					
			7						2.5					
			8.3	8.3 - 15' **SILTY CLAY:** CL/ML, brown (10YR 5/3), yellowish brown (10YR 5/6) mottling (10-15%), silt seams (0-5%) 1-3 mm thick, gravel (0-5%), sand (0-5%), stiff, no dilatancy, low to medium toughness, medium to low plasticity, moist to dry.	CL/ML									
			9						2.25					
3 CS	60 60		10											
			11						2.5					

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature]

Firm: Ramboll
234 W. Florida Street, Milwaukee, WI 53204
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Boring Number MW-23

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Soil Properties: Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			13–14	8.3 - 15' **SILTY CLAY:** CL/ML, brown (10YR 5/3), yellowish brown (10YR 5/6) mottling (10-15%), silt seams (0-5%) 1-3 mm thick, gravel (0-5%), sand (0-5%), stiff, no dilatancy, low to medium toughness, medium to low plasticity, moist to dry. *(continued)* 13.3' very dark grayish brown (10YR 3/2), organic material (5-10%), stiff, no dilatancy, medium toughness, medium plasticity, moist to dry.	CL/ML				2.5					
4 SH	24 24		15	15 - 17' **LEAN CLAY:** CL.	CL				2.5	28.4	43	26	97.5	SH = Shelby Tube
5 CS	96 83		17	17 - 25' **LEAN CLAY:** CL, brown (10YR 5/3), yellowish brown (10YR 5/6) mottling (5-10%), gray (10YR 5/1) mottling (5-10%), sand (0-5%), silt seams (0-5%) 1 mm thick, firm, slow dilatancy, low toughness, high plasticity, moist.	CL				1.25					
			19						1.25					
			21						1					
			23						0.75					
6 CS	60 60		25	25 - 27' **LEAN CLAY:** CL. 25.3' - 25.8' sand (10-15%).	CL				1.25	15.6	32	18	58.4	
			27	27 - 27.3' **LEAN CLAY:** CL, brown (10YR 5/3), yellowish brown (10YR 5/6) mottling (5-10%), gray (10YR 5/1) mottling (5-10%), sand (0-5%), silt seams (0-5%) 1 mm thick, firm, slow dilatancy, low toughness, high plasticity, moist.	CL				4.5					
			29	27.3 - 40' **CLAYEY SILT** ML/CL, gray (10YR 5/1), sand (0-5%), gravel (0-5%), hard, no dilatancy, medium toughness, non-plastic to low plasticity, dry.	ML/CL				4.5					
7 CS	60 54		30											
			31–32						4.5					

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SOIL BORING LOG INFORMATION SUPPLEMENT

Boring Number MW-23

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Soil Properties: Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			33	27.3 - 40' **CLAYEY SILT** ML/CL, gray (10YR 5/1), sand (0-5%), gravel (0-5%), hard, no dilatancy, medium toughness, non-plastic to low plasticity, dry. *(continued)*					4.5					
8 CS	60 60		35	35' sand seams 1mm thick, loose, dry.	ML/CL				4.5					
			37						4.5					
			39						4.5					
9 CS	60 60		40	40 - 50' **SILTY CLAY:** CL/ML, gray (10YR 5/1), sand (5-10%), gravel (0-5%), hard, no dilatancy, medium to high toughness, medium plasticity, dry to moist.					4.5					
			43						4.5					
			44	44' yellowish brown (10YR 5/4) mottling (10-15%).										
12 CS	60 60		45		CL/ML				4.5					Shelby Tube and Modified California samples attempted with refusal at 45 feet below ground surface.
			47						4.5					
			49						4.5					
			50	50' End of Boring.										

RAMBOLL

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Kincaid Power Station		MW-24

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Adam Jochimsen Cascade Drilling	2/2/2021	2/2/2021	Mini Sonic

Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
MW-24	Feet (NAVD88)	613.01 Feet (NAVD88)	6.0 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,066,424.59 N, 2,486,349.15 E E/W
1/4 of 1/4 of Section 12, T 13 N, R 4 W

Lat 39° 35' 35.7504"
Long -89° 29' 35.7612"

Local Grid Location: Feet ☐N ☐S Feet ☐E ☐W

Facility ID	County	State	Civil Town/City/ or Village
	Christian	IL	Kincaid

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 CS	60 60		0–5	0 - 10.6' ASH, very dark gray (10YR 3/1) to black (10YR 2/1), silt to clay sized grains, coal (5-10%), gravel (0-5%), wood (0-5%), brick (0-5%), firm, slow to rapid dilatancy, low toughness, low plasticity, moist to dry.	(FILL) ASH									CS = Core Sample Advanced 8-inch override casing to 15 feet below ground surface.
2 CS	60 60		5–10											
3 CS	60 60		10–13	10.6 - 32' **LEAN CLAY:** CL, brown (10YR 5/3), yellowish brown (10YR 5/6) mottling (5-10%), silt (5-10%), sand (0-5%), gravel (0-5%), firm, slow dilatancy, low toughness, medium plasticity, moist.	CL				0.75					

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature

Firm Ramboll
234 W. Florida Street, Milwaukee, WI 53204
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Boring Number MW-24

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Soil Properties: Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
				10.6 - 32' **LEAN CLAY:** CL, brown (10YR 5/3), yellowish brown (10YR 5/6) mottling (5-10%), silt (5-10%), sand (0-5%), gravel (0-5%), firm, slow dilatancy, low toughness, medium plasticity, moist. *(continued)*					1					
			14											
4 CS	120 73		15						1					
			16											
			17						2					
			18											
			19						4					
			20											
			21						4					
			22		CL									
			23						2.25					
			24											
5 CS	84 71		25						2.5					
			26											
			27						1.5					
			28											
			29						2.25					
			30	29.6' - 30' layer of sandy clay.										
			31						4.5					
				31.5' hard.										
			32	32' End of Boring.										

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SOIL BORING LOG INFORMATION

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Kincaid Power Station		MW-25

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Russ Gordon Cascade Drilling	2/2/2021	2/2/2021	Mini Sonic

Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
MW-25	Feet (NAVD88)	604.60 Feet (NAVD88)	6.0 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,066,830.95 N, 2,485,840.34 E E/W (W circled)
1/4 of 1/4 of Section 12, T 13 N, R 4 W
Lat 39° 35' 39.804"
Long -89° 29' 42.2232"
Local Grid Location: Feet ☐ N ☐ S; Feet ☐ E ☐ W

Facility ID	County	State	Civil Town/City/ or Village
	Christian	IL	Kincaid

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 NR	60 0		0	0 - 5' No Recovery.										NR = No Recovery
2 CS	60 60		5	5 - 5.8' **WELL-GRADED SAND WITH GRAVEL:** (SW)g, grayish brown (10YR 5/2), wet.	(SW)g									CS = Core Sample
			5.8	5.8 - 6.6' **LEAN CLAY:** CL, brown (10YR 5/3), sand (0-5%), gravel (0-5%), stiff, medium plasticity, moist.	CL									
			6.6	6.6 - 10' **SILTY CLAY:** CL/ML, gray (10YR 5/1), gravel (0-5%), hard, low plasticity.	CL/ML				1.5					
			8						4					
			9						4					
3 CS	60 60		10	10 - 12' **WELL-GRADED SAND WITH SILT:** SW-SM, gray (10YR 5/1), clay (15-25%), wet.	SW-SM				4					

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature]

Firm Ramboll
234 W. Florida Street, Milwaukee,WI 53204
Tel: (414) 837-3607
Fax: (414) 837-3608

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Soil Properties: Compressive Strength (tsf)	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
			12 - 14.2	12 - 14.2' **LEAN CLAY:** CL, yellowish brown (10YR 5/6), orange mottling (15-25%), silt (15-25%), medium to high plasticity, soft, moist.	CL				0.25					
4 CS	60 60		14.2 - 19.6	14.2 - 19.6' **SILTY CLAY:** CL/ML, reddish yellow (7.5YR 6/8), sand (0-5%), gravel (0-5%), stiff, medium plasticity, moist.	CL/ML				1					
5 CS	60 60		19.6 - 25	19.6 - 25' **SILTY CLAY WITH GRAVEL** (CL/ML)g, gray (10YR 6/1), gravel (15-25%), sand (0-5%), hard, low plasticity, dry.	(CL/ML)g									
			25	25' End of Boring.										

SOIL BORING LOG INFORMATION

RAMBOLL

Facility/Project Name	License/Permit/Monitoring Number	Boring Number	
Kincaid Power Station		MW-26	
Boring Drilled By: Name of crew chief (first, last) and Firm	**Date Drilling Started**	**Date Drilling Completed**	**Drilling Method**
Dave Gordon Cascade Drilling	2/2/2021	2/2/2021	Mini Sonic
Common Well Name	**Final Static Water Level**	**Surface Elevation**	**Borehole Diameter**
MW-26	Feet (NAVD88)	593.33 Feet (NAVD88)	6.0 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,067,258.09 N, 2,485,127.12 E E/Ⓦ
1/4 of 1/4 of Section 11, T 13 N, R 4 W

Lat 39° 35' 44.0772"
Long -89° 29' 51.2952"

Local Grid Location: Feet ☐ N ☐ S; Feet ☐ E ☐ W

Facility ID	County	State	Civil Town/City/ or Village
	Christian	IL	Kincaid

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 CS	120 79		0–2	0 - 2.1' **SILT:** ML, dark grayish brown (10YR 4/2), dark yellowish brown (10YR 4/4) mottling (5-15%), very dark gray (10YR 3/1) mottling (0-5%), organic material (5-15%), roots (5-15%), sand (0-5%), slow dilatancy, medium toughness, low plasticity, moist.	ML									CS = Core Sample
			2–10	2.1 - 10' **LEAN CLAY:** CL, grayish brown (10YR 5/2) to yellowish brown (10YR 5/6), silt (15-30%), sand (0-5%), organic material (0-5%), very soft, no dilatancy, low toughness, medium plasticity, moist.	CL				0.25 0.25 0.25					
2 CS	120 120		10	10 - 10.9' **CLAYEY SAND:** (SM)g, yellowish brown (10YR 5/4), gravel (5-15%), dense, wet.	(SM)g									
			11	10.9 - 11.7' **CLAYEY SILT to SILTY CLAY:** ML/CL, gray (10YR 5/1), grayish brown (10YR 5/2), to yellowish brown (10YR 5/4), sand (5-15%), gravel (0-5%), no dilatancy, low to high toughness, low to medium plasticity, dry to wet.	ML/CL									
			12–15	11.7 - 20' **SILT:** ML, gray (10YR 5/1) to grayish brown (10YR 5/2), clay (15-30%), sand (5-15%), gravel (0-5%), hard, no dilatancy, high toughness, low plasticity, dry.	ML									

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature]

Firm Ramboll
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SOIL BORING LOG INFORMATION SUPPLEMENT

RAMBOLL

Boring Number MW-26

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Soil Properties: Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			16 17 18 19 20	11.7 - 20' **SILT:** ML, gray (10YR 5/1) to grayish brown (10YR 5/2), clay (15-30%), sand (5-15%), gravel (0-5%), hard, no dilatancy, high toughness, low plasticity, dry. *(continued)*	ML				4.5 4.5					
				20' End of Boring.										

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SOIL BORING LOG INFORMATION

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Kincaid Power Station		MW-27

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Dave Gordon Cascade Drilling	2/2/2021	2/2/2021	Mini Sonic

Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
MW-27	Feet (NAVD88)	597.35 Feet (NAVD88)	6.0 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,067,661.72 N, 2,485,026.71 E E/W (W circled)
1/4 of 1/4 of Section 11, T 13 N, R 4 W
Lat 39° 35' 48.0732"
Long -89° 29' 52.5372"
Local Grid Location: ☐ N ☐ S Feet; ☐ E ☐ W Feet

Facility ID	County	State	Civil Town/City/ or Village
	Christian	IL	Kincaid

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 CS	120 95		0–1	0 - 1.2' **SILT:** ML, very dark grayish brown (10YR 3/2) to dark yellowish brown (10YR 4/6), clay (15-30%), gravel (0-5%), roots (0-5%), very soft, no dilatancy, low to medium toughness, low plasticity, wet.	ML				0.25					CS = Core Sample
			2–9	1.2 - 9.6' **LEAN CLAY:** CL, dark yellowish brown (10YR 4/6), yellowish brown (10YR 5/6) mottling 5-15%), silt (15-30%), sand (0-5%), firm to very soft, no dilatancy, low toughness, medium plasticity, moist. 4.5' grayish brown (10YR 5/2), yellowish brown (10YR 5/6) mottling (5-15%). 5.3' - 5.8' very dark grayish brown (10YR 3/2) mottling (15-30%), roots (5-15%).	CL				0.75 1.25 0.25 0.25					
2 CS	120 86		10	9.6 - 10.8' **CLAYEY SAND:** SC, yellowish brown (10YR 5/4), subrounded, fine sand, gravel (5-15%), wet.	SC									
			11–13	10.8 - 13.5' **SANDY LEAN CLAY:** s(CL), grayish brown (10YR 5/2), yellowish brown (10YR 5/4) mottling (30-45%), silt (15-30%), very soft, low toughness, low plasticity, wet.	s(CL)				0.25					
			14–15	13.5 - 17.5' **SILT:** ML, gray (10YR 5/1), clay (15-30%), sand (5-15%), gravel (0-5%), no dilatancy, medium toughness, non-plastic to low plasticity, dry.	ML									

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature]

Firm Ramboll
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RAMBOLL

Boring Number MW-27

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Soil Properties: Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			16 17	13.5 - 17.5' **SILT:** ML, gray (10YR 5/1), clay (15-30%), sand (5-15%), gravel (0-5%), no dilatancy, medium toughness, non-plastic to low plasticity, dry. *(continued)*	ML									
			18 19 20	17.5 - 20' **SILTY SAND:** SM, gray (10YR 5/1), rounded to subangular, fine sand, gravel (0-5%), loose, dry.	SM									
				20' End of Boring.										

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Kincaid Power Station		MW-28

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Dave Gordon Cascade Drilling	2/2/2021	2/2/2021	Mini Sonic

Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
MW-28	Feet (NAVD88)	598.33 Feet (NAVD88)	6.0 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,068,595.29 N, 2,485,010.02 E E/W (W circled)
1/4 of 1/4 of Section 2, T 13 N, R 4 W

Lat 39° 35' 57.3"
Long -89° 29' 52.6632"

Local Grid Location: Feet ☐N ☐S Feet ☐E ☐W

Facility ID	County	State	Civil Town/City/ or Village
	Christian	IL	Kincaid

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 CS	120 91		0–5.2	0 - 5.2' **LEAN CLAY:** CL, dark yellowish brown (10YR 4/4), dark grayish brown (10YR 4/2) mottling (0-5%), silt (15-30%), sand (0-5%), organic material (0-5%), no dilatancy, low toughness, medium plasticity, moist to wet.	CL									CS = Core Sample
			5.2–6.8	5.2 - 6.8' **SILTY CLAY:** CL/ML, dark yellowish brown (10YR 4/4), sand (5-15%), no dilatancy, low toughness, low plasticity, moist.	CL/ML									
			6.8–8.4	6.8 - 8.4' **SILT:** ML, yellowish brown (10YR 5/6), clay (15-30%), sand (5-15%), gravel (0-5%), no dilatancy, medium toughness, low plasticity, moist.	ML									
2 CS	120 103		8.4–11.2	8.4 - 11.2' **CLAYEY SILT to SILTY CLAY:** ML/CL, yellowish brown (10YR 5/6), sand (15-30%), gravel (0-5%), no dilatancy, low toughness, non-plastic to low plasticity, wet.	ML/CL									
			11.2–14	11.2 - 17.6' **SILT:** ML, yellowish brown (10YR 5/4), clay (15-30%), sand (5-15%), gravel (0-5%), no dilatancy, medium toughness, non-plastic, moist.	ML									

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature [signature]

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RAMBOLL

Boring Number MW-28

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Soil Properties: Compressive Strength (tsf)	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
			15 16 17	11.2 - 17.6' **SILT:** ML, yellowish brown (10YR 5/4), clay (15-30%), sand (5-15%), gravel (0-5%), no dilatancy, medium toughness, non-plastic, moist. *(continued)*	ML									
			18 19	17.6 - 19.5' **SILT WITH SAND:** (ML)s, yellowish brown (10YR 5/4), yellowish brown (10YR 5/6) mottling (5-15%), gravel (0-5%), no dilatancy, medium toughness, non-plastic, moist.	(ML)s									
3 CS	60 60		20 21	19.5 - 22' **SANDY SILT:** s(ML), gray (10YR 5/1), wet to moist. 21' - 21.5' layer of sand, gray (10YR 5/1) subrounded fine sand, loose, wet.	s(ML)									
			22 23 24	22 - 24.3' **SILTY SAND:** SM, grayish brown (10YR 5/2) to gray (10YR 5/1), subrounded, fine sand, gravel (0-5%), dense, wet.	SM									
			25	24.3 - 25' **CLAYEY SAND:** SC, grayish brown (10YR 5/2), gravel (5-15%), loose, wet.	SC									
				25' End of Boring.										

SOIL BORING LOG INFORMATION

RAMBOLL

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Kincaid Power Station		MW-29

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Dave Gordon Cascade Drilling	2/1/2021	2/1/2021	Mini Sonic

Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
MW-29	Feet (NAVD88)	596.86 Feet (NAVD88)	6.0 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,068,754.64 N, 2,485,209.80 E E/W
1/4 of 1/4 of Section 2, T 13 N, R 4 W

Lat 39° 35' 58.8624"
Long -89° 29' 50.0964"

Local Grid Location: ☐ N ☐ S Feet; ☐ E ☐ W Feet

Facility ID	County	State	Civil Town/City/ or Village
	Christian	IL	Kincaid

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 CS	120 120		0–3.7	0 - 3.7' **LEAN CLAY:** CL, grayish brown (10YR 5/2), dark yellowish brown (10YR 4/6) mottling (15-30%), very dark grayish brown (10YR 3/2) mottling (0-5%), silt (15-30%), roots (0-5%), organic material (0-5%), slow dilatancy, low toughness, medium to high plasticity, moist.	CL				0.25 0.25					CS = Core Sample
			3.7–6.8	3.7 - 6.8' **SILTY CLAY:** ML/CL, dark yellowish brown (10YR 4/6), sand (0-5%), low to medium plasticity, moist.	ML/CL				0.25					
			6.8–8.4	6.8 - 8.4' **LEAN CLAY:** CL, dark yellowish brown (10YR 4/6), silt (15-30%), sand and sand seams (15-30%), no dilatancy, low toughness, low to medium plasticity, moist.	CL									
			8.4–10.0	8.4 - 10' **SANDY LEAN CLAY:** s(CL), dark yellowish brown (10YR 4/6), silt (15-30%), gravel (0-5%), no dilatancy, medium toughness, low plasticity.	s(CL)									

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature]

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Boring Number MW-29

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
2 CS	120 95		10 - 11.6	10 - 11.6' **CLAYEY SAND:** SC, dark yellowish brown (10YR 4/4), subrounded medium sand, gravel (5-15%), wet.	SC									
			11.6 - 16	11.6 - 16' **SANDY SILT:** s(ML), dark yellowish brown (10YR 4/6), grayish brown (10YR 5/2) mottling (5-15%), clay (5-15%), gravel (0-5%), slow dilatancy, medium toughness, non-plastic to low plasticity, dry.	s(ML)									
			16 - 17.5	16 - 17.5' **WELL-GRADED SAND:** GW, dark yellowish brown (10YR 4/6), gravel (5-15%), clay (5-15%), wet.	GW									
			17.5 - 20	17.5 - 20' **SILT:** ML, dark yellowish brown (10YR 4/6), grayish brown (10YR 5/2) mottling (5-15%), sand (5-15%), clay (5-15%), gravel (0-5%), no dilatancy, medium toughness, low plasticity, dry.	ML									
			20.0	20' End of Boring.										

Depth scale: 10.5, 11.0, 11.5, 12.0, 12.5, 13.0, 13.5, 14.0, 14.5, 15.0, 15.5, 16.0, 16.5, 17.0, 17.5, 18.0, 18.5, 19.0, 19.5, 20.0

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SOIL BORING LOG INFORMATION

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Kincaid Power Station		MW-30

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Dave Gordon Cascade Drilling	2/3/2021	2/3/2021	Mini Sonic

Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
MW-30	Feet (NAVD88)	616.00 Feet (NAVD88)	6.0 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,069,336.19 N, 2,486,121.89 E E/W (W circled)
1/4 of 1/4 of Section 1, T 13 N, R 4 W
Lat 39° 36' 4.6044"
Long -89° 29' 19.1148"
Local Grid Location: Feet ☐N ☐S Feet ☐E ☐W

Facility ID	County	State	Civil Town/City/ or Village
	Christian	IL	Kincaid

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 CS	120 120		0.5 1.0 1.5	0 - 1.5' **FILL, SILT:** ML, dark gray (10YR 4/1) to very dark gray (10YR 3/1), medium sand sized ash (5-15%), roots (5-15%), gravel (0-5%), soft, slow dilatancy, low toughness, low plasticity, wet. 1.1' - 1.2' layer of ash.	(FILL) ML									CS = Core Sample
			2.0 2.5 3.0 3.5 4.0 4.5 5.0	1.5 - 7.4' **SILTY CLAY:** CL/ML, grayish brown (10YR 5/2), very dark grayish brown (10YR 3/2) mottling (0-5%), dark gray (10YR 4/1) laminations (5-15%), yellowish brown (10YR 5/6) laminations (0-5%), sand (0-5%), gravel (0-5%), firm to stiff, no dilatancy, high toughness, low plasticity, dry yellowish brown (10YR 5/6 sand seams (0-5%), 1/8" thick.	CL/ML									

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature]

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Boring Number MW-30

Sample Number and Type	Sample Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			5.5, 6.0, 6.5, 7.0	1.5 - 7.4' **SILTY CLAY:** CL/ML, grayish brown (10YR 5/2), very dark grayish brown (10YR 3/2) mottling (0-5%), dark gray (10YR 4/1) laminations (5-15%), yellowish brown (10YR 5/6) laminations (0-5%), sand (0-5%), gravel (0-5%), firm to stiff, no dilatancy, high toughness, low plasticity, dry yellowish brown (10YR 5/6 sand seams (0-5%), 1/8" thick. *(continued)*	CL/ML									
			7.5	7.4 - 7.9' **LEAN CLAY:** CL, very dark grayish brown (10YR 3/2), yellowish brown (10YR 5/6) mottling (5-15%), silt (5-15%), organic material (5-15%), slow dilatancy, low toughness, high plasticity, moist.	CL									
			8.0, 8.5	7.9 - 8.7' **SILT WITH SAND:** (ML)s, light brownish gray (10YR 6/2), gray (10YR 6/1) mottling (0-5%), clay (5-15%), gravel (0-5%), high toughness, low plasticity, dry.	(ML)s									
			9.0	8.7 - 9.5' **SILT:** ML, dark grayish brown (10YR 4/2), yellowish brown (10YR 5/6) mottling (0-5%), clay (5-15%), sand (5-15%), gravel (0-5%), stiff, no dilatancy, high toughness, low plasticity, dry.	ML									
2 CS	120 96		9.5, 10.0, 10.5, 11.0, 11.5, 12.0, 12.5, 13.0	9.5 - 24.5' **LEAN CLAY:** CL, very dark grayish brown (10YR 3/2), silt (15-30%), sand (0-5%), gravel (0-5%), slow dilatancy, low toughness, medium plasticity. 11.3' greenish gray (GLEY2 6/10BG) mottling (5-15%), olive brown (2.5Y 4/4) mottling (5-15%), yellowish brown (10YR 5/6) mottling (0-5%). 12.5' greenish gray (GLEY2 6/10BG), very dark grayish brown (10YR 3/2) mottling (15-30%), olive brown (2.5Y 4/4) mottling (5-15%), dark yellowish brown (10YR 4/6) mottling (0-5%).	CL									

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			13.5	9.5 - 24.5' **LEAN CLAY:** CL, very dark grayish brown (10YR 3/2), silt (15-30%), sand (0-5%), gravel (0-5%), slow dilatancy, low toughness, medium plasticity. *(continued)*										
			14.0	14' very dark grayish brown (10YR 3/2), greenish gray (GLEY2 6/10BG) mottling (5-15%), olive brown (2.5Y 4/4) mottling (5-15%), yellowish brown (10YR 5/6) mottling (0-5%).										
			14.5											
			15.0	15' very dark grayish brown (10YR 3/2) to very dark gray (10YR 3/1), dark grayish brown (10YR 4/2) mottling, organic material (0-5%), high plasticity.										
			15.5											
			16.0											
			16.5											
			17.0											
			17.5		CL									
			18.0											
			18.5											
			19.0											
			19.5											
3 CS	120 116		20.0											
			20.5											
			21.0											
			21.5											

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Boring Number MW-30

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Soil Properties: Compressive Strength (tsf)	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
			22.0 – 24.5	9.5 - 24.5' **LEAN CLAY:** CL, very dark grayish brown (10YR 3/2), silt (15-30%), sand (0-5%), gravel (0-5%), slow dilatancy, low toughness, medium plasticity. *(continued)*	CL									
			24.5 – 25.0	24.5 - 25' **CLAYEY SILT** to **SILTY CLAY:** ML/CL, dark grayish brown (10YR 4/2) to grayish brown (10YR 5/2), gray (10YR 5/1) mottling (15-30%), sand (0-5%), gravel (0-5%), no dilatancy, medium toughness, low to medium plasticity, moist.	ML/CL									
			25.0 – 26.5	25 - 26.6' **SILT:** ML, gray (10YR 5/1), dark grayish brown (10YR 4/2) mottling (5-15%), yellowish brown (10YR 5/4) laminations (5-15%), clay (15-30%), sand (5-15%), gravel (0-5%), moist.	ML									
			27.0 – 30.0	26.6 - 35' **CLAYEY SILT** to **SILTY CLAY:** ML/CL, dark grayish brown (10YR 4/2) to grayish brown (10YR 5/2), gray (10YR 5/1) mottling (15-30%), greenish gray (GLEY2 6/10BG) mottling (0-5%), sand (0-5%), gravel (0-5%), no dilatancy, medium toughness, low to medium plasticity, moist. 27.1' - 28.5' very dark gray (10YR 3/1) to dark gray (10YR 4/1).	ML/CL									

Boring Number MW-30

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Soil Properties: Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
4 CS	120 113		30.5, 31.0, 31.5, 32.0, 32.5, 33.0, 33.5, 34.0, 34.5	26.6 - 35' **CLAYEY SILT** to **SILTY CLAY:** ML/CL, dark grayish brown (10YR 4/2) to grayish brown (10YR 5/2), gray (10YR 5/1) mottling (15-30%), greenish gray (GLEY2 6/10BG) mottling (0-5%), sand (0-5%), gravel (0-5%), no dilatancy, medium toughness, low to medium plasticity, moist. *(continued)*	ML/CL									
			35.0, 35.5, 36.0, 36.5, 37.0	35 - 37.2' **SANDY LEAN CLAY:** to **CLAYEY SAND:** (CL)g, yellowish brown (10YR 5/6), grayish brown (10YR 5/2) mottling (0-10%), gravel (0-5%), low toughness, low plasticity to non-plastic, loose, wet.	(CL)g									
			37.5, 38.0	37.2 - 39.2' **SILT WITH SAND:** (ML)s, yellowish brown (10YR 5/4), yellowish brown (10YR 5/6) mottling (5-15%), dark grayish brown (10YR 4/2) mottling (0-5%), gravel (0-5%), moist.	(ML)s									

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Boring Number MW-30

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Soil Properties: Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			38.5 39.0	37.2 - 39.2' **SILT WITH SAND:** (ML)s, yellowish brown (10YR 5/4), yellowish brown (10YR 5/6) mottling (5-15%), dark grayish brown (10YR 4/2) mottling (0-5%), gravel (0-5%), moist. *(continued)*	(ML)s									
			39.5	39.2 - 40' **SILTY SAND:** SM, yellowish brown (10YR 5/4), yellowish brown (10YR 5/6) mottling (0-5%), gravel (0-5%), moist.	SM									
5 CS	60 45.6		40.0 40.5 41.0 41.5 42.0 42.5 43.0 43.5 44.0 44.5	40 - 45' **CLAYEY SILT** ML/CL, dark grayish brown (10YR 4/2) to dark gray (10YR 4/1), sand (5-15%), gravel (0-5%).	ML/CL									
			45.0	45' End of Boring.										

RAMBOLL

SOIL BORING LOG INFORMATION

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Kincaid Power Station		MW-31

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Dave Gordon Cascade Drilling	2/3/2021	2/3/2021	Mini Sonic

Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
MW-31	Feet (NAVD88)	615.02 Feet (NAVD88)	6.0 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,069,352.71 N, 2,486,768.38 E E/W
1/4 of 1/4 of Section 1, T 13 N, R 4 W
Lat 39° 36' 4.6584"
Long -89° 29' 30.1272"
Local Grid Location ☐ N ☐ S Feet ☐ E ☐ W Feet

Facility ID	County	State	Civil Town/City/ or Village
	Christian	IL	Kincaid

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 CS	120 95		1.5	0 - 2' ASH, dark gray (10YR 4/1), silt sized grains, clay (5-15%), moist.	(FILL) ASH				0.5					CS = Core Sample
			3.0 4.5 6.0 7.5	2 - 8' **SILTY CLAY:** CL/ML, grayish brown (10YR 5/2), sand (5-15%), gravel (0-5%), hard to firm, no dilatancy, medium toughness, low plasticity, moist.	CL/ML				3 1					
			9.0	8 - 9' **SILTY SAND:** SM, brown (10YR 5/3), clay (15-30%), gravel (0-5%), loose, moist.	SM									
2 CS	240 240		10.5 12.0 13.5 15.0 16.5 18.0	9 - 18' **SILTY CLAY:** CL/ML, yellowish brown (10YR 5/4), grayish brown (10YR 5/2) mottling (5-15%), sand (0-5%), organic material (0-5%), soft to firm, low toughness, medium to low plasticity, moist. 11.4' dark brown (10YR 3/3) mottling (5-15%). 11.9' dark brown (10YR 3/3) mottling (0-5%), silt (15-30%), medium plasticity. 14.6' dark brown (10YR 3/3) mottling (5-15%), yellowish brown (10YR 5/6) silt seams (0-5%).	CL/ML				0.5 0.5 0.5 0.5					

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature

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RAMBOLL

Boring Number MW-31

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			19.5	18 - 20.2' **LEAN CLAY:** CL, very dark grayish brown (10YR 3/2), grayish brown (10YR 5/2) mottling (5-15%), yellowish brown (10YR 5/6) mottling (0-5%), silt (15-30%), organic material (15-30%), medium to high plasticity.	CL				1					
			21.0 22.5	20.2 - 23.8' **SILTY CLAY:** CL/ML, yellowish brown (10YR 5/4), dark brown (10YR 3/3) mottling 5-15%), yellowish brown (10YR 5/6) silt seams (0-5%). 22.8' wet in clay fracture.	CL/ML									
			24.0 25.5	23.8 - 26.1' **LEAN CLAY:** CL, very dark grayish brown (10YR 3/2), grayish brown (10YR 5/2) mottling (5-15%), yellowish brown (10YR 5/6) mottling (0-5%), silt (15-30%), organic material (15-30%), medium to high plasticity.	CL									
			27.0	26.1 - 26.7' **LEAN CLAY:** CL, yellowish brown (10YR 5/4), dark grayish brown (10YR 4/2) mottling (5-15%), very dark gray (10YR 3/1) mottling (0-5%), no dilatancy, medium toughness, medium to high plasticity, moist.	CL									
			28.5	26.7 - 28' **LEAN CLAY:** CL, very dark grayish brown (10YR 3/2), grayish brown (10YR 5/2) mottling (5-15%), yellowish brown (10YR 5/6) mottling (0-5%), silt (15-30%), organic material (15-30%), sand (0-5%), medium to high plasticity.	CL									
3 CS	120 120		30.0 31.5 33.0	28 - 32.8' **LEAN CLAY:** CL, yellowish brown (10YR 5/4), dark grayish brown (10YR 4/2) mottling (5-15%), very dark gray (10YR 3/1) mottling (0-5%), no dilatancy, medium toughness, medium to high plasticity, moist. 31.4' dark grayish brown (10YR 4/2) to dark gray (10YR 4/1).	CL									
			34.5 36.0	32.8 - 35.4' **CLAYEY SILT** ML/CL, grayish brown (10YR 5/2), yellowish brown (10YR 5/4) mottling (5-15%), light gray (10YR 7/2) mottling (0-5%), very dark gray (10YR 3/1) mottling (0-5%), sand (0-5%), gravel (0-5%), no dilatancy, medium toughness, low plasticity. 34.6' olive brown (2.5Y 4/3) mottling (15-30%) in sand seams, sand (15-30%).	ML/CL									
			37.5	35.4 - 38.3' **SANDY LEAN CLAY:** s(CL), olive brown (2.5Y 4/3), dark gray (10YR 4/1) mottling (5-15%), gravel (0-5%), no dilatancy, low toughness, low plasticity, wet.	s(CL)									
			39.0	38.3 - 39.8' **POORLY-GRADED SAND:** SP, yellowish brown (10YR 5/4), yellowish brown (10YR 5/6) mottling (5-15%), subrounded, fine sand, silt (5-15%), clay (5-15%), gravel (0-5%), dense, moist to wet.	SP									
4 CS	120 120		40.5 42.0 43.5 45.0 46.5 48.0	39.8 - 50' **SILT:** ML, dark gray (10YR 4/1) to gray (10YR 5/1), clay (15-30%), sand (5-15%), gravel (0-5%), no dilatancy, high toughness, low plasticity to non-plastic, dry. 42' low plasticity. 43.6' - 43.7' layer of medium to coarse sand, wet. 46' fine sand seams 1/8" to 1/2" thick, moist to dry.	ML									

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Boring Number MW-31

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Soil Properties: Compressive Strength (tsf)	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
			49.5	39.8 - 50' **SILT:** ML, dark gray (10YR 4/1) to gray (10YR 5/1), clay (15-30%), sand (5-15%), gravel (0-5%), no dilatancy, high toughness, low plasticity to non-plastic, dry. *(continued)*	ML									
				50' End of Boring.										

RAMBOLL

SOIL BORING LOG INFORMATION

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Kincaid Power Station		MW-31S

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Dave Gordon Cascade Drilling	2/3/2021	2/3/2021	Mini Sonic

Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
MW-31S	Feet (NAVD88)	615.13 Feet (NAVD88)	6.0 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,069,353.41 N, 2,486,774.19 E E/W (W circled)
1/4 of 1/4 of Section 1, T 13 N, R 4 W
Lat 39° 36' 4.662"
Long -89° 29' 30.0516"
Local Grid Location: Feet ☐ N ☐ S; Feet ☐ E ☐ W

Facility ID	County	State	Civil Town/City/ or Village
	Christian	IL	Kincaid

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 CS	120 88		0 - 2	0 - 2' ASH, Blind drill to 10 feet below ground surface. See MW-31 boring log for detailed lithologies.	(FILL) ASH									CS = Core Sample
			2 - 8	2 - 8' **SILTY CLAY:** CL/ML.	CL/ML									
			8 - 9	8 - 9' **SILTY SAND:** SM.	SM									
			9 - 10	9 - 10' **SILTY CLAY:** CL/ML.	CL/ML									

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature]

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Boring Number MW-31S

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Soil Properties: Compressive Strength (tsf)	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
2 CS	120 120		10.5 11.0 11.5 12.0	10 - 12.4' **SILT:** ML, grayish brown (10YR 5/2), yellowish brown (10YR 5/6) mottling (5-15%), very dark grayish brown (10YR 3/2) mottling (0-5%), clay (15-30%), sand (5-15%), gravel (0-5%), no dilatancy, medium toughness, moist. 10.8' - 11.2' yellowish brown (10YR 5/6), grayish brown (10YR 5/2) mottling (5-15%), sand (15-30%), hard.	ML									
			12.5 13.0 13.5 14.0 14.5 15.0	12.4 - 15.4' **LEAN CLAY:** CL, dark grayish brown (10YR 4/2), very dark grayish brown (10YR 3/2) mottling (5-15%), olive brown (2.5Y 4/4) mottling (0-5%), yellowish brown (10YR 5/6) mottling (0-5%), silt (15-30%), organic material (0-5%), sand (0-5%), gravel (0-5%), no dilatancy, medium toughness, medium plasticity, moist. 14' olive brown (2.5Y 4/4), dark grayish brown (10YR 4/2) mottling (5-15%), dry.	CL									
			15.5 16.0 16.5	15.4 - 16.6' **SILT:** ML, yellowish brown (10YR 5/4), yellowish brown (10YR 5/6) mottling (5-15%), clay (15-30%), sand (5-15%), gravel (0-5%), no dilatancy, high toughness, low plasticity, dry.	ML									
			17.0 17.5 18.0 18.5 19.0 19.5	16.6 - 26.8' **LEAN CLAY:** CL, very dark grayish brown (10YR 3/2), dark grayish brown (10YR 4/2) and yellowish brown (10YR 5/4) laminations (15-30%), olive brown (2.5Y 4/4) laminations (0-5%), silt (5-15%), organic material (5-15%), gravel (0-5%), sand (0-5%), slow dilatancy, low to medium toughness, high plasticity, moist.										
3 CS	120 120		20.0 20.5 21.0 21.5 22.0 22.5 23.0 23.5 24.0 24.5 25.0 25.5 26.0 26.5		CL									

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Boring Number MW-31S

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Soil Properties: Compressive Strength (tsf)	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
			27.0 27.5 28.0 28.5 29.0 29.5	26.8 - 30' **LEAN CLAY:** CL, yellowish brown (10YR 5/6), very dark grayish brown (10YR 3/2) mottling (0-5%), yellowish brown (10YR 5/6) mottling (0-5%), silt (15-30%), organic material (0-5%), sand (0-5%), gravel (0-5%), no dilatancy, medium toughness, low plasticity, moist.	CL									
			30.0	30' End of Boring.										

SOIL BORING LOG INFORMATION

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Kincaid Power Station		MW-32

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Adam Jochimsen Cascade Drilling	2/3/2021	2/3/2021	Mini Sonic

Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
MW-32	Feet (NAVD88)	617.20 Feet (NAVD88)	6.0 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,069,353.90 N, 2,487,630.18 E E/W(circled)
1/4 of 1/4 of Section 1, T 13 N, R 4 W
Lat 39° 36' 4.6044"
Long -89° 29' 19.1148"
Local Grid Location: Feet ☐N ☐S Feet ☐E ☐W

Facility ID	County	State	Civil Town/City/ or Village
	Christian	IL	Kincaid

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 CS	60 36			0 - 1.2' ASH, very dark gray (10YR 3/1), gravel to sand sized grians, loose, dry.	(FILL) ASH									CS = Core Sample Advanced 8-inch override casing to 10 feet below ground surface.
			1–4	1.2 - 4.6' **FILL, SILT WITH SAND:** (ML)s, yellowish brown (10YR 5/4), gravel (0-5%), soft, slow dilatancy, low toughness, non-plastic, moist.	(FILL) (ML)s				0.25					
2 CS	60 45		5–6	4.6 - 6.3' ASH, black (10YR 2/1) to very dark gray (10YR 3/1), sand to silt sized grains, loose.	(FILL) ASH				0.25					
			7–10	6.3 - 10.3' **SILTY CLAY:** ML/CL, pale brown (10YR 6/3), sand (5-10%), gravel (0-5%), very stiff, slow dilatancy, low toughness, low plasticity, moist.	ML/CL				3.25					
3 CS	60 43		11	10.3 - 11.7' **LEAN CLAY:** CL, pale brown (10YR 6/3), silt (15-25%), sand (0-5%), gravel (0-5%), stiff, no dilatancy, medium toughness, medium plasticity, moist.	CL				2.75					
			12–14	11.7 - 20.1' **LEAN CLAY:** CL, grayish brown (2.5Y 5/2), gray (10YR 5/1) mottling (5-15%), silt (15-25%), organic material (5-10%), sand (0-5%), stiff, no dilatancy, medium toughness, medium plasticity, moist.	CL				2.75					

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature

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Boring Number MW-32

Sample Number and Type	Sample Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Soil Properties: Compressive Strength (tsf)	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
4 CS	60 35		15 16 17 18 19	11.7 - 20.1' **LEAN CLAY:** CL, grayish brown (2.5Y 5/2), gray (10YR 5/1) mottling (5-15%), silt (15-25%), organic material (5-10%), sand (0-5%), stiff, no dilatancy, medium toughness, medium plasticity, moist. *(continued)* 14.9' layer of wood.	CL				2.75 3 4					Wood in shoe of core barrel.
5 CS	60 56		20 21 22	20.1 - 22.9' **LEAN CLAY:** CL, light yellowish brown (10YR 6/4) to light brownish gray (10YR 6/2), yellowish brown (10YR 5/6) mottling (5-10%), silt (15-25%), gravel (0-5%), sand (0-5%), stiff, slow dilatancy, low toughness, medium plasticity, moist.	CL				0.75					
			23 24	22.9 - 25' **LEAN CLAY:** CL, grayish brown (2.5Y 5/2), gray (10YR 5/1) mottling (5-15%), silt (15-25%), organic material (5-10%), sand (0-5%), stiff, no dilatancy, medium toughness, medium plasticity, moist.	CL				1.75					
6 CS	120 120		25 26 27 28 29 30 31	25 - 31.6' **LEAN CLAY:** CL, yellowish brown (10YR 5/4), yellowish brown (10YR 5/8) mottling, silt (10-15%), sand (0-5%), firm, slow dilatancy, low toughness, medium plasticity, moist.	CL				3 0.75 1.25 0.5					
7 CS	60 60		32 33 34 35 36	31.6 - 36.2' **SANDY LEAN CLAY WITH GRAVEL:** to **LEAN CLAY WITH SAND:** s(CL), yellowish brown (10YR 5/8), gravel (0-5%), soft, slow dilatancy, low toughness, low to medium plasticity, moist.	s(CL)				0.5 4.5					
			37	36.2 - 40' **SILTY CLAY:** ML/CL, gray (10YR 5/1), sand (0-10%), gravel (0-5%), hard, no dilatancy, high toughness, low plasticity, wet.	ML/CL				4.5					

Boring Number MW-32

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Soil Properties: Compressive Strength (tsf)	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
			38 39 40	36.2 - 40' **SILTY CLAY:** ML/CL, gray (10YR 5/1), sand (0-10%), gravel (0-5%), hard, no dilatancy, high toughness, low plasticity, wet. *(continued)*	ML/CL				4.5					
				40' End of Boring.										

SOIL BORING LOG INFORMATION

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Kincaid Power Station		MW-7S

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Dave Gordon Cascade Drilling	2/2/2021	2/2/2021	Mini Sonic

Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
MW-7S	Feet (NAVD88)	595.59 Feet (NAVD88)	6.0 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,068,011.16 N, 2,484,728.09 E E/W (W circled)
1/4 of 1/4 of Section 2, T 13 N, R 4 W
Lat 39° 35' 51.5472"
Long -89° 29' 56.3208"
Local Grid Location: Feet ☐ N ☐ S; Feet ☐ E ☐ W

Facility ID	County	State	Civil Town/City/ or Village
	Christian	IL	Kincaid

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 CS	120 104		0 - 3.5	0 - 3.5' **CLAYEY SILT** ML/CL, very dark grayish brown (10YR 3/2), dark grayish brown (10YR 4/2) mottling (5-15%), dark yellowish brown (10YR 4/6) mottling (5-15%), sand (5-15%), gravel (0-5%), roots (0-5%), firm, slow dilatancy, low to medium toughness, low plasticity, moist.	ML/CL				1 1.25					CS = Core Sample
			3.5 - 7.5	3.5 - 7.5' **LEAN CLAY:** CL, grayish brown (10YR 5/2), very dark grayish brown (10YR 3/2) mottling (5-15%), dark yellowish brown (10YR 4/6) mottling (5-15%), silt (15-30%), sand (0-5%), gravel (0-5%), stiff to soft, no dilatancy, medium toughness, low to medium plasticity, moist. 7.2' red brick (15-30%).	CL				2.75 0.5					
2 CS	60 60		7.5 - 13	7.5 - 13' **LEAN CLAY:** CL, grayish brown (10YR 5/2), silt (15-30%), dark yellowish brown (10YR 4/4) mottling (5-15%), sand (0-5%), gravel (0-5%), no dilatancy, low to medium toughness, medium plasticity, moist.	CL				0.25					

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature]

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Boring Number MW-7S

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Soil Properties: Compressive Strength (tsf)	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
			11.5 12.0 12.5	7.5 - 13' **LEAN CLAY:** CL, grayish brown (10YR 5/2), silt (15-30%), dark yellowish brown (10YR 4/4) mottling (5-15%), sand (0-5%), gravel (0-5%), no dilatancy, low to medium toughness, medium plasticity, moist. *(continued)*	CL									
			13.0 13.5 14.0 14.5	13 - 15' **SANDY LEAN CLAY:** to **CLAYEY SAND:** s(CL), dark yellowish brown (10YR 4/4), gravel (0-5%), non-cohesive to cohesive, low plasticity, wet.	s(CL)									
			15.0	15' End of Boring.										

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SOIL BORING LOG INFORMATION

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Kincaid Power Station		MW-8S

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Dave Gordon Cascade Drilling	2/2/2021	2/2/2021	Mini Sonic

Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
MW-8S	Feet (NAVD88)	600.57 Feet (NAVD88)	6.0 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,066,821.52 N, 2,485,344.57 E E/Ⓦ
1/4 of 1/4 of Section 12, T 13 N, R 4 W

Lat 39° 35' 39.7464"
Long -89° 29' 48.5592"

Local Grid Location: Feet ☐ N ☐ S; Feet ☐ E ☐ W

Facility ID	County	State	Civil Town/City/ or Village
	Christian	IL	Kincaid

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 CS	120 120		0–1.9	0 - 1.9' **LEAN CLAY:** CL, grayish brown (10YR 5/2), dark yellowish brown (10YR 4/4) mottling (5-15%), very dark gray (10YR 3/1) mottling (0-5%), silt (15-30%), gravel (0-5%), no dilatancy, low toughness, medium plasticity, wet to moist.	CL									CS = Core Sample
			1.9–5.6	1.9 - 5.6' **SILT:** ML, dark grayish brown (10YR 4/2), very dark grayish brown (10YR 3/2) mottling (5-15%), dark yellowish brown (10YR 4/6) mottling (0-5%), clay (15-30%), sand (0-5%), gravel (0-5%), roots (0-5%), no dilatancy, high toughness, low plasticity, moist.	ML									
			5.6–7.1	5.6 - 7.1' **LEAN CLAY:** CL, very dark gray (10YR 3/1) to very dark grayish brown (10YR 3/2), silt (15-30%), organic material (0-5%), slow dilatancy, low toughness, medium to high plasticity, moist.	CL									
			7.1–8.8	7.1 - 8.8' **SILTY CLAY:** CL/ML, grayish brown (10YR 5/2), yellowish brown (10YR 5/4) mottling (15-30%), no dilatancy, low toughness, medium plasticity, moist.	CL/ML									
2 CS	120 120		8.8–12	8.8 - 15' **SILT WITH SAND:** (ML)s, gray (10YR 5/1), dark yellowish brown (10YR 4/6) mottling (5-15%), clay (15-30%), no dilatancy, low toughness, non-plastic to low plasticity, moist to wet.	(ML)s									

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature]

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Boring Number MW-8S

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Soil Properties: Compressive Strength (tsf)	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
			13, 14	8.8 - 15' **SILT WITH SAND:** (ML)s, gray (10YR 5/1), dark yellowish brown (10YR 4/6) mottling (5-15%), clay (15-30%), no dilatancy, low toughness, non-plastic to low plasticity, moist to wet. *(continued)*	(ML)s									
			15, 16, 17, 18	15 - 18.5' **SANDY LEAN CLAY:** to **CLAYEY SAND:** s(CL), yellowish brown (10YR 5/4), gravel (0-5%), dense, non-plastic to low plasticity, wet.	s(CL)									
			19	18.5 - 20' **SILT:** ML, gray (10YR 5/1) to grayish brown (10YR 5/2), clay (15-30%), sand (0-5%), gravel (0-5%), dry.	ML									
			20	20' End of Boring.										

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Kincaid Power Station		XPW01

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Russ Gordon Cascade Drilling	2/1/2021	2/2/2021	Mini Sonic

Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
XPW01	Feet (NAVD88)	625.48 Feet (NAVD88)	6.0 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,066,842.23 N, 2,486,392.09 E E/Ⓦ
1/4 of 1/4 of Section 12, T 13 N, R 4 W
Lat 39° 35 ' 39.8724 "
Long -89° 29 ' 35.1744"
Local Grid Location: Feet ☐N ☐S Feet ☐E ☐W

Facility ID	County	State	Civil Town/City/ or Village
	Christian	IL	Kincaid

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 CS	60 60		0	0 - 8' ASH, black (10YR 2/1), silt to sand sized grains, fine to medium sand, gravel (0-5%), slag-like material (0-5%), dry.	(FILL) ASH									CS = Core Sample
2 CS	36 36		5											
3 MC	24 24		8	8 - 10' ASH, sand sized grains.	(FILL) ASH					19.4	12		2.6	MC = Modified California
4 CS	60 60		10	10 - 15.6' ASH, black (10YR 2/1), silt to sand sized grains, gravel (0-5%), slag-like material (0-5%), dry.	(FILL) ASH									

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature]

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Boring Number XPW01

Sample Number and Type	Sample Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			14	10 - 15.6' ASH, black (10YR 2/1), silt to sand sized grains, gravel (0-5%), slag-like material (0-5%), dry. *(continued)*	(FILL) ASH									
5 CS	36 36		15											
			16–17	15.6 - 18' ASH, black (10YR 2/1), sand to silt sized grains, slag-like material (0-5%), gravel (0-5%), dry.	(FILL) ASH									
6 MC	24 12		18–19	18 - 20' ASH, Not Analyzed.	(FILL) ASH									
7 MC	24 24		20–21	20 - 22' ASH, sand sized grains.	(FILL) ASH					26.8	17	2	3.7	
8 CS	36 36		22–23	22 - 30' ASH, black (10YR 2/1), sand to silt sized grains, slag-like material (0-5%), gravel (0-5%), dry. 23' wet.	(FILL) ASH									
9 CS	60 60		24–29	28' - 28.2' layer of clay, brown.										
10 MC	24 24		30–31	30 - 32' **LEAN CLAY:** CL, Not Analyzed.	CL									
			32	32' End of Boring.										

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Kincaid Power Station		XPW02

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Russ Gordon Cascade Drilling	1/26/2021	1/26/2021	Mini Sonic

Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
XPW02	Feet (NAVD88)	617.91 Feet (NAVD88)	6.0 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,068,109.66 N, 2,485,321.31 E E/W(circled W)
1/4 of 1/4 of Section 1, T 13 N, R 4 W
Lat 39° 35' 52.4796" Long -89° 29' 48.732"
Local Grid Location ☐N ☐S Feet ☐E ☐W Feet

Facility ID	County	State	Civil Town/City/ or Village
	Christian	IL	Kincaid

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 CS	60 60		0–5	0 - 8' ASH, black (10YR 2/1), sand sized grains, gravel (0-5%), slag-like material (0-5%), silt (0-5%), dry.	(FILL) ASH									CS = Core Sample
2 CS	36 36		5–8											
3 MC	24 18		8–10	8 - 10' ASH, sand sized grains.	(FILL) ASH					11.8	4		5.9	MC = Modified California
4 CS	60 60		10–12	10 - 15' ASH, black (10YR 2/1), sand sized grains, gravel (0-5%), slag-like material (0-5%), silt (0-5%), dry.	(FILL) ASH									

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature [signature]

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Fax: (414) 837-3608

Boring Number XPW02

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Soil Properties: Compressive Strength (tsf)	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
			13 14	10 - 15' ASH, black (10YR 2/1), sand sized grains, gravel (0-5%), slag-like material (0-5%), silt (0-5%), dry. *(continued)*	(FILL) ASH									
5 CS	36 25		15 16 17	15 - 18' ASH, black (10YR 2/1), sand to gravel sized grains, slag-like material (0-5%), silt (0-5%), wet.	(FILL) ASH									
6 MC	24 0		18 19	18 - 20' ASH, Not Analyzed.	(FILL) ASH									
7 MC	24 24		20 21	20 - 22' ASH, sand sized grains.	(FILL) ASH					13.9	8		5.5	
			22	22 - 23' Blind drilled to 23 feet below ground surface.										
				23' End of Boring.										

Facility/Project Name	License/Permit/Monitoring Number	Boring Number	
Kincaid Power Station		XPW03	
Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Russ Gordon Cascade Drilling	1/26/2021	1/26/2021	Mini Sonic
Common Well Name: XPW03	Final Static Water Level: Feet (NAVD88)	Surface Elevation: 616.08 Feet (NAVD88)	Borehole Diameter: 6.0 inches
Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒ State Plane 1,068,720.21 N, 2,485,628.19 E E/W 1/4 of 1/4 of Section 1, T 13 N, R 4 W	Lat 39° 35' 58.4916" Long -89° 29' 44.754"	Local Grid Location Feet ☐ N ☐ S	Feet ☐ E ☐ W
Facility ID:	County: Christian	State: IL	Civil Town/City/ or Village: Kincaid

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 CS	60 49		0	0 - 3.2' ASH, black (10YR 2/1), sand sized grains, gravel (0-5%), slag-like material (0-5%), dry.	(FILL) ASH									CS = Core Sample
			3.2	3.2 - 5.8' **FILL, SILTY CLAY WITH SAND** (CL/ML)S, yellowish brown (10YR 5/8), sand (15-25%), gravel (0-5%), brick (0-5%), stiff, low plasticity, moist.	(FILL) (CL/ML)S				1.5					
2 CS	36 36		5											
			5.8	5.8 - 8' ASH, black (10YR 2/1), sand sized grains, gravel (0-5%), brick (0-5%), slag-like material (0-5%), dry.	(FILL) ASH									
3 MC	24 18		8	8 - 10' ASH.	(FILL) ASH					27.4	14	1	8.4	MC = Modified California
4 CS	60 40		10	10 - 10.2' ASH, black (10YR 2/1), sand sized grains, gravel (0-5%), brick (0-5%), slag-like material (0-5%), dry.	(FILL) ASH									
			10.2	10.2 - 10.8' **FILL, SANDY LEAN CLAY:** s(CL), grayish brown (10YR 5/2), gravel (0-5%), brick (0-5%), very stiff, low plasticity, wet.	(FILL) s(CL)									
			10.8		(FILL) ASH									

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature]

Firm: Ramboll
234 W. Florida Street, Milwaukee, WI 53204
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SOIL BORING LOG INFORMATION SUPPLEMENT

Boring Number XPW03

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Soil Properties: Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
				10.8 - 18' ASH, black (10YR 2/1), sand sized grains, gravel (0-5%), slag-like material (0-5%), brick (0-5%), wet. *(continued)*	(FILL) ASH									
5 CS	36 36		15	15 - 16' ASH, black (10YR 2/1), sand to clay sized grains, gravel (0-5%), slag-like material (0-5%), brick (0-5%), wet.	(FILL) ASH									
			16	16 - 18' ASH, black (10YR 2/1), sand sized grains, gravel (0-5%), slag-like material (0-5%), brick (0-5%), wet.	(FILL) ASH									
6 MC	24 24		18	18 - 20' ASH.	(FILL) ASH					36.4	5		1.3	
			20	20' End of Boring.										

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Facility/Project Name	License/Permit/Monitoring Number	Boring Number	
Kincaid Power Station		XPW04	
Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Russ Gordon Cascade Drilling	1/26/2021	1/26/2021	Mini Sonic
Common Well Name: XPW04	Final Static Water Level: Feet (NAVD88)	Surface Elevation: 604.57 Feet (NAVD88)	Borehole Diameter: 6.0 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,069,145.99 N, 2,486,608.19 E E/W (W)
1/4 of 1/4 of Section 1, T 13 N, R 4 W
Lat 39° 36' 2.6244"
Long -89° 29' 32.1936"
Local Grid Location: Feet ☐N ☐S Feet ☐E ☐W

Facility ID	County	State	Civil Town/City/ or Village
	Christian	IL	Kincaid

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 CS	60 34		0	0 - 3.6' ASH, dark gray (10YR 4/1), sand to silt sized grains, fine sand, moist.	(FILL) ASH									CS = Core Sample
			3.6	3.6 - 8' ASH, black (10YR 2/1), sand sized grains , gravel (0-5%), wet.	(FILL) ASH									
2 CS	36 24		5											
3 MC	24 0		8	8 - 10' ASH, No Recovery.	(FILL) ASH									MC = Modified California
4 MC	24 12		10	10 - 12' ASH, sand sized grains.	(FILL) ASH					18.3	3	1.4		

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature [signature]

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RAMBOLL

Boring Number XPW04

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Soil Properties: Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
5 CS	36 0		12–15	12 - 18' ASH, black (10YR 2/1), sand sized grains, gravel (0-5%), wet.	(FILL) ASH									
6 CS	36 0		15–18											
7 MC	24 0		18–20	18 - 20' ASH, No Recovery.	(FILL) ASH									
8 MC	24 24		20–22	20 - 22' ASH, sand sized grains.	(FILL) ASH					32.3	15	2.7		
9 CS	24 24		22–24	22 - 24' **LEAN CLAY:** CL, grayish brown (10YR 5/2), stiff, medium plasticity, moist.	CL				1					
			24	24' End of Boring.										

2021 Ramboll Well Construction Logs

RAMBOLL

MONITORING WELL CONSTRUCTION

Facility/Project Name	Local Grid Location of Well	Well Name
Kincaid Power Station	____ ft. ☐ N. ☐ S. ____ ft. ☐ E. ☐ W.	MW-11S
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒ Lat. 39° 35' 35.2" Long. -89° 29' 28.0" or	
Facility ID	St. Plane 1,066,375 ft. N, 2,486,960 ft. E. E /Ⓦ	Date Well Installed 01/26/2021
Type of Well: Well Code 71/dw	Section Location of Waste/Source ____ 1/4 of ____ 1/4 of Sec. 12, T. 13 N, R. 4 ☐ E ☒ W	Well Installed By: (Person's Name and Firm) Adam Jochimsen, Cascade Drilling
Distance from Waste/ Source ____ ft. State IL	Location of Well Relative to Waste/Source: u ☐ Upgradient; s ☐ Sidegradient; d ☐ Downgradient; n ☐ Not Known. Gov. Lot Number ____	

A. Protective pipe, top elevation 602.72 ft. (NAVD88)

B. Well casing, top elevation 601.76 ft. (NAVD88)

C. Land surface elevation 599.4 ft. (NAVD88)

D. Surface seal, bottom 598.4 ft. (NAVD88) or 1.0 ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☐ ML ☒ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐; Hollow Stem Auger ☐; Mini Sonic Other ☒

15. Drilling fluid used: Water ☒ 0 2; Air ☐; Drilling Mud ☐ 0 3; None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe ____

17. Source of water (attach analysis, if required):
Distilled Water

E. Bentonite seal, top 598.4 ft. (NAVD88) or 1.0 ft.

F. Fine sand, top ____ ft. (NAVD88) or ____ ft.

G. Filter pack, top 596.4 ft. (NAVD88) or 3.0 ft.

H. Screen joint, top 595.4 ft. (NAVD88) or 4.0 ft.

I. Well bottom 591.4 ft. (NAVD88) or 8.0 ft.

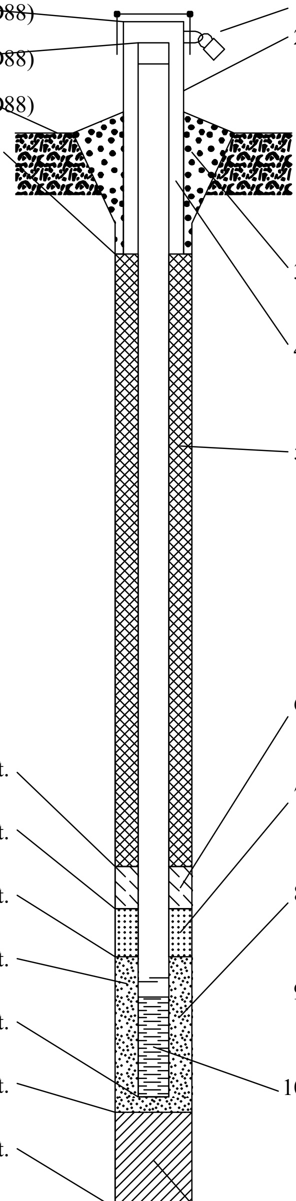
J. Filter pack, bottom 591.4 ft. (NAVD88) or 8.0 ft.

K. Borehole, bottom 591.4 ft. (NAVD88) or 8.0 ft.

L. Borehole, diameter 6.0 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.



1. Cap and lock? ☒ Yes ☐ No
2. Protective cover pipe:
   a. Inside diameter: 4.0 in.
   b. Length: 5.0 ft.
   c. Material: Steel ☒; Other ☐
   d. Additional protection? ☒ Yes ☐ No
   If yes, describe: Bollards
3. Surface seal: Bentonite ☐; Concrete ☒; Other ☐
4. Material between well casing and protective pipe: Bentonite ☐; Sand Other ☒
5. Annular space seal: a. Granular/Chipped Bentonite ☒
   b. ____ Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   c. ____ Lbs/gal mud weight . . . Bentonite slurry ☐
   d. ____ % Bentonite . . . Bentonite-cement grout ☐
   e. 0.349 Ft^3 volume added for any of the above
   f. How installed: Tremie ☐; Tremie pumped ☐; Gravity ☒
6. Bentonite seal: a. Bentonite granules ☐
   b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
   c. ____ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
   a. ____
   b. Volume added ____ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
   a. Filter Sil, Industrial Quartz
   b. Volume added 0.873 ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒; Flush threaded PVC schedule 80 ☐; Other ☐
10. Screen material: Schedule 40 PVC
    a. Screen Type: Factory cut ☒; Continuous slot ☐; Other ☐
    b. Manufacturer Johnson Screens
    c. Slot size: 0.010 in.
    d. Slotted length: 4.0 ft.
11. Backfill material (below filter pack): None ☒; Other ☐

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Date Modified: 5/3/2021

Signature [signature]

Firm: Ramboll
234 W. Florida Street, Milwaukee, WI 53204
Tel: (414) 837-3607
Fax: (414) 837-3608

RAMBOLL

MONITORING WELL CONSTRUCTION

Facility/Project Name Kincaid Power Station	Local Grid Location of Well _____ft. ☐ N. ☐ S. _____ft. ☐ E. ☐ W.	Well Name
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒ Lat. 39° 36' 0.7" Long. -89° 29' 47.1" or	MW-12D
Facility ID	St. Plane 1,068,940 ft. N, 2,485,443 ft. E. E/W	Date Well Installed 01/27/2021
Type of Well Well Code 72/dp	Section Location of Waste/Source _____1/4 of _____1/4 of Sec. 1, T. 13 N, R. 4 ☐ E ☒ W	Well Installed By: (Person's Name and Firm) Dave Gordon Cascade Drilling
Distance from Waste/Source ft. / State IL	Location of Well Relative to Waste/Source u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known / Gov. Lot Number	

A. Protective pipe, top elevation 591.33 ft. (NAVD88)

B. Well casing, top elevation 590.96 ft. (NAVD88)

C. Land surface elevation 589.1 ft. (NAVD88)

D. Surface seal, bottom 587.1 ft. (NAVD88) or 2.0 ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☐ ML ☐ MH ☐ CL ☐ CH ☐
Bedrock ☒

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐
Hollow Stem Auger ☐
Mini Sonic Other ☒

15. Drilling fluid used: Water ☒ 0 2 Air ☐
Drilling Mud ☐ 0 3 None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe _____

17. Source of water (attach analysis, if required):
Distilled Water

E. Bentonite seal, top 543.1 ft. (NAVD88) or 46.0 ft.

F. Fine sand, top _____ ft. (NAVD88) or _____ ft.

G. Filter pack, top 541.1 ft. (NAVD88) or 48.0 ft.

H. Screen joint, top 539.1 ft. (NAVD88) or 50.0 ft.

I. Well bottom 534.1 ft. (NAVD88) or 55.0 ft.

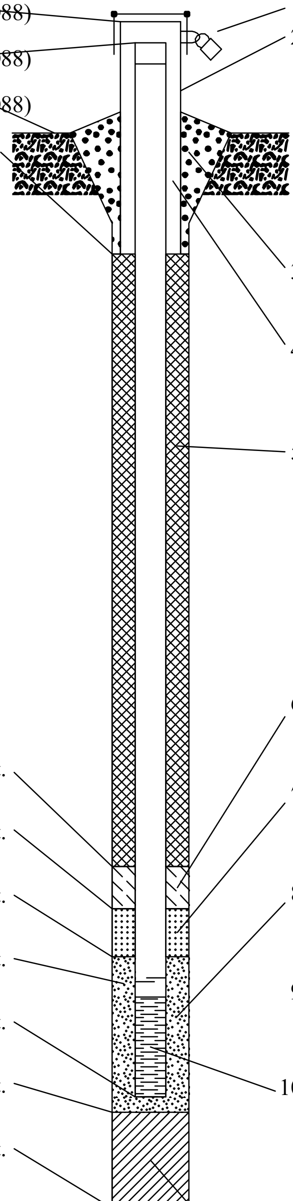
J. Filter pack, bottom 532.1 ft. (NAVD88) or 57.0 ft.

K. Borehole, bottom 489.1 ft. (NAVD88) or 100.0 ft.

L. Borehole, diameter 6.0 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.



1. Cap and lock? ☒ Yes ☐ No
2. Protective cover pipe:
   a. Inside diameter: 4.0 in.
   b. Length: 5.0 ft.
   c. Material: Steel ☒ Other ☐
   d. Additional protection? ☒ Yes ☐ No
   If yes, describe: Bollards
3. Surface seal: Bentonite ☐ Concrete ☒ Other ☐
4. Material between well casing and protective pipe: Bentonite ☐
   Sand Other ☒
5. Annular space seal: a. Granular/Chipped Bentonite ☐
   b. _____Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   c. 9.5 Lbs/gal mud weight . . . Bentonite slurry ☒
   d. _____% Bentonite . . . Bentonite-cement grout ☐
   e. 7.679 Ft^3 volume added for any of the above
   f. How installed: Tremie ☐ Tremie pumped ☒ Gravity ☐
6. Bentonite seal: a. Bentonite granules ☐
   b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
   c. _____ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
   a. _____
   b. Volume added _____ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
   a. Filter Sil, Industrial Quartz
   b. Volume added 1.614 ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒
   Flush threaded PVC schedule 80 ☐
   Other ☐
10. Screen material: Schedule 40 PVC
   a. Screen Type: Factory cut ☒ Continuous slot ☐ Other ☐
   b. Manufacturer Johnson Screens
   c. Slot size: 0.010 in.
   d. Slotted length: 5.0 ft.
11. Backfill material (below filter pack): None ☐
   Bentonite Slurry Grout Other ☒

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Date Modified: 5/3/2021

Signature [signature]

Firm Ramboll
234 W. Florida Street, Milwaukee, WI 53204
Tel: (414) 837-3607
Fax: (414) 837-3608

RAMBOLL

MONITORING WELL CONSTRUCTION

Facility/Project Name Kincaid Power Station	Local Grid Location of Well ______ ft. ☐ N. ☐ S. ______ ft. ☐ E. ☐ W.	Well Name
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒ Lat. 39° 36' 0.7" Long. -89° 29' 47.1" or	MW-12S
Facility ID	St. Plane 1,068,945 ft. N, 2,485,444 ft. E. E /(W)	Date Well Installed 01/27/2021
Type of Well Well Code 71/dw	Section Location of Waste/Source ____ 1/4 of ____ 1/4 of Sec. 1, T. 13 N, R. 4 ☐ E ☒ W	Well Installed By: (Person's Name and Firm) Dave Gordon Cascade Drilling
Distance from Waste/Source ft. / State IL	Location of Well Relative to Waste/Source u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known / Gov. Lot Number	

A. Protective pipe, top elevation 591.35 ft. (NAVD88)

B. Well casing, top elevation 591.10 ft. (NAVD88)

C. Land surface elevation 588.6 ft. (NAVD88)

D. Surface seal, bottom 587.6 ft. (NAVD88) or 1.0 ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☐ ML ☐ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐
Hollow Stem Auger ☐
Mini Sonic Other ☒

15. Drilling fluid used: Water ☒ 0 2 Air ☐
Drilling Mud ☐ 0 3 None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe ____________

17. Source of water (attach analysis, if required):
Distilled Water

E. Bentonite seal, top 587.6 ft. (NAVD88) or 1.0 ft.

F. Fine sand, top ______ ft. (NAVD88) or ______ ft.

G. Filter pack, top 586.1 ft. (NAVD88) or 2.5 ft.

H. Screen joint, top 584.6 ft. (NAVD88) or 4.0 ft.

I. Well bottom 579.6 ft. (NAVD88) or 9.0 ft.

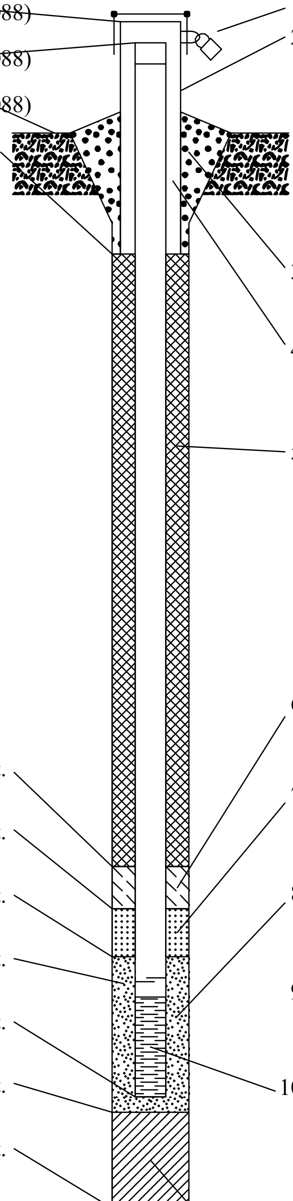
J. Filter pack, bottom 579.6 ft. (NAVD88) or 9.0 ft.

K. Borehole, bottom 579.1 ft. (NAVD88) or 9.5 ft.

L. Borehole, diameter 6.0 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.



1. Cap and lock? ☒ Yes ☐ No
2. Protective cover pipe:
a. Inside diameter: 4.0 in.
b. Length: 5.0 ft.
c. Material: Steel ☒
Other ☐
d. Additional protection? ☒ Yes ☐ No
If yes, describe: Bollards
3. Surface seal: Bentonite ☐
Concrete ☒
Other ☐
4. Material between well casing and protective pipe:
Bentonite ☐
Sand Other ☒
5. Annular space seal: a. Granular/Chipped Bentonite ☒
b. ____ Lbs/gal mud weight . . . Bentonite-sand slurry ☐
c. ____ Lbs/gal mud weight . . . Bentonite slurry ☐
d. ____ % Bentonite . . . Bentonite-cement grout ☐
e. 0.262 Ft^3 volume added for any of the above
f. How installed: Tremie ☐
Tremie pumped ☐
Gravity ☒
6. Bentonite seal: a. Bentonite granules ☐
b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
c. ____________ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
a. ____________
b. Volume added ______ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
a. Filter Sil, Industrial Quartz
b. Volume added 1.134 ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒
Flush threaded PVC schedule 80 ☐
Other ☐
10. Screen material: Schedule 40 PVC
a. Screen Type: Factory cut ☒
Continuous slot ☐
Other ☐
b. Manufacturer Johnson Screens
c. Slot size: 0.010 in.
d. Slotted length: 10.0 ft.
11. Backfill material (below filter pack): None ☒
Other ☐

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Date Modified: 5/3/2021

Signature	Firm	
[signature]	Ramboll 234 W. Florida Street, Milwaukee, WI 53204	Tel: (414) 837-3607 Fax: (414) 837-3608

RAMBOLL

MONITORING WELL CONSTRUCTION

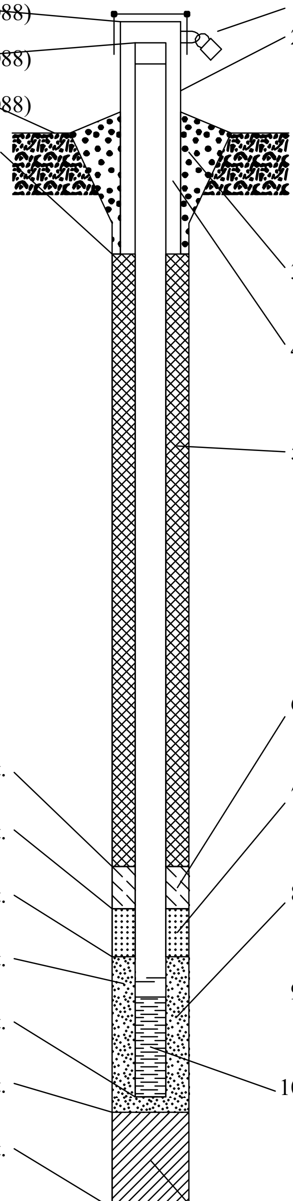
Facility/Project Name	Local Grid Location of Well	Well Name
Kincaid Power Station	____ft. ☐ N. ☐ S. ____ft. ☐ E. ☐ W.	MW-20
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒ Lat. 39° 35' 55.1" Long. -89° 29' 14.2" or	
Facility ID	St. Plane 1,068,398 ft. N, 2,488,022 ft. E. E /(W)	Date Well Installed 01/26/2021
Type of Well Well Code 72/dp	Section Location of Waste/Source ____1/4 of ____ 1/4 of Sec. 1, T. 13 N, R. 4 ☐ E ☒ W	Well Installed By: (Person's Name and Firm) Adam Jochimsen Cascade Drilling
Distance from Waste/ Source ft. | State IL	Location of Well Relative to Waste/Source u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known | Gov. Lot Number	

A. Protective pipe, top elevation 601.44 ft. (NAVD88)

B. Well casing, top elevation 600.77 ft. (NAVD88)

C. Land surface elevation 598.5 ft. (NAVD88)

D. Surface seal, bottom 596.5 ft. (NAVD88) or 2.0 ft.



12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☐ ML ☐ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐
Hollow Stem Auger ☐
Mini Sonic Other ☒

15. Drilling fluid used: Water ☒ 0 2 Air ☐
Drilling Mud ☐ 0 3 None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe ____

17. Source of water (attach analysis, if required):
Distilled Water

E. Bentonite seal, top 588.5 ft. (NAVD88) or 10.0 ft.

F. Fine sand, top ____ ft. (NAVD88) or ____ ft.

G. Filter pack, top 586.5 ft. (NAVD88) or 12.0 ft.

H. Screen joint, top 584.5 ft. (NAVD88) or 14.0 ft.

I. Well bottom 574.5 ft. (NAVD88) or 24.0 ft.

J. Filter pack, bottom 572.5 ft. (NAVD88) or 26.0 ft.

K. Borehole, bottom 547.5 ft. (NAVD88) or 51.0 ft.

L. Borehole, diameter 6.0 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.

1. Cap and lock? ☒ Yes ☐ No
2. Protective cover pipe:
   a. Inside diameter: 4.0 in.
   b. Length: 5.0 ft.
   c. Material: Steel ☒ Other ☐
   d. Additional protection? ☒ Yes ☐ No
   If yes, describe: Bollards
3. Surface seal: Bentonite ☐ Concrete ☒ Other ☐
4. Material between well casing and protective pipe:
   Bentonite ☐
   Sand Other ☒
5. Annular space seal: a. Granular/Chipped Bentonite ☒
   b. ____Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   c. ____Lbs/gal mud weight . . . Bentonite slurry ☐
   d. ____% Bentonite . . . Bentonite-cement grout ☐
   e. 1.396 Ft^3 volume added for any of the above
   f. How installed: Tremie ☐ Tremie pumped ☐ Gravity ☒
6. Bentonite seal: a. Bentonite granules ☐
   b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
   c. ____ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
   a. ____
   b. Volume added ____ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
   a. Filter Sil, Industrial Quartz
   b. Volume added 2.487 ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒
   Flush threaded PVC schedule 80 ☐
   Other ☐
10. Screen material: Schedule 40 PVC
   a. Screen Type: Factory cut ☒ Continuous slot ☐ Other ☐
   b. Manufacturer Johnson Screens
   c. Slot size: 0.010 in.
   d. Slotted length: 10.0 ft.
11. Backfill material (below filter pack): None ☐
   Bentonite Slurry Grout Other ☒

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Date Modified: 5/3/2021

Signature	Firm	
[signature]	Ramboll 234 W. Florida Street, Milwaukee,WI 53204	Tel: (414) 837-3607 Fax: (414) 837-3608

RAMBOLL

MONITORING WELL CONSTRUCTION

Facility/Project Name	Local Grid Location of Well	Well Name
Kincaid Power Station	______ ft. ☐ N. ☐ S. ______ ft. ☐ E. ☐ W.	
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒ Lat. 39° 35' 55.2" Long. -89° 29' 14.2" or	MW-20S
Facility ID	St. Plane 1,068,402 ft. N, 2,488,022 ft. E. E /(W)	Date Well Installed 01/26/2021
Type of Well: Well Code 71/dw	Section Location of Waste/Source: ____1/4 of ____ 1/4 of Sec. 1, T. 13 N, R. 4 ☐ E ☒ W	Well Installed By: (Person's Name and Firm) Adam Jochimsen, Cascade Drilling
Distance from Waste/Source ft. / State IL	Location of Well Relative to Waste/Source: u ☐ Upgradient; s ☐ Sidegradient; d ☐ Downgradient; n ☐ Not Known / Gov. Lot Number	

A. Protective pipe, top elevation 601.23 ft. (NAVD88)

B. Well casing, top elevation 600.64 ft. (NAVD88)

C. Land surface elevation 598.4 ft. (NAVD88)

D. Surface seal, bottom 597.4 ft. (NAVD88) or 1.0 ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☐ ML ☐ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐
Hollow Stem Auger ☐
Mini Sonic Other ☒

15. Drilling fluid used: Water ☒ 0 2 Air ☐
Drilling Mud ☐ 0 3 None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe ______

17. Source of water (attach analysis, if required):
Distilled Water

E. Bentonite seal, top 597.4 ft. (NAVD88) or 1.0 ft.

F. Fine sand, top ______ ft. (NAVD88) or ______ ft.

G. Filter pack, top 595.4 ft. (NAVD88) or 3.0 ft.

H. Screen joint, top 594.4 ft. (NAVD88) or 4.0 ft.

I. Well bottom 588.4 ft. (NAVD88) or 10.0 ft.

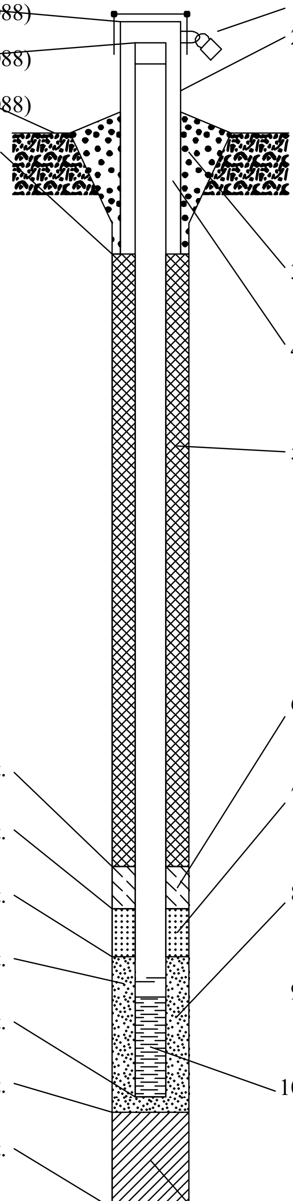
J. Filter pack, bottom 588.4 ft. (NAVD88) or 10.0 ft.

K. Borehole, bottom 588.4 ft. (NAVD88) or 10.0 ft.

L. Borehole, diameter 6.0 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.



1. Cap and lock? ☒ Yes ☐ No
2. Protective cover pipe:
   a. Inside diameter: 4.0 in.
   b. Length: 5.0 ft.
   c. Material: Steel ☒ Other ☐
   d. Additional protection? ☒ Yes ☐ No
   If yes, describe: Bollards
3. Surface seal: Bentonite ☐ Concrete ☒ Other ☐
4. Material between well casing and protective pipe: Bentonite ☐ Sand Other ☒
5. Annular space seal: a. Granular/Chipped Bentonite ☒
   b. ____Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   c. ____Lbs/gal mud weight . . . Bentonite slurry ☐
   d. ____% Bentonite . . . Bentonite-cement grout ☐
   e. 0.349 Ft^3 volume added for any of the above
   f. How installed: Tremie ☐ Tremie pumped ☐ Gravity ☒
6. Bentonite seal: a. Bentonite granules ☐
   b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
   c. ______ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
   a. ______
   b. Volume added ______ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
   a. Filter Sil, Industrial Quartz
   b. Volume added 1.222 ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒
   Flush threaded PVC schedule 80 ☐
   Other ☐
10. Screen material: Schedule 40 PVC
   a. Screen Type: Factory cut ☒ Continuous slot ☐ Other ☐
   b. Manufacturer Johnson Screens
   c. Slot size: 0.010 in.
   d. Slotted length: 6.0 ft.
11. Backfill material (below filter pack): None ☒ Other ☐

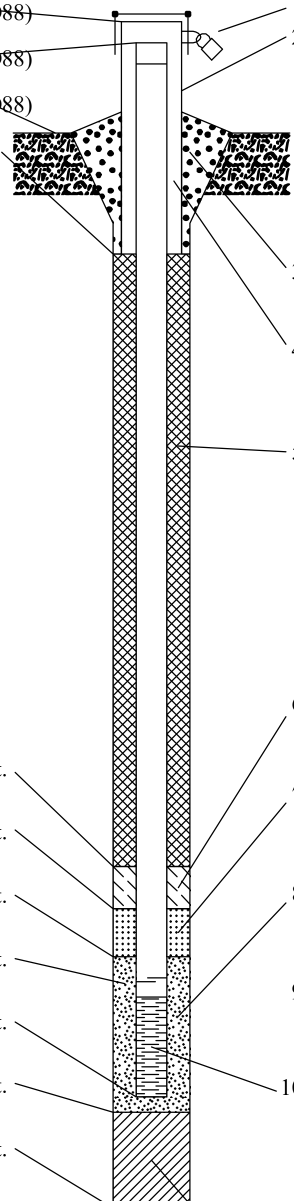
I hereby certify that the information on this form is true and correct to the best of my knowledge. Date Modified: 5/3/2021

Signature	Firm	
[signature]	Ramboll 234 W. Florida Street, Milwaukee, WI 53204	Tel: (414) 837-3607 Fax: (414) 837-3608

RAMBOLL

MONITORING WELL CONSTRUCTION

Facility/Project Name	Local Grid Location of Well	Well Name
Kincaid Power Station	____ft. ☐ N. ☐ S. ____ft. ☐ E. ☐ W.	MW-22
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒ Lat. 39° 35' 35.6" Long. -89° 29' 15.5" or	
Facility ID	St. Plane 1,066,423 ft. N, 2,487,936 ft. E. E/(W)	Date Well Installed 02/03/2021
Type of Well Well Code 72/dp	Section Location of Waste/Source ____1/4 of ____ 1/4 of Sec. 12, T. 13 N, R. 4 ☐ E ☒ W	Well Installed By: (Person's Name and Firm) Adam Jochimsen Cascade Drilling
Distance from Waste/ Source ft. | State IL	Location of Well Relative to Waste/Source u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known | Gov. Lot Number	



A. Protective pipe, top elevation 602.16 ft. (NAVD88)

B. Well casing, top elevation 601.77 ft. (NAVD88)

C. Land surface elevation 599.5 ft. (NAVD88)

D. Surface seal, bottom 597.5 ft. (NAVD88) or 2.0 ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☒
SM ☐ SC ☐ ML ☐ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐
Hollow Stem Auger ☐
Mini Sonic Other ☒

15. Drilling fluid used: Water ☒ 0 2 Air ☐
Drilling Mud ☐ 0 3 None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe ____

17. Source of water (attach analysis, if required):
Distilled Water

E. Bentonite seal, top 589.5 ft. (NAVD88) or 10.0 ft.

F. Fine sand, top ____ ft. (NAVD88) or ____ ft.

G. Filter pack, top 586.5 ft. (NAVD88) or 13.0 ft.

H. Screen joint, top 584.5 ft. (NAVD88) or 15.0 ft.

I. Well bottom 580.5 ft. (NAVD88) or 19.0 ft.

J. Filter pack, bottom 579.5 ft. (NAVD88) or 20.0 ft.

K. Borehole, bottom 579.5 ft. (NAVD88) or 20.0 ft.

L. Borehole, diameter 6.0 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.

1. Cap and lock? ☒ Yes ☐ No
2. Protective cover pipe:
   a. Inside diameter: 4.0 in.
   b. Length: 5.0 ft.
   c. Material: Steel ☒ Other ☐
   d. Additional protection? ☒ Yes ☐ No
   If yes, describe: Bollards
3. Surface seal: Bentonite ☐ Concrete ☒ Other ☐
4. Material between well casing and protective pipe:
   Bentonite ☐
   Sand Other ☒
5. Annular space seal: a. Granular/Chipped Bentonite ☒
   b. ____Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   c. ____Lbs/gal mud weight . . . Bentonite slurry ☐
   d. ____% Bentonite . . . Bentonite-cement grout ☐
   e. 1.396 Ft^3 volume added for any of the above
   f. How installed: Tremie ☐ Tremie pumped ☐ Gravity ☒
6. Bentonite seal: a. Bentonite granules ☐
   b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
   c. ____ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
   a. ____
   b. Volume added ____ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
   a. Filter Sil, Industrial Quartz
   b. Volume added 1.244 ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒
   Flush threaded PVC schedule 80 ☐
   Other ☐
10. Screen material: Schedule 40 PVC
   a. Screen Type: Factory cut ☒ Continuous slot ☐ Other ☐
   b. Manufacturer Johnson Screens
   c. Slot size: 0.010 in.
   d. Slotted length: 4.0 ft.
11. Backfill material (below filter pack): None ☒
   Bentonite Slurry Grout Other ☐

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Date Modified: 5/3/2021

Signature	Firm	
[signature]	Ramboll 234 W. Florida Street, Milwaukee, WI 53204	Tel: (414) 837-3607 Fax: (414) 837-3608

RAMBOLL

MONITORING WELL CONSTRUCTION

Facility/Project Name	Local Grid Location of Well	Well Name
Kincaid Power Station	____ ft. ☐ N. ☐ S. ____ ft. ☐ E. ☐ W.	
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒	
	Lat. 39° 35' 35.8" Long. -89° 29' 21.7" or	MW-23
Facility ID	St. Plane 1,066,441 ft. N, 2,487,452 ft. E. E/Ⓦ	Date Well Installed 02/02/2021
	Section Location of Waste/Source	
Type of Well: Well Code 72/dp	____ 1/4 of ____ 1/4 of Sec. 12, T. 13 N, R. 4 ☐ E ☒ W	Well Installed By: (Person's Name and Firm) Adam Jochimsen, Cascade Drilling
Distance from Waste/Source ____ ft. / State IL	Location of Well Relative to Waste/Source: u ☐ Upgradient; s ☐ Sidegradient; d ☐ Downgradient; n ☐ Not Known / Gov. Lot Number	

A. Protective pipe, top elevation 610.57 ft. (NAVD88)

B. Well casing, top elevation 610.32 ft. (NAVD88)

C. Land surface elevation 608.1 ft. (NAVD88)

D. Surface seal, bottom 606.1 ft. (NAVD88) or 2.0 ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☒
SM ☐ SC ☐ ML ☐ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐
Hollow Stem Auger ☐
Mini Sonic Other ☒

15. Drilling fluid used: Water ☒ 0 2 Air ☐
Drilling Mud ☐ 0 3 None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe ____

17. Source of water (attach analysis, if required):
Distilled Water

E. Bentonite seal, top 589.1 ft. (NAVD88) or 19.0 ft.

F. Fine sand, top ____ ft. (NAVD88) or ____ ft.

G. Filter pack, top 587.1 ft. (NAVD88) or 21.0 ft.

H. Screen joint, top 585.1 ft. (NAVD88) or 23.0 ft.

I. Well bottom 580.1 ft. (NAVD88) or 28.0 ft.

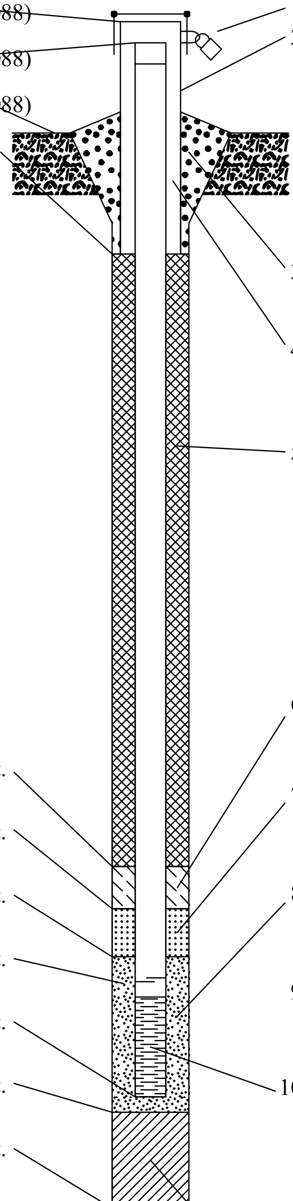
J. Filter pack, bottom 578.1 ft. (NAVD88) or 30.0 ft.

K. Borehole, bottom 558.1 ft. (NAVD88) or 50.0 ft.

L. Borehole, diameter 6.0 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.



1. Cap and lock? ☒ Yes ☐ No

2. Protective cover pipe:
a. Inside diameter: 4.0 in.
b. Length: 5.0 ft.
c. Material: Steel ☒ Other ☐
d. Additional protection? ☒ Yes ☐ No
If yes, describe: Bollards

3. Surface seal: Bentonite ☐ Concrete ☒ Other ☐

4. Material between well casing and protective pipe:
Bentonite ☐
Sand Other ☒

5. Annular space seal: a. Granular/Chipped Bentonite ☒
b. ____ Lbs/gal mud weight . . . Bentonite-sand slurry ☐
c. ____ Lbs/gal mud weight . . . Bentonite slurry ☐
d. ____ % Bentonite . . . Bentonite-cement grout ☐
e. 2.967 Ft^3 volume added for any of the above
f. How installed: Tremie ☐ Tremie pumped ☐ Gravity ☒

6. Bentonite seal: a. Bentonite granules ☐
b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
c. ____ Other ☐

7. Fine sand material: Manufacturer, product name & mesh size
a. ____
b. Volume added ____ ft^3

8. Filter pack material: Manufacturer, product name & mesh size
a. Filter Sil, Industrial Quartz
b. Volume added 1.614 ft^3

9. Well casing: Flush threaded PVC schedule 40 ☒
Flush threaded PVC schedule 80 ☐
Other ☐

10. Screen material: Schedule 40 PVC
a. Screen Type: Factory cut ☒ Continuous slot ☐ Other ☐
b. Manufacturer Johnson Screens
c. Slot size: 0.010 in.
d. Slotted length: 5.0 ft.

11. Backfill material (below filter pack): None ☐
Bentonite Slurry Grout Other ☒

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Date Modified: 5/3/2021

Signature [signature]

Firm Ramboll
234 W. Florida Street, Milwaukee, WI 53204
Tel: (414) 837-3607
Fax: (414) 837-3608

RAMBOLL

MONITORING WELL CONSTRUCTION

Facility/Project Name: Kincaid Power Station	Local Grid Location of Well: ____ft. ☐ N. ☐ S. ____ft. ☐ E. ☐ W.	Well Name: MW-24
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒ Lat. 39° 35' 35.8" Long. -89° 29' 35.8" or St. Plane 1,066,425 ft. N, 2,486,349 ft. E. E /(W)	
Facility ID	Section Location of Waste/Source ____1/4 of ____1/4 of Sec. 12, T. 13 N, R. 4 ☐ E ☒ W	Date Well Installed: 02/02/2021
Type of Well: Well Code 72/dp		Well Installed By: (Person's Name and Firm) Adam Jochimsen Cascade Drilling
Distance from Waste/ Source ft. / State: IL	Location of Well Relative to Waste/Source u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known Gov. Lot Number	

A. Protective pipe, top elevation 615.85 ft. (NAVD88)

B. Well casing, top elevation 615.48 ft. (NAVD88)

C. Land surface elevation 613.0 ft. (NAVD88)

D. Surface seal, bottom 611.0 ft. (NAVD88) or 2.0 ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☒
SM ☐ SC ☐ ML ☐ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐
Hollow Stem Auger ☐
Mini Sonic Other ☒

15. Drilling fluid used: Water ☒ 0 2 Air ☐
Drilling Mud ☐ 0 3 None ☐

16. Drilling additives used? ☐ Yes ☒ No
Describe ____

17. Source of water (attach analysis, if required):
Distilled Water

E. Bentonite seal, top 591.0 ft. (NAVD88) or 22.0 ft.

F. Fine sand, top ____ ft. (NAVD88) or ____ ft.

G. Filter pack, top 588.0 ft. (NAVD88) or 25.0 ft.

H. Screen joint, top 586.0 ft. (NAVD88) or 27.0 ft.

I. Well bottom 581.0 ft. (NAVD88) or 32.0 ft.

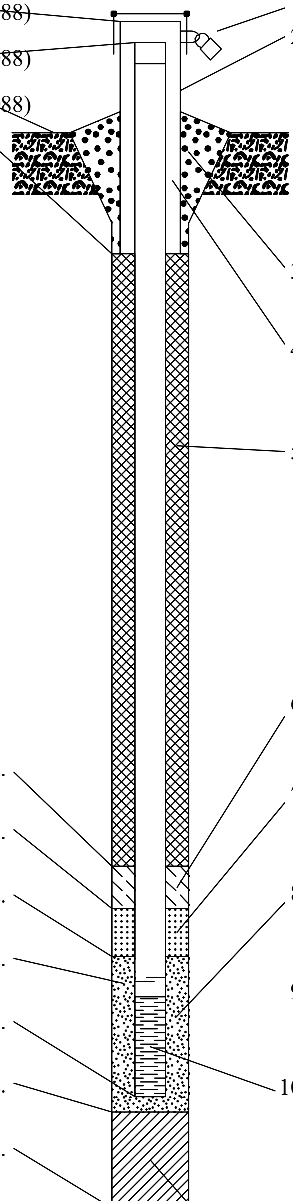
J. Filter pack, bottom 581.0 ft. (NAVD88) or 32.0 ft.

K. Borehole, bottom 581.0 ft. (NAVD88) or 32.0 ft.

L. Borehole, diameter 6.0 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.



1. Cap and lock? ☒ Yes ☐ No
2. Protective cover pipe:
   a. Inside diameter: 4.0 in.
   b. Length: 5.0 ft.
   c. Material: Steel ☒ Other ☐
   d. Additional protection? ☒ Yes ☐ No
   If yes, describe: Bollards
3. Surface seal: Bentonite ☐ Concrete ☒ Other ☐
4. Material between well casing and protective pipe: Bentonite ☐ Sand Other ☒
5. Annular space seal: a. Granular/Chipped Bentonite ☒
   b. ____Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   c. ____Lbs/gal mud weight . . . Bentonite slurry ☐
   d. ____% Bentonite . . . Bentonite-cement grout ☐
   e. 3.491 Ft^3 volume added for any of the above
   f. How installed: Tremie ☐ Tremie pumped ☐ Gravity ☒
6. Bentonite seal: a. Bentonite granules ☐
   b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
   c. ____ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
   a. ____
   b. Volume added ____ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
   a. Filter Sil, Industrial Quartz
   b. Volume added 1.222 ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒ Flush threaded PVC schedule 80 ☐ Other ☐
10. Screen material: Schedule 40 PVC
   a. Screen Type: Factory cut ☒ Continuous slot ☐ Other ☐
   b. Manufacturer Johnson Screens
   c. Slot size: 0.010 in.
   d. Slotted length: 5.0 ft.
11. Backfill material (below filter pack): None ☒ Other ☐

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Date Modified: 5/3/2021

Signature

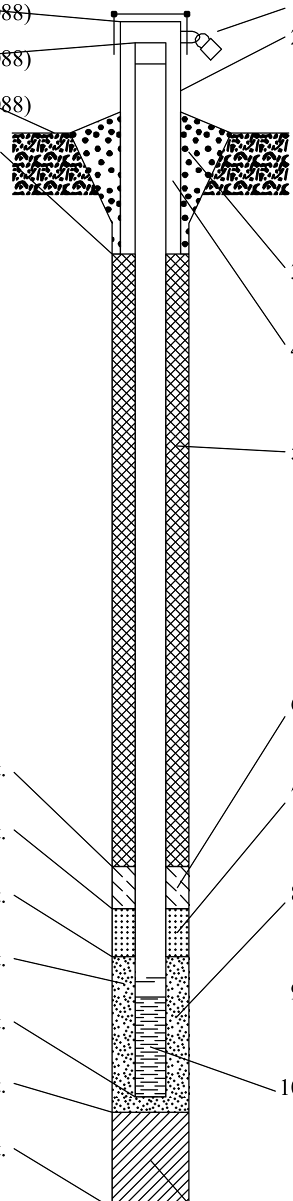
Firm: Ramboll
234 W. Florida Street, Milwaukee, WI 53204

Tel: (414) 837-3607
Fax: (414) 837-3608

RAMBOLL

MONITORING WELL CONSTRUCTION

Facility/Project Name	Local Grid Location of Well	Well Name
Kincaid Power Station	____ ft. ☐ N. ☐ S. ____ ft. ☐ E. ☐ W.	MW-25
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒ Lat. 39° 35' 39.8" Long. -89° 29' 42.2" or	
Facility ID	St. Plane 1,066,831 ft. N, 2,485,840 ft. E. E /Ⓦ	Date Well Installed 02/02/2021
Type of Well: Well Code 72/dp	Section Location of Waste/Source: ____ 1/4 of ____ 1/4 of Sec. 12, T. 13 N, R. 4 ☐ E ☒ W	Well Installed By: (Person's Name and Firm) Dave Gordon, Cascade Drilling
Distance from Waste/Source ft. — State IL	Location of Well Relative to Waste/Source: u ☐ Upgradient, s ☐ Sidegradient, d ☐ Downgradient, n ☐ Not Known — Gov. Lot Number	



A. Protective pipe, top elevation 607.53 ft. (NAVD88)

B. Well casing, top elevation 607.20 ft. (NAVD88)

C. Land surface elevation 604.6 ft. (NAVD88)

D. Surface seal, bottom 602.6 ft. (NAVD88) or 2.0 ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☒ SP ☐
SM ☐ SC ☐ ML ☒ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐ Hollow Stem Auger ☐ Mini Sonic Other ☒

15. Drilling fluid used: Water ☒ 0 2 Air ☐ Drilling Mud ☐ 0 3 None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe ____

17. Source of water (attach analysis, if required): Distilled Water

E. Bentonite seal, top 599.6 ft. (NAVD88) or 5.0 ft.

F. Fine sand, top ____ ft. (NAVD88) or ____ ft.

G. Filter pack, top 597.6 ft. (NAVD88) or 7.0 ft.

H. Screen joint, top 595.6 ft. (NAVD88) or 9.0 ft.

I. Well bottom 590.6 ft. (NAVD88) or 14.0 ft.

J. Filter pack, bottom 590.6 ft. (NAVD88) or 14.0 ft.

K. Borehole, bottom 579.6 ft. (NAVD88) or 25.0 ft.

L. Borehole, diameter 6.0 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.

1. Cap and lock? ☒ Yes ☐ No
2. Protective cover pipe:
   a. Inside diameter: 4.0 in.
   b. Length: 5.0 ft.
   c. Material: Steel ☒ Other ☐
   d. Additional protection? ☒ Yes ☐ No — If yes, describe: Bollards
3. Surface seal: Bentonite ☐ Concrete ☒ Other ☐
4. Material between well casing and protective pipe: Bentonite ☐ Sand Other ☒
5. Annular space seal: a. Granular/Chipped Bentonite ☒
   b. ____ Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   c. ____ Lbs/gal mud weight . . . Bentonite slurry ☐
   d. ____ % Bentonite . . . Bentonite-cement grout ☐
   e. 0.524 Ft^3 volume added for any of the above
   f. How installed: Tremie ☐ Tremie pumped ☐ Gravity ☒
6. Bentonite seal: a. Bentonite granules ☐
   b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
   c. ____ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
   a. ____
   b. Volume added ____ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
   a. Filter Sil, Industrial Quartz
   b. Volume added 1.222 ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒ Flush threaded PVC schedule 80 ☐ Other ☐
10. Screen material: Schedule 40 PVC
    a. Screen Type: Factory cut ☒ Continuous slot ☐ Other ☐
    b. Manufacturer Johnson Screens
    c. Slot size: 0.010 in.
    d. Slotted length: 5.0 ft.
11. Backfill material (below filter pack): None ☐ Bentonite Chips Other ☒

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Date Modified: 5/3/2021

Signature	Firm	
[signature]	Ramboll, 234 W. Florida Street, Milwaukee, WI 53204	Tel: (414) 837-3607 Fax: (414) 837-3608

RAMBOLL

MONITORING WELL CONSTRUCTION

Facility/Project Name: Kincaid Power Station	Local Grid Location of Well: ____ft. ☐ N. ☐ S. ____ft. ☐ E. ☐ W.	Well Name
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒ Lat. 39° 35' 44.1" Long. -89° 29' 51.3" or	MW-26
Facility ID	St. Plane 1,067,258 ft. N, 2,485,127 ft. E. E /(W)	Date Well Installed: 02/02/2021
Type of Well: Well Code 72/dp	Section Location of Waste/Source: ____1/4 of ____ 1/4 of Sec. 11, T. 13 N, R. 4 ☐ E ☒ W	Well Installed By: (Person's Name and Firm) Dave Gordon, Cascade Drilling
Distance from Waste/Source ft. / State: IL	Location of Well Relative to Waste/Source: u ☐ Upgradient; s ☐ Sidegradient; d ☐ Downgradient; n ☐ Not Known / Gov. Lot Number	

A. Protective pipe, top elevation 596.56 ft. (NAVD88)

B. Well casing, top elevation 596.16 ft. (NAVD88)

C. Land surface elevation 593.3 ft. (NAVD88)

D. Surface seal, bottom 591.3 ft. (NAVD88) or 2.0 ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☒ ML ☒ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐ Hollow Stem Auger ☐ Mini Sonic Other ☒

15. Drilling fluid used: Water ☒ 0 2 Air ☐ Drilling Mud ☐ 0 3 None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe ____

17. Source of water (attach analysis, if required): Distilled Water

E. Bentonite seal, top 591.3 ft. (NAVD88) or 2.0 ft.

F. Fine sand, top ____ ft. (NAVD88) or ____ ft.

G. Filter pack, top 588.3 ft. (NAVD88) or 5.0 ft.

H. Screen joint, top 586.3 ft. (NAVD88) or 7.0 ft.

I. Well bottom 581.3 ft. (NAVD88) or 12.0 ft.

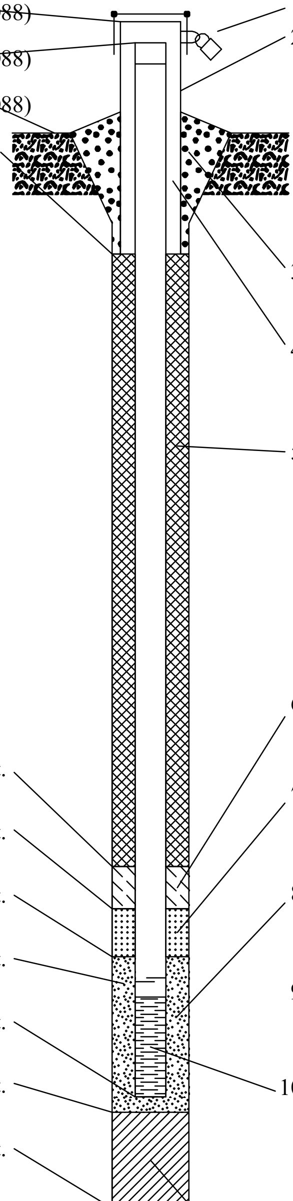
J. Filter pack, bottom 580.3 ft. (NAVD88) or 13.0 ft.

K. Borehole, bottom 573.3 ft. (NAVD88) or 20.0 ft.

L. Borehole, diameter 6.0 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.



1. Cap and lock? ☒ Yes ☐ No
2. Protective cover pipe:
   a. Inside diameter: 4.0 in.
   b. Length: 5.0 ft.
   c. Material: Steel ☒ Other ☐
   d. Additional protection? ☒ Yes ☐ No. If yes, describe: Bollards
3. Surface seal: Bentonite ☐ Concrete ☒ Other ☐
4. Material between well casing and protective pipe: Bentonite ☐ Sand Other ☒
5. Annular space seal: a. Granular/Chipped Bentonite ☒
   b. ____Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   c. ____Lbs/gal mud weight . . . Bentonite slurry ☐
   d. ____% Bentonite . . . Bentonite-cement grout ☐
   e. 0.524 Ft^3 volume added for any of the above
   f. How installed: Tremie ☐ Tremie pumped ☐ Gravity ☒
6. Bentonite seal: a. Bentonite granules ☐
   b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
   c. ____ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
   a. ____
   b. Volume added ____ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
   a. Filter Sil, Industrial Quartz
   b. Volume added 1.418 ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒ Flush threaded PVC schedule 80 ☐ Other ☐
10. Screen material: Schedule 40 PVC
   a. Screen Type: Factory cut ☒ Continuous slot ☐ Other ☐
   b. Manufacturer Johnson Screens
   c. Slot size: 0.010 in.
   d. Slotted length: 5.0 ft.
11. Backfill material (below filter pack): None ☐ Bentonite Chips Other ☒

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Date Modified: 5/3/2021

Signature	Firm	
[signature]	Ramboll 234 W. Florida Street, Milwaukee,WI 53204	Tel: (414) 837-3607 Fax: (414) 837-3608

RAMBOLL

MONITORING WELL CONSTRUCTION

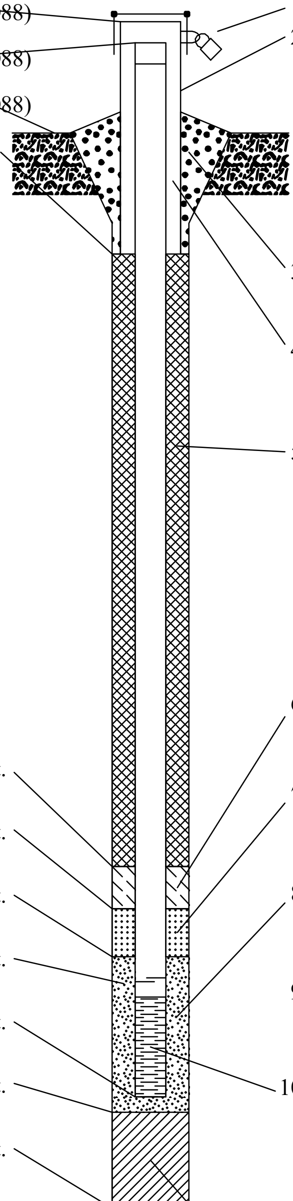
Facility/Project Name Kincaid Power Station	Local Grid Location of Well ______ ft. ☐ N. ☐ S. ______ ft. ☐ E. ☐ W.	Well Name
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒ Lat. 39° 35' 48.1" Long. -89° 29' 52.5" or	MW-27
Facility ID	St. Plane 1,067,662 ft. N, 2,485,027 ft. E. E /Ⓦ	Date Well Installed 02/02/2021
Type of Well Well Code 72/dp	Section Location of Waste/Source ____1/4 of ____ 1/4 of Sec. 11, T. 13 N, R. 4 ☐ E ☒ W	Well Installed By: (Person's Name and Firm) Dave Gordon Cascade Drilling
Distance from Waste/ Source ft. | State IL	Location of Well Relative to Waste/Source u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known | Gov. Lot Number	

A. Protective pipe, top elevation 600.37 ft. (NAVD88)

B. Well casing, top elevation 600.05 ft. (NAVD88)

C. Land surface elevation 597.3 ft. (NAVD88)

D. Surface seal, bottom 595.3 ft. (NAVD88) or 2.0 ft.



12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☒ ML ☒ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐
Hollow Stem Auger ☐
Mini Sonic Other ☒

15. Drilling fluid used: Water ☒ 0 2 Air ☐
Drilling Mud ☐ 0 3 None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe ______

17. Source of water (attach analysis, if required):
Distilled Water

E. Bentonite seal, top 591.3 ft. (NAVD88) or 6.0 ft.

F. Fine sand, top ______ ft. (NAVD88) or ______ ft.

G. Filter pack, top 589.3 ft. (NAVD88) or 8.0 ft.

H. Screen joint, top 587.3 ft. (NAVD88) or 10.0 ft.

I. Well bottom 582.3 ft. (NAVD88) or 15.0 ft.

J. Filter pack, bottom 581.3 ft. (NAVD88) or 16.0 ft.

K. Borehole, bottom 577.3 ft. (NAVD88) or 20.0 ft.

L. Borehole, diameter 6.0 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.

1. Cap and lock? ☒ Yes ☐ No
2. Protective cover pipe:
   a. Inside diameter: 4.0 in.
   b. Length: 5.0 ft.
   c. Material: Steel ☒ Other ☐
   d. Additional protection? ☒ Yes ☐ No
   If yes, describe: Bollards
3. Surface seal: Bentonite ☐ Concrete ☒ Other ☐
4. Material between well casing and protective pipe: Bentonite ☐
   Sand Other ☒
5. Annular space seal: a. Granular/Chipped Bentonite ☒
   b. ____Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   c. ____Lbs/gal mud weight . . . Bentonite slurry ☐
   d. ____% Bentonite . . . Bentonite-cement grout ☐
   e. 0.698 Ft^3 volume added for any of the above
   f. How installed: Tremie ☐ Tremie pumped ☐ Gravity ☒
6. Bentonite seal: a. Bentonite granules ☐
   b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
   c. ______ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
   a. ______
   b. Volume added ______ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
   a. Filter Sil, Industrial Quartz
   b. Volume added 1.418 ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒
   Flush threaded PVC schedule 80 ☐
   Other ☐
10. Screen material: Schedule 40 PVC
    a. Screen Type: Factory cut ☒ Continuous slot ☐ Other ☐
    b. Manufacturer Johnson Screens
    c. Slot size: 0.010 in.
    d. Slotted length: 5.0 ft.
11. Backfill material (below filter pack): None ☐
    Bentonite Chips Other ☒

I hereby certify that the information on this form is true and correct to the best of my knowledge. Date Modified: 5/3/2021

Signature	Firm	
[signature]	Ramboll 234 W. Florida Street, Milwaukee,WI 53204	Tel: (414) 837-3607 Fax: (414) 837-3608

RAMBOLL

MONITORING WELL CONSTRUCTION

Facility/Project Name: Kincaid Power Station	Local Grid Location of Well: ____ ft. ☐ N. ☐ S. ____ ft. ☐ E. ☐ W.	Well Name
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒ Lat. 39° 35' 57.3" Long. -89° 29' 52.7" or	MW-28
Facility ID	St. Plane 1,068,595 ft. N, 2,485,010 ft. E. E /(W)	Date Well Installed: 02/02/2021
Type of Well: Well Code 72/dp	Section Location of Waste/Source: ____ 1/4 of ____ 1/4 of Sec. 2, T. 13 N, R. 4 ☐ E ☒ W	Well Installed By: (Person's Name and Firm) Dave Gordon Cascade Drilling
Distance from Waste/Source ____ ft. | State: IL	Location of Well Relative to Waste/Source: u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known | Gov. Lot Number	

A. Protective pipe, top elevation 601.66 ft. (NAVD88)

B. Well casing, top elevation 601.40 ft. (NAVD88)

C. Land surface elevation 598.3 ft. (NAVD88)

D. Surface seal, bottom 596.3 ft. (NAVD88) or 2.0 ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☒
SM ☐ SC ☐ ML ☒ MH ☐ CL ☐ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐
Hollow Stem Auger ☐
Mini Sonic Other ☒

15. Drilling fluid used: Water ☒ 0 2 Air ☐
Drilling Mud ☐ 0 3 None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe ____

17. Source of water (attach analysis, if required):
Distilled Water

E. Bentonite seal, top 590.3 ft. (NAVD88) or 8.0 ft.

F. Fine sand, top ____ ft. (NAVD88) or ____ ft.

G. Filter pack, top 588.3 ft. (NAVD88) or 10.0 ft.

H. Screen joint, top 586.3 ft. (NAVD88) or 12.0 ft.

I. Well bottom 576.3 ft. (NAVD88) or 22.0 ft.

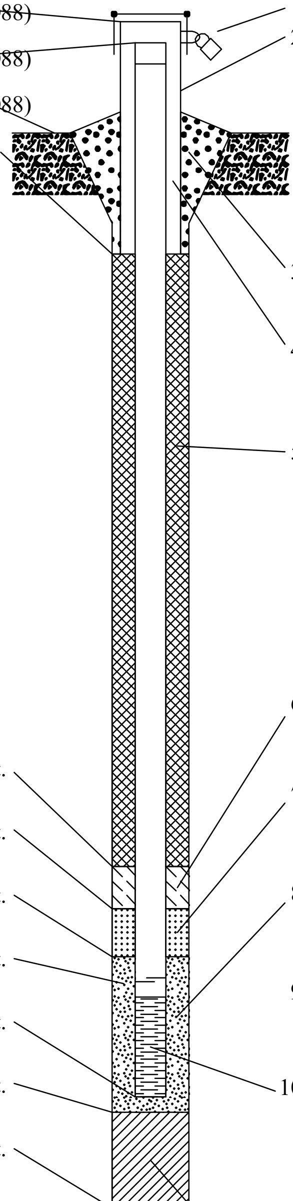
J. Filter pack, bottom 573.3 ft. (NAVD88) or 25.0 ft.

K. Borehole, bottom 573.3 ft. (NAVD88) or 25.0 ft.

L. Borehole, diameter 6.0 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.



1. Cap and lock? ☒ Yes ☐ No
2. Protective cover pipe:
a. Inside diameter: 4.0 in.
b. Length: 5.0 ft.
c. Material: Steel ☒ Other ☐
d. Additional protection? ☒ Yes ☐ No
If yes, describe: Bollards
3. Surface seal: Bentonite ☐ Concrete ☒ Other ☐
4. Material between well casing and protective pipe:
Bentonite ☐
Sand Other ☒
5. Annular space seal: a. Granular/Chipped Bentonite ☒
b. ____ Lbs/gal mud weight . . . Bentonite-sand slurry ☐
c. ____ Lbs/gal mud weight . . . Bentonite slurry ☐
d. ____ % Bentonite . . . Bentonite-cement grout ☐
e. 1.047 Ft^3 volume added for any of the above
f. How installed: Tremie ☐ Tremie pumped ☐ Gravity ☒
6. Bentonite seal: a. Bentonite granules ☐
b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
c. ____ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
a. ____
b. Volume added ____ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
a. Filter Sil, Industrial Quartz
b. Volume added 2.683 ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒
Flush threaded PVC schedule 80 ☐
Other ☐
10. Screen material: Schedule 40 PVC
a. Screen Type: Factory cut ☒ Continuous slot ☐ Other ☐
b. Manufacturer Johnson Screens
c. Slot size: 0.010 in.
d. Slotted length: 10.0 ft.
11. Backfill material (below filter pack): None ☒ Other ☐

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Date Modified: 5/3/2021

Signature [signature]

Firm: Ramboll
234 W. Florida Street, Milwaukee, WI 53204
Tel: (414) 837-3607
Fax: (414) 837-3608

RAMBOLL

MONITORING WELL CONSTRUCTION

Facility/Project Name	Local Grid Location of Well	Well Name
Kincaid Power Station	______ ft. ☐ N. ☐ S. ______ ft. ☐ E. ☐ W.	MW-29
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒ Lat. 39° 35' 58.9" Long. -89° 29' 50.1" or	
Facility ID	St. Plane 1,068,755 ft. N, 2,485,210 ft. E. E /Ⓦ	Date Well Installed 02/01/2021
Type of Well: Well Code 72/dp	Section Location of Waste/Source: ____ 1/4 of ____ 1/4 of Sec. 2, T. 13 N, R. 4 ☐ E ☒ W	Well Installed By: (Person's Name and Firm) Dave Gordon, Cascade Drilling
Distance from Waste/Source ft. / State: IL	Location of Well Relative to Waste/Source: u ☐ Upgradient; s ☐ Sidegradient; d ☐ Downgradient; n ☐ Not Known / Gov. Lot Number	

A. Protective pipe, top elevation 600.19 ft. (NAVD88)

B. Well casing, top elevation 599.94 ft. (NAVD88)

C. Land surface elevation 596.9 ft. (NAVD88)

D. Surface seal, bottom 594.9 ft. (NAVD88) or 2.0 ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☒ SP ☐
SM ☐ SC ☐ ML ☒ MH ☐ CL ☐ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐
Hollow Stem Auger ☐
Mini Sonic — Other ☒

15. Drilling fluid used: Water ☒ 0 2 Air ☐
Drilling Mud ☐ 0 3 None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe ______

17. Source of water (attach analysis, if required):
Distilled Water

E. Bentonite seal, top 586.9 ft. (NAVD88) or 10.0 ft.

F. Fine sand, top ______ ft. (NAVD88) or ______ ft.

G. Filter pack, top 584.9 ft. (NAVD88) or 12.0 ft.

H. Screen joint, top 582.9 ft. (NAVD88) or 14.0 ft.

I. Well bottom 577.9 ft. (NAVD88) or 19.0 ft.

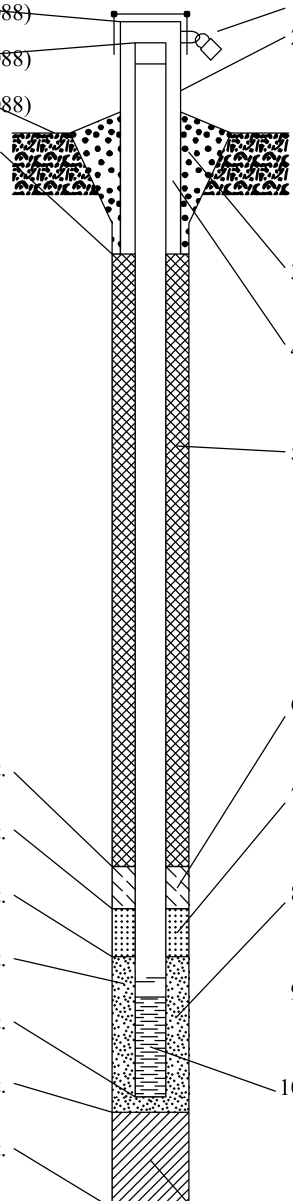
J. Filter pack, bottom 576.9 ft. (NAVD88) or 20.0 ft.

K. Borehole, bottom 576.9 ft. (NAVD88) or 20.0 ft.

L. Borehole, diameter 6.0 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.



1. Cap and lock? ☒ Yes ☐ No
2. Protective cover pipe:
   a. Inside diameter: 4.0 in.
   b. Length: 5.0 ft.
   c. Material: Steel ☒ Other ☐
   d. Additional protection? ☒ Yes ☐ No
   If yes, describe: Bollards
3. Surface seal: Bentonite ☐ Concrete ☒ Other ☐
4. Material between well casing and protective pipe: Bentonite ☐ Sand — Other ☒
5. Annular space seal: a. Granular/Chipped Bentonite ☒
   b. ____ Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   c. ____ Lbs/gal mud weight . . . Bentonite slurry ☐
   d. ____ % Bentonite . . . Bentonite-cement grout ☐
   e. 1.396 Ft^3 volume added for any of the above
   f. How installed: Tremie ☐ Tremie pumped ☐ Gravity ☒
6. Bentonite seal: a. Bentonite granules ☐
   b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
   c. ______ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
   a. ______
   b. Volume added ______ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
   a. Filter Sil, Industrial Quartz
   b. Volume added 1.418 ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒ Flush threaded PVC schedule 80 ☐ Other ☐
10. Screen material: Schedule 40 PVC
   a. Screen Type: Factory cut ☒ Continuous slot ☐ Other ☐
   b. Manufacturer Johnson Screens
   c. Slot size: 0.010 in.
   d. Slotted length: 5.0 ft.
11. Backfill material (below filter pack): None ☒ Other ☐

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Date Modified: 5/3/2021

Signature	Firm	
[signature]	Ramboll 234 W. Florida Street, Milwaukee, WI 53204	Tel: (414) 837-3607 Fax: (414) 837-3608

RAMBOLL

MONITORING WELL CONSTRUCTION

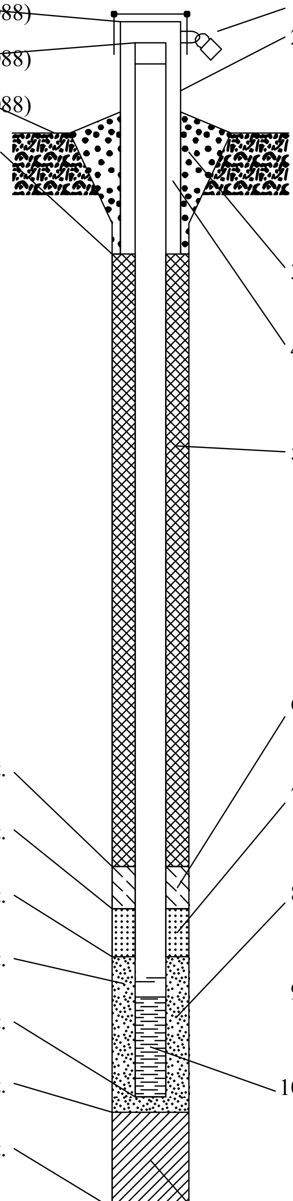
Facility/Project Name: Kincaid Power Station	Local Grid Location of Well: ____ft. ☐ N. ☐ S. ____ft. ☐ E. ☐ W.	Well Name
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒ Lat. 39° 36' 4.6" Long. -89° 29' 19.1" or	MW-30
Facility ID	St. Plane 1,069,336 ft. N, 2,486,122 ft. E. E /(W)	Date Well Installed: 02/03/2021
Type of Well: Well Code 72/dp	Section Location of Waste/Source: ____1/4 of ____ 1/4 of Sec. 1, T. 13 N, R. 4 ☐ E ☒ W	Well Installed By: (Person's Name and Firm): Dave Gordon, Cascade Drilling
Distance from Waste/ Source ft. / State: IL	Location of Well Relative to Waste/Source: u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known / Gov. Lot Number	

A. Protective pipe, top elevation 619.15 ft. (NAVD88)

B. Well casing, top elevation 618.47 ft. (NAVD88)

C. Land surface elevation 616.0 ft. (NAVD88)

D. Surface seal, bottom 614.0 ft. (NAVD88) or 2.0 ft.



12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☒ ML ☒ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐ Hollow Stem Auger ☐ Mini Sonic Other ☒

15. Drilling fluid used: Water ☒ 0 2 Air ☐ Drilling Mud ☐ 0 3 None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe ____

17. Source of water (attach analysis, if required): Distilled Water

E. Bentonite seal, top 585.0 ft. (NAVD88) or 31.0 ft.

F. Fine sand, top ____ ft. (NAVD88) or ____ ft.

G. Filter pack, top 583.0 ft. (NAVD88) or 33.0 ft.

H. Screen joint, top 581.0 ft. (NAVD88) or 35.0 ft.

I. Well bottom 576.0 ft. (NAVD88) or 40.0 ft.

J. Filter pack, bottom 574.0 ft. (NAVD88) or 42.0 ft.

K. Borehole, bottom 571.0 ft. (NAVD88) or 45.0 ft.

L. Borehole, diameter 6.0 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.

1. Cap and lock? ☒ Yes ☐ No
2. Protective cover pipe:
   a. Inside diameter: 4.0 in.
   b. Length: 5.0 ft.
   c. Material: Steel ☒ Other ☐
   d. Additional protection? ☒ Yes ☐ No
   If yes, describe: Bollards
3. Surface seal: Bentonite ☐ Concrete ☒ Other ☐
4. Material between well casing and protective pipe: Bentonite ☐ Sand Other ☒
5. Annular space seal: a. Granular/Chipped Bentonite ☒
   b. ____Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   c. ____Lbs/gal mud weight . . . Bentonite slurry ☐
   d. ____% Bentonite . . . Bentonite-cement grout ☐
   e. 5.061 Ft^3 volume added for any of the above
   f. How installed: Tremie ☐ Tremie pumped ☐ Gravity ☒
6. Bentonite seal: a. Bentonite granules ☐
   b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
   c. ____ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
   a. ____
   b. Volume added ____ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
   a. Filter Sil, Industrial Quartz
   b. Volume added 1.614 ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒ Flush threaded PVC schedule 80 ☐ Other ☐
10. Screen material: Schedule 40 PVC
    a. Screen Type: Factory cut ☒ Continuous slot ☐ Other ☐
    b. Manufacturer Johnson Screens
    c. Slot size: 0.010 in.
    d. Slotted length: 5.0 ft.
11. Backfill material (below filter pack): None ☐ Bentonite Chips Other ☒

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Date Modified: 5/3/2021

Signature [signature]

Firm Ramboll
234 W. Florida Street, Milwaukee, WI 53204
Tel: (414) 837-3607
Fax: (414) 837-3608

RAMBOLL

MONITORING WELL CONSTRUCTION

Facility/Project Name: Kincaid Power Station	Local Grid Location of Well: ______ ft. ☐ N. ☐ S. ______ ft. ☐ E. ☐ W.	Well Name
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒ Lat. 39° 36' 4.7" Long. -89° 29' 30.1" or	MW-31
Facility ID	St. Plane 1,069,353 ft. N, 2,486,768 ft. E. E /(W)	Date Well Installed: 02/03/2021
Type of Well: Well Code 72/dp	Section Location of Waste/Source: ____1/4 of ____ 1/4 of Sec. 1, T. 13 N, R. 4 ☐ E ☒ W	Well Installed By: (Person's Name and Firm) Dave Gordon Cascade Drilling
Distance from Waste/ Source ____ ft. / State: IL	Location of Well Relative to Waste/Source: u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known / Gov. Lot Number	

A. Protective pipe, top elevation 617.66 ft. (NAVD88)

B. Well casing, top elevation 617.34 ft. (NAVD88)

C. Land surface elevation 615.0 ft. (NAVD88)

D. Surface seal, bottom 613.0 ft. (NAVD88) or 2.0 ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☒
SM ☐ SC ☐ ML ☒ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐
Hollow Stem Auger ☐
Mini Sonic Other ☒

15. Drilling fluid used: Water ☒ 0 2 Air ☐
Drilling Mud ☐ 0 3 None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe ______

17. Source of water (attach analysis, if required):
Distilled Water

E. Bentonite seal, top 584.0 ft. (NAVD88) or 31.0 ft.

F. Fine sand, top ______ ft. (NAVD88) or ______ ft.

G. Filter pack, top 582.0 ft. (NAVD88) or 33.0 ft.

H. Screen joint, top 580.0 ft. (NAVD88) or 35.0 ft.

I. Well bottom 575.0 ft. (NAVD88) or 40.0 ft.

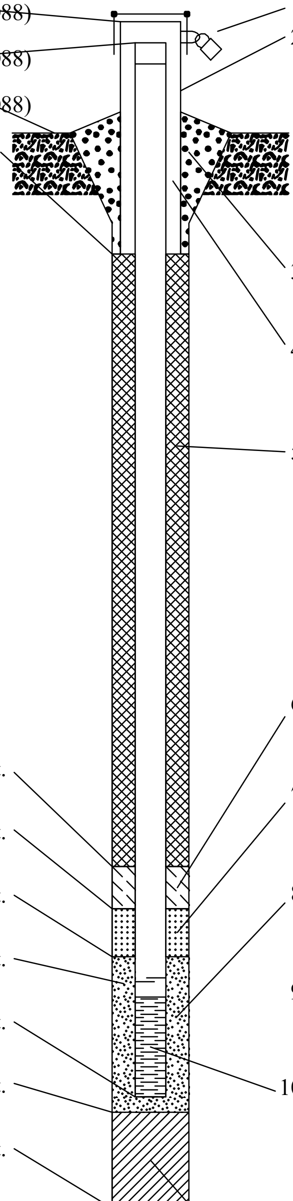
J. Filter pack, bottom 574.0 ft. (NAVD88) or 41.0 ft.

K. Borehole, bottom 565.0 ft. (NAVD88) or 50.0 ft.

L. Borehole, diameter 6.0 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.



1. Cap and lock? ☒ Yes ☐ No
2. Protective cover pipe:
   a. Inside diameter: 4.0 in.
   b. Length: 5.0 ft.
   c. Material: Steel ☒ Other ☐
   d. Additional protection? ☒ Yes ☐ No
   If yes, describe: Bollards
3. Surface seal: Bentonite ☐ Concrete ☒ Other ☐
4. Material between well casing and protective pipe: Bentonite ☐
   Sand Other ☒
5. Annular space seal: a. Granular/Chipped Bentonite ☒
   b. ____Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   c. ____Lbs/gal mud weight . . . Bentonite slurry ☐
   d. ____% Bentonite . . . Bentonite-cement grout ☐
   e. 5.061 Ft^3 volume added for any of the above
   f. How installed: Tremie ☐ Tremie pumped ☐ Gravity ☒
6. Bentonite seal: a. Bentonite granules ☐
   b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
   c. ______ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
   a. ______
   b. Volume added ______ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
   a. Filter Sil, Industrial Quartz
   b. Volume added 1.418 ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒
   Flush threaded PVC schedule 80 ☐
   Other ☐
10. Screen material: Schedule 40 PVC
   a. Screen Type: Factory cut ☒ Continuous slot ☐ Other ☐
   b. Manufacturer Johnson Screens
   c. Slot size: 0.010 in.
   d. Slotted length: 5.0 ft.
11. Backfill material (below filter pack): None ☐
   Bentonite Chips Other ☒

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Date Modified: 5/3/2021

Signature [signature]

Firm Ramboll
234 W. Florida Street, Milwaukee,WI 53204
Tel: (414) 837-3607
Fax: (414) 837-3608

RAMBOLL

MONITORING WELL CONSTRUCTION

Facility/Project Name: Kincaid Power Station	Local Grid Location of Well: ____ ft. ☐ N. ☐ S. ____ ft. ☐ E. ☐ W.	Well Name: MW-31S
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒ Lat. 39° 36' 4.7" Long. -89° 29' 30.1" or St. Plane 1,069,353 ft. N, 2,486,774 ft. E. E /Ⓦ	
Facility ID		Date Well Installed: 02/03/2021
Type of Well: Well Code 71/dw	Section Location of Waste/Source: ____1/4 of ____ 1/4 of Sec. 1, T. 13 N, R. 4 ☐ E ☒ W	Well Installed By: (Person's Name and Firm) Dave Gordon, Cascade Drilling
Distance from Waste/Source ft. / State: IL	Location of Well Relative to Waste/Source: u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known / Gov. Lot Number	

A. Protective pipe, top elevation 617.85 ft. (NAVD88)

B. Well casing, top elevation 617.54 ft. (NAVD88)

C. Land surface elevation 615.1 ft. (NAVD88)

D. Surface seal, bottom 613.1 ft. (NAVD88) or 2.0 ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☐ ML ☐ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐ Hollow Stem Auger ☐ Mini Sonic Other ☒

15. Drilling fluid used: Water ☒ 0 2 Air ☐ Drilling Mud ☐ 0 3 None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe ____

17. Source of water (attach analysis, if required): Distilled Water

E. Bentonite seal, top 594.1 ft. (NAVD88) or 21.0 ft.

F. Fine sand, top ____ ft. (NAVD88) or ____ ft.

G. Filter pack, top 592.1 ft. (NAVD88) or 23.0 ft.

H. Screen joint, top 590.1 ft. (NAVD88) or 25.0 ft.

I. Well bottom 585.1 ft. (NAVD88) or 30.0 ft.

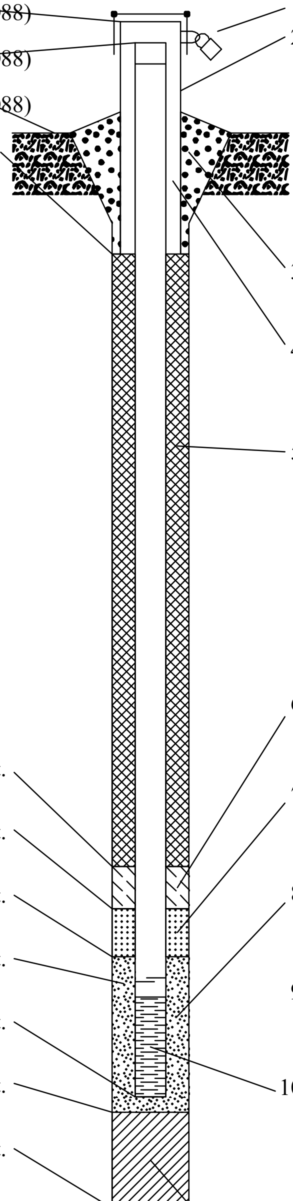
J. Filter pack, bottom 585.1 ft. (NAVD88) or 30.0 ft.

K. Borehole, bottom 585.1 ft. (NAVD88) or 30.0 ft.

L. Borehole, diameter 6.0 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.



1. Cap and lock? ☒ Yes ☐ No
2. Protective cover pipe:
   a. Inside diameter: 4.0 in.
   b. Length: 5.0 ft.
   c. Material: Steel ☒ Other ☐
   d. Additional protection? ☒ Yes ☐ No
   If yes, describe: Bollards
3. Surface seal: Bentonite ☐ Concrete ☒ Other ☐
4. Material between well casing and protective pipe: Bentonite ☐ Sand Other ☒
5. Annular space seal: a. Granular/Chipped Bentonite ☒
   b. ____Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   c. ____Lbs/gal mud weight . . . Bentonite slurry ☐
   d. ____% Bentonite . . . Bentonite-cement grout ☐
   e. 3.316 Ft^3 volume added for any of the above
   f. How installed: Tremie ☐ Tremie pumped ☐ Gravity ☒
6. Bentonite seal: a. Bentonite granules ☐
   b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
   c. ____ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
   a. ____
   b. Volume added ____ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
   a. Filter Sil, Industrial Quartz
   b. Volume added 1.222 ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒ Flush threaded PVC schedule 80 ☐ Other ☐
10. Screen material: Schedule 40 PVC
   a. Screen Type: Factory cut ☒ Continuous slot ☐ Other ☐
   b. Manufacturer Johnson Screens
   c. Slot size: 0.010 in.
   d. Slotted length: 5.0 ft.
11. Backfill material (below filter pack): None ☒ Other ☐

I hereby certify that the information on this form is true and correct to the best of my knowledge. Date Modified: 5/3/2021

Signature [signature]

Firm: Ramboll, 234 W. Florida Street, Milwaukee, WI 53204 Tel: (414) 837-3607 Fax: (414) 837-3608

RAMBOLL

MONITORING WELL CONSTRUCTION

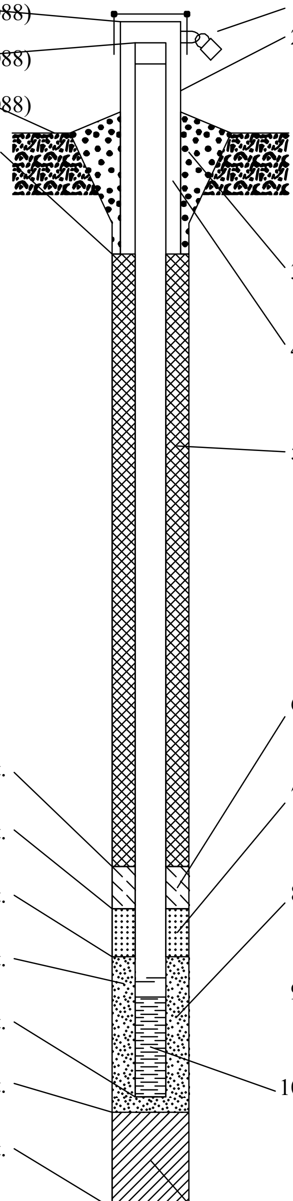
Facility/Project Name: Kincaid Power Station	Local Grid Location of Well: ____ ft. ☐ N. ☐ S. ____ ft. ☐ E. ☐ W.	Well Name
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒ Lat. 39° 36' 4.6" Long. -89° 29' 19.1" or St. Plane 1,069,354 ft. N, 2,487,630 ft. E. E /Ⓦ	MW-32
Facility ID	Section Location of Waste/Source	Date Well Installed: 02/03/2021
Type of Well: Well Code 72/dp	____ 1/4 of ____ 1/4 of Sec. 1, T. 13 N, R. 4 ☐ E ☒ W	Well Installed By: (Person's Name and Firm) Adam Jochimsen Cascade Drilling
Distance from Waste/ Source ____ ft. — State: IL	Location of Well Relative to Waste/Source: u ☐ Upgradient; s ☐ Sidegradient; d ☐ Downgradient; n ☐ Not Known — Gov. Lot Number	

A. Protective pipe, top elevation 619.76 ft. (NAVD88)

B. Well casing, top elevation 619.49 ft. (NAVD88)

C. Land surface elevation 617.2 ft. (NAVD88)

D. Surface seal, bottom 615.2 ft. (NAVD88) or 2.0 ft.



12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☐ ML ☒ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐; Hollow Stem Auger ☐; Mini Sonic — Other ☒

15. Drilling fluid used: Water ☒ 0 2; Air ☐; Drilling Mud ☐ 0 3; None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe ____

17. Source of water (attach analysis, if required):
Distilled Water

E. Bentonite seal, top 590.2 ft. (NAVD88) or 27.0 ft.

F. Fine sand, top ____ ft. (NAVD88) or ____ ft.

G. Filter pack, top 587.2 ft. (NAVD88) or 30.0 ft.

H. Screen joint, top 585.2 ft. (NAVD88) or 32.0 ft.

I. Well bottom 580.2 ft. (NAVD88) or 37.0 ft.

J. Filter pack, bottom 579.2 ft. (NAVD88) or 38.0 ft.

K. Borehole, bottom 577.2 ft. (NAVD88) or 40.0 ft.

L. Borehole, diameter 6.0 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.

1. Cap and lock? ☒ Yes ☐ No
2. Protective cover pipe:
   a. Inside diameter: 4.0 in.
   b. Length: 5.0 ft.
   c. Material: Steel ☒; Other ☐
   d. Additional protection? ☒ Yes ☐ No
   If yes, describe: Bollards
3. Surface seal: Bentonite ☐; Concrete ☒; Other ☐
4. Material between well casing and protective pipe: Bentonite ☐; Sand — Other ☒
5. Annular space seal: a. Granular/Chipped Bentonite ☒
   b. ____ Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   c. ____ Lbs/gal mud weight . . . Bentonite slurry ☐
   d. ____ % Bentonite . . . Bentonite-cement grout ☐
   e. 4.363 Ft^3 volume added for any of the above
   f. How installed: Tremie ☐; Tremie pumped ☐; Gravity ☒
6. Bentonite seal: a. Bentonite granules ☐
   b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
   c. ____ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
   a. ____
   b. Volume added ____ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
   a. Filter Sil, Industrial Quartz
   b. Volume added 1.418 ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒; Flush threaded PVC schedule 80 ☐; Other ☐
10. Screen material: Schedule 40 PVC
   a. Screen Type: Factory cut ☒; Continuous slot ☐; Other ☐
   b. Manufacturer Johnson Screens
   c. Slot size: 0.010 in.
   d. Slotted length: 5.0 ft.
11. Backfill material (below filter pack): None ☐; Formation Materials — Other ☒

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Date Modified: 5/3/2021

Signature: [signature]

Firm: Ramboll
234 W. Florida Street, Milwaukee, WI 53204
Tel: (414) 837-3607
Fax: (414) 837-3608

RAMBOLL

MONITORING WELL CONSTRUCTION

Facility/Project Name: Kincaid Power Station	Local Grid Location of Well: ______ ft. ☐ N. ☐ S. ______ ft. ☐ E. ☐ W.	Well Name
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒ Lat. 39° 35' 51.5" Long. -89° 29' 56.3" or	MW-7S
Facility ID	St. Plane 1,068,011 ft. N, 2,484,728 ft. E. E /W	Date Well Installed: 02/02/2021
Type of Well: Well Code 71/dw	Section Location of Waste/Source: ____ 1/4 of ____ 1/4 of Sec. 2, T. 13 N, R. 4 ☐ E ☒ W	Well Installed By: (Person's Name and Firm) Dave Gordon Cascade Drilling
Distance from Waste/Source: ft. / State: IL	Location of Well Relative to Waste/Source: u ☐ Upgradient, s ☐ Sidegradient, d ☐ Downgradient, n ☐ Not Known / Gov. Lot Number	

A. Protective pipe, top elevation 598.14 ft. (NAVD88)

B. Well casing, top elevation 597.64 ft. (NAVD88)

C. Land surface elevation 595.6 ft. (NAVD88)

D. Surface seal, bottom 593.6 ft. (NAVD88) or 2.0 ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☐ ML ☐ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐
Hollow Stem Auger ☐
Mini Sonic Other ☒

15. Drilling fluid used: Water ☒ 0 2 Air ☐
Drilling Mud ☐ 0 3 None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe ______

17. Source of water (attach analysis, if required):
Distilled Water

E. Bentonite seal, top 593.6 ft. (NAVD88) or 2.0 ft.

F. Fine sand, top ______ ft. (NAVD88) or ______ ft.

G. Filter pack, top 591.6 ft. (NAVD88) or 4.0 ft.

H. Screen joint, top 589.6 ft. (NAVD88) or 6.0 ft.

I. Well bottom 584.6 ft. (NAVD88) or 11.0 ft.

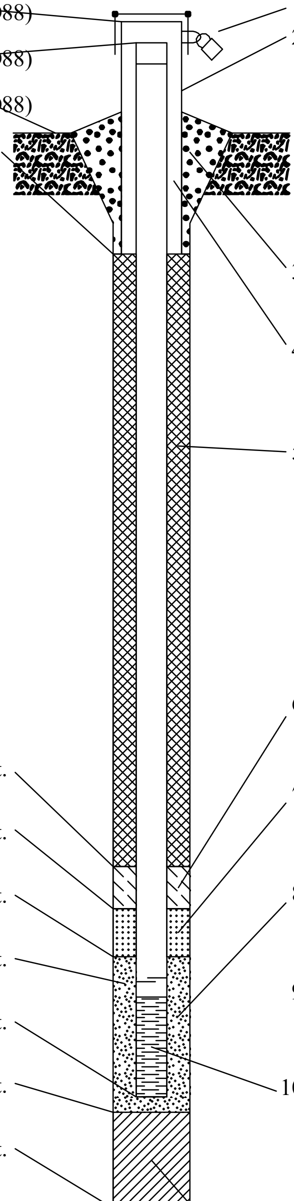
J. Filter pack, bottom 583.6 ft. (NAVD88) or 12.0 ft.

K. Borehole, bottom 580.6 ft. (NAVD88) or 15.0 ft.

L. Borehole, diameter 6.0 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.



1. Cap and lock? ☒ Yes ☐ No
2. Protective cover pipe:
   a. Inside diameter: 4.0 in.
   b. Length: 5.0 ft.
   c. Material: Steel ☒ Other ☐
   d. Additional protection? ☒ Yes ☐ No
   If yes, describe: Bollards
3. Surface seal: Bentonite ☐ Concrete ☒ Other ☐
4. Material between well casing and protective pipe:
   Bentonite ☐
   Sand Other ☒
5. Annular space seal: a. Granular/Chipped Bentonite ☒
   b. ____ Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   c. ____ Lbs/gal mud weight . . . Bentonite slurry ☐
   d. ____ % Bentonite . . . Bentonite-cement grout ☐
   e. 0.349 Ft^3 volume added for any of the above
   f. How installed: Tremie ☐ Tremie pumped ☐ Gravity ☒
6. Bentonite seal: a. Bentonite granules ☐
   b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
   c. ______ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
   a. ______
   b. Volume added ______ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
   a. Filter Sil, Industrial Quartz
   b. Volume added 1.418 ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒
   Flush threaded PVC schedule 80 ☐
   Other ☐
10. Screen material: Schedule 40 PVC
    a. Screen Type: Factory cut ☒ Continuous slot ☐ Other ☐
    b. Manufacturer Johnson Screens
    c. Slot size: 0.010 in.
    d. Slotted length: 5.0 ft.
11. Backfill material (below filter pack): None ☐
    Bentonite Chips Other ☒

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Date Modified: 5/3/2021

Signature [signature]

Firm: Ramboll
234 W. Florida Street, Milwaukee, WI 53204

Tel: (414) 837-3607
Fax: (414) 837-3608

RAMBOLL

MONITORING WELL CONSTRUCTION

Facility/Project Name	Local Grid Location of Well	Well Name
Kincaid Power Station	___ ft. ☐ N. ☐ S. ___ ft. ☐ E. ☐ W.	MW-8S
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒	
	Lat. 39° 35' 39.7" Long. -89° 29' 48.6" or	
Facility ID	St. Plane 1,066,822 ft. N, 2,485,345 ft. E. E /Ⓦ	Date Well Installed 02/02/2021
Type of Well: Well Code 71/dw	Section Location of Waste/Source: ___ 1/4 of ___ 1/4 of Sec. 12, T. 13 N, R. 4 ☐ E ☒ W	Well Installed By: (Person's Name and Firm) Dave Gordon, Cascade Drilling
Distance from Waste/Source: ft. / State: IL	Location of Well Relative to Waste/Source: u ☐ Upgradient; s ☐ Sidegradient; d ☐ Downgradient; n ☐ Not Known / Gov. Lot Number	

A. Protective pipe, top elevation 603.68 ft. (NAVD88)

B. Well casing, top elevation 603.30 ft. (NAVD88)

C. Land surface elevation 600.6 ft. (NAVD88)

D. Surface seal, bottom 599.6 ft. (NAVD88) or 1.0 ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☐ ML ☒ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐ Hollow Stem Auger ☐ Mini Sonic Other ☒

15. Drilling fluid used: Water ☒ 0 2 Air ☐ Drilling Mud ☐ 0 3 None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe ___

17. Source of water (attach analysis, if required): Distilled Water

E. Bentonite seal, top 599.6 ft. (NAVD88) or 1.0 ft.

F. Fine sand, top ___ ft. (NAVD88) or ___ ft.

G. Filter pack, top 598.1 ft. (NAVD88) or 2.5 ft.

H. Screen joint, top 596.6 ft. (NAVD88) or 4.0 ft.

I. Well bottom 593.6 ft. (NAVD88) or 7.0 ft.

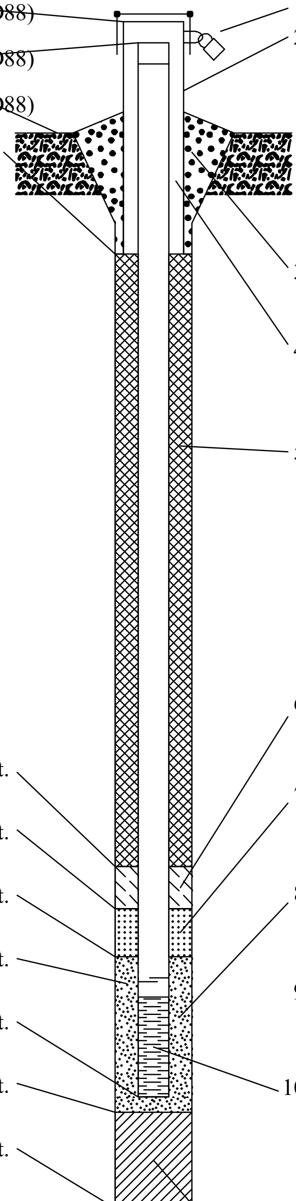
J. Filter pack, bottom 592.6 ft. (NAVD88) or 8.0 ft.

K. Borehole, bottom 580.6 ft. (NAVD88) or 20.0 ft.

L. Borehole, diameter 6.0 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.



1. Cap and lock? ☒ Yes ☐ No
2. Protective cover pipe:
   a. Inside diameter: 4.0 in.
   b. Length: 5.0 ft.
   c. Material: Steel ☒ Other ☐
   d. Additional protection? ☒ Yes ☐ No
   If yes, describe: Bollards
3. Surface seal: Bentonite ☐ Concrete ☒ Other ☐
4. Material between well casing and protective pipe: Bentonite ☐ Sand Other ☒
5. Annular space seal: a. Granular/Chipped Bentonite ☒
   b. ___ Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   c. ___ Lbs/gal mud weight . . . Bentonite slurry ☐
   d. ___ % Bentonite . . . Bentonite-cement grout ☐
   e. 0.262 Ft^3 volume added for any of the above
   f. How installed: Tremie ☐ Tremie pumped ☐ Gravity ☒
6. Bentonite seal: a. Bentonite granules ☐
   b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
   c. ___ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
   a. ___
   b. Volume added ___ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
   a. Filter Sil, Industrial Quartz
   b. Volume added 0.982 ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒ Flush threaded PVC schedule 80 ☐ Other ☐
10. Screen material: Schedule 40 PVC
    a. Screen Type: Factory cut ☒ Continuous slot ☐ Other ☐
    b. Manufacturer Johnson Screens
    c. Slot size: 0.010 in.
    d. Slotted length: 3.0 ft.
11. Backfill material (below filter pack): None ☒ Formation Materials and Bentonite Chips Other ☐

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Date Modified: 5/3/2021

Signature	Firm	
[signature]	Ramboll, 234 W. Florida Street, Milwaukee, WI 53204	Tel: (414) 837-3607 Fax: (414) 837-3608

RAMBOLL

MONITORING WELL CONSTRUCTION

Facility/Project Name	Local Grid Location of Well	Well Name
Kincaid Power Station	____ ft. ☐ N. ☐ S. ____ ft. ☐ E. ☐ W.	XPW01
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒ Lat. 39° 35' 39.9" Long. -89° 29' 35.2" or	
Facility ID	St. Plane 1,066,842 ft. N, 2,486,392 ft. E. E /(W)	Date Well Installed 02/02/2021
Type of Well: Well Code 99/ot	Section Location of Waste/Source: ____ 1/4 of ____ 1/4 of Sec. 12, T. 13 N, R. 4 ☐ E ☒ W	Well Installed By: (Person's Name and Firm) Russ Gordon, Cascade Drilling
Distance from Waste/Source ____ ft. / State IL	Location of Well Relative to Waste/Source: u ☐ Upgradient; s ☐ Sidegradient; d ☐ Downgradient; n ☐ Not Known / Gov. Lot Number ____	

A. Protective pipe, top elevation 628.23 ft. (NAVD88)

B. Well casing, top elevation 627.84 ft. (NAVD88)

C. Land surface elevation 625.5 ft. (NAVD88)

D. Surface seal, bottom 623.5 ft. (NAVD88) or 2.0 ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☒ SP ☐
SM ☐ SC ☐ ML ☐ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐ Hollow Stem Auger ☐ Mini Sonic Other ☒

15. Drilling fluid used: Water ☒ 0 2 Air ☐ Drilling Mud ☐ 0 3 None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe ____

17. Source of water (attach analysis, if required): Distilled Water

E. Bentonite seal, top 607.5 ft. (NAVD88) or 18.0 ft.

F. Fine sand, top ____ ft. (NAVD88) or ____ ft.

G. Filter pack, top 605.5 ft. (NAVD88) or 20.0 ft.

H. Screen joint, top 603.5 ft. (NAVD88) or 22.0 ft.

I. Well bottom 593.5 ft. (NAVD88) or 32.0 ft.

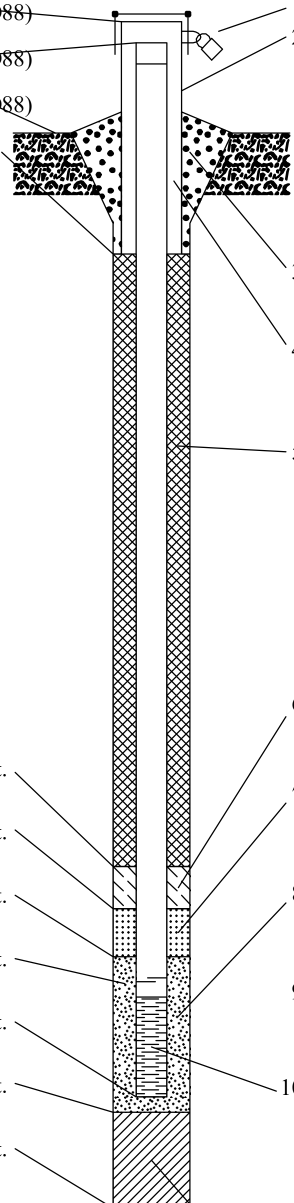
J. Filter pack, bottom 593.5 ft. (NAVD88) or 32.0 ft.

K. Borehole, bottom 593.5 ft. (NAVD88) or 32.0 ft.

L. Borehole, diameter 6.0 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.



1. Cap and lock? ☒ Yes ☐ No
2. Protective cover pipe:
   a. Inside diameter: 4.0 in.
   b. Length: 5.0 ft.
   c. Material: Steel ☒ Other ☐
   d. Additional protection? ☒ Yes ☐ No
   If yes, describe: Bollards
3. Surface seal: Bentonite ☐ Concrete ☒ Other ☐
4. Material between well casing and protective pipe: Bentonite ☐ Sand Other ☒
5. Annular space seal: a. Granular/Chipped Bentonite ☒
   b. ____ Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   c. ____ Lbs/gal mud weight . . . Bentonite slurry ☐
   d. ____ % Bentonite . . . Bentonite-cement grout ☐
   e. 2.793 Ft^3 volume added for any of the above
   f. How installed: Tremie ☐ Tremie pumped ☐ Gravity ☒
6. Bentonite seal: a. Bentonite granules ☐
   b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
   c. ____ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
   a. ____
   b. Volume added ____ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
   a. Filter Sil, Industrial Quartz
   b. Volume added 2.094 ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒ Flush threaded PVC schedule 80 ☐ Other ☐
10. Screen material: Schedule 40 PVC
    a. Screen Type: Factory cut ☒ Continuous slot ☐ Other ☐
    b. Manufacturer Johnson Screens
    c. Slot size: 0.010 in.
    d. Slotted length: 10.0 ft.
11. Backfill material (below filter pack): None ☒ Other ☐

I hereby certify that the information on this form is true and correct to the best of my knowledge. Date Modified: 5/3/2021

Signature	Firm	
[signature]	Ramboll 234 W. Florida Street, Milwaukee, WI 53204	Tel: (414) 837-3607 Fax: (414) 837-3608

RAMBOLL

MONITORING WELL CONSTRUCTION

Facility/Project Name: Kincaid Power Station	Local Grid Location of Well: ____ ft. ☐ N. ☐ S. ____ ft. ☐ E. ☐ W.	Well Name: XPW02
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒ Lat. 39° 35' 52.5" Long. -89° 29' 48.7" or	
Facility ID	St. Plane 1,068,110 ft. N, 2,485,321 ft. E. E /Ⓦ	Date Well Installed: 01/26/2021
Type of Well: Well Code 99/ot	Section Location of Waste/Source: ____ 1/4 of ____ 1/4 of Sec. 1, T. 13 N, R. 4 ☐ E ☒ W	Well Installed By: (Person's Name and Firm) Russ Gordon, Cascade Drilling
Distance from Waste/ Source ____ ft. / State: IL	Location of Well Relative to Waste/Source: u ☐ Upgradient; s ☐ Sidegradient; d ☐ Downgradient; n ☐ Not Known / Gov. Lot Number	

A. Protective pipe, top elevation 620.71 ft. (NAVD88)

B. Well casing, top elevation 620.19 ft. (NAVD88)

C. Land surface elevation 617.9 ft. (NAVD88)

D. Surface seal, bottom 615.9 ft. (NAVD88) or 2.0 ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☒ SP ☐
SM ☐ SC ☐ ML ☒ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐
Hollow Stem Auger ☐
Mini Sonic Other ☒

15. Drilling fluid used: Water ☒ 0 2 Air ☐
Drilling Mud ☐ 0 3 None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe ____

17. Source of water (attach analysis, if required):
Distilled Water

E. Bentonite seal, top 608.9 ft. (NAVD88) or 9.0 ft.

F. Fine sand, top ____ ft. (NAVD88) or ____ ft.

G. Filter pack, top 606.9 ft. (NAVD88) or 11.0 ft.

H. Screen joint, top 604.9 ft. (NAVD88) or 13.0 ft.

I. Well bottom 594.9 ft. (NAVD88) or 23.0 ft.

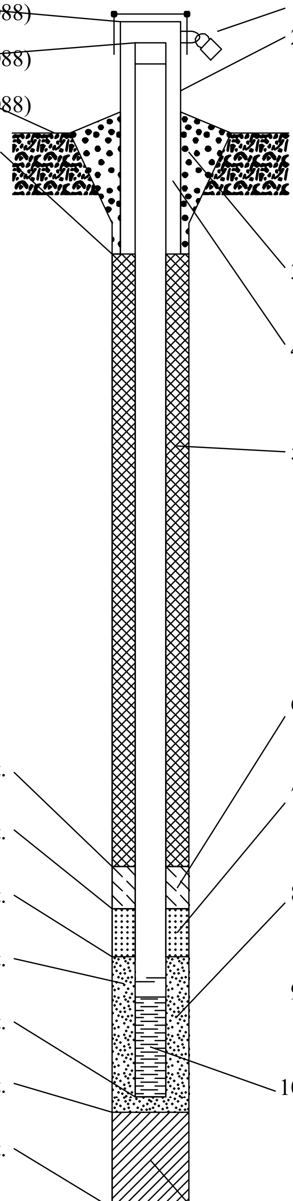
J. Filter pack, bottom 594.9 ft. (NAVD88) or 23.0 ft.

K. Borehole, bottom 595.9 ft. (NAVD88) or 22.0 ft.

L. Borehole, diameter 6.0 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.



1. Cap and lock? ☒ Yes ☐ No
2. Protective cover pipe:
a. Inside diameter: 4.0 in.
b. Length: 5.0 ft.
c. Material: Steel ☒ Other ☐
d. Additional protection? ☒ Yes ☐ No
If yes, describe: Bollards
3. Surface seal: Bentonite ☐ Concrete ☒ Other ☐
4. Material between well casing and protective pipe: Bentonite ☐
Sand Other ☒
5. Annular space seal: a. Granular/Chipped Bentonite ☒
b. ____ Lbs/gal mud weight . . . Bentonite-sand slurry ☐
c. ____ Lbs/gal mud weight . . . Bentonite slurry ☐
d. ____ % Bentonite . . . Bentonite-cement grout ☐
e. 1.222 Ft^3 volume added for any of the above
f. How installed: Tremie ☐ Tremie pumped ☐ Gravity ☒
6. Bentonite seal: a. Bentonite granules ☐
b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
c. ____ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
a. ____
b. Volume added ____ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
a. Filter Sil, Industrial Quartz
b. Volume added 2.094 ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒
Flush threaded PVC schedule 80 ☐
Other ☐
10. Screen material: Schedule 40 PVC
a. Screen Type: Factory cut ☒ Continuous slot ☐ Other ☐
b. Manufacturer Johnson Screens
c. Slot size: 0.010 in.
d. Slotted length: 10.0 ft.
11. Backfill material (below filter pack): None ☒ Other ☐

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Date Modified: 5/3/2021

Signature	Firm	
[signature]	Ramboll, 234 W. Florida Street, Milwaukee, WI 53204	Tel: (414) 837-3607 Fax: (414) 837-3608

RAMBOLL

MONITORING WELL CONSTRUCTION

Facility/Project Name Kincaid Power Station	Local Grid Location of Well ____ft. ☐ N. ☐ S. ____ft. ☐ E. ☐ W.	Well Name
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒ Lat. 39° 35' 58.5" Long. -89° 29' 44.8" or	XPW03
Facility ID	St. Plane 1,068,720 ft. N, 2,485,628 ft. E. E /(W)	Date Well Installed 01/26/2021
Type of Well Well Code 99/ot	Section Location of Waste/Source ____1/4 of ____ 1/4 of Sec. 1, T. 13 N, R. 4 ☐ E ☒ W	Well Installed By: (Person's Name and Firm) Russ Gordon Cascade Drilling
Distance from Waste/ Source ft. / State IL	Location of Well Relative to Waste/Source u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known / Gov. Lot Number	

A. Protective pipe, top elevation 619.03 ft. (NAVD88)

B. Well casing, top elevation 618.86 ft. (NAVD88)

C. Land surface elevation 616.1 ft. (NAVD88)

D. Surface seal, bottom 614.1 ft. (NAVD88) or 2.0 ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☒ SP ☐
SM ☐ SC ☒ ML ☐ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐
Hollow Stem Auger ☐
Mini Sonic Other ☒

15. Drilling fluid used: Water ☒ 0 2 Air ☐
Drilling Mud ☐ 0 3 None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe ____

17. Source of water (attach analysis, if required):
Distilled Water

E. Bentonite seal, top 610.1 ft. (NAVD88) or 6.0 ft.

F. Fine sand, top ____ ft. (NAVD88) or ____ ft.

G. Filter pack, top 608.1 ft. (NAVD88) or 8.0 ft.

H. Screen joint, top 606.1 ft. (NAVD88) or 10.0 ft.

I. Well bottom 596.1 ft. (NAVD88) or 20.0 ft.

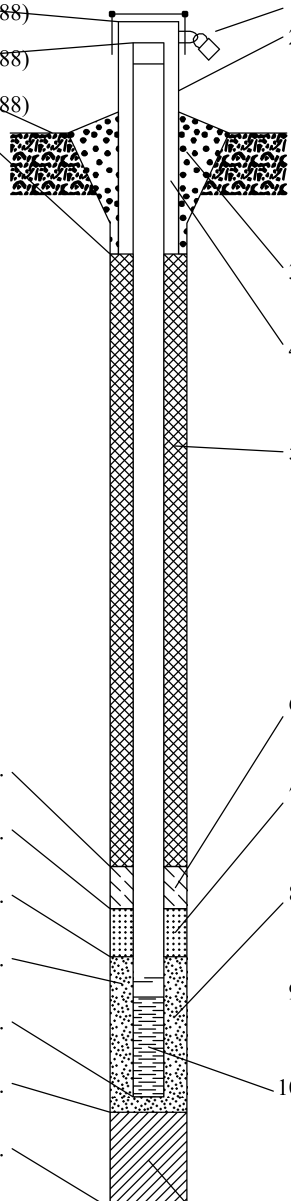
J. Filter pack, bottom 596.1 ft. (NAVD88) or 20.0 ft.

K. Borehole, bottom 596.1 ft. (NAVD88) or 20.0 ft.

L. Borehole, diameter 6.0 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.



1. Cap and lock? ☒ Yes ☐ No
2. Protective cover pipe:
   a. Inside diameter: 4.0 in.
   b. Length: 5.0 ft.
   c. Material: Steel ☒ Other ☐
   d. Additional protection? ☒ Yes ☐ No
   If yes, describe: Bollards
3. Surface seal: Bentonite ☐ Concrete ☒ Other ☐
4. Material between well casing and protective pipe: Bentonite ☐ Sand Other ☒
5. Annular space seal: a. Granular/Chipped Bentonite ☒
   b. ____Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   c. ____Lbs/gal mud weight . . . Bentonite slurry ☐
   d. ____% Bentonite . . . Bentonite-cement grout ☐
   e. 0.698 Ft^3 volume added for any of the above
   f. How installed: Tremie ☐ Tremie pumped ☐ Gravity ☒
6. Bentonite seal: a. Bentonite granules ☐
   b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
   c. ____ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
   a. ____
   b. Volume added ____ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
   a. Filter Sil, Industrial Quartz
   b. Volume added 2.094 ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒
   Flush threaded PVC schedule 80 ☐
   Other ☐
10. Screen material: Schedule 40 PVC
   a. Screen Type: Factory cut ☒ Continuous slot ☐ Other ☐
   b. Manufacturer Johnson Screens
   c. Slot size: 0.010 in.
   d. Slotted length: 10.0 ft.
11. Backfill material (below filter pack): None ☒ Other ☐

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Date Modified: 5/3/2021

Signature	Firm
[signature]	Ramboll 234 W. Florida Street, Milwaukee, WI 53204 Tel: (414) 837-3607 Fax: (414) 837-3608

RAMBOLL

MONITORING WELL CONSTRUCTION

Facility/Project Name	Local Grid Location of Well	Well Name
Kincaid Power Station	____ ft. ☐ N. ☐ S. ____ ft. ☐ E. ☐ W.	XPW04
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒ Lat. 39° 36' 2.6" Long. -89° 29' 32.2" or St. Plane 1,069,146 ft. N, 2,486,608 ft. E. E /(W)	
Facility ID	Section Location of Waste/Source	Date Well Installed 01/26/2021
Type of Well: Well Code 99/ot	____ 1/4 of ____ 1/4 of Sec. 1, T. 13 N, R. 4 ☐ E ☒ W	Well Installed By: (Person's Name and Firm) Russ Gordon Cascade Drilling
Distance from Waste/Source ____ ft. / State IL	Location of Well Relative to Waste/Source u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known Gov. Lot Number ____	

A. Protective pipe, top elevation 606.78 ft. (NAVD88)

B. Well casing, top elevation 606.53 ft. (NAVD88)

C. Land surface elevation 604.6 ft. (NAVD88)

D. Surface seal, bottom 602.6 ft. (NAVD88) or 2.0 ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☒ SP ☐
SM ☐ SC ☐ ML ☐ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐
Hollow Stem Auger ☐
Mini Sonic Other ☒

15. Drilling fluid used: Water ☒ 0 2 Air ☐
Drilling Mud ☐ 0 3 None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe ____

17. Source of water (attach analysis, if required):
Distilled Water

E. Bentonite seal, top 595.6 ft. (NAVD88) or 9.0 ft.

F. Fine sand, top ____ ft. (NAVD88) or ____ ft.

G. Filter pack, top 593.6 ft. (NAVD88) or 11.0 ft.

H. Screen joint, top 591.6 ft. (NAVD88) or 13.0 ft.

I. Well bottom 581.6 ft. (NAVD88) or 23.0 ft.

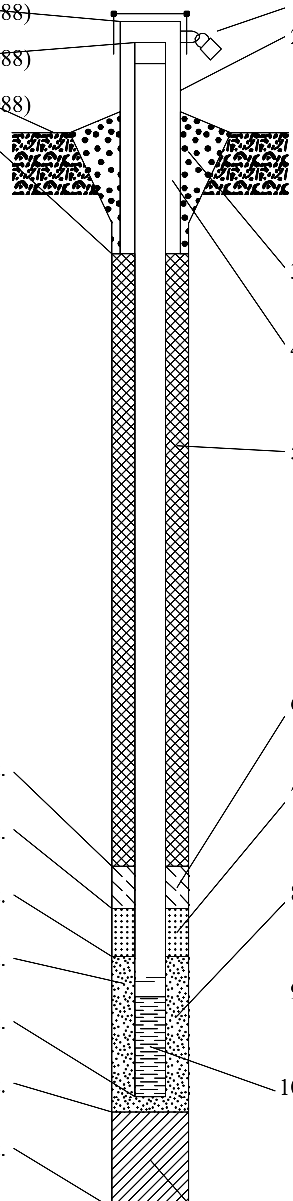
J. Filter pack, bottom 580.6 ft. (NAVD88) or 24.0 ft.

K. Borehole, bottom 580.6 ft. (NAVD88) or 24.0 ft.

L. Borehole, diameter 6.0 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.



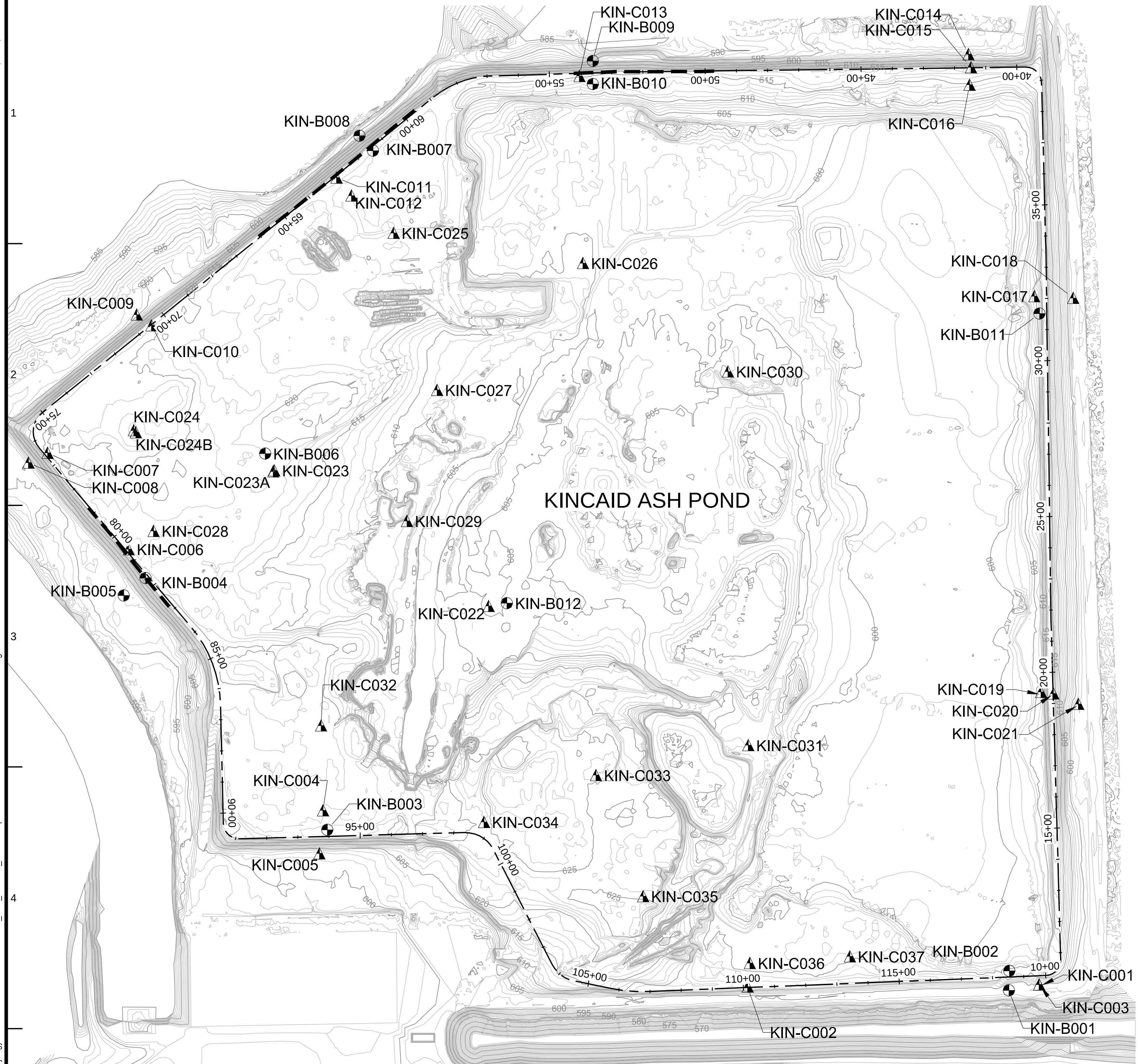
1. Cap and lock? ☒ Yes ☐ No
2. Protective cover pipe:
   a. Inside diameter: 4.0 in.
   b. Length: 5.0 ft.
   c. Material: Steel ☒ Other ☐
   d. Additional protection? ☒ Yes ☐ No
   If yes, describe: Bollards
3. Surface seal: Bentonite ☐ Concrete ☒ Other ☐
4. Material between well casing and protective pipe: Bentonite ☐ Sand Other ☒
5. Annular space seal: a. Granular/Chipped Bentonite ☒
   b. ____ Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   c. ____ Lbs/gal mud weight . . . Bentonite slurry ☐
   d. ____ % Bentonite . . . Bentonite-cement grout ☐
   e. 1.222 Ft^3 volume added for any of the above
   f. How installed: Tremie ☐ Tremie pumped ☐ Gravity ☒
6. Bentonite seal: a. Bentonite granules ☐
   b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
   c. ____ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
   a. ____
   b. Volume added ____ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
   a. Filter Sil, Industrial Quartz
   b. Volume added 2.291 ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒
   Flush threaded PVC schedule 80 ☐
   Other ☐
10. Screen material: Schedule 40 PVC
   a. Screen Type: Factory cut ☒ Continuous slot ☐ Other ☐
   b. Manufacturer Johnson Screens
   c. Slot size: 0.010 in.
   d. Slotted length: 10.0 ft.
11. Backfill material (below filter pack): None ☒ Other ☐

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Date Modified: 5/3/2021

Signature	Firm
[signature]	Ramboll 234 W. Florida Street, Milwaukee, WI 53204 Tel: (414) 837-3607 Fax: (414) 837-3608

Pre-2021 Soil Boring and Well Construction Logs



LEGEND

KIN-B000	AECOM BORING LOCATION
KIN-C000	AECOM CONE PENETROMETER TESTING LOCATION
— — —	LOCATION OF ELECTRICAL RESISTIVITY IMAGING LINE (ERI)

NOTES:

1. CONTOURS ARE 2 FOOT ELEVATION INTERVALS.
2. SURVEY BENCHMARKS WILL BE PROVIDED BY THE OWNER.
3. GROUND CONTOURS ARE INTERPRETED FROM HISTORIC TOPOGRAPHIC MAPS PROVIDED BY DYNEGY, RECENT GROUND SHOTS BY AECOM, AND FINAL RESULTS OF LIDAR SURVEYING PERFORMED BY SURDEX CORPORATION IN AUGUST 2015.
4. BATHYMETRY CONTOURS ARE BASED ON A BATHYMETRIC SURVEY PERFORMED BY WEAVER CONSULTANTS IN OCTOBER 2015.

N

0 200 400 600
SCALE IN FEET

AECOM
1001 Highlands Plaza Drive, Suite 300
St. Louis, Mo. 63110
314 429-0100 (phone)
314-429-0462 (fax)

DYNEGY
Dynegy Inc.
1500 East Port Plaza Drive
Collinsville, IL 62234

CCR RULE ASSESSMENT OF PLANTS

KINCAID POWER PLANT
KINCAID, ILLINOIS

30% DESIGN DRAWINGS FOR REMEDIATION OF ASH POND

ISSUED FOR BIDDING DATE BY

ISSUED FOR CONSTRUCTION DATE BY

REVISIONS

NO.	DESCRIPTION	DATE
△		
△		
△		
△		
△		

AECOM PROJECT NO:	
DRAWN BY:	GJH
DESIGNED BY:	EJV
CHECKED BY:	MCR
DATE CREATED:	12/23/2015
PLOT DATE:	1/5/2016
SCALE:	AS SHOWN
ACAD VER:	2014

SHEET TITLE

EXPLORATION LOCATIONS

D-01

SHEET 1 OF 3

SMITH, CURT 1/5/2016 3:39 PM
DRAWING PATH: P:\Projects\Geotech\60428794_DynegyCCR\04Tasks\13 Kincaid Tasks\7.0_CAD_GIS\7.09_Exhibits\Exploration Location Plans\KIN-EXPLORATION.dwg

Project: Dynegy

Project Location: Kincaid Power Station, IL

Project Number: 60440697

Log of Boring KIN-B001

Date(s) Drilled	08/14/2015 8:20 AM to 08/14/2015 12:00 AM	Logged By	Matthew Stone	Checked By	Elliott Drumright
Drilling Method	Hollow Stem Auger	Drill Bit Size/Type	7.75 in. O.D. HSA	Borehole Depth	30.0 ft
Drill Rig Type	CME-550X	Drilling Contractor	Terracon	Surface Elevation	598.0 ft NAVD 88
Borehole Backfill	Piezometer KIN-P001	Sampling Method(s)	SS / ST	Hammer Data	Automatic
Boring Location	N 1066408.5 E 2487814 (ft NAD83)	Groundwater Level(s)	Not Encountered		

Elevation (feet)	Depth (feet)	Sample Number	Sampling Resist. OR Core RQD (%)	Recovery (%)	Material Description (Elevation / Depth)	Natural Moisture Content (%)	Total Unit Weight (pcf)	Liquid Limit	Plasticity Index	Pocket Pen. Su (ksf)	Torvane Su (ksf)	TXUU (ksf)	Remarks
598.0	0.0				Medium dense, brown and gray, CLAY with fine to medium sand, trace fine gravel, with topsoil and roots, (CL) (FILL)								
		S1	6 6 7	100		11.8				3.0			
		S2	6 6 6	0									*Rock blocked S2.*
592.0	6.0				Stiff, moist, brown, high plasticity, SILT with sand, with topsoil, (ML) (FILL)								
		S3	4 5 7	83		20.8		39	23	4.0			
		S4	2 2 3	0									
586.0	12.0				Stiff, gray, silty CLAY (CL) with reddish brown silt seams, trace fine sand								
		S5											
		S6		0									
		S7											
580.0	18.0				Hard, very moist, brown and gray, low plasticity, sandy silty CLAY with orange brown silt seams, trace fine gravel, (CL) (TILL)								
		S8	12 24 32	100		8.9		23	8	> 4.5			*Shelby tube refusal at 18 ft.*
					Hard, wet, gray, sandy CLAY, trace fine gravel, (CL) (TILL)								
		S9	26 50 / 5"	67		8.9				> 4.5			
		S10	27 41 50 / 4 "	59	Hard, wet, gray, sandy CLAY (CL) (TILL)	10.8				4.5			*Installed Piezometer KIN - P001 in boring.*
568.0	30.0												

End of Boring at 30 ft

AECOM

Project: Dynegy

Project Location: Kincaid Power Station, IL

Project Number: 60440697

Log of Boring KIN-B002

Date(s) Drilled	08/12/2015 9:00 AM to 08/13/2015 12:00 AM	Logged By	Matthew Stone	Checked By	Elliott Drumright
Drilling Method	Hollow Stem Auger / Rotary Wash	Drill Bit Size/Type	7.75 in. O.D. HSA	Borehole Depth	50.0 ft
Drill Rig Type	CME-550X	Drilling Contractor	Terracon	Surface Elevation	604.1 ft NAVD 88
Borehole Backfill	Cement-Bentonite Grout (Installed KIN-P002 5 ft East of KIN-B002)	Sampling Method(s)	SS / ST	Hammer Data	Automatic
Boring Location	N 1066471 E 2487815.2 (ft NAD83)	Groundwater Level(s)	Not Encountered		

Elevation (feet)	Depth (feet)	SAMPLES Type	Number	Sampling Resist. OR Core RQD (%)	Recovery (%)	MATERIAL DESCRIPTION	Natural Moisture Content (%)	Total Unit Weight (pcf)	Liquid Limit	Plasticity Index	Pocket Pen. Su (ksf)	Torvane Su (ksf)	TXUU (ksf)	REMARKS
604.1	0.0					Moist, light gray, sandy GRAVEL, trace silt, (GM) (FILL)								
603.1	1.0	SS	S1	3 5 5	78	Stiff, moist, brown and gray, high plasticity, CLAY, trace sand and gravel with topsoil and roots, (CL) (EMBANKEMENT FILL)	18.1				3.5			
		ST	S2		71		19.0	130.7	38	21				
		SS	S3	2 5 6	100	Stiff, moist, brown and gray, sandy CLAY, trace fine gravel, (CL) (EMBANKMENT FILL)	13.9				3.5			
596.1	8.0	SS	S4	2 3 4	94	Medium stiff, moist, dark gray, high plasticity, CLAY with topsoil, (CL)	28.4		48	26	0.5			*Organic content 5.9%.*
		SS	S5	2 2 2	100	Soft, wet, brown and gray, CLAY (CL)	26.2				1.5			
		ST	S6		100	Gray and yellowish brown, trace dark gray, high plasticity, CLAY, trace sand and gravel, (CL)	27.5	121.4	41	24				
		SS	S7	WOH 2 2	100	Soft, very wet, brown and gray, CLAY, trace fine sand, (CL)	27.1				0.5			
581.1	23.0	SS	S8	12 23 41	78	Hard, very moist to wet, brown, low plasticity, sandy CLAY, trace fine gravel, (CL) (TILL)	12.6	153.0	22	8	> 4.5			*Shelby tube refusal at 23' bgs. No recovery.*
		SS	S9	30 41 50 / 5"	94	Hard, wet, gray, sandy CLAY, (CL) (TILL)	8.4				> 4.5			

Elevation scale: 600, 595, 590, 585, 580, 575. Depth scale: 0, 5, 10, 15, 20, 25, 30.

AECOM

Project: Dynegy

Project Location: Kincaid Power Station, IL

Project Number: 60440697

Log of Boring KIN-B002

Elevation (feet)	Depth (feet)	Type	Number	Sampling Resist. OR Core RQD (%)	Recovery (%)	Graphic Symbol	MATERIAL DESCRIPTION	Natural Moisture Content (%)	Total Unit Weight (pcf)	Liquid Limit	Plasticity Index	Pocket Pen. Su (ksf)	Torvane Su (ksf)	TXUU (ksf)	REMARKS
	30														
570	35		S10	16 41 50 / 3"	78		Hard, wet, gray, sandy CLAY, trace fine gravel, (CL) (TILL)	8.9				> 4.5			*8/12/15* *Rig needs to be repaired at site, work stopped 12 N.*
565	40		S11	10 32 50	89			8.8				> 4.5			*8/13/15* *Work continued on hole at 9:45 a.m.*
															Switch to Rotary drilling.
560	45		S12	27 27 34	100		Hard, very wet, brown and gray, sandy CLAY, (CL) (TILL)	11.9				> 4.5			
555	50		S13	17 23 29			Hard, wet, brown and gray, sandy CLAY, trace fine gravel, (CL) (TILL)								
554.1	50.0						End of Boring at 50 ft								*Installed Piezometer KIN-P002 with 5 ft offset to the East. Coordinates shown are for Boring KIN-B002.*
550	55														
545	60														
540	65														

AECOM

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Project: Dynegy

Project Location: Kincaid Power Station, IL

Project Number: 60440697

Log of Boring KIN-B003

Date(s) Drilled	08/14/2015 1:20 PM to 08/15/2015 3:35 PM	Logged By	Matthew Stone	Checked By	Elliott Drumright
Drilling Method	Hollow Stem Auger	Drill Bit Size/Type	7.75 in. O.D. HSA	Borehole Depth	50.0 ft
Drill Rig Type	CME-550X	Drilling Contractor	Terracon	Surface Elevation	621.8 ft NAVD 88
Borehole Backfill	Piezometer KIN-P003	Sampling Method(s)	SS / ST	Hammer Data	Automatic
Boring Location	N 1066923.6 E 2485626.8 (ft NAD83)	Groundwater Level(s)	29 ft on 8/14/2015 1:20:00 PM		

Elevation (feet)	Depth (feet)	Sample Type	Sample Number	Sampling Resist. OR Core RQD (%)	Recovery (%)	MATERIAL DESCRIPTION (Elevation (feet) / Depth (feet))	Natural Moisture Content (%)	Total Unit Weight (pcf)	Liquid Limit	Plasticity Index	Pocket Pen. Su (ksf)	Torvane Su (ksf)	TXUU (ksf)	REMARKS
621.8	0.0					Stiff, brown and gray, CLAY with fine to coarse sand, trace fine gravel with roots and topsoil, (CL) (EMBANKMENT FILL)								
620		SS	S1	4 4 5	94		11.6				> 4.5			
	5	SS	S2	3 4 10	94	Stiff, brown and gray, CLAY with fine to medium sand, trace fine gravel, (CL) (EMBANKMENT FILL)	15.5				> 4.5			
615		SS	S3	3 4 7	100		16.4				> 4.5			
	10	SS	S4	3 5 7	72	Stiff, brown and gray, sandy CLAY, trace fine gravel, (CL) (EMBANKMENT FILL)	9.5				3.0			
610														
	15	SS	S5	3 4 5	100	Stiff, moist, brown and gray, CLAY, trace fine to medium sand, (CL) (EMBANKMENT FILL)	18.0				1.5			
605														
603.3	18.5													
	20	SS	S6	3 5 7	100	Stiff, moist, brown and gray, very plastic, CLAY, trace fine to medium sand, (CH) (EMBANKMENT FILL)	23.9	144.2	54	34	2.0			
600														
599.8	22.0	ST	S7		100	Moist, dark grayish brown with gray and olive, trace yellowish brown, high plasticity, CLAY with sand, with organics (CL)	21.4	125.6	47	27				
	25	ST	S8		92	Stiff to very stiff, moist, grayish green, medium plastic, sandy CLAY, trace fine gravel with reddish brown silt seams (CL)	18.4	129.9	31	15				
595														
592.8	29.0	SS	S9	3 4 4		Medium stiff, wet, brown and gray, CLAY (CL-CH)	29.7							
	30													

AECOM

Elevation (feet)	Depth (feet)	Type	Number	Sampling Resist. OR Core RQD (%)	Recovery (%)	Graphic Symbol	MATERIAL DESCRIPTION	Natural Moisture Content (%)	Total Unit Weight (pcf)	Liquid Limit	Plasticity Index	Pocket Pen. Su (ksf)	Torvane Su (ksf)	TXUU (ksf)	REMARKS
588.8	33.0														
			S10	WOH WOH 1	100		Very soft, very wet, brown and gray, medium plastic, CLAY, trace fine sand, with reddish brown silt seams, (CL)	25.2		36	17	0.5			
			S11		96										
			S12	WOH 1 3	100		Soft, very wet, brown and gray, high plasticity, sandy CLAY (CL)	26.0		41	23	0.5			
580.8	41.0						Hard, gray, sandy CLAY, trace fine gravel, (CL) (TILL)								
			S13	7 16 46	100			9.2				> 4.5			
572.8	49.0		S14	19 19 50 / 5"			Very dense, very wet, brown and gray, silty fine to medium SAND, trace clay and fine gravel (SM) (TILL)	17.3				2.0			
571.8	50.0						End of Boring at 50 ft								*Installed Piezometer KIN-P003 in boring.*

Elevation scale: 590, 585, 580, 575, 570, 565, 560. Depth scale: 30, 35, 40, 45, 50, 55, 60, 65.

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Project: Dynegy

Project Location: Kincaid Power Station, IL

Project Number: 60440697

Log of Boring KIN-B004

Date(s) Drilled	08/18/2015 3:50 PM to 08/19/2015 12:00 AM	Logged By	Matthew Stone	Checked By	Elliott Drumright
Drilling Method	Hollow Stem Auger	Drill Bit Size/Type	7.75 in. O.D. HSA	Borehole Depth	50.0 ft
Drill Rig Type	CME-550X	Drilling Contractor	Terracon	Surface Elevation	617.8 ft NAVD 88
Borehole Backfill	Cement-Bentonite Grout Piezometer KIN-P005	Sampling Method(s)	SS / ST	Hammer Data	Automatic
Boring Location	N 1067731.3 E 2485043.6 (ft NAD83)	Groundwater Level(s)	Not Encountered		

Elevation (feet)	Depth (feet)	Sample Number	Sampling Resist. OR Core RQD (%)	Recovery (%)	MATERIAL DESCRIPTION (Elevation (feet) / Depth (feet))	Natural Moisture Content (%)	Total Unit Weight (pcf)	Liquid Limit	Plasticity Index	Pocket Pen. Su (ksf)	Torvane Su (ksf)	TXUU (ksf)	REMARKS
617.8	0.0				Very stiff, moist, brown, sandy CLAY, trace fine gravel, (CL) (EMBANKMENT FILL)								
		S1	9 9 9	72		9.1				> 4.5			
615													
	5	S2	4 6 10	100	Very stiff, brown, medium plastic, sandy CLAY, trace fine gravel (CL) (EMBANKMENT FILL)	12.1		31	16	> 4.5			
		S3	4 3 4	61	Medium stiff, brown, sandy CLAY, trace fine gravel, (CL) (EMBANKMENT FILL)	9.8							
610													
	10	S4	2 2 3	67	Medium stiff, moist, brown, sandy CLAY, trace fine gravel with reddish brown silt seams (CL) (EMBANKMENT FILL)	19.3				1.25			
605													*No S5 Sample.*
	15	S6	6 7 7	0									
600		S7		79	Stiff, moist, dark grayish brown with dark yellowish brown, medium plastic, CLAY with sand, with reddish brown silt seams (CL) (EMBANKMENT FILL)	14.6	135.1	29	14				
	20	S8		92	Dark brown and green, medium plastic, CLAY with sand (CL) (EMBANKMENT FILL)	21.6	125.1	32	14				
595.8	22.0				Very stiff, moist, brown and gray, CLAY, with fine to medium sand, trace fine gravel, with organics (CL)								
595													
		S9	4 9 10	100		19.0				2.5			
592.8	25.0				Very stiff, moist, greenish gray, silty CLAY, (CH).								
590													
		S10	2 4 5	100	Stiff, moist, brown and dark brown, high plasticity, CLAY (CH)	29.0		55	33	2.0			
587.8	30.0												

AECOM

Elevation (feet)	Depth (feet)	Sample Type	Sample Number	Sampling Resist. OR Core RQD (%)	Recovery (%)	MATERIAL DESCRIPTION	Natural Moisture Content (%)	Total Unit Weight (pcf)	Liquid Limit	Plasticity Index	Pocket Pen. Su (ksf)	Torvane Su (ksf)	TXUU (ksf)	REMARKS
	30		S11		100	Brown and gray, CLAY (CL)	25.9	126.0						
585														
	35		S12	WOH 2 3	100	Medium stiff, wet, brown and gray, high plasticity, CLAY with reddish orange silt seams (CL)	21.2	135.6	42	25	1.0			
580			S13			Brown and gray, high plasticity, CLAY, trace fine gravel (CL)	21.2	132.8	43	28				*ST refusal at 39 ft.*
	40													
575														
573.8	44.0		S14	20 50 / 3"	67	Hard, wet, brown and gray, sandy CLAY, trace fine gravel (CL) (TILL)	9.0				> 4.5			
	45													
570			S15	25 30 33		Hard, very moist, brownish gray, sandy CLAY, trace fine gravel (CL) (TILL)	7.7				> 4.5			
567.8	50.0					End of Boring at 50 ft								*Installed Piezometer KIN-P005 in boring.*
565	55													
560	60													
555	65													

Project: Dynegy

Project Location: Kincaid Power Station, IL

Project Number: 60440697

Log of Boring KIN-B005

Date(s) Drilled	08/21/2015 8:00 AM to 08/23/2015 12:00 PM	Logged By	Matthew Stone	Checked By	Elliott Drumright
Drilling Method	Hollow Stem Auger / Mud Rotary / Rock Core	Drill Bit Size/Type	7.75 in. O.D. HSA	Borehole Depth	85.0 ft
Drill Rig Type	CME-550X	Drilling Contractor	Terracon	Surface Elevation	594.5 ft NAVD 88
Borehole Backfill	Cement-Bentonite Grout (Installed KIN-P006 5 ft Southeast of KIN-B005)	Sampling Method(s)	SS / ST	Hammer Data	Automatic
Boring Location	N 1067675.7 E 2484973.6 (ft NAD83)	Groundwater Level(s)	Not Encountered		

Elevation (feet)	Depth (feet)	SAMPLES: Type	SAMPLES: Number	SAMPLES: Sampling Resist. OR Core RQD (%)	SAMPLES: Recovery (%)	Graphic Symbol	MATERIAL DESCRIPTION (Elevation (feet) / Depth (feet))	Natural Moisture Content (%)	Total Unit Weight (pcf)	Liquid Limit	Plasticity Index	Pocket Pen. Su (ksf)	Torvane Su (ksf)	TXUU (ksf)	REMARKS
	0						594.5 / 0.0 Stiff, moist, brown and gray with dark brown, CLAY, with fine to coarse sand (FILL)								
		SS	S1	2 4 6	83			9.8				4.5			
							591.5 / 3.0 Medium stiff, moist, brown and gray, CLAY with silt seams (CH)								
590	5	SS	S2	2 3 4	100			29.2				2.5			
							588.5 / 6.0 Grayish brown, medium plastic, CLAY, trace sand (CL)								
		ST	S3		92			23.9	127.0	35	12	1.5			
585	10	ST	S4		83		Stiff, moist, grayish brown, medium plastic, CLAY with sand, with reddish brown silt seams (CL).	24.2	126.6	38	16	1.25			
580	15	SS	S5	2 2 2	100		Soft, very moist to wet, brown and gray, CLAY, with fine to medium sand, trace fine gravel, (CL)	21.9				1.0			
		ST	S6		100		577.5 / 17.0 Brown and gray, low plasticity, clayey SAND, trace fine gravel, with reddish brown silt seams, (SC) (TILL)	13.8	139.3	22	8	> 4.5			
575	20	SS	S7	5 6 8	78		576.0 / 18.5 Stiff, brown and gray, medium plastic, sandy CLAY, trace fine gravel (CL) (TILL)	10.2				> 4.5			
570	25	SS	S8	22 29 35	100		Hard, moist, low plasticity, sandy CLAY, trace fine gravel (CL) (TILL)	6.7		20	7	2.0			
							566.0 / 28.5 Very stiff, dry, brownish gray, shaley CLAY, trace silt seams (CL-CH)								
565	30	SS	S9	6 10 14	100			27.7				3.5			

Project: Dynegy

Project Location: Kincaid Power Station, IL

Project Number: 60440697

Log of Boring KIN-B005

Elevation (feet)	Depth (feet)	Type	Number	Sampling Resist. OR Core RQD (%)	Recovery (%)	MATERIAL DESCRIPTION	Natural Moisture Content (%)	Total Unit Weight (pcf)	Liquid Limit	Plasticity Index	Pocket Pen. Su (ksf)	Torvane Su (ksf)	TXUU (ksf)	REMARKS
560.5	34.0		S10	13 18 23	100	Hard, moist, brown, sandy CLAY, trace fine gravel (CL) (TILL)	7.7				> 4.5			
			S11	16 24 30	100	Hard, brown and gray, sandy CLAY, trace fine gravel (CL) (TILL)	7.8				> 4.5			
			S12A	12 23 36	100		8.2				> 4.5			*Auger head broke at 10 a.m. Restart 8/23/15. Grout hole; offset 8 ft. SE, set 14 ft. HSA as casing, drill mud rotary and start sampling at 42 ft (S 12A).*
			S12	20 23 30	100		9.5				> 4.5			
			S13	8 14 21	100	Hard, brown, medium plastic, CLAY, trace fine sand (CL) (TILL)	17.5	129.6	36	18	> 4.5			
			S14	10 16 26	94	Hard, very wet, brown and gray, sandy CLAY (CL) (TILL)	16.6				> 4.5			

Elevation scale: 560, 555, 550, 545, 540, 535, 530. Depth scale: 30, 35, 40, 45, 50, 55, 60, 65.

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Project: Dynegy

Project Location: Kincaid Power Station, IL

Project Number: 60440697

Log of Boring KIN-B005

Elevation (feet)	Depth (feet)	Type	Number	Sampling Resist. OR Core RQD (%)	Recovery (%)	Material Description (Elevation (feet) / Depth (feet))	Natural Moisture Content (%)	Total Unit Weight (pcf)	Liquid Limit	Plasticity Index	Pocket Pen. Su (ksf)	Torvane Su (ksf)	TXUU (ksf)	REMARKS
525	70													
523.0	71.5					Hard, gray, shaley CLAY, trace fine gravel (CL)								
522.0	72.5		S15A	23 50 / 5"	72	Very soft, gray, sandy shaley CLAY, trace fine gravel, (CL) (BEDROCK)	15.2 8.4				> 4.5			
520														Switch to roller bit. Hard drilling 74 - 75'. Rollerbit refusal at 75 ft. Start wireline coring on 8/24/15.
519.5	75.0		C1	79	100	Limestone, hard, medium strong, light to medium gray. qu = 6,500 psi (75.9 - 76.5 ft)	1.0	163.6						
515														
514.9	79.6					SHALE, very soft, laminated, waxy, dark gray SHALE, moderately hard, laminated, black								
	80		C2	53	91		8.4	116.3						
510														Installed Piezometer KIN-P006 with 5 ft offset to the Southeast. Coordinates shown are for Boring KIN-B005.
509.5	85.0					End of Boring at 85 ft								
505	90													
500	95													
495	100													

Project: Dynegy

Project Location: Kincaid Power Station, IL

Project Number: 60440697

Log of Boring KIN-B006

Date(s) Drilled	08/14/2015 9:30 AM to 08/18/2015 12:00 PM	Logged By	Matthew Stone	Checked By	Elliott Drumright
Drilling Method	Hollow Stem Auger / Cased, Rotary Wash	Drill Bit Size/Type	7.75 in. O.D. HSA	Borehole Depth	41.0 ft
Drill Rig Type	CME-550X	Drilling Contractor	Terracon	Surface Elevation	617.2 ft NAVD 88
Borehole Backfill	Cement-Bentonite Grout	Sampling Method(s)	SS / ST/ Piston Sample	Hammer Data	Automatic
Boring Location	N 1068130.5 E 2485427.3 (ft NAD83)	Groundwater Level(s)	Not Encountered		

Elevation (feet)	Depth (feet)	Sample Number	Sampling Resist. OR Core RQD (%)	Recovery (%)	MATERIAL DESCRIPTION (Elevation / Depth, feet)	Natural Moisture Content (%)	Total Unit Weight (pcf)	Liquid Limit	Plasticity Index	Pocket Pen. Su (ksf)	Torvane Su (ksf)	TXUU (ksf)	REMARKS
617.2	0.0				Dry, black, CINDERS with fine to coarse grained sand (ASH)								
615		S1	3 3 3	100	Loose, wet, brown and gray, CINDERS with clayey silt (ASH)	34.2							
613.7	3.5	S2	WOH 1 WOH	100	Very soft, wet, brown with black, CLAY, with cinders (CL)	71.4				0.5			
	5	S3		0									
610		S4		100	Dark brown, very wet, fine to medium grained sandy CLAY with ash (CL)								*Piston sample.*
605	10	S5	WOH	100	Very soft, very wet, dark brown and gray, sandy CLAY, with organics, with ash (CL)	48.0				0.25			
		S6		47									*Piston sample. 8/14/15 12:05 work stopped.*
602.2	15.0				Very loose, wet, coarse grained CINDERS (ASH)								
600		S7	1 1 1	100	Very loose, very wet, dark brown, CINDERS, with organics and clay (ASH)	38.5							
	20	S8		0	Very loose, very wet, black, fine to coarse grained CINDERS (ASH)								*8/18/15 9:15 work resumed. Piston sample.*
595		S9		100	Very loose, wet, coarse grained CINDERS (ASH)								
590	25												
588.2	29.0	S10	2 2 3	56	Medium stiff, very wet, brown and gray, medium plastic CLAY, trace fine sand, with	30.4		36	15	1.0			
	30												

Elevation (feet)	Depth (feet)	SAMPLES Type	Number	Sampling Resist. OR Core RQD (%)	Recovery (%)	Graphic Symbol	MATERIAL DESCRIPTION (Elevation (feet) / Depth (feet))	Natural Moisture Content (%)	Total Unit Weight (pcf)	Liquid Limit	Plasticity Index	Pocket Pen. Su (ksf)	Torvane Su (ksf)	TXUU (ksf)	REMARKS
	30						reddish brown silt seams (CL)								
585															
			S11	WOH 2 3	100		583.7 / 33.5 Medium stiff, very wet, CLAY, with reddish brown silt seams (CH)	28.2				1.0			
	35														
580			S12		100										
	40		S13		46										
							576.2 / 41.0 End of Boring at 41 ft								
575															
	45														
570															
	50														
565															
	55														
560															
	60														
555															
	65														

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Project: Dynegy

Project Location: Kincaid Power Station, IL

Project Number: 60440697

Log of Boring KIN-B007

Date(s) Drilled	08/20/2015 11:35 AM to 08/20/2015 2:15 PM	Logged By	Matthew Stone	Checked By	Elliott Drumright
Drilling Method	Hollow Stem Auger	Drill Bit Size/Type	7.75 in. O.D. HSA	Borehole Depth	50.0 ft
Drill Rig Type	CME-550X	Drilling Contractor	Terracon	Surface Elevation	616.8 ft NAVD 88
Borehole Backfill	Cement-Bentonite Grout (Installed KIN-P007 adj. to KIN-B007).	Sampling Method(s)	SS / ST	Hammer Data	Automatic
Boring Location	N 1069102.7 E 2485773.3 (ft NAD83)	Groundwater Level(s)	Not Encountered		

Elevation (feet)	Depth (feet)	Sample Type	Sample Number	Sampling Resist. OR Core RQD (%)	Recovery (%)	MATERIAL DESCRIPTION (Elevation (feet) / Depth (feet))	Natural Moisture Content (%)	Total Unit Weight (pcf)	Liquid Limit	Plasticity Index	Pocket Pen. Su (ksf)	Torvane Su (ksf)	TXUU (ksf)	REMARKS
616.8	0.0					Hard, dry, brown, sandy CLAY, trace fine gravel (CL) (EMBANKMENT FILL)								
615		SS	S1	21 26 31	78		5.5				> 4.5			
612.8	4.0	SS	S2	9 12 15	100	Very stiff, moist, brown, low plasticity, sandy CLAY, trace fine gravel (CL)	8.0				> 4.5			
610		SS	S3	20 15 8	100		20.8				> 4.5			
608.3	8.5	SS	S4	4 6 9	100	Stiff, moist, brown to dark brown, sandy CLAY, trace fine gravel (CL) (EMBANKMENT FILL)	6.2				3.0			*Organic content 3.9%.*
		SS	S5	4 5 7	100		15.0				4.25			
600		ST	S6		83	Green, brown and gray, medium plastic CLAY, with sand (CL) (EMBANKMENT FILL)			35	15				
		SS	S7	3 6 8	100	Stiff, very moist, brown and gray, sandy CLAY, trace fine gravel, (CL) (EMBANKMENT FILL)	10.3				3.0			
592.8	24.0	SS	S8	3 5 6	100	Stiff, very moist, brown and gray with dark gray, CLAY, with fine to medium sand, trace fine gravel (CL - CH) (EMBANKMENT FILL)	24.9				1.5			
591.8	25.0	ST	S9		100	Soft, grayish brown, silty CLAY (CL)					0.5			
		ST	S10		100	Medium stiff, very moist, brown to light brown, sandy CLAY, trace silt, trace fine gravel, with roots (CL)	10.8				1.0			

Elevation scale: 615, 610, 605, 600, 595, 590. Depth scale: 0, 5, 10, 15, 20, 25, 30.

Project: Dynegy

Project Location: Kincaid Power Station, IL

Project Number: 60440697

Log of Boring KIN-B007

Elevation (feet)	Depth (feet)	SAMPLES Type	Number	Sampling Resist. OR Core RQD (%)	Recovery (%)	Graphic Symbol	MATERIAL DESCRIPTION (Elevation (feet) / Depth (feet))	Natural Moisture Content (%)	Total Unit Weight (pcf)	Liquid Limit	Plasticity Index	Pocket Pen. Su (ksf)	Torvane Su (ksf)	TXUU (ksf)	REMARKS
585	30														
			S11		100		Medium stiff, wet, light brown, sandy CLAY (CL)								
580	35		S12		100										
							578.8 / 38.0 Very loose, very wet, brown, clayey SAND, trace fine gravel (SC)								
			S13	WOH WOH 6	67		577.3 / 39.5 Medium stiff, wet, light brown, Sandy CLAY, trace silt (CL) (TILL)	13.8				0.75			
575	40														
			S14	24 38 42	100		Hard, very wet, gray, medium plastic, sandy CLAY, trace fine gravel (CL) (TILL)	11.2		27	13	> 4.5			
570	45														
			S15	25 34 50			Hard, brownish gray, sandy CLAY, trace fine gravel (CL) (TILL)	7.7				> 4.5			
	50						566.8 / 50.0 End of Boring at 50 ft								*Installed Piezometer KIN-P007 with offset. Coordinates shown are for Boring KIN-B007.*
565															
560	55														
555	60														
	65														

Project: Dynegy

Project Location: Kincaid Power Station, IL

Project Number: 60440697

Log of Boring KIN-B008

Date(s) Drilled	08/20/2015 7:45 AM to 08/20/2015 11:10 AM	Logged By	Matthew Stone	Checked By	Elliott Drumright
Drilling Method	Hollow Stem Auger	Drill Bit Size/Type	7.75 in. O.D. HSA	Borehole Depth	30.0 ft
Drill Rig Type	CME-550X	Drilling Contractor	Terracon	Surface Elevation	590.5 ft NAVD 88
Borehole Backfill	Piezometer KIN-P008	Sampling Method(s)	SS / ST	Hammer Data	Automatic
Boring Location	N 1069150.5 E 2485729.9 (ft NAD83)	Groundwater Level(s)	Not Encountered		

Elevation (feet)	Depth (feet)	Type	Number	Sampling Resist. OR Core RQD (%)	Recovery (%)	Graphic Symbol	MATERIAL DESCRIPTION	Natural Moisture Content (%)	Total Unit Weight (pcf)	Liquid Limit	Plasticity Index	Pocket Pen. Su (ksf)	Torvane Su (ksf)	TXUU (ksf)	REMARKS
590.5	0.0						Rockfill (3 - 7 inch), little topsoil.								
589.5	1.0	SS	S1	7 5 5	0		Medium stiff, very moist, brown and gray, sandy CLAY, (CL) (FILL)								*Rock lodged in S1.*
		SS	S2	2 2 4	100			25.4				2.25			
							Soft to medium stiff, wet, brown, sandy CLAY (CL) (FILL)								
		SS	S3	2 2 3	100			22.8				0.25 1.0			
581.5	9.0	ST	S4		100		Low plasticity, sandy CLAY (CL) (TILL)	11.4	140.0	19	7				*Till material at the bottom of S4.*
		SS	S5	15 30 39	100		Hard, wet, brown and gray, medium plastic, sandy CLAY, trace fine to coarse gravel (CL) (TILL)	13.3		25	11	> 4.5			
		SS	S6	13 31 41	100		Hard, brownish gray, sandy CLAY, trace fine gravel (CL) (TILL)	10.7	144.8			> 4.5			
		SS	S7	20 35 43	100		Hard, slightly moist, brownish gray, sandy CLAY, trace fine gravel (CL) (TILL)	7.6				> 4.5			
560.5	30.0	SS	S8	18 32 50 / 4"				7.1				> 4.5			*Installed Piezometer KIN-P008 in boring.*

Elevation scale (feet): 590, 585, 580, 575, 570, 565. Depth scale (feet): 0, 5, 10, 15, 20, 25, 30.

End of Boring at 30 ft

AECOM

Project: Dynegy

Project Location: Kincaid Power Station, IL

Project Number: 60440697

Log of Boring KIN-B009

Date(s) Drilled	08/14/2015 1:15 PM to 08/14/2015 2:35 PM	Logged By	Matthew Stone	Checked By	Elliott Drumright
Drilling Method	Hollow Stem Auger	Drill Bit Size/Type	7.75 in. O.D. HSA	Borehole Depth	30.0 ft
Drill Rig Type	CME-550X	Drilling Contractor	Terracon	Surface Elevation	593.6 ft NAVD 88
Borehole Backfill	Cement-Bentonite Grout (Installed KIN-P009 adj. to KIN-B009)	Sampling Method(s)	SS / ST	Hammer Data	Automatic
Boring Location	N 1069390.8 E 2486478.7 (ft NAD83)	Groundwater Level(s)	Not Encountered		

Elevation (feet)	Depth (feet)	Sample Number	Sampling Resist. OR Core RQD (%)	Recovery (%)	Material Description (Elevation / Depth)	Natural Moisture Content (%)	Total Unit Weight (pcf)	Liquid Limit	Plasticity Index	Pocket Pen. Su (ksf)	Torvane Su (ksf)	TXUU (ksf)	REMARKS
593.6	0.0												
		S1	3 3 4	100	Medium stiff, moist, dark brown, CLAY, with fine sand, with roots (CL) (FILL)	20.3				1.75			
589.6	4.0	S2	2 2 3	100	Medium stiff, moist, dark brown, high plasticity, CLAY, with sand, with roots (CL)	23.8		42	23	1.5			
588.6	5.0	S3	2 3 5	100	Medium stiff, moist, brown and gray, CLAY, with fine to medium sand, with silt seams (CH)	21.3				1.0			
586.1	7.5	S4		100	Grayish brown, medium plastic, sandy CLAY, with pebbles	19.9	123.7	28	13				
	10	S9		63									*S9 and S10 collocated hole.*
		S10		0									
		S5	6 15 19	100	Hard, wet, brown, sandy CLAY, trace fine gravel, (CL) (TILL)	10.3	113.6			> 4.5			*Shelby tube refusal.*
		S6	16 29 40	100	Gray	7.5				> 4.5			
		S7	18 32 50 / 5"	94	Hard, gray, sandy silty CLAY, trace fine gravel (CL) (TILL)	11.5				> 4.5			
		S8	16 33 50 / 5"	94	Hard, brownish gray, sandy CLAY, trace fine gravel (CL) (TILL)	9.2	105.4			> 4.5			*Installed Piezometer KIN-P009 in boring.*
563.6	30.0												

Elevation scale: 590, 585, 580, 575, 570, 565. Depth scale: 0, 5, 10, 15, 20, 25, 30.

End of Boring at 30 ft

AECOM

Project: Dynegy

Project Location: Kincaid Power Station, IL

Project Number: 60440697

Log of Boring KIN-B010

Date(s) Drilled	08/26/2015 8:00 AM to 08/26/2015 5:00 PM	Logged By	Elliott Drumright	Checked By	Elliott Drumright
Drilling Method	Hollow Stem Auger / Rotary	Drill Bit Size/Type	7.75 in. O.D. HSA / 4 in. Roller Bit	Borehole Depth	75.0 ft
Drill Rig Type	CME-550X	Drilling Contractor	Terracon	Surface Elevation	611.4 ft NAVD 88
Borehole Backfill	Cement-Bentonite Grout (Installed KIN-010 12 ft West of KIN-B010)	Sampling Method(s)	SS / ST	Hammer Data	Automatic
Boring Location	N 1069316.4 E 2486478.7 (ft NAD83)	Groundwater Level(s)	Not Encountered		

Elevation (feet)	Depth (feet)	Sample Type	Sample Number	Sampling Resist. OR Core RQD (%)	Recovery (%)	Material Description (Elevation (feet) / Depth (feet))	Natural Moisture Content (%)	Total Unit Weight (pcf)	Liquid Limit	Plasticity Index	Pocket Pen. Su (ksf)	Torvane Su (ksf)	TXUU (ksf)	Remarks
611.4	0.0					Topsoil and gravel basecourse (fill).								
610.4	1.0	SS	S1	4 4 6	78	Stiff, moist, brown, sandy CLAY, trace fine gravel (CL) (EMBANKMENT FILL)	4.9				> 4.5			
		SS	S2	4 5 7	89		8.9				4.0			
		SS	S3	3 3 4	100	Medium stiff, moist, brown, low plasticity, sandy CLAY, trace fine to coarse gravel (CL) (EMBANKMENT FILL)	9.5		23	9	1.75 3.0			
		SS	S4	4 6 7	89	Stiff, moist, brown and dark brown, sandy CLAY, trace fine gravel (CL) (EMBANKMENT FILL)	11.8	135.8			> 4.5			
		SS	S5	2 5 5	100	Brown and gray	19.5				0.75			
		ST	S6		20	Stiff, moist, grayish brown, medium plastic, CLAY, with sand (CL) (EMBANKMENT FILL)	21.1	128.1	33	19	1.5			
590.4	21.0	ST	S7		18	Very stiff, CLAY, with sand (CL)	11.8	137.7	31	16	3.5			*ST refusal*
							23.3							
587.0	24.4	SS	S8	3 5 7	94	Stiff, very wet, brown and gray with dark brown, CLAY, with fine to medium sand (CH)	17.6	136.5			1.25			
582.4	29.0	SS	S9	2 2 3	100	Medium stiff, dark brown, medium plastic, CLAY (CL)	28.9		40	20	0.5			*Organic content 5.3%.*

Elevation (feet)	Depth (feet)	Type	Number	Sampling Resist. OR Core RQD (%)	Recovery (%)	Material Description (Elevation / Depth)	Natural Moisture Content (%)	Total Unit Weight (pcf)	Liquid Limit	Plasticity Index	Pocket Pen. Su (ksf)	Torvane Su (ksf)	TXUU (ksf)	Remarks
	30													*30 - 32': Duttings appear as topsoil.*
579.4	32.0					Medium stiff, very wet, brown and gray, sandy CLAY, trace fine gravel, (CL - CH) (TILL)								
			S10		22						1.75			
	35		S11	3 4 4	100		20.9				1.75			
573.4	38.0					Very dense, very wet, brown and gray, clayey SAND, trace fine gravel (SC) (TILL)								*38': Hard augering.*
			S12	13 32 50 / 3"	89		9.8							
	40													*40': Mud rotary*
568.4	43.0					Hard, wet, gray, sandy CLAY, trace fine gravel (CL) (TILL)								
			S13	23 42 50	89		10.7				> 4.5			
	45													
			S14	27 50 / 5"	89	Low plasticity	9.9	149.4	23	9	> 4.5			
	50													
	55													
			S15	23 35 50 / 5"	100		9.5				> 4.5			
	60													
														61 - 63': Easier drilling.
	65													

Elevation scale: 580, 575, 570, 565, 560, 555, 550

Elevation (feet)	Depth (feet)	Type	Number	Sampling Resist. OR Core RQD (%)	Recovery (%)	Graphic Symbol	MATERIAL DESCRIPTION (Elevation (feet) / Depth (feet))	Natural Moisture Content (%)	Total Unit Weight (pcf)	Liquid Limit	Plasticity Index	Pocket Pen. Su (ksf)	Torvane Su (ksf)	TXUU (ksf)	REMARKS
545															
541.9	69.5		S16	13 50 50 / 1"	89		Greenish gray and brown Shale (BEDROCK)	17.0				> 4.5			
541.1	70.3						Shale, dark gray, very soft, waxy								*Roller bit refusal. S17-SPT bouncing. Switch to rock coring.*
540			C1	53	95		Run #1 70.3 - 75': Limestone, gray, thinly bedded, strong, moderately hard, qu = 11,380 psi (70.6 - 71.2 ft)	0.3	165.8						
536.4	75.0						End of Boring at 75 ft								*Installed Piezometer KIN-P010 with 12 ft offset West.*
535															
530	80														
525	85														
520	90														
515	95														
	100														

Project: Dynegy

Project Location: Kincaid Power Station, IL

Project Number: 60440697

Log of Boring KIN-B011

Date(s) Drilled	08/11/2015 11:30 AM to 08/11/2015 4:30 PM	Logged By	Matthew Stone	Checked By	Elliott Drumright
Drilling Method	Hollow Stem Auger	Drill Bit Size/Type	6.50 in. O.D. HSA	Borehole Depth	50.0 ft
Drill Rig Type	CME-550X	Drilling Contractor	Terracon	Surface Elevation	611.8 ft NAVD 88
Borehole Backfill	Cement-Bentonite Grout	Sampling Method(s)	SS / ST	Hammer Data	Automatic
Boring Location	N 1068580.1 E 2487911.8 (ft NAD83)	Groundwater Level(s)	26 ft on 8/11/2015		

Elevation (feet)	Depth (feet)	Sample Type	Sample Number	Sampling Resist. OR Core RQD (%)	Recovery (%)	Material Description (Elevation / Depth)	Natural Moisture Content (%)	Total Unit Weight (pcf)	Liquid Limit	Plasticity Index	Pocket Pen. Su (ksf)	Torvane Su (ksf)	TXUU (ksf)	Remarks
611.8	0.0					Sandy gravel fill.								
610.8	1.0		S1	3 4 4	33	Medium stiff, moist, brown, CLAY, with fine sand, (CL) (EMBANKMENT FILL)	16.6							
			S2	3 6 7	83	Stiff, moist, brown and dark brown, medium plastic, CLAY, with fine sand, trace fine gravel (CL) (EMBANKMENT FILL)	18.6		38	18				*Organic Content of 2.9%.*
			S3	3 5 8	100	Stiff, brown and dark brown, high plasticity, sandy CLAY, trace fine gravel (CL) (EMBANKMENT FILL)	17.2		44	26				
603.3	8.5		S4	3 5 8	100	Stiff, brown to gray, CLAY, trace fine sand (CL - CH) (EMBANKMENT FILL)	20.4							
597.3	14.5		S5		96	Dark brown, high plasticity, CLAY (CH) (EMBANKMENT FILL) 16 - 18': Possible topsoil	22.9	118.0	58	37				*Organic content 2.5%.*
593.8	18.0		S6	3 5 6	100	Stiff, brown and gray, high plasticity, CLAY, trace fine sand (CL - CH)	27.7	140.7	49	29				
587.8	24.0		S7	2 2 3	100	Medium stiff, moist, brown and gray, CLAY, trace fine sand, with reddish brown silt seams (CL) ▽	26.8				0.75			
			S8		96						0.5			
			S9	WOH	100	Very soft, moist, brown and gray, high plasticity, CLAY, trace fine sand, with reddish	26.5		40	21	0.3			

AECOM

Project: Dynegy

Project Location: Kincaid Power Station, IL

Project Number: 60440697

Log of Boring KIN-B011

Elevation (feet)	Depth (feet)	Type	Number	Sampling Resist. OR Core RQD (%)	Recovery (%)	Graphic Symbol	MATERIAL DESCRIPTION (Elevation (feet) / Depth (feet))	Natural Moisture Content (%)	Total Unit Weight (pcf)	Liquid Limit	Plasticity Index	Pocket Pen. Su (ksf)	Torvane Su (ksf)	TXUU (ksf)	REMARKS
	30						brown silt seams (CL)								
580															
	35		S10	WOH 1 1	100		Very soft, wet, brown and gray, medium plastic, sandy CLAY (CL)	25.0		33	17				
575							574.8 / 37.0 Very dense, wet, brown and gray, low plasticity, clayey SAND, trace fine gravel (SC) (TILL)								
	40		S11	12 21 50 / 2"	100			8.2		23	9				
570							569.8 / 42.0 Hard, wet, brownish gray, sandy CLAY, trace fine gravel, (CL) (TILL)								
	45		S12	37 50 / 3"	61			9.0				> 4.5			
565															
	50		S13	50 / 5"	33		561.8 / 50.0 End of Boring at 50 ft	9.6				> 4.5			
560															
	55														
555															
	60														
550															
	65														

Project: Dynegy

Project Location: Kincaid Power Station, IL

Project Number: 60440697

Log of Boring KIN-B012

Date(s) Drilled	08/25/2015 8:00 AM to 08/25/2015 12:00 PM	Logged By	Elliott Drumright	Checked By	Elliott Drumright
Drilling Method	Hollow Stem Auger	Drill Bit Size/Type	7.75 in. O.D. HSA	Borehole Depth	40.0 ft
Drill Rig Type	CME-550X	Drilling Contractor	Terracon	Surface Elevation	604.2 ft NAVD 88
Borehole Backfill	Cement-Bentonite Grout	Sampling Method(s)	SS / ST/ Piston Sample	Hammer Data	Automatic
Boring Location	N 1067650.8 E 2486203 (ft NAD83)	Groundwater Level(s)	Not Encountered		

Elevation (feet)	Depth (feet)	Samples: Type	Samples: Number	Samples: Sampling Resist. OR Core RQD (%)	Samples: Recovery (%)	Graphic Symbol	MATERIAL DESCRIPTION (Elevation (feet) / Depth (feet))	Natural Moisture Content (%)	Total Unit Weight (pcf)	Liquid Limit	Plasticity Index	Pocket Pen. Su (ksf)	Torvane Su (ksf)	TXUU (ksf)	REMARKS
	0						604.2 / 0.0								
		SS	S1	7 8 12	83		Medium dense, moist, black, fine to coarse grained CINDERS (ASH)	11.2							
600	5	SS	S2	12 18 18	100		Very dense, very wet, black, CINDERS (ASH)	12.0							
		Piston	S3		0										*Piston sample 6' to 8': NR. Auger to 8.5'.*
595	10	SS	S4	3 3 4	44		Loose, very wet, black, CINDERS (ASH)	19.4							*Ash flowing into auger at 8.5'. Use SPT.*
							590.4 / 13.8								*Piston sampler.*
590	15	Piston	S5		60		Very soft, wet, light brown, silty CLAY (CL)					0.25			
		Piston	S6		100		Very soft to soft					0.5			
585	20	Piston	S7		92		Soft					0.75			
580	25	Piston	S8		100		Soft, grayish brown, sandy silty CLAY, trace fine gravel (CL)					0.6			
575	30	SS	S9	11 28 43	100		Hard, brown and gray, low plasticity, sandy silty CLAY, trace fine gravel (CL)	8.4		19	6	> 4.5			*28' Harder drilling*

AECOM

Project: Dynegy

Project Location: Kincaid Power Station, IL

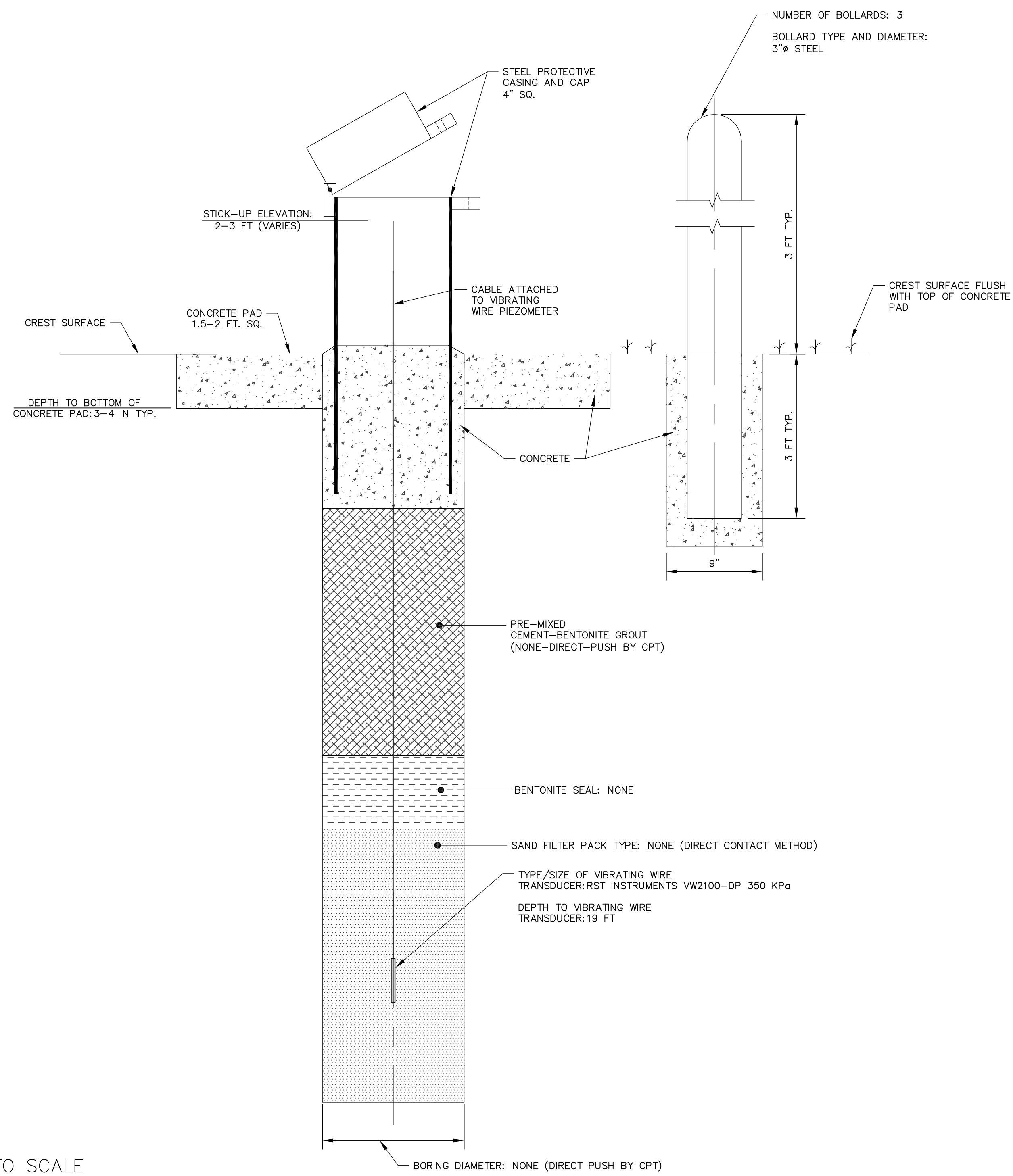
Project Number: 60440697

Log of Boring KIN-B012

Elevation (feet)	Depth (feet)	SAMPLES Type	Number	Sampling Resist. OR Core RQD (%)	Recovery (%)	Graphic Symbol	MATERIAL DESCRIPTION	Elevation (feet)	Depth (feet)	Natural Moisture Content (%)	Total Unit Weight (pcf)	Liquid Limit	Plasticity Index	Pocket Pen. Su (ksf)	Torvane Su (ksf)	TXUU (ksf)	REMARKS
	30																
570	35		S10	22 47 50 / 3"	89		Hard, brown and gray, sandy CLAY, trace fine gravel (CL)			7.1							*35' Very hard drilling*
								566.2	38.0								
565	40		S11	27 38 50 / 4"	89		Very dense, very wet, brown and gray, clayey SAND, trace fine gravel (SC)			14.9							
								564.2	40.0								
							End of Boring at 40 ft										
560	45																
555	50																
550	55																
545	60																
540	65																

Project: Dynegy	Log of Piezometer
Project Location: KINCAID POWER STATION, ILLINOIS	
Project Number: 60440697	Sheet 1 of 1

Piezometer Location	KIN-P004	Date Installed	8 / 2015	Time	
Installed By		Observed By	AECOM	Total Depth	19 FT
Method of Installation	CPT - DIRECT PUSH	Drilling Contractor	CONETEC, INC.	Surface Elevation	601.7 FT
Screened Interval	N/A	Completion Zone	FOUNDATION		
Remarks		Groundwater Level(s)	14.3 FT BGS (10/7/2015)		



NOT TO SCALE

AECOM

Project: Dynegy

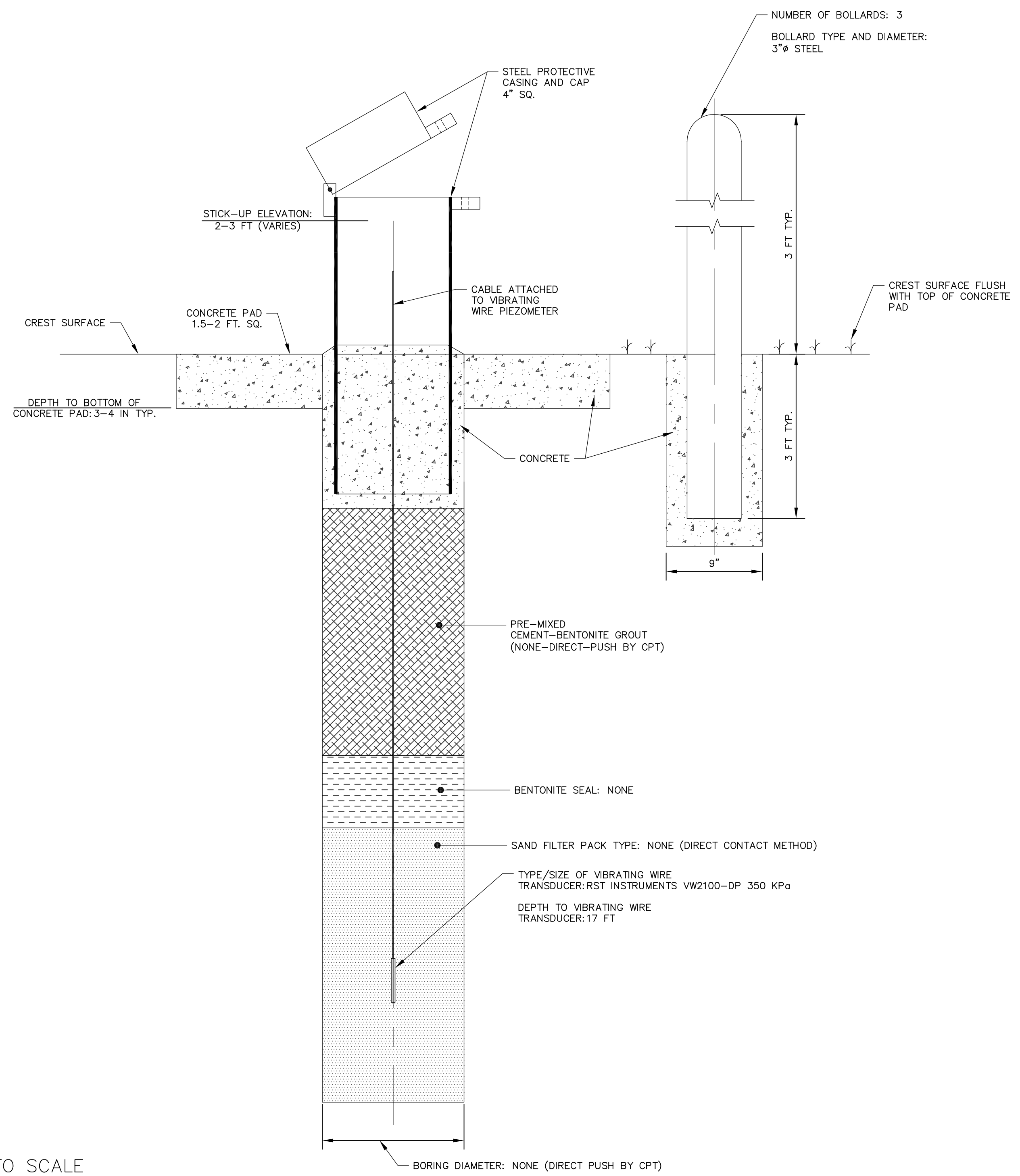
Project Location: KINCAID POWER STATION, ILLINOIS

Project Number: 60440697

Log of Piezometer

Sheet 1 of 1

Piezometer Location	KIN-P011	Date Installed	8 / 2015	Time	
Installed By		Observed By	AECOM	Total Depth	17 FT
Method of Installation	CPT - DIRECT PUSH	Drilling Contractor	CONETEC, INC.	Surface Elevation	605.5 FT
Screened Interval	N/A	Completion Zone	FOUNDATION		
Remarks		Groundwater Level(s)	13.9 FT BGS (10/7/2015)		



NOT TO SCALE

AECOM

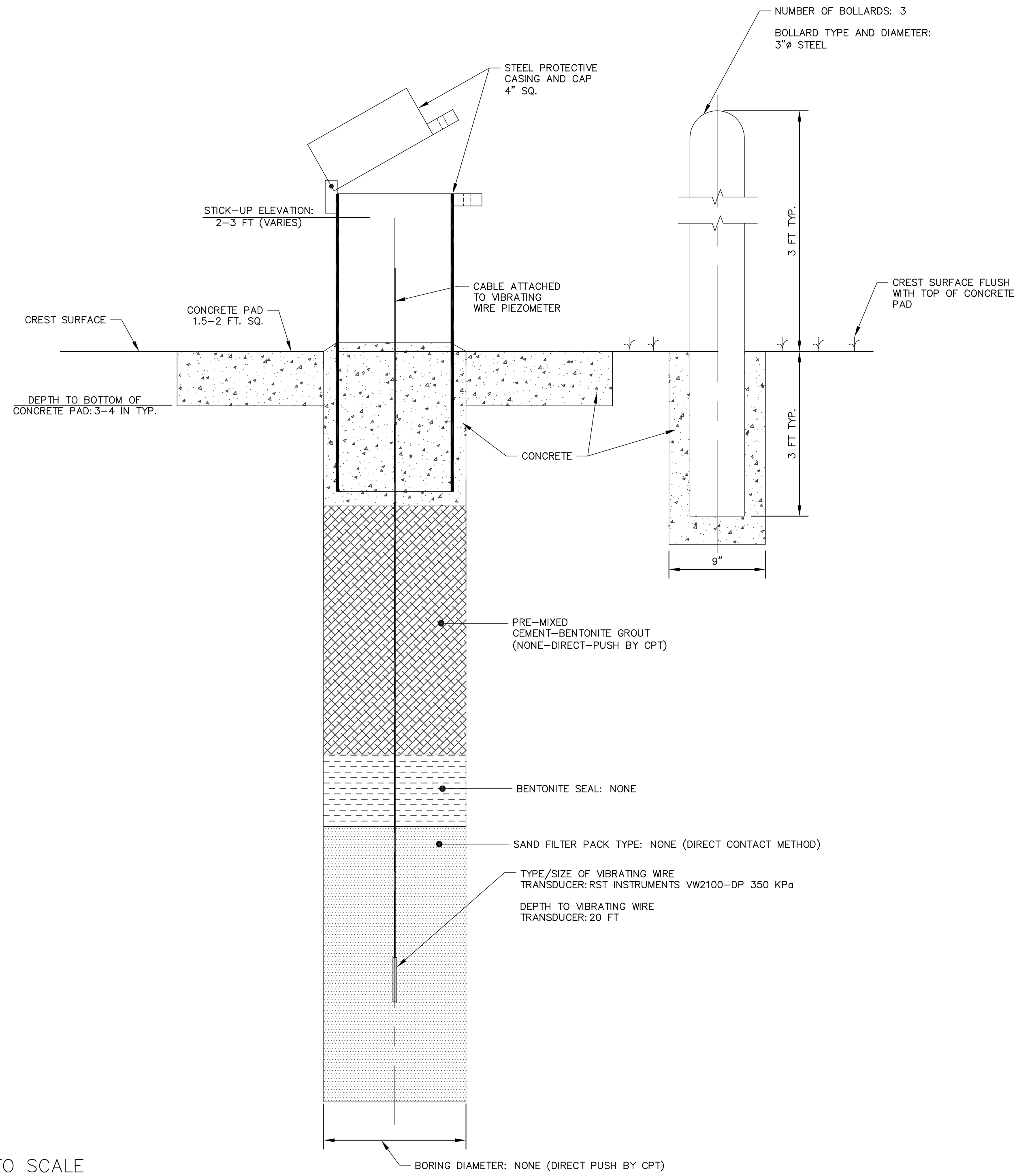
Project: Dynegy

Project Location: KINCAID POWER STATION, ILLINOIS

Project Number: 60440697

Log of Piezometer

Piezometer Location	KIN-P012	Date Installed	8 / 2015	Time	
Installed By		Observed By	AECOM	Total Depth	20 FT
Method of Installation	CPT - DIRECT PUSH	Drilling Contractor	CONETEC, INC.	Surface Elevation	617.0 FT
Screened Interval	N/A	Completion Zone	FOUNDATION		
Remarks		Groundwater Level(s)	16.1 FT BGS (10/7/2015)		



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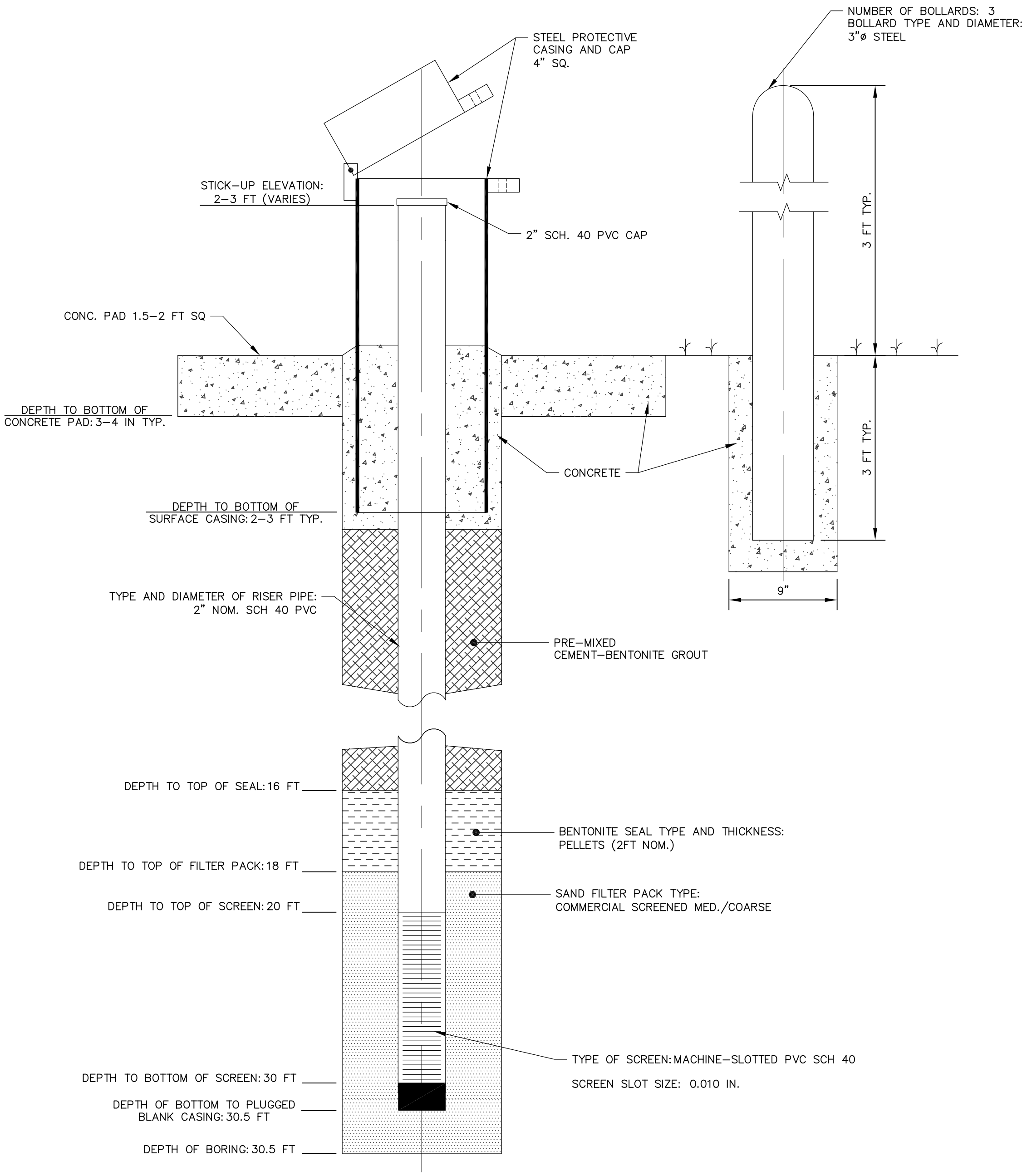
AECOM

Project: Dynegy	Log of Piezometer
Project Location: KIDCAID POWER STATION, ILLINOIS	Sheet 1 of 1
Project Number: 60440697	

Piezometer Location	KIN-P001	Date Installed	8/14/2015	Time	
Installed By		Observed By	AECOM	Total Depth	30 FT
Method of Installation	HOLLOW STEM AUGER	Drilling Contractor	TERRACON, INC.	Surface Elevation	598.0 FT
Screened Interval	20-30 FT	Completion Zone	FOUNDATION		
Remarks	INSTALLED IN KIN-B001	Groundwater Level(s)	12.5 FT BGS ON 10/7/2015		



NOT TO SCALE

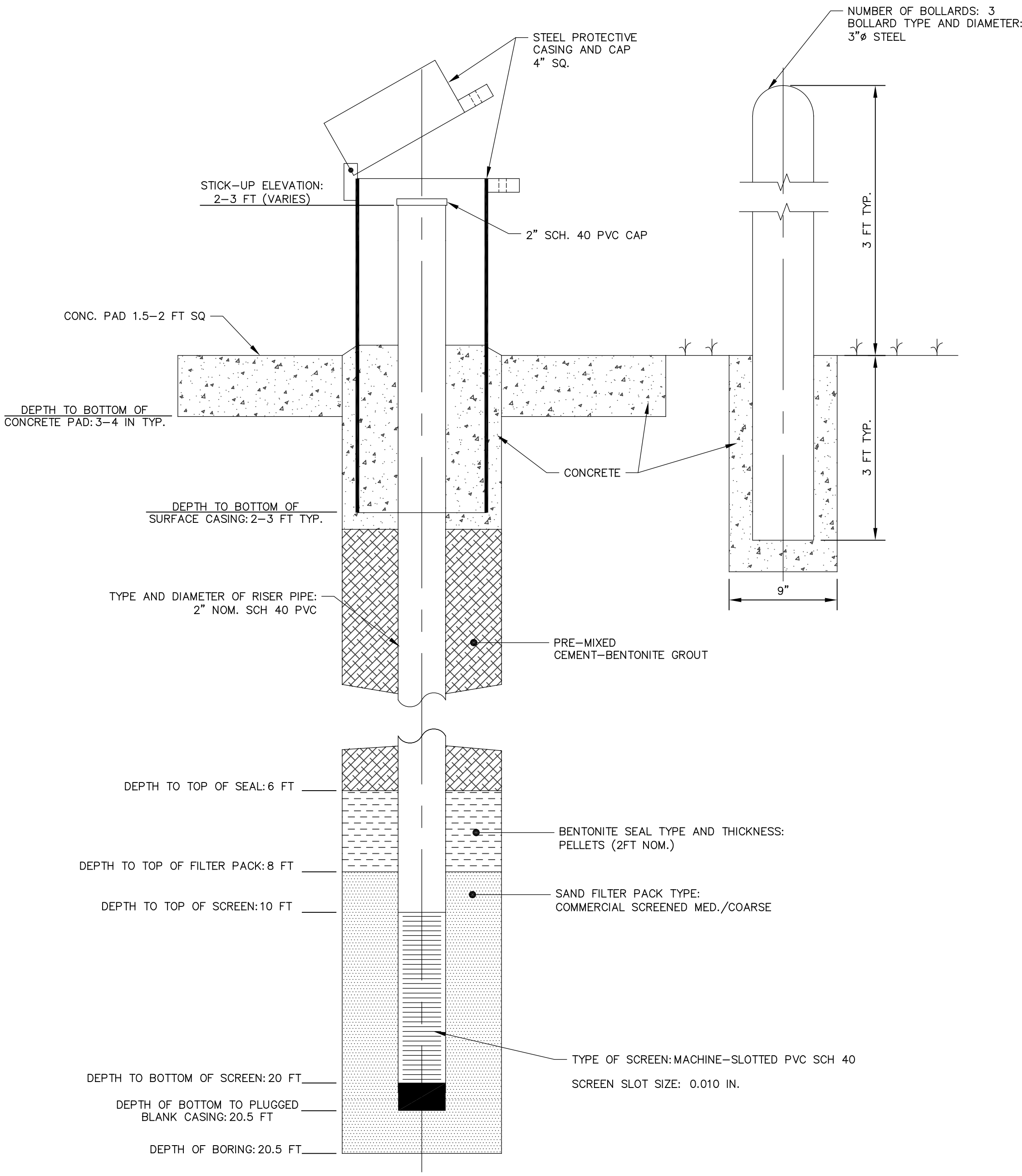
Project: Dynegy

Project Location: KIDCAID POWER STATION, ILLINOIS

Project Number: 60440697

Log of Piezometer

Piezometer Location	KIN-P002	Date Installed	8/13/2015	Time	
Installed By		Observed By	AECOM	Total Depth	20 FT
Method of Installation	HOLLOW STEM AUGER	Drilling Contractor	TERRACON, INC.	Surface Elevation	604.1 FT
Screened Interval	10-20 FT	Completion Zone	FOUNDATION		
Remarks	OFFSET 5 FT EAST OF KIN-B002	Groundwater Level(s)	5.9 FT BGS ON 10/7/2015		



NOT TO SCALE

Project: Dynegy

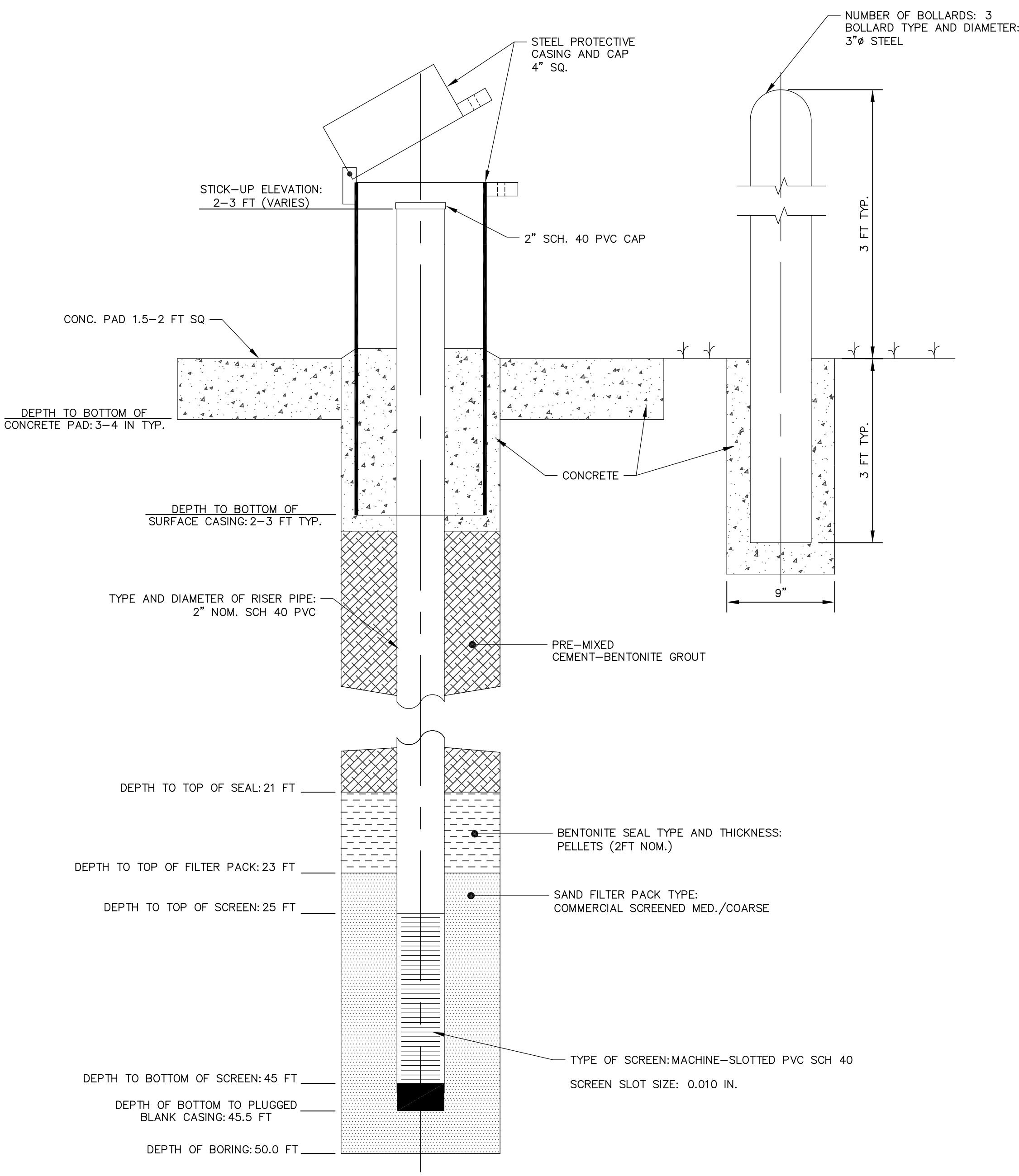
Project Location: KIDCAID POWER STATION, ILLINOIS

Project Number: 60440697

Log of Piezometer

Sheet 1 of 1

Piezometer Location	KIN-P003	Date Installed	8/15/2015	Time	
Installed By		Observed By	AECOM	Total Depth	50 FT
Method of Installation	HOLLOW STEM AUGER	Drilling Contractor	TERRACON, INC.	Surface Elevation	621.8 FT
Screened Interval	25-45 FT	Completion Zone	FOUNDATION		
Remarks	INSTALL IN KIN-B003	Groundwater Level(s)	21.8 FT BGS ON 10/7/2015		



NOT TO SCALE

AECOM

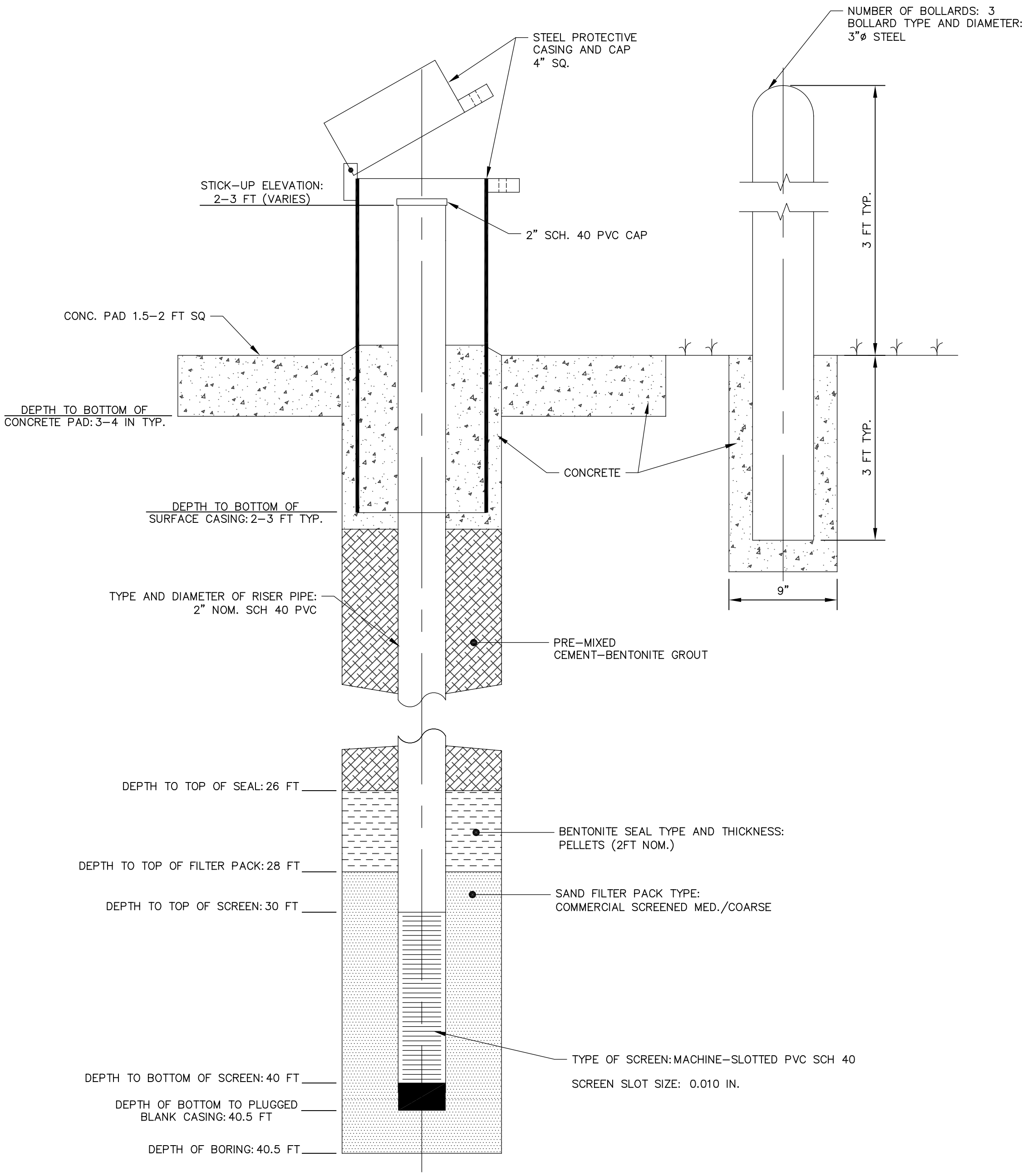
Project: Dynegy

Project Location: KIDCAID POWER STATION, ILLINOIS

Project Number: 60440697

Log of Piezometer

Piezometer Location	KIN-P005	Date Installed	8/19/2015	Time	
Installed By		Observed By	AECOM	Total Depth	40 FT
Method of Installation	HOLLOW STEM AUGER	Drilling Contractor	TERRACON, INC.	Surface Elevation	617.8 FT
Screened Interval	30-40 FT	Completion Zone	FOUNDATION		
Remarks	OFFSET FROM KIN-B004	Groundwater Level(s)	25.9 FT BGS ON 10/7/2015		



NOT TO SCALE

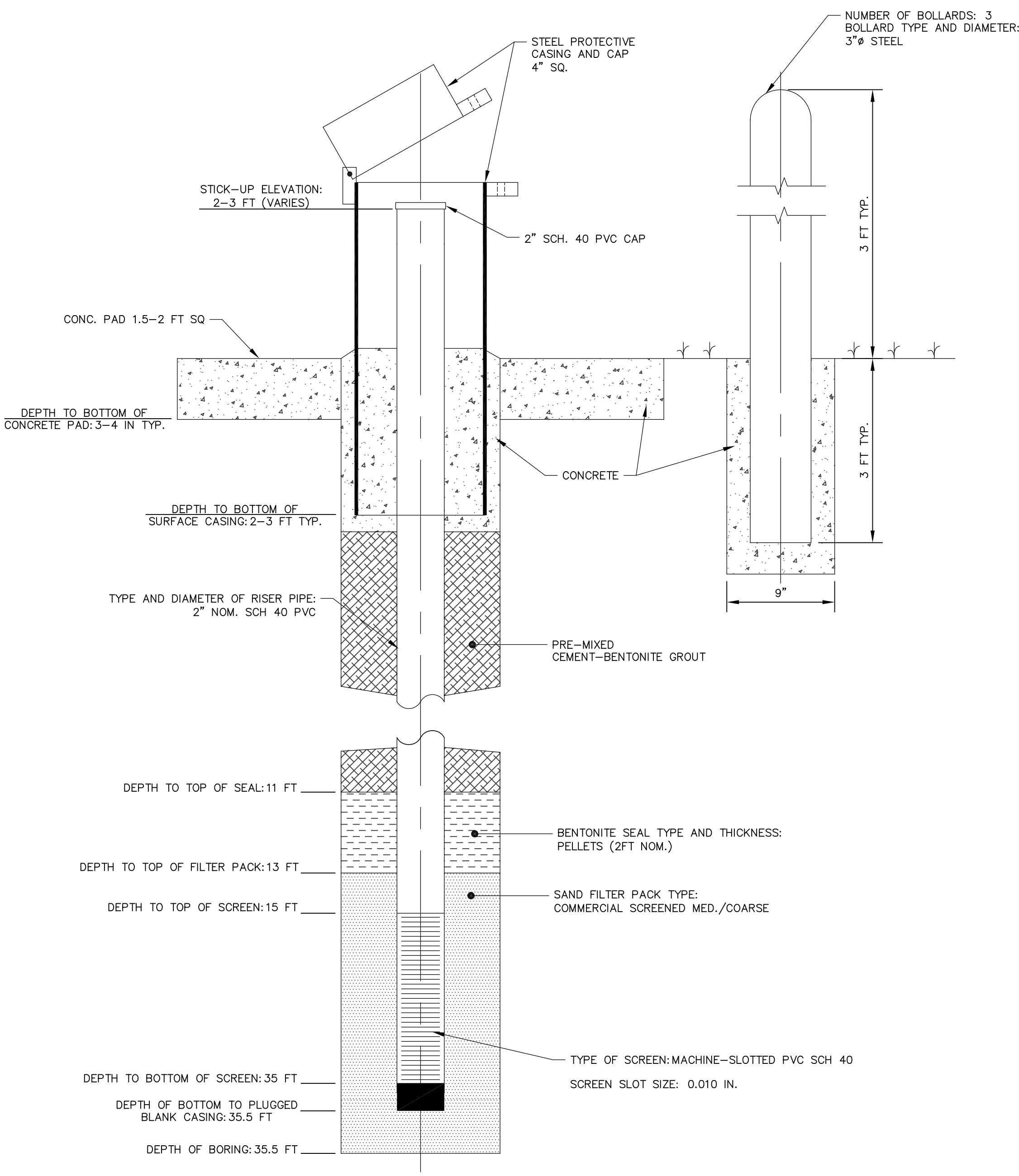
Project: Dynegy

Project Location: KIDCAID POWER STATION, ILLINOIS

Project Number: 60440697

Log of Piezometer

Piezometer Location	KIN-P006	Date Installed	8/23/2015	Time	
Installed By		Observed By	AECOM	Total Depth	35 FT
Method of Installation	HOLLOW STEM AUGER	Drilling Contractor	TERRACON, INC.	Surface Elevation	594.5 FT
Screened Interval	15-35 FT	Completion Zone	FOUNDATION		
Remarks	OFFSET 5 FT SE OF KIN-B005	Groundwater Level(s)	10.3 FT BGS ON 10/7/2015		



NOT TO SCALE

AECOM

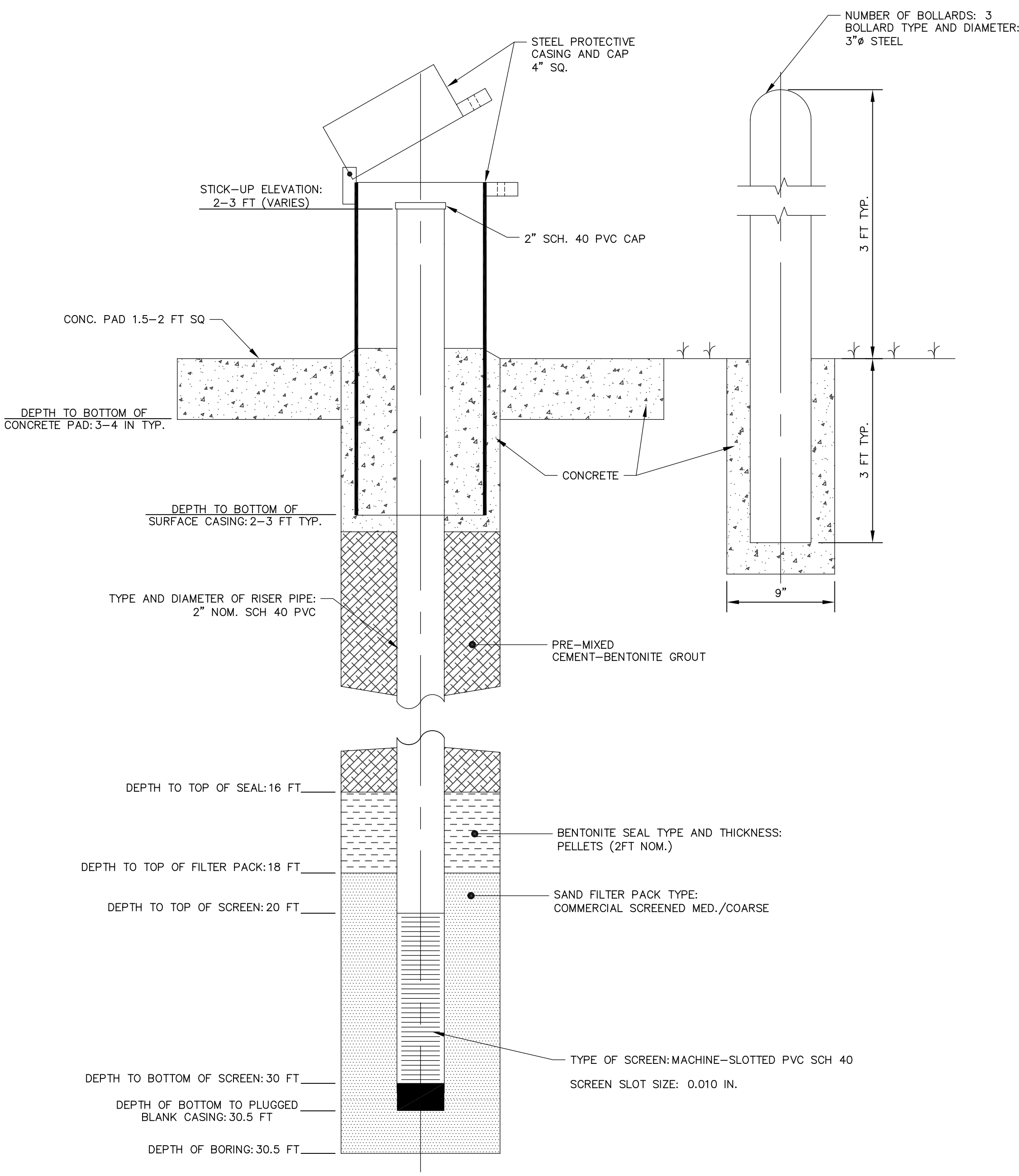
Project: Dynegy

Project Location: KIDCAID POWER STATION, ILLINOIS

Project Number: 60440697

Log of Piezometer

Piezometer Location	KIN-P007	Date Installed	8/20/2015	Time	
Installed By		Observed By	AECOM	Total Depth	30 FT
Method of Installation	HOLLOW STEM AUGER	Drilling Contractor	TERRACON, INC.	Surface Elevation	616.8 FT
Screened Interval	20-30 FT	Completion Zone	FOUNDATION		
Remarks	OFFSET FROM KIN-B007	Groundwater Level(s)	24.0 FT BGS ON 10/7/2015		

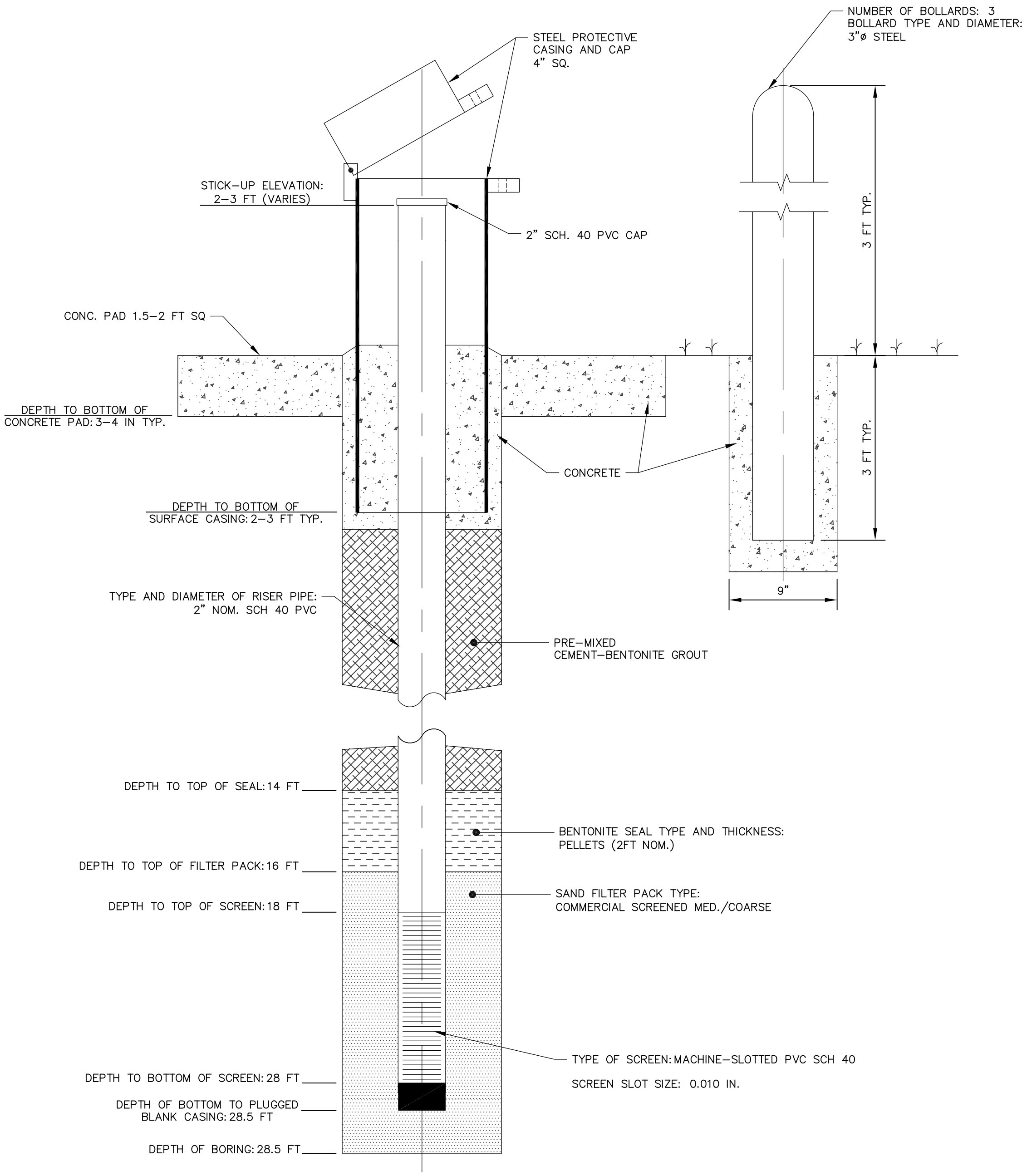


NOT TO SCALE

AECOM

Project: Dynegy	Log of Piezometer
Project Location: KIDCAID POWER STATION, ILLINOIS	Sheet 1 of 1
Project Number: 60440697	

Piezometer Location	KIN-P008	Date Installed	8/20/2015	Time	
Installed By		Observed By	AECOM	Total Depth	30 FT
Method of Installation	HOLLOW STEM AUGER	Drilling Contractor	TERRACON, INC.	Surface Elevation	590.5 FT
Screened Interval	18-28 FT	Completion Zone	FOUNDATION		
Remarks	INSTALL IN KIN-B008	Groundwater Level(s)	5.2 FT BGS ON 10/7/2015		



NOT TO SCALE

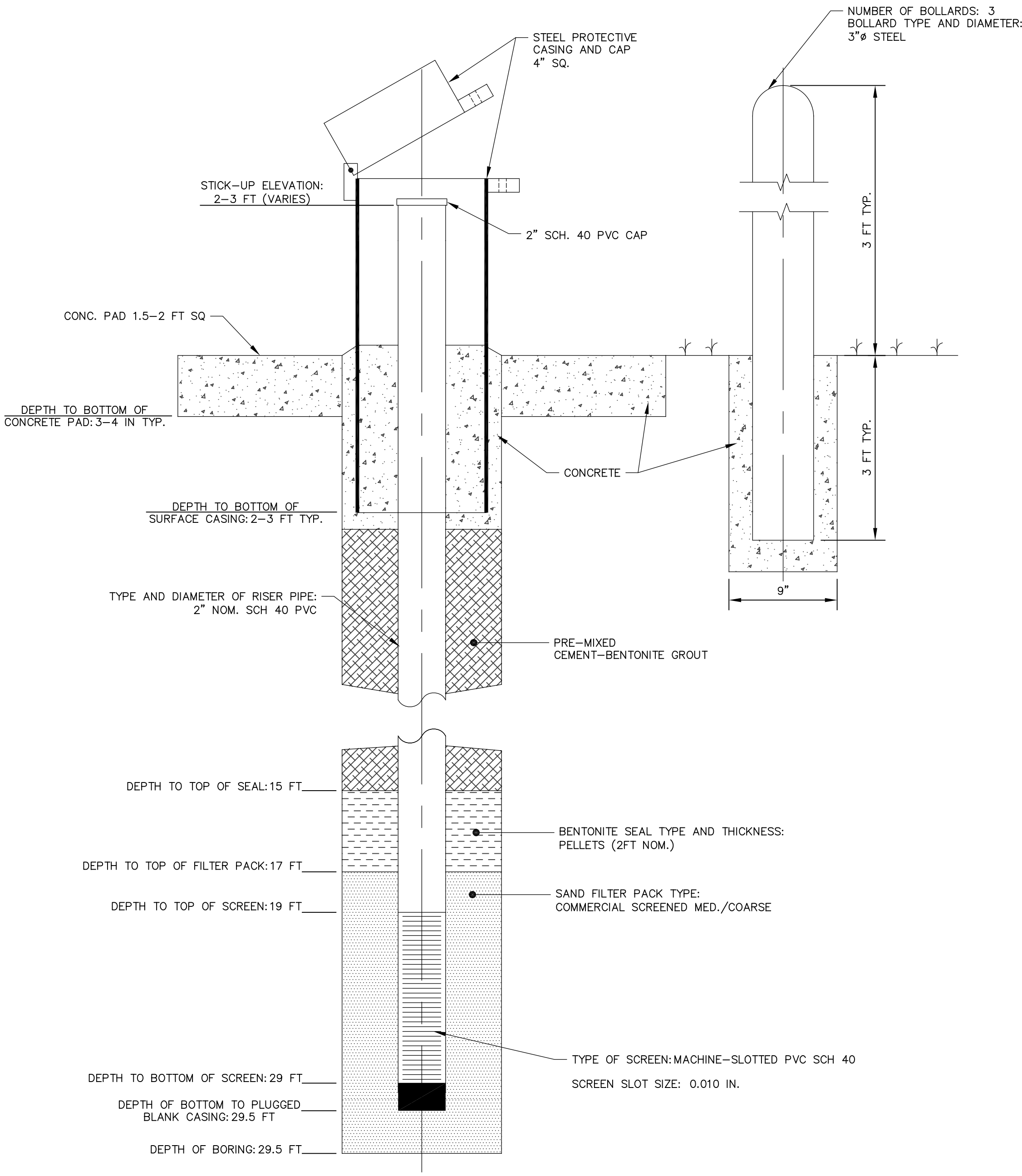
Project: Dynegy

Project Location: KIDCAID POWER STATION, ILLINOIS

Project Number: 60440697

Log of Piezometer

Piezometer Location	KIN-P009	Date Installed	8/20/2015	Time	
Installed By		Observed By	AECOM	Total Depth	30 FT
Method of Installation	HOLLOW STEM AUGER	Drilling Contractor	TERRACON, INC.	Surface Elevation	593.6 FT
Screened Interval	19-29 FT	Completion Zone	FOUNDATION		
Remarks	INSTALL IN KIN-B009	Groundwater Level(s)	6.2 FT BGS ON 10/7/2015		



NOT TO SCALE

AECOM

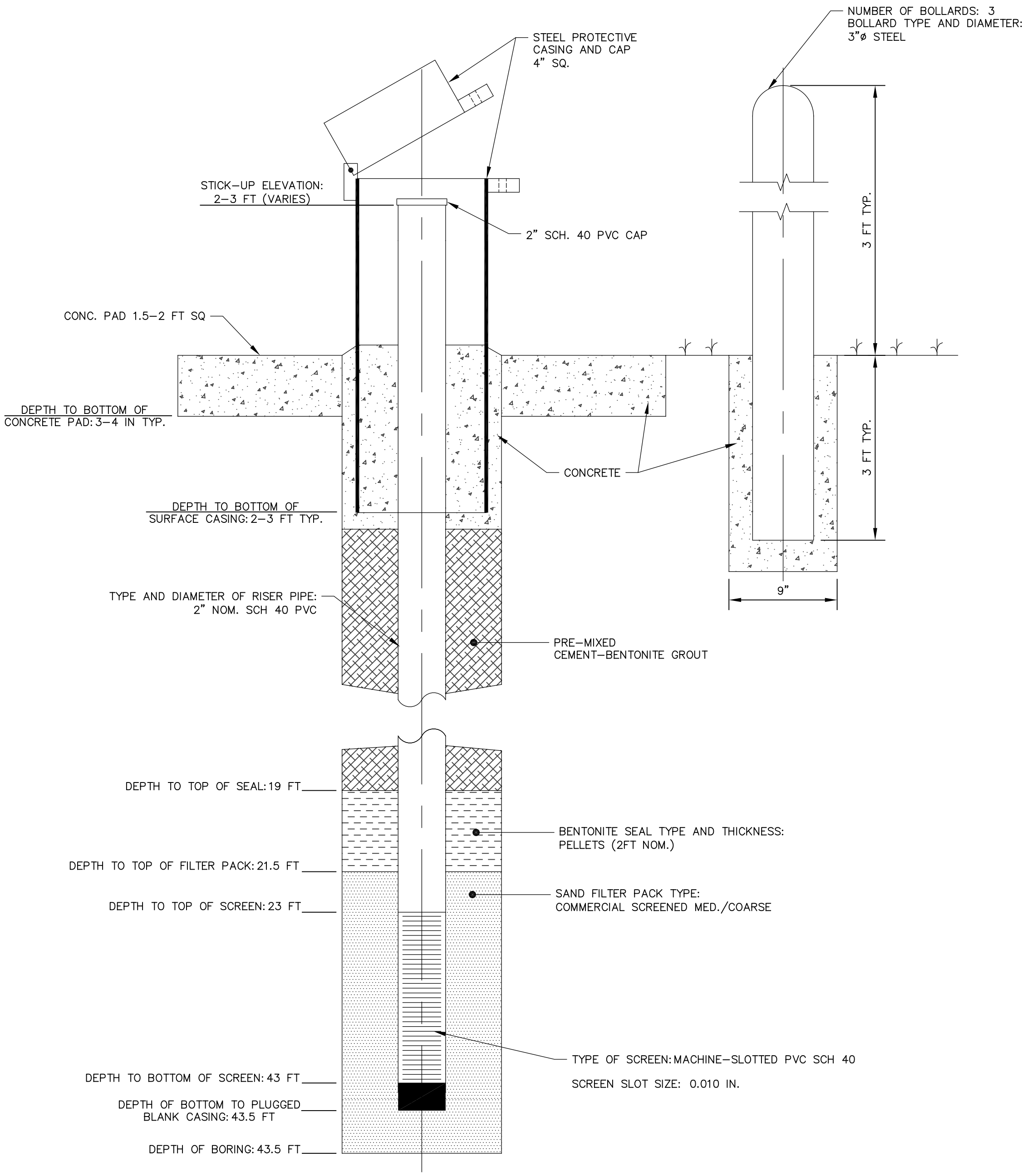
Project: Dynegy

Project Location: KIDCAID POWER STATION, ILLINOIS

Project Number: 60440697

Log of Piezometer

Piezometer Location	KIN-P010	Date Installed	8/26/2015	Time	
Installed By		Observed By	AECOM	Total Depth	43 FT
Method of Installation	HOLLOW STEM AUGER	Drilling Contractor	TERRACON, INC.	Surface Elevation	611.4 FT
Screened Interval	23-43 FT	Completion Zone	FOUNDATION		
Remarks	OFFSET 12 FT W OF KIN-B010	Groundwater Level(s)	13.9 FT BGS ON 10/7/2015		



NOT TO SCALE

AECOM

Civil & Environmental Consultants, Inc.

Chicago Cincinnati Columbus Export Detroit
Indianapolis Nashville Pittsburgh St. Louis

Project Name:
Dominion Energy
Kincaid Power Station
Kincaid, Illinois

Project No.: 100-399

Borehole/Well ID: MW-1

Casing Elevation: 605.12

Ground Elevation: NA

Groundwater Ele.: 591.52

Date Started: 4/19/2010 Completed: 4/20/2010

Drilling Company: Roberts Environmental Drilling, Inc.

Driller:

CEC Representative: Corey Strain

Drilling Method: HSA

Bore Hole: 4.25" Core Size: 2"

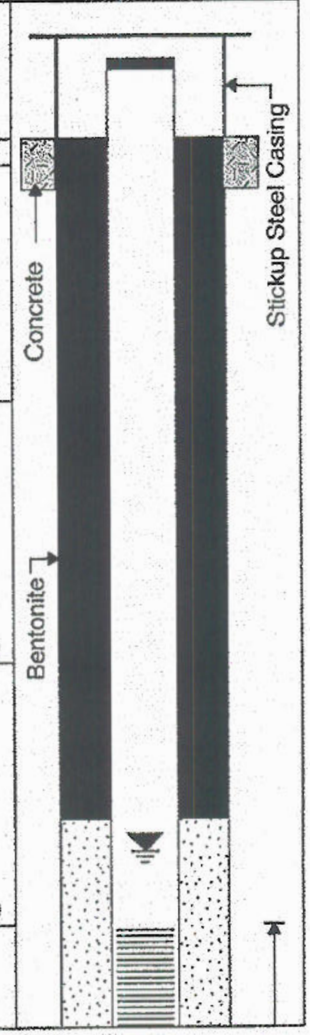
Well Installed: ☑

Screened Interval: 15-25' bgs

Sample Information:
No analytical analysis was performed.

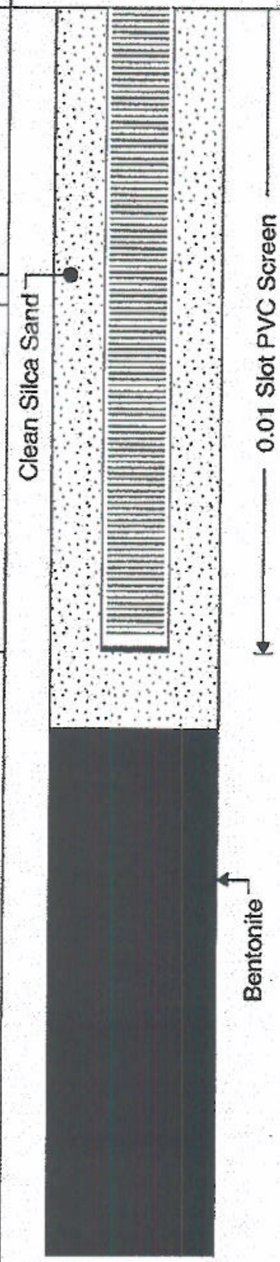
Comments/Problems:

Sample No./ Core Run	Recovery (feet)	Blow Counts/ RQD	Organic Vapor Reading (ppm)	Sample Type	Depth (feet)	Material Description and Comments	Elevation (feet, msl)
					-2		
					0	Ground Surface	0.0
1	1.2	4-6-6	0.0	SS		Topsoil	-0.5
					2	FILL Brown SILTY CLAY, trace gravel, stiff, dry	
					4		
2	0.8	4-4-5	0.0	SS	6	Brownish grey CLAYEY SILT, moist, medium stiff, slightly plastic	-5.0
					8		
3	0.0	2-1-3	NA	SS	10	No Recovery	-10.0
					12		
					14		
4	0.8	2-2-2	0.0	SS	16	Orangish tan SILTY CLAY, soft, plastic, moist	-15.0



Civil & Environmental Consultants, Inc.	Project Name:	Borehole/Well ID: MW-1
	Project No.: 100-399	

Sample No./ Core Run	Recovery	Blow Counts/ RQD	Organic Vapor	Sample Type	Depth (feet)	Material Description and Comments	Graphic Log	Elevation (feet, msl)	Well Diagram
					18				
					20			-20.0	
5	1.5	12-30-50/5	0.0	SS		Brown SILTY SAND, some chert fragments, wet		-20.4	
						GLACIAL TILL Brown SANDY SILT, very stiff, moist			
					22				
					24			-25.0	
6	1.4	24-34-50/5	0.0	SS		Grey SILTY CLAY, some gravel, very stiff, moist(-)			
					26				
					28				
					30			-30.0	
7	1.4	22-25-50/5	0.0	SS		Grey SILTY SAND, coarse grained, wet		-30.4	
						Grey SILTY CLAY, some sand and gravel, very stiff, moist(-)			
					32			-33.0	
8	1.3	24-45-50/3	0.0	SS		Grey SILTY CLAY, some gravel, hard, dry to moist(-)			
					34	Auger refusal @ 33'		-34.5	



Civil & Environmental Consultants, Inc.

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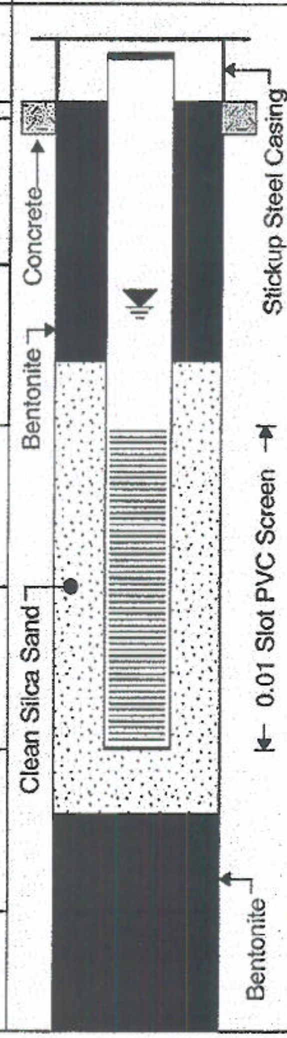
Project Name: Dominion Energy Kincaid Power Station Kincaid, Illinois		Borehole/Well ID: MW-2
		Casing Elevation: 601.44
		Ground Elevation: NA
Project No.: 100-399		Groundwater Ele.: 595.14

Date Started: 4/20/2010 Completed: 4/21/2010	Sample Information: No analytical analysis was performed.
Drilling Company: Roberts Environmental Drilling, Inc.	
Driller:	
CEC Representative: Corey Strain	
Drilling Method: HSA	Comments/Problems:
Bore Hole: 4.25" Core Size: 2"	
Well Installed: ☑	
Screened Interval: 10-20' bgs	

Sample No./ Core Run	Recovery (feet)	Blow Counts/ RQD	Organic Vapor Reading (ppm)	Sample Type	Depth (feet)	Material Description and Comments	Graphic Log	Elevation (feet, msl)
					-2	Ground Surface		0.0
1	0.9	4-4-4	0.0	SS	0, 2, 4	Topsoil Brown SILTY CLAY, medium stiff, moist(-)		-5.0
2	0.8	2-2-2	0.0	SS	6, 8	Brownish grey SILTY CLAY, soft, slightly plastic, moist		-10.0
3	1.3	2-2-2	0.0	SS	10, 12, 14	Dark grey SILTY CLAY, trace sand and gravel, medium stiff, plastic, moist		-15.0
4	1.5	1-2-6	0.0	SS	16, 18	Greyish brown SANDY SILT, trace gravel, soft, slightly plastic, wet		-20.0
5	1.3	22-50/5	0.0	SS	20, 22, 24	GLACIAL TILL Grey SILTY CLAY, trace sand and gravel, hard, dry		-25.0
6	1.0	14-50/5	0.0	SS	26, 28	Grey SILTY CLAY, some sand and gravel, very hard, dry to moist		

Well Diagram



Civil & Environmental Consultants, Inc.	Project Name:	Borehole/Well ID: MW-2
	Project No.: 100-399	

Sample No./ Core Run	Recovery	Blow Counts/ RQD	Organic Vapor	Sample Type	Depth (feet)	Material Description and Comments	Elevation (feet, msl)
7	1.4	26-43-50/5.5	0.0	SS	30	Sand(-)	
					32		
					34		
8	1.3	26-41-50/4	0.0	SS	36		
					38		
9	0.8	30-50/4	0.0	SS	40	Started air-rotary drilling	
					42		
					44		
					46		
					48		-50.0
10	1.5	21-26-31	NA	SS	50	Grey SILTY CLAY, some pebbles, very stiff, moist	
					52		
					54		-56.0
11	1.5	11-23-25	NA	SS	56	BEDROCK Grey SHALE, weathered	-57.5
					58		

Well Diagram: Bentonite

Civil & Environmental Consultants, Inc.
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Project Name: Dominion Energy Kincaid Power Station Kincaid, Illinois	Borehole/Well ID: MW-3
	Casing Elevation: 601.79
	Ground Elevation: NA
Project No.: 100-399	Groundwater Ele.: 593.94

Date Started: 4/15/2010	Completed: 4/15/2010
Drilling Company: Roberts Environmental Drilling, Inc.	
Driller:	
CEC Representative: Corey Strain	
Drilling Method: HSA	
Bore Hole: 4.25"	Core Size: 2"
Well Installed: ☑	
Screened Interval: 14-24' bgs	

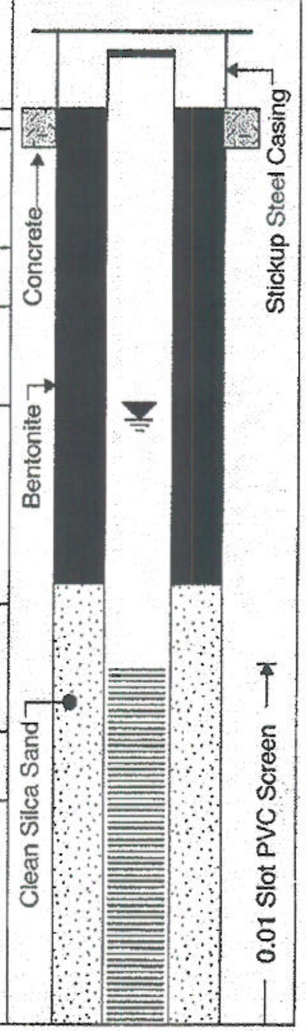
Sample Information:
No analytical analysis was performed.

Comments/Problems:

Sample No./ Core Run	Recovery (feet)	Blow Counts/ RQD	Organic Vapor Reading (ppm)	Sample Type
1	1.4	4-5-7	0.0	SS
2	0.6	2-2-3	0.0	SS
3	1.3	2-2-3	0.0	SS
4	1.5	2-1-2	0.0	SS
5	1.3	2-1-3	0.0	SS
6	0.8	2-1-4	0.0	SS
7	1.5	1-6-7	0.0	SS
8	1.5	7-6-7	0.0	SS

Material Description and Comments	Elevation (feet, msl)
Ground Surface	0.0
Topsoil	
Dark brown SILTY CLAY, moist	-3.5
Brown SILTY CLAY, moist	-5.0
Orange brown CLAYEY SILT, soft, mottled, moist	-7.5
Orangish tan CLAYEY SILT, soft, slightly plastic, mottled, moist Trace gravel	-12.5
Orangish tan SILTY CLAY, trace gravel, plastic, moist	-15.8
SAND, coarse grained, wet	-17.5
GLACIAL TILL Grey SILTY CLAY, trace sand and gravel, soft, moist Thin sand lense	

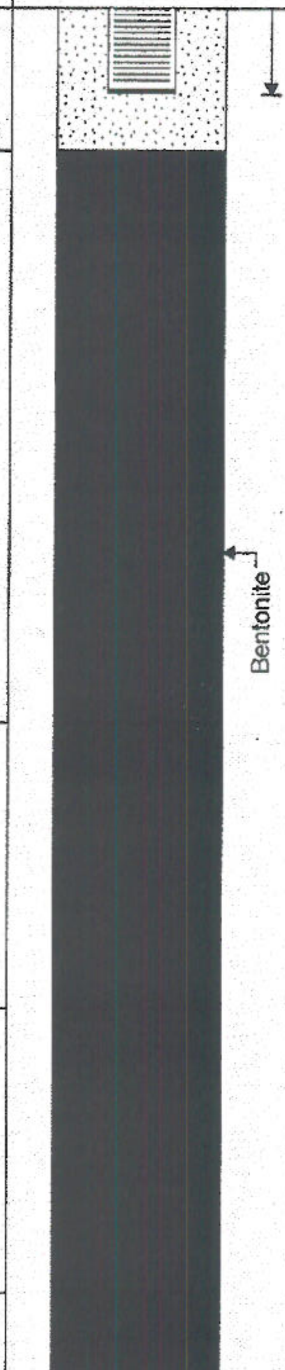
Depth (feet): -2, 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22



Civil & Environmental Consultants, Inc.	Project Name: / Project No.: 100-399	Borehole/Well ID: MW-3

Sample No./ Core Run	Recovery	Blow Counts/ RQD	Organic Vapor	Sample Type	Depth (feet)	Material Description and Comments	Elevation (feet, msl)
					24		-25.0
9	1.5	10-15-23	0.0	SS	26	Grey SILTY CLAY, trace sand and gravel, stiff, dry	
					28		
10	1.5	10-15-22	0.0	SS	30		
					32		
					34		-35.0
11	1.5	6-10-13	0.0	SS	36	Dark grey SILTY CLAY, trace organics, medium stiff, dry	
					38		-40.0
12	1.5	3-5-10	0.0	SS	40	Dark grey to black CLAYEY SILT, trace organics, medium stiff, moist	
					42		
					44		-45.0
13	1.5	8-13-18	0.0	SS	46	Dark grey green SILTY CLAY, trace sand and gravel, very stiff, moist	-46.5

Well Diagram



Civil & Environmental Consultants, Inc.

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Project Name: Dominion Energy Kincaid Power Station Kincaid, Illinois	Borehole/Well ID: MW-4	
	Casing Elevation: 601.18	
	Ground Elevation: NA	
Project No.: 100-399	Groundwater Ele.: 593.73	

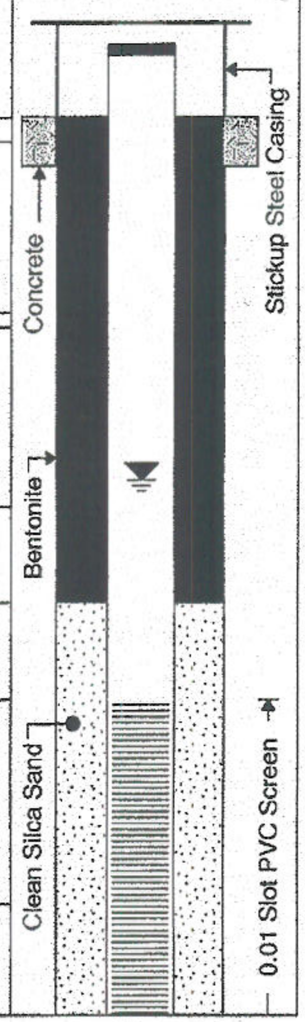
Date Started: 4/14/2010 Completed: 4/14/2010	Sample Information: No analytical analysis was performed.
Drilling Company: Roberts Environmental Drilling, Inc.	
Driller:	
CEC Representative: Corey Strain	
Drilling Method: HSA	Comments/Problems:
Bore Hole: 4.25" Core Size: 2"	
Well Installed: ☑	
Screened Interval: 12-22' bgs	

Sample No./ Core Run	Recovery (feet)	Blow Counts/ RQD	Organic Vapor Reading (ppm)	Sample Type
1	1.3	3-4-5	0.0	SS
2	1.4	4-5-6	0.0	SS
3	1.2	2-2-3	0.0	SS
4	1.0	1-1-2	0.0	SS
5	0.9	1-2-2	0.0	SS
6	1.5	2-2-4	0.0	SS
7	1.5	1-3-3	0.0	SS
8	1.2	2-4-5	0.0	SS

Depth (feet)	Material Description and Comments	Elevation (feet, msl)
0	Ground Surface	0.0
0	Topsoil	
	Dark brown SILTY CLAY, very stiff, mottled, moist(-)	
4	Orange brown SILTY CLAY, moist	-4.0
	Orangish tan CLAYEY SILT, medium stiff, mottled, moist	
8	Light tan CLAYEY SILT, soft, slightly plastic, moist	-8.0
10	Greyish tan CLAYEY SILT, soft, slightly plastic, mottled, moist	-10.0
12	Orangish tan CLAYEY SILT, medium stiff, mottled, moist, grades to a silty clay	-12.0
	Trace sand and gravel, very moist	
16	GLACIAL TILL Grey SILTY CLAY, trace gravel, medium stiff	-16.2

Depth scale: -2, 0, 2, 4, 6, 8, 10, 12, 14, 16, 18

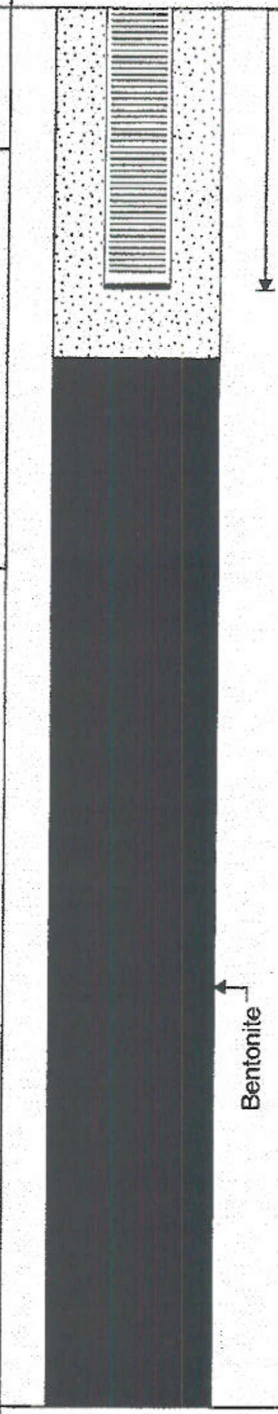
Well Diagram



Civil & Environmental Consultants, Inc.	Project Name:	Borehole/Well ID: MW-4
	Project No.: 100-399	

Sample No./ Core Run	Recovery	Blow Counts/ RQD	Organic Vapor	Sample Type	Depth (feet)	Material Description and Comments	Elevation (feet, msl)
9	1.2	3-7-30	0.0	SS		Thin sand lense, wet	
					20	Grey SILTY CLAY, trace gravel, moist to moist(-)	-20.0
10	1.0	44-41-50/2	0.0	SS			
					22		
11	0.8	42-50/2.5	0.0	SS			
					24		
12	1.0	28-30-40	0.0	SS			
					26	Grey SILTY CLAY, trace gravel, very stiff, dry to moist	-26.0
13	1.5	17-20-35	0.0	SS			
					28		
14	1.5	7-20-40	0.0	SS			
					30		
15	0.0	50/0	0.0	SS			
					32	Trace sand and gravel	
16	1.0	31-50/0	0.0	SS			
					34		
17	0.7	40-50/2.5	0.0	SS			
					36		
					38	Auger refusal @ 38'	-38.0

Well Diagram



Civil & Environmental Consultants, Inc.

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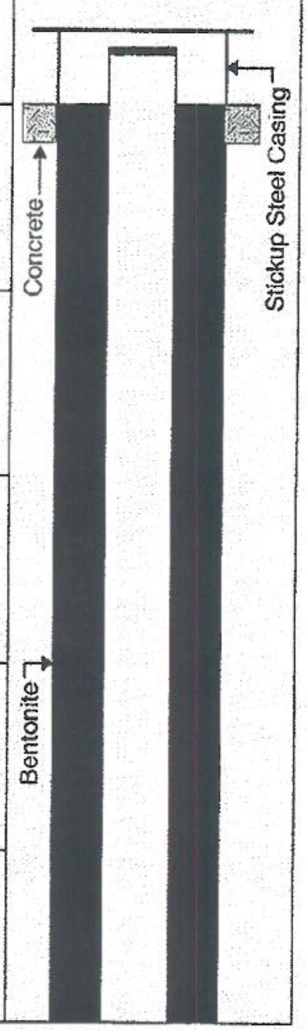
Project Name: Dominion Energy Kincaid Power Station Kincaid, Illinois	Borehole/Well ID: MW-5
	Casing Elevation: 619.91
	Ground Elevation: NA
Project No.: 100-399	Groundwater Ele.: 594.83

Date Started: 4/21/2010 Completed: 4/22/2010	Sample Information: No analytical analysis was performed.
Drilling Company: Roberts Environmental Drilling, Inc.	
Driller:	
CEC Representative: Corey Strain	
Drilling Method: HSA	Comments/Problems:
Bore Hole: 4.25" Core Size: 2"	
Well Installed: ☑	
Screened Interval: 30-40' bgs	

Sample No./ Core Run	Recovery (feet)	Blow Counts/ RQD	Organic Vapor Reading (ppm)	Sample Type	Depth (feet)	Material Description and Comments	Elevation (feet, msl)
					-2		
					0	Ground Surface	0.0
					0–5	FILL Brown SILTY CLAY, some gravel	
1	1.3	4-6-10	0.0	SS	5–10	Grey brown SILTY CLAY, some sand and gravel, very stiff, moist	-5.0
2	1.5	3-5-7	0.0	SS	10–15	Greenish grey SILTY CLAY, trace gravel, very stiff, moist	-10.0
3	1.3	2-3-5	0.0	SS	15–20	Dark grey to black CLAYEY SILT, soft, moist	-15.0
4	1.4	4-5-7	0.0	SS	20–24	Grey brown SILTY CLAY, medium stiff, moist	-20.0

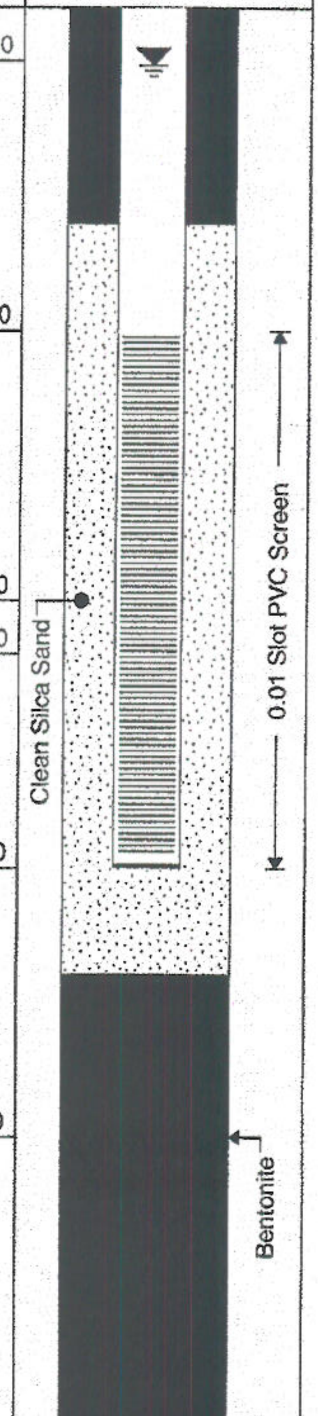
Well Diagram



Civil & Environmental Consultants, Inc.	Project Name: Project No.: 100-399	Borehole/Well ID: MW-5

Sample No./ Core Run	Recovery	Blow Counts/ RQD	Organic Vapor	Sample Type	Depth (feet)	Material Description and Comments	Elevation (feet, msl)
							-25.0
5	1.5	3-3-4	0.0	SS	26	Light to dark grey CLAYEY SILT, soft, moist	
					28		-30.0
6	1.0	3-2-2	0.0	SS	30	Brownish grey SILTY CLAY, plastic, medium stiff, moist	
					32, 34		-35.0
7	1.5	2-4-5	0.0	SS	36	Orangish tan CLAYEY SILT, medium stiff, moist, native	-36.0
						Orangish brown SILTY SAND, wet	
					38		-40.0
8	1.3	23-41-50/5	0.0	SS	40	GLACIAL TILL Light grey SILTY CLAY, some gravel, hard, moist(-)	
					42, 44		-45.0
9	0.7	45-50/2	0.0	SS	46	Grey SILTY CLAY, some sand and gravel, hard, moist(-)	
					48, 50		

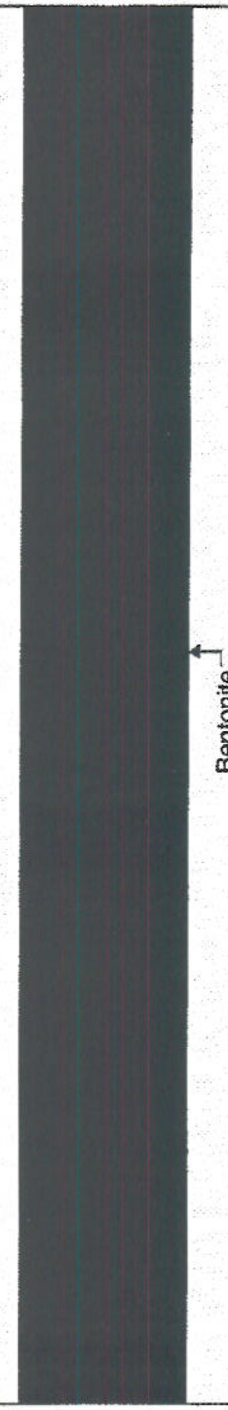
Well Diagram



Civil & Environmental Consultants, Inc.	Project Name: Project No.: 100-399	Borehole/Well ID: MW-5

Sample No./ Core Run	Recovery	Blow Counts/ RQD	Organic Vapor	Sample Type	Depth (feet)	Material Description and Comments	Elevation (feet, msl)
							-55.0
10		50/2.5	0.0	SS	56	Dark grey SANDY SILT, trace gravel, stiff, moist	-65.0
11	1.3	16-30-36	0.0	SS	66	Dark greyish green SANDY SILT, trace gravel, stiff, moist	-75.0
12	0.4	30-42-3	0.0	SS	76	BEDROCK SHALE, weathered	-76.0

Well Diagram



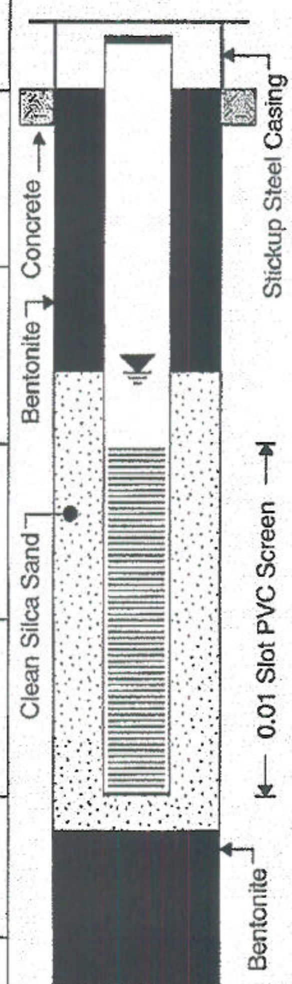
CEC
Civil & Environmental Consultants, Inc.
Chicago Cincinnati Columbus Export Detroit
Indianapolis Nashville Pittsburgh St. Louis

Project Name: Dominion Energy Kincaid Power Station Kincaid, Illinois	Borehole/Well ID: MW-6
	Casing Elevation: 600.83
	Ground Elevation: NA
Project No.: 100-399	Groundwater Ele.: 592.85

Date Started: 4/16/2010 Completed: 4/16/2010	Sample Information: No analytical analysis was performed.
Drilling Company: Roberts Environmental Drilling, Inc.	
Driller:	
CEC Representative: Corey Strain	
Drilling Method: HSA	Comments/Problems:
Bore Hole: 4.25" Core Size: 2"	
Well Installed: ☑	
Screened Interval: 10-20' bgs	

Sample No./ Core Run	Recovery (feet)	Blow Counts/ RQD	Organic Vapor Reading (ppm)	Sample Type	Depth (feet)	Material Description and Comments	Elevation (feet, msl)
					-2	Ground Surface	0.0
1	1.3	2-4-4	0.0	SS	0	Dark brown CLAYEY SILT, some organics, slightly plastic, medium stiff, moist	-5.0
2	1.3	2-1-2	0.0	SS	5	Tan brown CLAYEY SILT, trace organics, slightly plastic, soft, moist	-10.0
3	1.5	2-3-4	0.0	SS	10	Brown SANDY SILT, some clay, trace gravel, medium stiff, moist to wet	-15.0
4	1.3	3-1-1	0.0	SS	15	Orangish brown SILTY SAND, coarse grained, trace gravel, soft, wet	-20.0
5	0.8	30-50/5.5	0.0	SS	20	GLACIAL TILL Grey SILTY CLAY, trace gravel, medium stiff, moist	-24.0
6	1.3	20-36-50/5.5	0.0	SS	24	Grey SILTY CLAY, trace gravel, very stiff, dry	-25.5

Well Diagram



Civil & Environmental Consultants, Inc.

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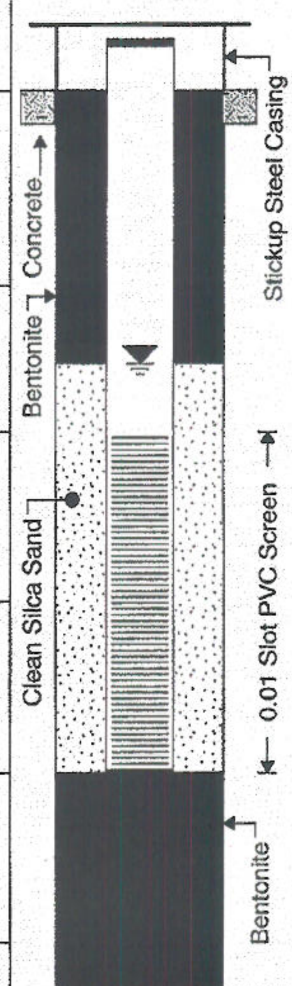
Project Name: Dominion Energy Kincaid Power Station Kincaid, Illinois	Borehole/Well ID: MW-7	
	Casing Elevation: 598.02	
	Ground Elevation: NA	
Project No.: 100-399	Groundwater Ele.: 589.32	

Date Started: 4/16/2010 Completed: 4/16/2010	Sample Information: No analytical analysis was performed.
Drilling Company: Roberts Environmental Drilling, Inc.	
Driller:	
CEC Representative: Corey Strain	
Drilling Method: HSA	Comments/Problems:
Bore Hole: 4.25" Core Size: 2"	
Well Installed: ☑	
Screened Interval: 10-20' bgs	

Sample No./ Core Run	Recovery (feet)	Blow Counts/ RQD	Organic Vapor Reading (ppm)	Sample Type	Depth (feet)	Material Description and Comments	Graphic Log	Elevation (feet, msl)
					-2	Ground Surface		0.0
1	1.5	3-4-3	0.0	SS	0	Brown CLAYEY SILT, trace sand and gravel, medium stiff, moist		-5.7
2	1.5	3-2-4	0.0	SS	6	Dark grey CLAYEY SILT, trace gravel, some organics, slightly plastic, moist		-10.0
3	1.4	2-3-4	0.0	SS	10	Brown grey SILTY CLAY, trace gravel, plastic, medium stiff, mottled, moist		-15.0
4	1.5	1-1-2	0.0	SS	16	Orangish brown SANDY SILT, trace gravel, soft, wet		-20.0
5	1.5	10-25-35	0.0	SS	20	GLACIAL TILL Grey SILTY CLAY, trace gravel, non-plastic, moist(-)		-25.0
6	1.5	20-35-45	0.0	SS	26	Grey SILTY CLAY, trace sand and gravel, stiff, non-plastic, dry		-26.5

Well Diagram



Civil & Environmental Consultants, Inc.

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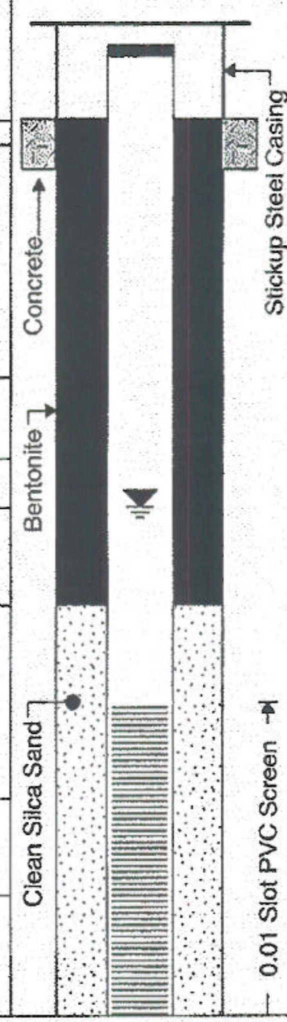
Indianapolis Nashville Pittsburgh St. Louis

Civil & Environmental Consultants, Inc.	Project Name: Dominion Energy Kincaid Power Station Kincaid, Illinois	Borehole/Well ID: MW-8
		Casing Elevation: 603.54
		Ground Elevation: NA
	Project No.: 100-399	Groundwater Ele.: 595.55
Date Started: 4/13/2010 Completed: 4/13/2010	Sample Information: No analytical analysis was performed.	
Drilling Company: Roberts Environmental Drilling, Inc.		
Driller:		
CEC Representative: Corey Strain		
Drilling Method: HSA	Comments/Problems:	
Bore Hole: 4.25" Core Size: 2"		
Well Installed: ☑		
Screened Interval: 12-22' bgs.		

Sample No./ Core Run	Recovery (feet)	Blow Counts/ RQD	Organic Vapor Reading (ppm)	Sample Type	Depth (feet)	Material Description and Comments	Graphic Log	Elevation (feet, msl)
					-2			
					0	Ground Surface		0.0
						Topsoil		
						Brown SILTY CLAY, trace sand, medium stiff, moist, no odor		
					2			
1	1.0	2-4-8	0.4	SS				
					4			
2	1.0	2-3-4	0.0	SS				-5.3
					6	Grey brown SILTY CLAY, trace gravel, moist		
3	1.5	3-3-5	0.0	SS				-7.0
						Grey SILTY CLAY, medium stiff, moist		-8.0
					8			
4	1.4	3-3-2	0.0	SS		Orangish brown SILTY CLAY, trace sand, moist to wet		-10.0
					10	Orangish tan CLAYEY SILT, trace sand, slightly plastic, medium stiff, wet		
5	1.5	2-2-3	0.0	SS				
					12			
6	1.8	4-1-1	0.0	SS				-14.0
					14	Tan CLAYEY SILT, trace sand, slightly plastic, soft, moist to wet		
7	1.7	1-2-2	0.0	SS				-16.0
					16	Orangish tan SILTY CLAY, trace sand, slightly plastic, medium stiff, wet		
8	1.5	1-1-3	0.0	SS				
					18			

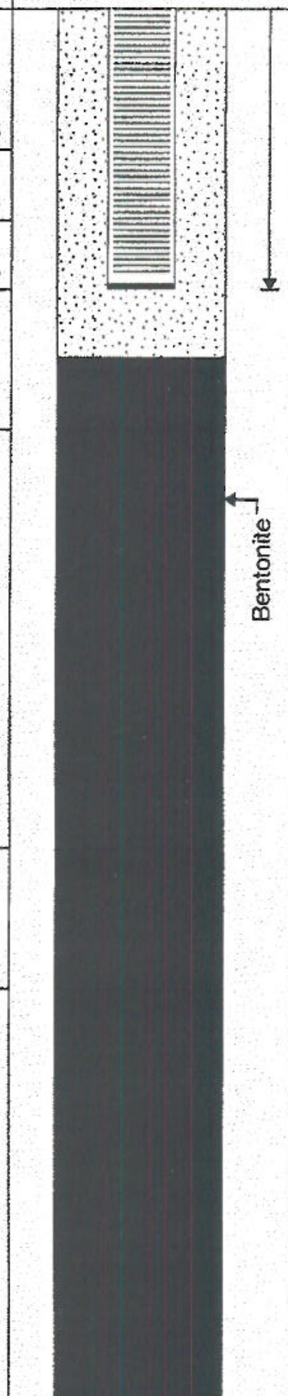
Well Diagram



Civil & Environmental Consultants, Inc.	Project Name: Project No.: 100-399	Borehole/Well ID: MW-8

Sample No./ Core Run	Recovery	Blow Counts/ RQD	Organic Vapor	Sample Type	Depth (feet)	Material Description and Comments	Elevation (feet, msl)
9	1.9	1-1-2	0.0	SS		Thin sand lens	-20.0
10	1.4	1-2-6	0.0	SS	20	Orangish brown SILTY SAND, soft, wet Brown grey SILTY CLAY, medium stiff, moist	-21.0 -22.0
11	1.3	10-50	0.0	SS	22	GLACIAL TILL Grey SILTY CLAY, trace sand and gravel, moist	-24.0
12	1.9	21-25-48	0.0	SS	24	Grey SILTY CLAY, trace gravel, dry	
13	1.0	30-50/5	0.0	SS	26		
14	0.9	25-50/5	0.0	SS	28	Thin sand lens, wet	-30.0
15	0.9	27-50/3	0.0	SS	30	Grey SILTY SAND, dense, moist to wet	-32.0
16	0.9	41-50/5	0.0	SS	32	Grey SILTY CLAY, trace sand and gravel, stiff, dry to moist	
17	0.9	40-50/5	0.0	SS	34		
18	0.8	40-50	0.0	SS	36		-38.0
					38		

Well Diagram



Civil & Environmental Consultants, Inc.

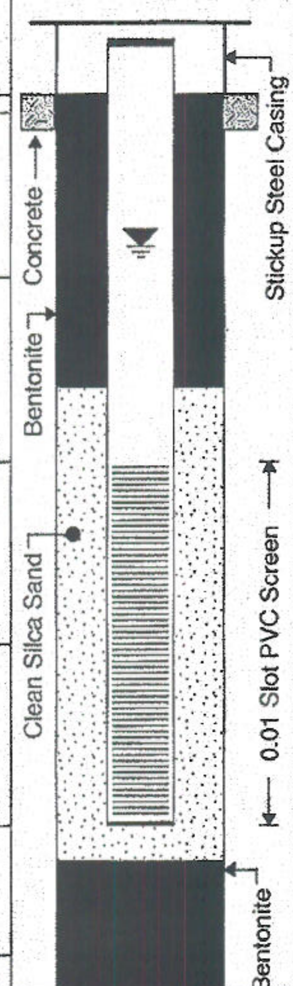
Chicago Cincinnati Columbus Export Detroit
Indianapolis Nashville Pittsburgh St. Louis

Project Name: Dominion Energy Kincaid Power Station Kincaid, Illinois	Borehole/Well ID: MW-9	
	Casing Elevation: 599.73	
	Ground Elevation: NA	
Project No.: 100-399	Groundwater Ele.: 595.59	

Date Started: 4/19/2010 Completed: 4/19/2010	Sample Information: No analytical analysis was performed.
Drilling Company: Roberts Environmental Drilling, Inc.	
Driller:	
CEC Representative: Corey Strain	
Drilling Method: HSA	Comments/Problems:
Bore Hole: 4.25" Core Size: 2"	
Well Installed: ☑	
Screened Interval: 10-20' bgs	

Sample No./ Core Run	Recovery (feet)	Blow Counts/ RQD	Organic Vapor Reading (ppm)	Sample Type	Depth (feet)	Material Description and Comments	Elevation (feet, msl)
					-2		
					0	Ground Surface	0.0
1	1.3	2-5-4	0.4	SS		Topsoil	
					2	Dark brown CLAYEY SILT, medium stiff, moist	
					4		-5.0
2	1.1	2-2-4	0.0	SS	6	Brownish tan CLAYEY SILT, soft, slightly plastic, mottled, moist	
					8		-10.0
3	1.3	2-3-4	0.0	SS	10	Brownish tan SILTY CLAY, trace sand, medium stiff, slightly plastic, moist	
					12		
					14		-15.0
4	0.8	2-2-4	0.0	SS	16	Brown CLAYEY SILT, trace sand and gravel, medium stiff, moist to wet	
					18	Thin sand lens	-20.0
5	0.9	22-50/5	0.0	SS	20	GLACIAL TILL Grey CLAYEY SILT, some sand, trace gravel, medium stiff, moist (-) to dry	
					22		-23.5
6	0.8	24-50/5	0.0	SS	24	Grey SILTY CLAY, trace sand	-24.5

Well Diagram



Civil & Environmental Consultants, Inc.

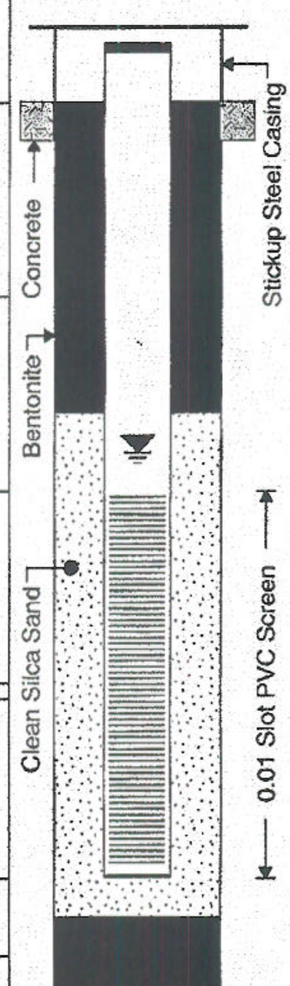
Chicago Cincinnati Columbus Export Detroit
Indianapolis Nashville Pittsburgh St. Louis

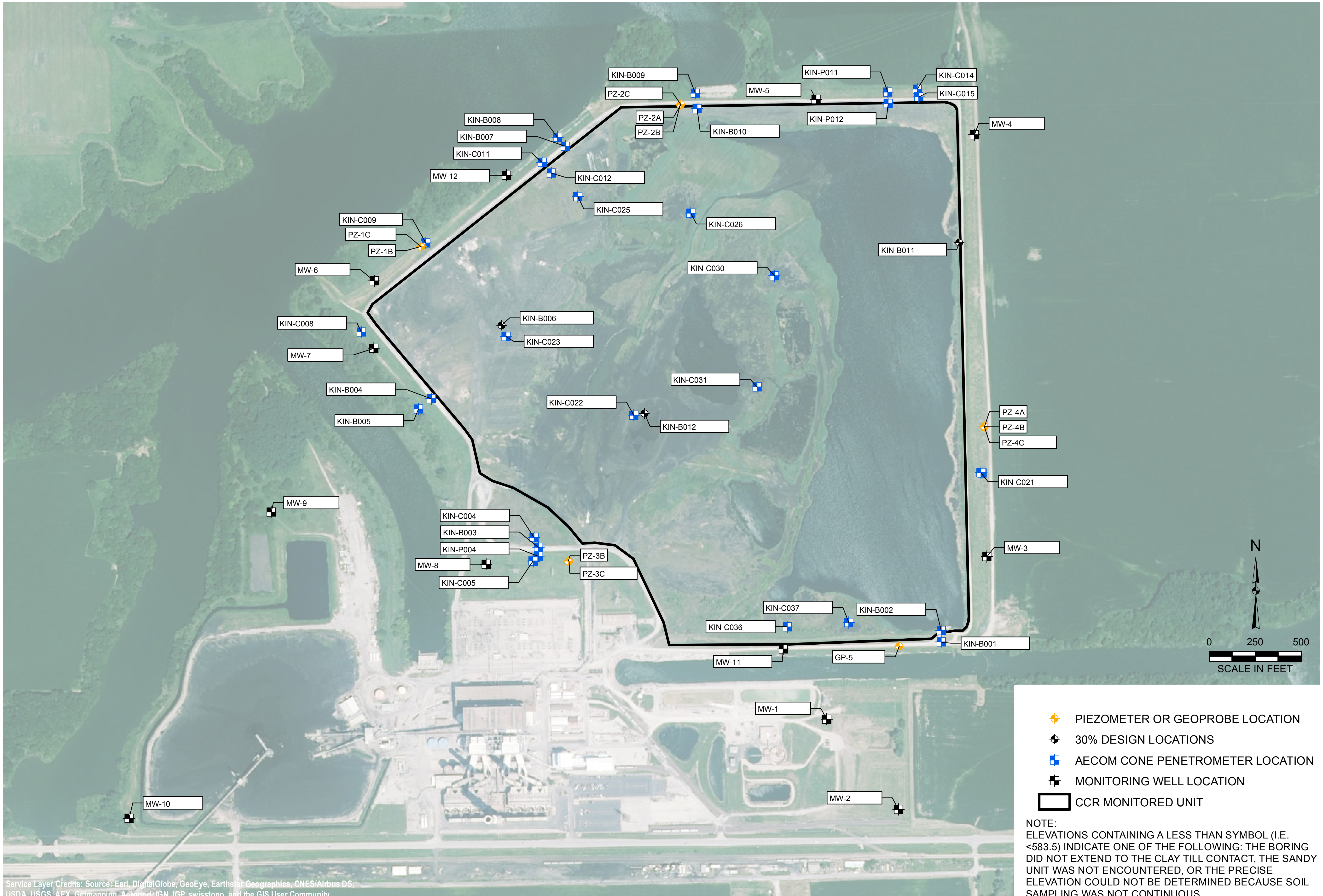
Project Name: Dominion Energy Kincaid Power Station Kincaid, Illinois		Borehole/Well ID: MW-10
		Casing Elevation: 600.40
		Ground Elevation: NA
Project No.: 100-399		Groundwater Ele.: 591.40

Date Started: 4/19/2010 Completed: 4/19/2010	Sample Information: No analytical analysis was performed.
Drilling Company: Roberts Environmental Drilling, Inc.	
Driller:	
CEC Representative: Corey Strain	
Drilling Method: HSA	Comments/Problems:
Bore Hole: 4.25" Core Size: 2"	
Well Installed: ☑	
Screened Interval: 10-20' bgs	

Sample No./ Core Run	Recovery (feet)	Blow Counts/ RQD	Organic Vapor Reading (ppm)	Sample Type	Depth (feet)	Material Description and Comments	Graphic Log	Elevation (feet, msl)
					-2	Ground Surface		0.0
1	1.4	4-5-5	0.4	SS	0–5	FILL Dark brown SILTY CLAY, trace sand, medium stiff, some coal fragments, moist		-5.0
2	0.9	2-2-4	0.0	SS	5–10	Greenish grey CLAYEY SILT, trace coal fragments, medium stiff, slightly plastic, moist		-10.0
3	1.5	2-2-5	0.0	SS	10–15	Orangish tan CLAYEY SILT, some sand, medium stiff, slightly plastic, moist		-15.0
4	1.5	1-4-10	0.0	SS	15–20	Brown SILTY SAND, trace gravel, wet GLACIAL TILL Brown SILTY CLAY, some gravel, very stiff, moist Thin sand lens		-20.0
5	1.5	15-32-46	0.0	SS	20–22	Grey SILTY CLAY, some gravel, very stiff, moist(-) to dry		-22.0
6	0.9	35-50/5	0.0	SS	22–23	Grey SILTY CLAY, trace gravel, very stiff, dry		-23.0

Well Diagram





- PIEZOMETER OR GEOPROBE LOCATION
- 30% DESIGN LOCATIONS
- AECOM CONE PENETROMETER LOCATION
- MONITORING WELL LOCATION
- CCR MONITORED UNIT

NOTE:
ELEVATIONS CONTAINING A LESS THAN SYMBOL (I.E. <583.5) INDICATE ONE OF THE FOLLOWING: THE BORING DID NOT EXTEND TO THE CLAY TILL CONTACT, THE SANDY UNIT WAS NOT ENCOUNTERED, OR THE PRECISE ELEVATION COULD NOT BE DETERMINED BECAUSE SOIL SAMPLING WAS NOT CONTINUOUS.

Y:\Mapping\Projects\22\2285_Kincaid\MXD\Figure 2_Top of Aquifer_rev2.mxd Author: toushman Date/Time: 5/19/2016, 3:55:29 PM

DRAWN BY/DATE: TDC 5/19/16
REVIEWED BY/DATE: NRK 5/19/16
APPROVED BY/DATE: SJC 5/19/16

INVESTIGATION LOCATIONS

CCR RULE GROUNDWATER MONITORING
KINCAID ASH POND
KINCAID POWER STATION
KINCAID, ILLINOIS

DRAFT

PROJECT NO: 2365/5

FIGURE NO: 2

NATURAL RESOURCE TECHNOLOGY

SOIL BORING LOG INFORMATION

NATURAL RESOURCE TECHNOLOGY

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Kincaid Power Station		PZ-4C

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
John Gates Bulldog Drilling	3/30/2016	3/30/2016	hollow stem auger

Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
PZ-4C	Feet (NAVD88)	597.83 Feet (NAVD88)	8.3 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒	Lat / Long	Local Grid Location
State Plane 1,067,582.54 N, 2,488,047.98 E E/Ⓦ 1/4 of 1/4 of Section , T N, R	Lat ° ' " Long ° ' "	Feet ☐N ☐S Feet ☐E ☐W

Facility ID	County	State	Civil Town/City/ or Village
	Christian	Illinois	Kincaid

Sample: Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
CS	42 39		0–3	0 - 0.5' **FILL, SILT:** ML, very dark grayish brown (10YR 3/2), trace roots, sand, and sand sized ash, cohesive, low plasticity, stiff (2.0 tsf), dry.	(FILL) ML								Sampling completed using 2" macro core
				0.5 - 15.5' **LEAN CLAY:** CL, very dark grayish brown (10YR 3/2), trace sand and fine gravel, cohesive, medium to high plasticity, very stiff to hard (3.0 - 4.5 tsf), dry to moist. 1.7' black (10YR 2/1).	CL								
CS	60 54		3.5–8.5	3.5' soft to stiff (0.5 - 2.0 tsf), moist. 3.8' pale brown (10YR 6/3) with dark yellowish brown (10YR 4/4) and dark gray (10YR 4/1) mottling.									
CS	60 57		8.5–12	8.5' dark gray (10YR 4/1), soft (0.5 tsf).									

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm	
[signature]	Natural Resource Technology 234 W. Florida St., Fifth Floor, Milwaukee, WI 53204	Tel: (414) 837-3607 Fax: (414) 837-3608

NATURAL RESOURCE TECHNOLOGY

Boring Number PZ-4C

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram		Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			13	0.5 - 15.5' **LEAN CLAY:** CL, very dark grayish brown (10YR 3/2), trace sand and fine gravel, cohesive, medium to high plasticity, very stiff to hard (3.0 - 4.5 tsf), dry to moist. *(continued)*										
CS	60 56		14	13.8' yellowish brown (10YR 5/4), 0-25% gravel, cohesive, medium plasticity, soft (0.0 - 0.5 tsf), moist.	CL									
			15, 16, 17	15.5 - 18.5' **SANDY LEAN CLAY:** s(CL), 15-25% gravel, cohesive, nonplastic, soft (0.5 tsf), wet.	s(CL)									
			18	17.5' very stiff (3.0 tsf), dry.										
SS	20 24		19	18.5 - 20' **LEAN CLAY:** CL, brown (10YR 4/3), trace sand and gravel, very stiff (3.5 tsf), dry.	CL									Split spoon sample used for final 2'
			20	20 - 20.5' **SILT:** ML, dark gray (10YR 4/1), very stiff (3.5 tsf), dry.	ML									
				20.5' End of Boring.										

SOIL BORING LOG INFORMATION

NATURAL RESOURCE TECHNOLOGY

Facility/Project Name	License/Permit/Monitoring Number	Boring Number	
Kincaid Power Station		PZ-4B	
Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
John Gates Bulldog Drilling	3/30/2016	3/30/2016	hollow stem auger
Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
PZ-4B	Feet (NAVD88)	597.81 Feet (NAVD88)	8.3 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,067,579.46 N, 2,488,049.31 E E/W
1/4 of 1/4 of Section , T N, R
Lat ° ' "
Long ° ' "
Local Grid Location: Feet ☐N ☐S Feet ☐E ☐W

Facility ID	County	State	Civil Town/City/ or Village
	Christian	Illinois	Kincaid

Sample: Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0	0 - 0.5' **FILL, SILT:** ML.	(FILL) ML									Blind Drilled, see PZ-3C for details
			0.5	0.5 - 13' **LEAN CLAY:** CL.	CL									
			13	13' End of Boring.										

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature]

Firm: Natural Resource Technology
234 W. Florida St., Fifth Floor, Milwaukee, WI 53204
Tel: (414) 837-3607
Fax: (414) 837-3608

Template: ILLINOIS BORING LOG - Project: KINCAID POWER STATION CCR RULE 2015 LOGS.GPJ

SOIL BORING LOG INFORMATION

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Kincaid Power Station		PZ-4A

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
John Gates Bulldog Drilling	3/30/2016	3/30/2016	hollow stem auger

Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
PZ-4A	Feet (NAVD88)	597.81 Feet (NAVD88)	8.3 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,067,576.32 N, 2,488,049.24 E E/Ⓦ
1/4 of 1/4 of Section , T N, R

Lat ___° ___' ___"
Long ___° ___' ___"

Local Grid Location
Feet ☐N ☐S Feet ☐E ☐W

Facility ID	County	State	Civil Town/City/ or Village
	Christian	Illinois	Kincaid

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Soil Properties: Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0 - 0.5	0 - 0.5' **FILL, SILT:** ML.	(FILL) ML									Blind Drilled, see PZ-4C for details
			0.5 - 10	0.5 - 10' **LEAN CLAY:** CL.	CL									
			10	10' End of Boring.										

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature [signature]

Firm Natural Resource Technology
234 W. Florida St., Fifth Floor, Milwaukee, WI 53204
Tel: (414) 837-3607
Fax: (414) 837-3608

Template: ILLINOIS BORING LOG - Project: KINCAID POWER STATION CCR RULE 2015 LOGS.GPJ

SOIL BORING LOG INFORMATION

NATURAL RESOURCE TECHNOLOGY

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Kincaid Power Station		PZ-3C

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
John Gates Bulldog Drilling	3/29/2016	3/30/2016	hollow stem auger

Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
PZ-3C	Feet (NAVD88)	603.49 Feet (NAVD88)	8.3 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,066,849.23 N, 2,485,786.53 E E/W(circled)
1/4 of 1/4 of Section , T N, R
Lat ° ' "
Long ° ' "
Local Grid Location: Feet ☐N ☐S Feet ☐E ☐W

Facility ID	County	State	Civil Town/City/ or Village
	Christian	Illinois	Kincaid

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 CS	60 57			0 - 1.2' **FILL, SANDY SILT:** (ML)s, black (10YR 2/1) to very dark grayish brown (10YR 3/2), 15-25% sand sized ash, noncohesive, nonplastic, very soft (0.0 tsf), dry.	(FILL) (ML)s								Sampling completed using 2" macro core
			1	1.2 - 3.2' **FILL, LEAN CLAY WITH SAND:** (CL)s, dark yellowish brown (10YR 4/4), and very dark grayish brown (10YR 3/2), trace gravel, cohesive, nonplastic, very stiff to hard (3.5 - 4.5 tsf), dry.	(FILL) (CL)s								
			3	3.2 - 3.4' **FILL, POORLY-GRADED SAND:** SP, mostly fine sand, trace coarse sand, moist.	(FILL) SP								
			4	3.4 - 3.9' **FILL, LEAN CLAY:** CL, dark gray (10YR 4/1), cohesive, high plasticity, very stiff (2.5 - 3.0 tsf), moist.	(FILL) CL								
2 CS	60 26		5	3.9 - 5' **SILT:** ML, black (10YR 2/1), cohesive, nonplastic, very stiff (2.0 - 2.5), dry to moist.	ML								
			5	5 - 14.3' **LEAN CLAY:** CL, black (10YR 2/1) grading to dark yellowish brown (10YR 4/4), cohesive, medium to high plasticity, soft to very stiff (0.5 - 3.0 tsf), moist.	CL								
3 CS	60 56		10	10' dark yellowish brown (10YR 4/4).									

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature [signature]

Firm Natural Resource Technology
234 W. Florida St., Fifth Floor, Milwaukee, WI 53204
Tel: (414) 837-3607
Fax: (414) 837-3608

NATURAL RESOURCE TECHNOLOGY

Boring Number PZ-3C

Sample Number and Type	Sample Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram		Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			13–14	5 - 14.3' **LEAN CLAY:** CL, black (10YR 2/1) grading to dark yellowish brown (10YR 4/4), cohesive, medium to high plasticity, soft to very stiff (0.5 - 3.0 tsf), moist. *(continued)*	CL									
4 CS	60 57		15	14.3 - 15' **SILTY CLAY** CL/ML, dark yellowish brown (10YR 4/4), cohesive, medium to low plasticity, soft (0.5 tsf), wet.	CL/ML									
			16–19	15 - 20' **LEAN CLAY:** CL, dark yellowish brown (10YR 4/4) with dark gray (10YR 4/1) mottling, trace fine gravel, cohesive, nonplastic, soft to stiff (0.5 - 1.5 tsf), moist.	CL									
5 CS	60 57		20–21	20 - 21.5' **SILTY CLAY** CL/ML, dark yellowish brown (10YR 4/4), cohesive, nonplastic, very soft (0.0 tsf), wet.	CL/ML									
			22	21.5 - 22' **LEAN CLAY:** CL, dark grayish brown (10YR 4/2), trace sand and gravel, cohesive, low plasticity, very stiff to hard (3.5 - 4.5 tsf), moist to wet [TILL].	CL									
				22 - 22.3' **POORLY-GRADED SAND:** SP, dark gray (10YR 4/1), little gravel and clay, wet.	SP									
			23–24	22.3 - 24.8' **LEAN CLAY:** CL, dark gray (10YR 4/1), 15-25% gravel, trace sand, hard (4.5 tsf), dry.	CL									
				24.8' End of Boring.										

NATURAL RESOURCE TECHNOLOGY

SOIL BORING LOG INFORMATION

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Kincaid Power Station		PZ-3B

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
John Gates Bulldog Drilling	3/29/2016	3/30/2016	hollow stem auger

Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
PZ-3B	Feet (NAVD88)	603.47 Feet (NAVD88)	8.3 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,066,848.81 N, 2,485,789.93 E E/W
1/4 of 1/4 of Section , T N, R
Lat ° ' " Long ° ' "
Local Grid Location Feet ☐N ☐S Feet ☐E ☐W

Facility ID	County	State	Civil Town/City/ or Village
	Christian	Illinois	Kincaid

Sample: Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0 - 1.2	0 - 1.2' **FILL, SANDY SILT:** (ML)s.	(FILL) (ML)s									Blind Drilled, see PZ-3C for details
			1.2 - 3.2	1.2 - 3.2' **FILL, LEAN CLAY WITH SAND:** (CL)s.	(FILL) (CL)s									
			3.2 - 3.4	3.2 - 3.4' **FILL, POORLY-GRADED SAND:** SP.	(FILL) SP									
			3.4 - 3.9	3.4 - 3.9' **FILL, LEAN CLAY:** CL.	(FILL) CL									
			3.9 - 5	3.9 - 5' **SILT:** ML.	ML									
			5 - 12	5 - 14.3' **LEAN CLAY:** CL.	CL									

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature

Firm Natural Resource Technology
234 W. Florida St., Fifth Floor, Milwaukee, WI 53204
Tel: (414) 837-3607
Fax: (414) 837-3608

SOIL BORING LOG INFORMATION SUPPLEMENT

NATURAL RESOURCE TECHNOLOGY

Boring Number PZ-3B

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Soil Properties: Compressive Strength (tsf)	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
			13 14	5 - 14.3' **LEAN CLAY:** CL. *(continued)*	CL									
				14.3 - 15' **SILTY CLAY** CL/ML.	CL/ML									
			15 16 17	15 - 17' **LEAN CLAY:** CL.	CL									
				17' End of Boring.										

NATURAL RESOURCE TECHNOLOGY

SOIL BORING LOG INFORMATION

Facility/Project Name	License/Permit/Monitoring Number	Boring Number	
Kincaid Power Station		PZ-3A	
Boring Drilled By: Name of crew chief (first, last) and Firm	**Date Drilling Started**	**Date Drilling Completed**	**Drilling Method**
John Gates Bulldog Drilling	3/29/2016	3/30/2016	hollow stem auger
Common Well Name	**Final Static Water Level**	**Surface Elevation**	**Borehole Diameter**
PZ-3A	Feet (NAVD88)	603.33 Feet (NAVD88)	8.3 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,066,848.40 N, 2,485,792.80 E E/Ⓦ
1/4 of 1/4 of Section , T N, R

Lat ° ' "
Long ° ' "

Local Grid Location
Feet ☐N ☐S
Feet ☐E ☐W

Facility ID	County	State	Civil Town/City/ or Village
	Christian	Illinois	Kincaid

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	Soil Properties: Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0 - 1.2	0 - 1.2' **FILL, SANDY SILT:** (ML)s.	(FILL) (ML)s								Blind Drilled, see PZ-3C for details
			1.2 - 3.2	1.2 - 3.2' **FILL, LEAN CLAY WITH SAND:** (CL)s.	(FILL) (CL)s								
			3.2 - 3.4	3.2 - 3.4' **FILL, POORLY-GRADED SAND:** SP.	(FILL) SP								
			3.4 - 3.9	3.4 - 3.9' **FILL, LEAN CLAY:** CL.	(FILL) CL								
			3.9 - 5	3.9 - 5' **SILT:** ML.	ML								
			5 - 12	5 - 12' **LEAN CLAY:** CL.	CL								
			12	12' End of Boring.									

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature [signature]

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234 W. Florida St., Fifth Floor, Milwaukee, WI 53204
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Fax: (414) 837-3608

SOIL BORING LOG INFORMATION

NATURAL RESOURCE TECHNOLOGY

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Kincaid Power Station		PZ-2C

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
John Gates Bulldog Drilling	3/31/2016	4/1/2016	hollow stem auger

Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
PZ-2C	Feet (NAVD88)	614.10 Feet (NAVD88)	8.3 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,069,329.19 N, 2,486,393.15 E E/W (W circled)
1/4 of 1/4 of Section , T N, R

Lat ° ' "
Long ° ' "

Local Grid Location: Feet ☐N ☐S Feet ☐E ☐W

Facility ID	County	State	Civil Town/City/ or Village
	Christian	Illinois	Kincaid

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 CS	42 24		0–3.6	0 - 3.6' ASH (Coal), very dark brown (10YR 2/2), mostly fine sand sized ash, trace fine gravel sized, dry.	(FILL) ASH (Coal)								Sampling completed using 2" macro core
2 CS	60 57		3.6–24	3.6 - 24' **FILL, LEAN CLAY:** CL, brown (10YR 4/3) to gray (10YR 5/1), 15-25% silt, trace sand and fine gravel, cohesive, low to high plasticity, very stiff to hard (2.0 - 4.0 tsf), moist to dry.	(FILL) CL								
3 CS	60 55		10.5	10.5' color change to gray (10YR 4/1). 10.7' color change to brown (10YR 4/3).									
4 CS	60 56		13.5	13.5' brown (10YR 4/3) with brownish yellow (10YR 6/8) and dark gray (10YR 4/1) mottling, trace dark gray (10YR 4/1) silt seams.									

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NATURAL RESOURCE TECHNOLOGY

Boring Number PZ-2C

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			16	3.6 - 24' **FILL, LEAN CLAY:** CL, brown (10YR 4/3) to gray (10YR 5/1), 15-25% silt, trace sand and fine gravel, cohesive, low to high plasticity, very stiff to hard (2.0 - 4.0 tsf), moist to dry. *(continued)*	(FILL) CL						
5 CS	60 57		19	18.5' no silt seams, no dark gray (10YR 4/1) mottling.							
6 CS	60 56		24	24 - 29.2' **LEAN CLAY:** CL, black (10YR 2/1) grading to dark gray (10YR 4/1), cohesive, medium to high plasticity, medium stiff to stiff (0.5 - 1.5 tsf), moist to wet.	CL						
7 CS	60 57		29	28.5' moist to wet.							
			29.2	29.2 - 31.6' **SILTY CLAY** CL/ML, brown (10YR 4/3), trace fine sand, cohesive, medium to low plasticity, stiff (1.0 tsf), wet.	CL/ML						
			31.6	31.6 - 35.1' **LEAN CLAY:** CL, brown (10YR 4/3), trace fine sand and fine gravel, cohesive, medium to high plasticity, stiff to very stiff (1.5 - 2.5 tsf), moist.	CL						
8 CS	56 60		34	33.5' dark yellowish brown (10YR 4/6).							
			35.1	35.1 - 37.5' **SANDY ORGANIC CLAY WITH GRAVEL:** s(CL), dark yellowish brown (10YR 4/6), trace gravel, cohesive, nonplastic, very soft (0.0 tsf), wet.	s(CL)						
			37.5	37.5 - 38.1' **LEAN CLAY:** CL, dark yellowish brown (10YR 4/6), trace sand and gravel, very hard (4.5 tsf), dry.	CL						
			38.1	38.1' End of Boring.							

SOIL BORING LOG INFORMATION

NATURAL RESOURCE TECHNOLOGY

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Kincaid Power Station		PZ-2B

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
John Gates Bulldog Drilling	3/31/2016	4/1/2016	hollow stem auger

Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
PZ-2B	Feet (NAVD88)	613.96 Feet (NAVD88)	8.3 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,069,329.32 N, 2,486,397.79 E E/Ⓦ
1/4 of 1/4 of Section , T N, R
Lat ° ' "
Long ° ' "
Local Grid Location
Feet ☐N ☐S Feet ☐E ☐W

Facility ID	County	State	Civil Town/City/ or Village
	Christian	Illinois	Kincaid

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Soil Properties: Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–3.6	0 - 3.6' ASH (Coal).	(FILL) ASH (Coal)									Blind Drilled, see PZ-2C for details
			3.6–13	3.6 - 24' **FILL, LEAN CLAY:** CL.	(FILL) CL									

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm
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NATURAL RESOURCE TECHNOLOGY

SOIL BORING LOG INFORMATION SUPPLEMENT

Boring Number PZ-2B

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Soil Properties: Compressive Strength (tsf)	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
			13–24	3.6 - 24' **FILL, LEAN CLAY:** CL. *(continued)*	(FILL) CL									
			24–29.2	24 - 29.2' **LEAN CLAY:** CL.	CL									
			29.2–31.6	29.2 - 31.6' **SILTY CLAY** CL/ML.	CL/ML									
			31.6–32	31.6 - 32' **LEAN CLAY:** CL.	CL									
			32	32' End of Boring.										

Depth scale: 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32

NATURAL RESOURCE TECHNOLOGY

Facility/Project Name	License/Permit/Monitoring Number	Boring Number	
Kincaid Power Station		PZ-2A	
Boring Drilled By: Name of crew chief (first, last) and Firm	**Date Drilling Started**	**Date Drilling Completed**	**Drilling Method**
John Gates Bulldog Drilling	3/31/2016	4/1/2016	hollow stem auger
Common Well Name	**Final Static Water Level**	**Surface Elevation**	**Borehole Diameter**
PZ-2A	Feet (NAVD88)	614.17 Feet (NAVD88)	8.3 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,069,329.92 N, 2,486,401.04 E E/Ⓦ
1/4 of 1/4 of Section , T N, R

Lat ° ' "
Long ° ' "

Local Grid Location
Feet ☐N ☐S Feet ☐E ☐W

Facility ID	County	State	Civil Town/City/ or Village
	Christian	Illinois	Kincaid

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Soil Properties: Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–3.6	0 - 3.6' ASH (Coal).	(FILL) ASH (Coal)									Blind Drilled, see PZ-2C for details
			3.6–13	3.6 - 24' FILL, LEAN CLAY: CL.	(FILL) CL									

I hereby certify that the information on this form is true and correct to the best of my knowledge.

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SOIL BORING LOG INFORMATION SUPPLEMENT

NATURAL RESOURCE TECHNOLOGY

Boring Number PZ-2A

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Soil Properties: Compressive Strength (tsf)	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
			14–23	3.6 - 24' **FILL, LEAN CLAY:** CL. *(continued)*	(FILL) CL									
			24–27	24 - 28' **LEAN CLAY:** CL.	CL									
			28	28' End of Boring.										

NATURAL RESOURCE TECHNOLOGY

SOIL BORING LOG INFORMATION

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Kincaid Power Station		PZ-1C

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
John Gates Bulldog Drilling	3/28/2016	3/29/2016	hollow stem auger

Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
PZ-1C	Feet (NAVD88)	598.86 Feet (NAVD88)	8.3 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,068,557.43 N, 2,484,987.72 E E/Ⓦ
1/4 of 1/4 of Section , T N, R
Lat ° ' "
Long ° ' "
Local Grid Location ☐N ☐S Feet ☐E ☐W Feet

Facility ID	County	State	Civil Town/City/ or Village
	Christian	Illinois	Kincaid

Sample: Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram		Soil Properties: Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–1.8	0 - 1.8' **SILT:** ML.	ML									Blind Drilled, see GP-1 for details
			1.8–8	1.8 - 8' **LEAN CLAY:** CL.	CL									
			8–11.2	8 - 11.2' **SANDY LEAN CLAY:** s(CL).	s(CL)									
			11.2–12	11.2 - 15' **SANDY SILT:** s(ML).	s(ML)									

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Template: ILLINOIS BORING LOG - Project: KINCAID POWER STATION CCR RULE 2015 LOGS.GPJ

NATURAL RESOURCE TECHNOLOGY

SOIL BORING LOG INFORMATION SUPPLEMENT

Boring Number PZ-1C

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram		Soil Properties: Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			13 14 15	11.2 - 15' **SANDY SILT:** s(ML). *(continued)*	s(ML)									
				15' End of Boring.										

SOIL BORING LOG INFORMATION

NATURAL RESOURCE TECHNOLOGY

Facility/Project Name: Kincaid Power Station		License/Permit/Monitoring Number:	Boring Number: PZ-1B
Boring Drilled By: Name of crew chief (first, last) and Firm: John Gates, Bulldog Drilling	Date Drilling Started: 3/28/2016	Date Drilling Completed: 3/29/2016	Drilling Method: hollow stem auger
Common Well Name: PZ-1B	Final Static Water Level: Feet (NAVD88)	Surface Elevation: 599.05 Feet (NAVD88)	Borehole Diameter: 8.3 inches
Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒ State Plane 1,068,559.28 N, 2,484,990.01 E E/Ⓦ 1/4 of 1/4 of Section , T N, R	Lat ° ' " Long ° ' "	Local Grid Location ☐N ☐S Feet ☐E ☐W Feet	
Facility ID:	County: Christian	State: Illinois	Civil Town/City/ or Village: Kincaid

Sample: Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID 10.6 eV Lamp	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–1.8	0 - 1.8' **SILT:** ML.	ML									Blind Drilled, see GP-1 for details
			1.8–7.5	1.8 - 7.5' **LEAN CLAY:** CL.	CL									
			7.5	7.5' End of Boring.										

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature]

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Template: ILLINOIS BORING LOG - Project: KINCAID POWER STATION CCR RULE 2015 LOGS.GPJ

NATURAL RESOURCE TECHNOLOGY

SOIL BORING LOG INFORMATION

Facility/Project Name	License/Permit/Monitoring Number	Boring Number	
Kincaid Power Station		GP-5	
Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
John Gates Bulldog Drilling	3/30/2016	3/31/2016	hollow stem auger
Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
	Feet (NAVD88)	598.90 Feet (NAVD88)	8.3 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,066,386.90 N, 2,487,586.87 E E/Ⓦ
1/4 of 1/4 of Section , T N, R
Lat ° ' "
Long ° ' "
Local Grid Location: Feet ☐N ☐S Feet ☐E ☐W

Facility ID	County	State	Civil Town/City/ or Village
	Christian	Illinois	Kincaid

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 CS	36 37		0	0 - 0.5' **SILT:** ML, very dark grayish brown (10YR 3/2), trace roots, sand, and gravel, cohesive, nonplastic, dry.	ML								
			1	0.5 - 18.8' **LEAN CLAY:** CL, dark yellowish brown (10YR 4/4) grading to black (10YR 2/1), trace roots in top 1' of unit, trace fine gravel, cohesive, high plasticity, very stiff (3.5 - 4.0 tsf), dry to moist, increase in moisture content with depth.									
2 CS	60 60		3	3' (soft to very stiff 0.5 to 4.0 tsf).									
			4	4.2' grayish brown (10YR 5/2).									
			6	6' brown (10YR 4/3) with gray (10YR 5/1) and yellowish brown (10YR 5/8) mottling.	CL								
3 CS	60 53		8	8' (soft to stiff 0.5 - 2.0 tsf).									
			9	8.8' dark gray (10YR 4/1) with dark yellowish brown (10YR 4/4) mottling and trace black (10YR 2/1) oxidation staining.									
			12										

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NATURAL RESOURCE TECHNOLOGY

Boring Number GP-5

Sample Number and Type	Sample Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram		Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
4 CS	60 60		13, 14, 15, 16, 17	0.5 - 18.8' **LEAN CLAY:** CL, dark yellowish brown (10YR 4/4) grading to black (10YR 2/1), trace roots in top 1' of unit, trace fine gravel, cohesive, high plasticity, very stiff (3.5 - 4.0 tsf), dry to moist, increase in moisture content with depth. *(continued)* 13' soft (0.5 tsf), wet. 13.3' light yellowish brown (10YR 6/4). 13.8' dark gray (10YR 4/1). 15.5' -16.0' trace sand, saturated in fractures for 6".	CL									
5 CS	24 24		18	17.4' dark yellowish brown (10YR 4/4), with dark gray (10YR 4/1) mottling, trace gravel.										
			19, 20	18.8 - 20' **LEAN CLAY:** CL, dark yellowish brown (10YR 4/4) to dark gray (10YR 4/1), trace sand and gravel, noncohesive, nonplastic, hard (4.5 tsf), dry.	CL									
				20' End of Boring.										

SOIL BORING LOG INFORMATION

NATURAL RESOURCE TECHNOLOGY

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Kincaid Power Station		GP-1

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
John Gates Bulldog Drilling	3/28/2016	3/29/2016	hollow stem auger

Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
	Feet (NAVD88)	598.86 Feet (NAVD88)	8.3 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,068,557.43 N, 2,484,987.72 E E/Ⓦ
1/4 of 1/4 of Section , T N, R

Lat ° ' "
Long ° ' "

Local Grid Location ☐N ☐S Feet ☐E ☐W Feet

Facility ID	County	State	Civil Town/City/ or Village
	Christian	Illinois	Kincaid

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram		Soil Properties: Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 CS	60 33		0–1.8	0 - 1.8' **SILT:** ML, very dark grayish brown (10YR 3/2), 15-25% clay, trace roots and ash in top 6", cohesive, nonplastic, stiff (1.75 tsf), dry to moist.	ML									
			1.8–8	1.8 - 8' **LEAN CLAY:** CL, brown (10YR 4/3) with yellowish red (5YR 5/6) mottling, trace black (10YR 2/1) oxidation stains, cohesive, medium to high plasticity, medium to stiff (0.5 - 1.75 tsf), moist.	CL									
2 CS	60 53		5											
			8–11.2	8 - 11.2' **SANDY LEAN CLAY:** s(CL), dark yellowish brown (10YR 4/4), 10-25% fine gravel, cohesive, nonplastic, stiff to very stiff (1.5 - 2.5 tsf), moist to wet.	s(CL)									
3 CS	60 58		10											
			11.2–12		s(ML)									

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Signature: [signature]

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NATURAL RESOURCE TECHNOLOGY

Boring Number GP-1

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram		Soil Properties: Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			13 14	11.2 - 15' **SANDY SILT:** s(ML), dark yellowish brown (10YR 4/4), trace fine gravel, cohesive, nonplastic, very soft to soft (0.0 - 0.5 tsf), wet. *(continued)*	s(ML)									
4 CS	60 60		15 16 17 18 19	15 - 20' **LEAN CLAY:** CL, dark yellowish brown (10YR 4/4) with darker yellowish brown mottling (10YR 3/4), 15-25% sand, trace gravel, very stiff to hard (2.0 - 4.5 tsf), increasing hardness with depth, moist to dry.	CL									
			20	20' End of Boring.										

SOIL BORING LOG INFORMATION

NATURAL RESOURCE TECHNOLOGY

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Kincaid Power Station		B-12

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Chad Dutton Bulldog Drilling	7/20/2015	7/21/2015	hollow stem auger

Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
	Feet (NAVD88)	588.86 Feet (NAVD88)	8.3 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,068,944.76 N, 2,485,453.08 E E/Ⓦ
1/4 of 1/4 of Section , T N, R

Lat 39° 36' 0.722"
Long -89° 29' 46.969"

Local Grid Location ☐ N ☐ S Feet ☐ E ☐ W Feet

Facility ID	County	State	Civil Town/City/ or Village
	Christian	Illinois	Kincaid

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 SS	24 15	1 3 7 6	0 - 2	0 - 2' **FILL, SILT:** ML, very dark gray (2.5YR 3/1), mostly silt, trace clay, roots, and subangular gravel, noncohesive, dry. 0.9' dark grayish brown (2.5YR 4/2), no roots, noncohesive to cohesive.	(FILL) ML								
2 SS	24 20	4 6 7 7	2 - 4	2 - 4' **FILL, CLAYEY SILT** ML/CL, dark grayish brown (2.5YR 4/2), trace gravel, trace fine sand seams, nonplastic, cohesive, dry to moist. 3.3' very dark grayish brown (2.5YR 3/2), trace ash, trace slag, trace clear glass fragments.	(FILL) ML/CL								
3 ST	24 17		4 - 6	4 - 6' Shelby Tube Sample.									ST3: 24" push at 150 lbs of pressure.
4 SS	24 17	2 1 2 1	6 - 8	6 - 6.2' **FILL, CLAYEY SILT** ML/CL, dark grayish brown (2.5YR 4/2), trace gravel, trace fine sand seams, trace fine to coarse ash, nonplastic, cohesive, moist. 6.2 - 8' **SILTY CLAY** CL/ML, yellowish brown (10YR 5/4), trace sand seams, trace gravel. 6.9' noncohesive to cohesive, wet.	(FILL) ML/CL CL/ML								
5 SS	24 20	1 1 1 4	8 - 10	8 - 10' **CLAYEY SILT** ML/CL, yellowish brown (10YR 5/4), trace gravel, trace to few fine sand, wet. 9.4' nonplastic, noncohesive to cohesive.	ML/CL								
6 SS	24 16.5	5 9 13 19	10 - 12	10 - 12' **CLAYEY SAND:** SC, yellowish brown (10YR 5/4), trace yellowish brown (10YR 5/8) mottling, clay content decreasing with depth, trace fine gravel, noncohesive, moist.	SC								

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature

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NATURAL RESOURCE TECHNOLOGY

Boring Number B-12

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram		Soil Properties: Compressive Strength (tsf)	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
7 SS	24 18	2 4 5 7	13	12 - 14.4' **WELL-GRADED SAND:** SW, yellowish brown (10YR 5/4), trace clay, trace subrounded gravel, noncohesive, wet.	SW									
8 SS	24 22	13 23 45 50	14											
			15	14.4 - 16' **SILTY SAND:** SW-SM, yellowish brown (10YR 5/4), mostly very fine sand, trace yellowish brown (10YR 5/8) mottling, trace fine sand seams, trace gravel, trace black silt, trace clay, nonplastic, cohesive, moist to dry.	SW-SM									
9 ST	9 5		16 17	16 - 18' Shelby Tube Sample.										ST9: 9" push at 950lbs of pressure.
10 SS	23 20	20 28 34 50 for 5"	18 19	18 - 30' **SILTY CLAY** to **POORLY-GRADED SAND:** CL/ML, gray (2.5YR 5/1), some very fine sand, little clay, nonplastic, cohesive, dry.	CL/ML									
				19.2' dark gray (2.5YR 4/1), trace coarse sand.										
11 SS	12 13	28 50 for 6"	20 21	20' - 21.2' trace clay, trace coarse sand to fine gravel.										
12 SS	17 14	16 39 50 for 5"	22 23	22' - 23.2' trace to little clay, trace coarse sand.										
				22.8' trace gravel.										
13 SS	12 13	31 50 for 6"	24 25	24' -25.1' clay (0-15%), trace coarse sand.										
14 SS	11 4.5	43 50 for 5"	26 27	26' clay (15-30%).										
15 SS	12 11	37 50 for 6"	28 29											
16 ST	8 0		30 31 32	30 - 32' Shelby Tube Sample, No Recovery.										ST16: 8" push at 650lbs of pressure.

SOIL BORING LOG INFORMATION SUPPLEMENT

NATURAL RESOURCE TECHNOLOGY

Boring Number B-12

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram		Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
17 ST	6 4		32–34	32 - 34' Shelby Tube Sample.										ST17: 6" push at 650lbs of pressure.
18 SS	23 21.5	12 23 42 50 for 5"	34	34 - 42' **CLAYEY SILT** ML/CL, gray (2.5YR 5/1), trace to few fine to coarse sand, nonplastic to low plasticity, cohesive, hard (>4.5 tsf), moist.	ML/CL									
			35	35.2' trace gravel.										
19 SS	23 24	10 18 34 50 for 5"	36	36' olive brown (2.5YR 4/4) mottling, trace fine sand, trace coarse sand, hard (>4.5 tsf), moist to dry.										
20 SS	18 18	16 24 50 for 6"	38	37.9' trace fine sand seams, hard (4.0 - 4.5+ tsf).										
21 SS	17 22	25 33 50 for 5"	40	40' low plasticity, stiff to very stiff (1.5 - 3.0 tsf), dry.										
22 ST	4.5 5		42	42 - 44' Shelby Tube Sample.										ST22: 4.5" push at 700lbs of pressure.
23 SS	6 6	50 for 6"	44	44 - 48' **LEAN CLAY:** CL, very dark gray (10YR 3/1), trace silt, medium plasticity, cohesive, soft (0.5 tsf), dry.	CL									
24 SS	6 6	50 for 6"	46	46 - 48' trace gravel-sized shale pieces, very stiff to hard (3.0 - 4.5+ tsf).										
25 ST	5 5		48	48 - 50' Shelby Tube Sample.										ST25: 5" push at 700lbs of pressure.
26 SS	6 5	50 for 6"	50	50 - 52' **LEAN CLAY:** CL, as above, hard (>4.5 tsf).	CL									
			52											

SOIL BORING LOG INFORMATION SUPPLEMENT

NATURAL RESOURCE TECHNOLOGY

Boring Number B-12

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram		Soil Properties: Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
27 SS	1 0	50 for 1"		52 - 52.1' No Recovery.										Split Spoon Refusal at 52.1' bgs.
28 CORE	119 116			52.1 - 62' **LIMESTONE:** BDX (LS), white (GLEY 1 8/N), trace shaley limestone, fossiliferous, vuggy texture, microcrystalline, massive, intensely fractured, very narrow to moderately narrow apertures. 53.5' no vuggy texture. 54.8' mud-filled fracture. 57.6' color change to light gray (GLEY 17/N). 60.2' shale layer (0.1" thick).	BDX (LS)									RQD = 61.3% (fair).
				62' End of Boring.										

SOIL BORING LOG INFORMATION

NATURAL RESOURCE TECHNOLOGY

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Kincaid Power Station		MW-11

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Adam Jochimsen Cascade	6/17/2015	6/17/2015	hollow stem auger

Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
MW-11	Feet (NAVD88)	599.27 Feet (NAVD88)	8.3 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,066,371.19 N, 2,486,955.55 E E/W
1/4 of 1/4 of Section , T N, R
Lat 39° 35' 35.176"
Long -89° 29' 28.013"
Local Grid Location ☐N ☐S Feet ☐E ☐W Feet

Facility ID	County	State	Civil Town/City/ or Village
	Christian	Illinois	Kincaid

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 SS	24 21.5	5 6 6 6		0 - 0.2' **SILTY CLAY** CL/ML, very dark gray (10YR 3/1), 5-50% roots, trace gravel, wet.	CL/ML								
			1	0.2 - 3' **CLAYEY SILT** ML/CL, dark brown (10YR 3/3), yellowish brown (10YR 5/6) mottling, trace gravel, dry. 1.5' dark yellowish brown (10YR 4/6).	ML/CL								
2 SS	24 24	8 8 11 17	2	2' trace coarse sand to fine gravel, color grades to yellowish brown (10YR 4/6).									
			3	3 - 4' **SILT:** ML, black (10YR 2/1), 5-15% clay, cohesive, nonplastic, moist.	ML								
3 SS	24 21	3 5 8 7	4	4 - 6' **CLAYEY SILT** ML/CL, very dark brown (10YR 2/2), cohesive, low plasticity. 4.5' grading to silty clay, color grades to light olive brown (2.5Y 5/3) with olive yellow (2.5Y 6/6) mottling, cohesive, medium to high plasticity. 5.5' color grades to very dark brown (10YR 2/2), cohesive, low plasticity.	ML/CL								
4 ST	24 12		6	6 - 8' Shelby Tube Sample.									ST4: 24" push.
			7										
5 SS	24 24	2 2 5 7	8	8 - 15.3' **SILTY CLAY** CL/ML, light olive brown (2.5Y 5/3), olive yellow (2.5Y 6/6) and very dark brown (10YR 2/2) mottling, cohesive, medium plasticity, moist.									
			9	9.3' very dark grayish brown (2.5Y 3/2).									
6 SS	24 23.5	2 3 5 7	10	10' low to medium plasticity, moist.	CL/ML								
			11										
			12										

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature Pat M. Hull

Firm Natural Resource Technology
234 W. Florida St., Fifth Floor, Milwaukee, WI 53204
Tel: (414) 837-3607
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Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram		Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
7 SS	24 21	1 2 3 5	13	8 - 15.3' **SILTY CLAY** CL/ML, light olive brown (2.5Y 5/3), olive yellow (2.5Y 6/6) and very dark brown (10YR 2/2) mottling, cohesive, medium plasticity, moist. *(continued)* 12.2' dark grayish brown (2.5Y 4/2) with olive yellow (2.5Y 6/6) mottling. 12.5' wet.	CL/ML									
8 SS	24 24	1 2 4 5	14, 15											
				15.3 - 16.9' **SILTY CLAY** CL/ML, light olive brown (2.5Y 5/4), trace sand, trace fine gravel, cohesive, nonplastic, wet.	CL/ML									
9 SS	24 21	2 2 2 3	16, 17											
				16.9 - 18' **SILTY SAND:** SM, light olive brown (2.5Y 5/4), mostly fine grained sand, silt is cohesive and nonplastic.	SM									
10 SS	24 23	1 2 25 50 for 6"	18	18 - 18.4' **SILT:** ML, light olive brown (2.5Y 5/4), trace sand, cohesive, nonplastic, wet.	ML									
			19	18.4 - 20.8' **SILTY CLAY** CL/ML, light olive brown (2.5Y 5/3), 5-15% sand and gravel, hard, dry.	CL/ML									
11 SS	9 9	44 53 for 3"	20	20' trace sand and gravel.										
			21	20.8 - 21' Overdrilled to Install Monitoring Well. 21' End of Boring.										

NATURAL RESOURCE TECHNOLOGY

SOIL BORING LOG INFORMATION

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Kincaid Power Station		MW-12

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Chad Dutton Bulldog Drilling	7/22/2015	7/23/2015	hollow stem auger

Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
MW-12	Feet (NAVD88)	588.86 Feet (NAVD88)	8.3 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,068,944.76 N, 2,485,453.08 E E/W
1/4 of 1/4 of Section , T N, R
Lat 39° 36' 0.722"
Long -89° 29' 46.969"
Local Grid Location ☐ N ☐ S Feet ☐ E ☐ W Feet

Facility ID	County	State	Civil Town/City/ or Village
	Christian	Illinois	Kincaid

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	Soil Properties: Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0-2	0 - 2' **FILL, SILT:** ML.	(FILL) ML								0-15' Blind Drilled. See log B-12 for soil description details.
			2-4	2 - 4' **FILL, CLAYEY SILT** ML/CL.	(FILL) ML/CL								
			4-6	4 - 6' Shelby Tube Sample Collected at Location B-12.									
			6-6.2	6 - 6.2' **FILL, CLAYEY SILT** ML/CL.	(FILL) ML/CL								
			6.2-8	6.2 - 8' **SILTY CLAY** CL/ML.	CL/ML								
			8-10	8 - 10' **CLAYEY SILT** ML/CL.	ML/CL								
			10-12	10 - 12' **CLAYEY SAND:** SC.	SC								

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature]

Firm Natural Resource Technology
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NATURAL RESOURCE TECHNOLOGY

Boring Number MW-12

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram		Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			12–14.4	12 - 14.4' **WELL-GRADED SAND:** SW.	SW									
			14.4–15	14.4 - 15' **SILTY SAND:** SW-SM.	SW-SM									
1 SS	24 20	9 19 26 26	15–15.2	15 - 15.2' **SILT:** ML, very dark gray (2.5YR 3/1), trace roots, clay, gravel, and sand, noncohesive, moist.	ML									
			15.2–17	15.2 - 17' **CLAYEY SILT** to **SANDY SILT:** ML/CL, yellowish brown (10YR 5/4), very fine sand, sand content increasing with depth, nonplastic, cohesive, moist. 15.9' gray (2.5YR 5/1).	ML/CL									
2 SS	24 15	9 19 32 48	17–17.4	17 - 17.4' **SILTY SAND:** SM, gray (2.5YR 5/1), trace clay, moist.	SM									
			17.4–19	17.4 - 19' **SILTY CLAY** to **CLAYEY SILT** CL/ML, gray (2.5YR 5/1), trace coarse sand, clay content decreasing with depth, low to medium plasticity, cohesive.	CL/ML									
3 SS	23 22	19 36 40 50 for 5"	19–23	19 - 23' **CLAYEY SILT** ML/CL, gray (2.5YR 5/1), trace coarse sand, low plasticity, cohesive, moist.	ML/CL									
4 SS	17 15	25 43 50 for 5"												
			23–25	23 - 25' **SILTY CLAY** to **POORLY-GRADED SAND:** CL/ML.	CL/ML									23-25' Overdrilled. See log B-12 for soil description details.
			25	25' End of Boring.										

SOIL BORING LOG INFORMATION

NATURAL RESOURCE TECHNOLOGY

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Kincaid Power Station		TW-12

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Chad Dutton Bulldog Drilling	7/22/2015	7/22/2015	hollow stem auger

Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
TW-12	Feet (NAVD88)	588.86 Feet (NAVD88)	8.3 inches

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 1,068,944.76 N, 2,485,453.08 E E/Ⓦ
1/4 of 1/4 of Section , T N, R

Lat 39° 36' 0.722"
Long -89° 29' 46.969"

Local Grid Location: Feet ☐N ☐S Feet ☐E ☐W

Facility ID	County	State	Civil Town/City/ or Village
	Christian	Illinois	Kincaid

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	Soil Properties: Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0-2	0 - 2' **FILL, SILT:** ML.	(FILL) ML								0-39' Blind Drilled. See log B-12 for soil description details.
			2-4	2 - 4' **FILL, CLAYEY SILT** ML/CL.	(FILL) ML/CL								
			4-6	4 - 6' Shelby Tube Sample Collected at Location B-12.									
			6-6.2	6 - 6.2' **FILL, CLAYEY SILT** ML/CL.	(FILL) ML/CL								
			6.2-8	6.2 - 8' **SILTY CLAY** CL/ML.	CL/ML								
			8-10	8 - 10' **CLAYEY SILT** ML/CL.	ML/CL								
			10-12	10 - 12' **CLAYEY SAND:** SC.	SC								

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature [signature]

Firm Natural Resource Technology
234 W. Florida St., Fifth Floor, Milwaukee, WI 53204
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SOIL BORING LOG INFORMATION SUPPLEMENT

NATURAL RESOURCE TECHNOLOGY

Boring Number TW-12

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram		Soil Properties: Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			12 - 14.4	12 - 14.4' **WELL-GRADED SAND:** SW.	SW									
			14.4 - 16	14.4 - 16' **SILTY SAND:** SW-SM.	SW-SM									
			16 - 18	16 - 18' Shelby Tube Sample Collected at Location B-12.										
			18 - 30	18 - 30' **SILTY CLAY** to **POORLY-GRADED SAND:** CL/ML.	CL/ML									
			30 - 32	30 - 32' Shelby Tube Sample Collected at Location B-12.										

SOIL BORING LOG INFORMATION SUPPLEMENT

NATURAL RESOURCE TECHNOLOGY

Boring Number TW-12

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram		Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			32 - 34	32 - 34' Shelby Tube Sample Collected at Location B-12.										
			34 - 39	34 - 39' **CLAYEY SILT** ML/CL.	ML/CL									
1 SS	17 16	26 36 50 for 5"	39 - 43	39 - 43' **CLAYEY SILT** ML/CL, gray (2.5YR 5/1) with olive brown (2.5YR 4/4) mottling, trace fine to coarse sand and gravel, low plasticity, cohesive, dry.	ML/CL									
2 SS	16 14.5	19 30 50 for 4"		41.8' - 42' increased clay content.										
3 SS	12 10	22 50 for 6"	43 - 45	43 - 45' **LEAN CLAY:** CL, very dark gray (10YR 3/1), trace silt, trace gravel-sized pieces of weathered shale (very hard, dry), very stiff (2.5-3.0 tsf), dry, low plasticity, cohesive.	CL									
4 ST	5 0		45 - 47	45 - 47' Shelby Tube Sample. No Recovery.										ST4: 5" at 700lbs of pressure.
5 SS	22 12	15 31 36 50 for 4"	47 - 49	47 - 49' **LEAN CLAY:** CL, very dark gray (10YR 3/1), trace silt, no gravel, cohesive, medium plasticity, stiff to very stiff (2.0 tsf), dry.	CL									
			49	49' End of Boring.										

NATURAL RESOURCE TECHNOLOGY

MONITORING WELL CONSTRUCTION

Facility/Project Name: Kincaid Power Station	Local Grid Location of Well: ______ ft. ☐ N. ☐ S. ______ ft. ☐ E. ☐ W.		Well Name: PZ-1B
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒ Lat. ___ ° ___ ' ___ " Long. ___ ° ___ ' ___ " or		
Facility ID	St. Plane 1,068,559.28 ft. N, 2,484,990.01 ft. E. E/(W)		Date Well Installed: 03/29/2016
Type of Well: pz	Section Location of Waste/Source: ___ 1/4 of ___ 1/4 of Sec. ___, T. ___ N, R. ___ ☐ E ☐ W		Well Installed By: (Person's Name and Firm) John Gates, Bulldog Drilling
Distance from Waste/ Source: ___ ft. / State: Illinois	Location of Well Relative to Waste/Source: u ☐ Upgradient; s ☐ Sidegradient; d ☐ Downgradient; n ☐ Not Known	Gov. Lot Number	

A. Protective pipe, top elevation ______ ft. (NAVD88)

B. Well casing, top elevation 602.43 ft. (NAVD88)

C. Land surface elevation 599.05 ft. (NAVD88)

D. Surface seal, bottom ______ ft. (NAVD88) or ___ ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☐ ML ☐ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐ Hollow Stem Auger ☒ ______ Other ☐

15. Drilling fluid used: Water ☒ 0 2 Air ☐ Drilling Mud ☐ 0 3 None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe ______

17. Source of water (attach analysis, if required): Village of Pawnee, IL

E. Bentonite seal, top 599.1 ft. (NAVD88) or 0.0 ft.

F. Fine sand, top ______ ft. (NAVD88) or ___ ft.

G. Filter pack, top 596.6 ft. (NAVD88) or 2.5 ft.

H. Screen joint, top 595.6 ft. (NAVD88) or 3.5 ft.

I. Well bottom ______ ft. (NAVD88) or ___ ft.

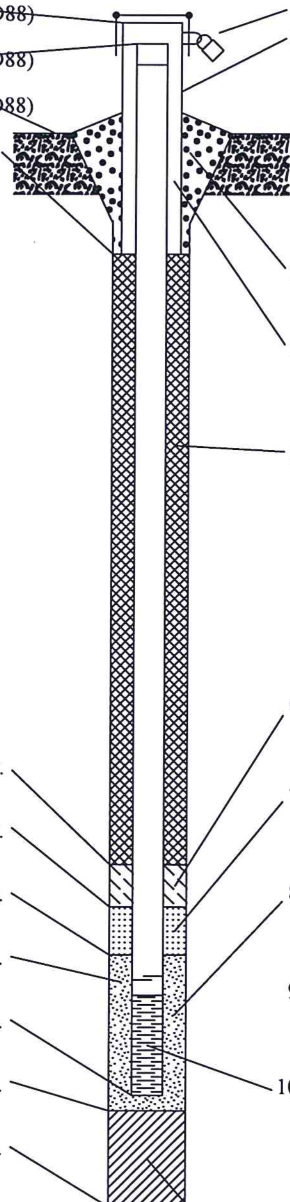
J. Filter pack, bottom 591.6 ft. (NAVD88) or 7.5 ft.

K. Borehole, bottom 591.6 ft. (NAVD88) or 7.5 ft.

L. Borehole, diameter 8.3 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.



1. Cap and lock? ☐ Yes ☒ No
2. Protective cover pipe:
   a. Inside diameter: ______ in.
   b. Length: ______ ft.
   c. Material: Steel ☒ ______ Other ☐
   d. Additional protection? ☐ Yes ☒ No
   If yes, describe: ______
3. Surface seal: Bentonite ☐ Concrete ☐ ______ Other ☐
4. Material between well casing and protective pipe: Bentonite ☒ ______ Other ☐
5. Annular space seal: a. Granular/Chipped Bentonite ☐
   b. ___ Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   c. ___ Lbs/gal mud weight . . . Bentonite slurry ☐
   d. 30 % Bentonite . . . Bentonite-cement grout ☒
   e. ______ Ft^3 volume added for any of the above
   f. How installed: Tremie ☐ Tremie pumped ☒ Gravity ☐
6. Bentonite seal: a. Bentonite granules ☐
   b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
   c. ______ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
   a. ______
   b. Volume added ______ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
   a. Unimin Corporation, FILTERSIL
   b. Volume added ______ ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒ Flush threaded PVC schedule 80 ☐ ______ Other ☐
10. Screen material: Schedule 40 PVC
    a. Screen Type: Factory cut ☒ Continuous slot ☐ ______ Other ☐
    b. Manufacturer ______
    c. Slot size: 0.010 in.
    d. Slotted length: 4.0 ft.
11. Backfill material (below filter pack): None ☒ ______ Other ☐

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Date Modified: 4/14/2016

Signature: [signature]

Firm: Natural Resource Technology
234 W. Florida Street, Floor 5, Milwaukee, WI 53204
Tel: (414) 837-3607
Fax: (414) 837-3608

NATURAL RESOURCE TECHNOLOGY

MONITORING WELL CONSTRUCTION

Facility/Project Name: Kincaid Power Station	Local Grid Location of Well: ____ ft. ☐ N. ☐ S. ____ ft. ☐ E. ☐ W.	Well Name: PZ-1C
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒ Lat. ___° ___' ___" Long. ___° ___' ___" or	
Facility ID	St. Plane 1,068,557.43 ft. N, 2,484,987.72 ft. E. E/Ⓦ	Date Well Installed: 03/29/2016
Type of Well: pz	Section Location of Waste/Source: ____1/4 of ____ 1/4 of Sec. ____, T. ____ N, R. ____ ☐ E ☐ W	Well Installed By: (Person's Name and Firm) John Gates, Bulldog Drilling
Distance from Waste/Source: ft. / State: Illinois	Location of Well Relative to Waste/Source: u ☐ Upgradient, s ☐ Sidegradient, d ☐ Downgradient, n ☐ Not Known / Gov. Lot Number	

A. Protective pipe, top elevation ________ ft. (NAVD88)

B. Well casing, top elevation 602.38 ft. (NAVD88)

C. Land surface elevation 598.86 ft. (NAVD88)

D. Surface seal, bottom ________ ft. (NAVD88) or ____ ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☒ SC ☐ ML ☒ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐ Hollow Stem Auger ☒ Other ☐

15. Drilling fluid used: Water ☒ 0 2 Air ☐ Drilling Mud ☐ 0 3 None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe ________

17. Source of water (attach analysis, if required): Village of Pawnee, IL

E. Bentonite seal, top 598.9 ft. (NAVD88) or 0.0 ft.

F. Fine sand, top ________ ft. (NAVD88) or ____ ft.

G. Filter pack, top 589.9 ft. (NAVD88) or 9.0 ft.

H. Screen joint, top 588.9 ft. (NAVD88) or 10.0 ft.

I. Well bottom ________ ft. (NAVD88) or ____ ft.

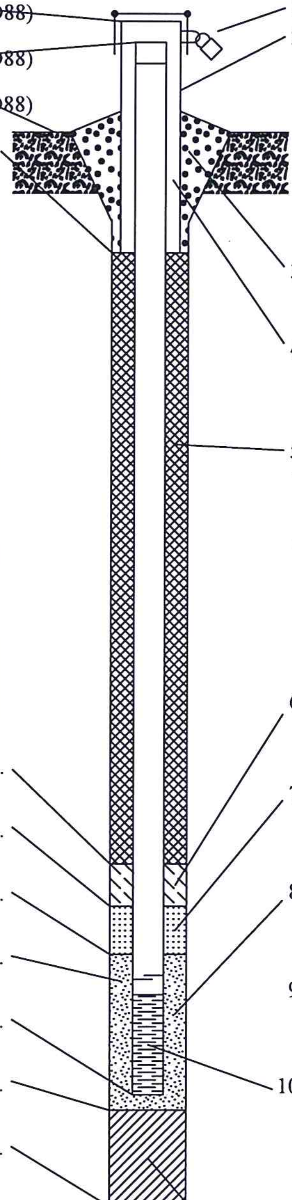
J. Filter pack, bottom 583.9 ft. (NAVD88) or 15.0 ft.

K. Borehole, bottom 578.9 ft. (NAVD88) or 20.0 ft.

L. Borehole, diameter 8.3 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.



1. Cap and lock? ☐ Yes ☒ No
2. Protective cover pipe:
   a. Inside diameter: ____ in.
   b. Length: ____ ft.
   c. Material: Steel ☒ Other ☐
   d. Additional protection? ☐ Yes ☒ No
   If yes, describe: ________
3. Surface seal: Bentonite ☐ Concrete ☐ Other ☐
4. Material between well casing and protective pipe: Bentonite ☒ Other ☐
5. Annular space seal: a. Granular/Chipped Bentonite ☐
   b. ____ Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   c. ____ Lbs/gal mud weight . . . Bentonite slurry ☐
   d. 30 % Bentonite . . . Bentonite-cement grout ☒
   e. ____ Ft^3 volume added for any of the above
   f. How installed: Tremie ☐ Tremie pumped ☒ Gravity ☐
6. Bentonite seal: a. Bentonite granules ☐
   b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
   c. ____ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
   a. ________
   b. Volume added ____ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
   a. Unimin Corporation, FILTERSIL
   b. Volume added ____ ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒ Flush threaded PVC schedule 80 ☐ Other ☐
10. Screen material: Schedule 40 PVC
    a. Screen Type: Factory cut ☒ Continuous slot ☐ Other ☐
    b. Manufacturer ________
    c. Slot size: 0.010 in.
    d. Slotted length: 5.0 ft.
11. Backfill material (below filter pack): None ☒ Other ☐

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Date Modified: 4/14/2016

Signature: [signature]

Firm: Natural Resource Technology
234 W. Florida Street, Floor 5, Milwaukee, WI 53204
Tel: (414) 837-3607
Fax: (414) 837-3608

NATURAL RESOURCE TECHNOLOGY

MONITORING WELL CONSTRUCTION

Facility/Project Name	Local Grid Location of Well	Well Name
Kincaid Power Station	______ ft. ☐ N. ☐ S. ______ ft. ☐ E. ☐ W.	PZ-2A
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒ Lat. ___ ° ___ ' ___ " Long. ___ ° ___ ' ___ " or St. Plane 1,069,329.92 ft. N, 2,486,401.04 ft. E. E / (W)	
Facility ID	Section Location of Waste/Source	Date Well Installed 04/01/2016
Type of Well pz	___ 1/4 of ___ 1/4 of Sec. ___, T. ___ N, R. ___ ☐ E ☐ W	Well Installed By: (Person's Name and Firm) John Gates
Distance from Waste/ Source ___ ft. / State: Illinois	Location of Well Relative to Waste/Source u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known Gov. Lot Number	Bulldog Drilling

A. Protective pipe, top elevation ______ ft. (NAVD88)

B. Well casing, top elevation 616.93 ft. (NAVD88)

C. Land surface elevation 614.17 ft. (NAVD88)

D. Surface seal, bottom ______ ft. (NAVD88) or ______ ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☐ ML ☐ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐
Hollow Stem Auger ☒
______ Other ☐

15. Drilling fluid used: Water ☒ 0 2 Air ☐
Drilling Mud ☐ 0 3 None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe ______

17. Source of water (attach analysis, if required):
Village of Pawnee, IL

E. Bentonite seal, top 614.2 ft. (NAVD88) or 0.0 ft.

F. Fine sand, top ______ ft. (NAVD88) or ______ ft.

G. Filter pack, top 591.2 ft. (NAVD88) or 23.0 ft.

H. Screen joint, top 590.2 ft. (NAVD88) or 24.0 ft.

I. Well bottom ______ ft. (NAVD88) or ______ ft.

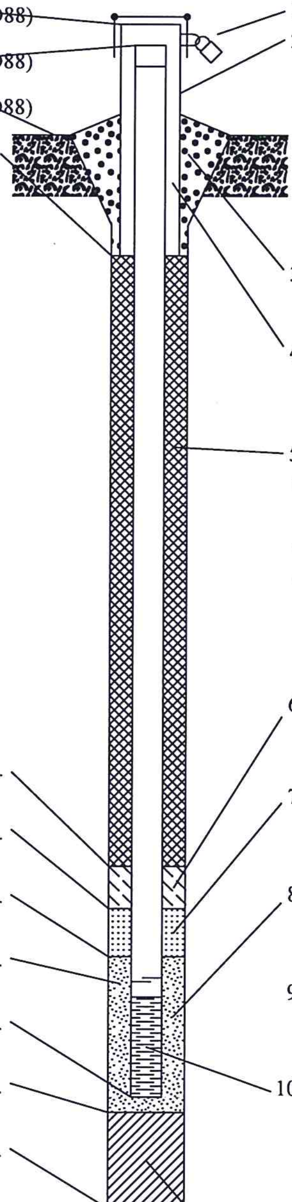
J. Filter pack, bottom 586.2 ft. (NAVD88) or 28.0 ft.

K. Borehole, bottom 586.2 ft. (NAVD88) or 28.0 ft.

L. Borehole, diameter 8.3 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.



1. Cap and lock? ☐ Yes ☒ No
2. Protective cover pipe:
   a. Inside diameter: ______ in.
   b. Length: ______ ft.
   c. Material: Steel ☒
   ______ Other ☐
   d. Additional protection? ☐ Yes ☒ No
   If yes, describe: ______
3. Surface seal: Bentonite ☐
   Concrete ☐
   ______ Other ☐
4. Material between well casing and protective pipe:
   Bentonite ☒
   ______ Other ☐
5. Annular space seal: a. Granular/Chipped Bentonite ☐
   b. ______ Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   c. ______ Lbs/gal mud weight . . . Bentonite slurry ☐
   d. 30 % Bentonite . . . Bentonite-cement grout ☒
   e. ______ Ft^3 volume added for any of the above
   f. How installed: Tremie ☐
   Tremie pumped ☒
   Gravity ☐
6. Bentonite seal: a. Bentonite granules ☐
   b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
   c. ______ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
   a. ______
   b. Volume added ______ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
   a. Unimin Corporation, FILTERSIL
   b. Volume added ______ ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒
   Flush threaded PVC schedule 80 ☐
   ______ Other ☐
10. Screen material: Schedule 40 PVC
    a. Screen Type: Factory cut ☒
    Continuous slot ☐
    ______ Other ☐
    b. Manufacturer ______
    c. Slot size: 0.010 in.
    d. Slotted length: 4.0 ft.
11. Backfill material (below filter pack): None ☒
    ______ Other ☐

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Date Modified: 4/14/2016

Signature

Firm: Natural Resource Technology
234 W. Florida Street, Floor 5, Milwaukee, WI 53204
Tel: (414) 837-3607
Fax: (414) 837-3608

NATURAL RESOURCE TECHNOLOGY

MONITORING WELL CONSTRUCTION

Facility/Project Name	Local Grid Location of Well	Well Name
Kincaid Power Station	______ ft. ☐ N. ☐ S. ______ ft. ☐ E. ☐ W.	PZ-2B
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒	
	Lat. ___° ___' ___" Long. ___° ___' ___" or	
Facility ID	St. Plane 1,069,329.32 ft. N, 2,486,397.79 ft. E. E/Ⓦ	Date Well Installed 04/01/2016
Type of Well: pz	Section Location of Waste/Source: ___ 1/4 of ___ 1/4 of Sec. ___, T. ___ N, R. ___ ☐ E ☐ W	Well Installed By: (Person's Name and Firm) John Gates, Bulldog Drilling
Distance from Waste/Source: ___ ft. / State: Illinois	Location of Well Relative to Waste/Source: u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known / Gov. Lot Number: ___	

A. Protective pipe, top elevation ______ ft. (NAVD88)

B. Well casing, top elevation 616.60 ft. (NAVD88)

C. Land surface elevation 613.96 ft. (NAVD88)

D. Surface seal, bottom ______ ft. (NAVD88) or ______ ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☐ ML ☒ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐ Hollow Stem Auger ☒ ______ Other ☐

15. Drilling fluid used: Water ☒ 0 2 Air ☐ Drilling Mud ☐ 0 3 None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe ______

17. Source of water (attach analysis, if required): Village of Pawnee, IL

E. Bentonite seal, top 614.0 ft. (NAVD88) or 0.0 ft.

F. Fine sand, top ______ ft. (NAVD88) or ______ ft.

G. Filter pack, top 585.0 ft. (NAVD88) or 29.0 ft.

H. Screen joint, top 584.0 ft. (NAVD88) or 30.0 ft.

I. Well bottom ______ ft. (NAVD88) or ______ ft.

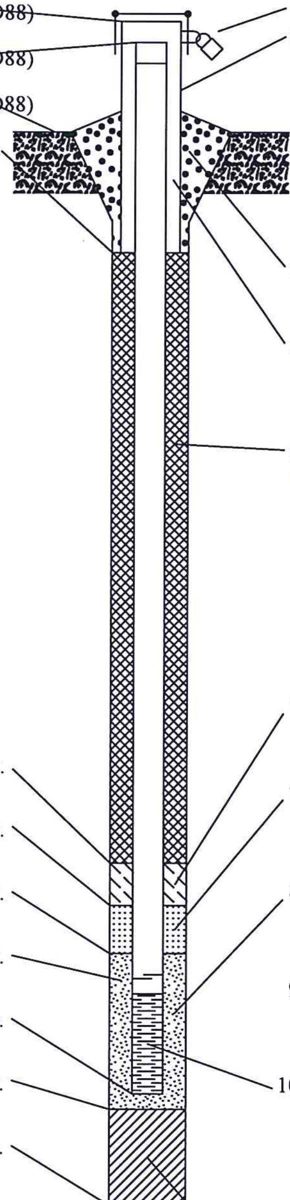
J. Filter pack, bottom 582.0 ft. (NAVD88) or 32.0 ft.

K. Borehole, bottom 582.0 ft. (NAVD88) or 32.0 ft.

L. Borehole, diameter 8.3 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.



1. Cap and lock? ☐ Yes ☒ No

2. Protective cover pipe:
   a. Inside diameter: ______ in.
   b. Length: ______ ft.
   c. Material: Steel ☒ ______ Other ☐
   d. Additional protection? ☐ Yes ☒ No
   If yes, describe: ______

3. Surface seal: Bentonite ☐ Concrete ☐ ______ Other ☐

4. Material between well casing and protective pipe: Bentonite ☒ ______ Other ☐

5. Annular space seal: a. Granular/Chipped Bentonite ☐
   b. ______ Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   c. ______ Lbs/gal mud weight . . . Bentonite slurry ☐
   d. 30 % Bentonite . . . Bentonite-cement grout ☒
   e. ______ Ft^3 volume added for any of the above
   f. How installed: Tremie ☐ Tremie pumped ☒ Gravity ☐

6. Bentonite seal: a. Bentonite granules ☐
   b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
   c. ______ Other ☐

7. Fine sand material: Manufacturer, product name & mesh size
   a. ______
   b. Volume added ______ ft^3

8. Filter pack material: Manufacturer, product name & mesh size
   a. Unimin Corporation, FILTERSIL
   b. Volume added ______ ft^3

9. Well casing: Flush threaded PVC schedule 40 ☒ Flush threaded PVC schedule 80 ☐ ______ Other ☐

10. Screen material: Schedule 40 PVC
    a. Screen Type: Factory cut ☒ Continuous slot ☐ ______ Other ☐
    b. Manufacturer ______
    c. Slot size: 0.010 in.
    d. Slotted length: 2.0 ft.

11. Backfill material (below filter pack): None ☒ ______ Other ☐

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Date Modified: 4/14/2016

Signature [signature]

Firm Natural Resource Technology
234 W. Florida Street, Floor 5, Milwaukee, WI 53204
Tel: (414) 837-3607
Fax: (414) 837-3608

NATURAL RESOURCE TECHNOLOGY

MONITORING WELL CONSTRUCTION

Facility/Project Name Kincaid Power Station	Local Grid Location of Well ____ ft. ☐ N. ☐ S. ____ ft. ☐ E. ☐ W.	Well Name
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒ Lat. ___ ° ___ ' ___ " Long. ___ ° ___ ' ___ " or	PZ-2C
Facility ID	St. Plane 1,069,329.19 ft. N, 2,486,393.15 ft. E. E/Ⓦ	Date Well Installed 04/01/2016
Type of Well pz	Section Location of Waste/Source ____ 1/4 of ____ 1/4 of Sec. ____, T. ____ N, R. ____ ☐ E ☐ W	Well Installed By: (Person's Name and Firm) John Gates
Distance from Waste/ Source ____ ft. / State Illinois	Location of Well Relative to Waste/Source u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known / Gov. Lot Number	Bulldog Drilling

A. Protective pipe, top elevation ____ ft. (NAVD88)

B. Well casing, top elevation 616.60 ft. (NAVD88)

C. Land surface elevation 614.10 ft. (NAVD88)

D. Surface seal, bottom ____ ft. (NAVD88) or ____ ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☒ ML ☐ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐
Hollow Stem Auger ☒
____ Other ☐

15. Drilling fluid used: Water ☒ 0 2 Air ☐
Drilling Mud ☐ 0 3 None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe ____

17. Source of water (attach analysis, if required):
Village of Pawnee, IL

E. Bentonite seal, top 614.1 ft. (NAVD88) or 0.0 ft.

F. Fine sand, top ____ ft. (NAVD88) or ____ ft.

G. Filter pack, top 579.6 ft. (NAVD88) or 34.5 ft.

H. Screen joint, top 578.6 ft. (NAVD88) or 35.5 ft.

I. Well bottom ____ ft. (NAVD88) or ____ ft.

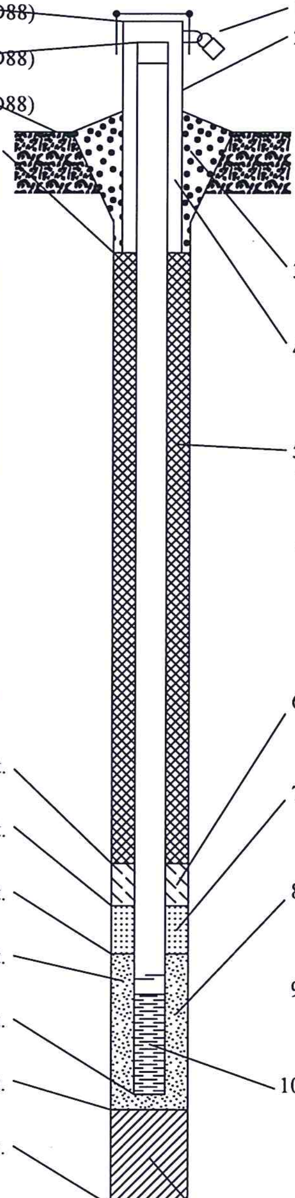
J. Filter pack, bottom 576.0 ft. (NAVD88) or 38.1 ft.

K. Borehole, bottom 576.0 ft. (NAVD88) or 38.1 ft.

L. Borehole, diameter 8.3 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.



1. Cap and lock? ☐ Yes ☒ No

2. Protective cover pipe:
a. Inside diameter: ____ in.
b. Length: ____ ft.
c. Material: Steel ☒
____ Other ☐
d. Additional protection? ☐ Yes ☒ No
If yes, describe: ____

3. Surface seal: Bentonite ☐
Concrete ☐
____ Other ☐

4. Material between well casing and protective pipe:
Bentonite ☒
____ Other ☐

5. Annular space seal: a. Granular/Chipped Bentonite ☐
b. ____ Lbs/gal mud weight . . . Bentonite-sand slurry ☐
c. ____ Lbs/gal mud weight . . . Bentonite slurry ☐
d. 30 % Bentonite . . . Bentonite-cement grout ☒
e. ____ Ft^3 volume added for any of the above
f. How installed: Tremie ☐
Tremie pumped ☒
Gravity ☐

6. Bentonite seal: a. Bentonite granules ☐
b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
c. ____ Other ☐

7. Fine sand material: Manufacturer, product name & mesh size
a. ____
b. Volume added ____ ft^3

8. Filter pack material: Manufacturer, product name & mesh size
a. Unimin Corporation, FILTERSIL
b. Volume added ____ ft^3

9. Well casing: Flush threaded PVC schedule 40 ☒
Flush threaded PVC schedule 80 ☐
____ Other ☐

10. Screen material: Schedule 40 PVC
a. Screen Type: Factory cut ☒
Continuous slot ☐
____ Other ☐
b. Manufacturer ____
c. Slot size: 0.010 in.
d. Slotted length: 2.0 ft.

11. Backfill material (below filter pack): None ☒
____ Other ☐

I hereby certify that the information on this form is true and correct to the best of my knowledge. Date Modified: 4/14/2016

Signature [signature]

Firm Natural Resource Technology
234 W. Florida Street, Floor 5, Milwaukee, WI 53204
Tel: (414) 837-3607
Fax: (414) 837-3608

Natural Resource Technology

MONITORING WELL CONSTRUCTION

Facility/Project Name: Kincaid Power Station	Local Grid Location of Well: ____ ft. ☐ N. ☐ S. ____ ft. ☐ E. ☐ W.	Well Name: PZ-3A
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒ Lat. ___° ___' ___" Long. ___° ___' ___" or	
Facility ID	St. Plane 1,066,848.40 ft. N, 2,485,792.80 ft. E. E/(W)	Date Well Installed: 03/30/2016
Type of Well: pz	Section Location of Waste/Source: ____ 1/4 of ____ 1/4 of Sec. ____, T. ____ N, R. ____ ☐ E ☐ W	Well Installed By: (Person's Name and Firm) John Gates, Bulldog Drilling
Distance from Waste/Source: ft. — State: Illinois	Location of Well Relative to Waste/Source: u ☐ Upgradient; s ☐ Sidegradient; d ☐ Downgradient; n ☐ Not Known — Gov. Lot Number:	

A. Protective pipe, top elevation ____ ft. (NAVD88)

B. Well casing, top elevation 606.26 ft. (NAVD88)

C. Land surface elevation 603.33 ft. (NAVD88)

D. Surface seal, bottom ____ ft. (NAVD88) or ____ ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☐ ML ☐ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐; Hollow Stem Auger ☒; Other ☐

15. Drilling fluid used: Water ☒ 0 2; Air ☐; Drilling Mud ☐ 0 3; None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe ____

17. Source of water (attach analysis, if required): Village of Pawnee, IL

E. Bentonite seal, top 603.3 ft. (NAVD88) or 0.0 ft.

F. Fine sand, top ____ ft. (NAVD88) or ____ ft.

G. Filter pack, top 596.3 ft. (NAVD88) or 7.0 ft.

H. Screen joint, top 595.3 ft. (NAVD88) or 8.0 ft.

I. Well bottom ____ ft. (NAVD88) or ____ ft.

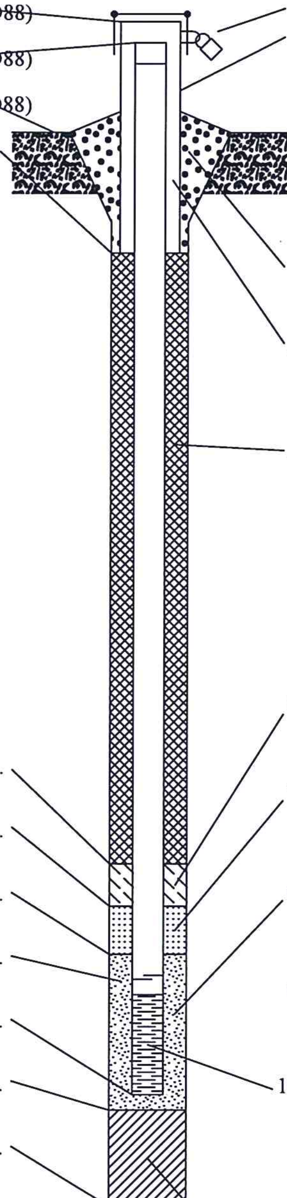
J. Filter pack, bottom 591.3 ft. (NAVD88) or 12.0 ft.

K. Borehole, bottom 591.3 ft. (NAVD88) or 12.0 ft.

L. Borehole, diameter 8.3 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.



1. Cap and lock? ☐ Yes ☒ No
2. Protective cover pipe:
   a. Inside diameter: ____ in.
   b. Length: ____ ft.
   c. Material: Steel ☒; Other ☐
   d. Additional protection? ☐ Yes ☒ No; If yes, describe: ____
3. Surface seal: Bentonite ☐; Concrete ☐; Other ☐
4. Material between well casing and protective pipe: Bentonite ☒; Other ☐
5. Annular space seal: a. Granular/Chipped Bentonite ☐
   b. ____ Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   c. ____ Lbs/gal mud weight . . . Bentonite slurry ☐
   d. 30 % Bentonite . . . Bentonite-cement grout ☒
   e. ____ Ft^3 volume added for any of the above
   f. How installed: Tremie ☐; Tremie pumped ☒; Gravity ☐
6. Bentonite seal: a. Bentonite granules ☐
   b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
   c. ____ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
   a. ____
   b. Volume added ____ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
   a. Unimin Corporation, FILTERSIL
   b. Volume added ____ ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒; Flush threaded PVC schedule 80 ☐; Other ☐
10. Screen material: Schedule 40 PVC
    a. Screen Type: Factory cut ☒; Continuous slot ☐; Other ☐
    b. Manufacturer ____
    c. Slot size: 0.010 in.
    d. Slotted length: 4.0 ft.
11. Backfill material (below filter pack): None ☒; Other ☐

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Date Modified: 4/14/2016

Signature: [signature]

Firm: Natural Resource Technology
234 W. Florida Street, Floor 5, Milwaukee, WI 53204
Tel: (414) 837-3607
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NATURAL RESOURCE TECHNOLOGY

MONITORING WELL CONSTRUCTION

Facility/Project Name: Kincaid Power Station	Local Grid Location of Well: ____ft. ☐ N. ☐ S. ____ft. ☐ E. ☐ W.	Well Name: PZ-3B
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒ Lat. ___° ___' ___" Long. ___° ___' ___" or	
Facility ID	St. Plane 1,066,848.81 ft. N, 2,485,789.93 ft. E. E /(W)	Date Well Installed: 03/30/2016
Type of Well: pz	Section Location of Waste/Source: ___1/4 of ___ 1/4 of Sec. ___, T. ___ N, R. ___ ☐ E ☐ W	Well Installed By: (Person's Name and Firm) John Gates, Bulldog Drilling
Distance from Waste/Source ___ ft. / State: Illinois	Location of Well Relative to Waste/Source: u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known / Gov. Lot Number ___	

A. Protective pipe, top elevation ____ ft. (NAVD88)

B. Well casing, top elevation 606.17 ft. (NAVD88)

C. Land surface elevation 603.47 ft. (NAVD88)

D. Surface seal, bottom ____ ft. (NAVD88) or ____ ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☐ ML ☒ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐ Hollow Stem Auger ☒ ____ Other ☐

15. Drilling fluid used: Water ☒ 0 2 Air ☐ Drilling Mud ☐ 0 3 None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe ____

17. Source of water (attach analysis, if required): Village of Pawnee, IL

E. Bentonite seal, top 603.5 ft. (NAVD88) or 0.0 ft.

F. Fine sand, top ____ ft. (NAVD88) or ____ ft.

G. Filter pack, top 589.5 ft. (NAVD88) or 14.0 ft.

H. Screen joint, top 588.5 ft. (NAVD88) or 15.0 ft.

I. Well bottom ____ ft. (NAVD88) or ____ ft.

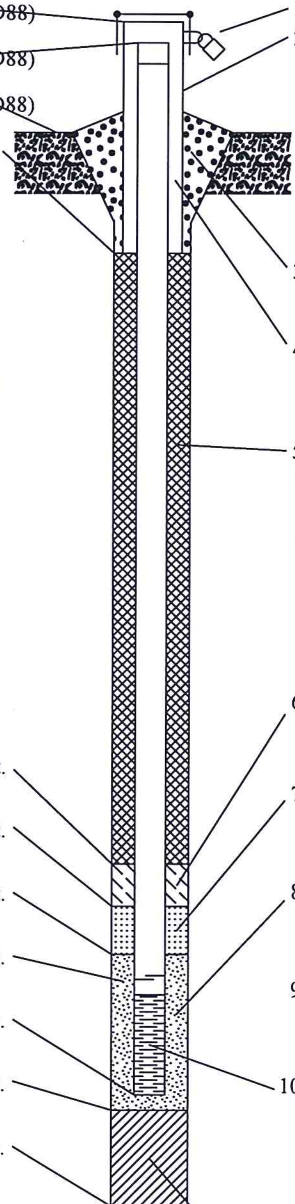
J. Filter pack, bottom 586.5 ft. (NAVD88) or 17.0 ft.

K. Borehole, bottom 586.5 ft. (NAVD88) or 17.0 ft.

L. Borehole, diameter 8.3 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.



1. Cap and lock? ☐ Yes ☒ No
2. Protective cover pipe:
   a. Inside diameter: ____ in.
   b. Length: ____ ft.
   c. Material: Steel ☒ ____ Other ☐
   d. Additional protection? ☐ Yes ☒ No
   If yes, describe: ____
3. Surface seal: Bentonite ☐ Concrete ☐ ____ Other ☐
4. Material between well casing and protective pipe: Bentonite ☒ ____ Other ☐
5. Annular space seal: a. Granular/Chipped Bentonite ☐
   b. ____Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   c. ____Lbs/gal mud weight . . . Bentonite slurry ☐
   d. 30 % Bentonite . . . Bentonite-cement grout ☒
   e. ____Ft^3 volume added for any of the above
   f. How installed: Tremie ☐ Tremie pumped ☒ Gravity ☐
6. Bentonite seal: a. Bentonite granules ☐
   b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
   c. ____ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
   a. ____
   b. Volume added ____ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
   a. Unimin Corporation, FILTERSIL
   b. Volume added ____ ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒ Flush threaded PVC schedule 80 ☐ ____ Other ☐
10. Screen material: Schedule 40 PVC
    a. Screen Type: Factory cut ☒ Continuous slot ☐ ____ Other ☐
    b. Manufacturer ____
    c. Slot size: 0.010 in.
    d. Slotted length: 2.0 ft.
11. Backfill material (below filter pack): None ☒ ____ Other ☐

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Date Modified: 4/14/2016

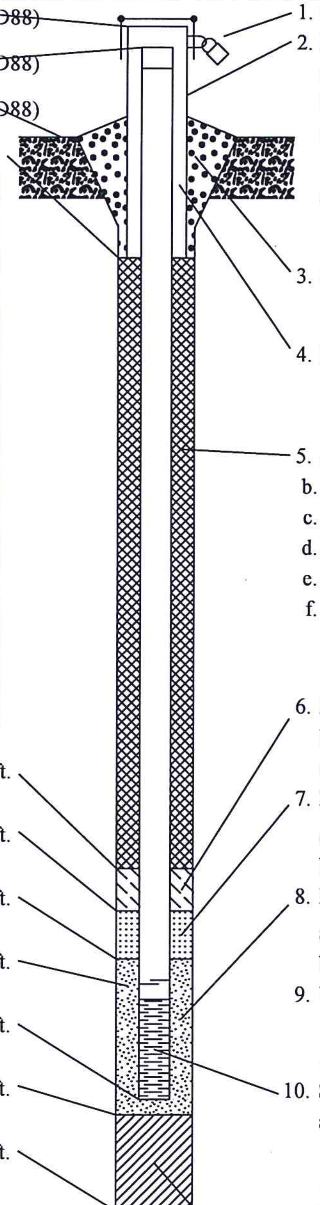
Signature [signature]

Firm: Natural Resource Technology
234 W. Florida Street, Floor 5, Milwaukee, WI 53204
Tel: (414) 837-3607
Fax: (414) 837-3608

NATURAL RESOURCE TECHNOLOGY

MONITORING WELL CONSTRUCTION

Facility/Project Name	Local Grid Location of Well	Well Name
Kincaid Power Station	____ ft. ☐ N. ☐ S. ____ ft. ☐ E. ☐ W.	
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒ Lat. ___° ___' ___" Long. ___° ___' ___" or	PZ-3C
Facility ID	St. Plane 1,066,849.23 ft. N, 2,485,786.53 ft. E. E/Ⓦ	Date Well Installed 03/30/2016
Type of Well: pz	Section Location of Waste/Source ___1/4 of ___ 1/4 of Sec. ___, T. ___ N, R. ___ ☐ E ☐ W	Well Installed By: (Person's Name and Firm) John Gates Bulldog Drilling
Distance from Waste/Source ft. / State: Illinois	Location of Well Relative to Waste/Source u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known / Gov. Lot Number	



A. Protective pipe, top elevation ______ ft. (NAVD88)

B. Well casing, top elevation 606.25 ft. (NAVD88)

C. Land surface elevation 603.49 ft. (NAVD88)

D. Surface seal, bottom ______ ft. (NAVD88) or ______ ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☒
SM ☐ SC ☐ ML ☒ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐
Hollow Stem Auger ☒
______ Other ☐

15. Drilling fluid used: Water ☒ 0 2 Air ☐
Drilling Mud ☐ 0 3 None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe ______

17. Source of water (attach analysis, if required):
Village of Pawnee, IL

E. Bentonite seal, top 603.5 ft. (NAVD88) or 0.0 ft.

F. Fine sand, top ______ ft. (NAVD88) or ______ ft.

G. Filter pack, top 584.5 ft. (NAVD88) or 19.0 ft.

H. Screen joint, top 583.5 ft. (NAVD88) or 20.0 ft.

I. Well bottom ______ ft. (NAVD88) or ______ ft.

J. Filter pack, bottom 578.7 ft. (NAVD88) or 24.8 ft.

K. Borehole, bottom 578.7 ft. (NAVD88) or 24.8 ft.

L. Borehole, diameter 8.3 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.

1. Cap and lock? ☐ Yes ☒ No

2. Protective cover pipe:
a. Inside diameter: ______ in.
b. Length: ______ ft.
c. Material: Steel ☒
______ Other ☐
d. Additional protection? ☐ Yes ☒ No
If yes, describe: ______

3. Surface seal: Bentonite ☐
Concrete ☐
______ Other ☐

4. Material between well casing and protective pipe:
Bentonite ☒
______ Other ☐

5. Annular space seal: a. Granular/Chipped Bentonite ☐
b. ____Lbs/gal mud weight . . . Bentonite-sand slurry ☐
c. ____Lbs/gal mud weight . . . Bentonite slurry ☐
d. 30 % Bentonite . . . Bentonite-cement grout ☒
e. ______ Ft^3 volume added for any of the above
f. How installed: Tremie ☐
Tremie pumped ☒
Gravity ☐

6. Bentonite seal: a. Bentonite granules ☐
b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
c. ______ Other ☐

7. Fine sand material: Manufacturer, product name & mesh size
a. ______
b. Volume added ______ ft^3

8. Filter pack material: Manufacturer, product name & mesh size
a. Unimin Corporation, FILTERSIL
b. Volume added ______ ft^3

9. Well casing: Flush threaded PVC schedule 40 ☒
Flush threaded PVC schedule 80 ☐
______ Other ☐

10. Screen material: Schedule 40 PVC
a. Screen Type: Factory cut ☒
Continuous slot ☐
______ Other ☐
b. Manufacturer ______
c. Slot size: 0.010 in.
d. Slotted length: 3.0 ft.

11. Backfill material (below filter pack): None ☒
______ Other ☐

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Date Modified: 4/14/2016

Signature [signature]

Firm: Natural Resource Technology
234 W. Florida Street, Floor 5, Milwaukee, WI 53204
Tel: (414) 837-3607
Fax: (414) 837-3608

NATURAL RESOURCE TECHNOLOGY

MONITORING WELL CONSTRUCTION

Facility/Project Name: Kincaid Power Station	Local Grid Location of Well: ____ft. ☐ N. ☐ S. ____ft. ☐ E. ☐ W.	Well Name: PZ-4A
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒ Lat. ___° ___' ___" Long. ___° ___' ___" or	
Facility ID	St. Plane 1,067,576.32 ft. N, 2,488,049.24 ft. E. E / (W)	Date Well Installed: 03/30/2016
Type of Well: pz	Section Location of Waste/Source: ____1/4 of ____ 1/4 of Sec. ____, T. ____ N, R. ____ ☐ E ☐ W	Well Installed By: (Person's Name and Firm) John Gates, Bulldog Drilling
Distance from Waste/Source: ft. / State: Illinois	Location of Well Relative to Waste/Source: u ☐ Upgradient; s ☐ Sidegradient; d ☐ Downgradient; n ☐ Not Known / Gov. Lot Number: ____	

A. Protective pipe, top elevation ________ ft. (NAVD88)

B. Well casing, top elevation 600.49 ft. (NAVD88)

C. Land surface elevation 597.81 ft. (NAVD88)

D. Surface seal, bottom ________ ft. (NAVD88) or ____ ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☐ ML ☐ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐
Hollow Stem Auger ☒
________ Other ☐

15. Drilling fluid used: Water ☒ 0 2 Air ☐
Drilling Mud ☐ 0 3 None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe ________

17. Source of water (attach analysis, if required):
Village of Pawnee, IL

E. Bentonite seal, top 597.8 ft. (NAVD88) or 0.0 ft.

F. Fine sand, top ________ ft. (NAVD88) or ____ ft.

G. Filter pack, top 593.8 ft. (NAVD88) or 4.0 ft.

H. Screen joint, top 592.8 ft. (NAVD88) or 5.0 ft.

I. Well bottom ________ ft. (NAVD88) or ____ ft.

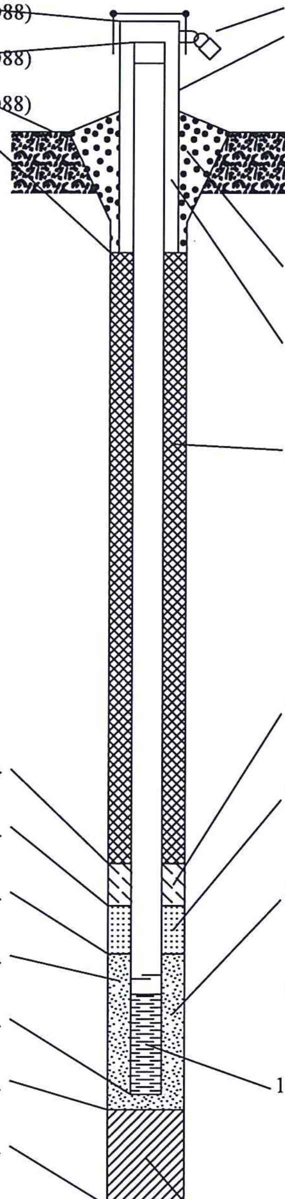
J. Filter pack, bottom 587.8 ft. (NAVD88) or 10.0 ft.

K. Borehole, bottom 587.8 ft. (NAVD88) or 10.0 ft.

L. Borehole, diameter 8.3 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.



1. Cap and lock? ☐ Yes ☒ No

2. Protective cover pipe:
a. Inside diameter: ____ in.
b. Length: ____ ft.
c. Material: Steel ☒
Other ☐
d. Additional protection? ☐ Yes ☒ No
If yes, describe: ________

3. Surface seal: Bentonite ☐
Concrete ☐
Other ☐

4. Material between well casing and protective pipe:
Bentonite ☒
Other ☐

5. Annular space seal: a. Granular/Chipped Bentonite ☐
b. ____Lbs/gal mud weight . . . Bentonite-sand slurry ☐
c. ____Lbs/gal mud weight . . . Bentonite slurry ☐
d. 30 % Bentonite . . . Bentonite-cement grout ☒
e. ____Ft^3 volume added for any of the above
f. How installed: Tremie ☐
Tremie pumped ☒
Gravity ☐

6. Bentonite seal: a. Bentonite granules ☐
b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
c. ________ Other ☐

7. Fine sand material: Manufacturer, product name & mesh size
a. ________
b. Volume added ________ ft^3

8. Filter pack material: Manufacturer, product name & mesh size
a. Unimin Corporation, FILTERSIL
b. Volume added ________ ft^3

9. Well casing: Flush threaded PVC schedule 40 ☒
Flush threaded PVC schedule 80 ☐
________ Other ☐

10. Screen material: Schedule 40 PVC
a. Screen Type: Factory cut ☒
Continuous slot ☐
________ Other ☐
b. Manufacturer ________
c. Slot size: 0.010 in.
d. Slotted length: 5.0 ft.

11. Backfill material (below filter pack): None ☒
________ Other ☐

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Date Modified: 4/14/2016

Signature: [signature]

Firm: Natural Resource Technology
234 W. Florida Street, Floor 5, Milwaukee, WI 53204
Tel: (414) 837-3607
Fax: (414) 837-3608

NATURAL RESOURCE TECHNOLOGY

MONITORING WELL CONSTRUCTION

Facility/Project Name: Kincaid Power Station	Local Grid Location of Well: ____ ft. ☐ N. ☐ S. ____ ft. ☐ E. ☐ W.	Well Name
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒ Lat. ___° ___' ___" Long. ___° ___' ___" or	PZ-4B
Facility ID	St. Plane 1,067,579.46 ft. N, 2,488,049.31 ft. E. E/Ⓦ	Date Well Installed: 03/30/2016
Type of Well: pz	Section Location of Waste/Source: ___ 1/4 of ___ 1/4 of Sec. ___, T. ___ N, R. ___ ☐ E ☐ W	Well Installed By: (Person's Name and Firm) John Gates Bulldog Drilling
Distance from Waste/Source ___ ft. / State: Illinois	Location of Well Relative to Waste/Source: u ☐ Upgradient; s ☐ Sidegradient; d ☐ Downgradient; n ☐ Not Known / Gov. Lot Number: ___	

A. Protective pipe, top elevation ____ ft. (NAVD88)

B. Well casing, top elevation 600.58 ft. (NAVD88)

C. Land surface elevation 597.81 ft. (NAVD88)

D. Surface seal, bottom ____ ft. (NAVD88) or ____ ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☐ ML ☐ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐; Hollow Stem Auger ☒; ____ Other ☐

15. Drilling fluid used: Water ☒ 0 2; Air ☐; Drilling Mud ☐ 0 3; None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe ____

17. Source of water (attach analysis, if required):
Village of Pawnee, IL

E. Bentonite seal, top 597.8 ft. (NAVD88) or 0.0 ft.

F. Fine sand, top ____ ft. (NAVD88) or ____ ft.

G. Filter pack, top 587.8 ft. (NAVD88) or 10.0 ft.

H. Screen joint, top 586.8 ft. (NAVD88) or 11.0 ft.

I. Well bottom ____ ft. (NAVD88) or ____ ft.

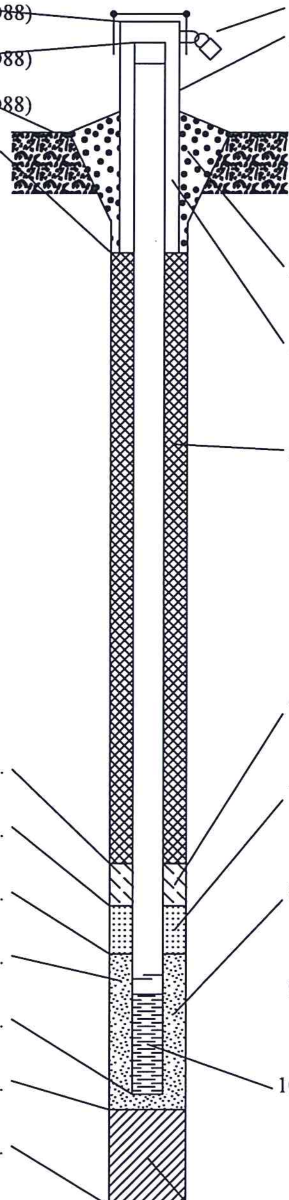
J. Filter pack, bottom 584.8 ft. (NAVD88) or 13.0 ft.

K. Borehole, bottom 584.8 ft. (NAVD88) or 13.0 ft.

L. Borehole, diameter 8.3 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.



1. Cap and lock? ☐ Yes ☒ No

2. Protective cover pipe:
   a. Inside diameter: ____ in.
   b. Length: ____ ft.
   c. Material: Steel ☒; ____ Other ☐
   d. Additional protection? ☐ Yes ☒ No
   If yes, describe: ____

3. Surface seal: Bentonite ☐; Concrete ☐; ____ Other ☐

4. Material between well casing and protective pipe: Bentonite ☒; ____ Other ☐

5. Annular space seal: a. Granular/Chipped Bentonite ☐
   b. ____ Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   c. ____ Lbs/gal mud weight . . . Bentonite slurry ☐
   d. 30 % Bentonite . . . Bentonite-cement grout ☒
   e. ____ Ft^3 volume added for any of the above
   f. How installed: Tremie ☐; Tremie pumped ☒; Gravity ☐

6. Bentonite seal: a. Bentonite granules ☐
   b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
   c. ____ Other ☐

7. Fine sand material: Manufacturer, product name & mesh size
   a. ____
   b. Volume added ____ ft^3

8. Filter pack material: Manufacturer, product name & mesh size
   a. Unimin Corporation, FILTERSIL
   b. Volume added ____ ft^3

9. Well casing: Flush threaded PVC schedule 40 ☒; Flush threaded PVC schedule 80 ☐; ____ Other ☐

10. Screen material: Schedule 40 PVC
   a. Screen Type: Factory cut ☒; Continuous slot ☐; ____ Other ☐
   b. Manufacturer ____
   c. Slot size: 0.010 in.
   d. Slotted length: 2.0 ft.

11. Backfill material (below filter pack): None ☒; ____ Other ☐

I hereby certify that the information on this form is true and correct to the best of my knowledge. Date Modified: 4/14/2016

Signature	Firm
[signature]	Natural Resource Technology 234 W. Florida Street, Floor 5, Milwaukee, WI 53204 Tel: (414) 837-3607 Fax: (414) 837-3608

NATURAL RESOURCE TECHNOLOGY

MONITORING WELL CONSTRUCTION

Facility/Project Name: Kincaid Power Station	Local Grid Location of Well: ____ ft. ☐ N. ☐ S. ____ ft. ☐ E. ☐ W.	Well Name: PZ-4C
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☒ Lat. ___° ___' ___" Long. ___° ___' ___" or St. Plane 1,067,582.54 ft. N, 2,488,047.98 ft. E. E/(W)	
Facility ID	Section Location of Waste/Source ___1/4 of ___ 1/4 of Sec. ___, T. ___ N, R. ___ ☐ E ☐ W	Date Well Installed: 03/30/2016
Type of Well: pz	Location of Well Relative to Waste/Source: u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known	Gov. Lot Number	Well Installed By: (Person's Name and Firm) John Gates, Bulldog Drilling
Distance from Waste/Source ___ ft. / State: Illinois		

A. Protective pipe, top elevation ________ ft. (NAVD88)

B. Well casing, top elevation 600.70 ft. (NAVD88)

C. Land surface elevation 597.83 ft. (NAVD88)

D. Surface seal, bottom ________ ft. (NAVD88) or ____ ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☒ ML ☒ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐ Hollow Stem Auger ☒ ________ Other ☐

15. Drilling fluid used: Water ☒ 0 2 Air ☐ Drilling Mud ☐ 0 3 None ☐

16. Drilling additives used? ☐ Yes ☒ No

Describe ________

17. Source of water (attach analysis, if required): Village of Pawnee, IL

E. Bentonite seal, top 597.8 ft. (NAVD88) or 0.0 ft.

F. Fine sand, top ________ ft. (NAVD88) or ____ ft.

G. Filter pack, top 583.3 ft. (NAVD88) or 14.5 ft.

H. Screen joint, top 582.3 ft. (NAVD88) or 15.5 ft.

I. Well bottom ________ ft. (NAVD88) or ____ ft.

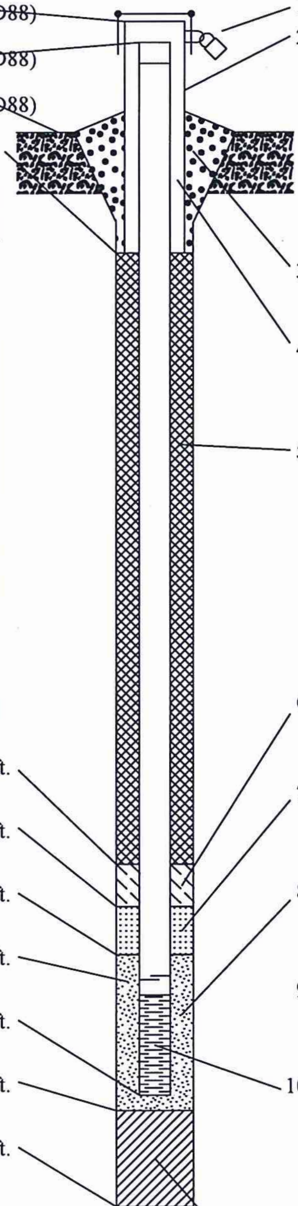
J. Filter pack, bottom 577.3 ft. (NAVD88) or 20.5 ft.

K. Borehole, bottom 577.3 ft. (NAVD88) or 20.5 ft.

L. Borehole, diameter 8.3 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.



1. Cap and lock? ☐ Yes ☒ No
2. Protective cover pipe:
   a. Inside diameter: ____ in.
   b. Length: ____ ft.
   c. Material: Steel ☒ Other ☐
   d. Additional protection? ☐ Yes ☒ No
   If yes, describe: ________
3. Surface seal: Bentonite ☐ Concrete ☐ Other ☐
4. Material between well casing and protective pipe: Bentonite ☒ Other ☐
5. Annular space seal: a. Granular/Chipped Bentonite ☐
   b. ____ Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   c. ____ Lbs/gal mud weight . . . Bentonite slurry ☐
   d. 30 % Bentonite . . . Bentonite-cement grout ☒
   e. ____ Ft^3 volume added for any of the above
   f. How installed: Tremie ☐ Tremie pumped ☒ Gravity ☐
6. Bentonite seal: a. Bentonite granules ☐
   b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
   c. ________ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
   a. ________
   b. Volume added ________ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
   a. Unimin Corporation, FILTERSIL
   b. Volume added ________ ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒ Flush threaded PVC schedule 80 ☐ Other ☐
10. Screen material: Schedule 40 PVC
    a. Screen Type: Factory cut ☒ Continuous slot ☐ Other ☐
    b. Manufacturer ________
    c. Slot size: 0.010 in.
    d. Slotted length: 2.0 ft.
11. Backfill material (below filter pack): None ☒ Other ☐

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Date Modified: 4/14/2016

Signature [signature]

Firm: Natural Resource Technology
234 W. Florida Street, Floor 5, Milwaukee, WI 53204
Tel: (414) 837-3607
Fax: (414) 837-3608

APPENDIX D
GEOTECHNICAL LABORATORY REPORTS

March 23, 2021
Revised: May 10, 2021

Mr. Scott Woods
Ramboll Environ U.S. Corporation
333 West Wacker Drive, Ste 2700
Chicago, IL 60606-2872

RE: Laboratory Testing Program for the Kinkaid Power Station Project – Terracon Project No. 11215018

Dear Mr. Woods,

We are pleased to submit our report pertaining to geotechnical laboratory testing of soil samples in reference to the Edwards Power Station Project. As instructed, Terracon performed the following tests on samples selected by Ramboll:

- Specific Gravity of Soils – ASTM D854
- Water Content of Soil and Rock – ASTM D2216
- Liquid Limit, Plastic Limit and Plasticity Index of Soils – ASTM D4318
- Permeability of Granular Soils (Constant Head) – ASTM D 2434
- Hydraulic Conductivity of Saturated Porous Materials Using a Flexible-Wall Permeameter – ASTM D5084
- Laboratory Determination of Density (Unit Weight) of Soil Specimens – ASTM D7263
- Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis – ASTM D6913
- Particle-Size Distribution (Gradation) of Fine-Grained Soils Using the Sedimentation (Hydrometer) Analysis – ASTM D7928

The permeability test method was changed to ASTM D2434 for several samples. Because of the granular matrix of the samples, use a flexible-wall permeameter was not a suitable test method.

The test data included in this report, only represent the samples tested and may not reflect actual site materials and/or conditions. The scope of services provided by Terracon did not include interpretation of the laboratory test data, and therefore, we are not liable for any interpretation performed by others. If you wish us to provide you with this service, we would be happy to discuss this matter with you at your convenience. Any reproduction of this report must be done in its entirety.

We are pleased to have the opportunity to provide you with our testing services. Should you have any questions, or require additional assistance, please feel free to contact us at any time.

Sincerely,
Terracon Consultants, Inc.

William P. Quinn
Department Manager – Laboratory Services

Attachments:

LABORATORY TESTING SUMMARY

PROJECT NAME: Kincaid Power Station PROJECT NUMBER: 11215018 CLIENT: Confidential

Boring Number	Sample Number	Depth	Description	USCS	WC %	Dry Density (pcf)	% Gravel	% Sand	% Silt	% Clay	LL	PL	PI	Permeability k (cm/sec)	Specific Gravity
MW-12D	0915	5.0'-7.0'	BROWN CLAYEY SAND	SC	18.6	97.8	4.9	49.8	27.2	18.1	22	13	9	3.16E-07	2.682
MW-12D	0940	11.5'-12.0'	BROWN TO GRAY SANDY LEAN CLAY	CL	18.2	94.5	1.1	34.7	41.2	23.0	22	12	10	7.21E-08	2.704
MW-12D	1025	20.5'-22.5'	GRAY CLAYEY SAND	SC	14.0	106.9	6.0	46.4	26.7	20.9	22	13	9	1.97E-07	2.672
MW-20	0815	15.0'-17.0'	BROWN AND GRAY SANDY LEAN CLAY	CL	18.9	107.7	0.6	29.9	46.2	23.3	32	14	18	1.19E-07	2.701
MW-23	1135	15.0'-17.0'	BROWN AND GRAYISH BROWN LEAN CLAY	CL	28.4	92.7	0.0	2.5	63.7	33.8	43	17	26	7.40E-08	2.705
MW-23	1245	25.0'-27.0'	YELLOWISH BROWN SANDY LEAN CLAY	CL	15.6	112.3	0.0	41.6	32.4	26.0	32	14	18	5.85E-08	2.731
XPW-01	1535	8.5'-9.0'	BLACK POORLY GRADED SAND - CINDERS AND BRICK NOTED	SP	19.4	74.8	0.0	97.4	1.1	1.5	12	14	NP	7.16E-04	2.790
XPW-01	1600	20.5'-21.0'	BLACK POORLY GRADED SAND - CINDERS AND ROOTS NOTED	SP	26.8	79.2	0.0	96.3	2.1	1.6	17	15	2	3.51E-04	2.838
XPW-02	0810	8.5'-9.0'	BLACK POORLY GRADED SAND WITH SILT - CINDERS NOTED	SP-SM	11.8	62.7	0.0	94.1	4.2	1.7	4	9	NP	4.04E-03	2.787
XPW-02	0845	21.0'-21.5'	DARK BROWN TO BLACK POORLY GRADED SAND WITH SILT - CINDERS NOTED	SP-SM	13.9	93.9	0.0	94.5	3.7	1.8	8	11	NP	1.94E-03	2.799
XPW-03	1015	8.0'-8.5'	BLACK WELL GRADED SAND WITH SILT - CINDERS NOTED	SW-SM	27.4	86.9	0.2	91.4	6.0	2.4	14	13	1	4.31E-03	2.805
XPW-03	1055	18.0'-18.5'	BLACK POORLY GRADED SAND - CINDERS NOTED	SP	36.4	89.3	1.6	97.1	0.2	1.1	5	10	NP	3.52E-03	2.770
XPW-04	1320	10.5'-11.0'	BLACK AND DARK BROWN POORLY GRADED SAND - CINDERS AND ROOTS NOTED	SP	18.3	77.4	0.2	98.4	0.4	1.0	3	6	NP	9.22E-04	2.786
XPW-04	1405	21.0'-21.5	BLACK AND DARK BROWN POORLY GRADED SAND - CINDERS NOTED	SP	32.3	81.3	0.0	97.3	1.7	1.0	15	16	NP	5.54E-04	2.795

Terracon

Specific Gravity of Soils
ASTM D854

SPECIFIC GRAVITY OF SOIL SOLIDS
ASTM D-854
AASHTO T 100

Laboratory Services Group 192 Exchange Blvd. Glendale Heights, Illinois 60139 Ph. (630) 717-4263

Project Number: 11215018
Project Name: Kincaid Power Station
Test Date: 3/1/2021

Results Summary

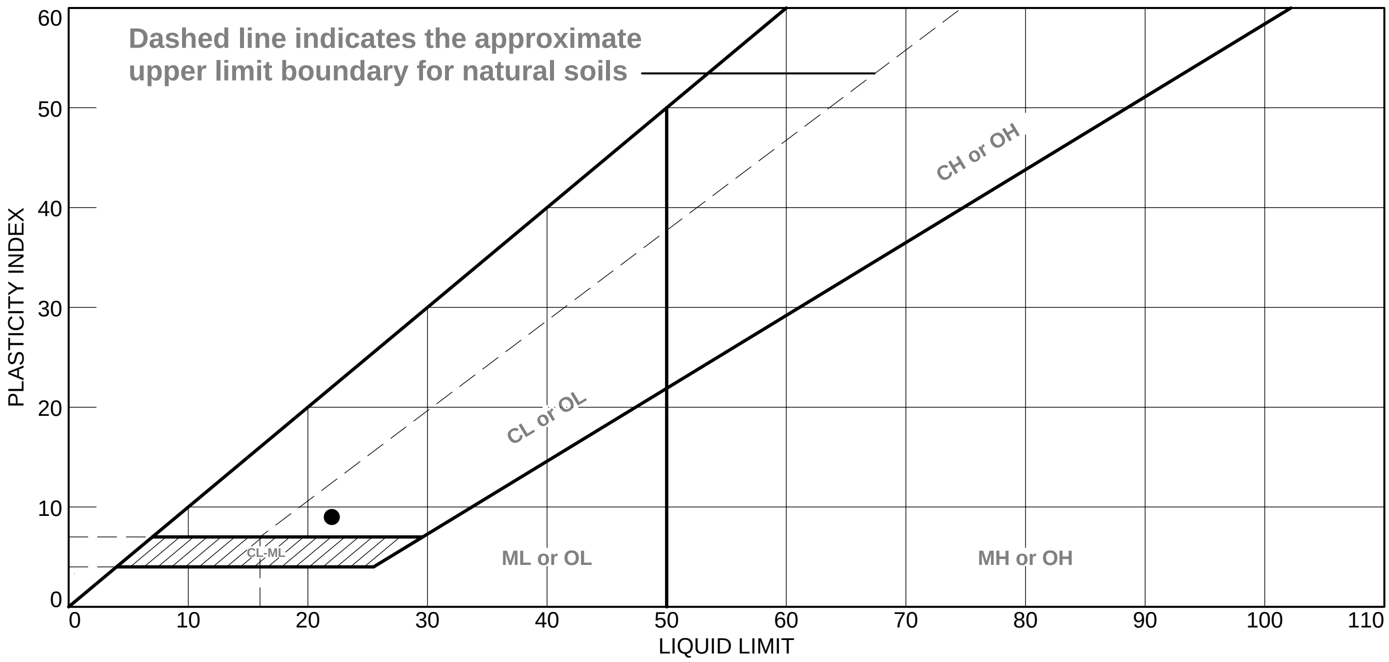
Boring / Sample	Sample Number	Depth (ft)		Specific Gravity (Gs)
MW-12D	0915	5.0'-7.0'		2.682
MW-12D	0940	11.5'-12.0'		2.704
MW-12D	1025	20.5'-22.5'		2.672
MW-20	0815	15.0'-17.0'		2.701
MW-23	1135	15.0'-17.0'		2.705
MW-23	1245	25.0'-27.0'		2.731
XPW-01	1535	8.5'-9.0'		2.790
XPW-01	1600	20.5'-21.0'		2.838
XPW-02	0810	8.5'-9.0'		2.787
XPW-02	0845	21.0'-21.5'		2.799
XPW-03	1015	8.0'-8.5'		2.805
XPW-03	1055	18.0'-18.5'		2.770
XPW-04	1320	10.5'-11.0'		2.786
XPW-04	1405	21.0'-21.5'		2.795

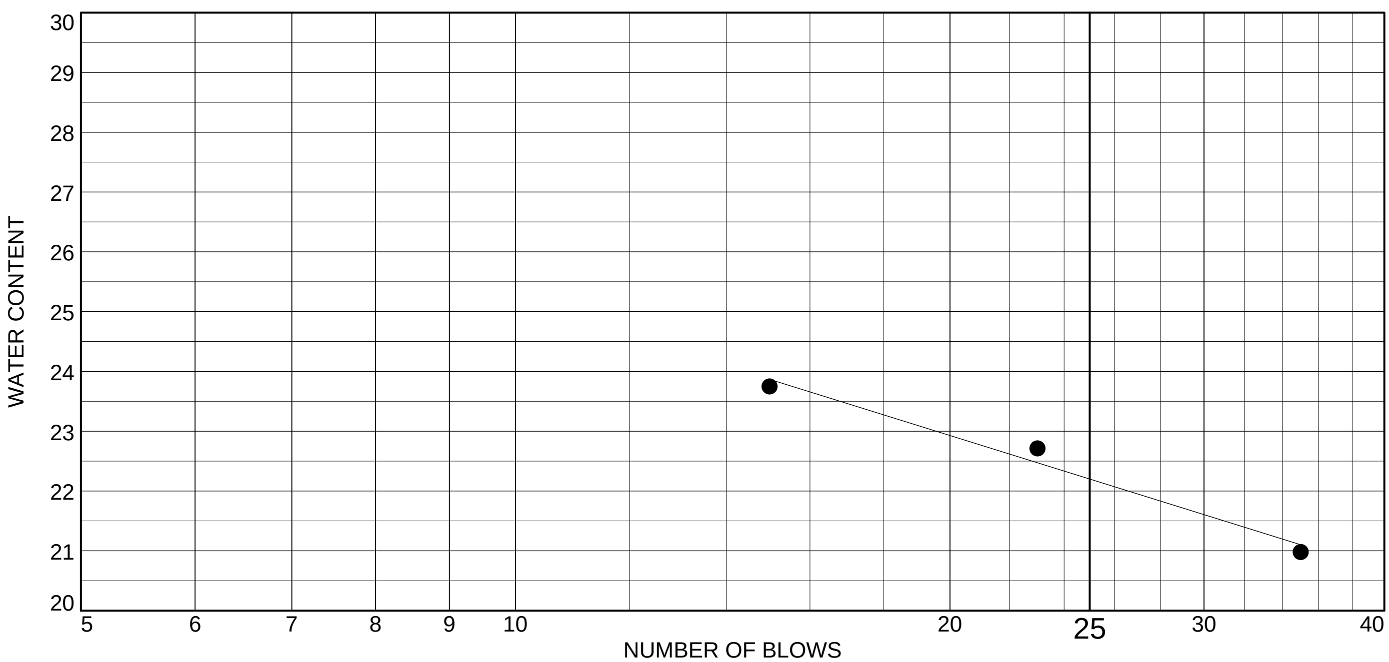
Tested By: SJH

Checked By: WPQ

Liquid Limit, Plastic Limit and Plasticity Index of Soils
ASTM D4318

LIQUID AND PLASTIC LIMITS ASTM D4318





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	BROWN CLAYEY SAND	22	13	9	76.8	45.3	SC

Project No. 11215018 **Client:** CONFIDENTIAL

Project: KINCAID POWER STATION

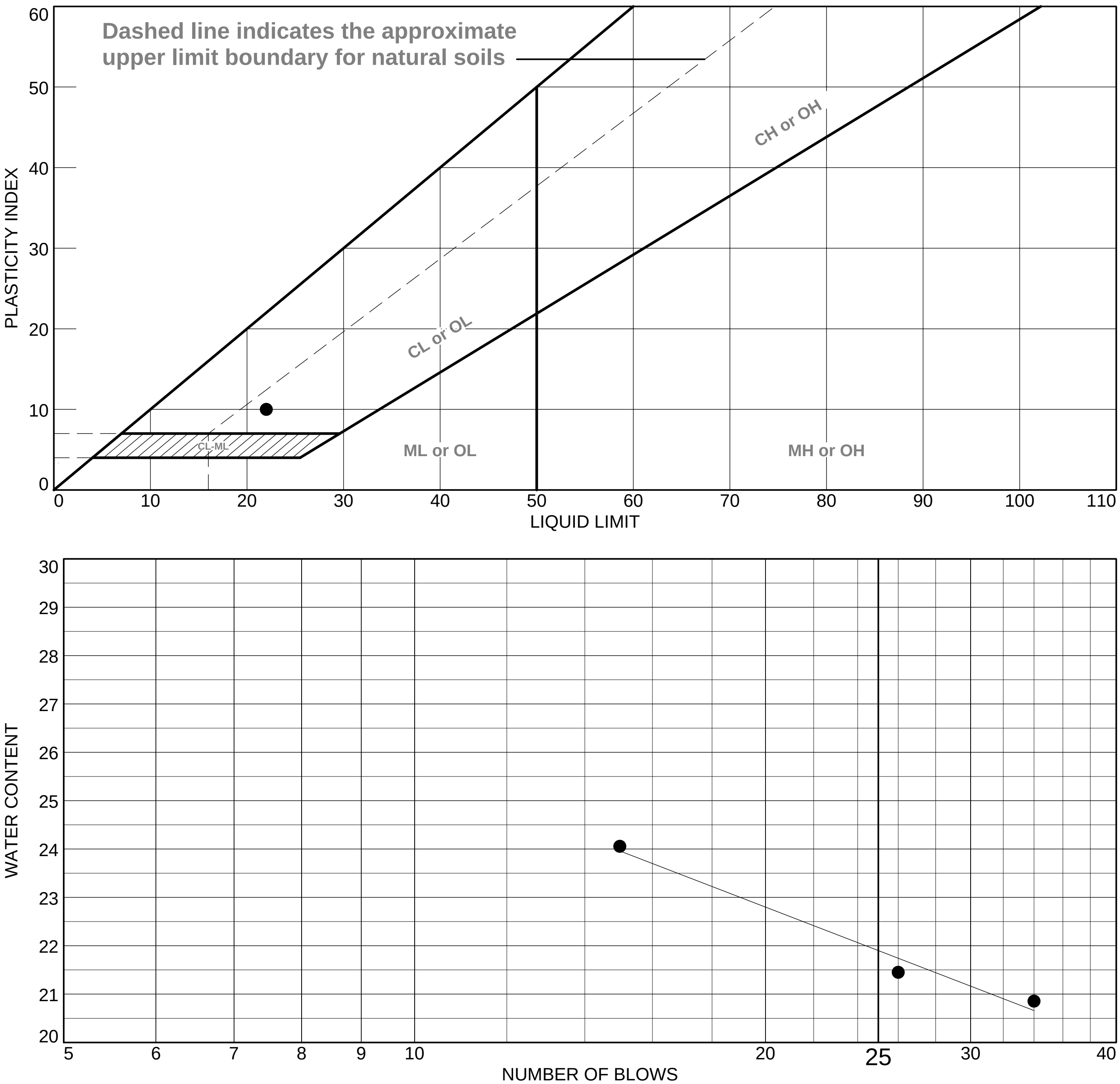
Source of Sample: MW-12D **Depth:** 5.0'-7.0'
Sample Number: 0915

Remarks:

Figure

Tested By: DT **Checked By:** WPQ

LIQUID AND PLASTIC LIMITS ASTM D4318



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	BROWN TO GRAY SANDY LEAN CLAY	22	12	10	87.3	64.2	CL

Project No. 11215018 **Client:** CONFIDENTIAL

Project: KINCAID POWER STATION

Source of Sample: MW-12D **Depth:** 11.5'-12.0'

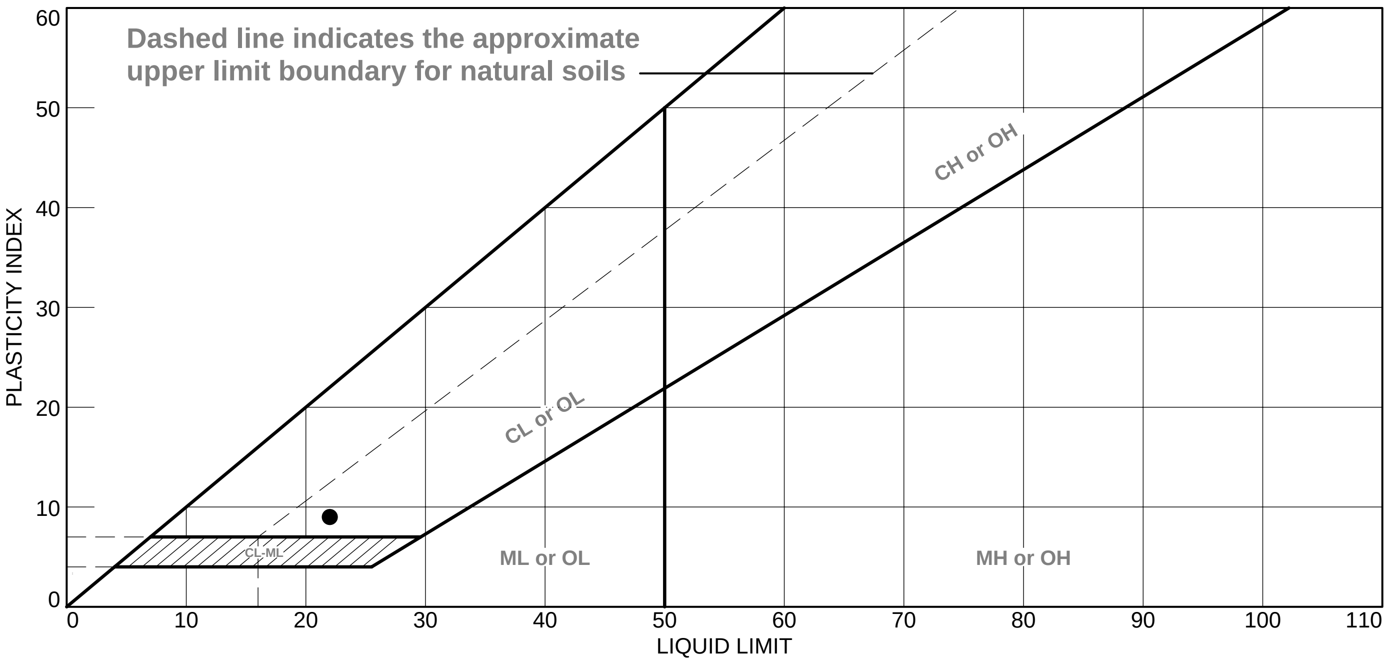
Sample Number: 0940

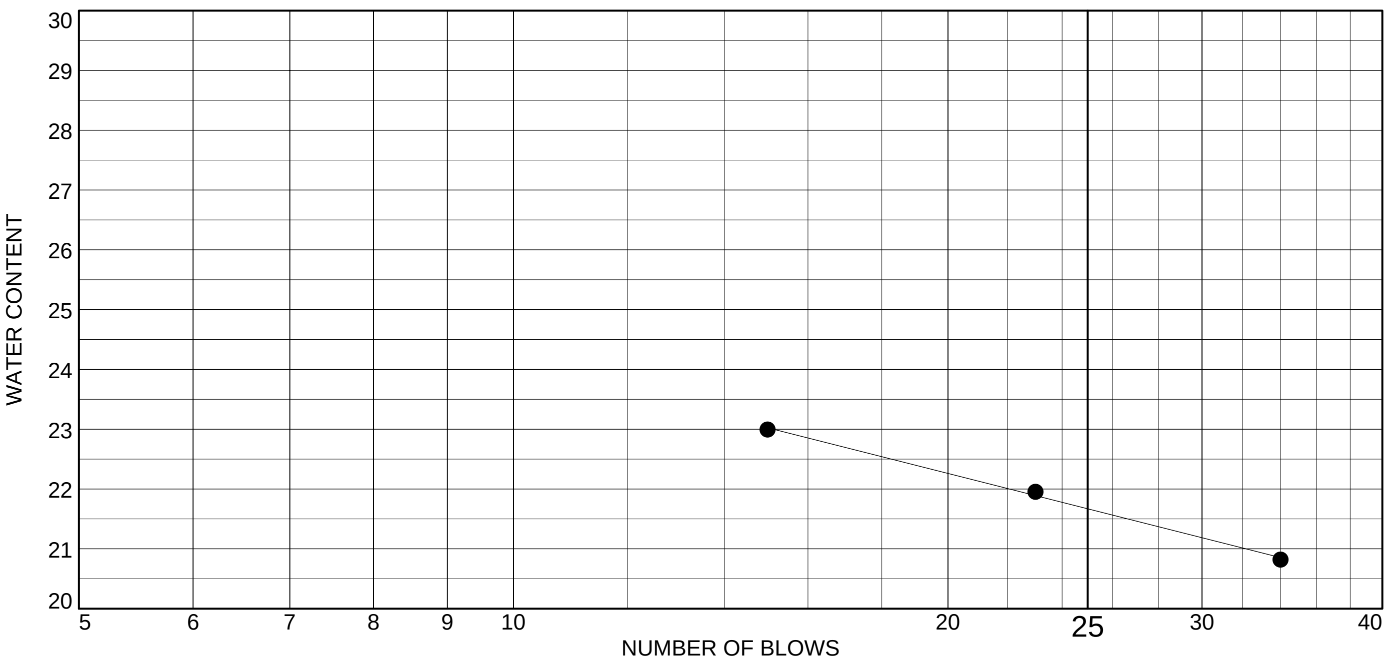
Remarks:

Figure

Tested By: DT **Checked By:** WPQ

LIQUID AND PLASTIC LIMITS ASTM D4318





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	GRAY CLAYEY SAND	22	13	9	73.5	47.6	SC

Project No. 11215018 **Client:** CONFIDENTIAL

Project: KINCAID POWER STATION

Source of Sample: MW-12D **Depth:** 20.5'-22.5'
Sample Number: 1025

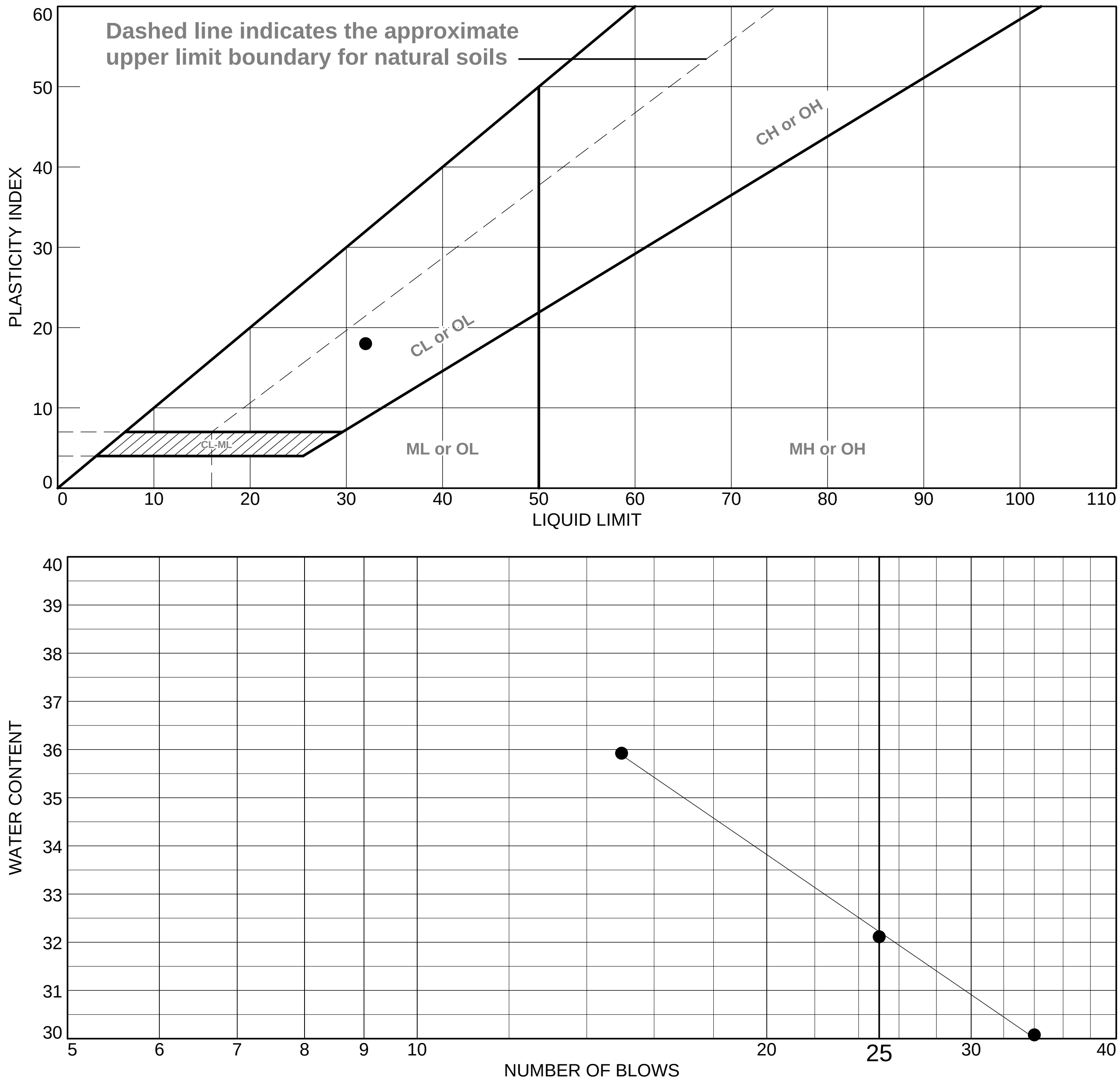
Terracon

Remarks:

Figure

Tested By: DT **Checked By:** WPQ

LIQUID AND PLASTIC LIMITS ASTM D4318



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	BROWN AND GRAY SANDY LEAN CLAY	32	14	18	93.6	69.5	CL

Project No. 11215018 **Client:** CONFIDENTIAL

Project: KINCAID POWER STATION

Source of Sample: MW-20 **Depth:** 15.0'-17.0'
Sample Number: 0815

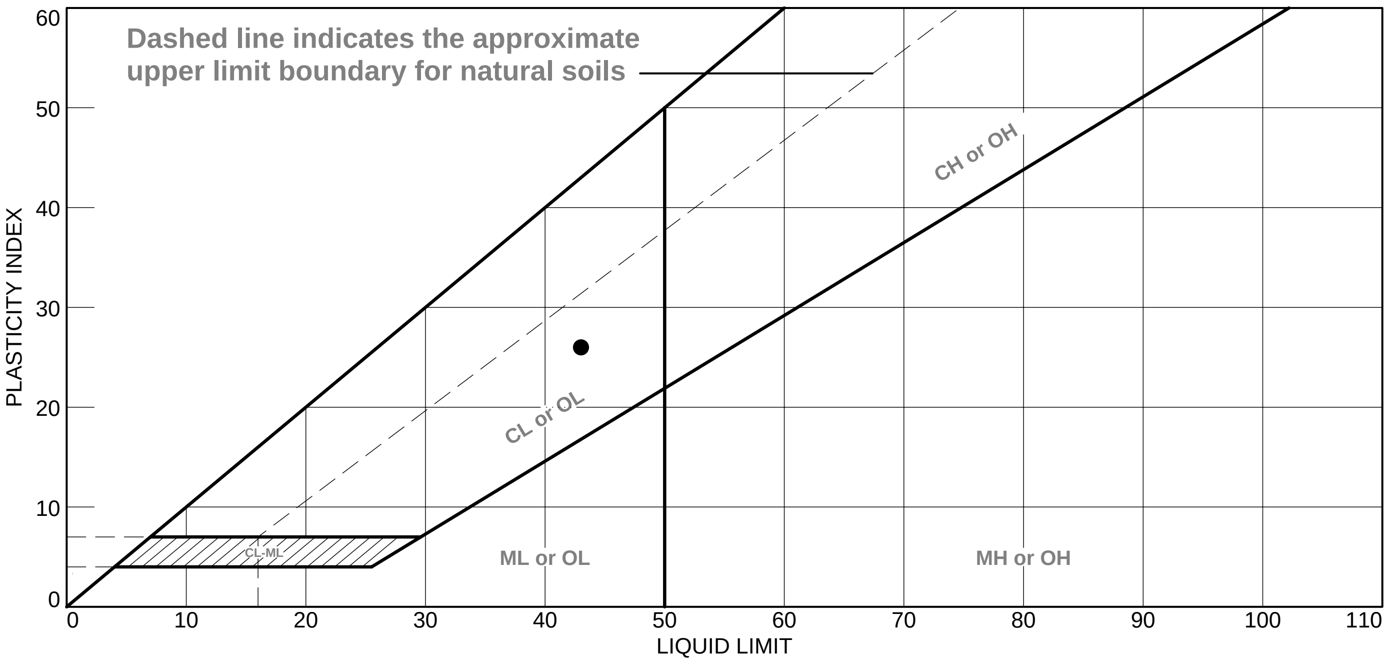
Terracon

Remarks:

Figure

Tested By: DT **Checked By:** WPQ

LIQUID AND PLASTIC LIMITS ASTM D4318



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	BROWN AND GRAYISH BROWN LEAN CLAY	43	17	26	99.0	97.5	CL

Project No. 11215018 **Client:** CONFIDENTIAL

Project: KINCAID POWER STATION

Source of Sample: MW-23 **Depth:** 15.0'-17.0'
Sample Number: 1135

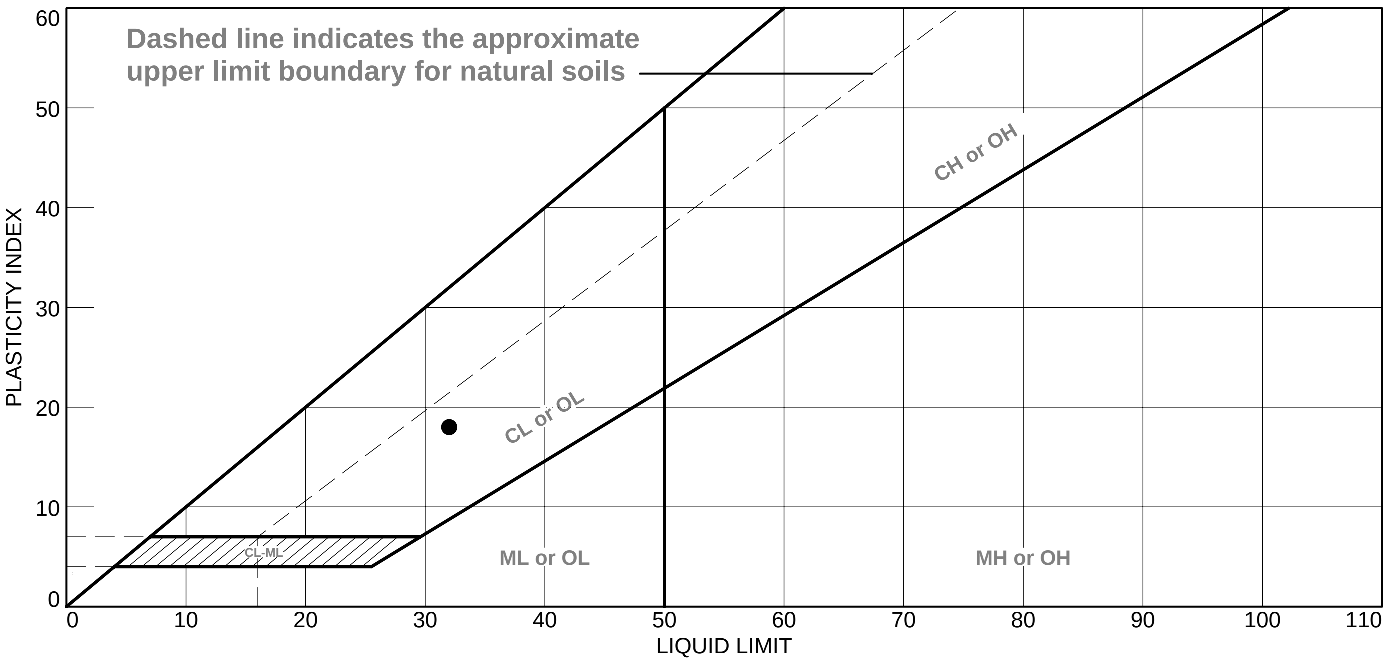
Remarks:

Terracon

Figure

Tested By: DT **Checked By:** WPQ

LIQUID AND PLASTIC LIMITS ASTM D4318



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	YELLOWISH BROWN SANDY LEAN CLAY	32	14	18	87.1	58.4	CL

Project No. 11215018 **Client:** CONFIDENTIAL

Project: KINCAID POWER STATION

Source of Sample: MW-23 **Depth:** 25.0'-27.0'

Sample Number: 1245

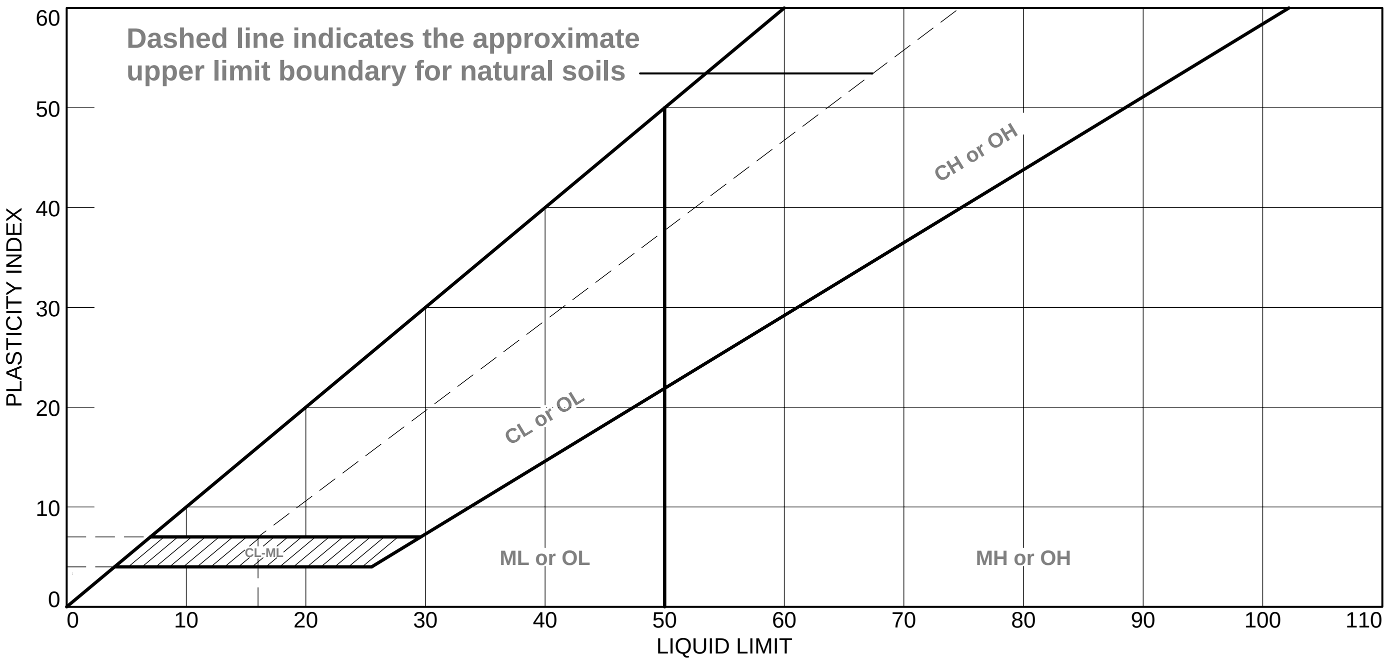
Terracon

Remarks:

Figure

Tested By: DT **Checked By:** WPQ

LIQUID AND PLASTIC LIMITS ASTM D4318



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	BLACK POORLY GRADED SAND - CINDERS AND BRICK NOTED	12	14	NP	16.2	2.6	SP

Project No. 11215018 **Client:** CONFIDENTIAL

Project: KINCAID POWER STATION

Source of Sample: XPW-01 **Depth:** 8.5'-9.0'
Sample Number: 1535

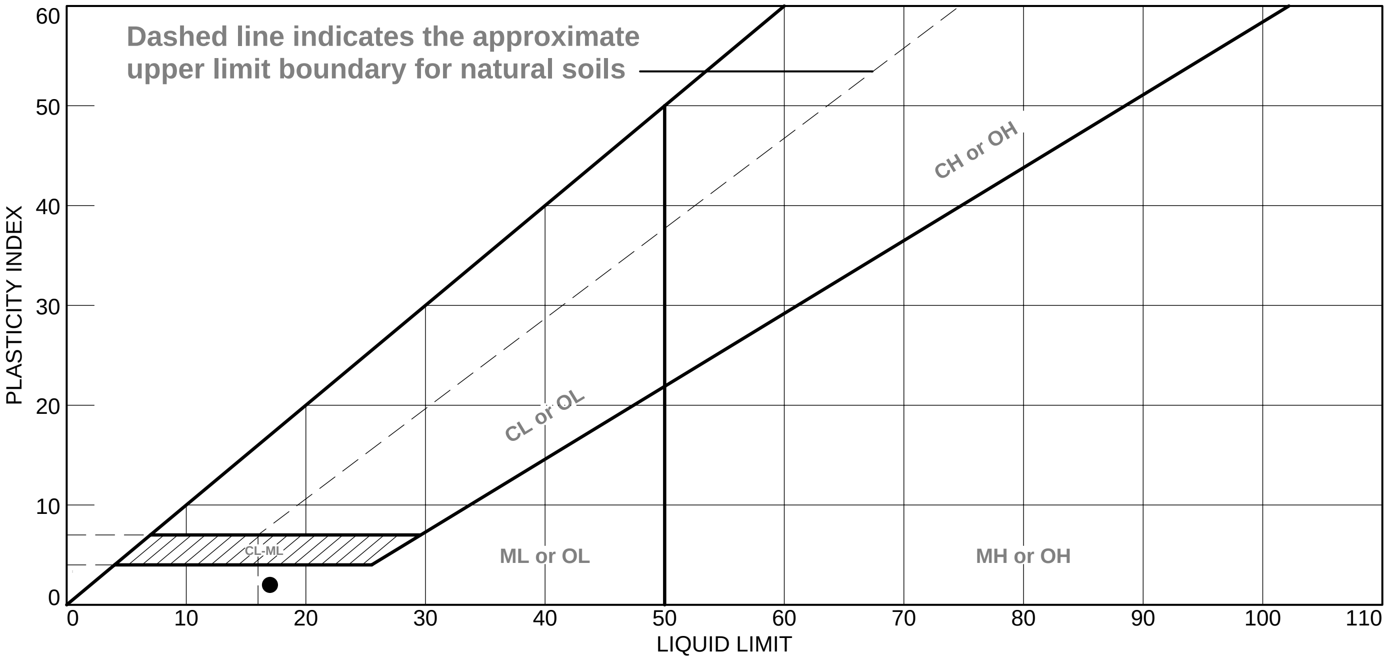
Terracon

Remarks:

Figure

Tested By: DT **Checked By:** WPQ

LIQUID AND PLASTIC LIMITS ASTM D4318



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	BLACK POORLY GRADED SAND - CINDERS AND ROOTS NOTED	17	15	2	17.1	3.7	SP

Project No. 11215018 **Client:** CONFIDENTIAL

Project: KINCAID POWER STATION

Source of Sample: XPW-01 **Depth:** 20.5'-21.0'

Sample Number: 1600

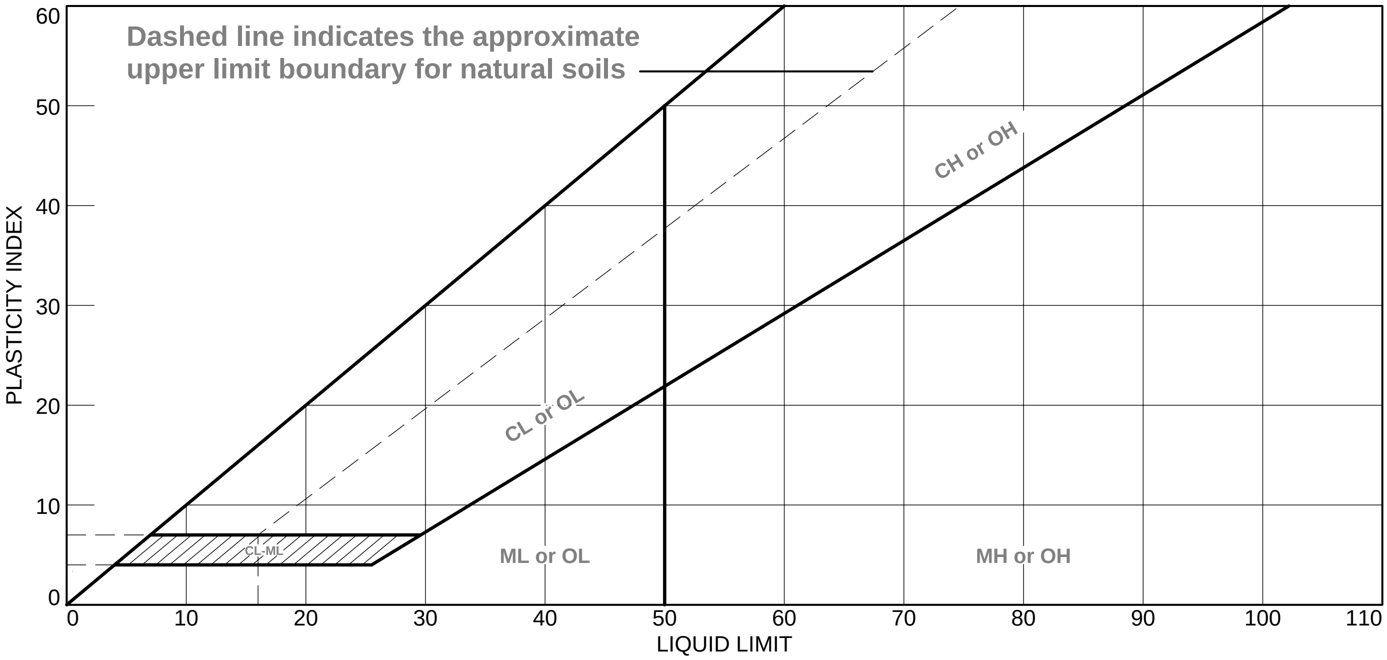
Terracon

Remarks:

Figure

Tested By: DT **Checked By:** WPQ

LIQUID AND PLASTIC LIMITS ASTM D4318



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	BLACK POORLY GRADED SAND WITH SILT - CINDERS NOTED	4	9	NP	44.5	5.9	SP-SM

Project No. 11215018 **Client:** CONFIDENTIAL

Project: KINCAID POWER STATION

Source of Sample: XPW-02 **Depth:** 8.5'-9.0'
Sample Number: 0810

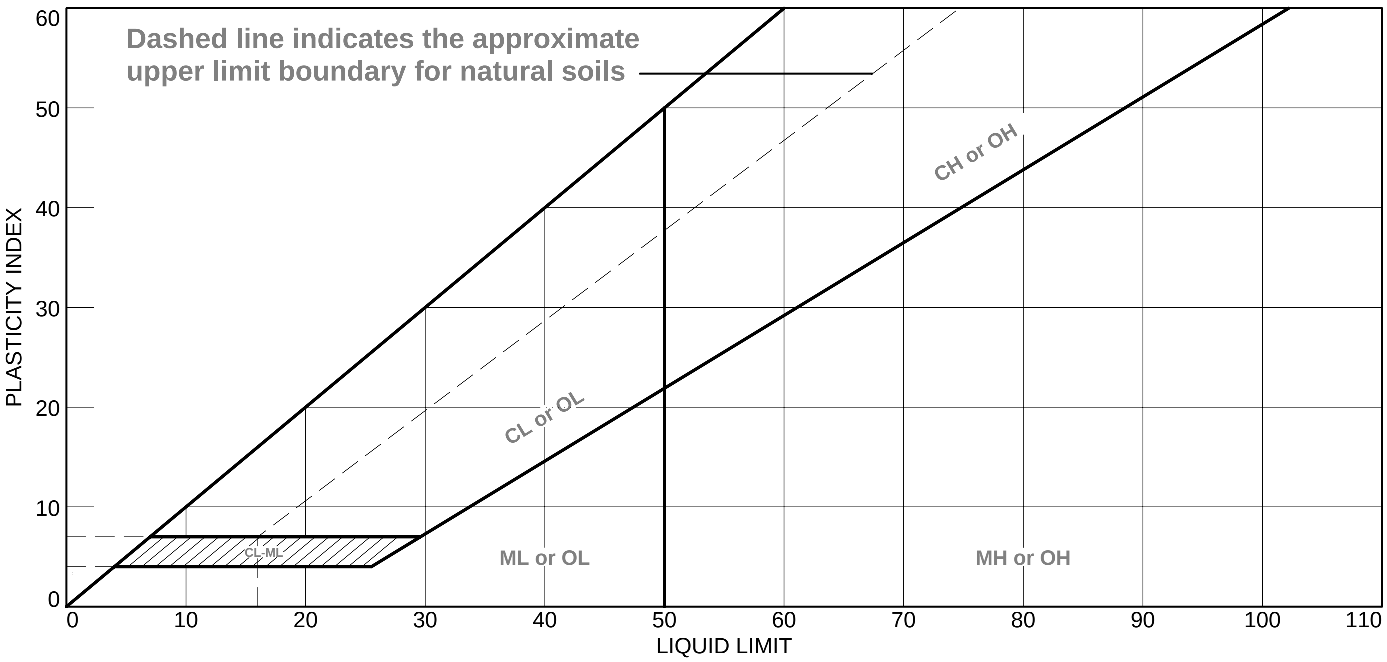
Terracon

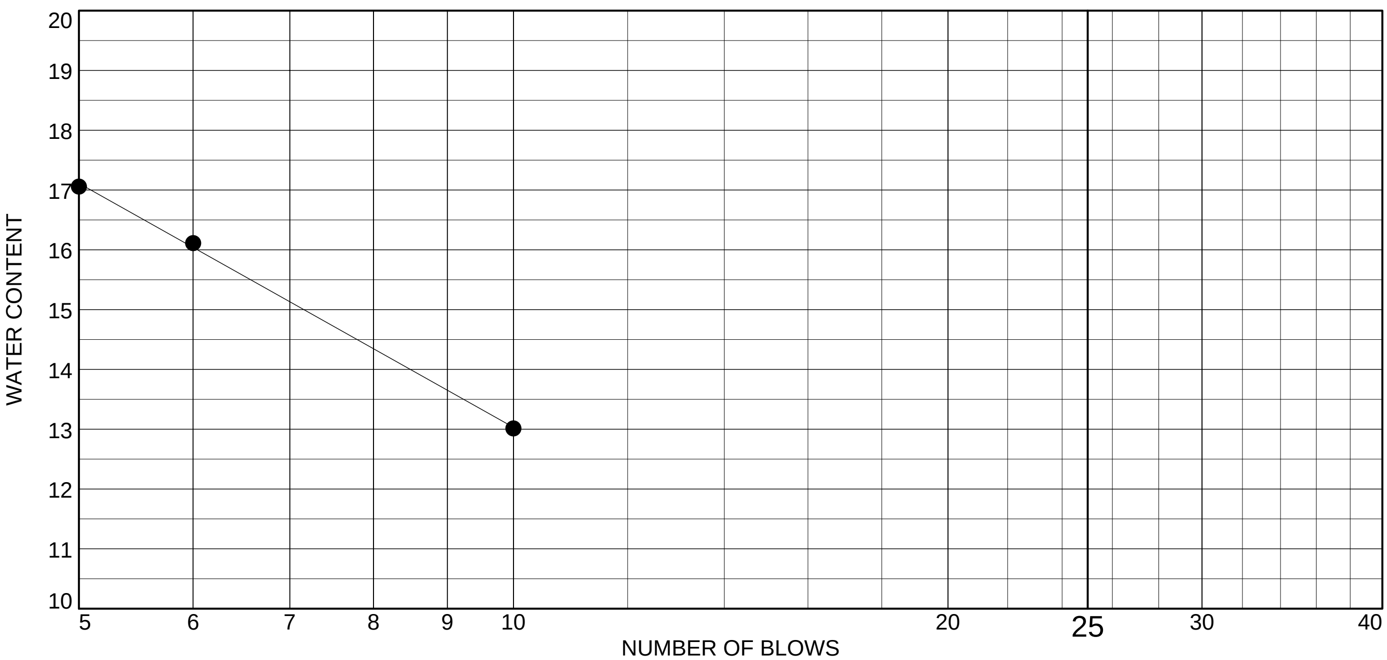
Remarks:

Figure

Tested By: DT **Checked By:** WPQ

LIQUID AND PLASTIC LIMITS ASTM D4318





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	DARK BROWN TO BLACK POORLY GRADED SAND WITH SILT - CINDERS NOTED	8	11	NP	38.4	5.5	SP-SM

Project No. 11215018 **Client:** CONFIDENTIAL

Project: KINCAID POWER STATION

Source of Sample: XPW-02 **Depth:** 21.0'-21.5'
Sample Number: 0845

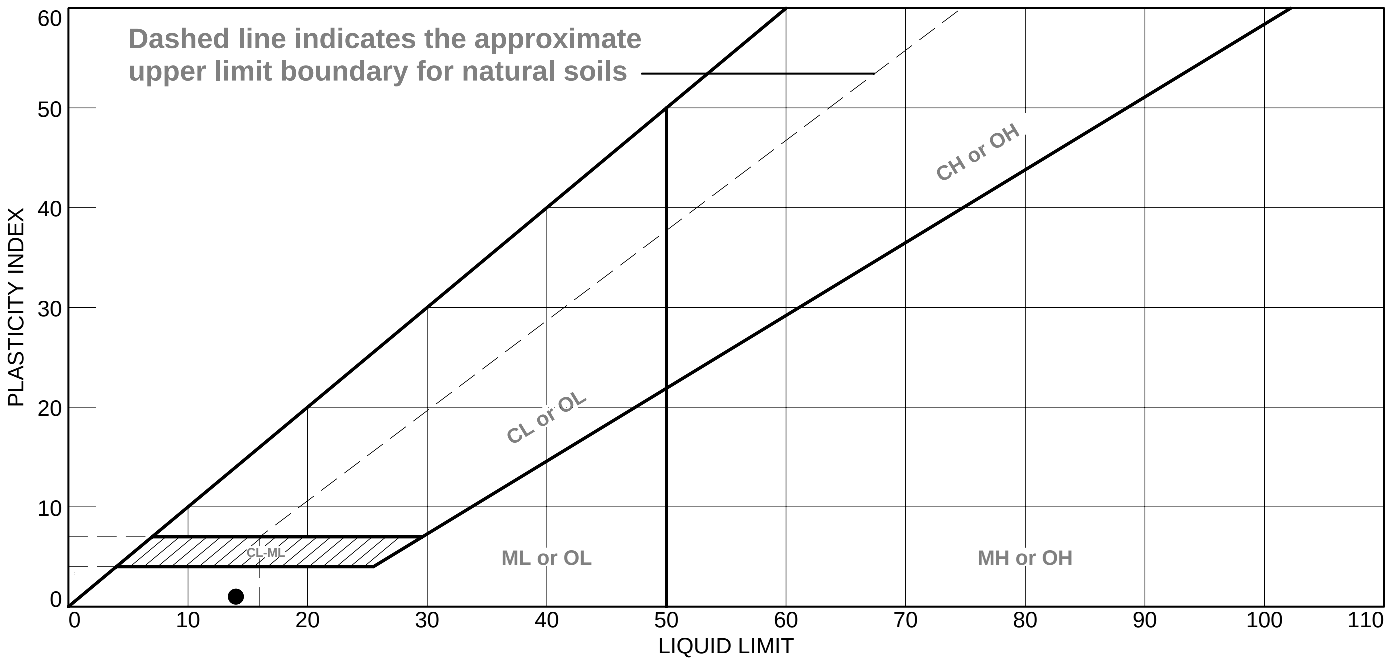
Terracon

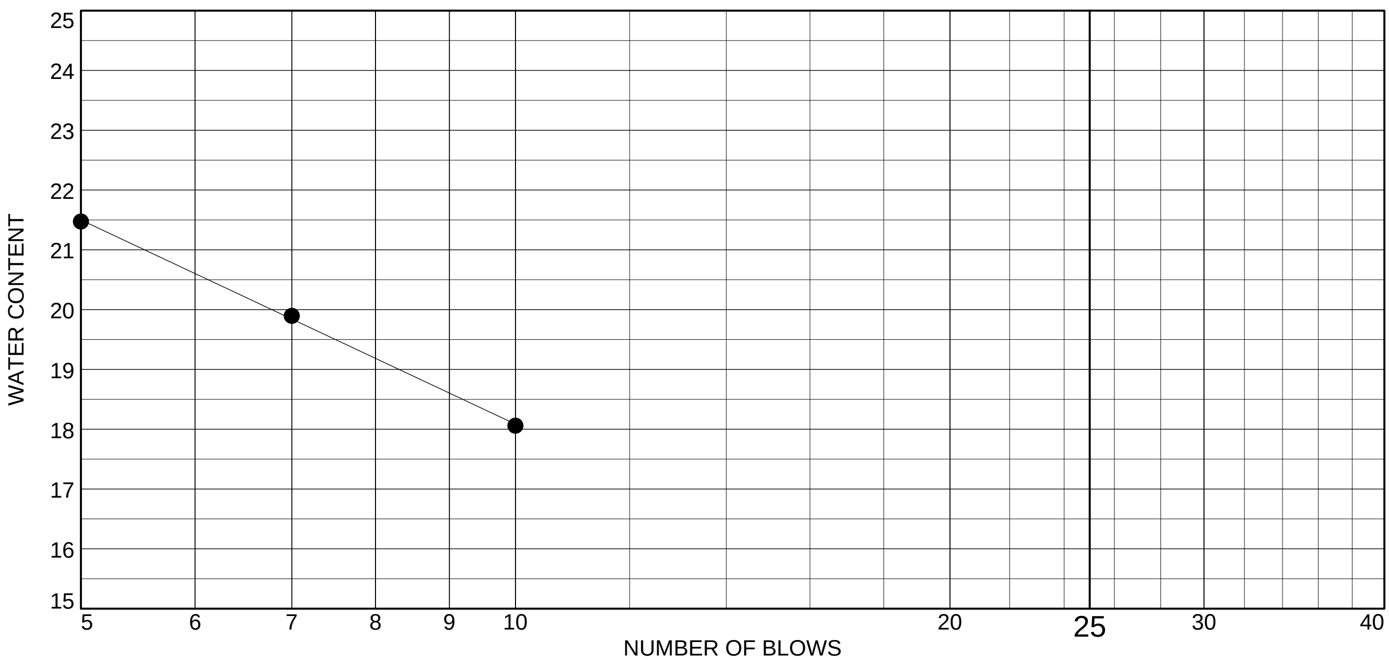
Remarks:

Figure

Tested By: DT **Checked By:** WPQ

LIQUID AND PLASTIC LIMITS ASTM D4318





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	BLACK WELL GRADED SAND WITH SILT - CINDERS NOTED	14	13	1	44.1	8.4	SW-SM

Project No. 11215018 **Client:** CONFIDENTIAL

Project: KINCAID POWER STATION

Source of Sample: XPW-03 **Depth:** 8.0'-8.5'
Sample Number: 1015

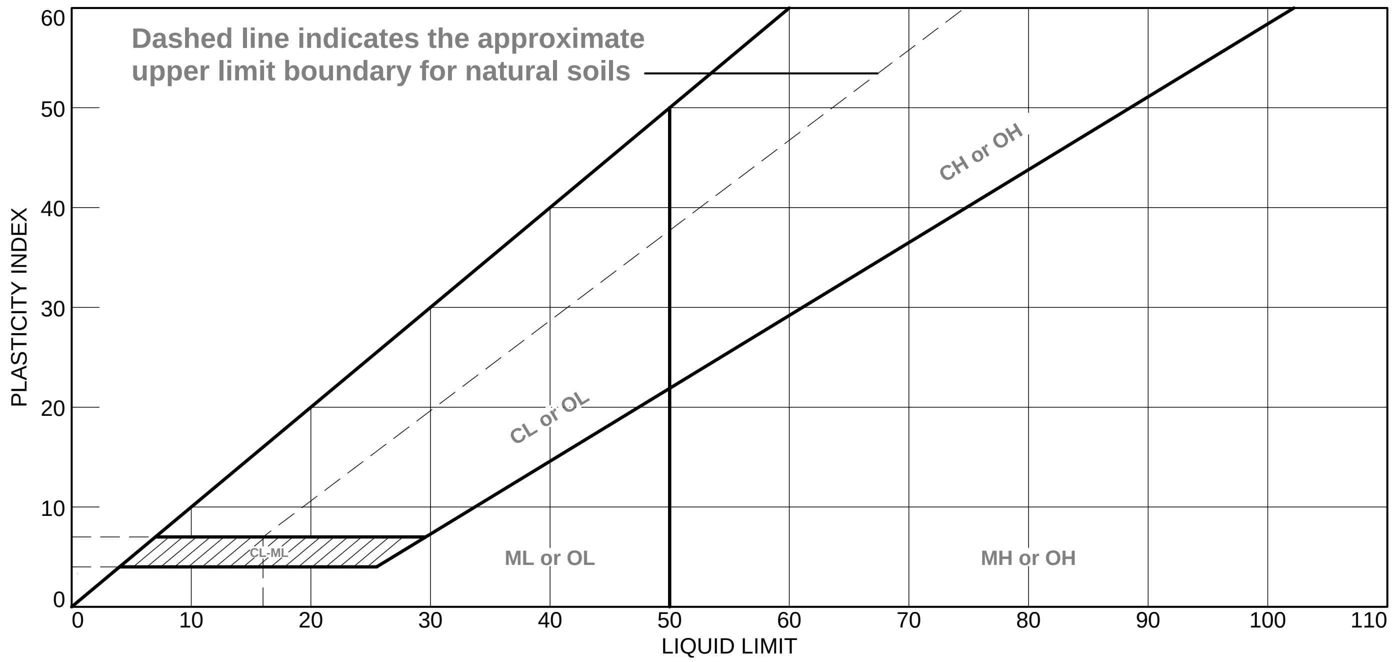
Terracon

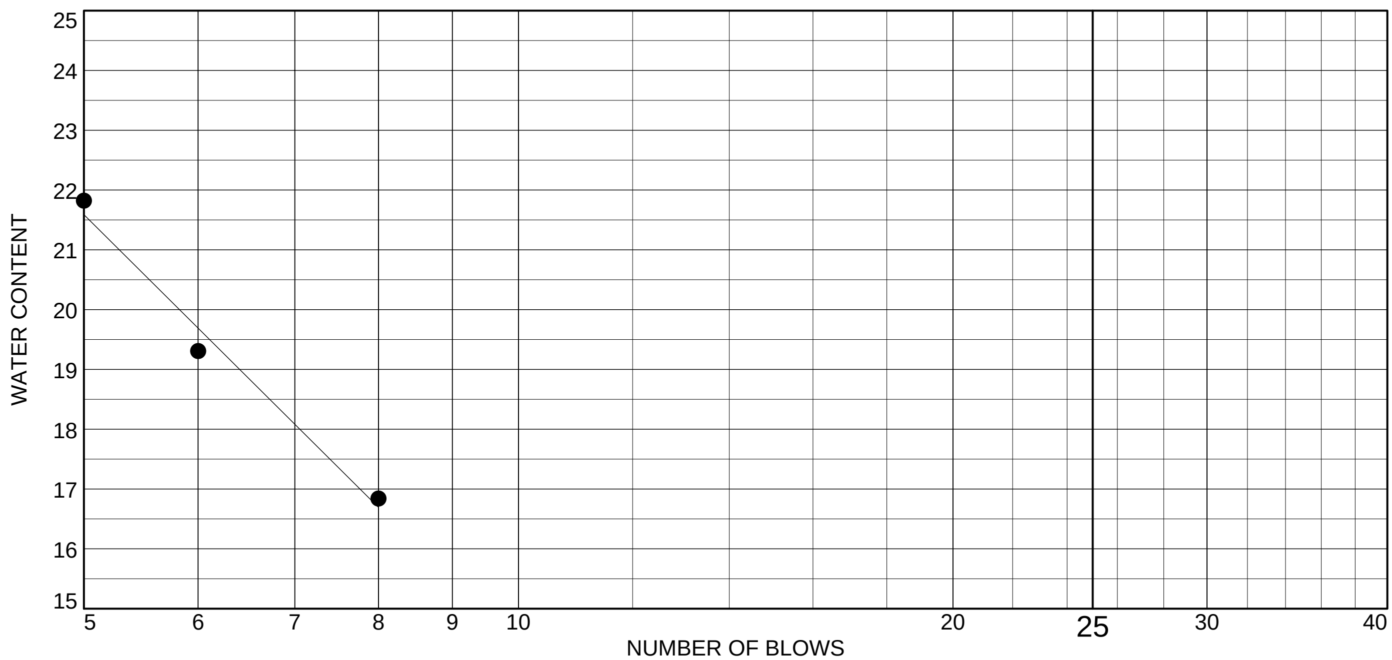
Remarks:

Figure

Tested By: DT **Checked By:** WPQ

LIQUID AND PLASTIC LIMITS ASTM D4318





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	BLACK POORLY GRADED SAND - CINDERS NOTED	5	10	NP	10.9	1.3	SP

Project No. 11215018 **Client:** CONFIDENTIAL

Project: KINCAID POWER STATION

Source of Sample: XPW-03 **Depth:** 18.0'-18.5'
Sample Number: 1055

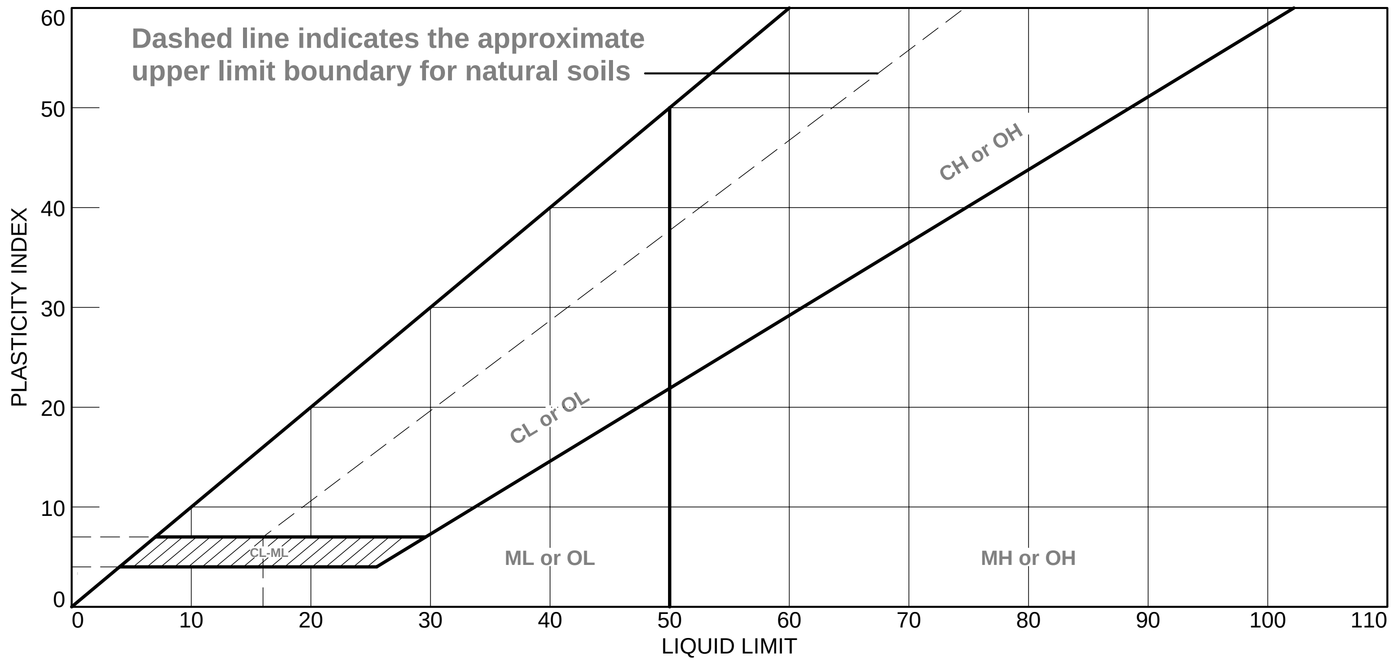
Terracon

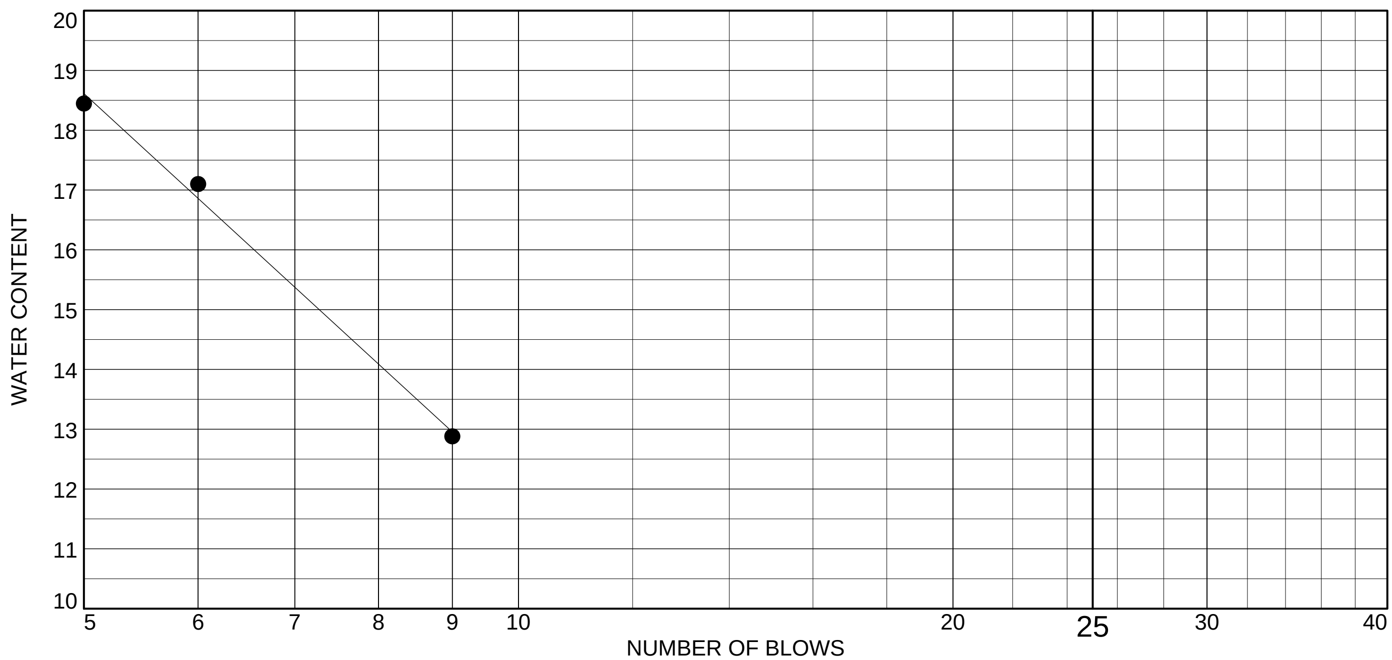
Remarks:

Figure

Tested By: DT **Checked By:** WPQ

LIQUID AND PLASTIC LIMITS ASTM D4318





●	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	BLACK AND DARK BROWN POORLY GRADED SAND - CINDERS AND ROOTS NOTED	3	6	NP	15.5	1.4	SP

Project No. 11215018 **Client:** CONFIDENTIAL

Project: KINCAID POWER STATION

Source of Sample: XPW-04 **Depth:** 10.5'-11.0'
Sample Number: 1320

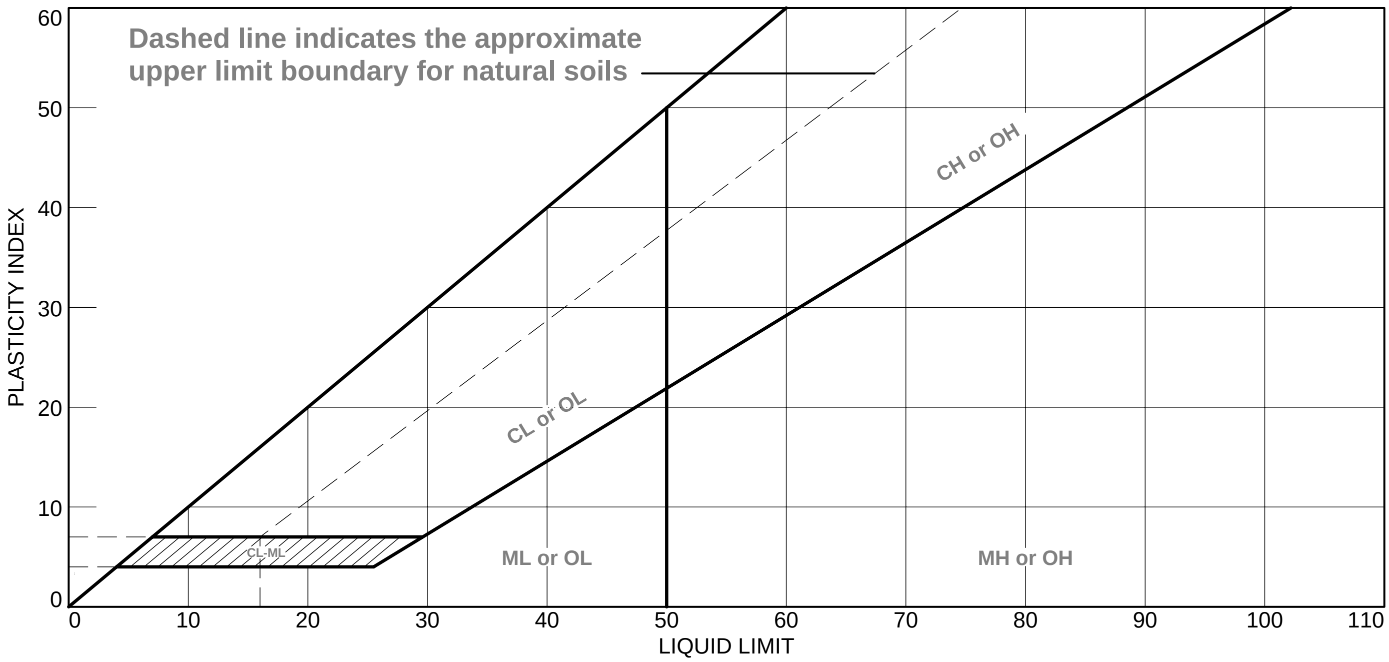
Terracon

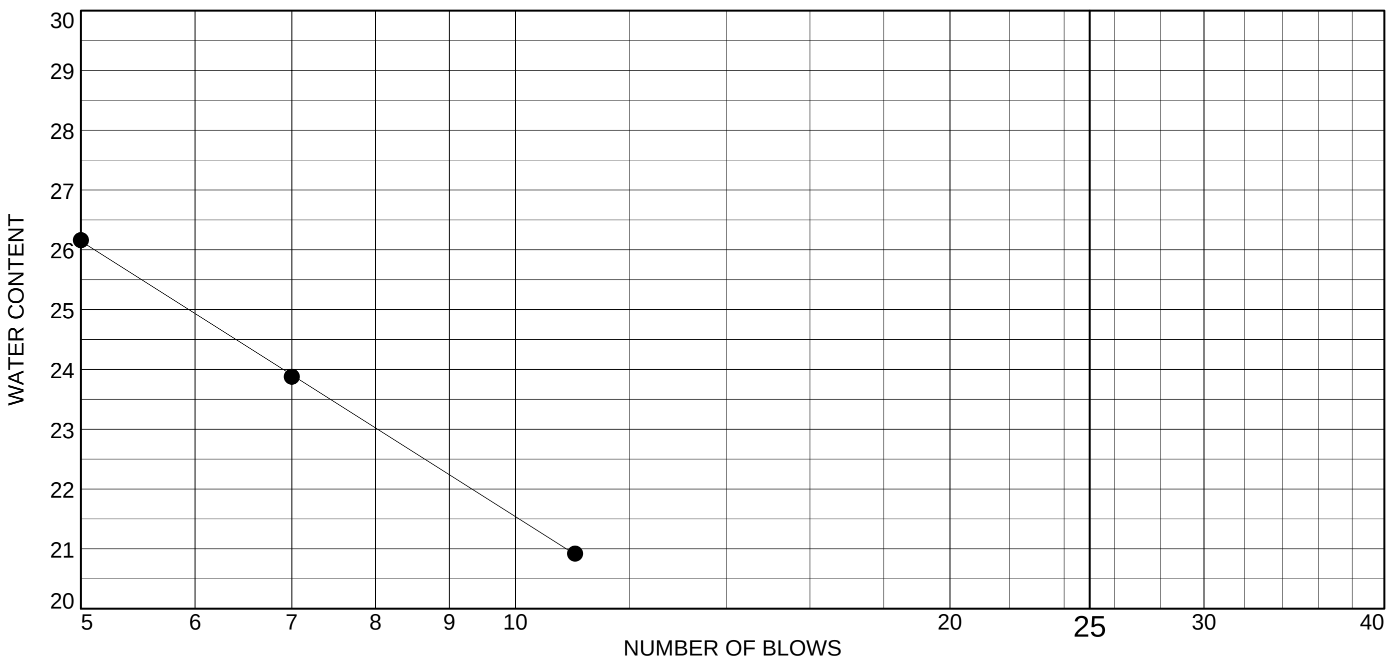
Remarks:

Figure

Tested By: DT **Checked By:** WPQ

LIQUID AND PLASTIC LIMITS ASTM D4318





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	BLACK AND DARK BROWN POORLY GRADED SAND - CINDERS NOTED	15	16	NP	11.9	2.7	SP

Project No. 11215018 **Client:** CONFIDENTIAL

Project: KINCAID POWER STATION

Source of Sample: XPW-04 **Depth:** 21.0'-21.5

Sample Number: 1405

Remarks:

Terracon

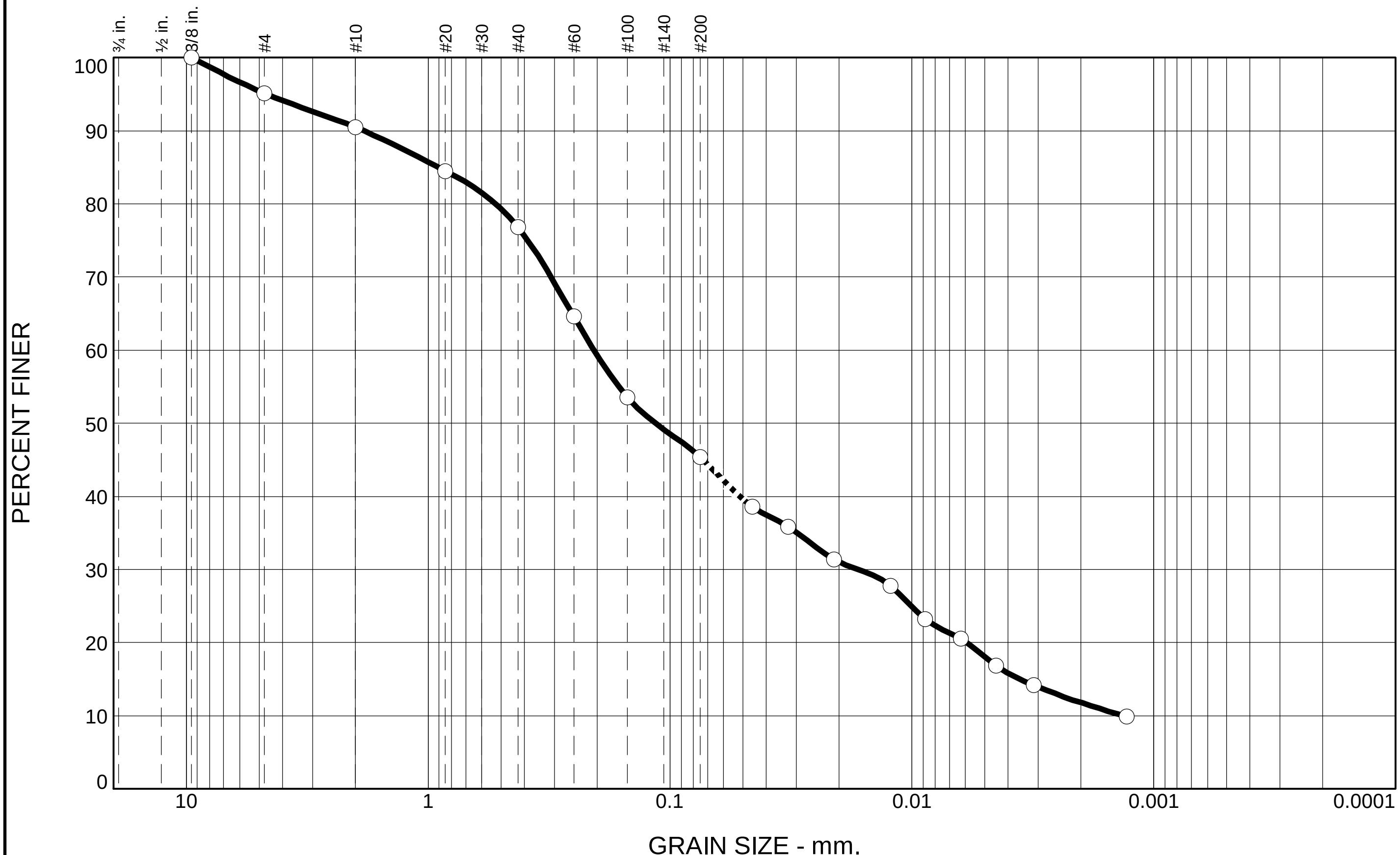
Figure

Tested By: DT **Checked By:** WPQ

Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis
ASTM D6913

Particle-Size Distribution (Gradation) of Fine-Grained Soils
Using the Sedimentation (Hydrometer) Analysis
ASTM D7928

Particle Size Analysis of Soils ASTM D6913 and D7928



% Gravel		% Sand			% Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	4.9	4.6	13.7	31.5	27.2	18.1

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.375	100.0		
#4	95.1		
#10	90.5		
#20	84.5		
#40	76.8		
#60	64.6		
#100	53.6		
#200	45.3		
0.0456 mm.	38.6		
0.0326 mm.	35.9		
0.0209 mm.	31.4		
0.0122 mm.	27.7		
0.0088 mm.	23.2		
0.0063 mm.	20.5		
0.0045 mm.	16.9		
0.0031 mm.	14.2		
0.0013 mm.	9.9		

* (no specification provided)

Soil Description

BROWN CLAYEY SAND

Atterberg Limits

PL= 13 LL= 22 PI= 9

Coefficients

D_{90}= 1.8498 D_{85}= 0.9081 D_{60}= 0.2064
D_{50}= 0.1148 D_{30}= 0.0167 D_{15}= 0.0036
D_{10}= 0.0013 C_u= 154.15 C_c= 1.01

Classification

USCS= SC AASHTO= A-4(1)

Remarks

F.M.=1.22

Source of Sample: MW-12D **Depth:** 5.0'-7.0'
Sample Number: 0915

Date: 2-25-21

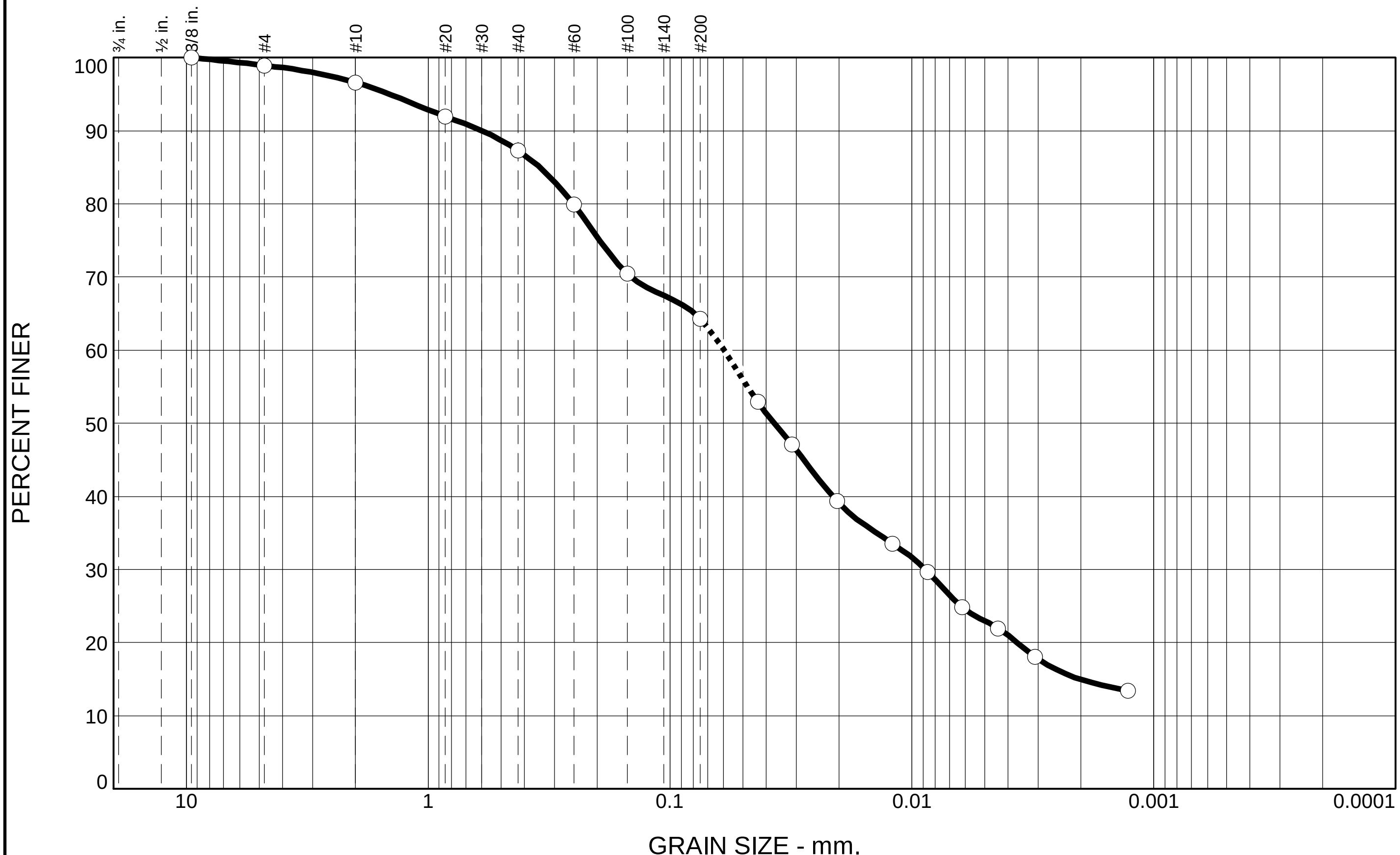
Terracon

Client: CONFIDENTIAL
Project: KINCAID POWER STATION

Project No: 11215018 **Figure**

Tested By: SJH **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D6913 and D7928



% Gravel		% Sand			% Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	1.1	2.3	9.3	23.1	41.2	23.0

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.375	100.0		
#4	98.9		
#10	96.6		
#20	92.0		
#40	87.3		
#60	79.9		
#100	70.4		
#200	64.2		
0.0434 mm.	52.9		
0.0314 mm.	47.1		
0.0204 mm.	39.4		
0.0120 mm.	33.6		
0.0086 mm.	29.7		
0.0062 mm.	24.8		
0.0044 mm.	21.9		
0.0031 mm.	18.1		
0.0013 mm.	13.5		

* (no specification provided)

Soil Description

BROWN TO GRAY SANDY LEAN CLAY

Atterberg Limits

PL= 12 LL= 22 PI= 10

Coefficients

D_{90}= 0.6011 D_{85}= 0.3458 D_{60}= 0.0598
D_{50}= 0.0371 D_{30}= 0.0088 D_{15}= 0.0020
D_{10}= C_u= C_c=

Classification

USCS= CL AASHTO= A-4(3)

Remarks

F.M.=0.67

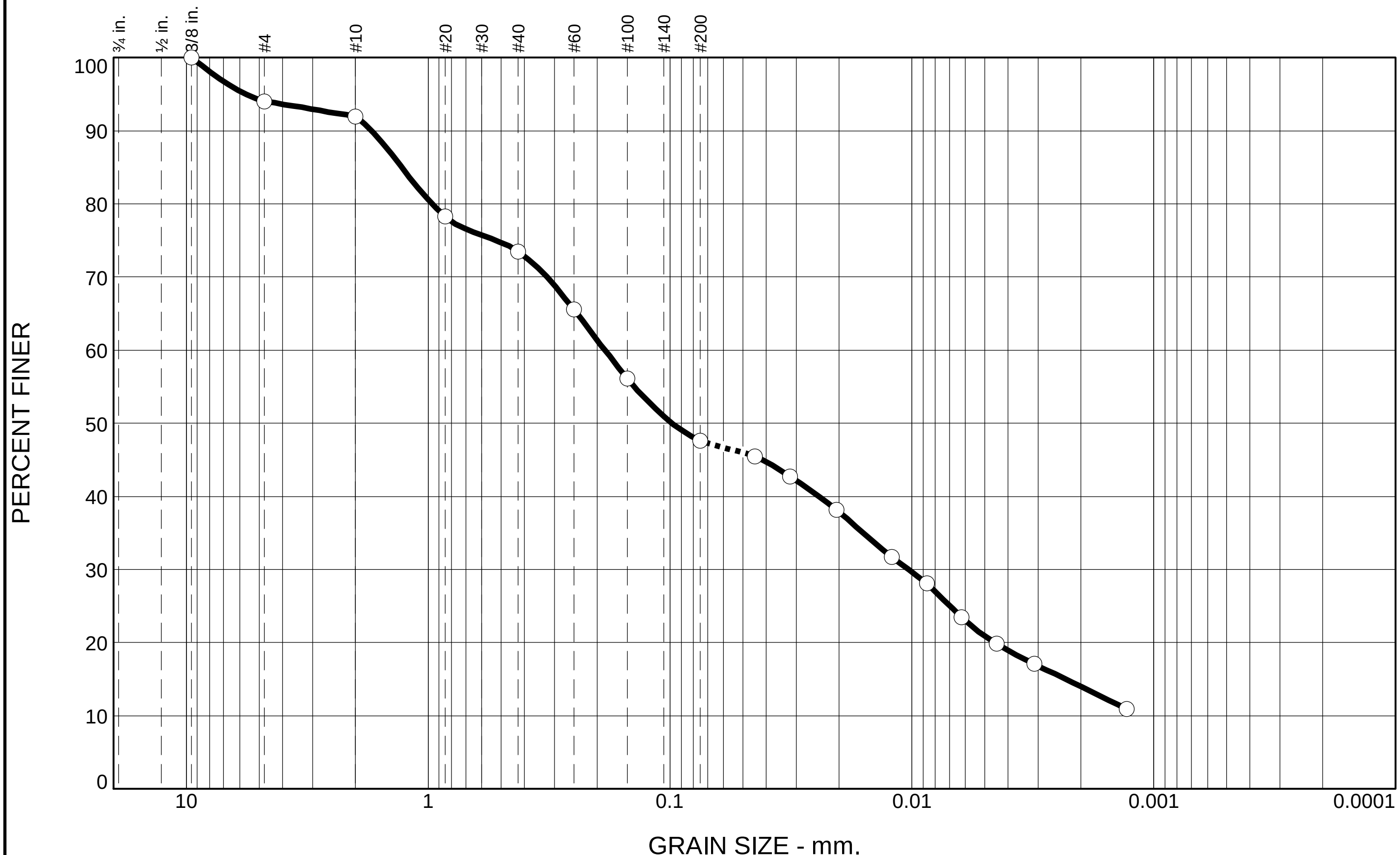
Source of Sample: MW-12D **Depth:** 11.5'-12.0'
Sample Number: 0940 **Date:** 2-25-21

Terracon

Client: CONFIDENTIAL
Project: KINCAID POWER STATION
Project No: 11215018 **Figure**

Tested By: SJH **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D6913 and D7928



% Gravel		% Sand			% Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	6.0	2.0	18.5	25.9	26.7	20.9

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.375	100.0		
#4	94.0		
#10	92.0		
#20	78.3		
#40	73.5		
#60	65.6		
#100	56.1		
#200	47.6		
0.0446 mm.	45.5		
0.0319 mm.	42.7		
0.0205 mm.	38.1		
0.0121 mm.	31.7		
0.0087 mm.	28.1		
0.0062 mm.	23.5		
0.0045 mm.	19.8		
0.0031 mm.	17.1		
0.0013 mm.	10.9		

* (no specification provided)

Soil Description

GRAY CLAYEY SAND

Atterberg Limits

PL= 13 LL= 22 PI= 9

Coefficients

D_{90}= 1.7145 D_{85}= 1.2854 D_{60}= 0.1859
D_{50}= 0.0983 D_{30}= 0.0103 D_{15}= 0.0023
D_{10}= C_u= C_c=

Classification

USCS= SC AASHTO= A-4(1)

Remarks

F.M.=1.30

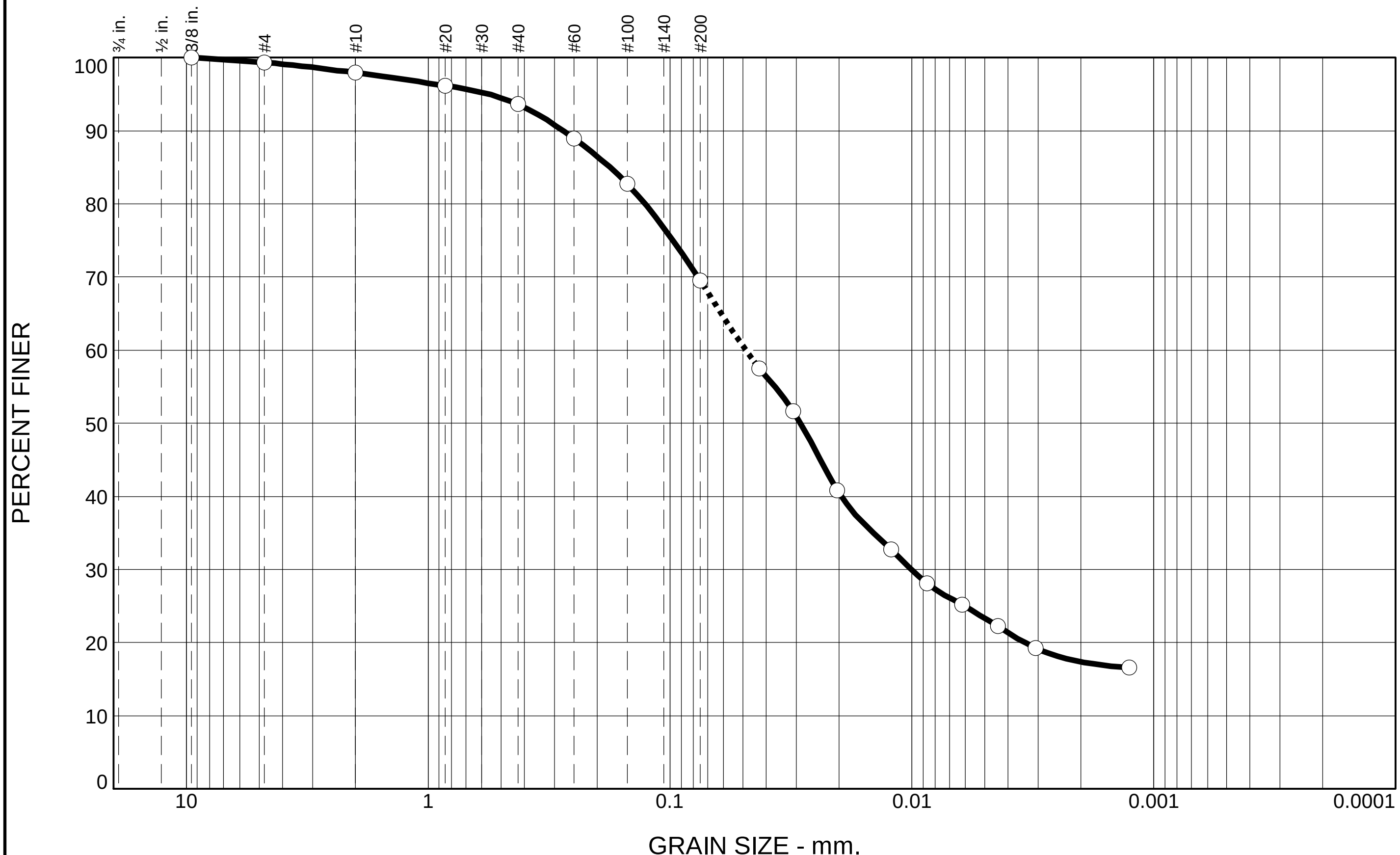
Source of Sample: MW-12D **Depth:** 20.5'-22.5'
Sample Number: 1025
Date: 2-25-21

Terracon

Client: CONFIDENTIAL
Project: KINCAID POWER STATION
Project No: 11215018 **Figure**

Tested By: SJH **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D6913 and D7928



% Gravel		% Sand			% Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.6	1.5	4.3	24.1	46.2	23.3

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.375	100.0		
#4	99.4		
#10	97.9		
#20	96.2		
#40	93.6		
#60	89.0		
#100	82.7		
#200	69.5		
0.0428 mm.	57.5		
0.0309 mm.	51.6		
0.0203 mm.	40.8		
0.0122 mm.	32.7		
0.0087 mm.	28.1		
0.0062 mm.	25.2		
0.0044 mm.	22.2		
0.0031 mm.	19.3		
0.0013 mm.	16.6		

* (no specification provided)

Soil Description

BROWN AND GRAY SANDY LEAN CLAY

Atterberg Limits

PL= 14 LL= 32 PI= 18

Coefficients

D_{90}= 0.2765 D_{85}= 0.1768 D_{60}= 0.0487
D_{50}= 0.0289 D_{30}= 0.0100 D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= CL AASHTO= A-6(10)

Remarks

F.M.=0.37

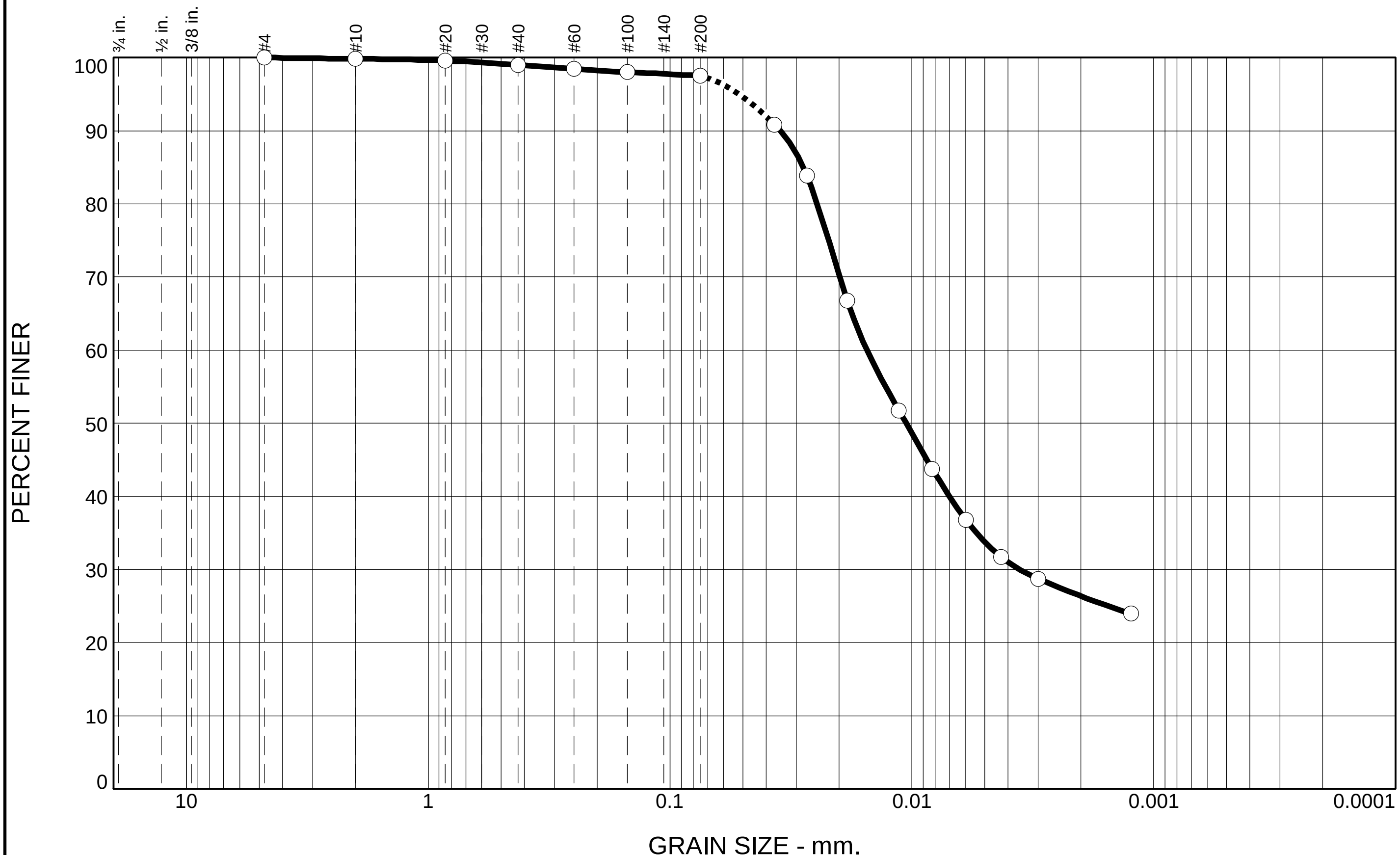
Source of Sample: MW-20 **Depth:** 15.0'-17.0'
Sample Number: 0815
Date: 2-25-21

Terracon

Client: CONFIDENTIAL
Project: KINCAID POWER STATION
Project No: 11215018 **Figure**

Tested By: SJH **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D6913 and D7928



% Gravel		% Sand			% Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.2	0.8	1.5	63.7	33.8

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#10	99.8		
#20	99.6		
#40	99.0		
#60	98.5		
#100	98.0		
#200	97.5		
0.0370 mm.	90.8		
0.0271 mm.	83.8		
0.0185 mm.	66.8		
0.0113 mm.	51.8		
0.0082 mm.	43.8		
0.0060 mm.	36.7		
0.0043 mm.	31.7		
0.0030 mm.	28.7		
0.0012 mm.	23.9		

* (no specification provided)

Soil Description

BROWN AND GRAYISH BROWN LEAN CLAY

Atterberg Limits

PL= 17 LL= 43 PI= 26

Coefficients

D_{90}= 0.0351 D_{85}= 0.0281 D_{60}= 0.0153
D_{50}= 0.0106 D_{30}= 0.0036 D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= CL AASHTO= A-7-6(27)

Remarks

F.M.=0.04

Source of Sample: MW-23 **Depth:** 15.0'-17.0'
Sample Number: 1135

Date: 2-25-21

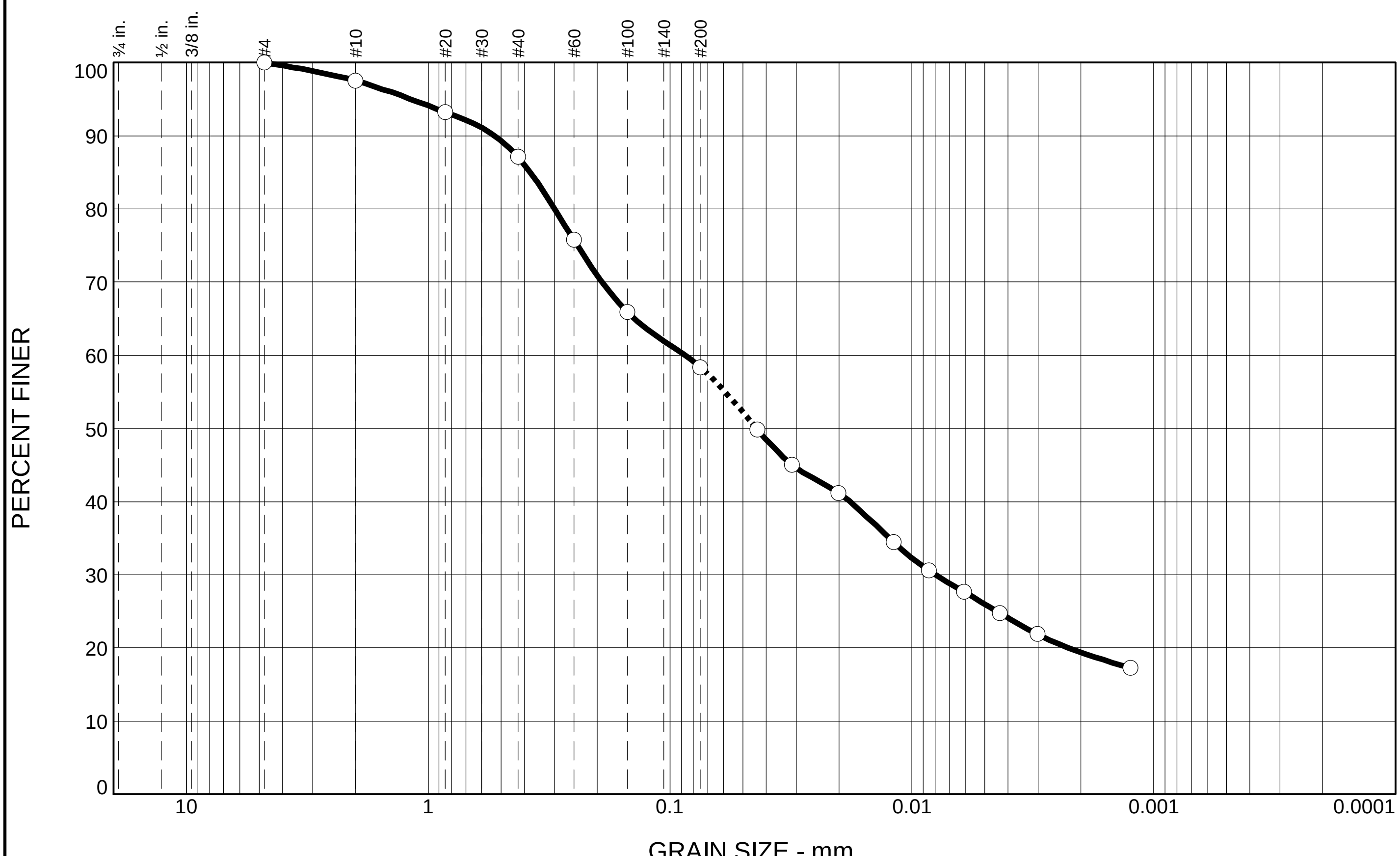
Terracon

Client: CONFIDENTIAL
Project: KINCAID POWER STATION

Project No: 11215018 **Figure**

Tested By: SJH **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D6913 and D7928



% Gravel		% Sand			% Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	2.5	10.4	28.7	32.4	26.0

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#10	97.5		
#20	93.2		
#40	87.1		
#60	75.8		
#100	65.9		
#200	58.4		
0.0435 mm.	49.9		
0.0313 mm.	45.0		
0.0201 mm.	41.2		
0.0119 mm.	34.4		
0.0085 mm.	30.6		
0.0061 mm.	27.7		
0.0043 mm.	24.8		
0.0030 mm.	21.9		
0.0013 mm.	17.3		

* (no specification provided)

Soil Description

YELLOWISH BROWN SANDY LEAN CLAY

Atterberg Limits

PL= 14 LL= 32 PI= 18

Coefficients

D_{90}= 0.5310 D_{85}= 0.3782 D_{60}= 0.0869
D_{50}= 0.0439 D_{30}= 0.0080 D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= CL AASHTO= A-6(7)

Remarks

F.M.=0.70

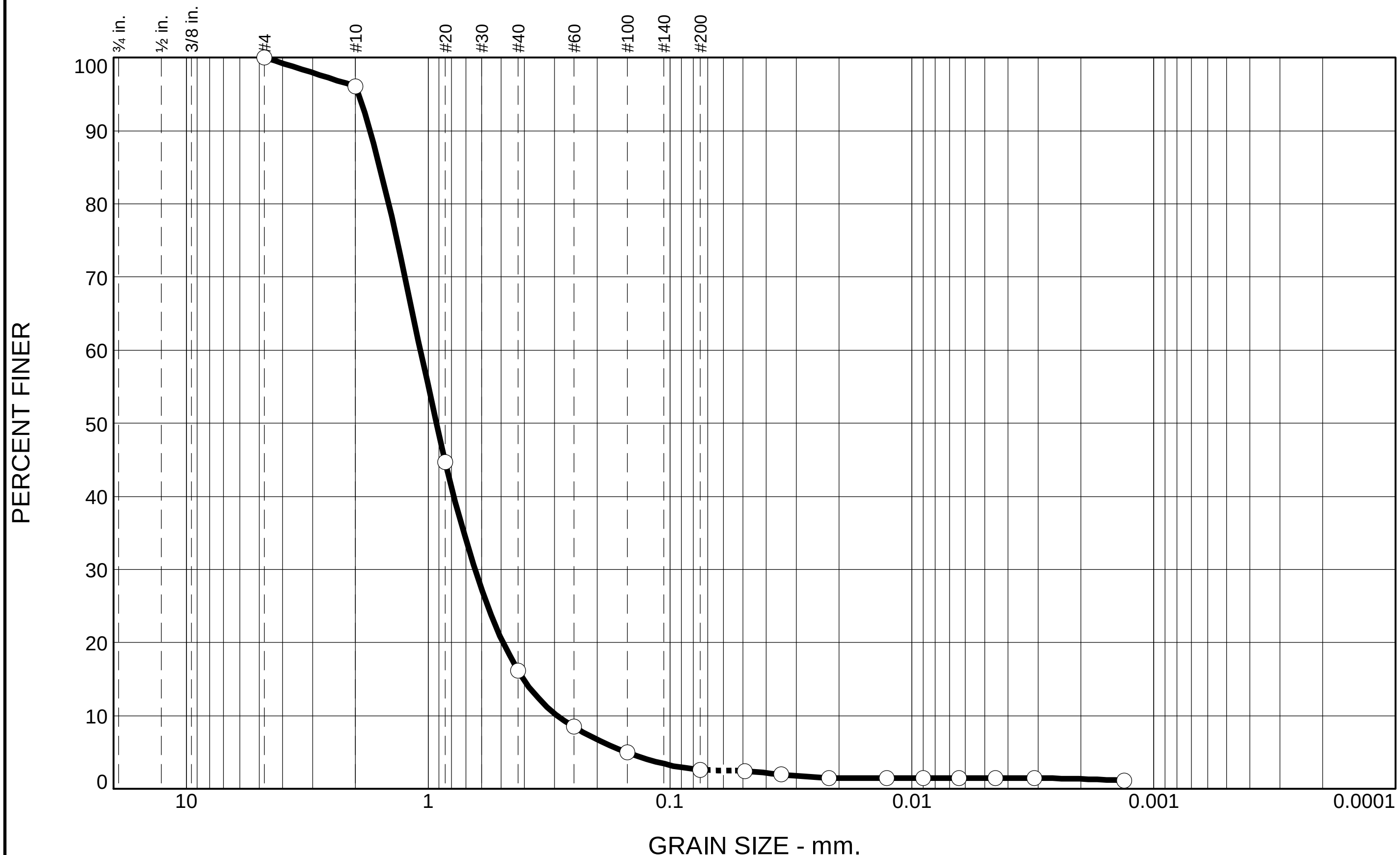
Source of Sample: MW-23 **Depth:** 25.0'-27.0'
Sample Number: 1245 **Date:** 2-19-21

Terracon

Client: CONFIDENTIAL
Project: KINCAID POWER STATION
Project No: 11215018 **Figure**

Tested By: SJH **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D6913 and D7928



% Gravel		% Sand			% Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	3.9	79.9	13.6	1.1	1.5

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#10	96.1		
#20	44.7		
#40	16.2		
#60	8.5		
#100	5.0		
#200	2.6		
0.0491 mm.	2.4		
0.0348 mm.	1.9		
0.0221 mm.	1.5		
0.0127 mm.	1.5		
0.0090 mm.	1.5		
0.0064 mm.	1.5		
0.0045 mm.	1.5		
0.0031 mm.	1.5		
0.0013 mm.	1.1		

* (no specification provided)

Soil Description

BLACK POORLY GRADED SAND - CINDERS AND BRICK NOTED

Atterberg Limits

PL= 14 LL= 12 PI= NP

Coefficients

D_{90}= 1.7391 D_{85}= 1.5843 D_{60}= 1.0768
D_{50}= 0.9256 D_{30}= 0.6402 D_{15}= 0.4036
D_{10}= 0.2921 C_u= 3.69 C_c= 1.30

Classification

USCS= SP AASHTO= A-1-b

Remarks

F.M.=2.94

Source of Sample: XPW-01 **Depth:** 8.5'-9.0'
Sample Number: 1535 **Date:** 2-19-21

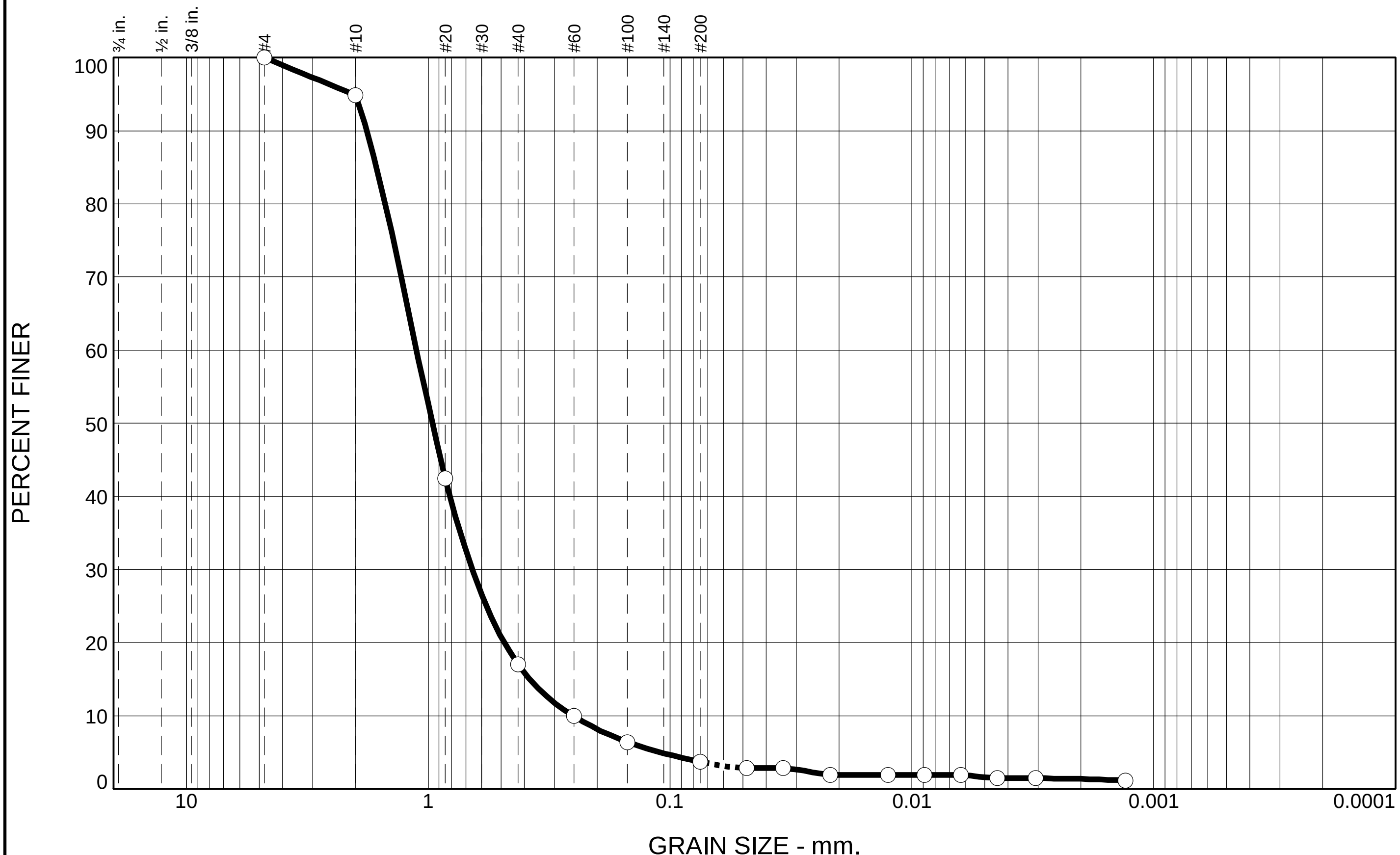
Terracon

Client: CONFIDENTIAL
Project: KINCAID POWER STATION

Project No: 11215018 **Figure**

Tested By: SJH **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D6913 and D7928



% Gravel		% Sand			% Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	5.1	77.8	13.4	2.1	1.6

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#10	94.9		
#20	42.5		
#40	17.1		
#60	9.9		
#100	6.4		
#200	3.7		
0.0483 mm.	2.8		
0.0341 mm.	2.8		
0.0217 mm.	1.9		
0.0125 mm.	1.9		
0.0089 mm.	1.9		
0.0063 mm.	1.9		
0.0044 mm.	1.4		
0.0031 mm.	1.4		
0.0013 mm.	1.1		

* (no specification provided)

Soil Description

BLACK POORLY GRADED SAND - CINDERS AND ROOTS NOTED

Atterberg Limits

PL= 15 LL= 17 PI= 2

Coefficients

D_{90}= 1.7938 D_{85}= 1.6347 D_{60}= 1.1167
D_{50}= 0.9615 D_{30}= 0.6575 D_{15}= 0.3802
D_{10}= 0.2514 C_u= 4.44 C_c= 1.54

Classification

USCS= SP AASHTO= A-1-b

Remarks

F.M.=2.96

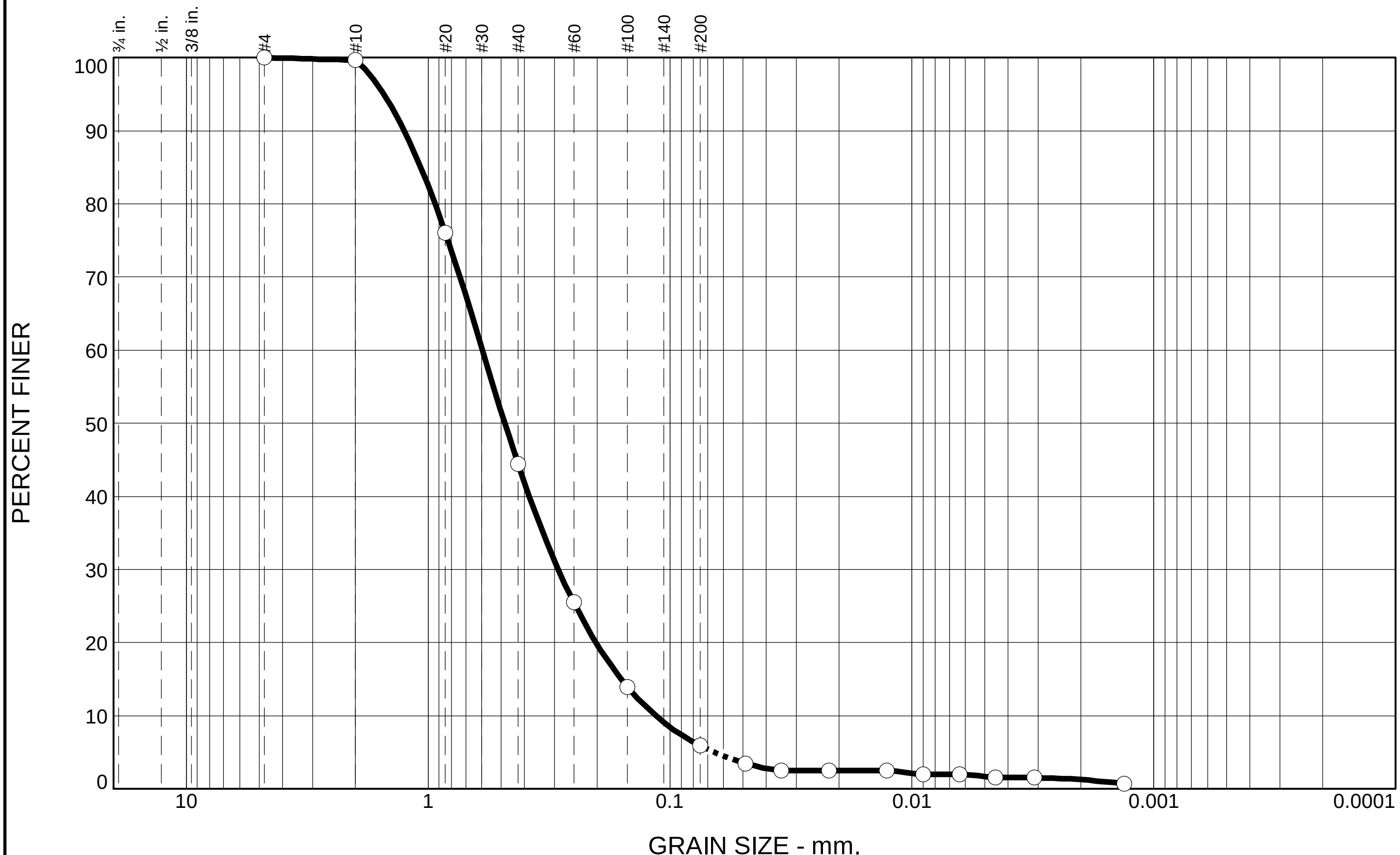
Source of Sample: XPW-01 **Depth:** 20.5'-21.0'
Sample Number: 1600 **Date:** 2-19-21

Terracon

Client: CONFIDENTIAL
Project: KINCAID POWER STATION
Project No: 11215018 **Figure**

Tested By: SJH **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D6913 and D7928



% Gravel		% Sand			% Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.3	55.2	38.6	4.2	1.7

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#10	99.7		
#20	76.1		
#40	44.5		
#60	25.5		
#100	14.0		
#200	5.9		
0.0488 mm.	3.5		
0.0347 mm.	2.5		
0.0220 mm.	2.5		
0.0127 mm.	2.5		
0.0090 mm.	2.0		
0.0064 mm.	2.0		
0.0045 mm.	1.5		
0.0031 mm.	1.5		
0.0013 mm.	0.7		

* (no specification provided)

Soil Description

BLACK POORLY GRADED SAND WITH SILT - CINDERS NOTED

Atterberg Limits

PL= 9 LL= 4 PI= NP

Coefficients

D_{90}= 1.2561 D_{85}= 1.0736 D_{60}= 0.5965
D_{50}= 0.4816 D_{30}= 0.2895 D_{15}= 0.1590
D_{10}= 0.1144 C_u= 5.21 C_c= 1.23

Classification

USCS= SP-SM AASHTO= A-1-b

Remarks

F.M.=2.07

Source of Sample: XPW-02 **Depth:** 8.5'-9.0'
Sample Number: 0810

Date: 2-19-21

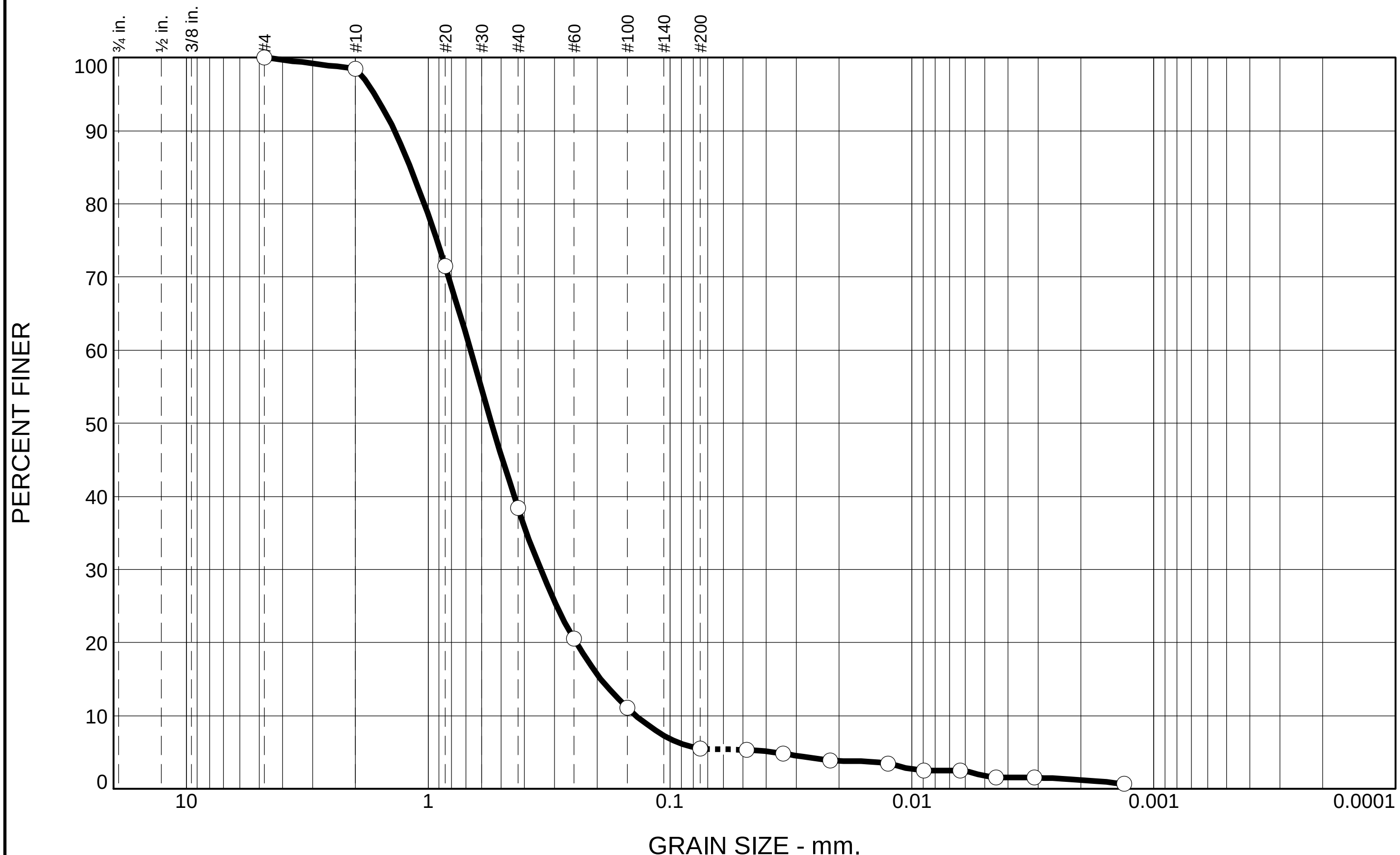
Terracon

Client: CONFIDENTIAL
Project: KINCAID POWER STATION

Project No: 11215018 **Figure**

Tested By: SJH **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D6913 and D7928



% Gravel		% Sand			% Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	1.5	60.1	32.9	3.7	1.8

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#10	98.5		
#20	71.5		
#40	38.4		
#60	20.6		
#100	11.1		
#200	5.5		
0.0481 mm.	5.3		
0.0341 mm.	4.9		
0.0217 mm.	3.9		
0.0126 mm.	3.4		
0.0089 mm.	2.5		
0.0063 mm.	2.5		
0.0045 mm.	1.5		
0.0031 mm.	1.5		
0.0013 mm.	0.7		

* (no specification provided)

Soil Description

DARK BROWN TO BLACK POORLY GRADED SAND WITH SILT - CINDERS NOTED

Atterberg Limits

PL= 11 LL= 8 PI= NP

Coefficients

D_{90}= 1.3786 D_{85}= 1.1845 D_{60}= 0.6692
D_{50}= 0.5464 D_{30}= 0.3422 D_{15}= 0.1928
D_{10}= 0.1381 C_u= 4.85 C_c= 1.27

Classification

USCS= SP-SM AASHTO= A-1-b

Remarks

F.M.=2.25

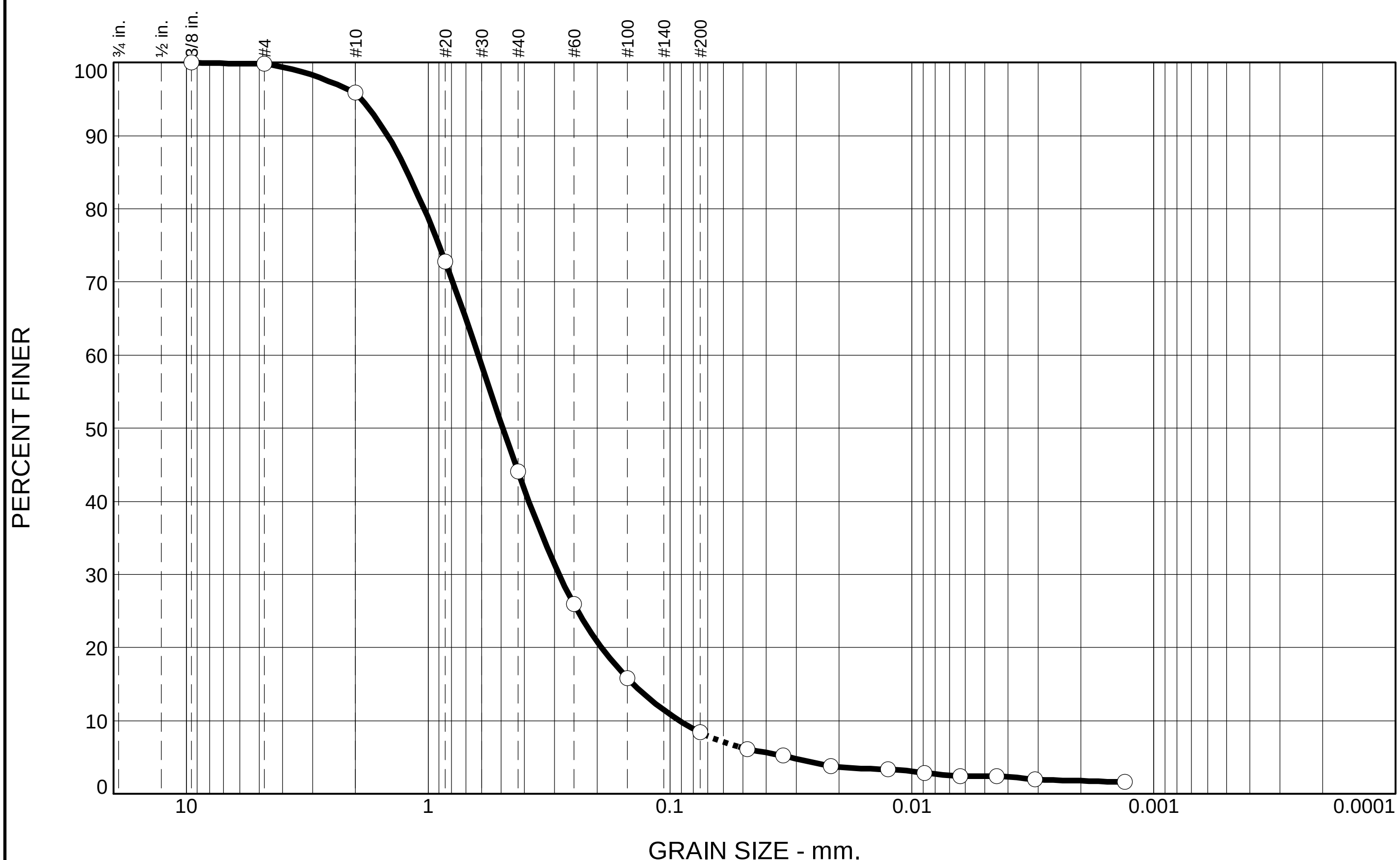
Source of Sample: XPW-02 **Depth:** 21.0'-21.5'
Sample Number: 0845 **Date:** 2-19-21

Terracon

Client: CONFIDENTIAL
Project: KINCAID POWER STATION
Project No: 11215018 **Figure**

Tested By: SJH **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D6913 and D7928



% Gravel		% Sand			% Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.2	3.9	51.8	35.7	6.0	2.4

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.375	100.0		
#4	99.8		
#10	95.9		
#20	72.8		
#40	44.1		
#60	26.0		
#100	15.8		
#200	8.4		
0.0478 mm.	6.1		
0.0340 mm.	5.2		
0.0217 mm.	3.8		
0.0125 mm.	3.3		
0.0089 mm.	2.9		
0.0063 mm.	2.4		
0.0045 mm.	2.4		
0.0031 mm.	1.9		
0.0013 mm.	1.6		

* (no specification provided)

Soil Description

BLACK WELL GRADED SAND WITH SILT - CINDERS NOTED

Atterberg Limits

PL= 13 LL= 14 PI= 1

Coefficients

D_{90}= 1.4720 D_{85}= 1.2199 D_{60}= 0.6214
D_{50}= 0.4909 D_{30}= 0.2872 D_{15}= 0.1414
D_{10}= 0.0915 C_u= 6.79 C_c= 1.45

Classification

USCS= SW-SM AASHTO= A-1-b

Remarks

F.M.=2.13

Source of Sample: XPW-03 **Depth:** 8.0'-8.5'
Sample Number: 1015

Date: 2-19-21

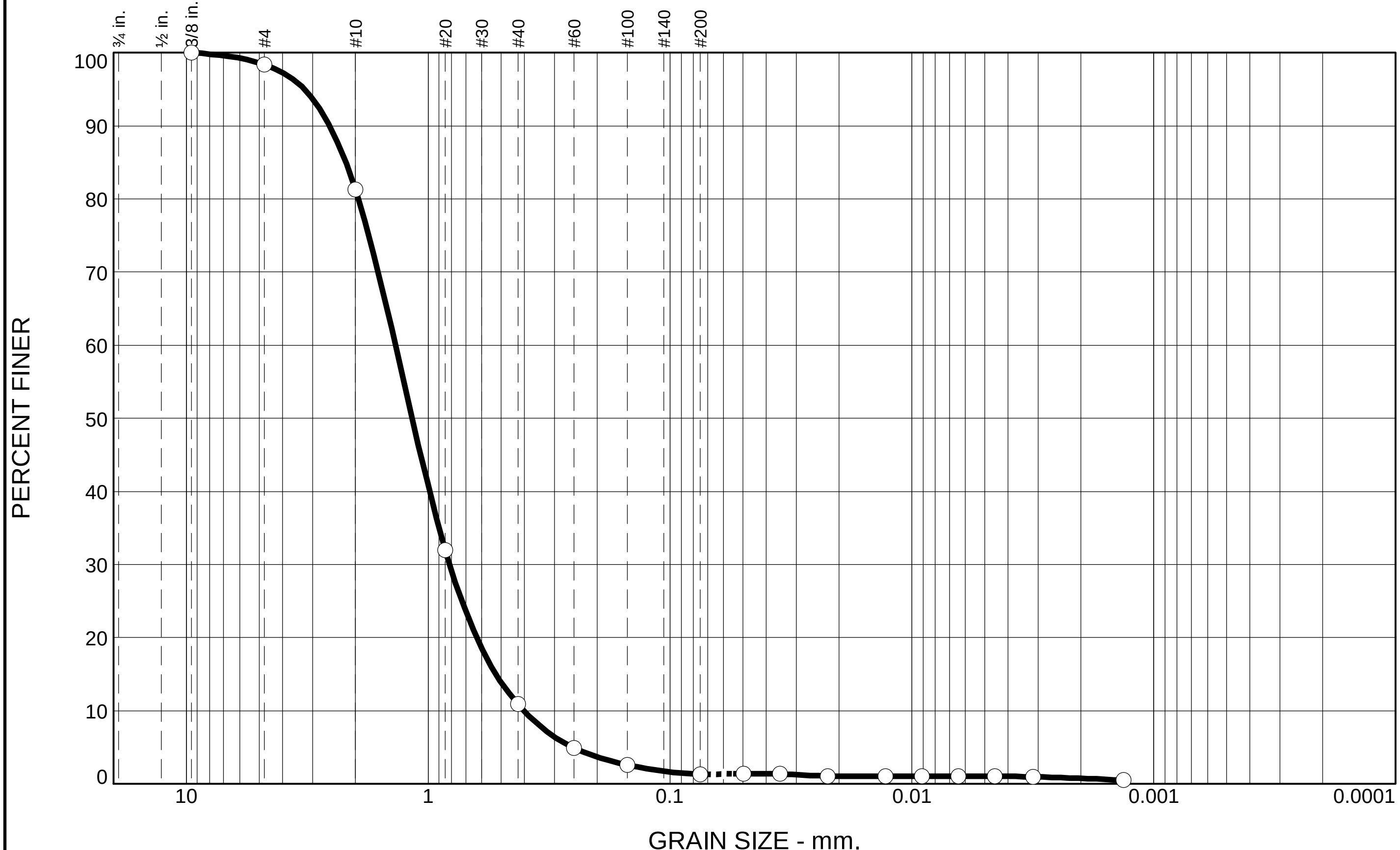
Terracon

Client: CONFIDENTIAL
Project: KINCAID POWER STATION

Project No: 11215018 **Figure**

Tested By: SJH **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D6913 and D7928



% Gravel		% Sand			% Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	1.6	17.1	70.4	9.6	0.2	1.1

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.375	100.0		
#4	98.4		
#10	81.3		
#20	32.0		
#40	10.9		
#60	4.9		
#100	2.6		
#200	1.3		
0.0497 mm.	1.3		
0.0351 mm.	1.3		
0.0222 mm.	1.1		
0.0128 mm.	1.1		
0.0091 mm.	1.1		
0.0064 mm.	1.1		
0.0045 mm.	1.1		
0.0031 mm.	1.0		
0.0013 mm.	0.5		

* (no specification provided)

Soil Description

BLACK POORLY GRADED SAND - CINDERS NOTED

Atterberg Limits

PL= 10 LL= 5 PI= NP

Coefficients

D_{90}= 2.5554 D_{85}= 2.1887 D_{60}= 1.3646
D_{50}= 1.1641 D_{30}= 0.8160 D_{15}= 0.5240
D_{10}= 0.4023 C_u= 3.39 C_c= 1.21

Classification

USCS= SP AASHTO= A-1-b

Remarks

F.M.=3.36

Source of Sample: XPW-03 **Depth:** 18.0'-18.5'
Sample Number: 1055 **Date:** 2-19-21

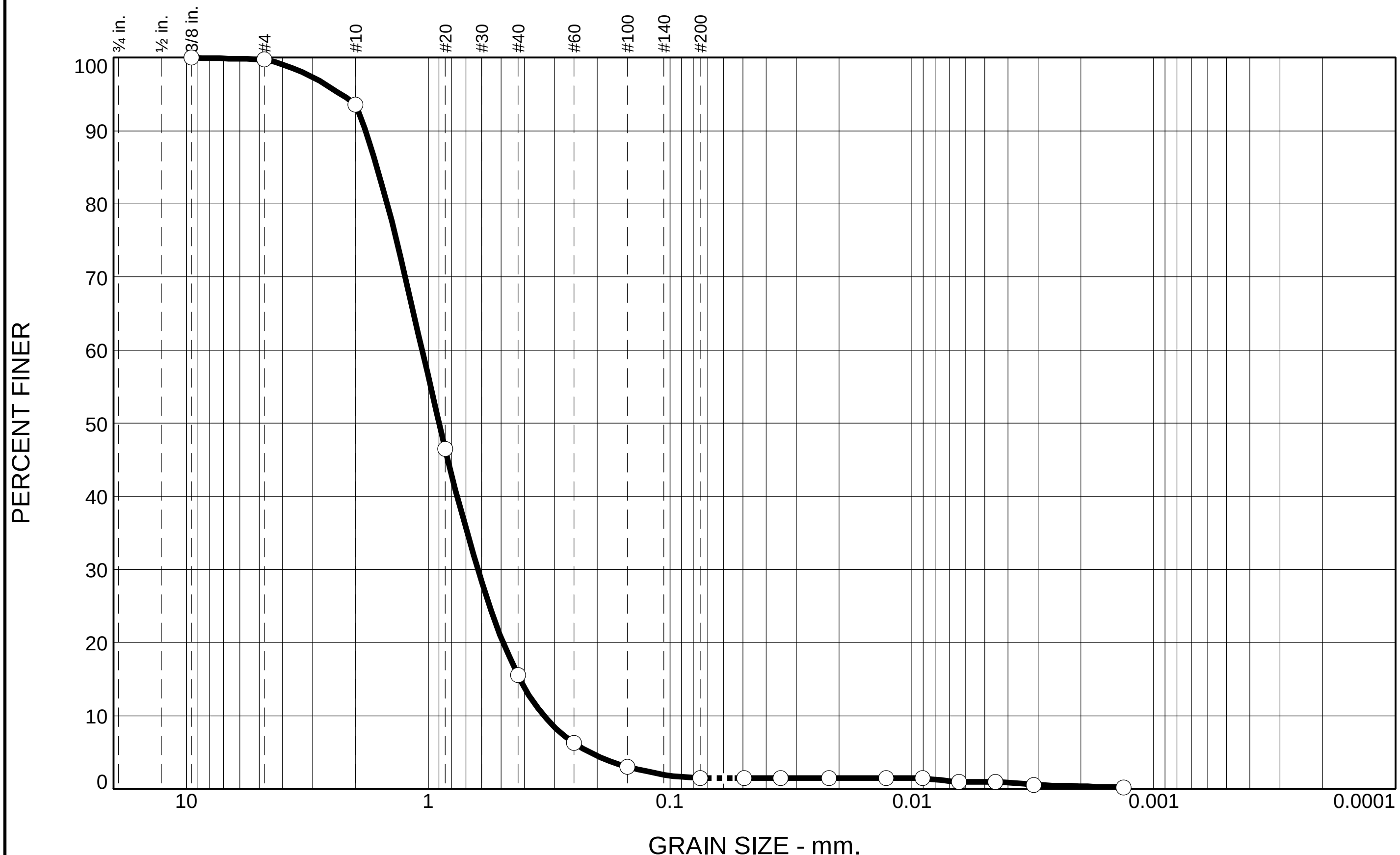
Terracon

Client: CONFIDENTIAL
Project: KINCAID POWER STATION

Project No: 11215018 **Figure**

Tested By: SJH **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D6913 and D7928



% Gravel		% Sand			% Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.2	6.2	78.1	14.1	0.4	1.0

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.375	100.0		
#4	99.8		
#10	93.6		
#20	46.4		
#40	15.5		
#60	6.3		
#100	3.0		
#200	1.4		
0.0494 mm.	1.4		
0.0349 mm.	1.4		
0.0221 mm.	1.4		
0.0128 mm.	1.4		
0.0090 mm.	1.4		
0.0064 mm.	1.0		
0.0045 mm.	1.0		
0.0031 mm.	0.5		
0.0013 mm.	0.2		

* (no specification provided)

Soil Description

BLACK AND DARK BROWN POORLY GRADED SAND - CINDERS AND ROOTS NOTED

Atterberg Limits

PL= 6 LL= 3 PI= NP

Coefficients

D_{90}= 1.8159 D_{85}= 1.6267 D_{60}= 1.0599
D_{50}= 0.9020 D_{30}= 0.6231 D_{15}= 0.4170
D_{10}= 0.3321 C_u= 3.19 C_c= 1.10

Classification

USCS= SP AASHTO= A-1-b

Remarks

F.M.=2.99

Source of Sample: XPW-04 **Depth:** 10.5'-11.0'
Sample Number: 1320

Date: 2-19-21

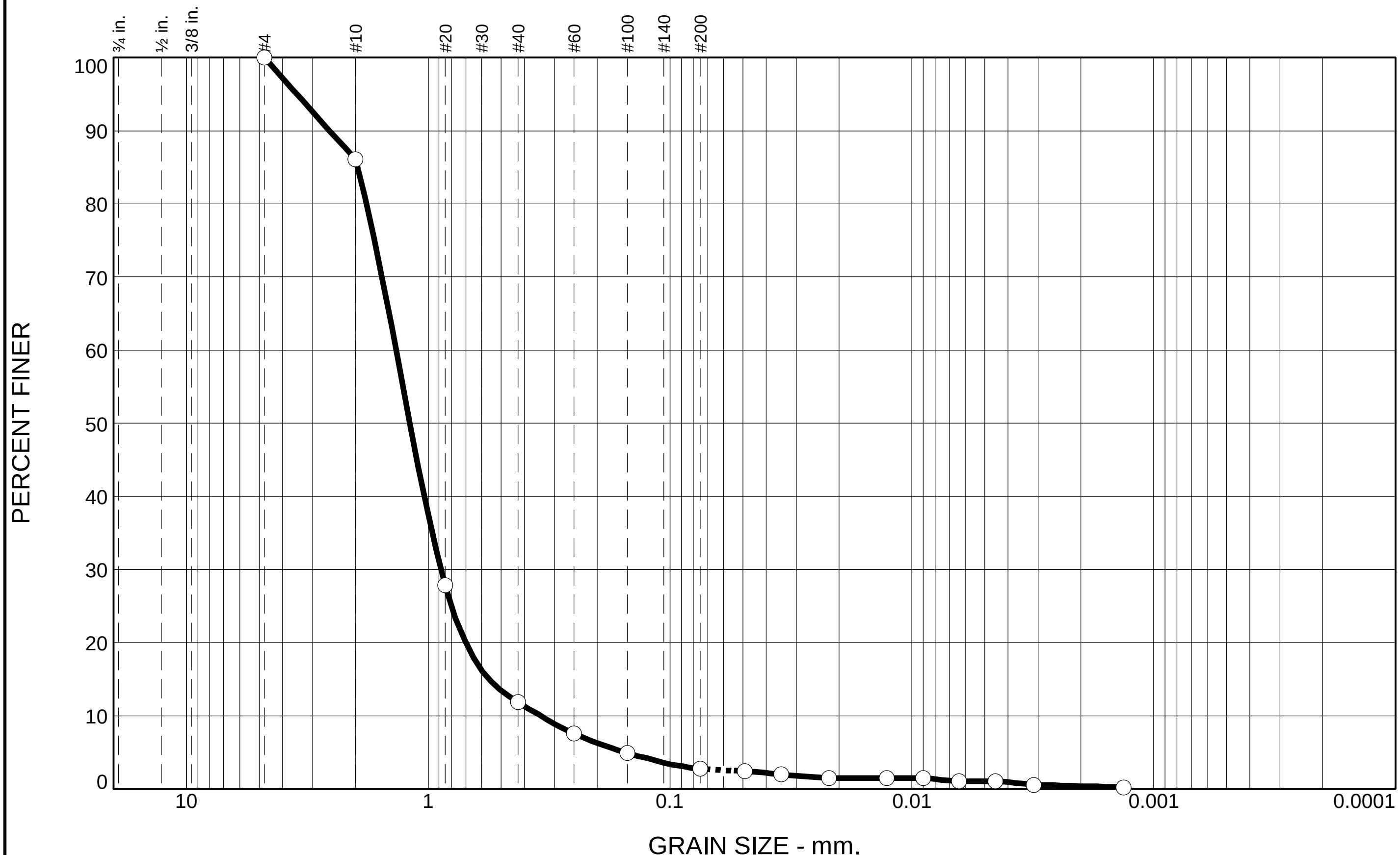
Terracon

Client: CONFIDENTIAL
Project: KINCAID POWER STATION

Project No: 11215018 **Figure**

Tested By: SJH **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D6913 and D7928



% Gravel		% Sand			% Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	13.9	74.2	9.2	1.7	1.0

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#10	86.1		
#20	27.8		
#40	11.9		
#60	7.6		
#100	4.9		
#200	2.7		
0.0490 mm.	2.4		
0.0347 mm.	2.0		
0.0220 mm.	1.5		
0.0127 mm.	1.5		
0.0090 mm.	1.5		
0.0064 mm.	1.0		
0.0045 mm.	1.0		
0.0031 mm.	0.5		
0.0013 mm.	0.2		

* (no specification provided)

Soil Description

BLACK AND DARK BROWN POORLY GRADED SAND - CINDERS NOTED

Atterberg Limits

PL= 16 LL= 15 PI= NP

Coefficients

D_{90}= 2.5540 D_{85}= 1.9597 D_{60}= 1.3571
D_{50}= 1.1905 D_{30}= 0.8856 D_{15}= 0.5606
D_{10}= 0.3429 C_u= 3.96 C_c= 1.69

Classification

USCS= SP AASHTO= A-1-b

Remarks

F.M.=3.32

Source of Sample: XPW-04 **Depth:** 21.0'-21.5
Sample Number: 1405 **Date:** 2-19-21

Terracon

Client: CONFIDENTIAL
Project: KINCAID POWER STATION
Project No: 11215018 **Figure**

Tested By: SJH **Checked By:** WPQ

Terracon

Hydraulic Conductivity of Saturated Porous Materials
Using a Flexible-Wall Permeameter
ASTM D5084

Terracon
Consulting Engineers & Scientists

HYDRAULIC CONDUCTIVITY DETERMINATION
ASTM D 5084, METHOD C
RISING TAILWATER LEVEL

Laboratory Services Group **192 Exchange Blvd** **Glendale Heights, Illinois 60139** **Ph. (630) 717-4263**

TERRACON PROJECT NO. **11215018** **3/23/2021**
PROJECT NAME: **KINCAID POWER STATION**
CLIENT: **CONFIDENTIAL**
LOCATION : **CONFIDENTIAL**

SUMMARY OF TEST RESULTS

BORING NO.	MW12D
TIME SAMPLED:	9:15
DEPTH:	5.0'-7.0'
CLASSIFICATION	BROWN CLAYEY SAND (SC)

	INITIAL	FINAL
DRY UNIT WEIGHT (pcf)	97.8	98.2
WATER CONTENT (%)	18.6	25.4
DIAMETER (cm)	7.147	7.144
LENGTH (cm)	10.536	10.501
B VALUE PARAMETER:	0.96	
HYDRAULIC GRADIENT (MAXIMUM)	18.96	
PERCENT SATURATION	97.1	
HYDRAULIC CONDUCTIVITY k (cm/sec)	3.16E-07	

SPECIMEN PHOTO

(Percent saturation calculation is based on final measurements and a measured specific gravity.)

Deaired water was used as the liquid permeant.

HYDRAULIC CONDUCTIVITY DETERMINATION
ASTM D 5084, METHOD C
RISING TAILWATER LEVEL

Laboratory Services Group **192 Exchange Blvd** **Glendale Heights, Illinois 60139** **Ph. (630) 717-4263**

TERRACON PROJECT NO. **11215018** **3/23/2021**
PROJECT NAME: **KINCAID POWER STATION**
CLIENT: **CONFIDENTIAL**
LOCATION : **CONFIDENTIAL**

SUMMARY OF TEST RESULTS

BORING NO.	MW12D
TIME SAMPLED:	9:40
DEPTH:	11.0'-11.5'
CLASSIFICATION	BROWN TO GRAY SANDY LEAN CLAY (CL)

	INITIAL	FINAL
DRY UNIT WEIGHT (pcf)	94.5	106.6
WATER CONTENT (%)	18.2	21.0
DIAMETER (cm)	6.155	6.143
LENGTH (cm)	9.627	8.564
B VALUE PARAMETER:	0.97	
HYDRAULIC GRADIENT (MAXIMUM)	20.75	
PERCENT SATURATION	99.6	
HYDRAULIC CONDUCTIVITY k (cm/sec)	7.21E-08	

SPECIMEN PHOTO

(Percent saturation calculation is based on final measurements and a measured specific gravity.)

Deaired water was used as the liquid permeant.

HYDRAULIC CONDUCTIVITY DETERMINATION
ASTM D 5084, METHOD C
RISING TAILWATER LEVEL

Laboratory Services Group **192 Exchange Blvd** **Glendale Heights, Illinois 60139** **Ph. (630) 717-4263**

TERRACON PROJECT NO. **11215018** **3/23/2021**
PROJECT NAME: **KINCAID POWER STATION**
CLIENT: **CONFIDENTIAL**
LOCATION : **CONFIDENTIAL**

SUMMARY OF TEST RESULTS

BORING NO. MW12D

TIME SAMPLED: 10:25

DEPTH: 20.5'-22.0'

CLASSIFICATION GRAY CLAYEY SAND (SC)

	INITIAL	FINAL
DRY UNIT WEIGHT (pcf)	106.9	107.0
WATER CONTENT (%)	14.0	20.9
DIAMETER (cm)	7.174	7.221
LENGTH (cm)	7.740	7.633
B VALUE PARAMETER:	0.97	
HYDRAULIC GRADIENT (MAXIMUM)	21.27	
PERCENT SATURATION	99.9	
HYDRAULIC CONDUCTIVITY k (cm/sec)	1.09E-07	

SPECIMEN PHOTO

(Percent saturation calculation is based on final measurements and a measured specific gravity.)

Deaired water was used as the liquid permeant.

HYDRAULIC CONDUCTIVITY DETERMINATION
ASTM D 5084, METHOD C
RISING TAILWATER LEVEL

Laboratory Services Group **192 Exchange Blvd** **Glendale Heights, Illinois 60139** **Ph. (630) 717-4263**

TERRACON PROJECT NO. **11215018** **3/23/2021**
PROJECT NAME: **KINCAID POWER STATION**
CLIENT: **CONFIDENTIAL**
LOCATION : **CONFIDENTIAL**

SUMMARY OF TEST RESULTS

BORING NO. MW-20

TIME SAMPLED: 8:15

DEPTH: 15.0'-17.0'

CLASSIFICATION BROWN AND GRAY SANDY LEAN CLAY (CL)

	INITIAL	FINAL
DRY UNIT WEIGHT (pcf)	107.7	110.6
WATER CONTENT (%)	18.9	19.2
DIAMETER (cm)	6.951	6.977
LENGTH (cm)	10.259	9.915
B VALUE PARAMETER:	0.99	
HYDRAULIC GRADIENT (MAXIMUM)	29.75	
PERCENT SATURATION	99.7	
HYDRAULIC CONDUCTIVITY k (cm/sec)	1.19E-07	

SPECIMEN PHOTO

(Percent saturation calculation is based on final measurements and a measured specific gravity.)

Deaired water was used as the liquid permeant.

Terracon
Consulting Engineers & Scientists

HYDRAULIC CONDUCTIVITY DETERMINATION
ASTM D 5084, METHOD C
RISING TAILWATER LEVEL

Laboratory Services Group **192 Exchange Blvd** **Glendale Heights, Illinois 60139** **Ph. (630) 717-4263**

TERRACON PROJECT NO.	**11215018**	**3/23/2021**
PROJECT NAME:	**KINCAID POWER STATION**	
CLIENT:	**CONFIDENTIAL**	
LOCATION :	**CONFIDENTIAL**	

SUMMARY OF TEST RESULTS

BORING NO.	MW-23
TIME SAMPLED:	11:35
DEPTH:	15.0'-17.0'
CLASSIFICATION	BROWN AND GRAYISH BROWN LEAN CLAY (CL)

	INITIAL	FINAL
DRY UNIT WEIGHT (pcf)	92.7	94.5
WATER CONTENT (%)	28.4	28.9
DIAMETER (cm)	7.199	7.132
LENGTH (cm)	9.515	9.516
B VALUE PARAMETER:	0.99	
HYDRAULIC GRADIENT (MAXIMUM)	24.69	
PERCENT SATURATION	99.7	
HYDRAULIC CONDUCTIVITY k (cm/sec)	7.40E-08	

SPECIMEN PHOTO

(Percent saturation calculation is based on final measurements and a measured specific gravity.)

Deaired water was used as the liquid permeant.

Terracon Consulting Engineers & Scientists
Laboratory Services Group 192 Exchange Blvd Glendale Heights, Illinois 60139 Ph. (630) 717-4263

TERRACON PROJECT NO. **11215018** **3/23/2021**
PROJECT NAME: **KINCAID POWER STATION**
CLIENT: **CONFIDENTIAL**
LOCATION : **CONFIDENTIAL**

SUMMARY OF TEST RESULTS

BORING NO. MW-23

TIME SAMPLED: 12:45

DEPTH: 25.0'-27.0'

CLASSIFICATION YELLOWISH BROWN SANDY LEAN CLAY (CL)

	INITIAL	FINAL
DRY UNIT WEIGHT (pcf)	112.3	112.6
WATER CONTENT (%)	15.6	18.5
DIAMETER (cm)	7.104	7.152
LENGTH (cm)	10.067	9.909
B VALUE PARAMETER:	0.95	
HYDRAULIC GRADIENT (MAXIMUM)	19.84	
PERCENT SATURATION	98.8	
HYDRAULIC CONDUCTIVITY k (cm/sec)	5.85E-08	

SPECIMEN PHOTO

(Percent saturation calculation is based on final measurements and a measured specific gravity.)

Deaired water was used as the liquid permeant.

Terracon

Permeability of Granular Soils (Constant Head)
ASTM D2434

Terracon Consulting Engineers & Scientists

PERMEABILITY OF GRANULAR SOILS
CONSTANT HEAD METHOD IN RIGID WALL PERMEAMETER
ASTM D 2434

Laboratory Services Group **192 Exchange Blvd** **Glendale Heights, Illinois 60139** **Ph. (630) 717-4263**

PROJECT NO.:	11215018
PROJECT:	KINCAID POWER STATION
DATE:	3/18/2021

SPECIMEN CHARATERISTICS

BORING NO.	XPW-01
TIME SAMPLED:	15:35
DEPTH:	8.5'-9.0'
CLASSIFICATION	BLACK POORLY GRADED SAND - CINDERS AND BRICK NOTED

	INITIAL
DRY UNIT WEIGHT (pcf)	74.8
WATER CONTENT (%)	19.4
DIAMETER (cm)	2.57
LENGTH (cm)	11.85

SUMMARY OF TEST RESULTS

HYDRAULIC GRADIENT	1.3
HEAD HEIGHT (cm)	15.00
VOID RATIO	1.323
HYDRAULIC CONDUCTIVITY k (cm/sec)	**7.16E-04**

Terracon
Consulting Engineers & Scientists

PERMEABILITY OF GRANULAR SOILS
CONSTANT HEAD METHOD IN RIGID WALL PERMEAMETER
ASTM D 2434

Laboratory Services Group **192 Exchange Blvd** **Glendale Heights, Illinois 60139** **Ph. (630) 717-4263**

PROJECT NO.:	11215018
PROJECT:	KINCAID POWER STATION
DATE:	3/18/2021

SPECIMEN CHARACTERISTICS

BORING NO.	XPW-01
TIME SAMPLED:	16:00
DEPTH:	21.0'-21.5'
CLASSIFICATION	BLACK POORLY GRADED SAND - CINDERS AND ROOTS NOTED

	INITIAL
DRY UNIT WEIGHT (pcf)	79.2
WATER CONTENT (%)	26.8
DIAMETER (cm)	2.57
LENGTH (cm)	11.85

SUMMARY OF TEST RESULTS

HYDRAULIC GRADIENT	1.3
HEAD HEIGHT (cm)	15.00
VOID RATIO	1.231
HYDRAULIC CONDUCTIVITY k (cm/sec)	**3.51E-04**

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Consulting Engineers & Scientists

PERMEABILITY OF GRANULAR SOILS
CONSTANT HEAD METHOD IN RIGID WALL PERMEAMETER
ASTM D 2434

Laboratory Services Group | 192 Exchange Blvd | Glendale Heights, Illinois 60139 | Ph. (630) 717-4263

PROJECT NO.:	11215018
PROJECT:	KINCAID POWER STATION
DATE:	3/18/2021

SPECIMEN CHARACTERISTICS

BORING NO.	XPW-02
TIME SAMPLED:	8:10
DEPTH:	9.0'-9.5'
CLASSIFICATION	BLACK POORLY GRADED SAND WITH SILT - CINDERS NOTED

	INITIAL
DRY UNIT WEIGHT (pcf)	62.7
WATER CONTENT (%)	11.8
DIAMETER (cm)	2.87
LENGTH (cm)	11.85

SUMMARY OF TEST RESULTS

HYDRAULIC GRADIENT	1.3
HEAD HEIGHT (cm)	15.00
VOID RATIO	1.769
HYDRAULIC CONDUCTIVITY k (cm/sec)	**4.04E-03**

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PERMEABILITY OF GRANULAR SOILS
CONSTANT HEAD METHOD IN RIGID WALL PERMEAMETER
ASTM D 2434

Laboratory Services Group **192 Exchange Blvd** **Glendale Heights, Illinois 60139** **Ph. (630) 717-4263**

PROJECT NO.:	11215018
PROJECT:	KINCAID POWER STATION
DATE:	3/18/2021

SPECIMEN CHARACTERISTICS

BORING NO.	XPW-02
TIME SAMPLED:	8:45
DEPTH:	20.5'-21.0'
CLASSIFICATION	BLACK TO DARK BROWN POORLY GRADED SAND - CINDERS NOTED

	INITIAL
DRY UNIT WEIGHT (pcf)	93.9
WATER CONTENT (%)	13.9
DIAMETER (cm)	2.57
LENGTH (cm)	11.85

SUMMARY OF TEST RESULTS

HYDRAULIC GRADIENT	1.3
HEAD HEIGHT (cm)	15.00
VOID RATIO	0.857
HYDRAULIC CONDUCTIVITY k (cm/sec)	**1.94E-03**

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PERMEABILITY OF GRANULAR SOILS
CONSTANT HEAD METHOD IN RIGID WALL PERMEAMETER
ASTM D 2434

Laboratory Services Group **192 Exchange Blvd** **Glendale Heights, Illinois 60139** **Ph. (630) 717-4263**

PROJECT NO.:	11215018
PROJECT:	KINCAID POWER STATION
DATE:	3/18/2021

SPECIMEN CHARACTERISTICS

BORING NO.	XPW-03
TIME SAMPLED:	10:15
DEPTH:	8.5'-9.0'
CLASSIFICATION	BLACK WELL GRADED SAND WITH SILT - CINDERS NOTED

	INITIAL
DRY UNIT WEIGHT (pcf)	86.9
WATER CONTENT (%)	27.4
DIAMETER (cm)	2.57
LENGTH (cm)	11.85

SUMMARY OF TEST RESULTS

HYDRAULIC GRADIENT	1.3
HEAD HEIGHT (cm)	15.00
VOID RATIO	1.011
HYDRAULIC CONDUCTIVITY k (cm/sec)	**4.31E-03**

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PERMEABILITY OF GRANULAR SOILS
CONSTANT HEAD METHOD IN RIGID WALL PERMEAMETER
ASTM D 2434

Laboratory Services Group **192 Exchange Blvd** **Glendale Heights, Illinois 60139** **Ph. (630) 717-4263**

PROJECT NO.:	11215018
PROJECT:	KINCAID POWER STATION
DATE:	3/18/2021

SPECIMEN CHARACTERISTICS

BORING NO.	XPW-03
TIME SAMPLED:	10:55
DEPTH:	18.5'-19.0'
CLASSIFICATION	BLACK POORLY GRADED SAND - CINDERS NOTED

	INITIAL
DRY UNIT WEIGHT (pcf)	89.3
WATER CONTENT (%)	36.4
DIAMETER (cm)	2.57
LENGTH (cm)	11.85

SUMMARY OF TEST RESULTS

HYDRAULIC GRADIENT	1.3
HEAD HEIGHT (cm)	15.00
VOID RATIO	0.932
HYDRAULIC CONDUCTIVITY k (cm/sec)	**3.52E-03**

PERMEABILITY OF GRANULAR SOILS
CONSTANT HEAD METHOD IN RIGID WALL PERMEAMETER
ASTM D 2434

Laboratory Services Group **192 Exchange Blvd** **Glendale Heights, Illinois 60139** **Ph. (630) 717-4263**

PROJECT NO.:	11215018
PROJECT:	KINCAID POWER STATION
DATE:	3/18/2021

SPECIMEN CHARACTERISTICS

BORING NO.	XPW-04
TIME SAMPLED:	13:20:00 AM
DEPTH:	10.0'-10.5'
CLASSIFICATION	BLACK AND DARK BROWN POORLY GRADED SAND - CINDERS AND ROOTS NOTED

	INITIAL
DRY UNIT WEIGHT (pcf)	77.4
WATER CONTENT (%)	18.3
DIAMETER (cm)	2.57
LENGTH (cm)	11.85

SUMMARY OF TEST RESULTS

HYDRAULIC GRADIENT	1.3
HEAD HEIGHT (cm)	15.00
VOID RATIO	1.242
HYDRAULIC CONDUCTIVITY k (cm/sec)	**9.22E-04**

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PERMEABILITY OF GRANULAR SOILS
CONSTANT HEAD METHOD IN RIGID WALL PERMEAMETER
ASTM D 2434

Laboratory Services Group **192 Exchange Blvd** **Glendale Heights, Illinois 60139** **Ph. (630) 717-4263**

PROJECT NO.:	11215018
PROJECT:	KINCAID POWER STATION
DATE:	3/18/2021

SPECIMEN CHARACTERISTICS

BORING NO.	XPW-04
TIME SAMPLED:	13:20:00 AM
DEPTH:	10.0'-10.5'
CLASSIFICATION	DARK BROWN TO BLACK POORLY GRADED SAND WITH SILT - CINDERS NOTED

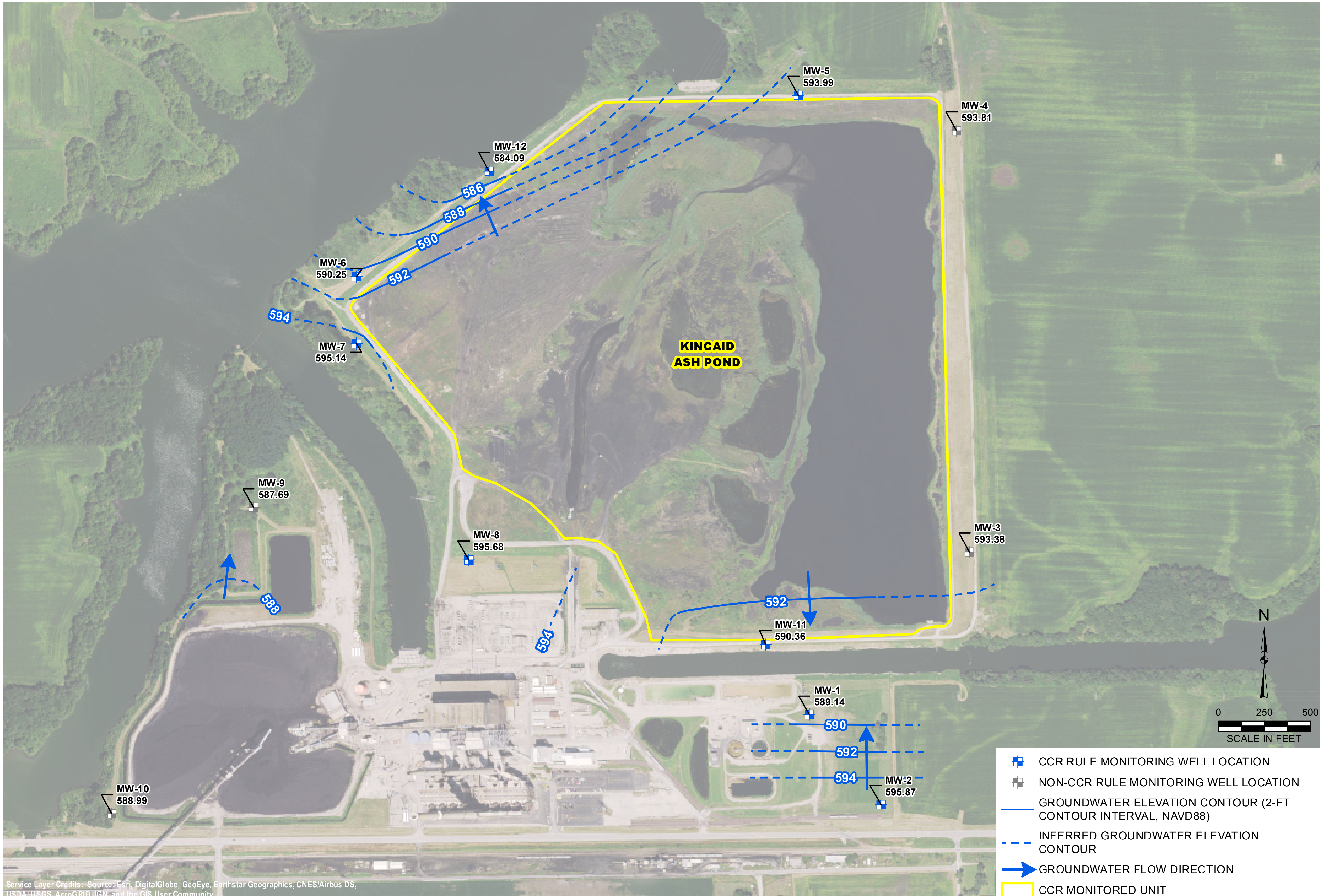
	INITIAL
DRY UNIT WEIGHT (pcf)	81.3
WATER CONTENT (%)	32.3
DIAMETER (cm)	2.57
LENGTH (cm)	11.85

SUMMARY OF TEST RESULTS

HYDRAULIC GRADIENT	1.3
HEAD HEIGHT (cm)	15.00
VOID RATIO	1.140
HYDRAULIC CONDUCTIVITY k (cm/sec)	**5.54E-04**

APPENDIX E
GROUNDWATER CONTOUR MAPS AND ELEVATIONS

GROUNDWATER CONTOUR MAPS



DRAWN BY/DATE: SDS 1/24/17
REVIEWED BY/DATE: ANS 1/25/17
APPROVED BY/DATE: JJW 2/8/17

KINCAID ASH POND (UNIT ID: 141)
UPPERMOST AQUIFER UNIT
GROUNDWATER ELEVATION CONTOUR MAP
ROUND 1: DECEMBER 14, 2015

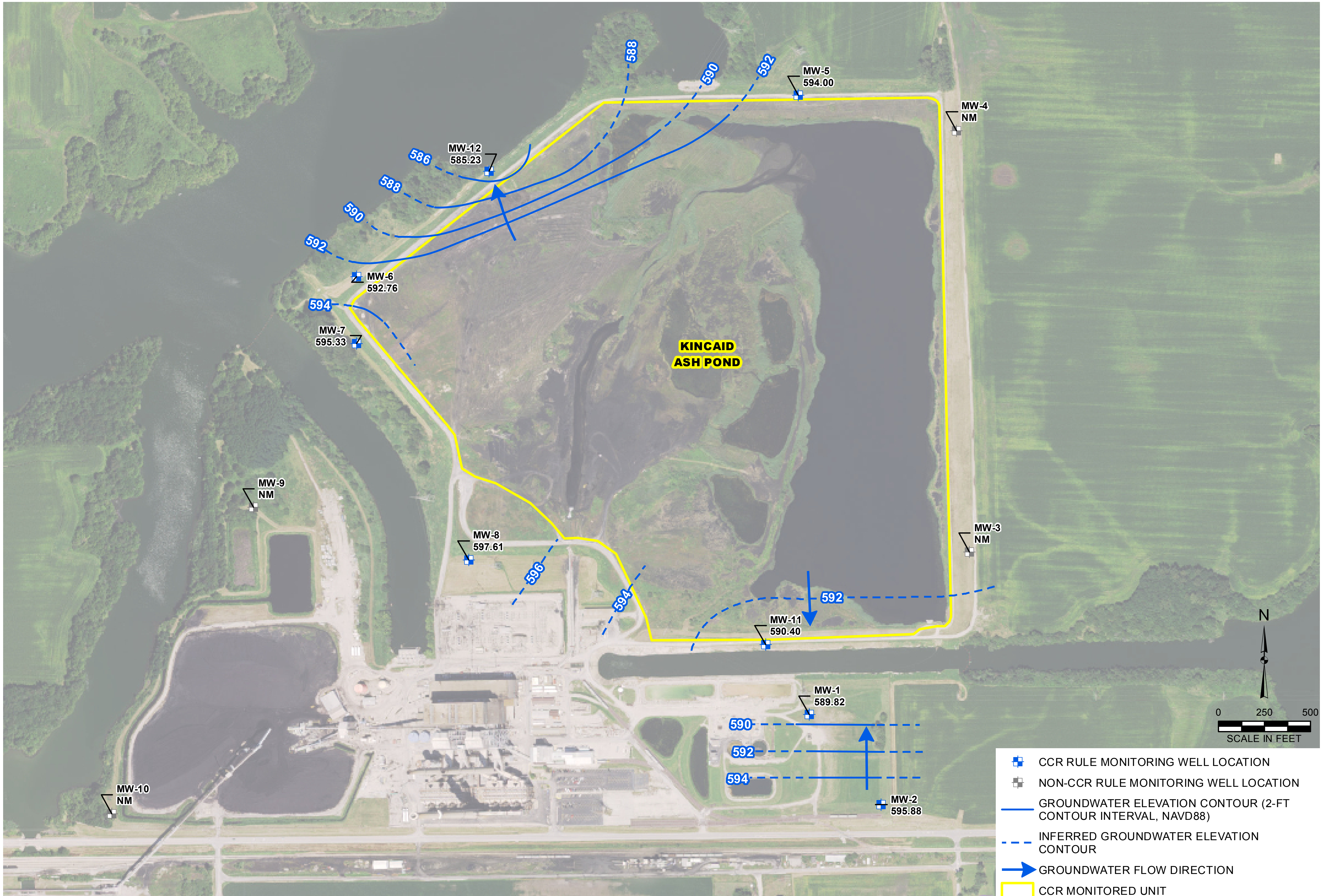
DYNEGY CCR RULE GROUNDWATER MONITORING
KINCAID POWER STATION
KINCAID, ILLINOIS

PROJECT NO: 2285

FIGURE NO: 1

Natural Resource Technology
AN OBG COMPANY

Y:\Mapping\Projects\22\2285\MXD\GW_Contours\Round_01\R1_Kincaid_GW_Contours.mxd Author: sstolz; Date/Time: 3/2/2017, 3:06:52 PM



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REVIEWED BY/DATE: ANS 1/25/17
APPROVED BY/DATE: JJW 2/8/17

KINCAID ASH POND (UNIT ID: 141) UPPERMOST AQUIFER UNIT GROUNDWATER ELEVATION CONTOUR MAP ROUND 2: FEBRUARY 29, 2016

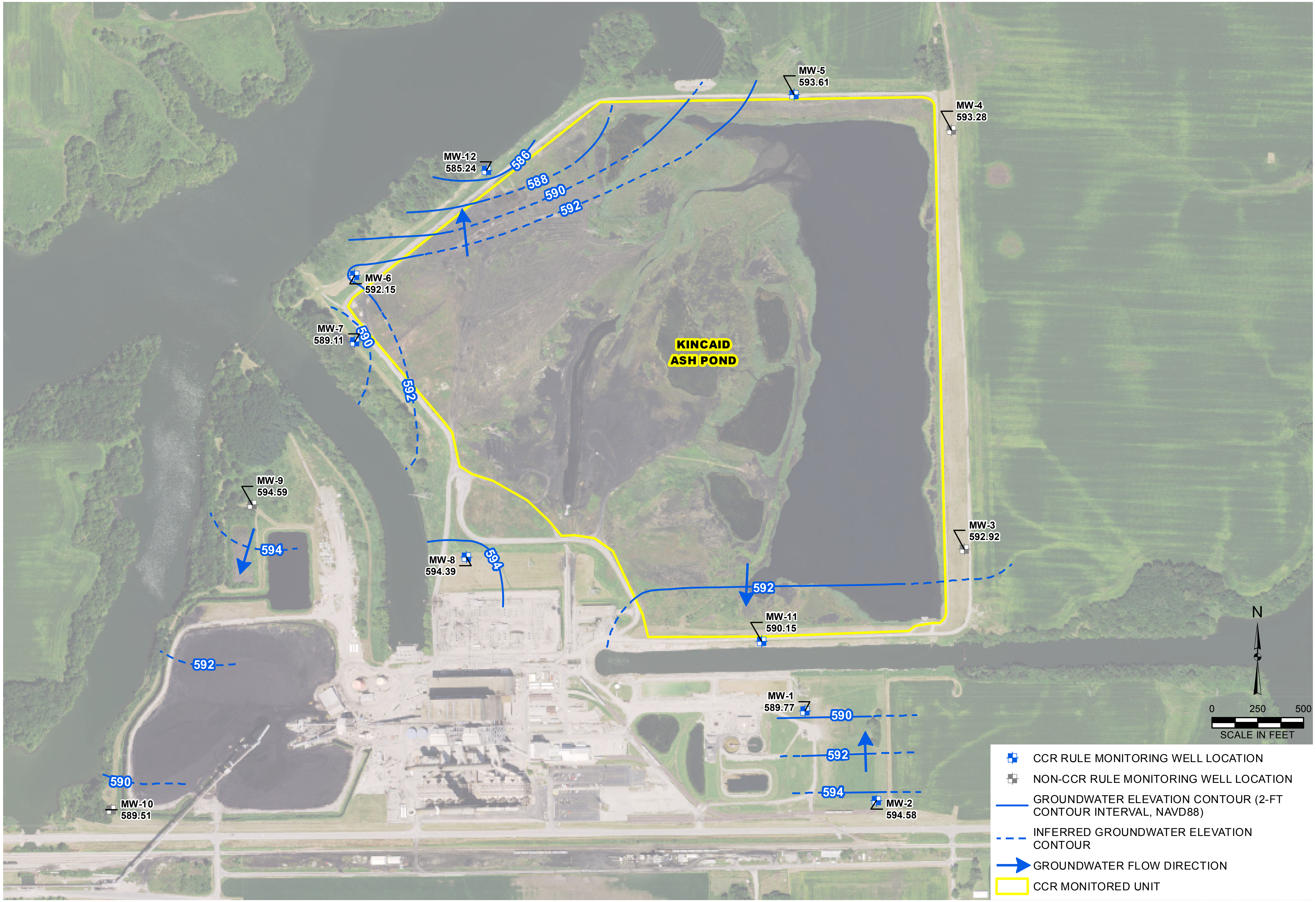
DYNEGY CCR RULE GROUNDWATER MONITORING
KINCAID POWER STATION
KINCAID, ILLINOIS

PROJECT NO: 2285/1.5

FIGURE NO: 1

Natural Resource Technology
AN OBG COMPANY

Y:\Mapping\Projects\22\2285\MXD\GW_Contours\Round_02\R2_Kincaid_GW_Contours.mxd Author: sstolz; Date/Time: 3/2/2017, 6:07:19 PM



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SDS 1/23/17
REVIEWED BY/DATE:
ANS 1/24/17
APPROVED BY/DATE:
JJW 2/8/17

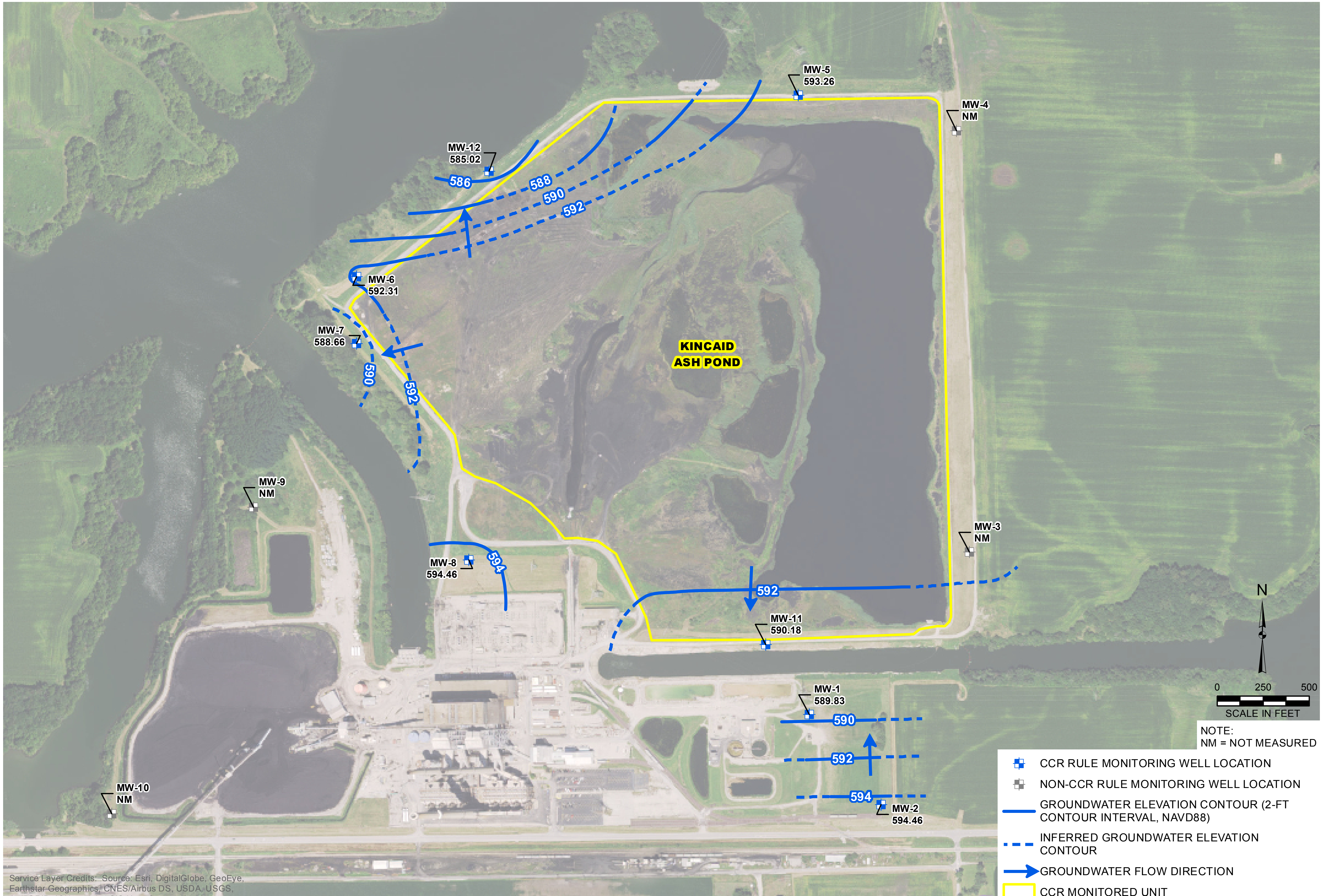
KINCAID ASH POND (UNIT ID: 141)
UPPERMOST AQUIFER UNIT
GROUNDWATER ELEVATION CONTOUR MAP
ROUND 3: MAY 16, 2016

DYNEGY CCR RULE GROUNDWATER MONITORING
KINCAID POWER STATION
KINCAID, ILLINOIS

PROJECT NO: 2285

FIGURE NO: 1

Natural Resource Technology
AN OBG COMPANY



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SDS 1/25/17
REVIEWED BY/DATE:
ANS 1/26/17
APPROVED BY/DATE:
JJW 2/8/17

KINCAID ASH POND (UNIT ID: 141)
UPPERMOST AQUIFER UNIT
GROUNDWATER ELEVATION CONTOUR MAP
ROUND 4: AUGUST 22, 2016

DYNEGY CCR RULE GROUNDWATER MONITORING
KINCAID POWER STATION
KINCAID, ILLINOIS

PROJECT NO: 2285

FIGURE NO: 1

Natural Resource Technology
AN OBG COMPANY

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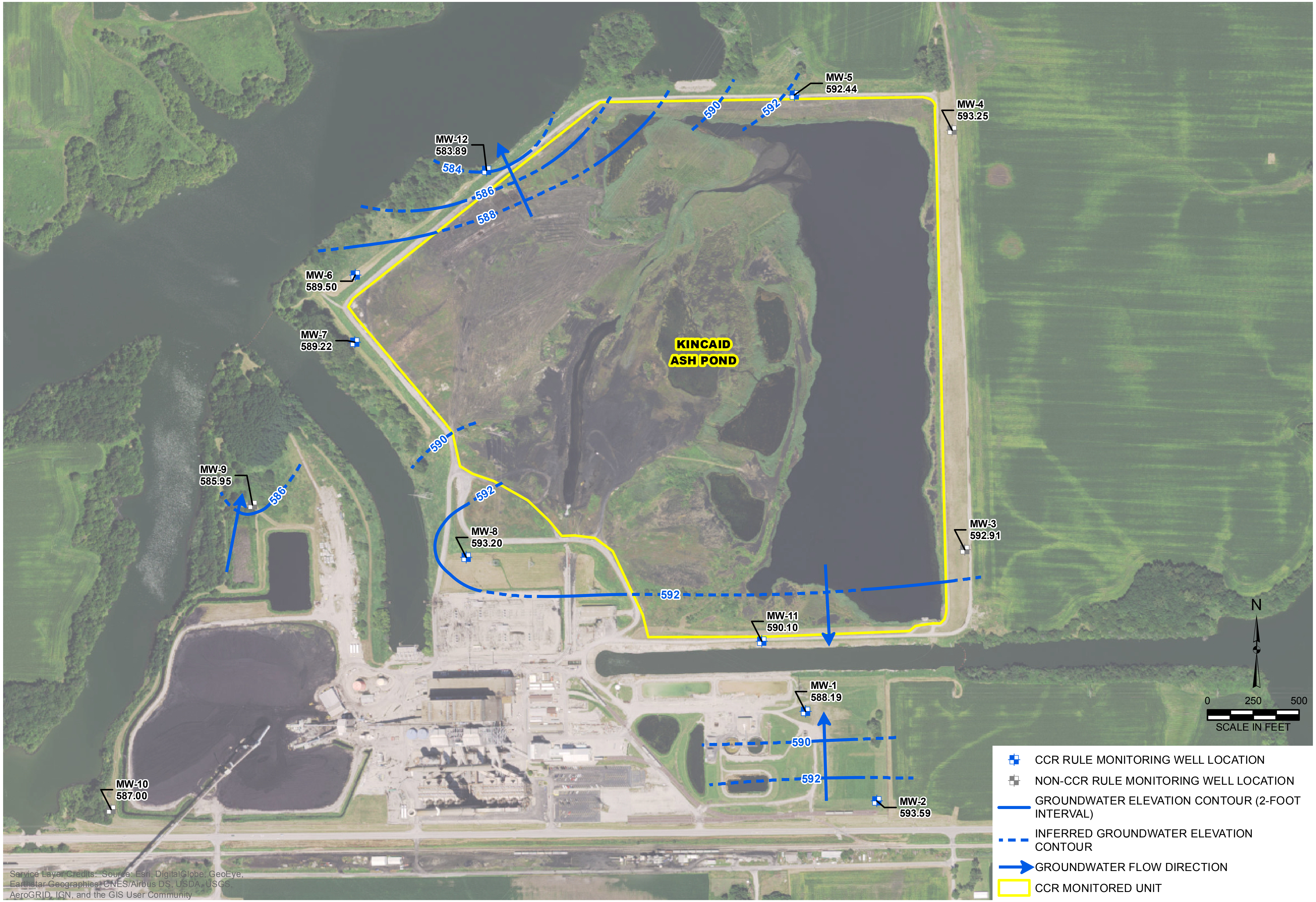


DRAWN BY/DATE:
SDS 3/7/17
REVIEWED BY/DATE:
ANS 3/7/17
APPROVED BY/DATE:
JJW 8/30/17

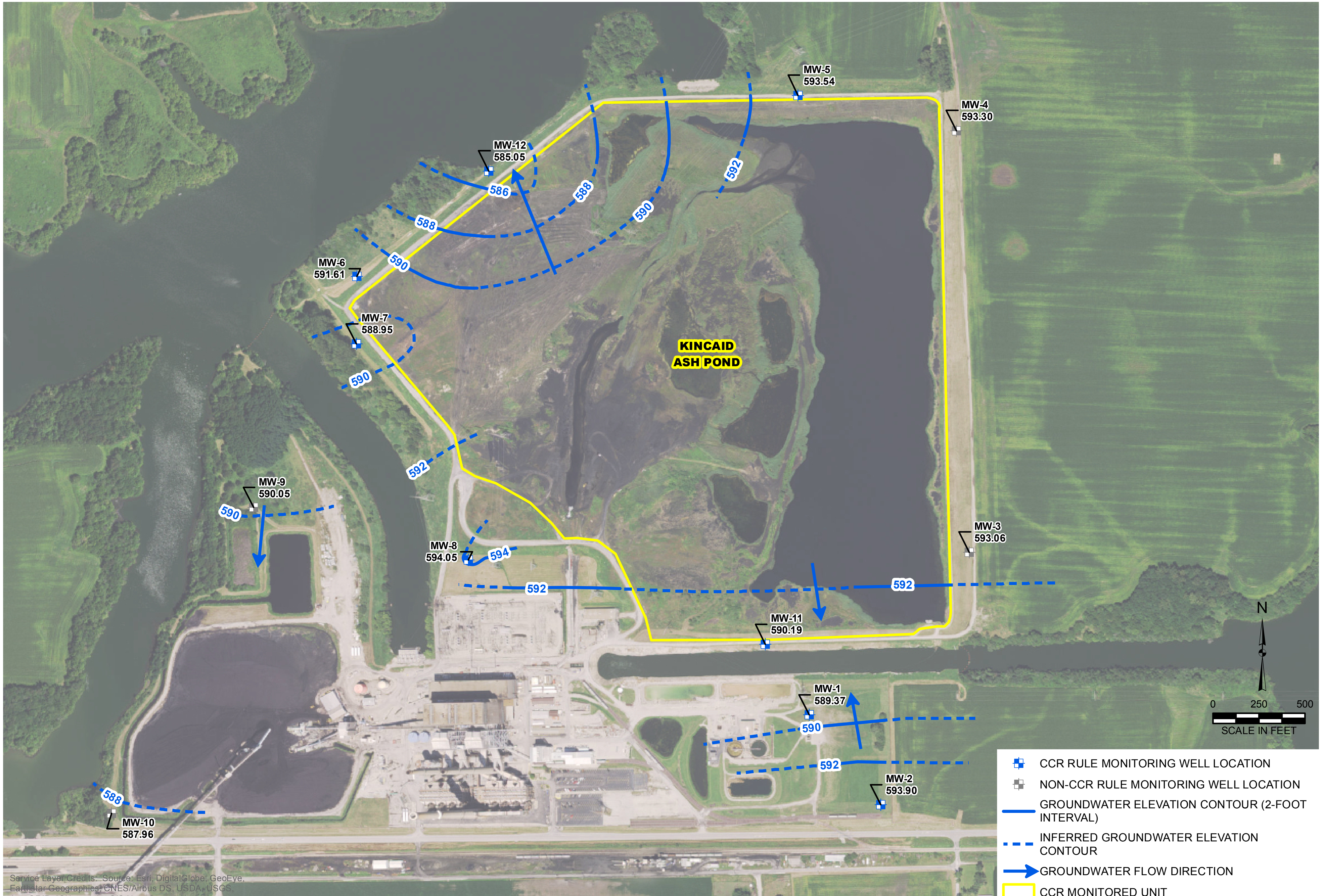
KINCAID ASH POND (UNIT ID: 141)
UPPERMOST AQUIFER UNIT
GROUNDWATER ELEVATION CONTOUR MAP
ROUND 5: NOVEMBER 15, 2016

DYNEGY CCR RULE GROUNDWATER MONITORING
KINCAID POWER STATION
KINCAID, ILLINOIS

PROJECT NO: 2285

FIGURE NO: 1

Natural Resource Technology
AN OBG COMPANY



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REVIEWED BY/DATE:
ANS 3/7/17
APPROVED BY/DATE:
JJW 9/1/17

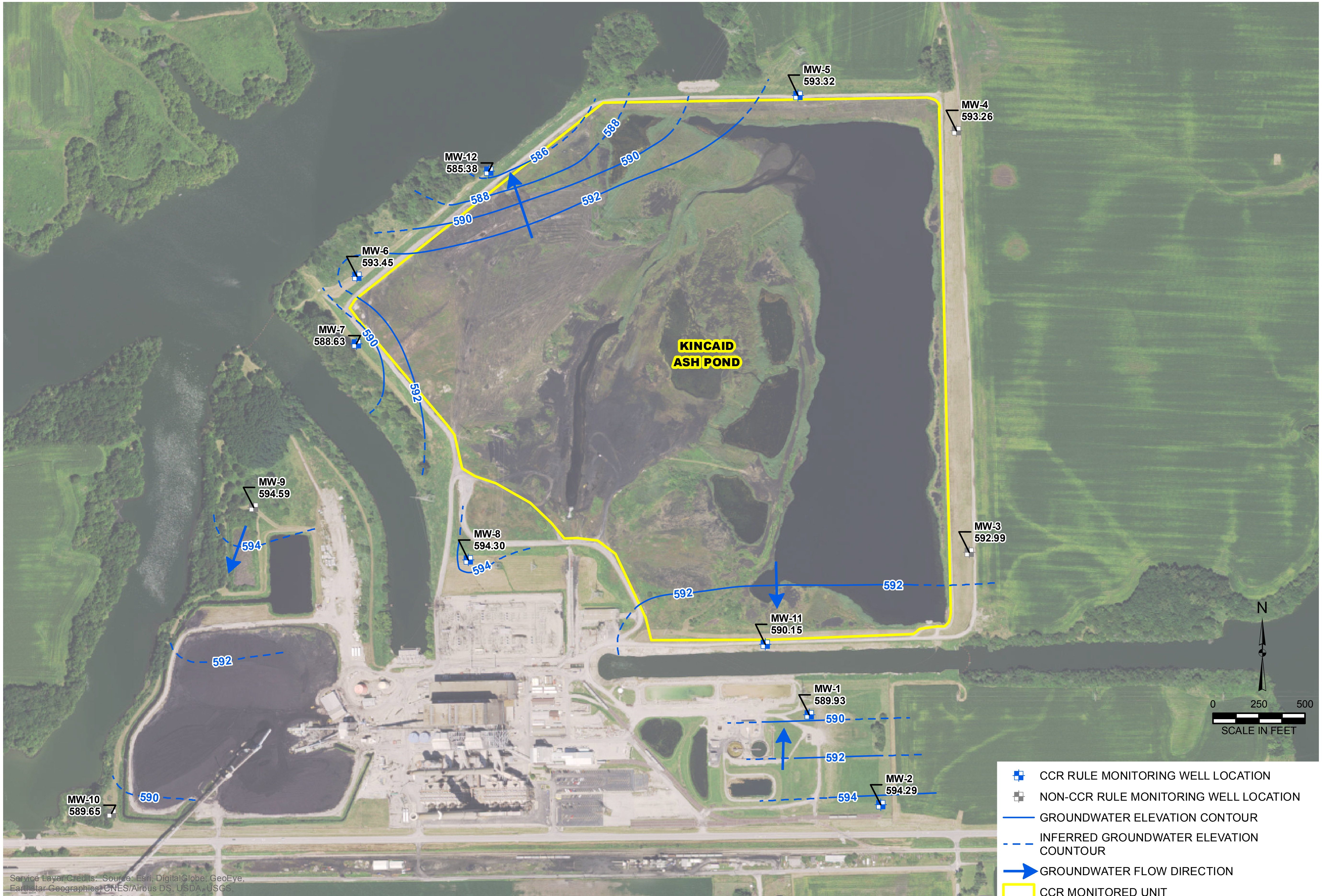
KINCAID ASH POND (UNIT ID: 141)
UPPERMOST AQUIFER UNIT
GROUNDWATER ELEVATION CONTOUR MAP
ROUND 6: FEBRUARY 13, 2017

DYNEGY CCR RULE GROUNDWATER MONITORING
KINCAID POWER STATION
KINCAID, ILLINOIS

PROJECT NO: 2285

FIGURE NO: 1

Natural Resource Technology
AN OBG COMPANY



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REVIEWED BY/DATE:
ANS 7/28/17
APPROVED BY/DATE:
JJW 9/1/17

KINCAID ASH POND (UNIT ID: 141)
UPPERMOST AQUIFER UNIT
GROUNDWATER ELEVATION CONTOUR MAP
ROUND 7: MAY 18, 2017

DYNEGY CCR RULE GROUNDWATER MONITORING
KINCAID POWER STATION
KINCAID, ILLINOIS

PROJECT NO: 2285

FIGURE NO: 1

Natural Resource Technology
AN OBG COMPANY

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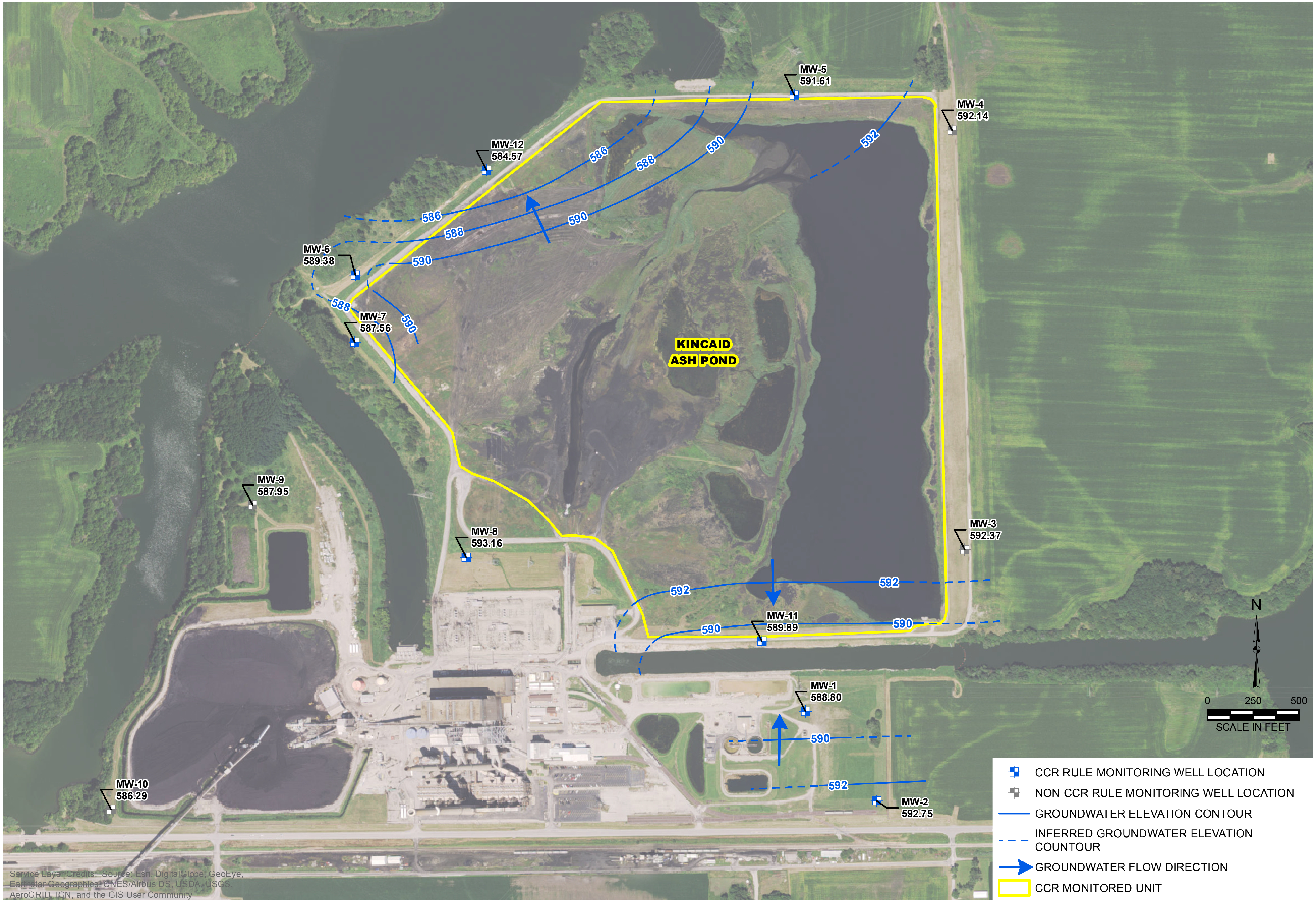

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SDS 8/16/17
REVIEWED BY/DATE:
ANS 8/16/17
APPROVED BY/DATE:
JJW 9/1/17

KINCAID ASH POND (UNIT ID: 141)
UPPERMOST AQUIFER UNIT
GROUNDWATER ELEVATION CONTOUR MAP
ROUND 8: JULY 18, 2017

DYNEGY CCR RULE GROUNDWATER MONITORING
KINCAID POWER STATION
KINCAID, ILLINOIS

PROJECT NO: 2285

FIGURE NO: 1

Natural Resource Technology
AN OBG COMPANY

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- CCR RULE MONITORING WELL LOCATION
- NON-CCR RULE MONITORING WELL LOCATION
- GROUNDWATER ELEVATION CONTOUR (2-FT CONTOUR INTERVAL, NAVD88)
- INFERRED GROUNDWATER ELEVATION CONTOUR
- GROUNDWATER FLOW DIRECTION
- CCR MONITORED UNIT

CCR RULE GROUNDWATER MONITORING
KINCAID POWER STATION
KINCAID, ILLINOIS

0 125 250 500
Feet

N

KINCAID ASH POND (UNIT ID: 141)
GROUNDWATER ELEVATION CONTOUR MAP
NOVEMBER 6, 2017

O'BRIEN & GERE ENGINEERS, INC.

NOTES:
**SANGCHRIS LAKE ELEVATION OBTAINED FROM A TRANSDUCER MONITORING WATER LEVELS LOCATED NEAR PLANT INTAKE. ELEVATION DATUM PRE-DATED NAVD88 AND WAS ASSUMED TO BE IN NGVD29. ELEVATION DATA WAS CONVERTED TO NAVD88. AT THE TIME OF THIS DRAWING, THE DATA WAS PRELIMINARY AND SUBJECT TO CHANGE. THE AVERAGE ELEVATION FROM AUG. 28, 2018 WAS ESTIMATED TO THE NEAREST 0.1 FOOT.

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- CCR RULE MONITORING WELL LOCATION
- NON-CCR RULE MONITORING WELL LOCATION
- GROUNDWATER ELEVATION CONTOUR (2-FT CONTOUR INTERVAL, NAVD88)
- INFERRED GROUNDWATER ELEVATION CONTOUR
- GROUNDWATER FLOW DIRECTION
- CCR MONITORED UNIT

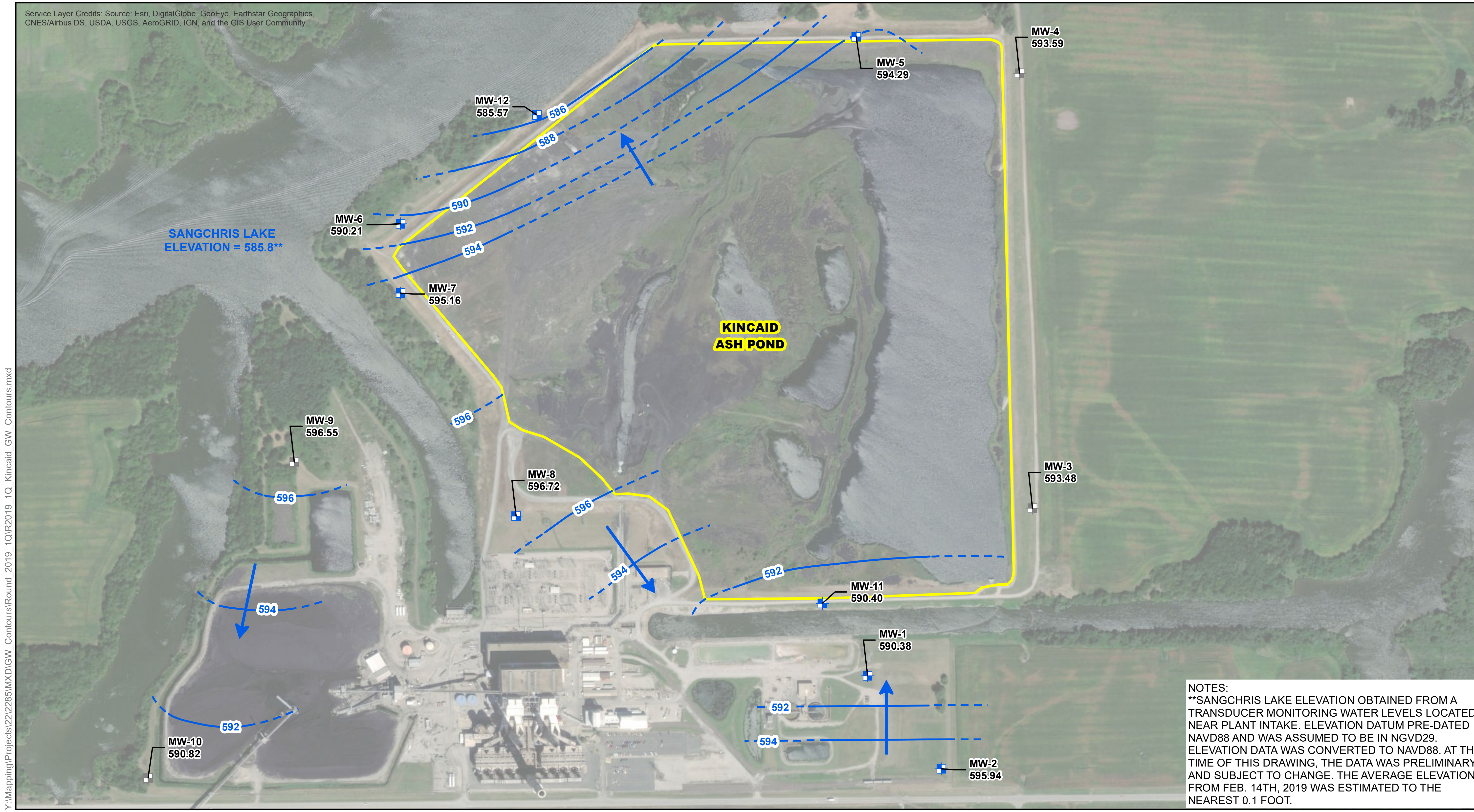
CCR RULE GROUNDWATER MONITORING
KINCAID POWER STATION
KINCAID, ILLINOIS

0 125 250 500
Feet

N

KINCAID ASH POND (UNIT ID: 141)
GROUNDWATER ELEVATION CONTOUR MAP
AUGUST 28, 2018

O'BRIEN & GERE ENGINEERS, INC.



CCR RULE MONITORING WELL LOCATION
NON-CCR RULE MONITORING WELL LOCATION
GROUNDWATER ELEVATION CONTOUR (2-FT CONTOUR INTERVAL, NAVD88)
INFERRED GROUNDWATER ELEVATION CONTOUR
GROUNDWATER FLOW DIRECTION
CCR MONITORED UNIT

CCR RULE GROUNDWATER MONITORING
KINCAID POWER STATION
KINCAID, ILLINOIS

KINCAID ASH POND (UNIT ID: 141)
GROUNDWATER ELEVATION CONTOUR MAP
FEBRUARY 14, 2019

O'BRIEN & GERE ENGINEERS, INC.

NOTES:
**SANGCHRIS LAKE ELEVATION OBTAINED FROM A TRANSDUCER MONITORING WATER LEVELS LOCATED NEAR PLANT INTAKE. ELEVATION DATUM PRE-DATED NAVD88 AND WAS ASSUMED TO BE IN NGVD29. ELEVATION DATA WAS CONVERTED TO NAVD88. AT THE TIME OF THIS DRAWING, THE DATA WAS PRELIMINARY AND SUBJECT TO CHANGE. THE AVERAGE ELEVATION FROM MAY 31 TO JUNE 1, 2018 WAS ESTIMATED TO THE NEAREST 0.1 FOOT.

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CCR RULE MONITORING WELL LOCATION
NON-CCR RULE MONITORING WELL LOCATION
GROUNDWATER ELEVATION CONTOUR (2-FT CONTOUR INTERVAL, NAVD88)
INFERRED GROUNDWATER ELEVATION CONTOUR
GROUNDWATER FLOW DIRECTION
CCR MONITORED UNIT

CCR RULE GROUNDWATER MONITORING
KINCAID POWER STATION
KINCAID, ILLINOIS

KINCAID ASH POND (UNIT ID: 141)
GROUNDWATER ELEVATION CONTOUR MAP
MAY 31 - JUNE 1, 2018

O'BRIEN & GERE ENGINEERS, INC.

NOTES:
**SANGCHRIS LAKE ELEVATION OBTAINED FROM A TRANSDUCER MONITORING WATER LEVELS LOCATED NEAR PLANT INTAKE. ELEVATION DATUM PRE-DATED NAVD88 AND WAS ASSUMED TO BE IN NGVD29. ELEVATION DATA WAS CONVERTED TO NAVD88. AT THE TIME OF THIS DRAWING, THE DATA WAS PRELIMINARY AND SUBJECT TO CHANGE. THE AVERAGE ELEVATION FROM AUG. 20TH, 2019 WAS ESTIMATED TO THE NEAREST 0.1 FOOT.

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- CCR RULE MONITORING WELL LOCATION
- NON-CCR RULE MONITORING WELL LOCATION
- GROUNDWATER ELEVATION CONTOUR (2-FT CONTOUR INTERVAL, NAVD88)
- INFERRED GROUNDWATER ELEVATION CONTOUR
- GROUNDWATER FLOW DIRECTION
- CCR MONITORED UNIT

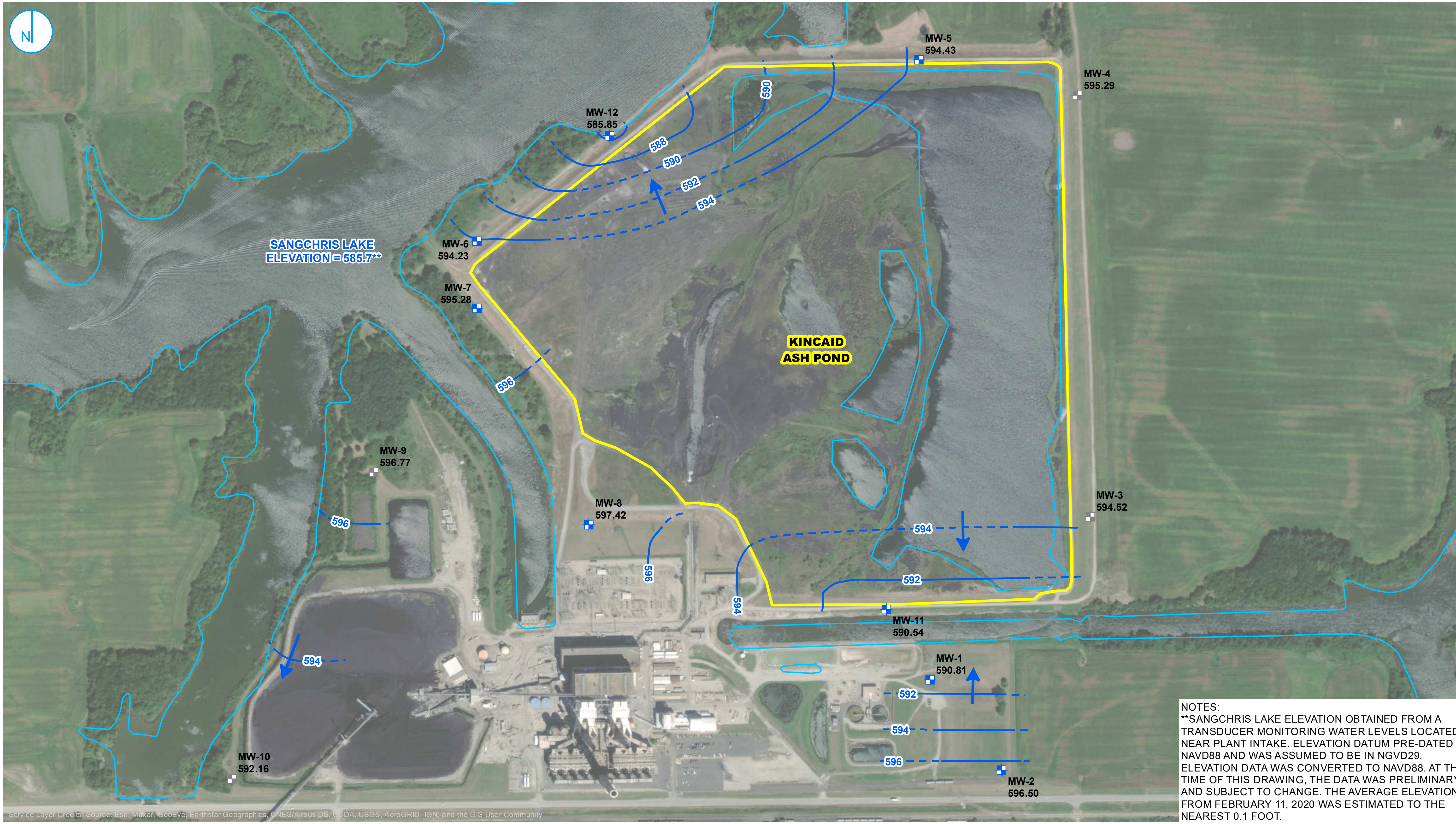
CCR RULE GROUNDWATER MONITORING
KINCAID POWER STATION
KINCAID, ILLINOIS

0 125 250 500
Feet

N

KINCAID ASH POND (UNIT ID: 141)
GROUNDWATER ELEVATION CONTOUR MAP
AUGUST 20, 2019

O'BRIEN & GERE ENGINEERS, INC.



NOTES:
**SANGCHRIS LAKE ELEVATION OBTAINED FROM A TRANSDUCER MONITORING WATER LEVELS LOCATED NEAR PLANT INTAKE. ELEVATION DATUM PRE-DATED NAVD88 AND WAS ASSUMED TO BE IN NGVD29. ELEVATION DATA WAS CONVERTED TO NAVD88. AT THE TIME OF THIS DRAWING, THE DATA WAS PRELIMINARY AND SUBJECT TO CHANGE. THE AVERAGE ELEVATION FROM FEBRUARY 11, 2020 WAS ESTIMATED TO THE NEAREST 0.1 FOOT.

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PROJECT: 169000XXXX | DATED: 9/15/2020 | DESIGNER: galarnmc

CCR RULE MONITORING WELL LOCATION
NON-CCR RULE MONITORING WELL LOCATION
GROUNDWATER ELEVATION CONTOUR (2-FT CONTOUR INTERVAL, NAVD88)
INFERRED GROUNDWATER ELEVATION CONTOUR
GROUNDWATER FLOW DIRECTION
SURFACE WATER FEATURE
CCR MONITORED UNIT

0 250 500 Feet

KINCAID ASH POND (UNIT ID: 141)
GROUNDWATER ELEVATION CONTOUR MAP
FEBRUARY 11, 2020

CCR RULE GROUNDWATER MONITORING
KINCAID POWER STATION
KINCAID, ILLINOIS

FIGURE 1

RAMBOLL US CORPORATION
A RAMBOLL COMPANY

RAMBOLL

TABLE E-1. GROUNDWATER ELEVATION RESULTS

Sample Location	Sample Date	Groundwater Elevation (ft NAVD88)
MW-1	06/16/2015	604.71
MW-1	12/14/2015	589.14
MW-1	12/15/2015	589.14
MW-1	02/29/2016	589.82
MW-1	05/16/2016	589.77
MW-1	08/22/2016	589.83
MW-1	11/15/2016	588.19
MW-1	02/13/2017	589.37
MW-1	05/18/2017	589.93
MW-1	07/18/2017	588.80
MW-1	11/06/2017	587.63
MW-1	05/31/2018	588.77
MW-1	08/28/2018	590.05
MW-1	11/08/2018	589.66
MW-1	02/14/2019	590.38
MW-1	05/14/2019	590.03
MW-1	08/20/2019	589.44
MW-1	11/13/2019	589.86
MW-1	02/11/2020	590.81
MW-1	05/12/2020	590.05
MW-1	08/26/2020	589.00
MW-1	12/02/2020	588.22
MW-1	02/23/2021	589.03
MW-1	02/24/2021	589.03
MW-1	03/15/2021	589.38
MW-1	03/30/2021	590.48
MW-1	04/05/2021	589.90
MW-1	05/19/2021	592.24
MW-1	06/10/2021	589.60
MW-1	07/01/2021	589.63
MW-1	07/22/2021	589.36
MW-1	08/10/2021	589.63
MW-1	09/01/2021	589.14
MW-2	06/16/2015	601.10
MW-2	12/14/2015	595.87
MW-2	12/15/2015	595.87
MW-2	02/29/2016	595.88
MW-2	05/16/2016	594.58
MW-2	08/22/2016	594.46
MW-2	11/15/2016	593.59
MW-2	02/13/2017	593.90
MW-2	05/18/2017	594.29
MW-2	07/18/2017	592.75
MW-2	11/06/2017	592.42
MW-2	05/31/2018	593.65

Sample Location	Sample Date	Groundwater Elevation (ft NAVD88)
MW-2	08/28/2018	595.30
MW-2	11/08/2018	595.32
MW-2	02/14/2019	595.94
MW-2	05/14/2019	594.78
MW-2	08/20/2019	593.94
MW-2	11/13/2019	594.15
MW-2	02/11/2020	596.50
MW-2	05/12/2020	594.48
MW-2	08/26/2020	593.43
MW-2	12/02/2020	593.53
MW-2	02/23/2021	594.92
MW-2	02/24/2021	594.92
MW-2	03/15/2021	595.03
MW-2	03/30/2021	596.21
MW-2	04/05/2021	594.46
MW-2	05/19/2021	596.68
MW-2	06/10/2021	594.12
MW-2	07/01/2021	594.79
MW-2	07/22/2021	593.95
MW-2	08/10/2021	595.70
MW-2	09/01/2021	594.10
MW-3	12/14/2015	593.38
MW-3	05/16/2016	592.92
MW-3	11/15/2016	592.91
MW-3	02/13/2017	593.06
MW-3	05/18/2017	592.99
MW-3	07/18/2017	592.37
MW-3	11/06/2017	592.97
MW-3	05/31/2018	591.72
MW-3	08/28/2018	593.40
MW-3	11/08/2018	593.00
MW-3	02/14/2019	593.48
MW-3	05/14/2019	593.18
MW-3	08/20/2019	592.94
MW-3	02/11/2020	594.52
MW-3	05/12/2020	593.17
MW-3	08/26/2020	592.83
MW-3	12/02/2020	592.82
MW-3	02/23/2021	593.71
MW-3	02/25/2021	593.71
MW-3	03/15/2021	593.20
MW-3	03/16/2021	593.20
MW-3	03/30/2021	594.05
MW-3	04/05/2021	593.15
MW-3	05/18/2021	598.11

Sample Location	Sample Date	Groundwater Elevation (ft NAVD88)
MW-3	06/09/2021	592.88
MW-3	07/01/2021	592.86
MW-3	07/22/2021	592.82
MW-3	08/10/2021	593.34
MW-3	09/01/2021	591.57
MW-4	12/14/2015	593.81
MW-4	05/16/2016	593.28
MW-4	11/15/2016	593.25
MW-4	02/13/2017	593.30
MW-4	05/18/2017	593.26
MW-4	07/18/2017	592.14
MW-4	11/06/2017	590.75
MW-4	05/31/2018	593.29
MW-4	08/28/2018	593.48
MW-4	11/08/2018	593.48
MW-4	02/14/2019	593.59
MW-4	05/14/2019	593.39
MW-4	08/20/2019	592.44
MW-4	02/11/2020	595.29
MW-4	05/12/2020	593.42
MW-4	08/26/2020	592.82
MW-4	12/02/2020	592.56
MW-4	02/23/2021	593.41
MW-4	02/25/2021	593.41
MW-4	03/15/2021	593.45
MW-4	03/16/2021	593.45
MW-4	03/30/2021	594.38
MW-4	04/05/2021	593.33
MW-4	04/06/2021	593.33
MW-4	05/19/2021	597.08
MW-4	06/09/2021	594.37
MW-4	07/01/2021	595.32
MW-4	07/22/2021	593.20
MW-4	08/10/2021	593.49
MW-4	09/01/2021	592.30
MW-5	06/16/2015	619.44
MW-5	12/14/2015	593.99
MW-5	12/15/2015	593.99
MW-5	02/29/2016	594.00
MW-5	05/16/2016	593.61
MW-5	08/22/2016	593.26
MW-5	11/15/2016	592.44
MW-5	02/13/2017	593.54
MW-5	05/18/2017	593.32
MW-5	07/18/2017	591.61

Sample Location	Sample Date	Groundwater Elevation (ft NAVD88)
MW-5	11/06/2017	590.64
MW-5	05/31/2018	592.94
MW-5	08/28/2018	593.77
MW-5	11/08/2018	593.84
MW-5	02/14/2019	594.29
MW-5	05/14/2019	593.85
MW-5	08/20/2019	592.94
MW-5	11/14/2019	593.77
MW-5	02/11/2020	594.43
MW-5	05/12/2020	593.91
MW-5	08/26/2020	591.82
MW-5	12/02/2020	591.53
MW-5	02/23/2021	594.09
MW-5	03/15/2021	594.36
MW-5	03/30/2021	594.41
MW-5	04/05/2021	593.84
MW-5	05/20/2021	594.57
MW-5	06/09/2021	593.15
MW-5	07/01/2021	593.94
MW-5	07/22/2021	593.09
MW-5	08/10/2021	594.66
MW-5	09/01/2021	593.13
MW-6	06/16/2015	600.46
MW-6	12/14/2015	590.25
MW-6	12/15/2015	590.25
MW-6	02/29/2016	592.76
MW-6	05/16/2016	592.15
MW-6	08/22/2016	592.31
MW-6	11/15/2016	589.50
MW-6	02/13/2017	591.61
MW-6	05/18/2017	593.45
MW-6	07/18/2017	589.38
MW-6	11/06/2017	588.21
MW-6	05/31/2018	590.71
MW-6	08/28/2018	593.18
MW-6	11/08/2018	592.61
MW-6	02/14/2019	590.21
MW-6	02/15/2019	594.21
MW-6	05/14/2019	593.46
MW-6	08/20/2019	590.14
MW-6	11/13/2019	592.19
MW-6	02/11/2020	594.23
MW-6	05/12/2020	593.49
MW-6	08/26/2020	590.40
MW-6	12/02/2020	588.64

Sample Location	Sample Date	Groundwater Elevation (ft NAVD88)
MW-6	02/23/2021	592.01
MW-6	03/15/2021	592.27
MW-6	03/30/2021	594.96
MW-6	04/05/2021	593.71
MW-6	05/21/2021	595.26
MW-6	06/10/2021	591.58
MW-6	07/01/2021	590.43
MW-6	07/22/2021	591.82
MW-6	08/10/2021	592.67
MW-6	09/01/2021	591.27
MW-7	06/17/2015	597.75
MW-7	12/14/2015	595.14
MW-7	12/15/2015	595.14
MW-7	02/29/2016	595.33
MW-7	05/16/2016	589.11
MW-7	08/22/2016	588.66
MW-7	11/15/2016	589.22
MW-7	02/13/2017	588.95
MW-7	05/18/2017	588.63
MW-7	05/19/2017	588.63
MW-7	07/18/2017	587.56
MW-7	11/06/2017	588.02
MW-7	11/07/2017	588.02
MW-7	06/01/2018	588.10
MW-7	08/28/2018	589.18
MW-7	11/08/2018	589.00
MW-7	02/14/2019	595.16
MW-7	02/15/2019	595.16
MW-7	05/14/2019	590.46
MW-7	08/20/2019	591.18
MW-7	11/13/2019	588.69
MW-7	02/11/2020	595.28
MW-7	05/12/2020	589.51
MW-7	08/26/2020	587.70
MW-7	12/02/2020	586.57
MW-7	02/23/2021	589.45
MW-7	03/15/2021	594.86
MW-7	03/30/2021	590.96
MW-7	04/05/2021	588.64
MW-7	05/21/2021	591.55
MW-7	06/10/2021	586.86
MW-7	07/01/2021	592.54
MW-7	07/22/2021	587.73
MW-7	08/10/2021	595.40
MW-7	09/01/2021	593.93

Sample Location	Sample Date	Groundwater Elevation (ft NAVD88)
MW-7S	02/23/2021	587.18
MW-7S	02/24/2021	587.18
MW-7S	03/15/2021	587.26
MW-7S	03/16/2021	587.26
MW-7S	04/05/2021	587.12
MW-7S	04/06/2021	587.12
MW-7S	05/21/2021	587.86
MW-7S	06/10/2021	587.44
MW-7S	07/02/2021	587.34
MW-7S	07/23/2021	587.33
MW-7S	08/11/2021	587.73
MW-8	06/17/2015	603.14
MW-8	12/14/2015	595.68
MW-8	12/15/2015	595.68
MW-8	02/29/2016	597.61
MW-8	05/16/2016	594.39
MW-8	08/22/2016	594.46
MW-8	11/15/2016	593.20
MW-8	02/13/2017	594.05
MW-8	05/18/2017	594.30
MW-8	05/19/2017	594.30
MW-8	07/18/2017	593.16
MW-8	11/06/2017	593.59
MW-8	11/07/2017	593.59
MW-8	06/01/2018	593.27
MW-8	08/28/2018	597.19
MW-8	11/08/2018	594.24
MW-8	02/14/2019	596.72
MW-8	05/14/2019	595.03
MW-8	08/20/2019	594.68
MW-8	11/14/2019	594.40
MW-8	02/11/2020	597.42
MW-8	05/12/2020	594.93
MW-8	08/26/2020	593.30
MW-8	12/02/2020	593.90
MW-8	02/23/2021	595.54
MW-8	03/15/2021	595.97
MW-8	03/30/2021	597.13
MW-8	04/05/2021	594.70
MW-8	05/21/2021	597.33
MW-8	06/10/2021	593.85
MW-8	07/01/2021	598.50
MW-8	07/22/2021	594.15
MW-8	08/10/2021	596.10
MW-8	09/01/2021	594.91

Sample Location	Sample Date	Groundwater Elevation (ft NAVD88)
MW-8S	02/23/2021	594.97
MW-8S	02/24/2021	594.97
MW-8S	03/15/2021	594.85
MW-8S	03/17/2021	594.85
MW-8S	04/05/2021	594.45
MW-8S	04/06/2021	594.45
MW-8S	05/21/2021	597.46
MW-8S	06/10/2021	593.90
MW-9	12/14/2015	587.69
MW-9	05/16/2016	594.59
MW-9	11/15/2016	585.95
MW-9	02/13/2017	590.05
MW-9	05/18/2017	594.59
MW-9	07/18/2017	587.95
MW-9	11/06/2017	583.15
MW-9	06/01/2018	590.00
MW-9	08/28/2018	589.59
MW-9	11/08/2018	587.86
MW-9	02/14/2019	596.55
MW-9	05/14/2019	595.34
MW-9	08/20/2019	590.03
MW-9	02/11/2020	596.77
MW-9	05/12/2020	595.14
MW-9	08/26/2020	590.19
MW-9	12/02/2020	584.93
MW-9	02/23/2021	590.65
MW-9	03/15/2021	593.28
MW-9	03/30/2021	596.07
MW-9	04/05/2021	595.16
MW-9	05/21/2021	595.70
MW-9	06/10/2021	590.55
MW-9	07/01/2021	590.54
MW-9	07/22/2021	588.84
MW-9	08/10/2021	590.23
MW-9	09/01/2021	587.63
MW-10	12/14/2015	588.99
MW-10	05/16/2016	589.51
MW-10	11/15/2016	587.00
MW-10	02/13/2017	587.96
MW-10	05/18/2017	589.65
MW-10	07/18/2017	586.29
MW-10	11/06/2017	586.27
MW-10	06/01/2018	587.14
MW-10	08/28/2018	588.90
MW-10	11/08/2018	585.03

Sample Location	Sample Date	Groundwater Elevation (ft NAVD88)
MW-10	02/14/2019	590.82
MW-10	05/14/2019	590.44
MW-10	08/20/2019	587.91
MW-10	02/11/2020	592.16
MW-10	05/12/2020	591.21
MW-10	08/26/2020	587.46
MW-10	12/02/2020	587.21
MW-10	02/23/2021	588.69
MW-10	03/15/2021	589.21
MW-10	03/30/2021	591.71
MW-10	04/05/2021	590.58
MW-10	05/21/2021	592.26
MW-10	06/10/2021	588.19
MW-10	07/01/2021	587.97
MW-10	07/22/2021	587.53
MW-10	08/10/2021	587.88
MW-10	09/01/2021	585.27
MW-11	12/14/2015	590.36
MW-11	02/29/2016	590.40
MW-11	05/16/2016	590.15
MW-11	08/22/2016	590.18
MW-11	11/15/2016	590.10
MW-11	02/13/2017	590.19
MW-11	05/18/2017	590.15
MW-11	07/18/2017	589.89
MW-11	11/06/2017	590.06
MW-11	05/31/2018	590.06
MW-11	08/28/2018	590.21
MW-11	11/08/2018	590.17
MW-11	02/14/2019	590.40
MW-11	05/14/2019	590.22
MW-11	08/20/2019	590.26
MW-11	11/13/2019	589.96
MW-11	02/11/2020	590.54
MW-11	05/12/2020	590.25
MW-11	08/26/2020	590.05
MW-11	12/02/2020	590.05
MW-11	02/23/2021	590.21
MW-11	03/15/2021	590.53
MW-11	03/30/2021	590.36
MW-11	04/05/2021	590.22
MW-11	05/18/2021	591.66
MW-11	06/09/2021	590.12
MW-11	07/01/2021	590.21
MW-11	07/22/2021	590.06

Sample Location	Sample Date	Groundwater Elevation (ft NAVD88)
MW-11	08/10/2021	590.32
MW-11	09/01/2021	590.21
MW-11S	05/19/2021	591.82
MW-12	12/14/2015	584.09
MW-12	02/29/2016	585.23
MW-12	05/16/2016	585.24
MW-12	08/22/2016	585.02
MW-12	11/15/2016	583.89
MW-12	02/13/2017	585.05
MW-12	05/18/2017	585.38
MW-12	07/18/2017	584.57
MW-12	11/06/2017	583.17
MW-12	05/31/2018	585.02
MW-12	08/28/2018	585.11
MW-12	11/08/2018	585.09
MW-12	02/14/2019	585.57
MW-12	05/14/2019	585.45
MW-12	08/20/2019	584.80
MW-12	11/13/2019	585.12
MW-12	02/11/2020	585.85
MW-12	05/12/2020	585.05
MW-12	08/26/2020	584.65
MW-12	12/02/2020	583.81
MW-12	02/23/2021	584.12
MW-12	03/15/2021	584.70
MW-12	03/30/2021	585.65
MW-12	04/05/2021	585.10
MW-12	05/20/2021	586.59
MW-12	06/10/2021	585.02
MW-12	07/01/2021	585.41
MW-12	07/22/2021	584.98
MW-12	08/10/2021	585.05
MW-12	09/01/2021	585.02
MW-12S	02/23/2021	584.81
MW-12S	02/25/2021	584.81
MW-12S	03/15/2021	585.43
MW-12S	03/16/2021	585.43
MW-12S	04/05/2021	585.53
MW-12S	04/06/2021	585.53
MW-12S	05/20/2021	587.19
MW-12S	06/10/2021	585.27
MW-12S	07/02/2021	585.60
MW-12S	07/23/2021	585.12
MW-12S	08/11/2021	585.31
MW-12D	02/23/2021	584.55

Sample Location	Sample Date	Groundwater Elevation (ft NAVD88)
MW-12D	02/25/2021	584.55
MW-12D	03/15/2021	585.36
MW-12D	03/16/2021	585.36
MW-12D	04/05/2021	586.23
MW-12D	04/06/2021	586.23
MW-12D	05/20/2021	587.18
MW-12D	06/10/2021	586.55
MW-12D	07/02/2021	586.71
MW-12D	07/23/2021	586.58
MW-12D	08/11/2021	586.71
MW-20	02/23/2021	594.82
MW-20	02/26/2021	594.82
MW-20	03/15/2021	595.12
MW-20	03/16/2021	595.12
MW-20	04/05/2021	595.05
MW-20	04/06/2021	595.05
MW-20	05/18/2021	598.93
MW-20	06/09/2021	594.68
MW-20	07/01/2021	595.07
MW-20	07/22/2021	594.18
MW-20	08/10/2021	594.91
MW-20S	02/23/2021	594.83
MW-20S	02/26/2021	594.83
MW-20S	03/15/2021	595.19
MW-20S	03/16/2021	595.19
MW-20S	04/05/2021	595.05
MW-20S	04/06/2021	595.05
MW-20S	05/19/2021	599.06
MW-20S	06/09/2021	594.64
MW-20S	07/01/2021	595.04
MW-20S	07/22/2021	594.17
MW-20S	08/10/2021	594.95
MW-22	02/23/2021	596.14
MW-22	02/26/2021	596.14
MW-22	03/15/2021	596.20
MW-22	03/17/2021	596.20
MW-22	04/05/2021	595.33
MW-22	04/07/2021	595.33
MW-22	05/18/2021	597.51
MW-22	06/09/2021	594.94
MW-22	07/01/2021	595.65
MW-22	07/22/2021	594.93
MW-22	08/10/2021	595.48
MW-23	02/23/2021	594.21
MW-23	02/26/2021	594.21

Sample Location	Sample Date	Groundwater Elevation (ft NAVD88)
MW-23	03/15/2021	594.14
MW-23	03/18/2021	594.14
MW-23	04/05/2021	594.03
MW-23	04/06/2021	594.03
MW-23	05/19/2021	595.87
MW-23	06/09/2021	593.63
MW-23	07/01/2021	593.82
MW-23	07/22/2021	593.54
MW-23	08/10/2021	593.93
MW-24	02/23/2021	592.21
MW-24	03/01/2021	592.21
MW-24	03/15/2021	593.41
MW-24	03/18/2021	593.41
MW-24	04/05/2021	593.93
MW-24	04/07/2021	593.93
MW-24	05/19/2021	594.36
MW-24	06/09/2021	593.65
MW-24	07/01/2021	590.51
MW-24	07/22/2021	593.47
MW-25	02/23/2021	601.41
MW-25	02/25/2021	601.41
MW-25	03/15/2021	601.60
MW-25	03/17/2021	601.60
MW-25	04/05/2021	601.24
MW-25	04/07/2021	601.24
MW-25	05/21/2021	602.14
MW-25	06/09/2021	583.98
MW-25	07/01/2021	601.23
MW-25	07/22/2021	600.36
MW-25	08/11/2021	601.24
MW-26	02/23/2021	588.87
MW-26	02/25/2021	588.87
MW-26	03/15/2021	589.61
MW-26	03/17/2021	589.61
MW-26	04/05/2021	591.21
MW-26	04/06/2021	591.21
MW-26	05/21/2021	592.50
MW-26	06/09/2021	589.04
MW-26	07/01/2021	586.18
MW-26	07/22/2021	585.02
MW-26	08/10/2021	586.14
MW-27	02/23/2021	586.05
MW-27	02/24/2021	586.05
MW-27	03/15/2021	587.14
MW-27	03/16/2021	587.14

Sample Location	Sample Date	Groundwater Elevation (ft NAVD88)
MW-27	04/05/2021	591.44
MW-27	04/06/2021	591.44
MW-27	05/21/2021	594.44
MW-27	06/10/2021	583.38
MW-27	07/02/2021	585.55
MW-27	07/23/2021	584.70
MW-27	08/11/2021	585.72
MW-28	02/23/2021	595.40
MW-28	02/24/2021	595.40
MW-28	03/15/2021	595.92
MW-28	03/16/2021	595.92
MW-28	04/05/2021	595.85
MW-28	04/07/2021	595.85
MW-28	05/18/2021	597.59
MW-28	06/10/2021	594.85
MW-28	07/02/2021	594.20
MW-28	07/23/2021	593.48
MW-28	08/11/2021	595.14
MW-29	02/23/2021	595.74
MW-29	02/25/2021	595.74
MW-29	03/15/2021	596.20
MW-29	03/16/2021	596.20
MW-29	04/05/2021	596.58
MW-29	04/06/2021	596.58
MW-29	05/21/2021	597.06
MW-29	06/10/2021	595.41
MW-29	07/02/2021	595.14
MW-29	07/23/2021	594.94
MW-29	08/11/2021	595.36
MW-30	02/23/2021	593.97
MW-30	02/25/2021	593.97
MW-30	03/15/2021	594.53
MW-30	03/17/2021	594.53
MW-30	04/05/2021	594.90
MW-30	04/07/2021	594.90
MW-30	05/20/2021	595.69
MW-30	06/09/2021	593.99
MW-30	07/01/2021	593.96
MW-30	07/22/2021	593.72
MW-30	08/10/2021	593.37
MW-31	02/23/2021	587.68
MW-31	02/24/2021	587.68
MW-31	03/15/2021	587.96
MW-31	03/17/2021	587.96
MW-31	04/05/2021	587.86

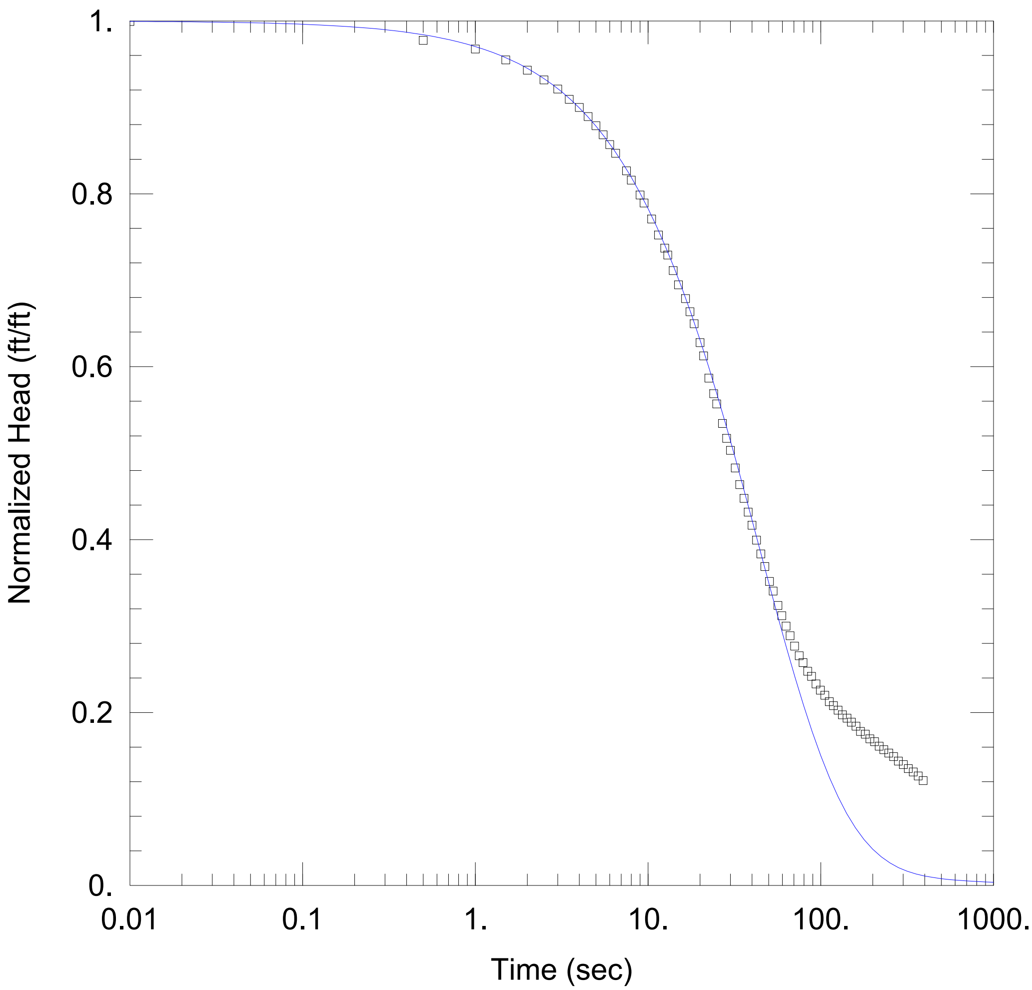
Sample Location	Sample Date	Groundwater Elevation (ft NAVD88)
MW-31	04/07/2021	587.86
MW-31	05/20/2021	588.63
MW-31	06/09/2021	586.66
MW-31	07/01/2021	594.19
MW-31	07/22/2021	586.69
MW-31	08/10/2021	587.49
MW-31S	02/23/2021	591.18
MW-31S	02/24/2021	591.18
MW-31S	03/15/2021	591.83
MW-31S	03/17/2021	591.83
MW-31S	04/05/2021	590.92
MW-31S	04/06/2021	590.92
MW-31S	05/20/2021	592.83
MW-31S	06/10/2021	588.77
MW-31S	07/01/2021	588.55
MW-31S	07/23/2021	588.55
MW-31S	08/10/2021	588.30
MW-32	02/23/2021	596.90
MW-32	02/25/2021	596.90
MW-32	03/15/2021	596.92
MW-32	03/17/2021	596.92
MW-32	04/05/2021	596.93
MW-32	04/07/2021	596.93
MW-32	05/19/2021	598.69
MW-32	06/09/2021	596.24
MW-32	07/01/2021	596.38
MW-32	07/22/2021	596.09
MW-32	08/10/2021	596.34
PZ-4C	02/23/2021	593.95
PZ-4C	02/25/2021	593.95
PZ-4C	03/15/2021	594.09
PZ-4C	03/16/2021	594.09
PZ-4C	04/05/2021	593.92
PZ-4C	05/20/2021	595.67
PZ-4C	06/10/2021	593.78
PZ-4C	07/02/2021	593.87
PZ-4C	07/23/2021	593.42
PZ-4C	08/11/2021	593.75
XPW01	02/23/2021	603.48
XPW01	03/01/2021	603.48
XPW01	03/15/2021	603.48
XPW01	03/18/2021	603.48
XPW01	04/05/2021	603.40
XPW01	04/07/2021	603.40
XPW01	05/21/2021	603.18

Sample Location	Sample Date	Groundwater Elevation (ft NAVD88)
XPW01	06/10/2021	603.19
XPW01	07/02/2021	603.28
XPW01	07/22/2021	603.14
XPW01	08/11/2021	603.39
XPW02	02/23/2021	603.78
XPW02	03/01/2021	603.78
XPW02	03/15/2021	603.71
XPW02	03/18/2021	603.71
XPW02	04/05/2021	603.91
XPW02	04/07/2021	603.91
XPW02	05/21/2021	603.91
XPW02	06/10/2021	603.79
XPW02	07/02/2021	603.59
XPW02	07/22/2021	603.50
XPW02	08/11/2021	603.61
XPW03	02/23/2021	600.95
XPW03	03/02/2021	600.95
XPW03	03/15/2021	600.93
XPW03	03/18/2021	600.93
XPW03	04/05/2021	601.23
XPW03	04/07/2021	601.23
XPW03	05/20/2021	601.02
XPW03	06/10/2021	601.63
XPW03	07/01/2021	600.76
XPW03	07/22/2021	600.86
XPW03	08/11/2021	600.85
XPW04	02/23/2021	603.42
XPW04	03/02/2021	603.42
XPW04	03/15/2021	603.42
XPW04	03/18/2021	603.42
XPW04	04/05/2021	603.21
XPW04	04/07/2021	603.21
XPW04	05/20/2021	603.24
XPW04	06/09/2021	602.79
XPW04	07/01/2021	602.88
XPW04	07/22/2021	602.92
XPW04	08/10/2021	603.10
XSG-01	05/21/2021	607.26
XSG-01	06/09/2021	606.93
XSG-01	07/01/2021	607.26
XSG-01	07/22/2021	607.38
SG-02	05/21/2021	585.62
SG-02	06/09/2021	585.20

Notes:
ft NAVD88 = feet relative to the North American Vertical Datum 1988, GEOID 12A

generated 09/30/2021, 12:28:01 AM CD

APPENDIX F
HYDRAULIC CONDUCTIVITY TEST DATA



12D FH-1

PROJECT INFORMATION

Company: Ramboll
Client: Kincaid Generation, LLC
Location: Kincaid Power Plant
Test Date: 04/09/2021

AQUIFER DATA

Saturated Thickness: 9.3 ft

WELL DATA (12D)

Initial Displacement: 1.51 ft
Total Well Penetration Depth: 7.7 ft
Casing Radius: 0.086 ft

Static Water Column Height: 52.3 ft
Screen Length: 5. ft
Well Radius: 0.25 ft

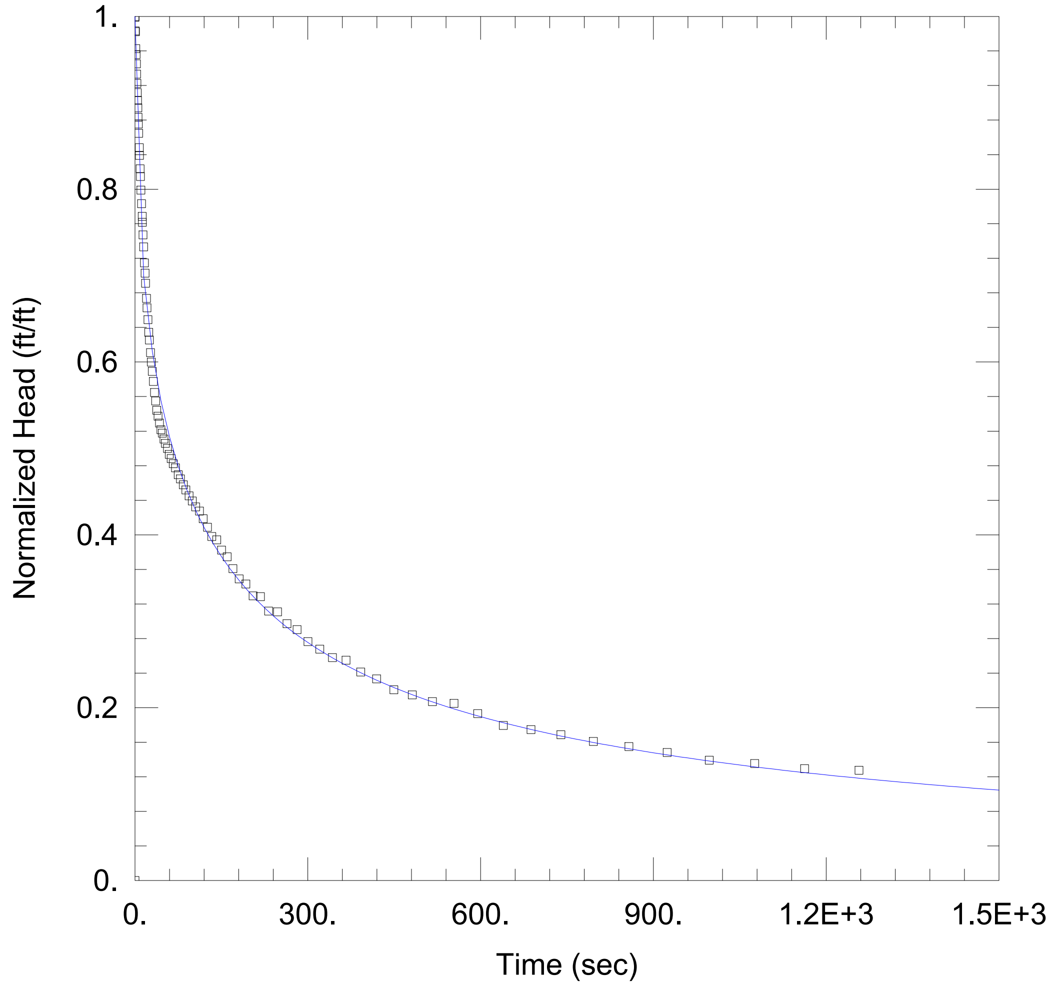
SOLUTION

Aquifer Model: Confined

Kr = 0.00169 cm/sec
Kz/Kr = 1.

Solution Method: KGS Model

Ss = 4.39E-7 ft^{-1}



12S FH-1

PROJECT INFORMATION

Company: Ramboll
Client: Kincaid Generation, LLC
Location: Kincaid Power Plant
Test Date: 04/09/2021

AQUIFER DATA

Saturated Thickness: 36.9 ft

WELL DATA (12S)

Initial Displacement: 1.02 ft
Total Well Penetration Depth: 5.97 ft
Casing Radius: 0.086 ft

Static Water Column Height: 5.969 ft
Screen Length: 5. ft
Well Radius: 0.25 ft

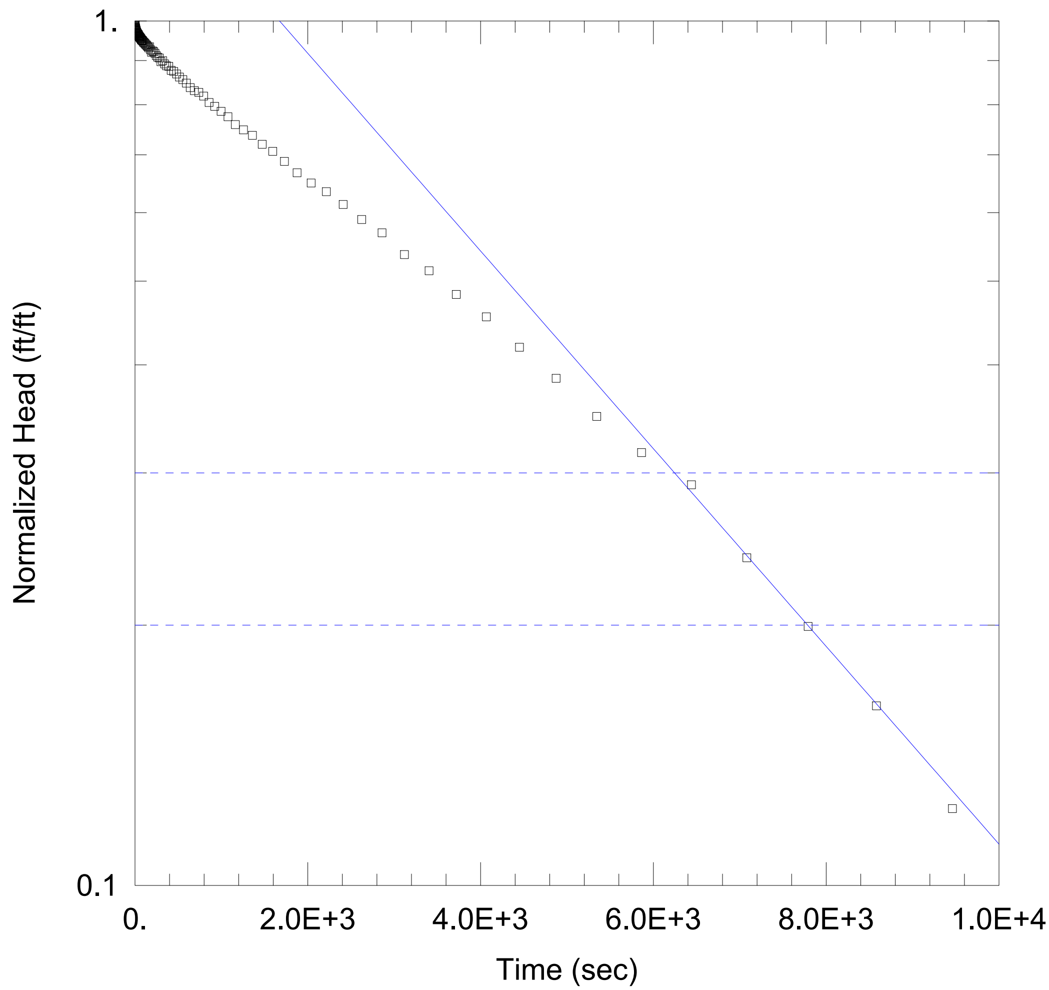
SOLUTION

Aquifer Model: Unconfined

Kr = 3.3E-5 cm/sec
Kz/Kr = 1.

Solution Method: KGS Model

Ss = 0.0472 ft^{-1}



20 FH-1

PROJECT INFORMATION

Company: Ramboll
Client: Kincaid Generation, LLC
Location: Kincaid Power Plant
Test Date: 04/09/2021

AQUIFER DATA

Saturated Thickness: 22.8 ft
Anisotropy Ratio (Kz/Kr): 1.

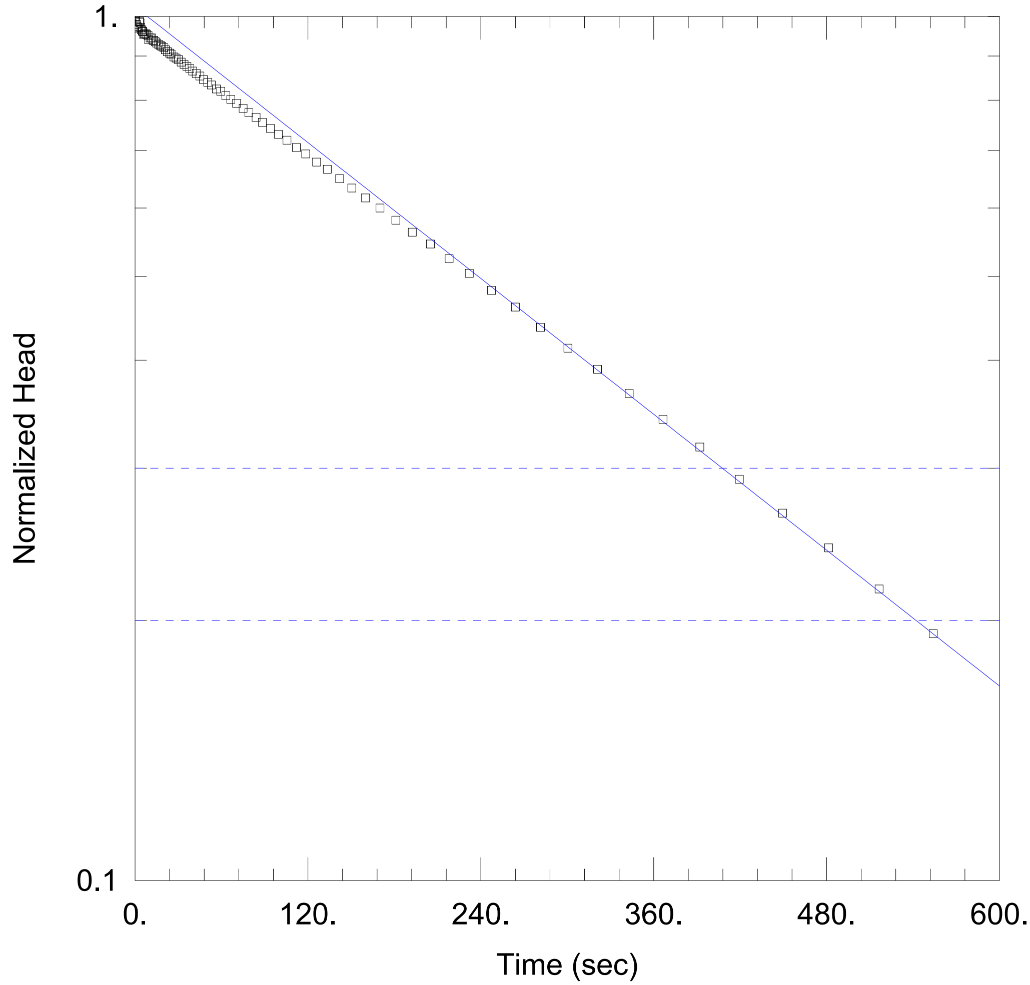
WELL DATA (20)

Initial Displacement: 1.5 ft
Total Well Penetration Depth: 9. ft
Casing Radius: 0.086 ft
Static Water Column Height: 6.44 ft
Screen Length: 9. ft
Well Radius: 0.25 ft

SOLUTION

Aquifer Model: Confined
Solution Method: Bouwer-Rice

K = 6.77E-6 cm/sec
y0 = 2.33 ft



20S FH-1	

PROJECT INFORMATION

Company: Ramboll
Client: Kincaid Generation, LLC
Location: Kincaid Power Plant
Test Date: 04/09/2021

AQUIFER DATA

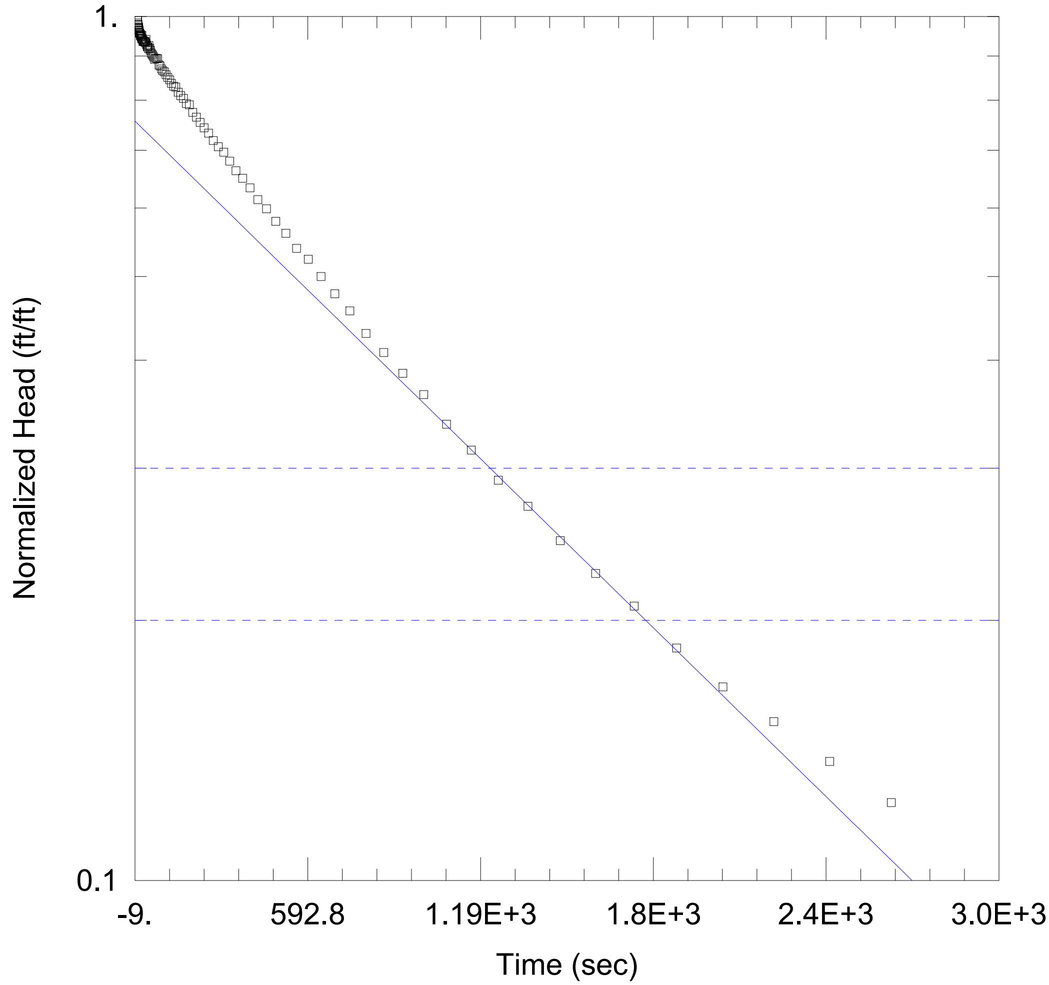
Saturated Thickness: 6.75 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (20S)

Initial Displacement: 1.15 ft
Total Well Penetration Depth: 6.75 ft
Casing Radius: 0.086 ft
Static Water Column Height: 6.75 ft
Screen Length: 6. ft
Well Radius: 0.25 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.000122 cm/sec
y0 = 1.18 ft



22 RH-1

PROJECT INFORMATION

Company: Ramboll
Client: Kincaid Generation, LLC
Location: Kincaid Power Plant
Test Date: 03/18/2021

AQUIFER DATA

Saturated Thickness: 50.3 ft
Anisotropy Ratio (Kz/Kr): 1.

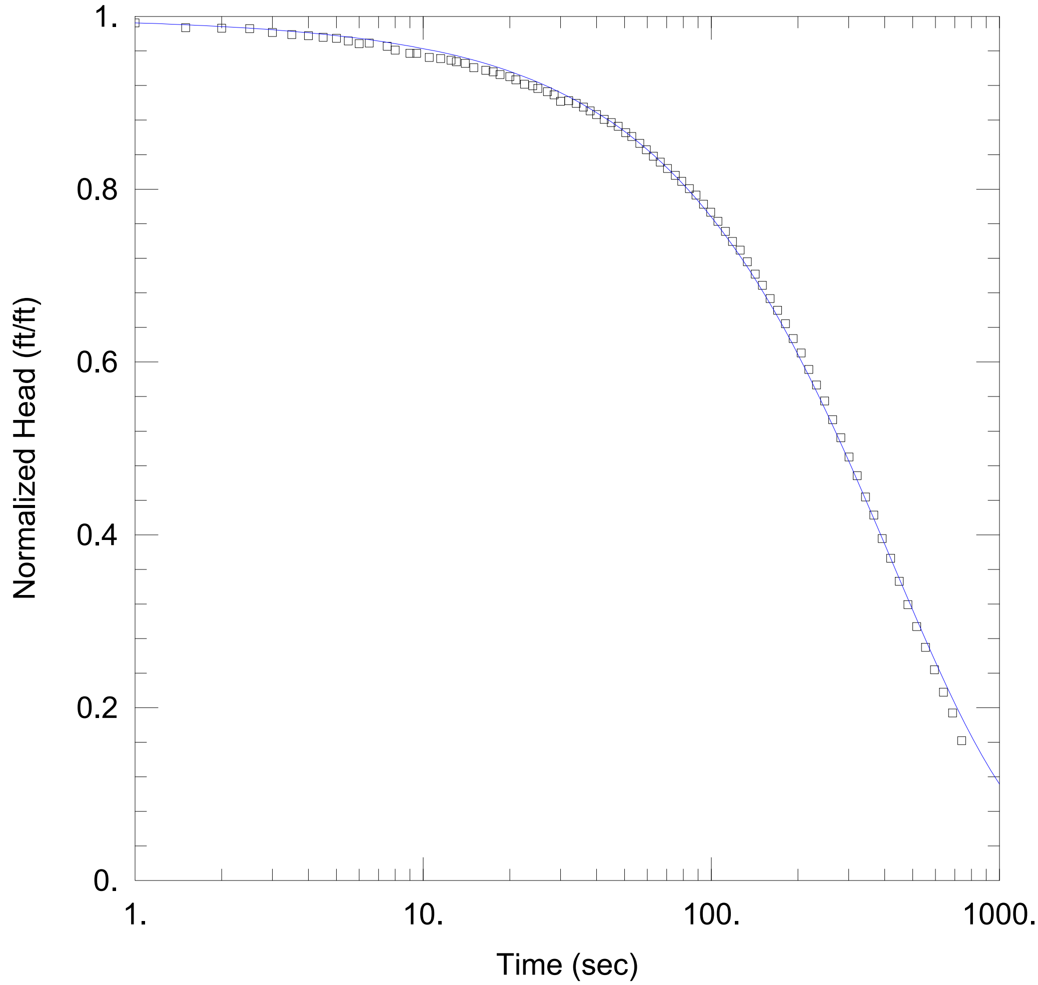
WELL DATA (22)

Initial Displacement: 1.69 ft
Total Well Penetration Depth: 2.3 ft
Casing Radius: 0.086 ft
Static Water Column Height: 16.8 ft
Screen Length: 2.3 ft
Well Radius: 0.25 ft

SOLUTION

Aquifer Model: Confined
Solution Method: Bouwer-Rice

K = 3.8E-5 cm/sec
y0 = 1.27 ft



23 FH-1

PROJECT INFORMATION

Company: Ramboll
Client: Kincaid Generation, LLC
Location: Kincaid Power Plant
Test Date: 04/08/2021

AQUIFER DATA

Saturated Thickness: 48.3 ft

WELL DATA (23)

Initial Displacement: 1.62 ft
Total Well Penetration Depth: 0.7 ft
Casing Radius: 0.08625 ft

Static Water Column Height: 14.2 ft
Screen Length: 0.7 ft
Well Radius: 0.25 ft

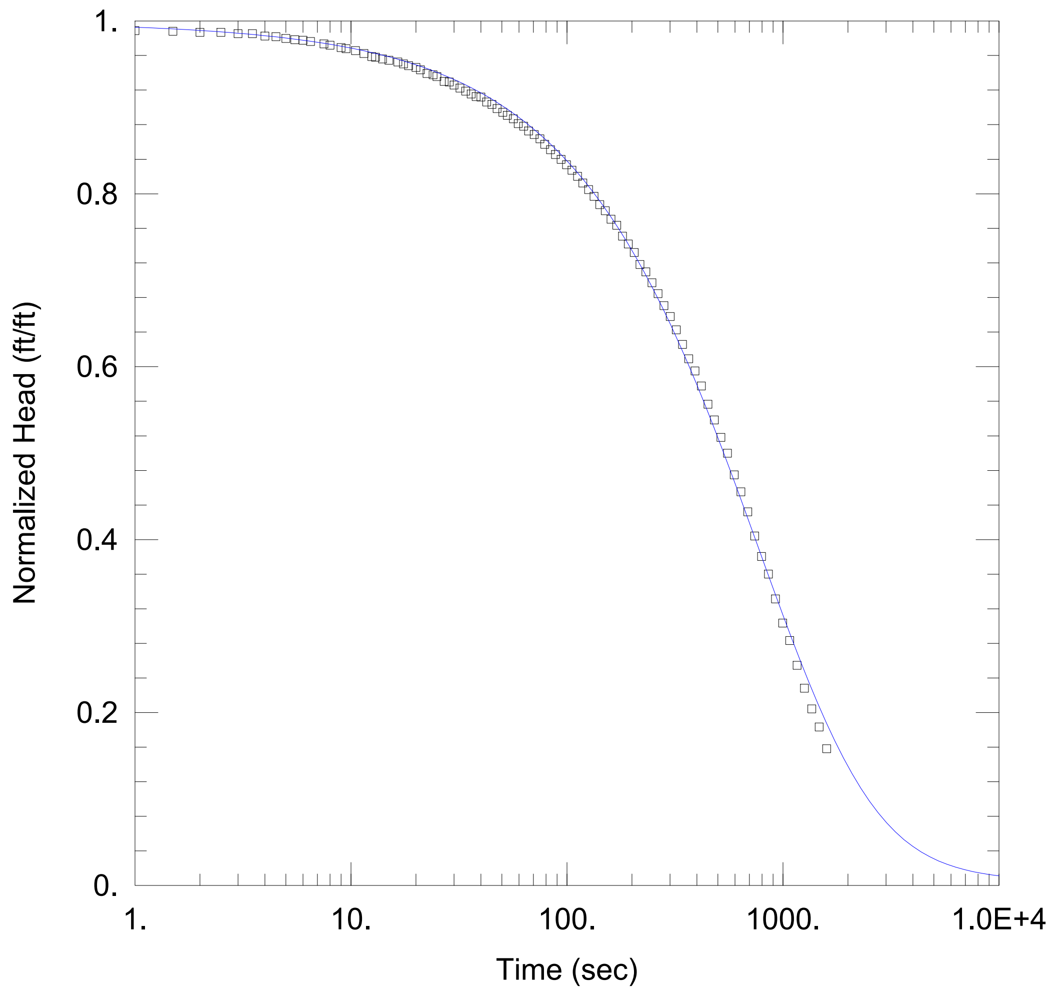
SOLUTION

Aquifer Model: Confined

Kr = 0.000535 cm/sec
Kz/Kr = 1.

Solution Method: KGS Model

Ss = 0.000399 ft^{-1}



25 FH-1

PROJECT INFORMATION

Company: Ramboll
Client: Kincaid Generation, LLC
Location: Kincaid Power Plant
Test Date: 04/08/2021

AQUIFER DATA

Saturated Thickness: 5.4 ft

WELL DATA (25)

Initial Displacement: 1.43 ft
Total Well Penetration Depth: 5.4 ft
Casing Radius: 0.086 ft

Static Water Column Height: 11. ft
Screen Length: 3. ft
Well Radius: 0.25 ft

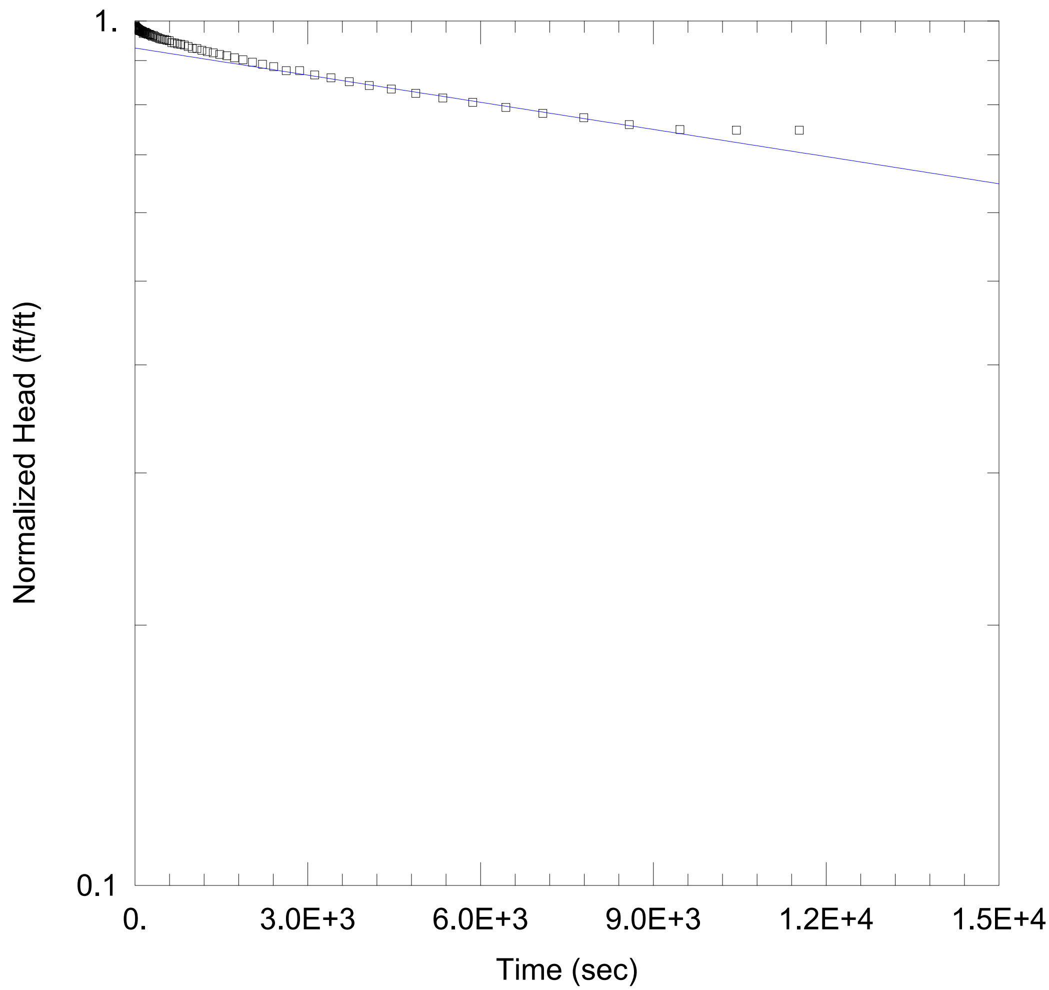
SOLUTION

Aquifer Model: Confined

Kr = 0.000103 cm/sec
Kz/Kr = 1.

Solution Method: KGS Model

Ss = 0.000145 ft^{-1}



26 FH-1

PROJECT INFORMATION

Company: Ramboll
Client: Kincaid Generation, LLC
Location: Kincaid Power Plant
Test Date: 03/19/2021

AQUIFER DATA

Saturated Thickness: 50.9 ft
Anisotropy Ratio (Kz/Kr): 1.

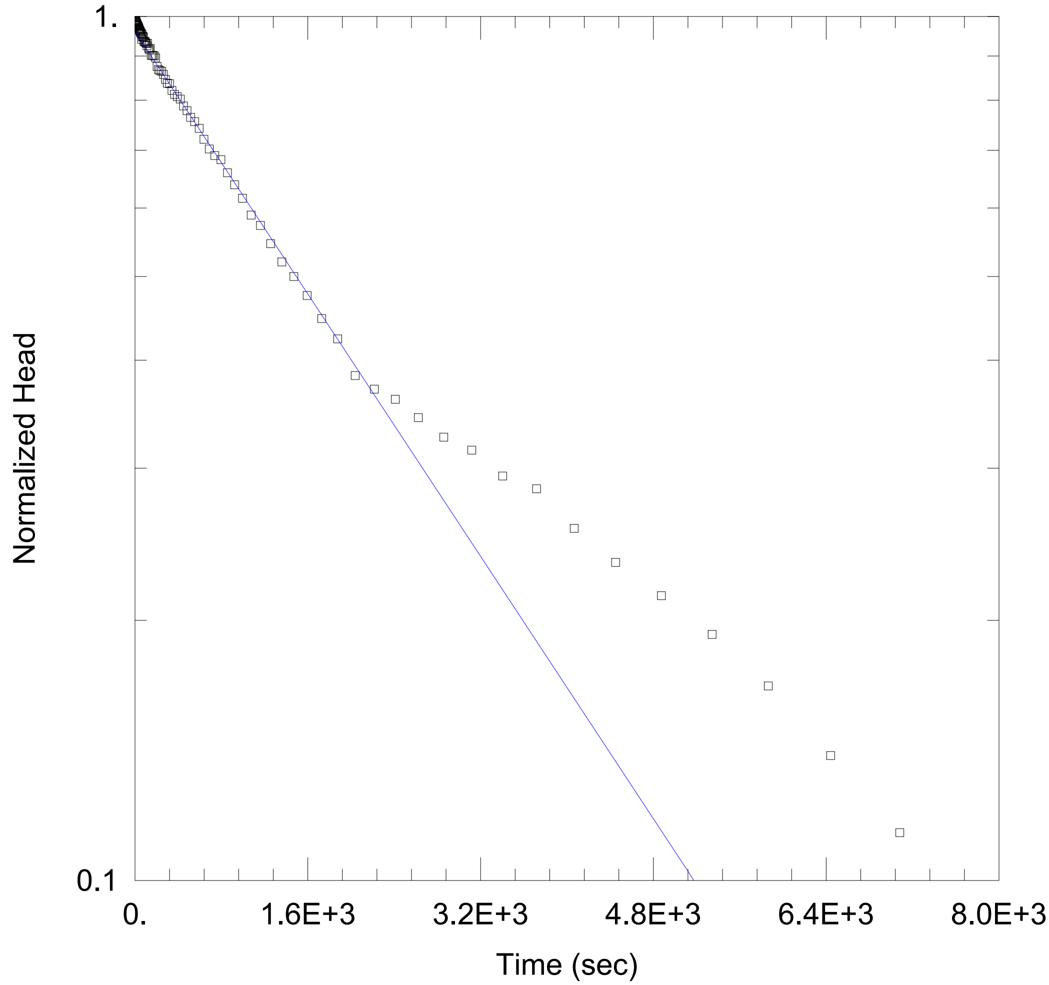
WELL DATA (26)

Initial Displacement: 1.58 ft
Total Well Penetration Depth: 2. ft
Casing Radius: 0.086 ft
Static Water Column Height: 10.5 ft
Screen Length: 2. ft
Well Radius: 0.25 ft

SOLUTION

Aquifer Model: Confined
Solution Method: Bouwer-Rice

K = 1.29E-6 cm/sec
y0 = 1.47 ft



27 FH-1

PROJECT INFORMATION

Company: Ramboll
Client: Kincaid Generation, LLC
Location: Kincaid Power Plant
Test Date: 04/28/2021

AQUIFER DATA

Saturated Thickness: 55.3 ft
Anisotropy Ratio (Kz/Kr): 1.

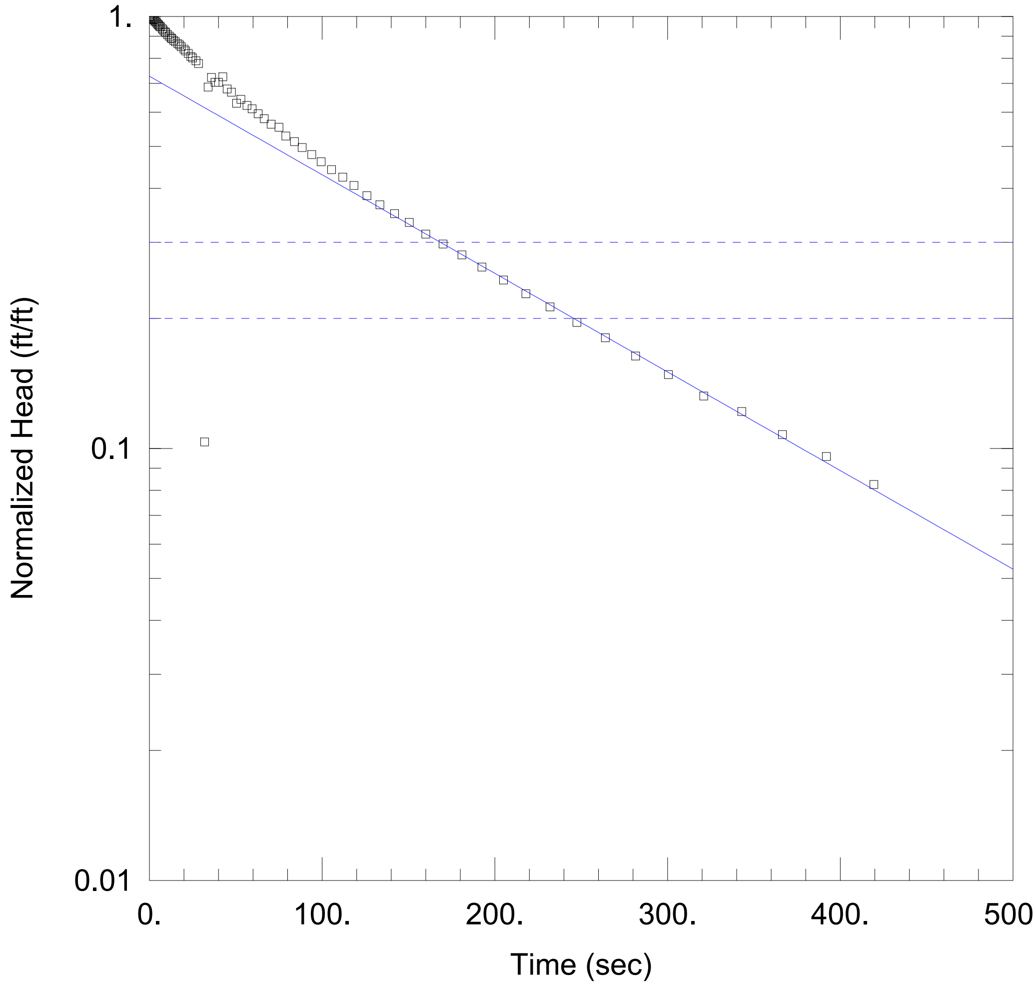
WELL DATA (27)

Initial Displacement: 0.81 ft
Total Well Penetration Depth: 5.4 ft
Casing Radius: 0.086 ft
Static Water Column Height: 7.37 ft
Screen Length: 5. ft
Well Radius: 0.25 ft

SOLUTION

Aquifer Model: Confined
Solution Method: Bouwer-Rice

K = 1.56E-5 cm/sec
y0 = 0.778 ft



28 FH-1

PROJECT INFORMATION

Company: Ramboll
Client: Kincaid Generation, LLC
Location: Kincaid Power Plant
Test Date: 04/08/2021

AQUIFER DATA

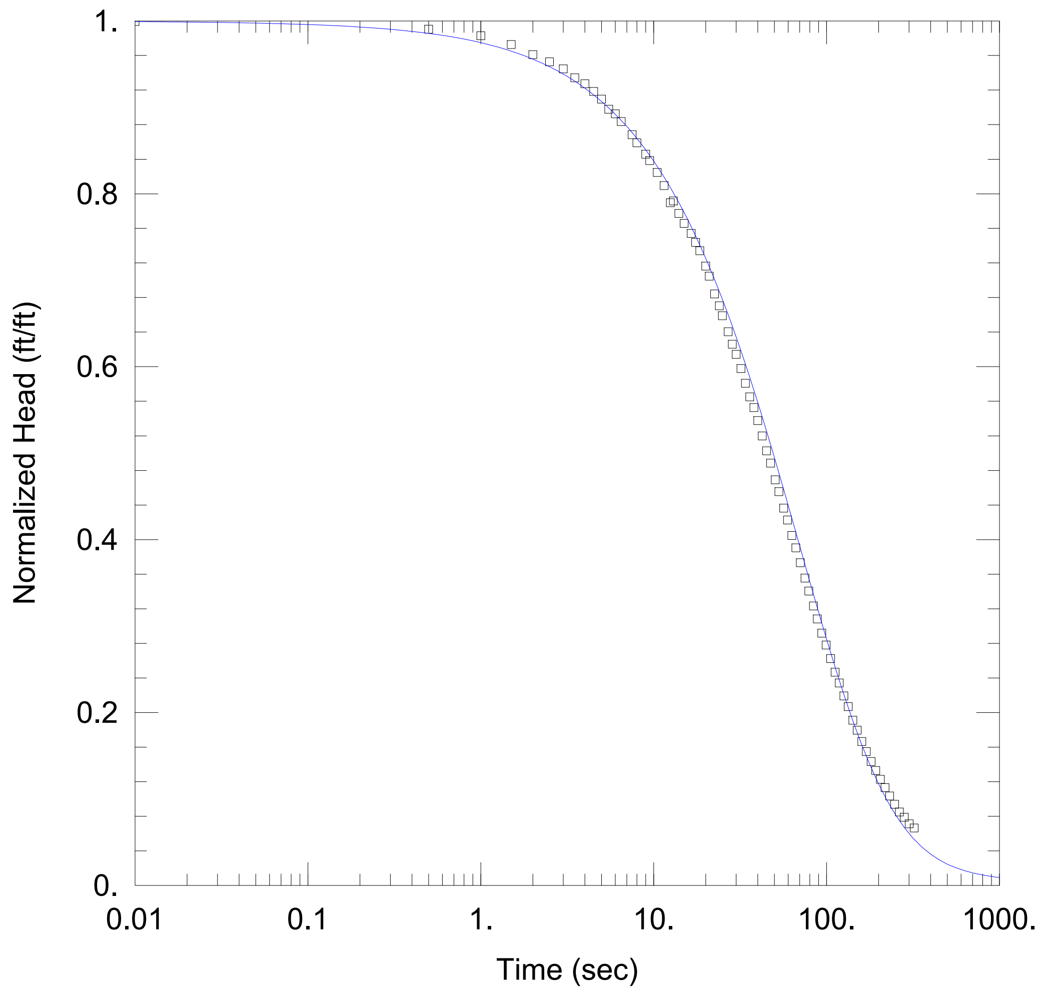
Saturated Thickness: 60.6 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (28)

Initial Displacement: 1.43 ft
Total Well Penetration Depth: 16.8 ft
Casing Radius: 0.086 ft
Static Water Column Height: 19.8 ft
Screen Length: 10. ft
Well Radius: 0.25 ft

SOLUTION

Aquifer Model: Confined
Solution Method: Bouwer-Rice
K = 0.000134 cm/sec
y0 = 1.04 ft



29 FH-1

PROJECT INFORMATION

Company: Ramboll
Client: Kincaid Generation, LLC
Location: Kincaid Power Plant
Test Date: 04/08/2021

AQUIFER DATA

Saturated Thickness: 56. ft
Anisotropy Ratio (Kz/Kr): 1.

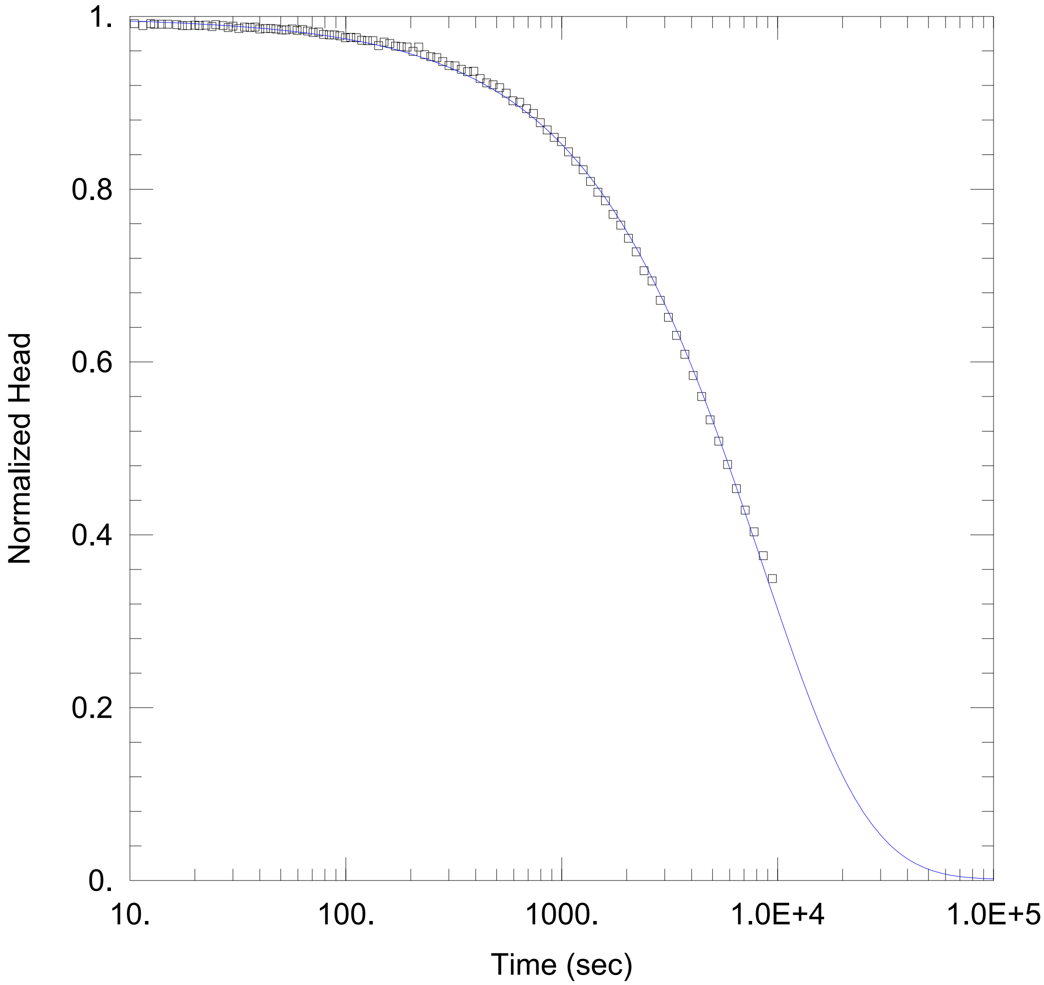
WELL DATA (29)

Initial Displacement: 1.46 ft
Total Well Penetration Depth: 10.6 ft
Casing Radius: 0.086 ft
Static Water Column Height: 18.97 ft
Screen Length: 5. ft
Well Radius: 0.25 ft

SOLUTION

Aquifer Model: Confined
Solution Method: Cooper-Bredehoeft-Papadopulos

T = 0.201 cm^2/sec
S = 1.88E-5



30 FH-1

PROJECT INFORMATION

Company: Ramboll
Client: Kincaid Generation, LLC
Location: Kincaid Power Plant
Test Date: 04/27/2021

AQUIFER DATA

Saturated Thickness: 48.5 ft

WELL DATA (30)

Initial Displacement: 1.78 ft
Total Well Penetration Depth: 5. ft
Casing Radius: 0.086 ft

Static Water Column Height: 18.3 ft
Screen Length: 5. ft
Well Radius: 0.25 ft

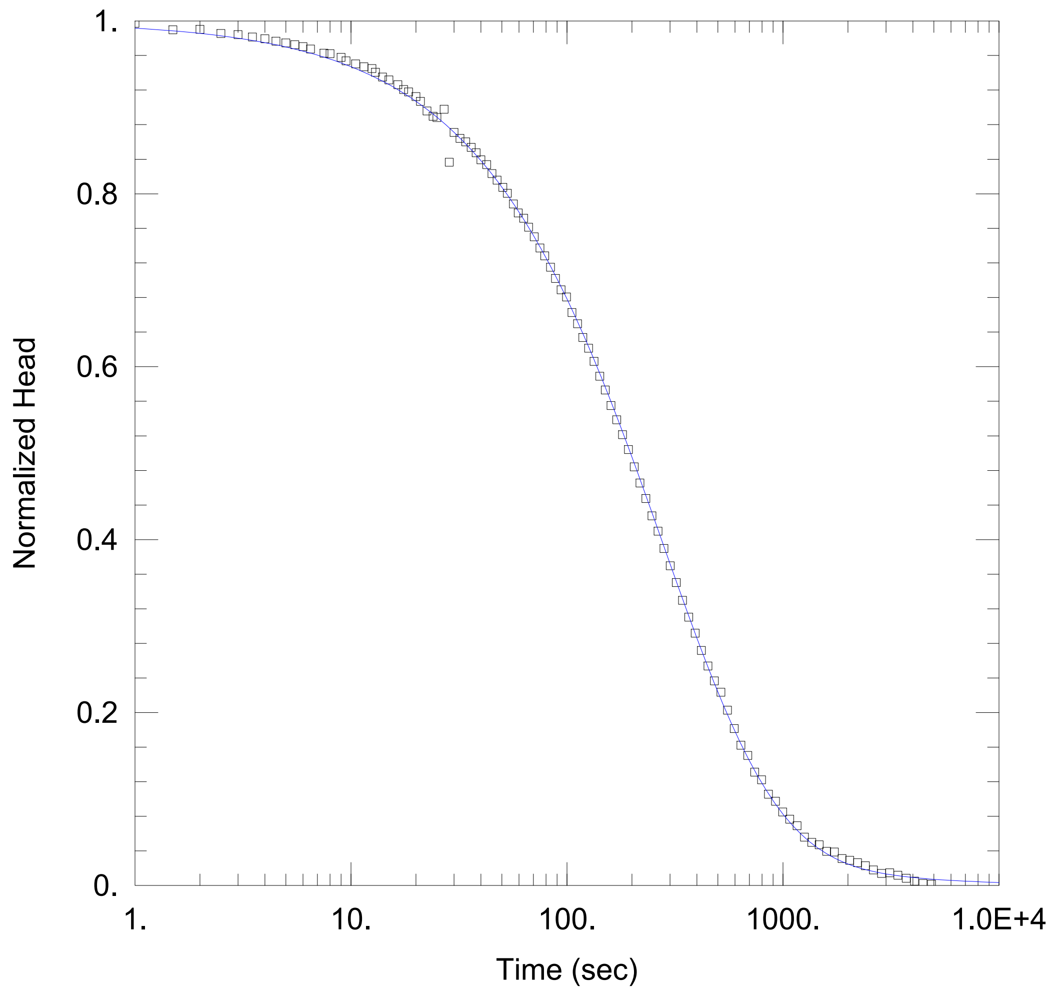
SOLUTION

Aquifer Model: Confined

Kr = 7.07E-6 cm/sec
Kz/Kr = 1.

Solution Method: KGS Model

Ss = 3.3E-5 ft^{-1}



31 FH-1

PROJECT INFORMATION

Company: Ramboll
Client: Kincaid Generation, LLC
Location: Kincaid Power Plant
Test Date: 04/27/2021

AQUIFER DATA

Saturated Thickness: 49.7 ft
Anisotropy Ratio (Kz/Kr): 1.

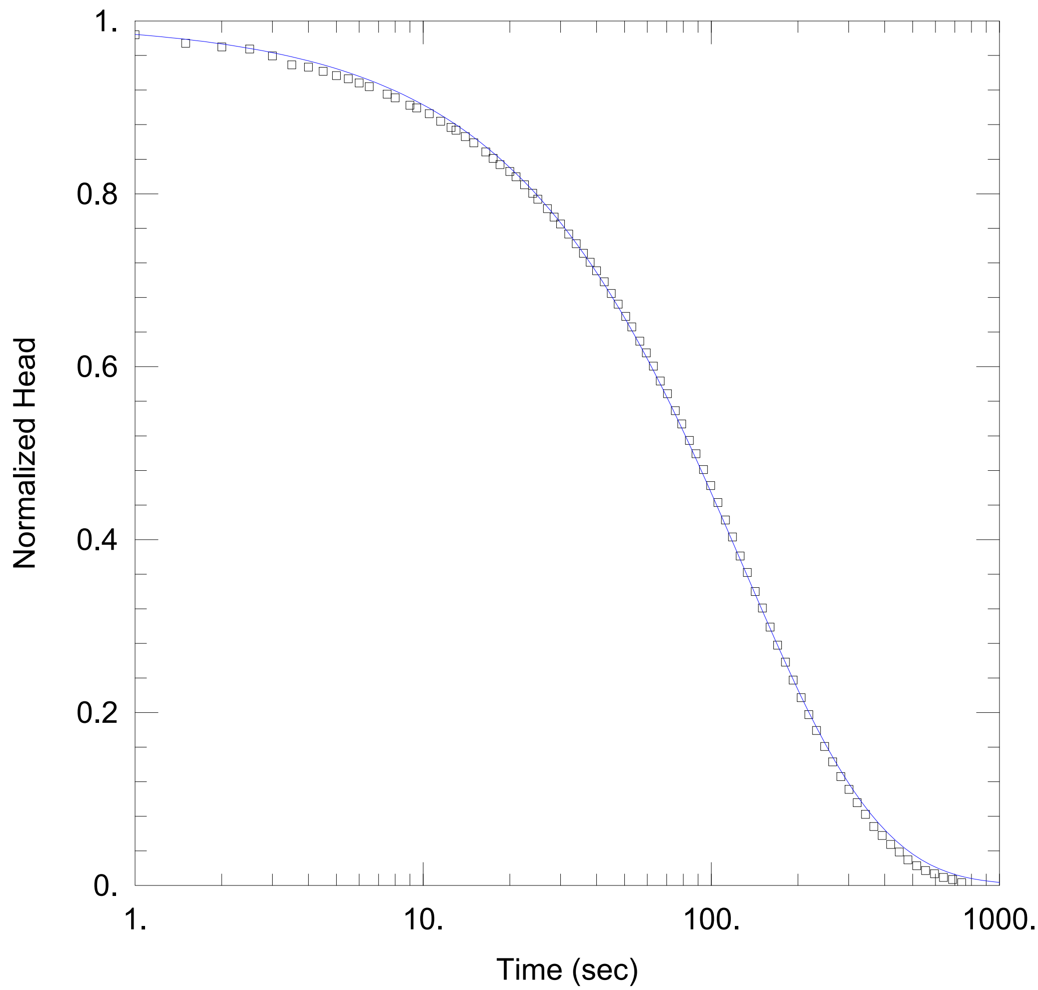
WELL DATA (31)

Initial Displacement: 1.45 ft
Total Well Penetration Depth: 5. ft
Casing Radius: 0.086 ft
Static Water Column Height: 12.6 ft
Screen Length: 5. ft
Well Radius: 0.25 ft

SOLUTION

Aquifer Model: Confined
Solution Method: Cooper-Bredehoeft-Papadopulos

T = 0.05 cm^2/sec
S = 1.91E-5



32 RH-1

PROJECT INFORMATION

Company: Ramboll
Client: Kincaid Generation, LLC
Location: Kincaid Power Plant
Test Date: 04/28/2021

AQUIFER DATA

Saturated Thickness: 53.1 ft

WELL DATA (32)

Initial Displacement: 1.63 ft
Total Well Penetration Depth: 5.4 ft
Casing Radius: 0.086 ft

Static Water Column Height: 16.27 ft
Screen Length: 5. ft
Well Radius: 0.25 ft

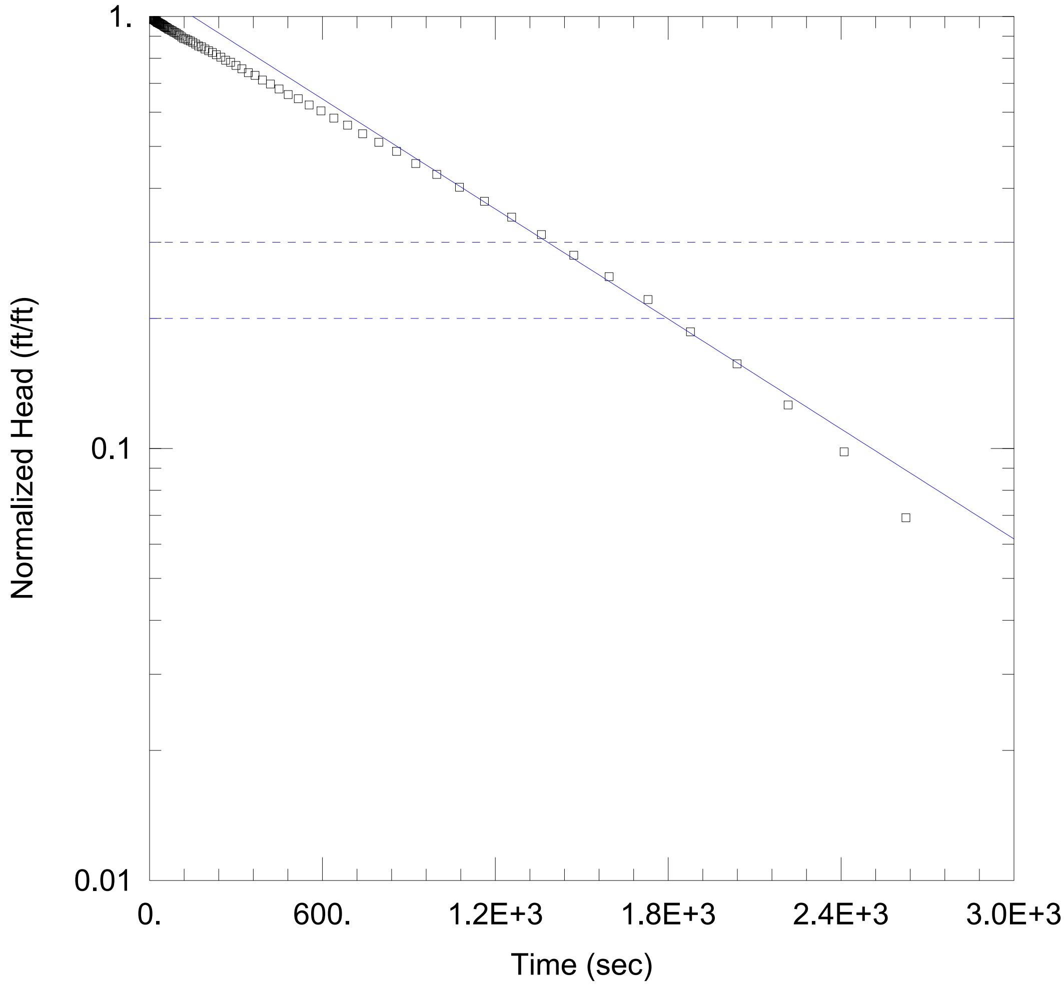
SOLUTION

Aquifer Model: Confined

Kr = 0.000461 cm/sec
Kz/Kr = 1.

Solution Method: KGS Model

Ss = 1.31E-5 ft^{-1}



PZ-4C FH-1

PROJECT INFORMATION

Company: Ramboll
Client: Kincaid Generation, LLC
Location: Kincaid Power Plant
Test Date: 04/08/2021

AQUIFER DATA

Saturated Thickness: 3. ft
Anisotropy Ratio (Kz/Kr): 1.

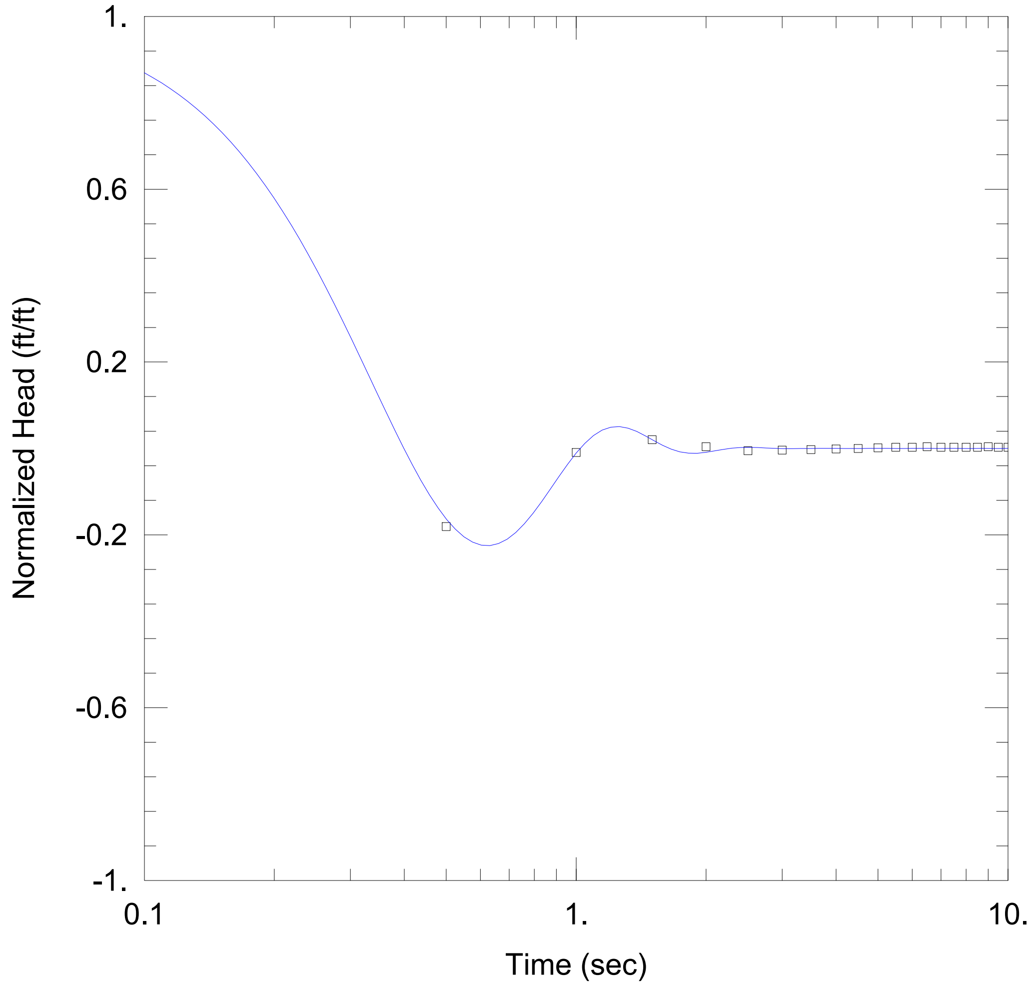
WELL DATA (PZ-4C)

Initial Displacement: 1.65 ft
Total Well Penetration Depth: 3. ft
Casing Radius: 0.086 ft
Static Water Column Height: 16.72 ft
Screen Length: 3. ft
Well Radius: 0.35 ft

SOLUTION

Aquifer Model: Confined
Solution Method: Bouwer-Rice

K = 4.95E-5 cm/sec
y0 = 1.91 ft



XPW-01 FH-1

PROJECT INFORMATION

Company: Ramboll
Client: Kincaid Generation, LLC
Location: Kincaid Power Plant
Test Date: 04/08/2021

AQUIFER DATA

Saturated Thickness: 8. ft
Anisotropy Ratio (Kz/Kr): 0.2158

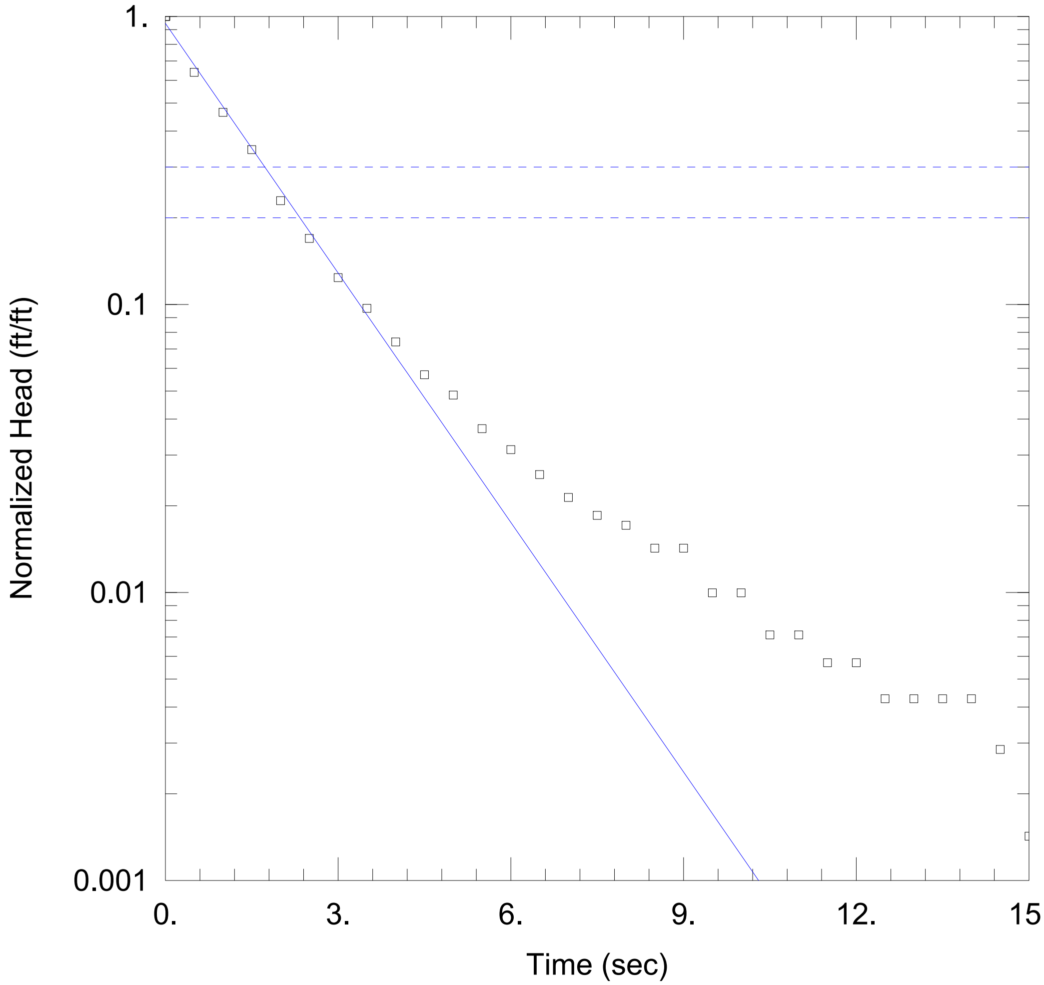
WELL DATA (XPW-01)

Initial Displacement: 0.74 ft
Total Well Penetration Depth: 7.97 ft
Casing Radius: 0.086 ft
Static Water Column Height: 2.71 ft
Screen Length: 7.97 ft
Well Radius: 0.25 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Springer-Gelhar

K = 0.264 cm/sec
Le = 1.03 ft



XPW-02 RH-1

PROJECT INFORMATION

Company: Ramboll
Client: Kincaid Generation, LLC
Location: Kincaid Power Plant
Test Date: 03/19/2021

AQUIFER DATA

Saturated Thickness: 8.4 ft
Anisotropy Ratio (Kz/Kr): 1.

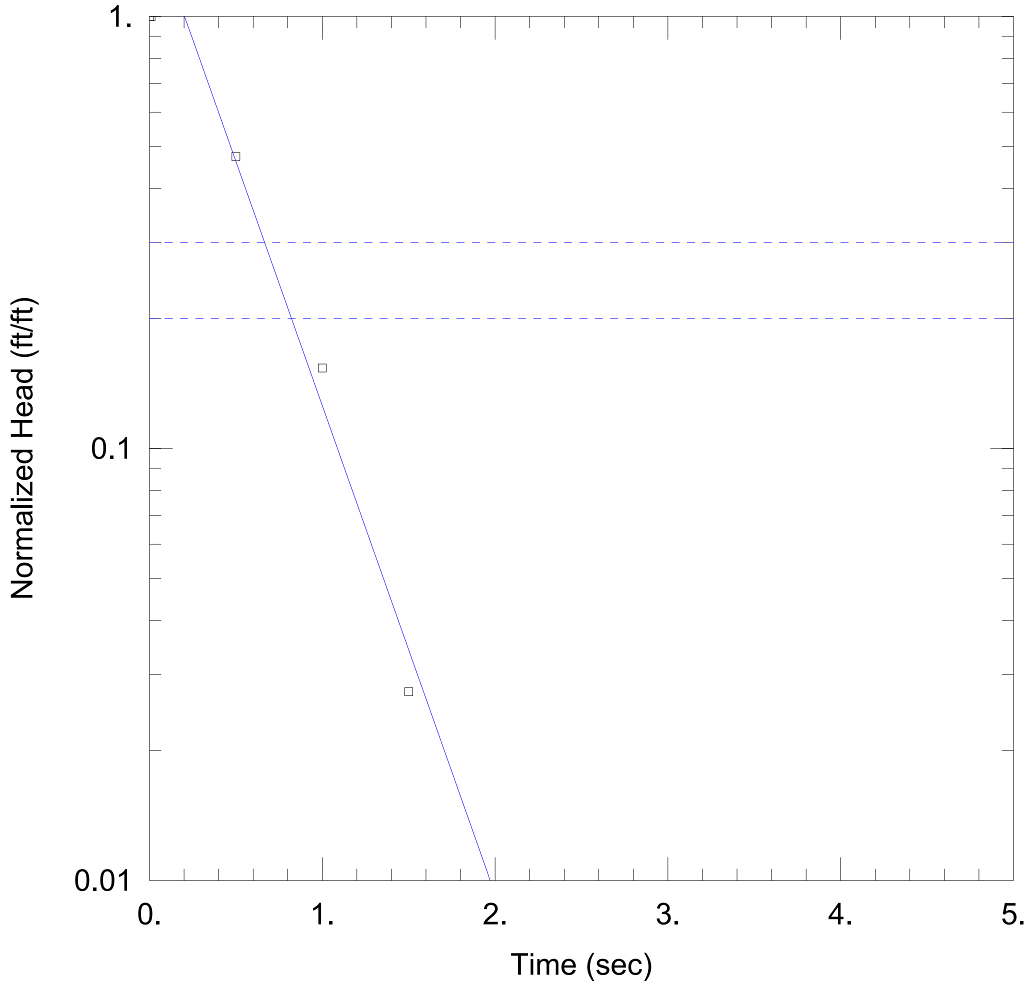
WELL DATA (XPW-02)

Initial Displacement: 0.702 ft
Static Water Column Height: 8.91 ft
Total Well Penetration Depth: 8.4 ft
Screen Length: 8.4 ft
Casing Radius: 0.086 ft
Well Radius: 0.25 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.0209 cm/sec
y0 = 0.664 ft



XPW-03 RH-2

PROJECT INFORMATION

Company: Ramboll
Client: Kincaid Generation, LLC
Location: Kincaid Power Plant
Test Date: 03/19/2021

AQUIFER DATA

Saturated Thickness: 6.74 ft
Anisotropy Ratio (Kz/Kr): 1.

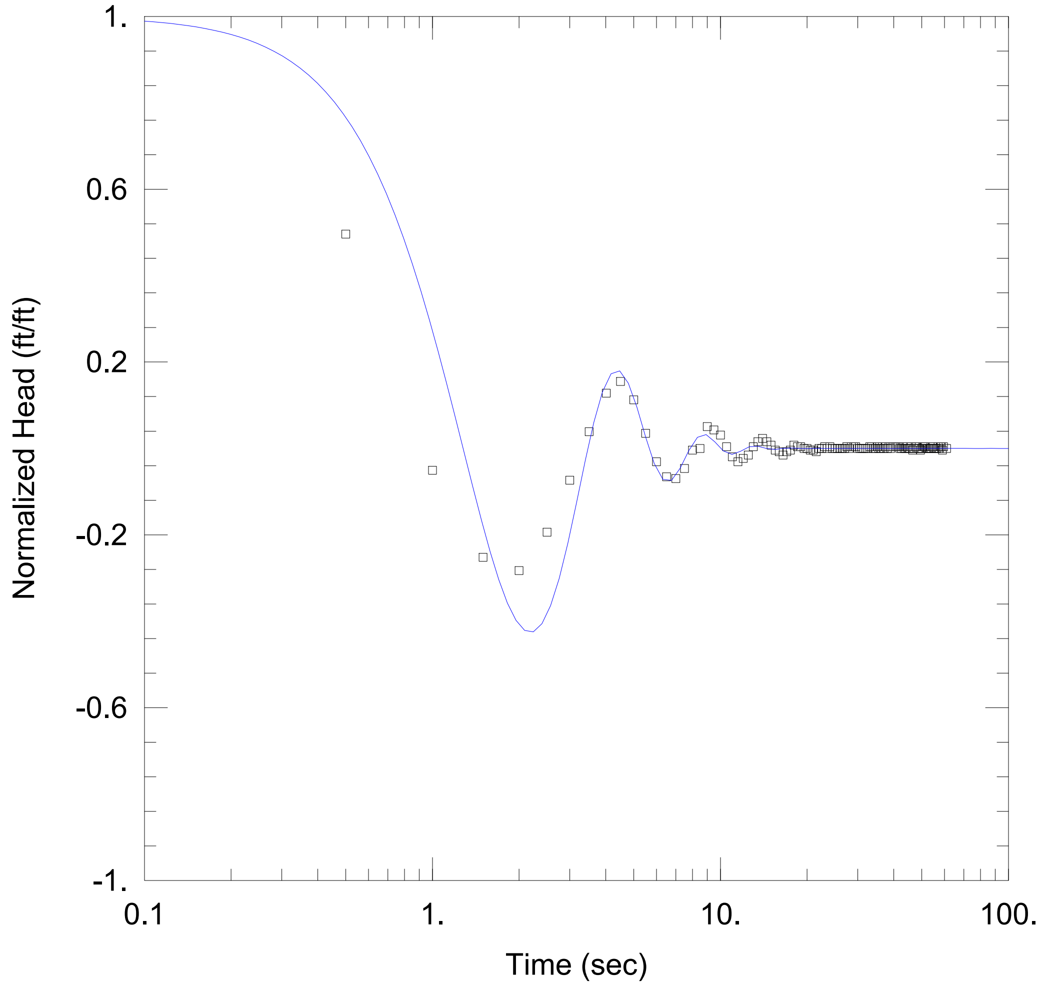
WELL DATA (XPW-03)

Initial Displacement: 2.45 ft
Total Well Penetration Depth: 6.74 ft
Casing Radius: 0.086 ft
Static Water Column Height: 7.74 ft
Screen Length: 6.74 ft
Well Radius: 0.25 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.0948 cm/sec
y0 = 4.16 ft



XPW-04 FH-1

PROJECT INFORMATION

Company: Ramboll
Client: Kincaid Generation, LLC
Location: Kincaid Power Plant
Test Date: 04/08/2021

AQUIFER DATA

Saturated Thickness: 20.81 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (XPW-04)

Initial Displacement: 0.258 ft
Total Well Penetration Depth: 20.81 ft
Casing Radius: 0.086 ft
Static Water Column Height: 21.81 ft
Screen Length: 9. ft
Well Radius: 0.25 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Springer-Gelhar

K = 0.103 cm/sec
Le = 14.5 ft

ATTACHMENT C: HISTORY OF CONSTRUCTION REPORT
845.220(a)(1)

October 2016

Kincaid Generation, L.L.C.
199 Illinois 104
Kincaid, IL 62540

RE: History of Construction
USEPA Final CCR Rule, 40 CFR § 257.73(c)
Kincaid Power Station
Kincaid, Illinois

On behalf of Kincaid Generation, L.L.C., AECOM has prepared the following history of construction for the Ash Pond at the Kincaid Power Station in accordance with 40 CFR § 257.73(c).

BACKGROUND

40 CFR § 257.73(c)(1) requires the owner or operator of an existing coal combustion residual (CCR) surface impoundment that either (1) has a height of five feet or more and a storage volume of 20 acre-feet or more, or (2) has a height of 20 feet or more to compile a history of construction by October 17, 2016 that contains, to the extent feasible, the information specified in 40 CFR § 257.73(c)(1)(i)–(xii).

The history of construction presented herein was compiled based on existing documentation, to the extent that it is reasonably and readily available (see 80 Fed. Reg. 21302, 21380 [April 17, 2015]) and AECOM's site experience. AECOM's document review included construction drawings, geotechnical investigations, operation and maintenance information, etc. for the Ash Pond at the Kincaid Power Station.

HISTORY OF CONSTRUCTION

§ 257.73(c)(1)(i): The name and address of the person(s) owning or operating the CCR unit; the name associated with the CCR unit; and the identification number of the CCR unit if one has been assigned by the state.

Owner: Kincaid Generation, L.L.C.

Address: 1500 Eastport Plaza Drive
Collinsville, IL 62234

CCR Unit: Ash Pond

The Ash Pond does not have a state assigned identification number.

§ 257.73(c)(1)(ii): The location of the CCR unit identified on the most recent USGS $7^1/_2$ or 15 minute topographic quadrangle map or a topographic map of equivalent scale if a USGS map is not available.

The location of the Ash Pond has been identified on an USGS 7-1/2 minute topographic quadrangle map in **Appendix A**.

§ 257.73(c)(1)(iii): A statement of the purpose for which the CCR unit is being used.

The Ash Pond is being used to store and dispose of sluiced bottom ash and to clarify other non-CCR waste streams to be used as recycled water for plant operations. Newly placed ash is recovered by a third party and recycled for beneficial use.

§ 257.73(c)(1)(iv): The name and size in acres of the watershed where the CCR unit is located.

Most of the Kincaid Power Plant property including the entire Kincaid Ash Pond is located in the northeastern portion of the Sangchris Lake Watershed with a 12-digit Hydrologic Unit Code (HUC) of 071300070402 and a drainage area of 23,382 acres (USGS, 2016). The remaining portion of the Kincaid Power Station property is located in the northwestern portion of the Town of Tovey Watershed and a 12-digit Hydrologic Unit Code (HUC) of 071300070401 with a drainage area of 23,341 acres (USGS, 2016).

§ 257.73(c)(1)(v): A description of the physical and engineering properties of the foundation and abutment materials on which the CCR unit is constructed.

The foundation materials consist of foundation clay overlying glacial till. The physical properties of the foundation clay for the Ash Pond are described as native fine grained soils of alluvial origin with occasional layers of coarse-grained soil. The fine-grained soils (clays) are generally classified as low to medium plasticity silty clay, sandy clay, clay with sand, or clay (CL) with trace amounts of sand or gravel; or high plasticity clay (CH). The CL and CH soils are soft to very stiff, very moist to very wet, and brown to gray with some occurrence of reddish brown silt seams. The coarse-grained soil is classified as clayey sand (SC), with a trace amount of gravel, very loose, very wet, and brown to gray. The fines portion of the clayey sand is low plastic. The foundation clay is underlain by glacial till that is predominantly classified as sandy clay (CL) with some occurrences of clayey sand (SC) or silty sand (SM), usually with a trace amount of fine gravel, generally hard, low to medium plasticity, slightly moist to very wet, and brown to gray. An available summary of the engineering properties of the foundation materials is presented in **Table 1** below.

Table 1. Summary of Foundation Material Engineering Properties

Material	Unit Weight (pcf)	Peak Drained Shear Strength		Peak Undrained Shear Strength	Post-Earthquake Shear Strength
		Cohesion, c′ (psf)	Friction Angle, f ' (deg)	S_u/p'	S_{ur}/p'
Foundation Clay (Under Embankment)	125	0	32 *with curved envelope for* $s'_{ff} < 2160$ *psf*	$S_u/p' = 0.48$, Minimum $S_u = 800$ psf	$S_{ur}/p' = 0.30$, Minimum $S_u = 400$ psf
Foundation Clay (Free Field)	125	0	30	$S_u/p' = 0.30$, Minimum $S_u = 400$ psf	$S_{ur}/p' = 0.30$, Minimum $S_u = 400$ psf
Till	135	0	40	$S_u/p' = 0.64$, Minimum $S_u = 800$ psf	$S_u/p' = 0.64$, Minimum $S_u = 800$ psf

The Ash Pond is an enclosed impoundment with embankments and does not have abutments.

§ 257.73(c)(1)(vi): A statement of the type, size, range, and physical and engineering properties of the materials used in constructing each zone or stage of the CCR unit; the method of site preparation and construction of each zone of the CCR unit; and the approximate dates of construction of each successive stage of construction of the CCR unit.

The physical properties of the materials used for embankment construction of the Ash Pond are described as low to medium plasticity sandy clay or clay with sand (CL), or high plasticity clay (CH). The CL and CH soils have occasional occurrences of trace levels of fine gravel, are medium stiff to very stiff with occasional soft zones, moist to very moist, and brown to gray. The embankment fill generally appears to be well-compacted. An available summary of the engineering properties of the embankment materials is presented in **Table 2** below.

Table 2. Summary of Construction Material Engineering Properties

Material	Unit Weight (pcf)	Peak Drained Shear Strength		Peak Undrained Shear Strength	Post-Earthquake Shear Strength
		Cohesion, c′ (psf)	Friction Angle, f ’ (deg)	S_u/p'	S_{ur}/p'
Embankment Fill	135	0	40 *with curved envelope for* $s'_{ff} < 1440$ *psf*	$S_u/p' = 0.68$, Minimum $S_u = 575$ psf	$S_u/p' = 0.68$, Minimum $S_u = 575$ psf

The method of site preparation and construction for the Ash Pond is not reasonably and readily available.

The approximate dates of construction of each successive stage of construction of the Ash Pond are provided in **Table 3** below.

Table 3. Approximate dates of construction of each successive stage of construction.

Date	Event
1964-1965	Construction of Ash Pond
1967	Ash Pond was put into service
1978-1980	Installation of Ash Pond recycle water intake structures and associated piping
Mid-1980’s	Erosion repair along north embankment adjacent to Sangchris Lake
2006	Replacement of emergency outlet piping
2009-2010	Tree removal, grading, and vegetation re-established along the north and east embankment
2010	Riprap placement along the northwest Ash Pond embankment adjacent to Sangchris Lake

§ 257.73(c)(1)(vii): At a scale that details engineering structures and appurtenances relevant to the design, construction, operation, and maintenance of the CCR unit, detailed dimensional drawings of the CCR unit, including a plan view and cross sections of the length and width of the CCR unit, showing all zones, foundation improvements, drainage provisions, spillways, diversion ditches, outlets, instrument locations, and slope protection, in addition to the normal operating pool surface elevation and the maximum pool surface elevation following peak discharge from the inflow design flood, the expected maximum depth of CCR within the CCR surface impoundment, and any identifiable natural or manmade features that could adversely affect operation of the CCR unit due to malfunction or mis-operation.

Drawings that contain items pertaining to the requested information for the Ash Pond are listed in **Table 4** below. Items marked as "Not Available" are items not found during a review of the reasonably and readily available record documentation.

Table 4. List of drawings containing items pertaining to the information requested in § 257.73(c)(1)(vii).

	Ash Pond
Dimensional plan view (all zones)	B-32
Dimensional cross sections	B-32
Foundation Improvements	Not Applicable
Drainage Provisions	Not Applicable
Spillways and Outlets	869D4-C12A, 869D4-C36 to C37, 869D-M69
Diversion Ditches	Not Applicable
Instrument Locations	Figure 2A
Slope Protection	B-32
Normal Operating Pool Elevation	Not Available
Maximum Pool Elevation	Not Available
Approximate Maximum Depth of CCR in 2016	30 feet

All drawings referenced in **Table 4** above can be found in **Appendix B** and **Appendix C**.

Based on the review of the drawings listed above, no natural or manmade features that could adversely affect operation of the CCR unit due to malfunction or mis-operation were identified.

§ 257.73(c)(1)(viii): A description of the type, purpose, and location of existing instrumentation.

Existing instrumentation within the Ash Pond consists of vibrating-wire and open standpipe piezometers and a water level gauge. The purpose of the piezometers is to measure the pore water pressures within the embankment. The purpose of the water level gauge is to measure the water surface level within the Ash Pond. Twelve (12) vibrating-wire and open-standpipe piezometers were installed in 2015 and the locations are presented on Figure 2A in **Appendix C**. Three (3) piezometers were installed in 2016 and the locations are presented on Figure 2A in **Appendix C**. The water level gauge is located adjacent to the emergency outlet structure in the southeast corner of the Ash Pond. A location map of the water level gauge is not reasonably and readily available.

§ 257.73(c)(1)(ix): Area-capacity curves for the CCR unit.

The area-capacity curve for the Ash Pond is presented in **Figure 1** below. “Area-capacity curves”, as defined by 40 CFR § 257.53, “means graphic curves which readily show the reservoir water surface area, in acres, at different elevations from the bottom of the reservoir to the maximum water surface, and the capacity or volume, in acre-feet, of the water contained in the reservoir at various elevations.”

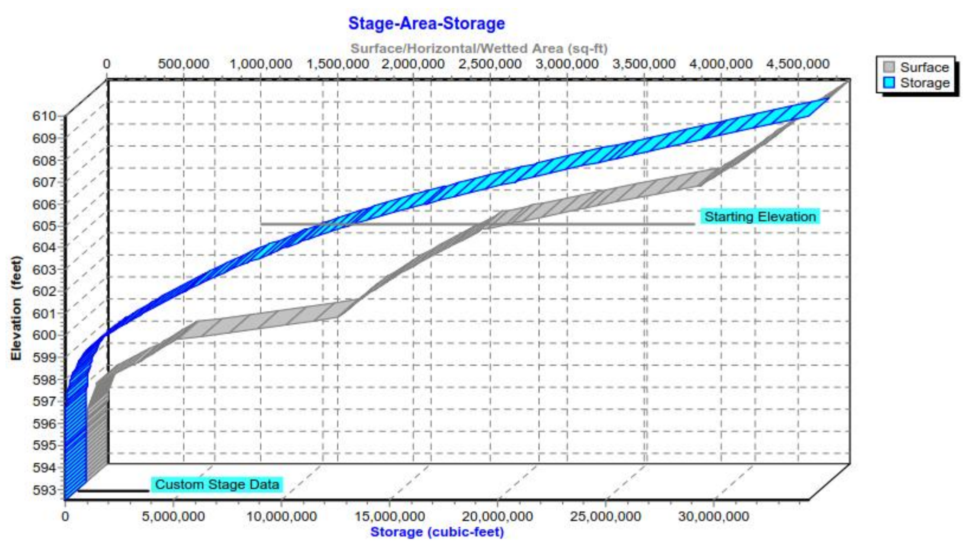


Figure 1. Area-capacity curve for Ash Pond

The area-capacity curve shown was taken from the pond modeling analysis. Actual pond capacity is limited to the approximate berm elevation listed in **Table 5** below. Any information above berm elevation should be disregarded.

§ 257.73(c)(1)(x): A description of each spillway and diversion design features and capacities and calculations used in their determination.

A recycle water intake structure (screen house) is located in the southeast corner of the Ash Pond. Impounded water from the Ash Pond is screened through the intake structure and fed into a gated 60-inch diameter (dia.) pipe (Invert El. 592.3 feet.) where it flows to the recycle pump house. Design drawings indicate that the 60-inch dia. pipe is reinforced concrete pipe (RCP). The Ash Pond also contains an emergency outlet structure in the southeast corner of the pond. The emergency outlet structure consists of a sluice gate (Invert El. 597.5 feet.) and concrete overflow weir (Invert El. 604.3 feet.), with an ungated 48-inch dia. corrugated metal pipe (CMP) outlet. Unless otherwise noted, all elevations in this report are based on the NAVD88 datum.

In 2016, the discharge capacity of the Ash Pond was evaluated using HydroCAD 10 software modeling a 1,000-year, 24-hour rainfall event. The model results indicate that the Ash Pond has enough storage capacity above the existing placed CCR, and will not overtop the embankment during the 1,000-year, 24-hour storm event. The results of the HydroCAD 10 analysis are presented below in **Table 5**.

Table 5. Results of HydroCAD 10 analysis

	Ash Pond
Approximate Minimum Berm Elevation[1] (ft)	605.2
Approximate Emergency Spillway Elevation[1] (ft)	Not Applicable
Starting Pool Elevation[1] (ft)	603.3
Peak Elevation[1] (ft)	605.1
Time to Peak (hr)	21.9
Surface Area (ac)	75.5
Storage[2] (ac-ft)	110.7

§ 257.73(c)(1)(xi): The construction specifications and provisions for surveillance, maintenance, and repair of the CCR unit.

Drawings for the Ash Pond refer to construction specification *Job Specification G-1943,* but that specification is not reasonably and readily available.

The operations and maintenance plans for the Ash Pond are currently being prepared by Kincaid Generation, L.L.C.

§ 257.73(c)(1)(xii): Any record or knowledge of structural instability of the CCR unit.

In 2013, minor subsidence of the embankment crest was observed along portions of the southwestern Ash Pond embankment. The subsidence was believed to have been caused by historical underground mining operations below the Ash Pond from the 1950s to the 1990s. Gravel and soil fill was placed in the settlement areas to restore the embankment crest elevation. The embankment is observed during the weekly inspections and no further evidence of subsidence has occurred since 2013. Information regarding the subsidence is presented in **Appendix D**.

There is no record or knowledge of any other structural instability of the Ash Pond at Kincaid Power Station.

LIMITATIONS

The signature of AECOM's authorized representative on this document represents that to the best of AECOM's knowledge, information and belief in the exercise of its professional judgment, it is AECOM's professional opinion that the aforementioned information is accurate as of the date of such signature. Any recommendation, opinion or decisions by AECOM are made on the basis of AECOM's experience, qualifications and professional judgment and are not to be construed as warranties or guaranties. In addition, opinions relating to environmental, geologic, and geotechnical conditions or other estimates are based on available data and that actual conditions may vary from those encountered at the times and locations where data are obtained, despite the use of due care.

Sincerely,

Claudia Prado
Project Manager

Victor Modeer, P.E., D.GE
Senior Project Manager

REFERENCES

United States Environmental Protection Agency (USEPA). (2015). *Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals From Electric Utilities; Final Rule.* 40 CFR Parts 257 and 261, 80 Fed. Reg. 21302, 21380 April 17, 2015.

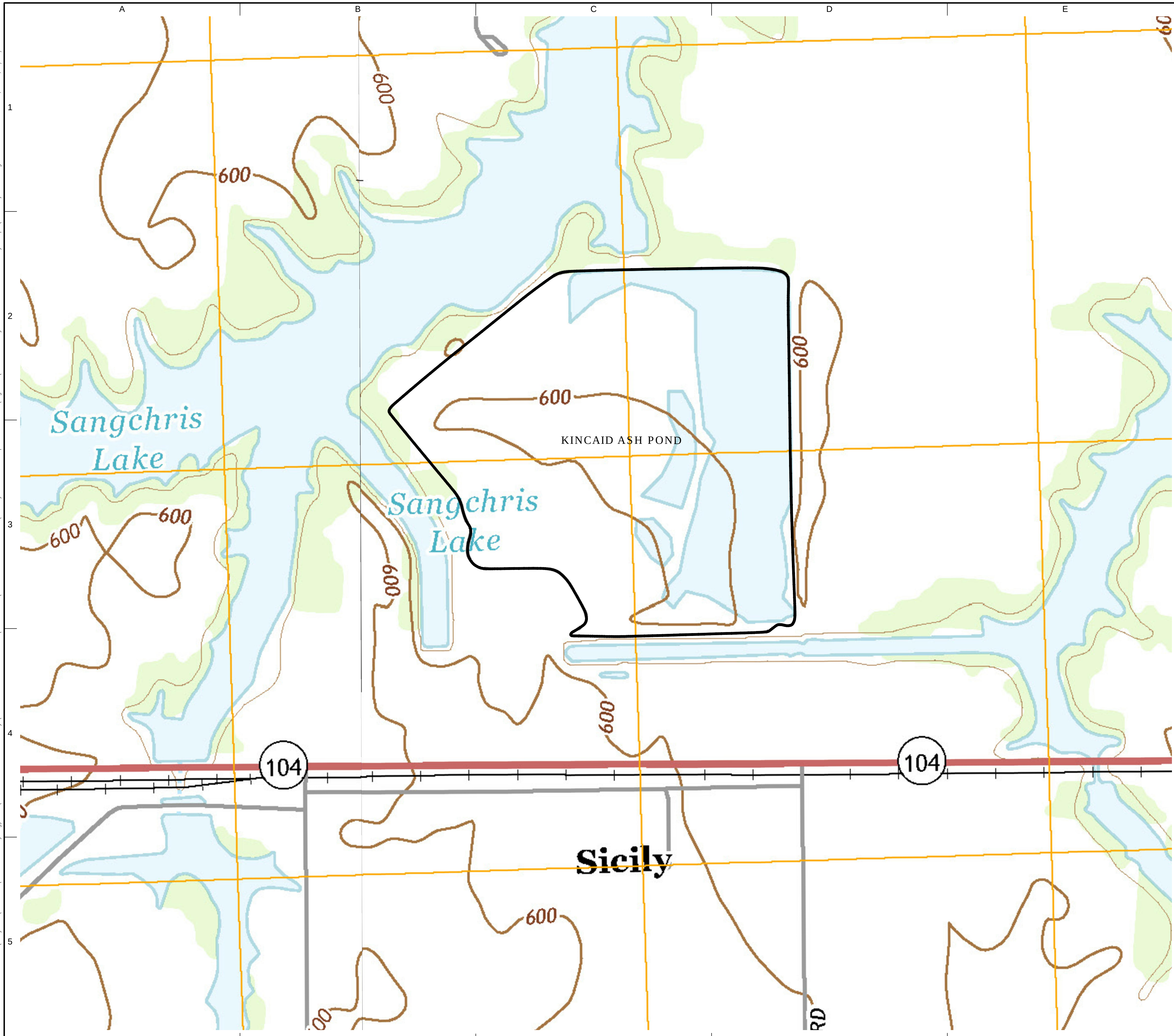
United States Geological Survey (USGS). (2016). The National Map Viewer. http://viewer.nationalmap.gov/viewer/. USGS data first accessed in March of 2016.

APPENDICES

Appendix A: History of Construction Vicinity Map
Appendix B: Kincaid Power Station Drawings
Appendix C: Kincaid Ash Pond Piezometer Locations
Appendix D: Ash Pond Embankment Settlement (2013)

AECOM

Appendix A: History of Construction Vicinity Map

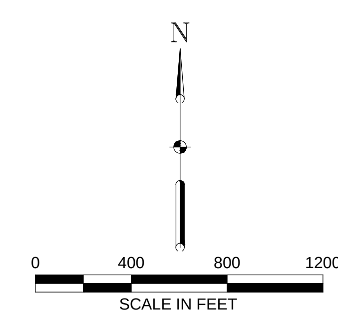


LEGEND

CCR UNITS

SOURCE:
MAP PROVIDED FROM ELECTRONIC USGS DIGITAL RASTER GRAPHIC 7.5 MINUTE TOPOGRAPHIC MAP OF KINCAID ILLINOIS AND PAWNEE ILLINOIS, REVISED 2015.

QUADRANGLE LOCATION



SCALE IN FEET

AECOM
1001 Highlands Plaza Drive, Suite 300
St. Louis, MO 63110
314 429-0100 (phone)
314-429-0462 (fax)

KINCAID GENERATION, L.L.C.
199 Illinois 104
Kincaid, IL 62540

HISTORY OF CONSTRUCTION

KINCAID POWER STATION
KINCAID, ILLINOIS

ISSUED FOR BIDDING — DATE BY

ISSUED FOR CONSTRUCTION — DATE BY

REVISIONS

NO.	DESCRIPTION	DATE
△		
△		
△		
△		
△		

AECOM PROJECT NO:	60489731
DRAWN BY:	DJD
DESIGNED BY:	DJD
CHECKED BY:	MN
DATE CREATED:	2016-04-13
PLOT DATE:	
SCALE:	1" = 400'
ACAD VER:	2014

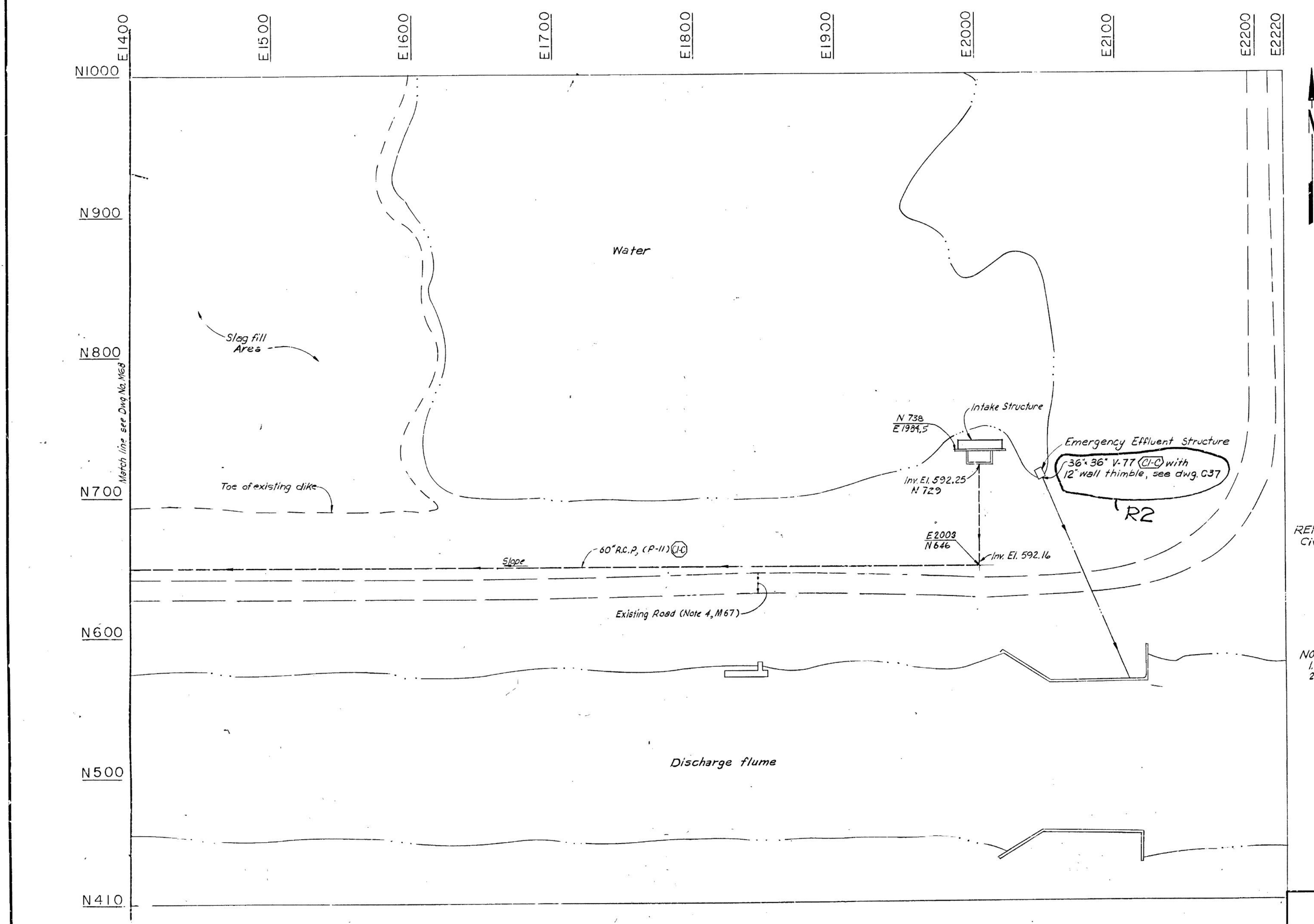
SHEET TITLE

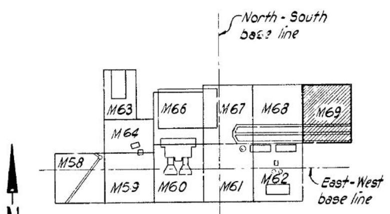
HISTORY OF CONSTRUCTION VICINITY MAP

01

Appendix B: Kincaid Power Station Drawings

1. “Outside Piping Sheet II”, Drawing No. 869D4-M69, Revision R2, 10 August, 1978, Harza Engineering Company.
2. “Ash Pond Dike Piping Prevention”, Drawing No. 869D4-C12A, Revision R1, 29 June, 1978, Harza Engineering Company.
3. “Ash Sluice Water Intake Structures”, Drawing No. 869D4-C36, Revision R2, 25 September, 1980, Harza Engineering Company.
4. “Ash Sluice Water Stilling Well and Emergency Effluent Sump Structures”, Drawing No. 869D4-C37, Revision R4, 8 May, 1979, Harza Engineering Company.
5. “Intake & Discharge Flumes, Plans & Sections”, Drawing No. B-32, Revision P, 2 December, 1965, Harza Engineering Company.





KEY PLAN
(N.T.S.)

REFERENCE DRAWINGS
Civil: C36, C37 R2

NOTES:
1. Work this dwg. with dwg. M68 & M67.
2. For general notes & symbols see M3.

Scale: 0 30 60 Feet
1" = 30'-0"

DSGN.	BL/OGR	REVIEWED	
CHKD.	S.S.	CIVIL	
DWN.	OGR	MECH.	
CHKD.	S.S.		
SUBM.		ELECT.	

REV. NO.	DWG. TRANSMITTAL LETTER NO.	DATE	NATURE OF REVISION	BY	CHKD.	APPD.
R2	DDR 869D4-C2 #8	8-10-78	Miscellaneous revisions	V.M.		
R2	DDR 869D4-C1 #13	7-14-78	Contract 869D4-C1 & 869D4-C2			
R1		4-12-78	Issued for construction contract 869D4 - C2			
R1			Issued for construction Contract 869D4-C1			
R0.		12-5-77	Issued for Bid 869D4-C2			
R0.		11-14-77	Issued for Bid 869D4-C1			

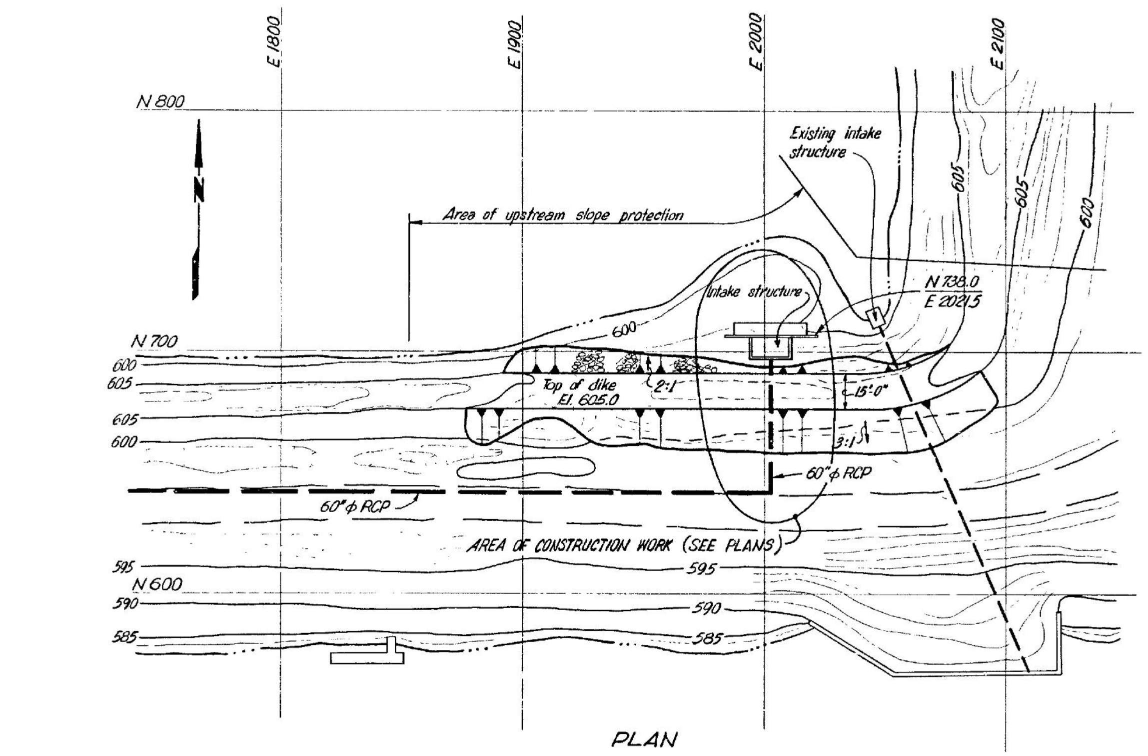
COMMONWEALTH EDISON COMPANY
CHICAGO, ILLINOIS

KINCAID STATION | WASTEWATER TREATMENT

OUTSIDE PIPING
SHEET 11

CONSULTING ENGINEERS
HARZA ENGINEERING COMPANY
APPROVED

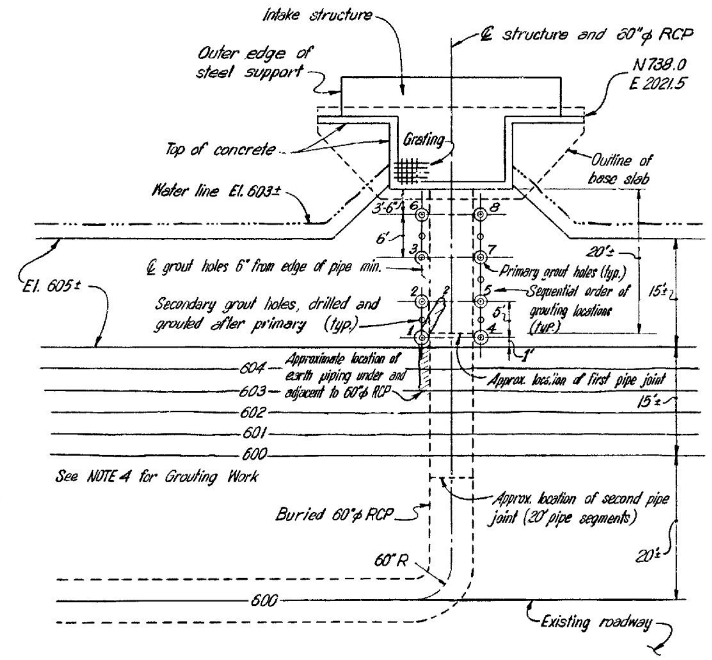
CHICAGO, ILLINOIS | DATE NOV. 1977 | DWG. NO. 869D4-M69



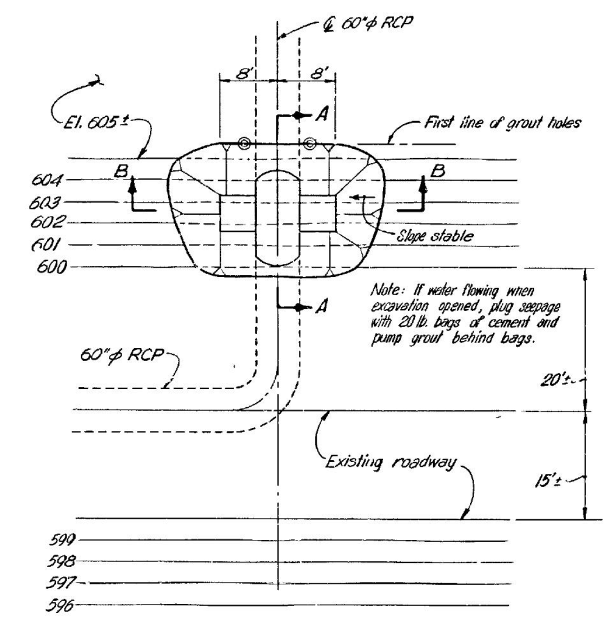
PLAN

ASH POND DIKE

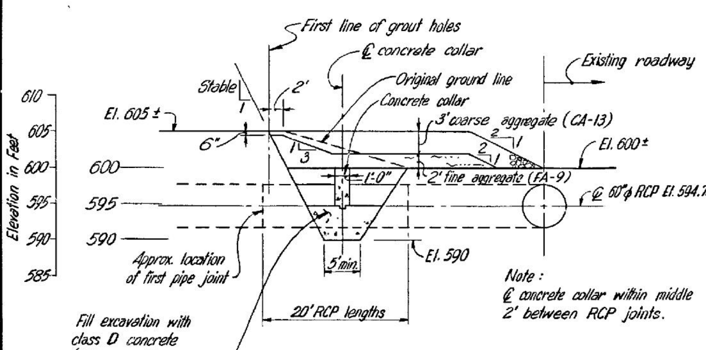
Scale 0 30 Feet



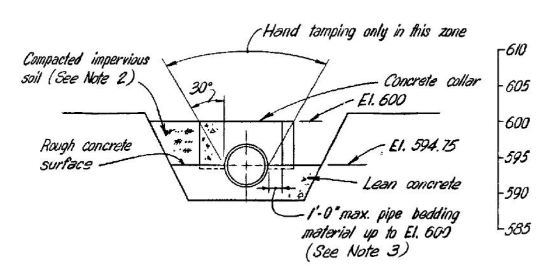
GROUTING PLAN



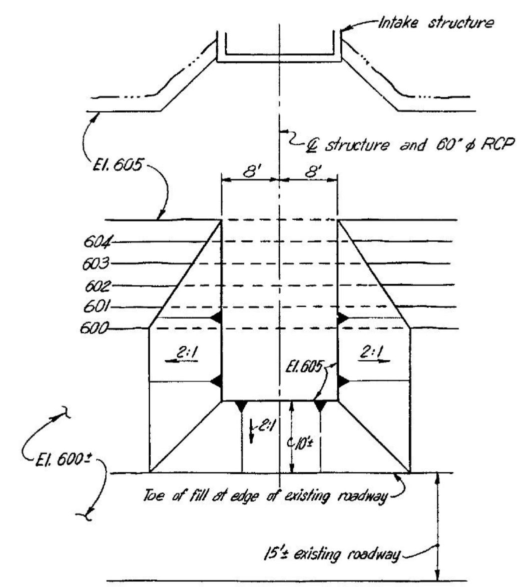
EXCAVATION PLAN



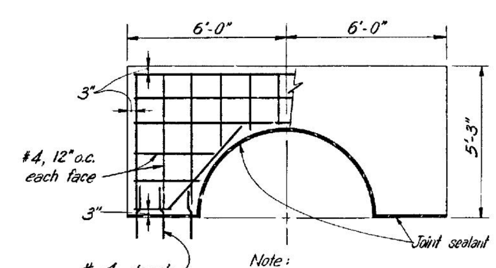
A-A



B-B

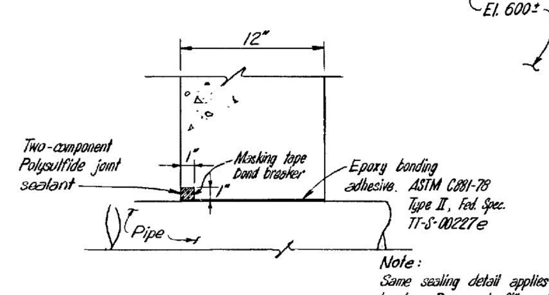


COMPLETED EARTHWORK PLAN



PIPE COLLAR STEEL REINFORCEMENT

Scale 0 2 Feet



PIPE COLLAR SEALING DETAIL

Scale 0 6 Inches

REFERENCE DRAWINGS:

No.	Title
869 D4-C36	Ash Sluice Water Intake Structures
869 D4-C12	Settling Ponds and Ash Pond Dike

NOTE:

1. Contract 869 D4-C1 specifications shall be followed unless noted otherwise on this drawing.
2. Impervious soil shall pass the No. 4 sieve, and shall have at least 25 percent passing the No. 200 sieve.
3. Pipe bedding material shall consist of fine aggregate (FA-9 State of Illinois)
4. Grout shall consist of a sand-cement mixture with possibly pea gravel. The mixture and pressures shall be as determined by the Owner's Representative in the field.

FRANK M. SCOTT 27756 REGISTERED PROFESSIONAL ENGINEER OF ILLINOIS

Scale 0 20 Feet
Except as noted

DSGN.	AJF	REVIEWED	
CHKD.		CIVIL	
DWN.		MECH.	
CHKD.	AJF		
SUBM.		ELECT.	

REV. NO.	DWG. TRANSMITTAL LETTER NO.	DATE	NATURE OF REVISION	BY	CHKD.	APPD.
R1	00.R 869D4-C1	6-23-78	Issued for Construction-C1			

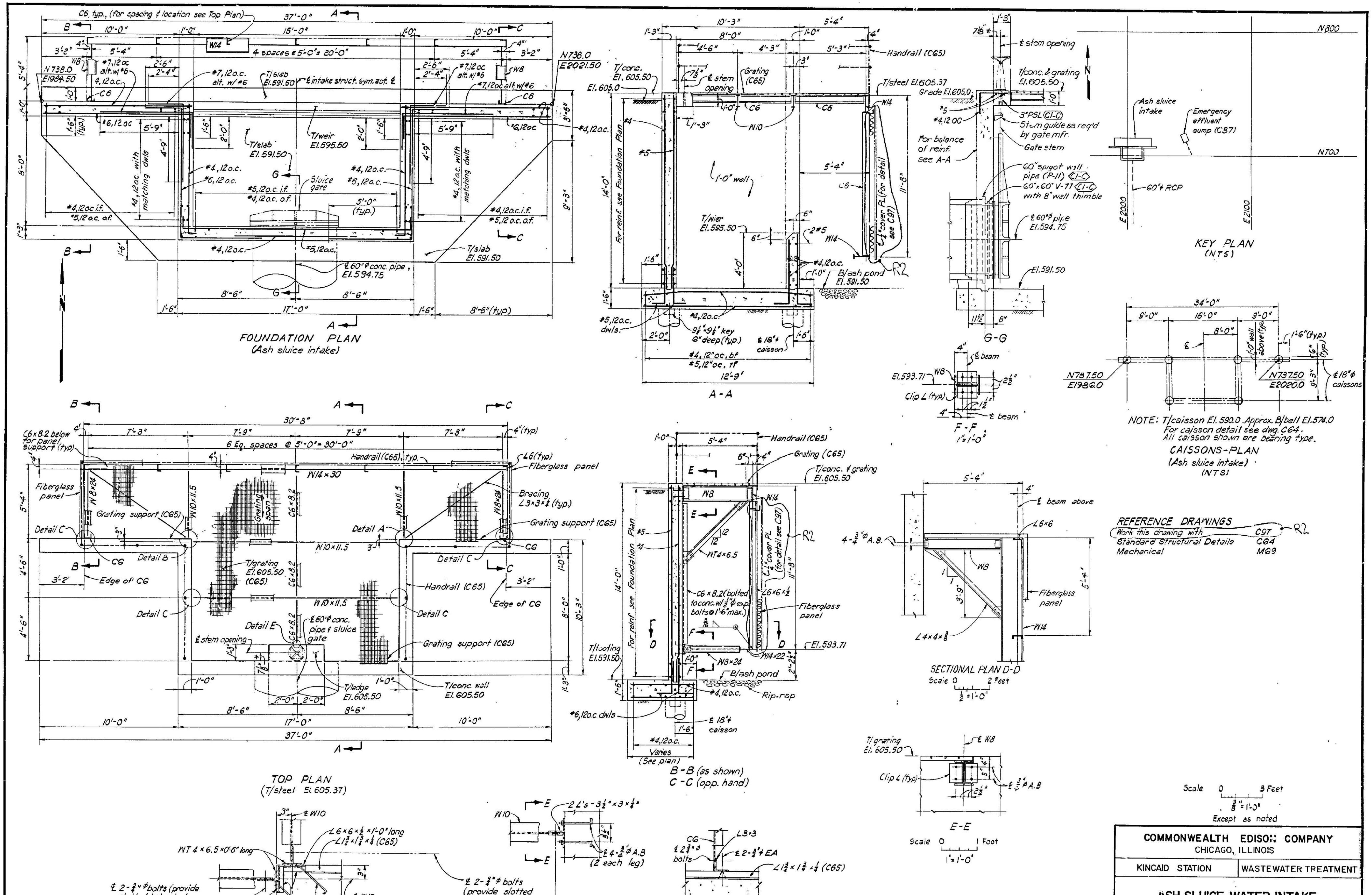
COMMONWEALTH EDISON COMPANY
CHICAGO, ILLINOIS

KINCAID STATION | WASTEWATER TREATMENT

ASH POND DIKE PIPING PREVENTION

CONSULTING ENGINEERS
HARZA ENGINEERING COMPANY
APPROVED

CHICAGO, ILLINOIS | DATE JULY, 1979 | DWG. NO. 869 D4-C12A



DSGN.	DBL	REVIEWED	
CHKD.	YCP	CIVIL	
DWN.	GC	MECH.	
CHKD.	GAH/VH		
SUBM.	EEG	ELECT.	

REV. NO.	DWG. TRANSMITTAL LETTER NO.	DATE	NATURE OF REVISION	BY	CHKD.	APPD.
R2	DDR 869D4-C3 #1	9/25/80	Issued for Construction 869D4-C3	GMC	DD	EEG
R2	Issued for Bid 869D4-C3	4/15/80	Added intake cover PL	GMC	D.D.	EEG
R1	869D4-C1 DDR#3	6-31-78	Issued for Construction 869D4-C1	GC	GAH	EEG
R0		12-5-77	Issued for Bids 869D4-C2			
R0		11-4-77	Issued for Bids 869D4-C1			

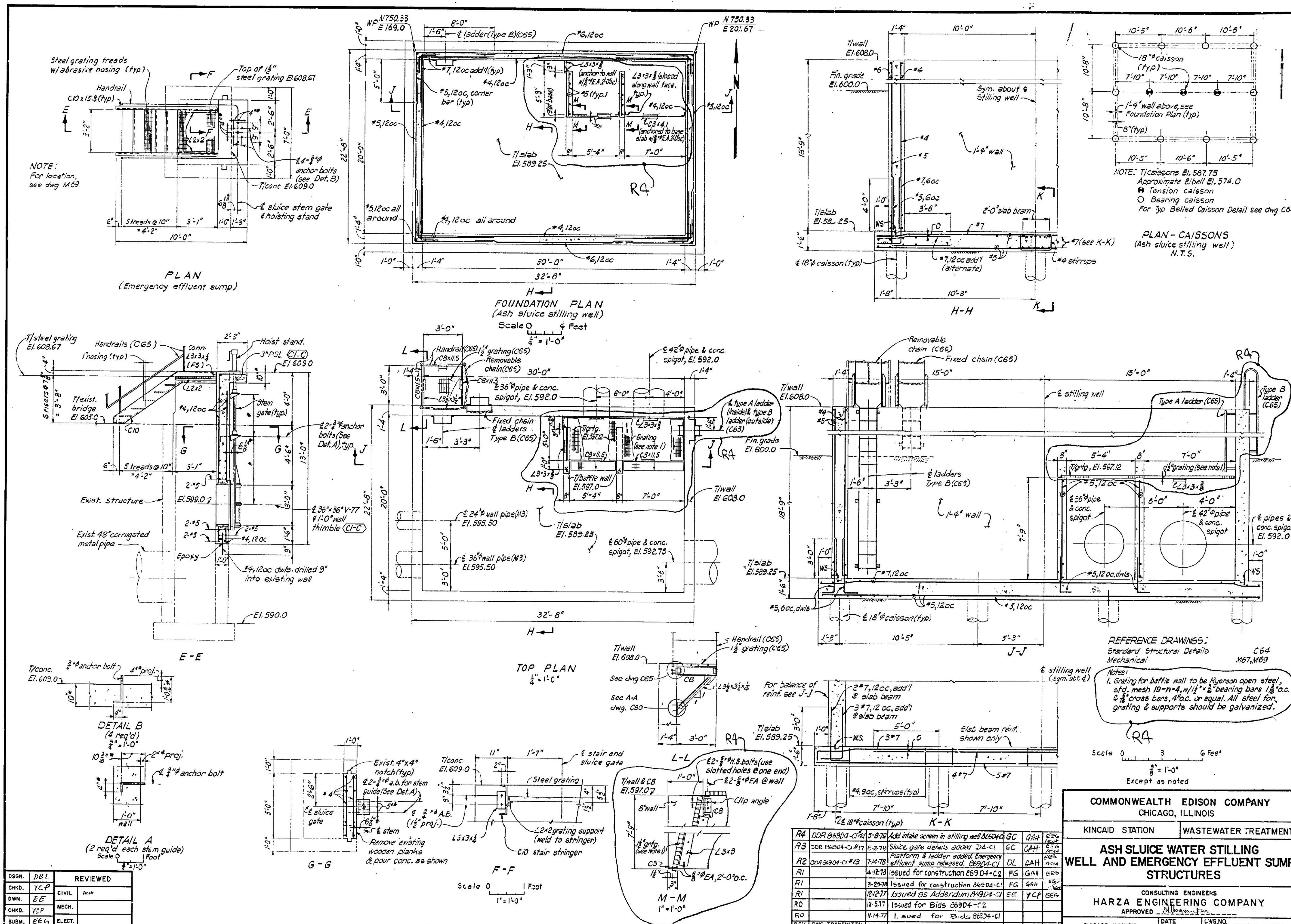
COMMONWEALTH EDISON COMPANY
CHICAGO, ILLINOIS

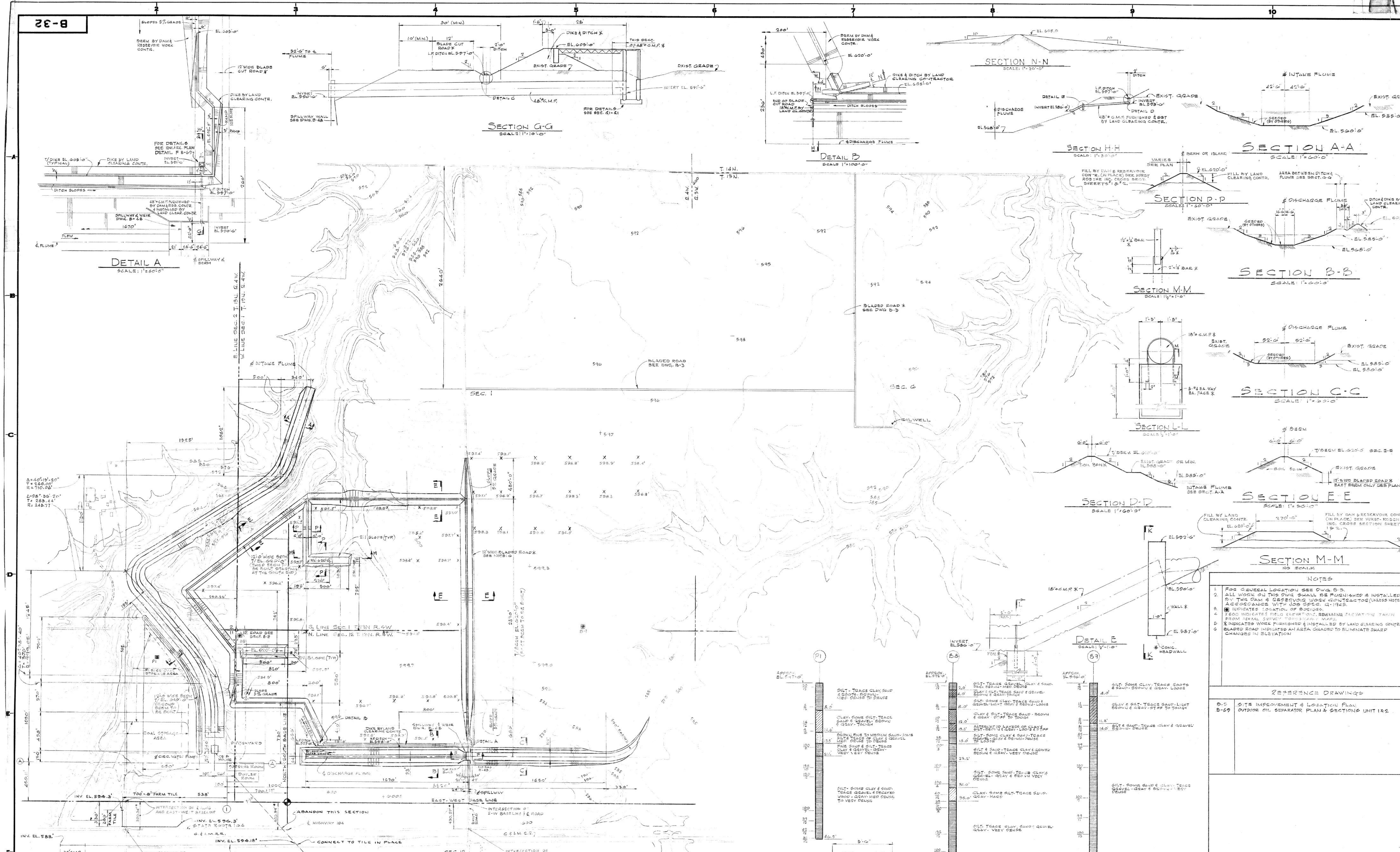
KINCAID STATION | WASTEWATER TREATMENT

ASH SLUICE WATER INTAKE STRUCTURES

CONSULTING ENGINEERS
HARZA ENGINEERING COMPANY
APPROVED

CHICAGO, ILLINOIS | DATE NOV. 1977 | DWG. NO. 869D4-C36


PLAN (Emergency effluent sump)
NOTE: For location, see dwg M69
FOUNDATION PLAN (Ash sluice stilling well)
Scale 0 4 Feet
1/4" = 1'-0"
H-H
PLAN - CAISSONS (Ash sluice stilling well) N.T.S.
NOTE: T/caissons El. 587.75
Approximate B/bell El. 574.0
Tension caisson
Bearing caisson
For Typ Belled Caisson Detail see dwg C64
E-E
TOP PLAN 1/4" = 1'-0"
J-J
DETAIL B (4 req'd) 3/4" = 1'-0"
DETAIL A (2 req'd each stem guide)
G-G
F-F
Scale 0 1 Foot 1" = 1'-0"
L-L
M-M 1" = 1'-0"
K-K
REFERENCE DRAWINGS:
Standard Structural Details C64
Mechanical M67, M69
Notes:
1. Grating for baffle wall to be Ryerson open steel, std. mesh 19-W-4, w/1 1/4" x 3/16" bearing bars 1 3/16" o.c. & 1/4" cross bars, 4" o.c. or equal. All steel for grating & supports should be galvanized.
Scale 0 3 6 Feet
3/8" = 1'-0"
Except as noted
R4 DDR 869D4-C1#44 5-8-79 Add intake screen in stilling well 869D4-C1 GC GAH EEG
R3 DDR 869D4-C1#17 8-2-78 Sluice gate details added D4-C1 GC GAH EEG
R2 DDR 869D4-C1#13 7-14-78 Platform & ladder added. Emergency effluent sump released. 869D4-C1 DL GAH
R1 4-12-78 Issued for construction 869D4-C2 FG GAH EEG
R1 3-29-78 Issued for construction 869D4-C1 FG GAH
R1 12-12-77 Issued as Addendum 869D4-C1 EE YCP EEG
R0 12-5-77 Issued for Bids 869D4-C2
R0 11-14-77 Issued for Bids 869D4-C1
REV. NO. DWG. TRANSMITTAL LETTER NO. DATE NATURE OF REVISION BY CHKD. APPD.
DSGN. DBL CHKD. YCP DWN. EE CHKD. YCP SUBM. EEG
REVIEWED CIVIL MECH. ELECT.
COMMONWEALTH EDISON COMPANY
CHICAGO, ILLINOIS
KINCAID STATION
WASTEWATER TREATMENT
ASH SLUICE WATER STILLING WELL AND EMERGENCY EFFLUENT SUMP STRUCTURES
CONSULTING ENGINEERS
HARZA ENGINEERING COMPANY
APPROVED
CHICAGO, ILLINOIS
DATE NOV. 1977
DWG. NO. 869D4-C37



NOTES

1. FOR GENERAL LOCATION SEE DWG. B-3.
2. ALL WORK ON THIS DWG SHALL BE FURNISHED & INSTALLED BY THE DAM & RESERVOIR WORK CONTRACTOR (UNLESS NOTED) IN ACCORDANCE WITH JOB SPEC. G-1943.
3. ▣ INDICATES LOCATION OF BORINGS.
4. X600 INDICATES FIELD ELEVATIONS, REMAINING ELEVATIONS TAKEN FROM AERIAL SURVEY TOPOGRAPHY MAPS.
5. ✱ INDICATES WORK FURNISHED & INSTALLED BY LAND CLEARING CONTRACTOR
6. BLADED ROAD INDICATES AN AREA GRADED TO ELIMINATE SHARP CHANGES IN ELEVATION

REFERENCE DRAWINGS

B-3	SITE IMPROVEMENT & LOCATION PLAN
B-69	OUTDOOR OIL SEPARATOR PLAN & SECTIONS UNIT 1&2

REVISIONS

	2-17-64	GAC	DAM & RESERVOIR BIDS
A	3-11-64	T.L.P.	ADDENDUM #1
B	4-17-64	T.L.P.	FOR CONST.
C	6-3-64	H.J.L.	REV. DISCH. FLUME AND BERM
D	6-19-64	GAC	DELETE ROAD & SEEDING
E	7-2-64		RELEASE "HOLD" ON DISCH. FLUME
F	7-28-64	GAC	REVISE TOWER ISLANDS
G	8-5-64		REVISE LENGTH OF DISCHARGE
H	9-16-64	GAC	REV. CULVERT
J	10-30-64	GAC	REL. HOLD ADD SECT. F-F
K	3-23-65	GAC	REL. HOLD ADD TRENCH & DIKE
L	4-30-65		Reng. Exc. Pipe
M	6-24-65		NORTH TOWER ISLAND
N	7-19-65		AS BUILT
P	12-2-65		DELETE SEEDING
R		RJS	ADD DRAINAGE STRUCTURE

INTAKE & DISCHARGE FLUMES
PLAN & SECTIONS
KINCAID STATION
COMMONWEALTH EDISON CO.
CHICAGO, ILLINOIS

SCALE 1"=400'-0" UNLESS NOTED
DRAWN G.J. MILLER 1-14-64
CHECKED G.A. CHAUVIN 3-27-64
ENGINEER T.L. Pettikas 4-9-64
APPROVED R.N. Bergstrom 4-9-64

JOB NO.	JOB NO.	JOB NO.	JOB NO.
3342			

SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS

DRAWING NO.
B-32

H. & F. & C.W.E. 6/21/66

Appendix C: Kincaid Ash Pond Piezometer Locations

LEGEND

AECOM PIEZOMETER LOCATION

APPROXIMATE NRT PIEZOMETER LOCATION

CCR UNIT BERM ALIGNMENT

SOURCE:
MAP PROVIDED BY GOOGLE EARTH PRO 2015

0 400
APPROXIMATE SCALE FEET

N

KINCAID GENERATION, L.L.C.	PROJECT NO. 60440697
AECOM	
DRN. BY: djd October 2015 DSGN. BY: eg CHKD. BY: eg	Kincaid Ash Pond Piezometer Locations
FIG. NO.	2A

File: P:\PROJECTS\GEOTECH\60428794_DYNEGYCCR\04TASKS\00 PROGRAM TASKS\1.0 TASK 1 INITIAL UNIT ASSESSMENT\CCR FACT SHEETS\SITE MAPS\FIGURE 2A PIEZOMETER LOCATION PLAN (KINCAID ASH POND).DWG Last edited: NOV. 03, 15 @ 11:33 a.m. by: david_deguire

Appendix D: Ash Pond Embankment Settlement (2013)

Hanson Professional Services Inc.
1525 S. Sixth Street
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(217) 788-2450
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www.hanson-inc.com

Engineering | Architecture | Planning | Allied Services

August 2, 2013

Mr. Don Torricelli
Performance Specialist
Kincaid Power Station

RE: Ash Pond Embankment Settlement

Dear Mr. Torricelli:

After a call by Kincaid personnel on July 31, 2013 regarding transverse cracking of the crest of a portion of the southwest embankment section of the Kincaid Station Ash Pond, James P. Knutelski, P.E. of Hanson visited the site to observe the cracks. He was accompanied by Don Torricelli of the Kincaid Power Station. The following observations were made:

- The affected area was approximately 250 ft by 250 ft. The area is situated on the southwest side of the ash pond adjacent to the water intake channel for the power station. The location of the affected area is shown on the attached aerial photo and coal mine map.

- Surface features within the affected area include tension cracks, compression heaving, and apparent settlement. There is no survey data showing that settlement has occurred, however the crest of the dam is approximately 2 ft lower in the affected area than the adjacent crest.

- Tension cracks cross the embankment perpendicular to the embankment crest. On the upstream side of the embankment where ash has been filled to the elevation of the crest, the tension cracks change direction slightly.

- Compression heaving of the ground surface was observed along two lines near the center of the affected area and the lines of heaving were separated by about 12 ft. Compression heaving only occurred in the low area of the depression.

- The tension cracks were not visible more than 5 ft down the downstream slope of the embankment due to dense vegetative cover. A noticeable depression in the downstream slope was observed in the affected area.

- Cracks, settlement, or other surface features were not observed between the toe of the embankment and the inlet channel. They either did not exist, or were not visible due to dense vegetative cover.

- There were no wet areas, seepage, or evidence of seepage observed on the downstream slope of the embankment, the toe of the embankment, or the area between the embankment toe and the inlet channel.

The surficial features at the southwest embankment of the ash pond appear to be related to mine subsidence of the Peabody No. 10 coal mine that was active between 1951 and 1994. The following points indicate data or observations to support this conclusion:

- The affected area is undermined according to the available map.
- There are no utilities or other underground structures within the affected area that could be a source of leakage and underground erosion.
- The tension cracking and surface heaving that was observed transverse to the embankment crest are consistent with a sag subsidence above room and pillar mining.

The Peabody No. 10 mine is listed as blind room and pillar mine. Between 40% and 70% of the coal is removed in this type of mining. The Herrin coal seam was mined at depths between 300 ft and 380 ft. The average thickness of the coal seam was between 6.5 ft and 7.5 ft in this mine and the maximum thickness was 13.0 ft. The coal was mined beneath the Anna Shale or a limestone roof. Generally 6 ft to 7 ft of the coal was removed.

In Illinois, the maximum settlement for a sag type subsidence is generally situated near the center of the subsided area and the maximum settlement magnitude is generally between 2 ft and 4 ft. A review of the map of the coal mine for the affected area would allow a more precise estimate of maximum settlement magnitude.

Subsidence events can manifest rapidly in a manner of days, or slowly over several months or years. Prediction of future or continued subsidence is generally not economical or reliable with the technology available today.

In order to protect critical components of the Kincaid Power Station from additional or future subsidence, methods to prevent or minimize subsidence are probably the most feasible and economical.

Since injection of coal combustion byproduct (CCB) materials into the abandoned mine around the power station is currently part of the plant operation, it is recommended that CCB injection into areas beneath critical components of the power plant be given priority. Filling these areas would most likely result in greatly reduced, or eliminate future surface subsidence. Filling undermined areas that have already experienced subsidence may reduce or prevent additional subsidence.

Repair of the embankment does not appear to be necessary at this time because: there is no observed seepage or evidence of seepage in the embankment in this area, the depression in the embankment crest does detrimentally affect the freeboard of the impoundment, and the water detention within the impoundment is hundreds of feet from the affected embankment

This area should be observed daily for a week following the date of subsidence event and weekly thereafter for a period of 2 months. Noticeable additional cracking or settlement, seepage through the embankment, or wet areas near the toe of then embankment should be reported to Hanson immediately.

The portion of the coal mine that extends under Sangchris Lake was likely mined around the same time period as the two recently subsided areas near the power station. A similar event occurring under the lake has the potential to flood the mine. A significant loss of lake water into the mine is unlikely; however, considering the consequences, it is prudent to be observant of unusual conditions on the lake. Non-typical surface disturbances such as bubbling, swirls, or whirlpools could be evidence of drainage into the abandoned mine. Hanson should be contacted if any of these occurrences are observed.

Please contact me at (217) 747-9380 if you have any questions concerning this letter or if you require additional information.

Sincerely,

HANSON PROFESSIONAL SERVICES INC.

James P. Knutelski, PE, GE
Geotechnical Engineer

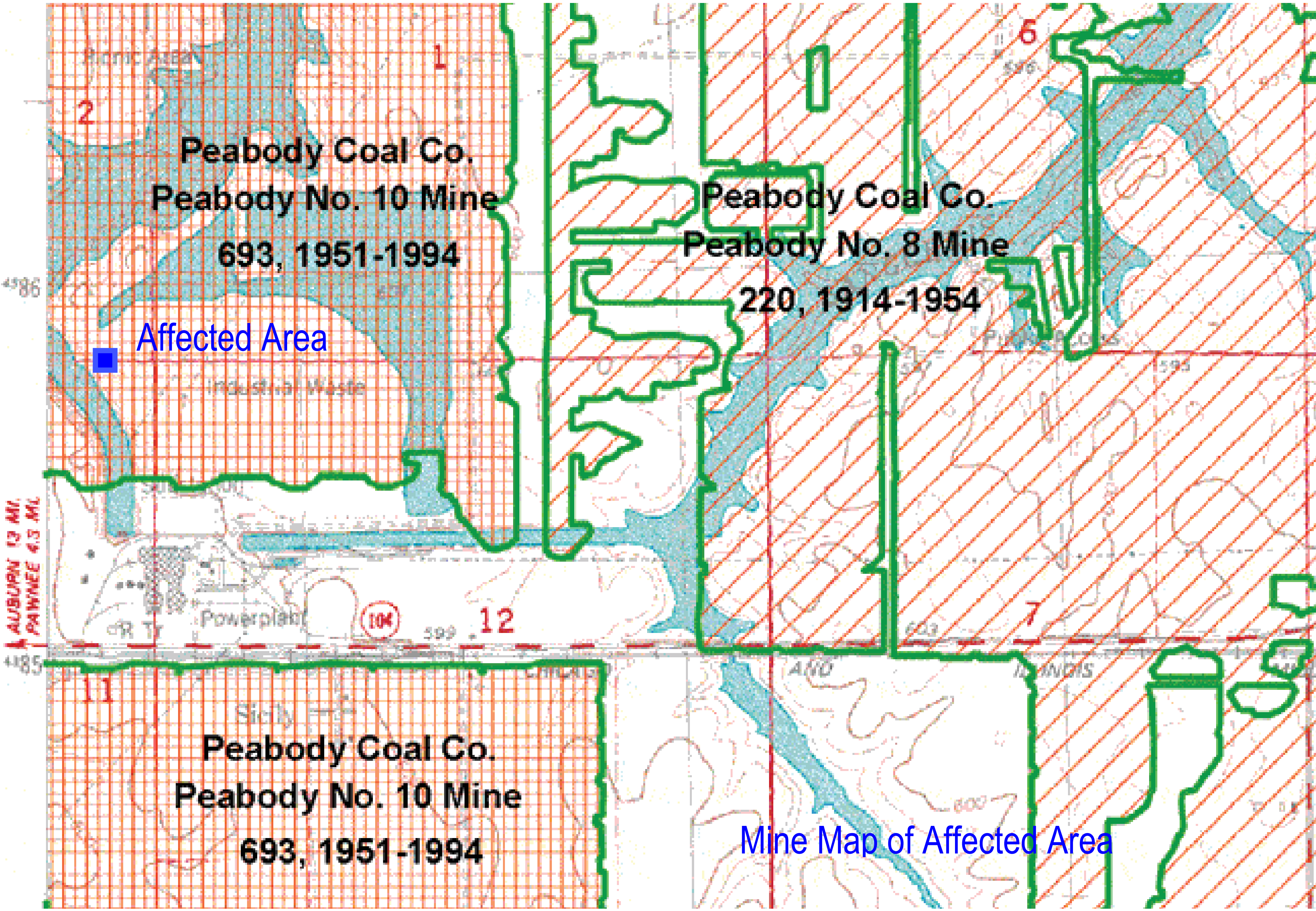
References

Coal Mines in Illinois, Kincaid Quadrangle retrieved July 31, 2013 from http://www.isgs.illinois.edu/maps-data-pub/coal-maps/topo-mines/kincaid.pdf

Mine Subsidence in Illinois: Facts for Homeowners, Bauer, Robert A., IDNR, ISGS Circular 569, 2006

Attachments

Aerial photo of affected area



Peabody Coal Co.
Peabody No. 10 Mine
693, 1951-1994
Affected Area
Industrial Waste
Peabody Coal Co.
Peabody No. 8 Mine
220, 1914-1954
Powerplant
AUBURN 13 MI.
PAWNEE 4.5 MI.
Peabody Coal Co.
Peabody No. 10 Mine
693, 1951-1994
Mine Map of Affected Area

Tension cracking in embankment crest

Compression heaving in crest of embankment

Depression in embankment crest and downstream slope, tension cracks visible

Geosyntec consultants

1 McBride and Son Center Drive, Suite 202
Chesterfield, MO 63005
PH 636-812-0800
www.geosyntec.com

October 11, 2021

Kincaid Generation, LLC
199 IL-104
Kincaid, Illinois 62540

Subject: USEPA CCR Rule and IEPA Part 845 Rule Applicability Cross-Reference
2021 USEPA CCR Rule Periodic Certification Report
Ash Pond, Kincaid Power Plant, Kincaid, Illinois

At the request of Kincaid Generation, LLC (KG), Geosyntec Consultants (Geosyntec) has prepared this letter to document how the attached 2021 United States Environmental Protection Agency (USEPA) CCR Rule Periodic Certification Report (Report) was prepared in accordance with both the Federal USEPA CCR Rule[1] and the state-specific Illinois Environmental Protection Agency (IEPA) Part 845 Rule[2]. Specific sections of the report and the applicable sections of the USEPA CCR Rule and Illinois Part 845 Rule are cross-referenced in **Table 1**. A certification from a Qualified Professional Engineer for each of the CCR Rule sections listed in **Table 1** is provided in Section 9 of the attached Report. This certification statement is also applicable to each section of the Part 845 Rule listed in **Table 1.**

Table 1 – USEPA CCR Rule and Illinois Part 845 Rule Cross-Reference

Report Section	USEPA CCR Rule		Illinois Part 845 Rule	
3	§257.73 (a)(2)	Hazard Potential Classification	845.440	Hazard Potential Classification Assessment[3]
4	§257.73 (c)(1)	History of Construction	845.220(a)	Design and Construction Plans (Construction History)
5	§257.73 (d)(1)	Structural Stability Assessment	845.450 (a) and (c)	Structural Stability Assessment
6	§257.73 (e)(1)	Safety Factor Assessment	845.460 (a-b)	Safety Factor Assessment
7	§257.82 (a)(1-3)	Adequacy of Inflow Design Control System Plan	845.510(a), (c)(1), (c)(3)	Hydrologic and Hydraulic Capacity Requirements / Inflow Design Flood Control System Plan
	§257.82 (b)	Discharge from CCR Unit	845.510(b)	Discharge from CCR Surface Impoundment

[1] United Stated Environmental Protection Agency, 2015. *40 CFR Parts 257 and 261, Hazardous and Solid Waste Management System, Disposal of Coal Combustion Residuals from Electric Utilities, Final Rule.*
[2] State of Illinois, Joint Committee on Administrative Rule, Administrative Code (2021). *Title 35: Environmental Protection, Subtitle G: Waste Disposal, Chapter I: Pollution Control Board, Subchapter j: Coal Combustion Waste Surface Impoundment, Part 845 Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments.*
[3] "Significant" and "High" hazard, per the CCR Rule[1], are equivalent to Class II and Class I hazard potential, respectively, per Part 845[2].

CLOSING

This letter has been prepared to demonstrate that the content and Qualified Professional Engineer Certification of the 2021 Periodic USEPA CCR Rule Certification Report fulfills the corresponding requirements of Part 845 of Illinois Administrative Code listed in **Table 1**.

Sincerely,

Thomas Ward, P.E.
Senior Engineer

John Seymour, P.E.
Senior Principal

2021 USEPA CCR RULE PERIODIC CERTIFICATION REPORT

§257.73(a)(2)-(3), (c), (d[1]), (e) and §257.82

ASH POND

Kincaid Power Plant

Kincaid, Illinois

Submitted to

Kincaid Generation, LLC

199 IL-104
Kincaid, Illinois 62540

Submitted by

Geosyntec consultants

engineers | scientists | innovators

1 McBride and Son Center Drive, Suite 202
Chesterfield, Missouri 63005

October 11, 2021

[1] Except for §257.73(d)(1)(vi).

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EXECUTIVE SUMMARY

This Periodic United States Environmental Protection Agency (USEPA) Coal Combustion Residuals (CCR) Rule [1] certification report (Periodic Certification Report) for the Ash Pond (AP) at the Kincaid Power Plant (KPP)[2], also known as the Kincaid Power Station (KIN), has been prepared in accordance with Rule 40, Code of Federal Regulations (CFR) §257, herein referred to as the "CCR Rule" [1]. The CCR Rule requires that initial certifications for existing CCR surface impoundment, completed in 2016 and subsequently posted on Kincaid Generation, LLC (KG) CCR Website ([2], [3], [4], [5], [6], [7]), be updated on a five-year basis.

The initial certification reports developed in 2016 and 2017 were independently reviewed by Geosyntec ([2], [3], [4], [5], [6], [7], [8], [9]). Additionally, field observations, interviews with plant staff, updated engineering analyses, and evaluations were performed to compare conditions in 2021 at the Ash Pond relative to the 2016 and 2017 initial certifications. These tasks determined that updates are not required for the Initial Hazard Potential Classification and Initial Safety Factor Assessment. However, due to changes at the site, updates were required and were performed for the:

- History of Construction Report;
- Initial Structural Stability Assessment, and
- Initial Inflow Design Flood Control System Plan.

Geosyntec's evaluations of the initial certification reports and updated analyses determined that the KPP Ash Pond meets all requirements for hazard potential classification, history of construction reporting, structural stability, safety factor assessment, and hydrologic and hydraulic control. **Table 1** provides a summary of the initial 2016 certifications and the updated 2021 periodic certifications.

[2] The Ash Pond is also referred to as ID Number W0218140002-01, Ash Pond by the Illinois Environmental Protection Agency (IEPA); CCR unit ID 141 by KG; and IL50706 within the National Inventory of Dams (NID) maintained by the Illinois Department of Natural Resources (IDNR). Within this document it is referred to as the AP.

Table 1 – Periodic Certification Summary

	CCR Rule Reference	Requirement Summary	2016 Initial Certification		2021 Periodic Certification	
			Requirement Met?	Comments	Requirement Met?	Comments
Hazard Potential Classification						
3	§257.73(a)(2)	Document Hazard Potential Classification	Yes	Impoundment was determined to have "Significant" hazard potential classification [2].	Yes	No changes were identified that may affect this requirement.
History of Construction						
5	§257.73(c)(1)	Compile a History of Construction	Yes	A History of Construction report was prepared for the Ash Pond [4].	Yes	A letter listing updates to the History of Construction report is provided in **Attachment C**.
Structural Stability Assessment						
6	§257.73(d)(1)(i)	Stable Foundations	Yes	Foundations were found to be stable [9].	Yes	No changes were identified that may affect this requirement.
	§257.73(d)(1)(ii)	Adequate Slope Protection	Yes	Slope protection was adequate [9].	Yes	No changes were identified that may affect this requirement.
	§257.73(d)(1)(iii)	Sufficiency of Dike Compaction	Yes	Dike compaction was sufficient for expected ranges in loading conditions [9].	Yes	No changes were identified that may affect this requirement.
	§257.73(d)(1)(iv)	Presence and Condition of Slope Vegetation	Yes	Vegetation was present on exterior slopes and is maintained [9].	Yes	No substantial bare or overgrown areas were observed.
	§257.73(d)(1)(v)(A) and (B)	Adequacy of Spillway Design and Management	Yes	Spillways were adequately designed and constructed and were expected to adequately manage flow during 1,000-year flood [9].	Yes	Spillways were found to be adequately designed and constructed and are expected to manage flow during the 1,000-year flood, after performing updated hydrologic and hydraulic analyses, if the starting water surface elevation does not exceed El. 602.8 ft.
	§257.73(d)(1)(vi)	Structural Integrity of Hydraulic Structures	No	Requirement could not be certified in 2016 due to inability to complete a CCTV inspection of the recycle intake structure pipe. AECOM recommended inspecting this pipe as soon as feasible to address the issue [9].	Periodic certification of §257.73(d)(1)(vi) was performed independently Luminant in 2020 [10].	
	§257.73(d)(1)(vii)	Stability of Downstream Slopes Inundated by Waterbody	Yes	A sudden drawdown factor of safety was determined to satisfy §257.73(d)(1)(vii) [9].	Yes	No changes were identified that may affect this requirement.
Safety Factor Assessment						
7	§257.73€(1)(i)	Maximum storage pool safety factor must be at least 1.50	Yes	The safety factor was calculated to be 1.57 [6].	Yes	No changes were identified that may affect this requirement.
	§257.73€(1)(ii)	Maximum surcharge pool safety factor must be at least 1.40	Yes	The safety factor was calculated to be 1.57 [6].	Yes	No changes were identified that may affect this requirement.
	§257.73(e)(1)(iii)	Seismic safety factor must be at least 1.00	Yes	Safety factor was calculated to be 1.27 [6].	Yes	No changes were identified that may affect this requirement.
	§257.73(e)(1)(iv)	For dike construction of soils that have susceptible to liquefaction, safety factor must be at least 1.20	Not Applicable	Dike soils were not susceptible to liquefaction [6].	Not Applicable	No changes were identified that may affect this requirement.
Inflow Design Flood Control System Plan						
8	§257.82(a)(1), (2), (3)	Adequacy of Inflow Design Control System Plan	Yes	Flood control system adequately managed inflow and peak discharge during the 1,000-year, 24-hour, Inflow Design Flood [9].	Yes	The flood control system was found to adequately manage inflow and peak discharge during the 1,000-year, 24-hour, Inflow Design Flood, after performing updated hydrologic and hydraulic analyses, if the starting water surface elevation does not exceed El. 602.8 ft.
	§257.82(b)	Discharge from CCR Unit	Yes	Discharge from the CCR Unit is routed through an NPDES-permitted outfall during both normal and 1,000-year, 24-hour Inflow Design Flood conditions [7].	Yes	Discharge in pollutants in violation of the NPDES permit were found to not be expected to occur during both normal and 1,000-year, 24-hour Inflow Design Flood conditions, after performing updated hydrologic and hydraulic analyses, if the starting water surface elevation does not exceed El. 602.8 ft.

SECTION 1

INTRODUCTION AND BACKGROUND

This Periodic United States Environmental Protection Agency (USEPA) Coal Combustion Residual (CCR) Rule [1] Certification Report was prepared by Geosyntec Consultants (Geosyntec) for Kincaid Generation, LLC (KG) to document the periodic certification of the Ash Pond (AP) at the Kincaid Power Plant (KPP), also known as the Kincaid Power Station, located at 199 IL-104, Kincaid, Illinois, 62540. The location of KPP is provided in **Figure 1**, and a site plan showing the location of the Ash Pond (AP) is provided in **Figure 2**.

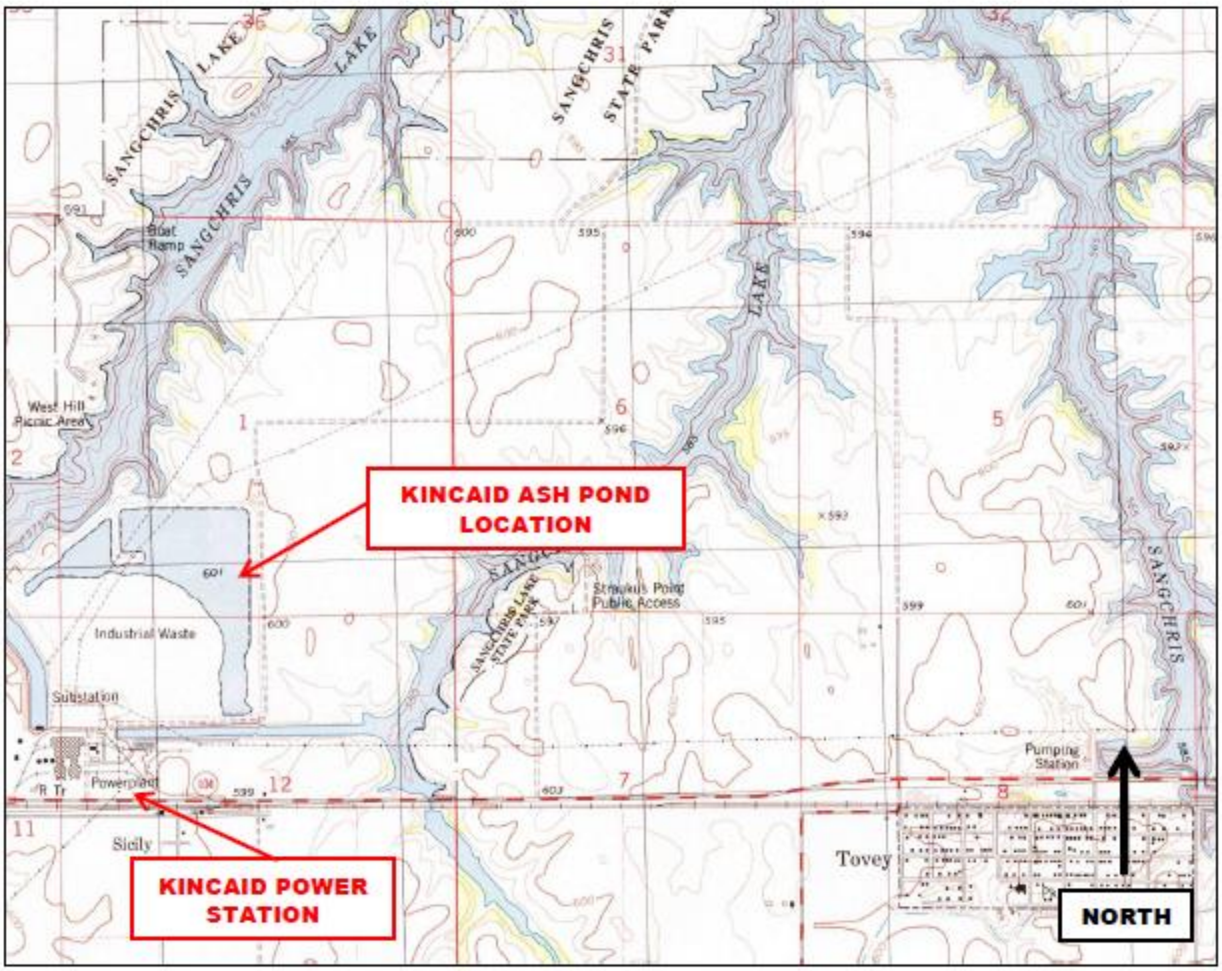

Figure 1 – Kincaid Power Plant Location Map (from AECOM, 2016)

Figure 2 – Kincaid Power Plant Site Plan (adapted from Google Earth Pro, October 2018)

1.1 Ash Pond Description

The Kincaid Ash Pond serves as the wet ash impoundment basin and contains materials such as bottom ash, fly ash, and miscellaneous non-CCR process water from the Kincaid Power Plant. The Kincaid Ash Pond receives sluiced bottom ash from the power plant through eight sluice pipes, which discharge into the southwest side of the basin. A third-party recycling company recovers acceptable ash for beneficial reuse, and unacceptable materials are left in the Kincaid Ash Pond. Due to the volumes of ash removed for beneficial reuse, the quantity of ash within the Kincaid Ash Pond does not significantly change from year to year [9].

Normal outflow from the Kincaid Ash Pond is conveyed into the recycle intake structure (screen house) located at the southeast corner of the embankment. This structure is comprised of a concrete headwall, a fiberglass and steel grating system to control (screen) debris, and a 60-in. diameter reinforced concrete recycle pipe (RCP) with an obvert centerline elevation of 589.45 feet[3], which is used to convey water approximately 2,000 feet westward to the recycle pump house, where it is recycled for use in plant processes or is diverted to the onsite wastewater treatment plant. Outflow

[3] All elevations in this report are in the North American Vertical Datum of 1988 (NAVD88) unless otherwise noted.

from the Kincaid Ash Pond into the recycle pipe is controlled by a steel gate valve installed on the pipe inlet, which can be operated from inside the screen house. A concrete weir is also present in front of the recycle pipe but has a top elevation of 595.21 feet, which is lower than the maximum normal operating pool of the Kincaid Ash Pond (El. 603.3 feet). Therefore, the weir is completely submerged during normal operations [9].

An emergency outlet (effluent) structure is also located at the southeast corner of the impoundment and serves to discharge pond water into the adjacent discharge flume during emergency or upset conditions. The discharge flume feeds into Sangchris Lake. The emergency outlet structure consists of a square concrete riser structure with an exterior steel 3-foot circular gate valve (invert El. 597.21 feet) and opening discharging into the center of the concrete riser structure, which leads into an open 48-inch corrugated metal pipe (CMP) emergency outlet (approximate centerline elevation of 529.5 feet, based on historic drawings). The gate valve can be operated from an access walkway leading to the emergency outlet structure. The top of the emergency outlet structure is open to the Kincaid Ash Pond on three sides, with open dimensions of 3-foot square. The opening effectively acts as a 9-foot-wide overflow weir that is activated when the pool level in the Kincaid Ash Pond exceeds El. 604.3 feet. As the 48-inch CMP is ungated, flow is transmitted freely into the emergency outlet structure when the pond level exceeds El. 604.3 feet and outflows to the discharge flume via the 48-inch CMP, without needing to manually operate the exterior gate valve [9].

An approximately 1,100-foot-long section of the south embankment, adjacent to the discharge flume, has a crest elevation around 6 to 17 feet lower than the rest of the embankment, with typical elevation of 605 ft, and is intended to act as a secondary emergency spillway. Outside of the gravel crest access road and riprap erosion protection at the embankment toe adjacent to the discharge channel, this area is not lined [9].

An engineered liner system is not present beneath the Kincaid Ash Pond. The surface area of the impoundment is approximately 178 acres, and the embankment portion of the Kincaid Ash Pond has a total length of approximately 11,000 feet and a maximum height above the exterior grade of 30 feet. The embankment was constructed as a homogenous earthen structure with well-compacted clayey fill. Portions of the north embankment adjacent to Sangchris Lake include crushed stone near the waterline for erosion protection. The north, northwest, and south embankment sections exhibit approximately 1.4H:1V (horizontal: vertical) downstream slopes, and the south embankment sections near the southeast corner exhibit a 6H:1V slope. Upstream slopes are typically around 3H:1V. Embankment crest width ranges from approximately 10 to 25 feet, and the crest is covered with a gravel access road [9].

As currently operated, the normal pool elevation ranges from 601.8 to 602.5 feet during non-winter conditions. A maximum pool elevation of 603.3 feet may be used during winter conditions to alleviate problems with freezing that may affect flow into the recycle intake structure. Dike crest elevations range from approximately 604.5 to 607 feet for the south embankment and 614 to 622 feet for all other embankments with erosion-resistant material [9].

Initial certifications for the AP for Hazard Potential Classification (§257.73(a)(2)), History of Construction (§257.73(c)), Structural Stability Assessment (§257.73(d)), Safety Factor Assessment (§257.73(e)(1)), and Inflow Design Flood Control System Plan (§257.82) were completed by Stantec and AECOM in 2016 and 2017 and subsequently posted to KG's CCR Website ([2], [3], [4], [5], [6], [7]). Additional documentation for the initial certifications included detailed operating record reports containing calculations and other information prepared for the hazard potential classification by Stantec [8] and for the structural stability assessment, safety factor assessment, and inflow design flood control system plan by AECOM [9]. These operating record reports were not posted to KG's CCR Website.

1.2 Report Objectives

These following are the objectives of this report:

- Compare site conditions from 2015/2016, when the initial certifications were developed, to site conditions in 2020/2021, when data for the periodic certification was obtained, and evaluate if updates are required for the:
    - §257.73(a)(2) Hazard Potential Classification [2];
    - §257.73(c) History of Construction [4];
    - §257.73(d) Structural Stability Assessment [5];
    - §257.73(e) Safety Factor Assessment [6]; and/or
    - §257.82 Inflow Design Flood Control System Plan [7].
- Independently review the Hazard Potential Classification ([2], [8]), Inundation Map [3], Structural Stability Assessment ([5], [9]), Safety Factor Assessment ([6], [9]), and Inflow Design Flood Control System Plan ([7], [9]) reports to assess if updates may be required based on technical considerations.
    - The History of Construction report [4] was not independently reviewed for technical considerations, as this report contained historical information primarily developed prior to promulgation of the CCR Rule [1] for the CCR units at KPP and did not include calculations or other information used to certify performance and/or integrity of the impoundments under §257.73(a)(2)-(3), §257.73(c)-(e), or §257.82.
- If updates are required, they will be performed and documented within this report.

- Confirm that the AP meets all the requirements associated with §257.73(a)(2)-(3), (c), (d), (e), and §257.82, or, if the AP does not meet all requirements, provide recommendations for compliance with these sections of the CCR Rule [1].

SECTION 2

COMPARISON OF INITIAL AND PERIODIC SITE CONDITIONS

2.1 Overview

This section describes the comparison of conditions at the Ash Pond (AP) between the start of the initial CCR certification program in 2015 and 2016 (initial conditions) and subsequent collection of periodic certification site data in 2020 and 2021 (periodic conditions).

2.2 Review of Annual Inspection Reports

Annual onsite inspections for the AP were performed between 2016 and 2020 ([11], [12], [13], [14], [15]) and were certified by a licensed professional engineer in accordance with §257.83(b). Each inspection report stated the following information, relative to the previous inspection:

- A statement that no changes in geometry of the impounding structure were observed since the previous inspection;
- Information on maximum recorded instrumentation readings and water levels;
- Approximate volumes of impounded water and CCR at the time of inspection;
- A statement that no appearances of actual or potential structural weakness or other disruptive conditions were observed; and
- A statement that no other changes which may have affected the stability or operation of the impounding structure were observed.

In summary, the reports did not indicate any significant changes to the Ash Pond between 2015 and 2020. No signs of instability, structural weakness, or changes which may have affected the operation or stability of the AP were noted in the inspection reports.

2.3 Review of Instrumentation Data

Fifteen piezometers are present at the AP and were monitored monthly by KG between August 23, 2015 and June 16, 2021 [16]. These piezometers consist of KIN-P001 through KIN-P012 and PZ-4A through PZ-4C. Geosyntec reviewed the piezometer data to evaluate if significant fluctuations, partially increases in phreatic levels, may have occurred between development of the initial structural stability and factor of safety certifications ([9], [5], [6]) and May 19, 2021. Available piezometer readings are plotted in **Attachment A**.

In summary, only minor changes in phreatic conditions were observed in the available piezometric data. Phreatic levels typically varied by five feet on average. Changes in these phreatic levels do not significantly differ from those utilized in the initial structural stability and factor of safety certifications ([9], [5], [6]).

2.4 Comparison of Initial to Periodic Surveys

The initial survey of the Ash Pond, conducted by Weaver Consultants Group (Weaver) in 2015 [17], was compared to the periodic survey of the AP, conducted by IngenAE, LLC (IngenAE) in 2020 [18], using AutoCAD Civil3D 2021 software. This comparison quantified changes in the volume of CCR placed within the AP and considered volumetric changes above and below the starting water surface elevation (SWSE) used for the 2016 §257.82 inflow design flood control plan hydraulic analysis [9]. Potential changes to embankment geometry were also evaluated. This comparison is presented in a side-by-side view of the surveys in **Drawing 1** and a plan view isopach map denoting changes in ground surface elevation in **Drawing 2**. A summary of the water elevations and changes in CCR volumes is provided in **Table 2**.

Table 2 – Initial to Periodic Survey Comparison

Initial Surveyed Pool Elevation (ft)	602.6
Periodic Surveyed Pool Elevation (ft)	602.4
Initial §257.82 Starting Water Surface Elevation (SWSE) (ft)	603.3
Total Change in CCR Volume (CY)	-77,671
Change in CCR Volume Above SWSE (CY)	-49,042
Change in CCR Volume Below SWSE (CY)	-28,819

The comparison indicated that approximately 78,000 CY of CCR may have been removed from the Ash Pond between the initial and periodic surveys. The periodic survey also indicated dike crest elevations of initial and periodic surveys on the order of two feet lower than the initial survey, with the minimum crest elevation being 604.5 feet, compared to 605.2 ft in the initial survey.

2.5 Comparison of Initial to Periodic Aerial Photography

Initial aerial photographs of the Ash Pond collected by Weaver in 2015 [17] were compared to periodic aerial photographs collected by IngenAE in 2020 [18] to visually evaluate if potential site changes (i.e., changes to the embankment, outlet structures, limits of CCR, other appurtenances) may have occurred. A comparison of these aerial photographs is provided in **Drawing 3**. No significant changes were identified.

2.6 Comparison of Initial to Periodic Site Visits

An initial site visit to the Ash Pond was conducted by AECOM in 2015 and documented with a Site Visit Summary and corresponding photographs [19].

A periodic site visit was conducted by Geosyntec on June 10, 2021, with Mr. Thomas Ward, P.E. and Ms. Crystal Luttrell conducting the site visit. The site visit was intended to evaluate potential changes at the site since the initial certifications were prepared (i.e., modification to the embankment, outlet structures or other appurtenances, limits of CCR, maintenance programs, repairs), in addition to performing visual observations of the AP to evaluate if the structural stability requirements (§257.73(d)) were met. The site visit included walking the perimeter of the

AP, visually observing conditions, recording filed notes, and collecting photographs. The site visit is documented in a field observation form and photographic log provided in **Attachment B**.

2.7 Interview with Power Plant Staff

An interview with Mr. Tim Arnold of KPP was conducted by Mr. Thomas Ward, P.E. and Ms. Crystal Luttrell of Geosyntec on June 10, 2021. Mr. Arnold was employed at KPP between 2019 and 2021 as the manager of environmental, with the responsibility of managing the Ash Pond from an environmental standpoint. The interview included a discussion of potential changes that may have occurred at the Ash Pond since development of the initial certifications ([2], [3], [4], [5], [6], [7]).

A summary of the interview is provided below.

- Were any construction projects completed for the CCR Surface Impoundment since 2015, and, if so, can you please describe the work, reason for the work, and provide any design drawings and/or details available?
    - No.
- Were there any changes to the purpose of the CCR Surface Impoundment since 2015?
    - No.
- Were there any changes to the instrumentation program and/or physical instruments for the CCR Surface Impoundment between 2015 and 2021, and, if so, are records available?
    - No.
- Have any area-capacity curves for the CCR Surface Impoundment been prepared since 2015?
    - No.
- Were there any changes to spillways and/or diversion features for the CCR Surface Impoundment completed since 2015, and, if so, are records available?
    - No.
- Were there any changes to construction specifications, surveillance, maintenance, and repair procedures for the CCR Surface Impoundment since 2015, and, if so, are records available?
    - No.
- Were there any instances of dike and/or structural instability for the CCR Surface Impoundment since 2015, and, if so, are records available?

- No.

SECTION 3

HAZARD POTENTIAL CLASSIFICATION - §257.73(a)(2)

3.1 Overview of Initial HPC

The Initial Hazard Potential Classification (Initial HPC) was prepared by Stantec Consulting Services, Inc. (Stantec) in 2016 ([2], [8]), following the requirements of §257.73(a)(2). The Initial HPC included the following information:

- Performing a breach analysis to evaluate the potential hazards associated with a failure of the AP's perimeter containment dike, along the east embankment and the lowest crest elevation on the AP embankment [2].
- Evaluation of potential breach flow paths were evaluated using elevation data and aerial imagery to evaluate potential impacts to downstream structures, infrastructure, frequently occupied facilities/areas, and waterways [2].
- While a breach map is not included within the Initial HPC, it included within the §257.73(a)(3) Initial Emergency Action Plan [3].

The visual analysis indicated that none of the breach scenarios appeared to impact occupied structures, although a breach of the east embankment could impact an infrequently used gravel site access road and a breach to the north would inundate the leachate pond. The Initial HPC concluded that neither breach would be likely to result in a probable loss of human life, although the breach could cause CCR to be released onto farmland, thereby causing environmental damage. The Initial HPC therefore recommended a "Significant" hazard potential classification for the Ash Pond [2].

3.2 Review of Initial HPC

Geosyntec performed a review of the Initial HPC ([2], [8]) in terms of technical approach, input parameters, assessment of the results, and applicable requirements of the CCR Rule [1]. Some technical issues were noted within the technical review, although a detailed review (e.g., check) of the calculations. The review included the following tasks:

- Review of all report documentation and figures
- Check that correct CCR Rule guidance is referenced and followed
- Review of appropriate failure mode selections
- Review for changes to the site and surrounding area
- Review that appropriate breach analysis methodology, model software, and inputs were utilized
- Check that selected HPC is appropriate per results of the breach analysis

No significant technical issues were noted within the technical review, although a detailed review (e.g., check) of the calculations was not performed.

3.3 Summary of Site Changes Affecting the Initial HPC

Geosytnec recommends retaining the "Significant" hazard potential classification for the Ash Pond, per §257.73(a)(2), based on the lack of site changes potentially affecting the Initial HPC occurring since the Initial HPC was developed, as described in **Section 3.3**, and the lack of significant review comments, as described in **Section 3.2**. Updates to the Initial HPC reports ([2], [8]) are not recommended at this time.

SECTION 4

HISTORY OF CONSTRUCTION REPORT - §257.73(c)

4.1 Overview of Initial HoC

The Initial History of Construction report (Initial HoC) was prepared by AECOM in 2016 [4], following the requirements of §257.73(c), and included information on the CCR surface impoundment, AP, at KPP. The Initial HoC included the following information for the CCR surface impoundment:

- The name and address of the owner/operator,
- Location maps,
- Statements of purpose,
- The names and size of the surrounding watershed,
- A description of the foundation and abutment materials,
- A description of the dike materials,
- Approximate dates and stages of construction,
- Available design and engineering drawings,
- A summary of instrumentation,
- A statement that area-capacity curves are not available,
- Information on spillway structures,
- Construction specifications,
- Inspection and surveillance plans,
- Information on operational and maintenance procedures, and
- A statement that historical structural instability had not occurred at any of the CCR surface impoundments.

4.2 Summary of Site Changes Affecting the Initial HoC

Several significant changes were identified at the site that occurred after development of the Initial HoC report [4] and are described below:

- A state identification number (ID) of W0218140002-01 was assigned to the AP by the Illinois Environmental Protection Agency (IEAP).

- Revised area-capacity curves and spillway design calculations for the AP were prepared as part of the Periodical Inflow Design Flood Control System Plan Assessment, as described in **Section 7.**

A letter documenting changes to the HoC report is provided in **Attachment C**.

SECTION 5

STRUCTURAL STABILITY ASSESSMENT - §257.73(d)

5.1 Overview of Initial SSA

The Initial Structural Stability Assessment (Initial SSA) was prepared by AECOM in 2016 ([5], [9]), following the requirements of §257.73(d)(1), and included the following evaluations:

- Stability of dike foundations, slope protection, dike compaction, and slope vegetation,
- Spillway stability including capacity, structural stability and integrity; and
- Downstream slope stability under sudden drawdown conditions for a downstream water body.

The Initial SSA concluded that the AP met all structural stability requirements for §257.73(d)(1)(i) through (v) and (vii), but recommended inspection of the recycle intake structure pipe in the southeast corner of the AP in order to verify that the AP meets the stability and structural integrity criteria for hydraulic outfall structures, per §257.73(d)(1)(vi). An inspection of this intake pipe was not previously performed due to high pipe flows required for operation precluding closed-circuit television (CCTV) inspections.

A periodic certification of the structural stability and structural integrity for hydraulic outfall structures (§257.73(d)(1)(vi)) was performed by Luminant in 2020 [10]. This certification independently determined that the criteria was met due to the condition of the spillway pipes and the soil types within the embankment. Therefore, the review and certification of §257.73(d)(1)(vi) is not included within the scope of this report.

The Initial SSA referenced the results of the Initial Structural Factor Assessment (Initial SFA) ([6], [9]), to demonstrate stability of the stability of foundations and abutments (§257.73(d)(1)(i)) and sufficiency of dike compaction (§257.73(d)(1)(iii)) portions of the SSA criteria. This included stating that slope stability analyses for slip surfaces passing through the foundation met or exceeded the criteria listed in §257.73(e)(1), for the stability of foundations and abutments. For the sufficiency of dike compaction, this included stating that slope stability analyses for slip surfaces passing through the dike also met or exceeded the §257.73(e)(1) criteria.

Additionally, the Initial SSA included a sudden drawdown slope stability analysis to evaluate the effect of a drawdown event in adjacent Sangchris Lake from normal pool to empty pool, as required by §257.73(d)(1)(vii) for CCR units where the downstream slopes are inundated by an adjacent water body. The minimum factor of safety for this loading condition was assumed to be 1.3 based on U.S. Army Corps of Engineers guidance [20].

5.2 Review of Initial SSA

Geosyntec performed a review of the Initial SSA ([5], [9]) in terms of technical approach, calculation input parameters and methodology, recommendations, and completeness. The review included the following tasks:

- Review of photographs collected in 2015 and used to demonstrate compliance with §257.73(d)(1)(i)-(vii).
- Reviewing geotechnical calculations used to demonstrate the stability of foundations, per §257.73(d)(1)(i); sufficiency of dike compaction, per §257.73(d)(1)(iii); and downstream slope stability, per §257.73(d)(1)(vii). Supporting geotechnical investigation and testing data, input parameters, analysis methodology, selection of critical cross-sections, and loading conditions were reviewed.
- Review of the methodology used to demonstrate that a downstream water body that could induce a sudden drawdown condition, per §257.73(d)(1)(vii), is not present.

No significant technical issues were noted within the technical review of the Initial SSA, although a detailed review (e.g., check) of the calculations was not performed.

5.3 Summary of Site Changes Affecting the Initial SSA

One change at the site that occurred after development of the Initial SSA was identified. This change required an update to the Initial SSA and is described below:

- The Initial SSA utilized the results of the Initial Inflow Design Flood Control System Plan (IDF) to demonstrate compliance with the adequacy of spillway design and management (§257.73(d)(1)(v)(A)-(B)). The Initial IDF was subsequently updated to develop a Periodic IDF, based on site changes, as discussed in **Section 7**.

5.4 Periodic SSA

The Periodic IDF (**Section 7**) indicates that spillways are adequately designed and constructed to adequately manage flow during the 1,000-year flood, as the spillways can adequately manage flow during peak discharge from the 1,000-year storm event without overtopping of the embankments. Therefore, the requirements of §257.73(d)(1)(v)(A)-(B) are met for the Periodic SSA.

Certification of §257.73(d)(1)(vi) was independently performed by Luminant [10].

SECTION 6

SAFETY FACTOR ASSESSMENT - §257.73(e)(1)

6.1 Overview of Initial SFA

The Initial Safety Factor Assessment (Initial SFA) was prepared by AECOM in 2016 ([6], [9]), following the requirements of §257.73(e)(1). The Initial SFA included the following information:

- A geotechnical investigation program with in-situ and laboratory testing;
- An assessment of the potential for liquefaction in the dike and foundation soils;
- The development of five slope stability cross-sections for limit equilibrium stability analysis utilizing GeoStudio SLOPE/W software; and
- The analysis of the critical cross-sections for maximum storage pool, maximum surcharge pool, and seismic loading conditions.
    - Liquefaction loading conditions were evaluated via post-earthquake analysis as liquefaction-susceptible soil layers were identified in the soft clay layer located between the foundation clay and glacial till layer in the Kincaid Ash Pond.

The Initial SFA concluded that the Ash Pond met all safety factor requirements, per §257.73(e), as all calculated safety factors were equal to or higher than the minimum required values.

6.2 Review of Initial SFA

Geosyntec performed a review of the Initial SFA ([6], [9]) in terms of technical approach, calculation input parameters and methodology, recommendations, and completeness. The review included the following tasks:

- Reviewing geotechnical calculations used to demonstrate the acceptable safety factors, per §257.73(e)(1), in terms of:
    - Completeness and adequacy of supporting geotechnical investigation and testing data;
    - Completeness and approach of liquefaction triggering assessments; and
    - Analyzed loading conditions relative to the applicable CCR Rule [1] requirements and site-specific conditions.
    - Input parameters, analysis methodology, selection of critical cross-sections, loading conditions, and piezometric/groundwater levels utilized for slope stability analyses.

- Reviewing the contents vs. the applicable CCR Rule requirements [1].

No significant technical issues were noted within the technical review, although a detailed review (e.g., check) of the calculations was not performed.

6.3 Summary of Site Changes Affecting the Initial SFA

No changes since development of the Initial SFA were identified that would require updates to the Initial SFA ([6], [9]). Although normal and peak (i.e., flood) water levels within the AP have changed as a result of the Periodic IDF (**Section 7**), water levels are lower than those utilized in the Initial SFA. Therefore, the water levels utilized in the Initial SFA are conservative relative to current conditions.

SECTION 7

INFLOW DESIGN FLOOD CONTROL SYSTEM PLAN - §257.82

7.1 Overview of Initial IDF

The Initial Inflow Design Flood Control System Plan (Initial IDF) was prepared by AECOM in 2016 ([7], [9]), following the requirements of §257.82. The Initial IDF included the following information:

- A hydraulic and hydrologic analysis, performed for the 1,000-year design flood event because of the hazard potential classification of "Significant", which corresponded to 8.08 inches of rainfall over a 24-hour period.

- The Initial IDF utilized a HydroCAD (Version 10) model to evaluate spillway flows and pool level increases during the design flood, with a SWSE of 603.3 feet.

The Initial IDF concluded that the Ash Pond met the requirements of §257.82, as the peak water surcharge elevation estimated by the HydroCAD model was 605.1 feet, relative to a minimum Ash Pond dike crest elevation of 605.2 feet. Therefore, overtopping was not expected. The Initial IDF also evaluated the potential for discharge from the CCR unit and concluded that discharge in violation of the existing NDPES for the Ash Pond was not expected, as all discharge from the Ash Pond during both normal and inflow design flood conditions was expected to be routed back to KPP for use in plant operations, is discharged via a NPDES-permitted outfall after treatment or is routed through the emergency outlet structure and NDPES-permitted outfall to Sangchris Lake [7].

7.2 Review of Initial IDF

Geosyntec performed a review of the Initial IDF ([7], [9]) in terms of technical approach, calculation input parameters and methodology, recommendations, and completeness. The review included the following tasks:

- Reviewing the return interval used vs. the hazard potential classification,

- Reviewing the rainfall depth and distribution for appropriateness,

- Performing a high-level review of the inputs to the hydrological modeling,

- Reviewing the hydrologic model parameters for spillway parameters, starting pool elevation, and storage vs. the reference data, and

- Reviewing the overall Initial IDF vs. the applicable requirements of the CCR Rule [1].

Several comments were identified during review of the Initial IDF. The comments are described below:

- The Initial IDF utilized the National Resource Conservation Service (NRCS) Type II rainfall distribution type [21]. Geosyntec recommends utilizing the Huff 3rd Quartile distribution for areas less than 10 square miles [22] for the reasons listed below.

  - Huff 3rd Quartile distribution was identified to be a more appropriate representation of a 1,000-year, 24-hour storm event per the Illinois State Water Survey (ISWS) Circular 173 [22] which developed standardized rainfall distributions from compiled rainfall data at sites throughout Illinois.

  - Illinois Department of Natural Resources, Office of Water Resources (IDNR-OWR) [23] recommends use of the Huff Quartile distributions in Circular 173 when using frequency events to determine the spillway design flood inflow hydrograph, "*The suggested method to distribute this rainfall is described in the ISWS publication, Circular 173, "Time Distributions of Heavy Rainstorms in Illinois".*

7.3 Summary of Site Changes Affecting the Initial IDF

Two changes at the site that occurred since development of the Initial IDF were identified. These changes required updates to the Initial IDF and are described below:

- The minimum elevation of the perimeter dike is estimated to be 604.5 feet based on the 2020 survey [18], which is 0.7 ft lower than the El. 605.2 ft perimeter dike elevation estimated from the 2015 survey [17].

- Approximately 78,000 CY of CCR were removed above the SWSE utilized for the Initial IDF certification, thereby altering the stage-storage curve, relative to the Initial IDF.

7.4 Periodic IDF

Geosyntec revised the HydroCAD model associated with the Initial IDF to account for the changes in the drainage area, changes in the time of concentration, changes in CCR volume, revised rainfall distribution type, and changes in the lowest point of the perimeter dike elevation, as described in **Section 7.3**.

The following approach and input data were used for the revised analyses:

- The SWSE was lowered from El. 603.3 ft to El. 602.8 ft, in order to provide additional capacity.

- The AP drainage area was updated from 178 acres to 171 acres to reflect the 2020 site survey.

- Time of concentration was updated from 5 minutes to 6 minutes in accordance with the recommended minimum time of concentration for direct entry of rainfall [24].

- The stage-storage (i.e., area-capacity) curve for the AP was updated based on the 2020 site survey [18].
    - A revised stage-volume curve for the AP was prepared based on measuring the storage volume of the AP at every one-foot increment of depth from an elevation at the bottom of the AP (594 ft) to the approximate minimum perimeter dike embankment crest elevation (605 ft). This analysis identified an overall increase of 90,378 CY (56 ac-ft) of storage volume at the AP from the storage used in the 2016 Initial IDF Certification.
- The rainfall distribution type was updated to the "Huff 3rd Quartile" storm type provided by HydroCAD [22].
- The minimum dike crest elevation was updated from 605.2 ft to 604.5 ft based on the 2020 site survey.
- All other input data and settings from the Initial IDF HydroCAD model were utilized, including, but not limited to software package and version, runoff method, analysis time span and analysis time step.

The results of the Periodical IDF Assessment are summarized in **Table 3** and confirm that the AP sill meets the requirements of §257.82(a)-(b) if the SWSE is maintained no higher than El. 602.8 ft, as the peak water surface elevation does not exceed the minimum perimeter dike crest elevations. Additionally, all discharge from the AP is routed through the existing spillway system to the NPDES-permitted outfall, during both normal and IDF conditions. Updated area-capacity curves and HydroCAD model output is provided in **Attachment D**.

Table 3 – Water Levels from Periodical IDF Assessment

Analysis	Starting Water Surface Elevation (ft)	Peak Water Surface Elevation (ft)	Minimum Dike Crest Elevation (ft)
Initial IDF	603.3	605.1	605.2
Periodical IDF Assessment	602.8	604.4	604.5
Initial to Periodic Change[1]	-0.5	-0.7	

Notes:
[1]Postive change indicates increase in the WSE, negative change indicates decrease in the WSE.

SECTION 8 CONCLUSIONS

The Ash Pond at KPP was evaluated relative to the USEPA CCR Rule periodic assessment requirements for:

- Hazard potential classification (§257.73(a)(2));
- History of Construction reporting (§257.73(d));
- Structural stability assessment (§257.73(d)) with the exception of §257.73(d)(1)(vi) that was independently certified by Luminant [10], and considering a starting water surface elevation no higher than El. 602.8 ft;
- Safety factor assessment (§257.73(e)); and
- Inflow design flood control system planning (§257.82), if the starting water surface elevation does not exceed El. 602.8 ft.

Based on the evaluations presented herein, the referenced requirements are satisfied.

SECTION 9

CERTIFICATION STATEMENT

CCR Unit: Kincaid Generation, LLC, Kincaid Power Plant, Ash Pond

I, Thomas W. Ward, being a Registered Professional Engineer in good standing in the State of Illinois, do hereby certify, to the best of my knowledge, information, and belief that the information contained in this 2021 USEPA CCR Rule Periodic Certification Report, has been prepared in accordance with the accepted practice of engineering. I certify, for the above-referenced CCR Unit, that the periodic assessment of the hazard potential classification, history of construction report, structural stability, safety factors, and inflow design flood control system planning, dated October 2016, were conducted in accordance with the requirements of 40 CFR §257.73(a)(2), (c), (d), (e), and §257.82, with the exception of §257.73(d)(1)(vi)) that was independently certified by others.

Thomas W. Ward

10/11/21

Date

Exp. 11/30/2021

SECTION 10

REFERENCES

[1] United States Environmental Protection Agency, 40 CFR Parts 257 and 261; Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities; Final Rule, 2015.

[2] Stantec Consulting Services, Inc., "Initial Hazard Potential Classification Assessment, EPA Final CCR Rule, Ash Pond, Kincaid Power Station, Christian County, Illinois," Fenton, MO, October 12, 2016.

[3] Stantec Consulting Services, Inc., "Kincaid Generation, LLC, Kincaid Power Station, Kincaid, Christian County, IL, Emergency Action Plan, Ash Pond (NID # IL50706)," Fenton, MO, April 13, 2017.

[4] AECOM, "History of Construction, USEPA Final CCR Rule, Kincaid Power Station, Kincaid, Illinois," October 2016.

[5] AECOM, "CCR Rule Report: Initial Structural Stability Assessment For Kincaid Ash Pond At Kincaid Power Station," St. Louis, MO, October 2016.

[6] AECOM, "CCR Rule Report: Initial Safety Factor Assessment For Kincaid Ash Pond At Kincaid Power Station," St. Louis, MO, October 2016.

[7] AECOM, "CCR Rule Report: Initial Inflow Design Flood Control System Plan For Kincaid Ash Pond At Kincaid Power Station," St. Louis, MO, October 2016.

[8] Stantec Consulting Services, Inc., "Documentation of Initial Hazard Potential Classificaiton Assessment, Ash Pond, Kincaid Power Station, Christian County, Illinois," October 12, 2016.

[9] AECOM, "CCR Certification Report: Initial Structural Stability Assessment, Initial Safety Factor Assessment, and Initial Inflow Design Flood Control System Plan for Kincaid Ash Pond at Kincaid Power Station," St. Louis, MO, October 2016.

[10] V. Modeer, *Office Memorandum: Ash Pond Structural Stability Assessment, Kincaid Generation, LLC, Kincaid Power Station*, Luminant, 2020.

[11] J. Knutelski and J. Campbell, *Annual CCR Surface Impoundment Inspection Report (per 40 CFR 257.83(b)(2)), Kincaid Power Station, Ash Pond*, August 30, 2016.

[12] J. Knutelski and J. Campbell, *Annual CCR Surface Impoundment Inspection Report (per 40 CFR 257.83(b)(2)), Kincaid Power Station, Ash Pond*, June 24, 2015.

[13] J. Knutelski, *Annual Inspection by a Qualified Professional Engineer, 40 CFR §257.83(b), Kincaid Generation, Ash Pond,* January 10, 2019.

[14] J. Knutelski, *Annual Inspection by a Qualified Professional Engineer, 40 CFR 257.83(b), Kincaid Generation, Ash Pond,* January 10, 2020.

[15] J. Knutelski, *Annual Inspection by a Qualified Professional Engineer, 40 CFR §257.83(b), Kincaid Generation, Ash Pond*, January 6, 2021.

[16] Kincaid Power Station, *2021 Piezometer Spreadsheet*, 2021.

[17] Weaver Consultants Group, "Dynegy, Collinsville, IL, 2015 - Kincaid Topography," Collinsville, IL, December 2015.

[18] IngenAE, "Luminant, Kincaid Generation, LLC, Kincaid Power Station, December 2020 Topography," Earth City, Missouri, February 26, 2021.

[19] AECOM, "Initial Station Site Visit Summary, Dynegy CCR Compliance Program," June 24, 2015.

[20] U.S. Army Corps of Engineers, "Slope Stability, EM 1110-2-1920," October 31, 2003.

[21] C. E. D. Natural Resource Conservation Service, "Urban Hydrology for Small Watersheds (TR-55)," United States Department of Agriculture, 1985.

[22] State of Illinois Department of Energy and Natural Resources, "Time Distributions of Heavy Rainstorms in Illinois," State Water Survey Division, Champaign, Illinois, 1990.

[23] State of Illinois Department of Natural Resources, "Procedural Guidelines for Preparation of Technical Data to be Included in Applications for Permits for Construction and Maintenance of Dams," Springfield, Illinois.

[24] USDA Natural Resources Conservation Service, "WinTR-20 Project Formulation Hydrology, Version 3.20".

DRAWINGS

INITIAL SURVEY
12-01-2015 TOPOGRAPHY

PERIODIC SURVEY
02-26-2021 TOPOGRAPHY

0 500
SCALE IN FEET

NOTES:

1. THE INITIAL SURVEY WAS TAKEN FROM THE DRAWING PACKAGE TITLED "DYNEGY, COLLINSVILLE, ILLINOIS, 2015 - KINCAID TOPOGRAPHY", PREPARED BY WEAVER CONSULTANTS GROUP, DATED DECEMBER 1, 2015.
2. THE PERIODIC SURVEY WAS TAKEN FROM THE DRAWING PACKAGE TITLED "LUMINANT, KINCAID GENERATION, LLC, KINCAID POWER STATION, DECEMBER 2020 TOPOGRAPHY", PREPARED BY INGENAE, DATED FEBRUARY 26, 2021.
3. ALL SURVEY DATA WAS COLLECTED IN THE NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD88) AND NORTH AMERICAN DATUM OF 1983 (NAD83) FOR VERTICAL AND HORIZONTAL COORDINATES, RESPECTIVELY.

INITIAL TO PERIODIC SURVEY COMPARISON ASH POND KINCAID POWER PLANT KINCAID, ILLINOIS	
Geosyntec consultants	DRAWING 1
GLP8027.07 JULY 2021	

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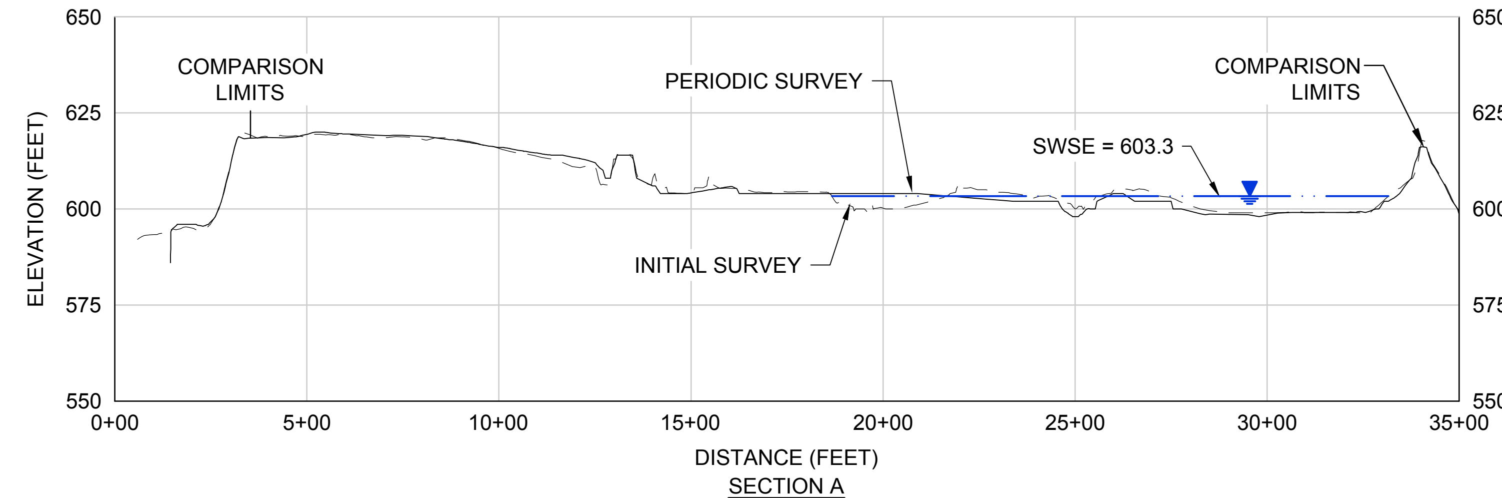

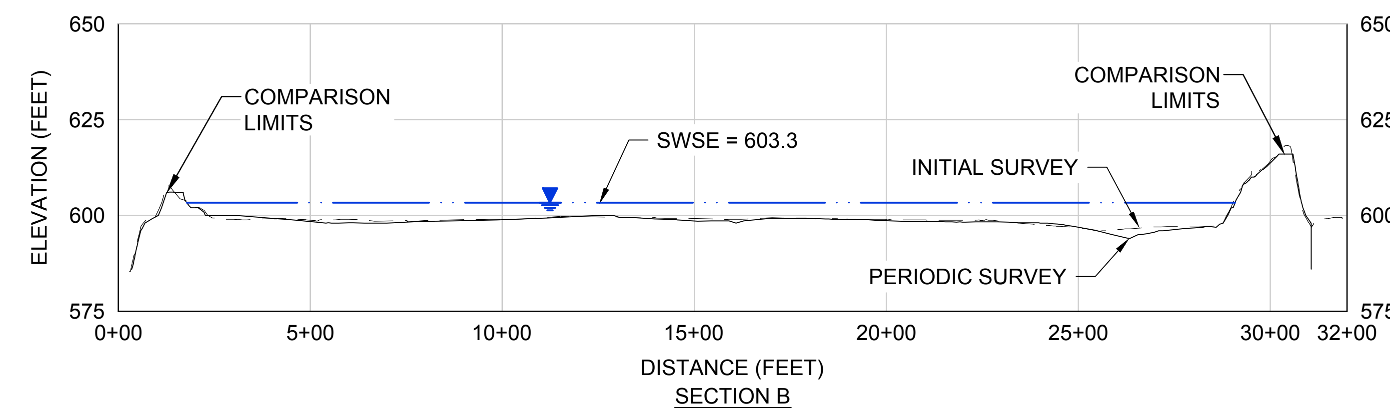

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VERT: SCALE IN FEET

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HORZ: SCALE IN FEET

ISOPACH CONTOUR KEY		
COLOR	MIN ELEV	MAX ELEV
(purple)	-32	-10
(light purple)	-10	-8
(blue)	-8	-6
(cyan)	-6	-4
(green)	-4	-2
(light green)	-2	0
(dark green)	0	2
(yellow)	2	4
(orange)	4	6
(magenta)	6	8
(pink)	8	10
(red)	10	12

NOTES:

1. THE INITIAL SURVEY WAS TAKEN FROM THE DRAWING PACKAGE TITLED "DYNEGY, COLLINSVILLE, ILLINOIS, 2015 - KINCAID TOPOGRAPHY", PREPARED BY WEAVER CONSULTANTS GROUP, DATED DECEMBER 1, 2015.
2. THE PERIODIC SURVEY WAS TAKEN FROM THE DRAWING PACKAGE TITLED "LUMINANT, KINCAID GENERATION, LLC, KINCAID POWER STATION, DECEMBER 2020 TOPOGRAPHY", PREPARED BY INGENAE, DATED FEBRUARY 26, 2021.
3. ALL SURVEY DATA WAS COLLECTED IN THE NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD88) AND NORTH AMERICAN DATUM OF 1983 (NAD83) FOR VERTICAL AND HORIZONTAL COORDINATES, RESPECTIVELY.
4. THE STARTING WATER SURFACE ELEVATION (SWSE) OF THE KINCAID ASH POND IS EL. 603.3 FT, AS NOTED IN THE REPORT TITLED "CCR CERTIFICATION REPORT: INITIAL STRUCTURAL STABILITY ASSESSMENT, INITIAL SAFETY FACTOR ASSESSMENT, AND INITIAL INFLOW DESIGN FLOOD CONTROL SYSTEM PLAN FOR KINCAID ASH POND AT KINCAID POWER STATION", PREPARED BY AECOM, DATED OCTOBER, 2016.

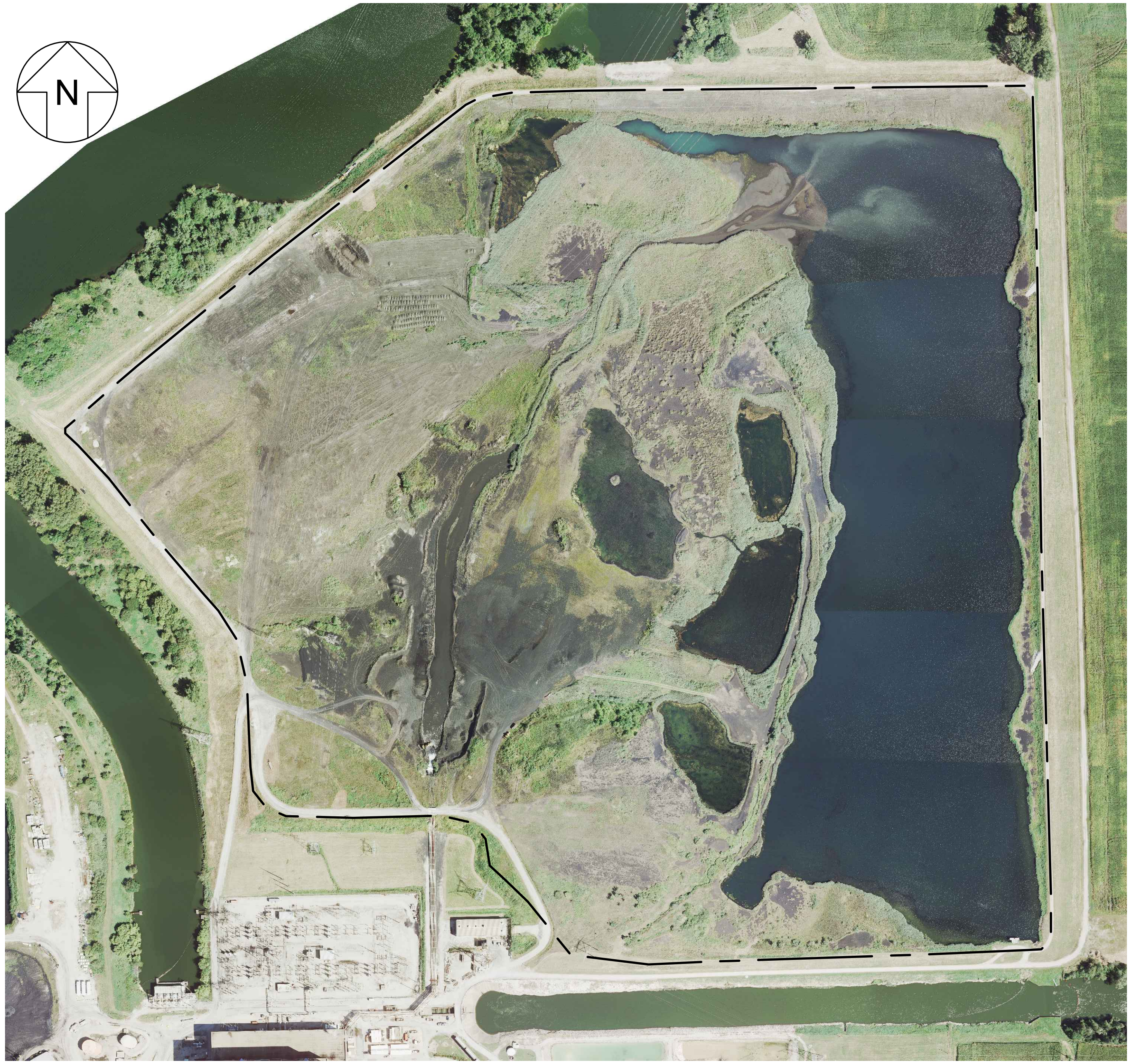
INITIAL TO PERIODIC SURVEY COMPARISON SUMMARY			
SURFACE IMPOUNDMENT	CUT	FILL	NET (CU. YD.)
ASH POND	172,876	95,205	77671 (CUT)
ABOVE SWSE	116,014	66,972	49,042 (CUT)
BELOW SWSE	56,953	28,133	28,819 (CUT)

SURVEY COMPARISON ISOPACH ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

Geosyntec consultants

DRAWING 2

GLP8027.07 | JULY 2021



INITIAL AERIAL
12-01-2015 IMAGERY

PERIODIC AERIAL
02-26-2021 IMAGERY

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SCALE IN FEET

NOTES:

1. THE INITIAL IMAGERY WAS TAKEN FROM THE DRAWING PACKAGE TITLED "DYNEGY, COLLINSVILLE, ILLINOIS, 2015 - KINCAID TOPOGRAPHY", PREPARED BY WEAVER CONSULTANTS GROUP, DATED DECEMBER 1, 2015.
2. THE PERIODIC IMAGERY WAS TAKEN FROM THE DRAWING PACKAGE TITLED "LUMINANT, KINCAID GENERATION, LLC, KINCAID POWER STATION, DECEMBER 2020 TOPOGRAPHY", PREPARED BY INGENAE, DATED FEBRUARY 26, 2021.

INITIAL TO PERIODIC AERIAL IMAGERY COMPARISON
ASH POND
KINCAID POWER PLANT
KINCAID, ILLINOIS

Geosyntec consultants

GLP8027.07	MAY 2021	DRAWING 3

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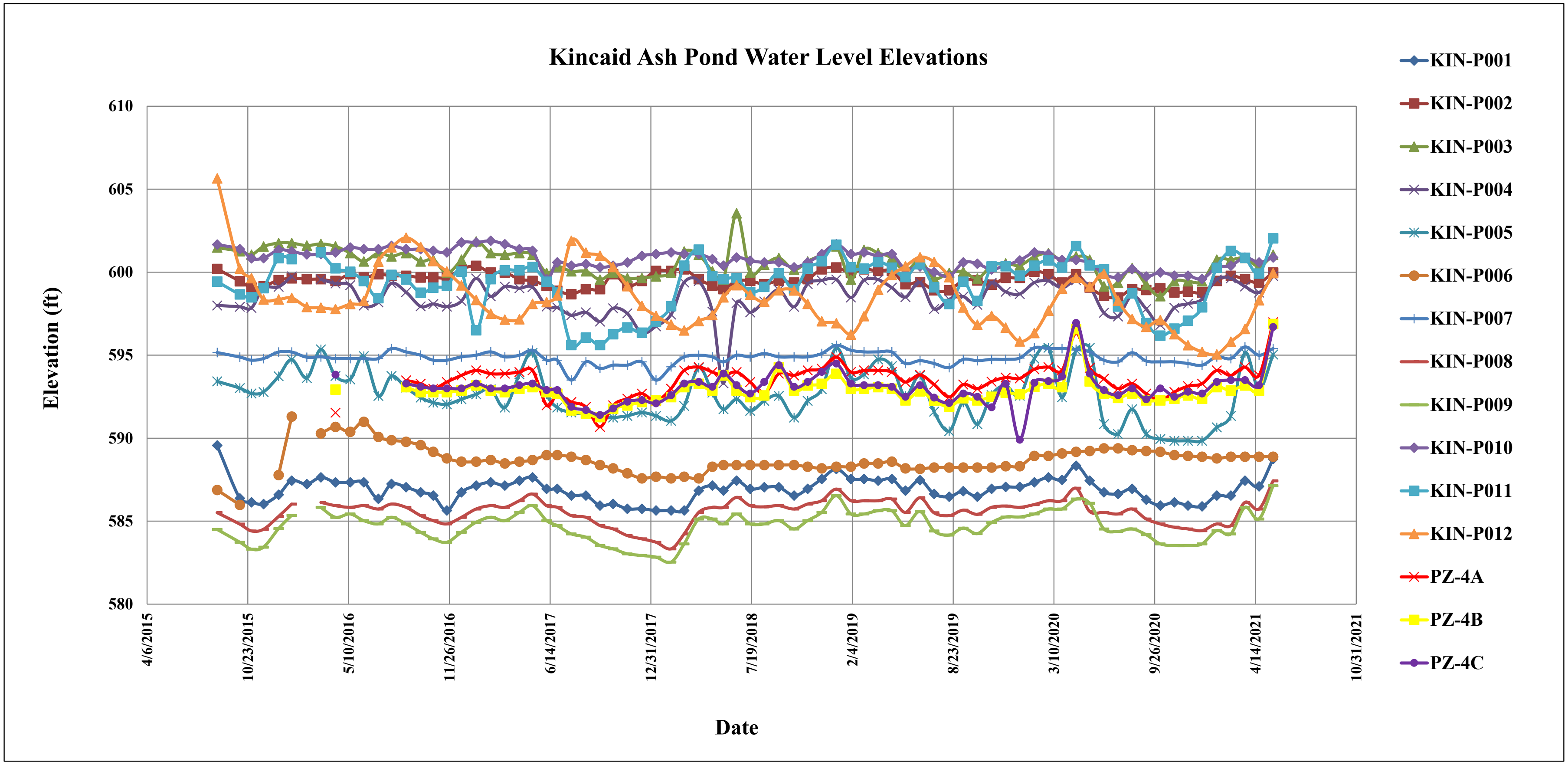
ATTACHMENTS

Attachment A

Ash Pond Piezometer Data Plots



NOTES:
1. Piezometer data was taken from the spreadsheet titled "2021 Piezometer Spreadsheet", provided by the Kincaid Power Station.

PIEZOMETER DATA PERIODIC CERTIFICATION KINCAID POWER STATION KINCAID, ILLINOIS		
Geosyntec consultants		ATTACH. A
GLP8027	6/24/2021	

Attachment B

Ash Pond Site Visit Photolog

GEOSYNTEC CONSULTANTS
Photographic Record

Site Owner: Kincaid Generation, LLC	**Project Number:** GLP8027
CCR Unit: Ash Pond	**Site Location:** Kincaid Power Plant

Photo: 01

Date: 06/10/2021

Direction Facing: West

Comments: Typical crest along the southern berm, north of the power station.

Photo: 02

Date: 06/10/2021

Direction Facing: South

Comments: Power station south of the ash pond.

GEOSYNTEC CONSULTANTS
Photographic Record

Site Owner: Kincaid Generation, LLC	**Project Number:** GLP8027
CCR Unit: Ash Pond	**Site Location:** Kincaid Power Plant

Photo: 03

Date: 06/10/2021

Direction Facing: West

Comments: Crest view of steep and uneven slopes of the southern berm, north of the power plant. Slopes previously noted in the initial site investigation by AECOM and not considered a change in site conditions.

Photo: 04

Date: 06/10/2021

Direction Facing: West

Comments: Erosion rills and bulging at southern berm toe. Straw laid. Slopes previously noted in the initial site investigation by AECOM and not considered a change in site conditions.

GEOSYNTEC CONSULTANTS
Photographic Record

Site Owner: Kincaid Generation, LLC	**Project Number:** GLP8027
CCR Unit: Ash Pond	**Site Location:** Kincaid Power Plant

Photo: 05

Date: 06/10/2021

Direction Facing: Northeast

Comments: 4- to 6-inch wide apparent animal borrows on slope. Straw laid in the area.

Photo: 06

Date: 06/10/2021

Direction Facing: West

Comments: Crest view of southern berm.

GEOSYNTEC CONSULTANTS
Photographic Record

Site Owner: Kincaid Generation, LLC	**Project Number:** GLP8027
CCR Unit: Ash Pond	**Site Location:** Kincaid Power Plant

Photo: 07

Date: 06/10/2021

Direction Facing: South

Comments: Typical perimeter berm slope along north-south access road.

Photo: 08

Date: 06/10/2021

Direction Facing: Northwest

Comments: Typical southwest perimeter berm slope. Slope is steep with some irregularities and some depressions. Slopes previously noted in the initial site investigation by AECOM and not considered a change in site conditions.

GEOSYNTEC CONSULTANTS
Photographic Record

Geosyntec consultants

Site Owner: Kincaid Generation, LLC	**Project Number:** GLP8027
CCR Unit: Ash Pond	**Site Location:** Kincaid Power Plant

Photo: 09

Date: 06/10/2021

Direction Facing: Northwest

Comments: Location of settlement noted in the History of Construction (AECOM, 2016) and mitigated at the southwestern berm crest. No indication of settlement observed during this site observation.

Photo: 10

Date: 06/10/2021

Direction Facing: Southwest

Comments: 6-foot wide by 8-inch deep depression along the southwestern berm roughly 400 feet northwest of KIN-P006. Slopes previously noted in the initial site investigation by AECOM and not considered a change in site conditions.

GEOSYNTEC CONSULTANTS
Photographic Record

Site Owner: Kincaid Generation, LLC	**Project Number:** GLP8027
CCR Unit: Ash Pond	**Site Location:** Kincaid Power Plant

Photo: 11

Date: 06/10/2021

Direction Facing: Northeast

Comments: Typical northwestern perimeter berm slope. Slopes are steep with areas of irregularity. Slopes previously noted in the initial site investigation by AECOM and not considered a change in site conditions.

Photo: 12

Date: 06/10/2021

Direction Facing: Southeast

Comments: Steep slope and minor depression at the edge of the crest. Located roughly 800 feet southwest of KIN-P007. See Photo 13. Slopes previously noted in the initial site investigation by AECOM and not considered a change in site conditions.

GEOSYNTEC CONSULTANTS

Site Owner: Dynegy Kincaid Generation, LLC	**Project Number:** GLP8027
CCR Unit: Ash Pond	**Site Location:** Kincaid Power Plant

Photo: 13

Date: 06/10/2021

Direction Facing: Southwest

Comments: Crest view of depression and steep slope. Slopes previously noted in the initial site investigation by AECOM and not considered a change in site conditions.

Photo: 14

Date: 06/10/2021

Direction Facing: Southeast

Comments: Steep slope and 8-foot by 6-inch depression located roughly 400 feet southwest of KIN-P007. Slopes previously noted in the initial site investigation by AECOM and not considered a change in site conditions.

GEOSYNTEC CONSULTANTS
Photographic Record

Site Owner: Kincaid Generation, LLC	**Project Number:** GLP8027
CCR Unit: Ash Pond	**Site Location:** Kincaid Power Plant

Photo: 15

Date: 06/10/2021

Direction Facing: Southwest

Comments: Disturbed area from apparent monitoring well installation.

Photo: 16

Date: 06/10/2021

Direction Facing: Northeast

Comments: Steep slope along the northwestern portion of the ash pond where the riverside bench is minimal. Slopes previously noted in the initial site investigation by AECOM and not considered a change in site conditions.

GEOSYNTEC CONSULTANTS
Photographic Record

Site Owner: Kincaid Generation, LLC	**Project Number:** GLP8027
CCR Unit: Ash Pond	**Site Location:** Kincaid Power Plant

Photo: 17

Date: 06/10/2021

Direction Facing: Northeast

Comments: Apparent riprap buttress along perimeter berm slope located along the northwestern portion of the ash pond where the riverside bench is minimal. The riprap appears to have been overgrown.

Photo: 18

Date: 06/10/2021

Direction Facing: Northeast

Comments: Riprap erosion protection.

GEOSYNTEC CONSULTANTS
Photographic Record

Site Owner: Kincaid Generation, LLC **Project Number:** GLP8027

CCR Unit: Ash Pond **Site Location:** Kincaid Power Plant

Photo: 19

Date: 06/10/2021

Direction Facing: Northeast

Comments: 20-foot long / wide depression of the perimeter berm slope located along the northwestern portion of the ash pond where the riverside bench is minimal. Slopes previously noted in the initial site investigation by AECOM and not considered a change in site conditions.

Photo: 20

Date: 06/10/2021

Direction Facing: Southwest

Comments: Typical crest view of northwestern perimeter berm.

GEOSYNTEC CONSULTANTS
Photographic Record

Geosyntec consultants

Site Owner: Kincaid Generation, LLC	**Project Number:** GLP8027
CCR Unit: Ash Pond	**Site Location:** Kincaid Power Plant

Photo: 21

Date: 06/10/2021

Direction Facing: Northeast

Comments: Typical crest view of northern perimeter berm.

Photo: 22

Date: 06/10/2021

Direction Facing: Northeast

Comments: Typical toe view of northern perimeter berm.

Site Owner: Kincaid Generation, LLC	**Project Number:** GLP8027
CCR Unit: Ash Pond	**Site Location:** Kincaid Power Plant

Photo: 23

Date: 06/10/2021

Direction Facing: South

Comments: Toe view of depressions and bulging along northern perimeter berm. Slopes previously noted in the initial site investigation by AECOM and not considered a change in site conditions.

Photo: 24

Date: 06/10/2021

Direction Facing: N/A

Comments: Straw and gravel filling on toe along northern perimeter berm.

GEOSYNTEC CONSULTANTS
Photographic Record

Site Owner: Dynegy Kincaid Generation, LLC	**Project Number:** GLP8027
CCR Unit: Ash Pond	**Site Location:** Kincaid Power Plant

Photo: 25

Date: 06/10/2021

Direction Facing: South

Comments: Crest view of eastern perimeter berm with straw on the slope and gravel along the toe.

Photo: 26

Date: 06/10/2021

Direction Facing: South

Comments: Crest view of eastern perimeter berm.

Site Owner: Kincaid Generation, LLC	**Project Number:** GLP8027
CCR Unit: Ash Pond	**Site Location:** Kincaid Power Plant

Photo: 27

Date: 06/10/2021

Direction Facing: East

Comments: Outfall east of ash pond.

Photo: 28

Date: 06/10/2021

Direction Facing: Northeast

Comments: Southeast corner of ash pond.

Site Owner: Kincaid Generation, LLC	**Project Number:** GLP8027
CCR Unit: Ash Pond	**Site Location:** Kincaid Power Plant

Photo: 29 **Date:** 06/10/2021 **Direction Facing:** Northeast **Comments:** Screen house at southeast corner of ash pond.	
Photo: 30 **Date:** 06/10/2021 **Direction Facing:** South **Comments:** Emergency spillway south of ash pond.	

GEOSYNTEC CONSULTANTS
Photographic Record

Geosyntec consultants

Site Owner: Kincaid Generation, LLC	**Project Number:** GLP8027
CCR Unit: Ash Pond	**Site Location:** Kincaid Power Plant

Photo: 31

Date: 06/10/2021

Direction Facing: Northeast

Comments: Two busted outflow pipes south of the ash pond.

Attachment C

Periodic History of Construction Report Update Letter

Geosyntec consultants

1 McBride and Son Center Drive, Suite 202
Chesterfield, MO 63005
PH 636-812-0800
www.geosyntec.com

October 11, 2021

Kincaid Generation, LLC
199 IL-104
Kincaid, Illinois 62540

Subject: Periodic History of Construction Report Update Letter
USEPA Final CCR Rule, 40 CFR §257.73(c)
Kincaid Power Plant
Kincaid, Illinois

At the request of Kincaid Generation, LLC (KG), Geosyntec Consultants (Geosyntec) has prepared this Letter to document updates to the Initial History of Construction (HoC) report for the Kincaid Power Plant (KPP), also known as the Kincaid Power Station (KIN). The Initial HoC report was prepared by AECOM in October of 2016 [1] in accordance with 40 Code of Federal Regulations (CFR) §257.73(c) of the United States Environmental Protection Agency (USEPA) Coal Combustion Residuals Rule, known as the CCR Rule [2]. This letter also includes information required by Section 845.220(a)(1)(B) (Design and Construction Plans) of the state-specific Illinois Environmental Protection Agency (IEPA) Part 845 CCR Rule [3] that is not expressly required by §257.73(c).

BACKGROUND

The CCR Rule required that, by October 17, 2016, Initial HoC reports to be compiled for existing CCR surface impoundments with: (1) a height of five feet or more and a storage volume of 20 acre-feet or more, or (2) a height of 20 feet or more. The Initial HoC report was required to contain, to the extent feasible, the information specified in 40 CFR §257.73(c)(1)(i)-(xii). The Initial HoC report for KPP, which included the existing CCR surface impoundment, the Ash Pond (AP), was prepared and subsequently posted to KG's CCR Website prior to October 17, 2016.

The CCR Rule requires that the Initial HoC to be updated if there is a significant change to any information complied in the Initial HoC report, as listed below:

§ 257.73(c)(2): If there is a significant change to any information complied under paragraph (c)(1) of this section, the owner or operator of the CCR unit must update the relevant information and place it in the facility's operating record as required by § 257.105(f)(9).

KG retained Geosyntec to review the Initial HoC report, review reasonably and readily available information for the AP generated since the Initial HoC report was prepared, and perform a site visit to KPP to evaluate if significant changes may have occurred since the Initial HoC report was prepared. This Letter contains the results of Geosyntec's evaluation and documents significant changes that have occurred at the AP and KPP, as they pertain the requirements of §257.73(c)(1)(i)-(xii).

UPDATES TO HISTORY OF CONSTRUCTION REPORT

Geosyntec's evaluation for the KPP AP determined that no known significant changes requiring updates to the information in the Initial HoC report pertaining to §257.73(c)(1)(ii)-(viii) and §257.73(c)(1)(xi)-(xii) of the CCR Rule had occurred since the Initial HoC report was developed.

However, Geosyntec's evaluation determined that significant changes at the KPP AP pertaining to §257.73(c)(1)(i) and (ix)-(x) of the CCR Rule had occurred since the Initial HoC report had been developed. Additionally, information how long the CCR surface impoundments have been operating and the types of CCR in the surface impoundments, as required by Section 845.220(a)(1)(B) of the Part 845 Rule were not included in the Initial HoC report, as this information is not required by the CCR Rule. Each change and the subsequent updates to the Initial HoC report is described within this section.

Section 845.220(a)(1)(B): A statement of … how long the CCR surface impoundment has been in operation, and the types of CCR that have been placed in the surface impoundment.

<u>*East Ash Pond*</u>
The AP is in operation since 1965. As of the date of this report, the AP has been present for approximately 56 years [4].

CCR placed in the AP is being used to store and dispose of sluiced bottom ash and to clarify other non-CCR waste streams to be used as recycled water for plant operations. Newly placed ash is recovered by a third party and recycled for beneficial use. [4].

§ 257.73(c)(1)(i): The name and address of the person(s) owning or operating the CCR unit; the name associated with the CCR unit; and the identification number of the CCR unit if one has been assigned by the state.

A State identification number (ID) for the AP has been assigned by the Illinois Environmental Protection Agency (IEPA). The ID is listed in **Table 1**.

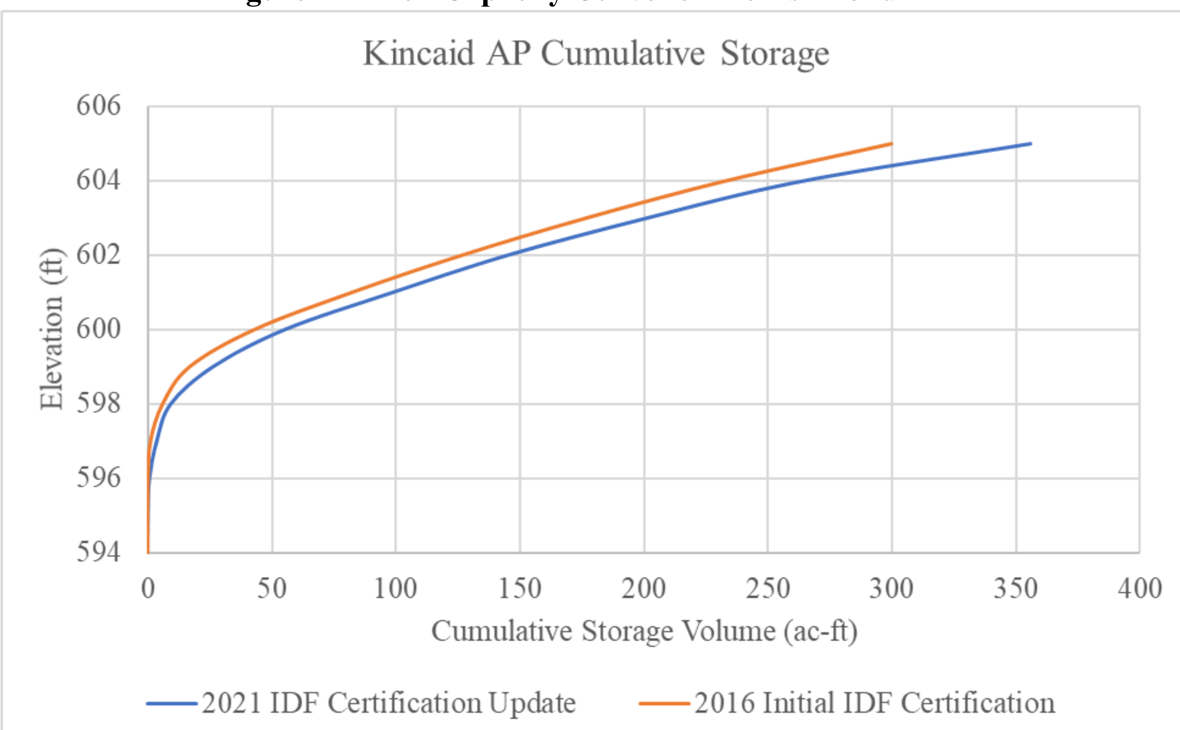
Table 1 – IEPA ID Numbers

CCR Surface Impoundment	State ID
Ash Pond (AP)	W0218140002-01

§ 257.73(c)(1)(ix): Area-capacity curves for the CCR unit.

An updated area-capacity curve was prepared for the AP in 2021. This curve is provided in **Figure 1**.

Figure 1 – Area-Capacity Curve for the Ash Pond



§ 257.73(c)(1)(x): A description of each spillway and diversion design features and capacities and calculations used in their determination.

Updated discharge capacity calculations for the existing spillway were prepared in 2021 using HydroCAD 10 modeling software. The calculations indicate that the AP has sufficient storage capacity and will not overtop the embankments during the 1,000-year, 24-hour, storm event. The results of the calculations are provided in **Table 2**.

Table 2 – Results of Updated Discharge Capacity Calculations

	Ash Pond
Approximate Berm Minimum Elevation[1], ft	604.5
Approximate Emergency Spillway Elevation[1], ft	Not Applicable
Starting Water Surface Elevation[1] (SWSE), ft	601.8
Peak Water Surface Elevation[1] (PWSE), ft	603.8
Time to Peak, hr	16
Surface Area[2], ac	65.0
Storage[3], ac-ft	115.1

Notes:
[1]Elevations are based on the NAVD88 datum
[2]Surface Area is defined as the water surface area at the PWSE
[3]Storage is defined as the volume between the SWSE and PWSE

CLOSING

This letter has been prepared to document Geosyntec's evaluation of changes that have occurred at the AP at the KPP since the Initial HoC was developed, based on reasonably and readily available information provided by KG, observed by Geosyntec during the site visit, or generated by Geosyntec as part of subsequent calculations.

Sincerely,

Thomas Ward, P.E.
Senior Engineer

John Seymour, P.E.
Senior Principal

REFERENCES

[1] AECOM, "History of Construction, USEPA 40 CFR § 257.73(c), Kincaid Power Station, Kincaid, Illinois," October 2016.

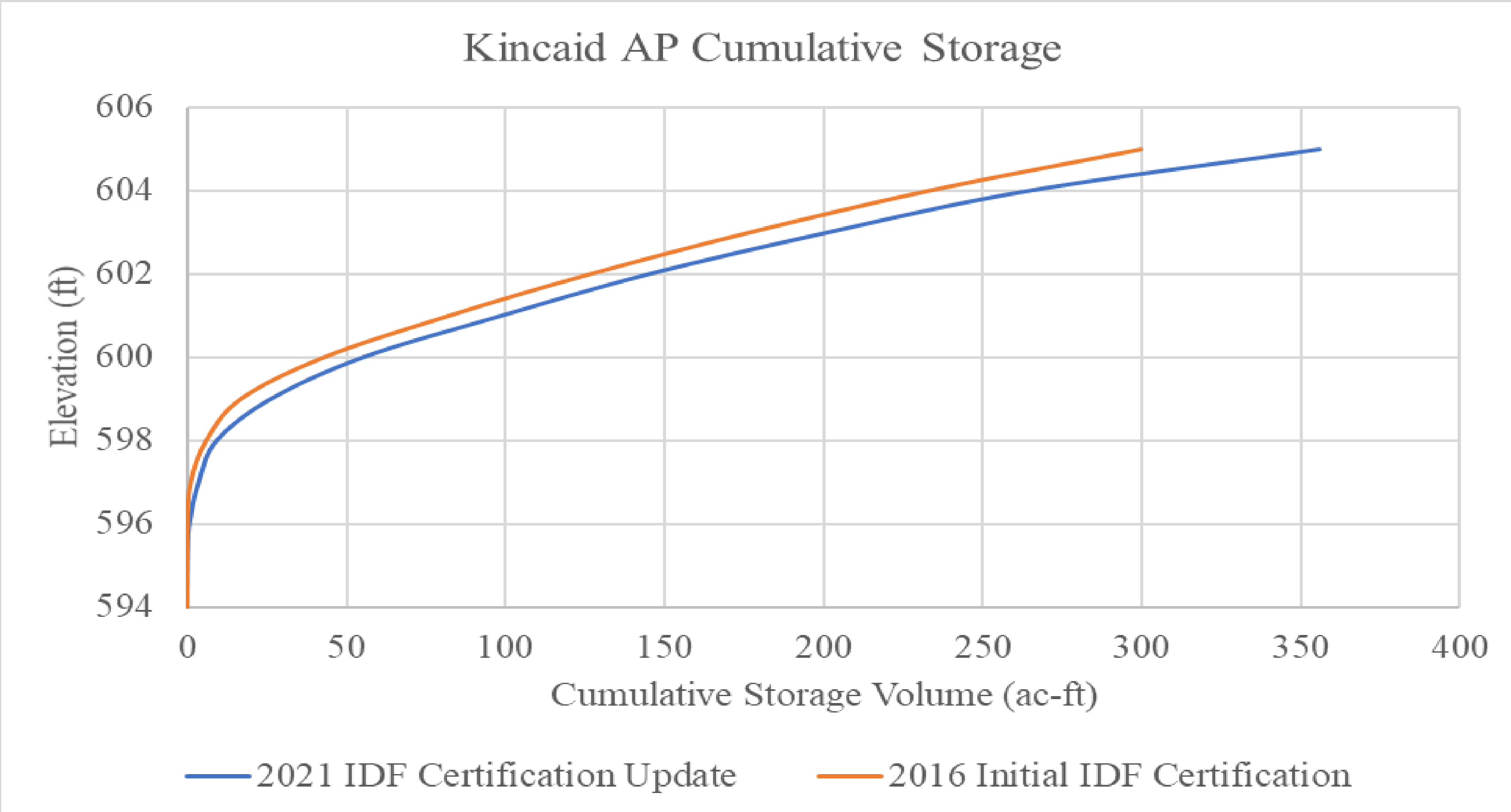
[2] United Stated Environmental Protection Agency, "40 CFR Parts 257 and 261, Hazardous and Solid Waste Management System, Disposal of Coal Combustion Residuals from Electric Utilities, Final Rule, 2015," 2015.

[3] Illinois Environmental Protection Agency, "35 Ill. Adm. Code Part 845, Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments," Springfield, IL, 2021.

[4] AECOM, "History of Construction, USEPA Final CCR Rule, 40 CFR § 257.73(c), Hennepin Power Station, Hennepin, Illinois," October 2016.

Attachment D

Periodic Inflow Design Flood Control System Plan Analyses

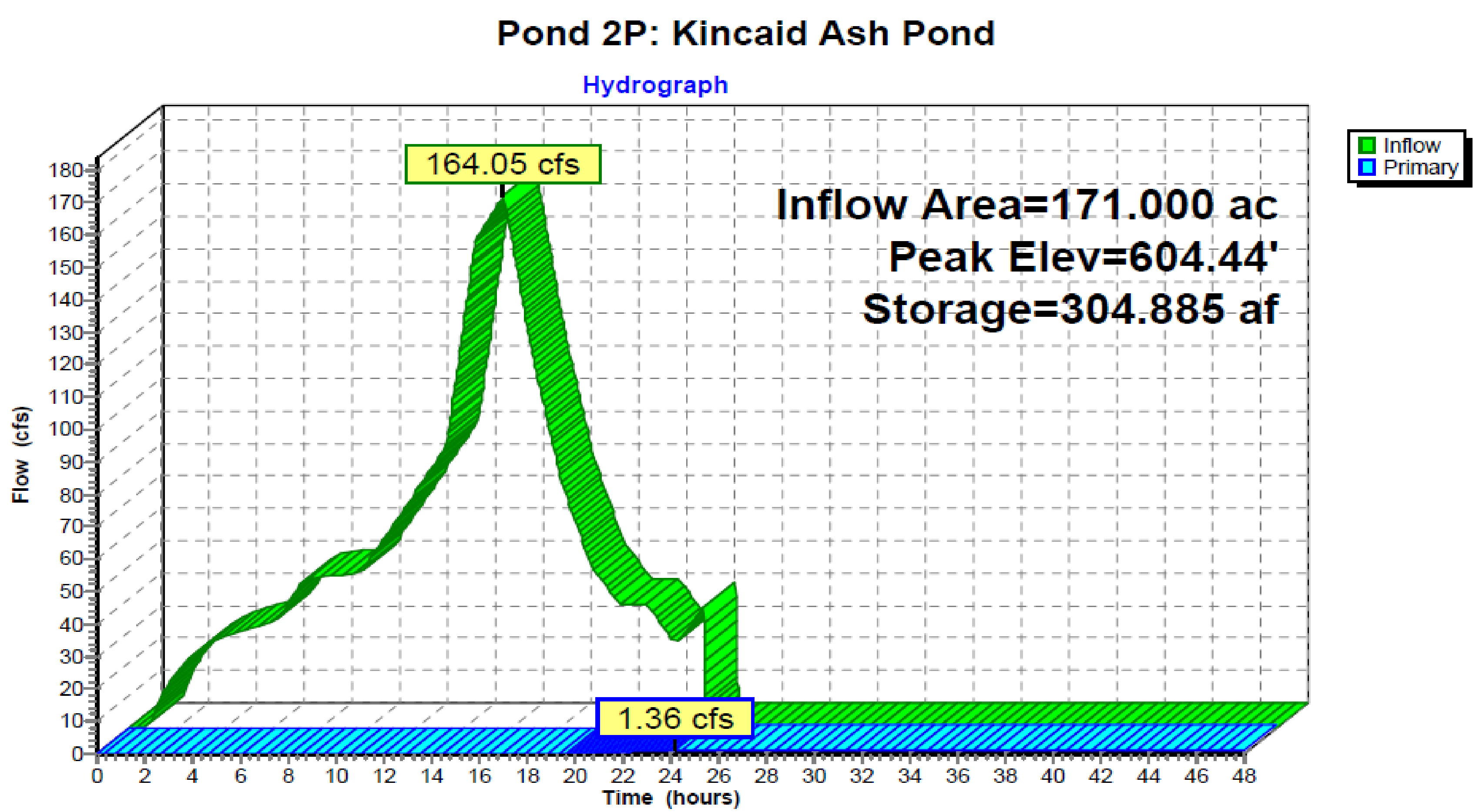


KINCAID AP CUMULATIVE STORAGE
PERIODIC CERTIFICATION
KINCAID POWER PLANT
KINCAID, ILLINOIS

Geosyntec consultants

Figure D-1

GLP8027 | 8/30/2021



ASH POND IDF HYDROGRAPH
PERIODIC CERTIFICATION
KINCAID POWER PLANT
KINCAID, ILLINOIS

Geosyntec consultants

GLP8027	8/30/2021	Figure D-2

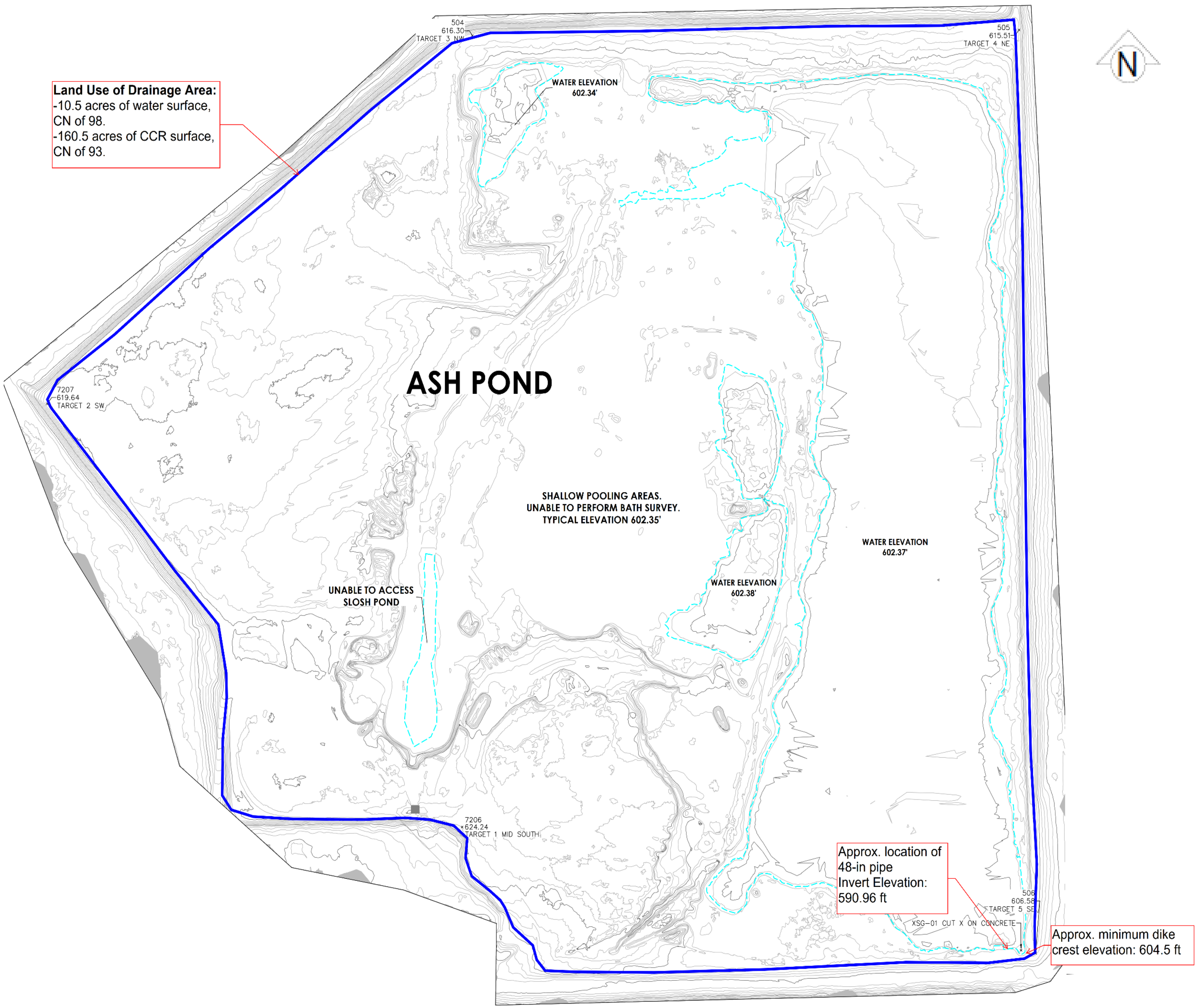


Figure based on IngenAE 2020 Site Topo

NOT TO SCALE

Kincaid Power Station Ash Pond
Hydrologic Workmap

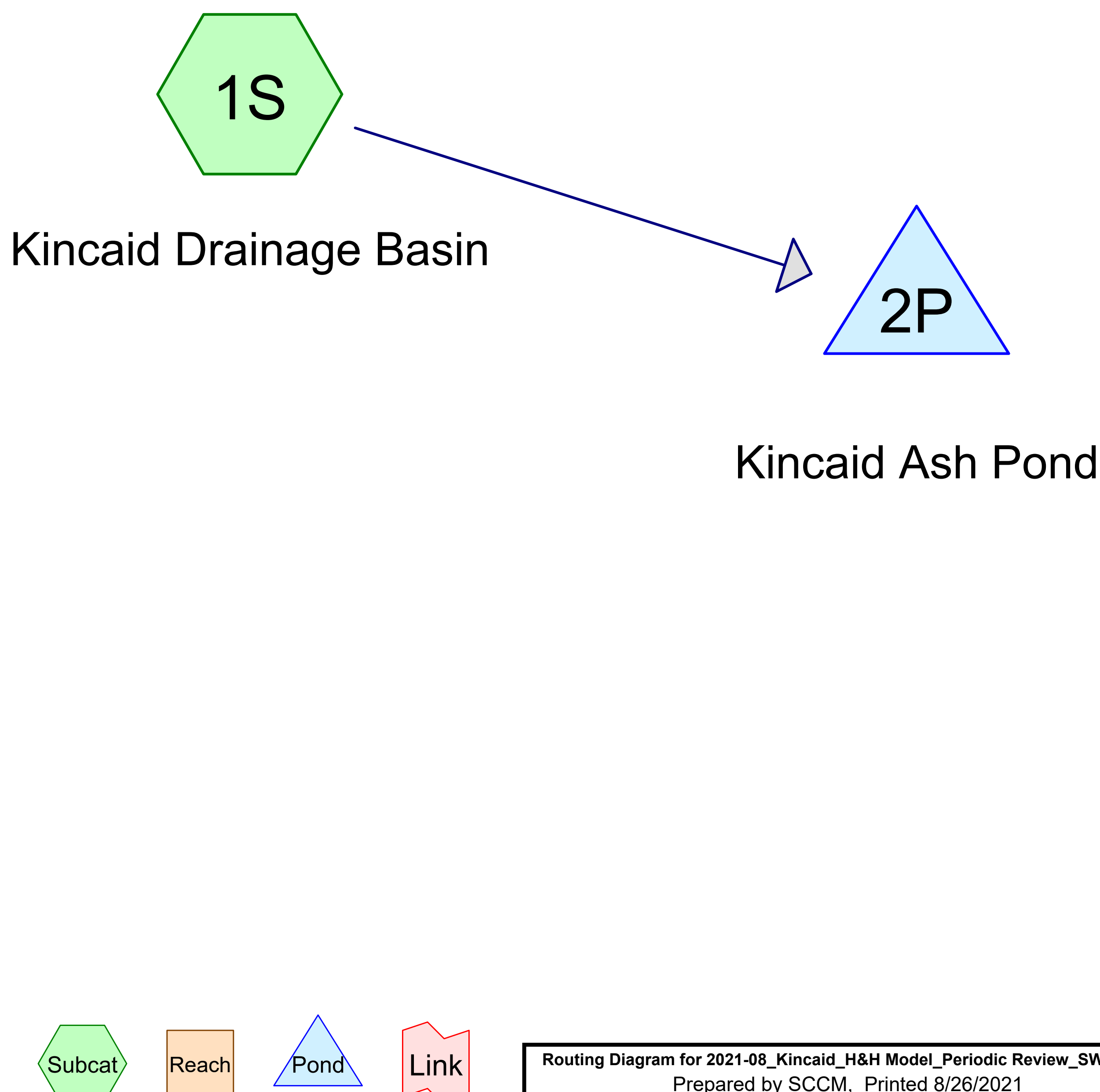
Geosyntec consultants

GLP8027

August 2021

Figure

D-3



Routing Diagram for 2021-08_Kincaid_H&H Model_Periodic Review_SWSE_602.8
Prepared by SCCM, Printed 8/26/2021
HydroCAD® 10.00-26 s/n 00928 © 2020 HydroCAD Software Solutions LLC

Area Listing (all nodes)

Area (acres)	CN	Description (subcatchment-numbers)
160.500	93	CCR Surface (1S)
10.500	98	Water Surface (1S)
171.000	**93**	**TOTAL AREA**

Soil Listing (all nodes)

Area (acres)	Soil Group	Subcatchment Numbers
0.000	HSG A	
0.000	HSG B	
0.000	HSG C	
0.000	HSG D	
171.000	Other	1S
171.000		**TOTAL AREA**

Ground Covers (all nodes)

HSG-A (acres)	HSG-B (acres)	HSG-C (acres)	HSG-D (acres)	Other (acres)	Total (acres)	Ground Cover	Subcatchment Numbers
0.000	0.000	0.000	0.000	160.500	160.500	CCR Surface	1S
0.000	0.000	0.000	0.000	10.500	10.500	Water Surface	1S
0.000	**0.000**	**0.000**	**0.000**	**171.000**	**171.000**	**TOTAL AREA**	

Pipe Listing (all nodes)

Line#	Node Number	In-Invert (feet)	Out-Invert (feet)	Length (feet)	Slope (ft/ft)	n	Diam/Width (inches)	Height (inches)	Inside-Fill (inches)
1	2P	590.96	590.00	158.0	0.0061	0.025	48.0	0.0	0.0

Time span=0.00-48.00 hrs, dt=0.01 hrs, 4801 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: Kincaid Drainage Basin Runoff Area=171.000 ac 6.14% Impervious Runoff Depth=8.08"
Tc=6.0 min CN=93 Runoff=164.05 cfs 115.093 af

Pond 2P: Kincaid Ash Pond Peak Elev=604.44' Storage=304.885 af Inflow=164.05 cfs 115.093 af
Outflow=1.36 cfs 2.632 af

Total Runoff Area = 171.000 ac Runoff Volume = 115.093 af Average Runoff Depth = 8.08"
93.86% Pervious = 160.500 ac 6.14% Impervious = 10.500 ac

Summary for Subcatchment 1S: Kincaid Drainage Basin

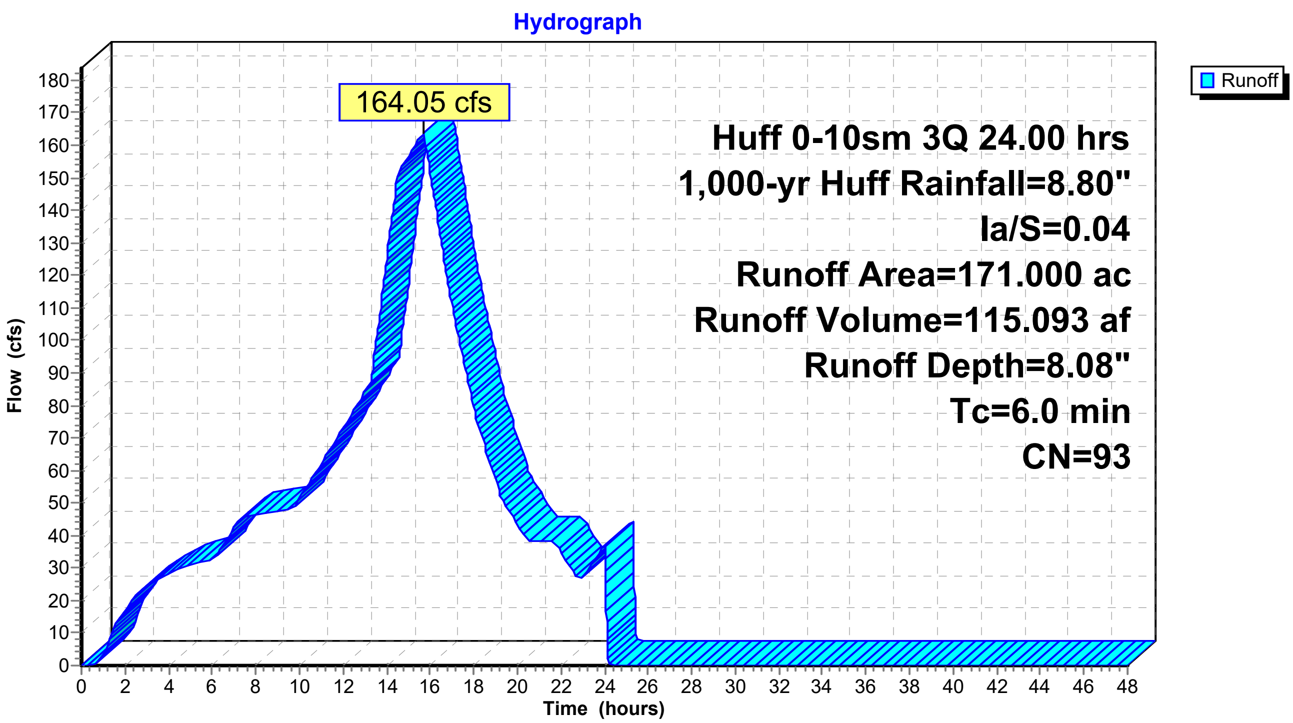
Runoff = 164.05 cfs @ 15.66 hrs, Volume= 115.093 af, Depth= 8.08"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs
Huff 0-10sm 3Q 24.00 hrs 1,000-yr Huff Rainfall=8.80", Ia/S=0.04

	Area (ac)	CN	Description
*	10.500	98	Water Surface
*	160.500	93	CCR Surface
	171.000	93	Weighted Average
	160.500		93.86% Pervious Area
	10.500		6.14% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Rainfall Directly Into Impoundment**

Subcatchment 1S: Kincaid Drainage Basin



Summary for Pond 2P: Kincaid Ash Pond

Inflow Area = 171.000 ac, 6.14% Impervious, Inflow Depth = 8.08" for 1,000-yr Huff event
Inflow = 164.05 cfs @ 15.66 hrs, Volume= 115.093 af
Outflow = 1.36 cfs @ 24.19 hrs, Volume= 2.632 af, Atten= 99%, Lag= 512.0 min
Primary = 1.36 cfs @ 24.19 hrs, Volume= 2.632 af

Routing by Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs
Starting Elev= 602.80' Surf.Area= 0.000 ac Storage= 190.055 af
Peak Elev= 604.44' @ 24.19 hrs Surf.Area= 0.000 ac Storage= 304.885 af (114.830 af above start)

Plug-Flow detention time= (not calculated: initial storage exceeds outflow)
Center-of-Mass det. time= 1,227.5 min (2,062.4 - 834.9)

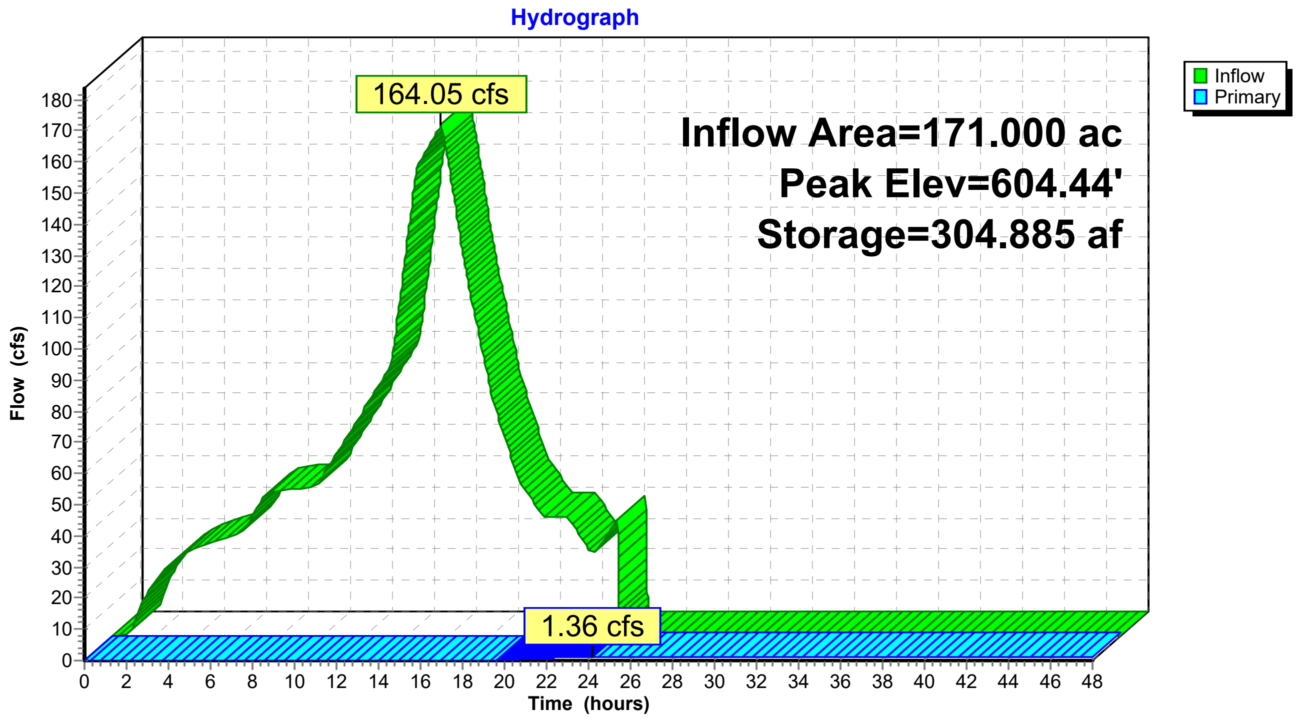
Volume	Invert	Avail.Storage	Storage Description
#1	594.00'	452.335 af	**Custom Stage Data_2021** Listed below

Elevation (feet)	Cum.Store (acre-feet)
594.00	0.000
595.00	0.141
596.00	0.766
597.00	3.702
598.00	9.361
599.00	26.387
600.00	55.333
601.00	98.783
602.00	145.198
603.00	201.269
604.00	264.392
605.00	355.929
606.00	452.335

Device	Routing	Invert	Outlet Devices
#1	Primary	590.96'	**48.0" Round Culvert** L= 158.0' CMP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 590.96' / 590.00' S= 0.0061 '/' Cc= 0.900 n= 0.025 Corrugated metal, Flow Area= 12.57 sf
#2	Device 1	604.30'	**9.0' long x 0.5' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 Coef. (English) 2.80 2.92 3.08 3.30 3.32

Primary OutFlow Max=1.35 cfs @ 24.19 hrs HW=604.44' (Free Discharge)
└─**1=Culvert** (Passes 1.35 cfs of 155.52 cfs potential flow)
  └─**2=Broad-Crested Rectangular Weir** (Weir Controls 1.35 cfs @ 1.06 fps)

Pond 2P: Kincaid Ash Pond



ATTACHMENT D: TYPES OF CCR AND CHEMICAL CONSTITUENTS
845.220(a)(2)(A)

Kincaid Power Plant – Ash Pond's Chemical Constituents

In accordance with 35 I.A.C. 845.230(d)(2)(C), Kincaid Generation L.L.C. is submitting available/existing analyses of "the chemical constituents of all waste streams, chemical additives and sorbent materials entering or contained in" the CCR impoundment, Ash Pond.

A list of the chemical constituents' analyses contained in the CCR surface impoundment can be found in Appendix A. As determined through antidegradation studies, this list contains chemical constituents found in the surface free liquid and the subsurface free liquids. Kincaid Generation L.L.C. is also including a list of chemical additives, sorbent materials and waste streams that were submitted in the facility's NPDES permit applications to IEPA within the past ten years at a minimum and/or listed in the current NPDES permit (IL0001554) in Appendix B.

Appendix A: Chemical Constituents Contained in the Ash Pond

Pollutant	Units	Surface Free Liquids Average Concentration	Subsurface Free Liquids Average Concentration
Acidity (total)	mg/L	< 20.0	< 20.0
Alkalinity (total)	mg/L	102	305
Ammonia Nitrogen	mg/L	0.10 U	0.3
Antimony (dissolved)	mg/L	< 0.00018	0.0008
Antimony (total)	mg/L	< 0.00021	0.0006
Arsenic (dissolved)	mg/L	0.0018	0.002
Arsenic (total)	mg/L	0.0023	0.0033
Barium (dissolved)	mg/L	0.215	0.123
Barium (total)	mg/L	0.258	0.12
Beryllium (dissolved)	mg/L	< 0.0005	< 0.0005
Beryllium (total)	mg/L	< 0.0005	0.0005
Boron (dissolved)	mg/L	1.33	2.4
Boron (total)	mg/L	1.34	2.4
Cadmium (dissolved)	mg/L	< 0.0005	0.0003
Cadmium (total)	mg/L	0.0003	0.0003
Calcium (total recoverable)	mg/L	51	104
Chemical Oxygen Demand	mg/L	< 6.7	9.2
Chloride (total)	mg/L	26.6	7.8
Chromium (dissolved)	mg/L	< 0.00067	< 0.00048
Chromium (hexavalent)	mg/L	0.00038	0.00013
Chromium (total)	mg/L	0.0009	0.0017
Cobalt (dissolved)	mg/L	0.001	0.001
Cobalt (total)	mg/L	< 0.00018	0.001
Copper (dissolved)	mg/L	< 0.00065	0.0005
Copper (total)	mg/L	0.0013	0.001
Cyanide (dissociable)	mg/L	< 0.0050	< 0.0050
Cyanide	mg/L	0.0045	< 0.0050
Fluoride	mg/L	0.63	0.4
Iron (dissolved)	mg/L	< 0.0312	9.72
Iron (Ferric)	mg/L	0.12	11.7
Iron (Ferrous)	mg/L	0.14	0.6
Iron (total)	mg/L	0.157	12.3
Kjeldahl Nitrogen (total)	mg/L	1.0	0.5
Lead (dissolved)	mg/L	< 0.001	< 0.001
Lead (total)	mg/L	0.001	0.001
Lithium (total recoverable)	mg/L	0.0170	0.02
Magnesium (total recoverable)	mg/L	30.3	30.4
Manganese (dissolved)	mg/L	0.0042	0.184
Manganese (total)	mg/L	0.0167	0.171
Mercury (dissolved)	mg/L	0.0000004	0.0000004
Mercury (total)	mg/L	7.295E-07	0.0000005

Pollutant	Units	Surface Free Liquids Average Concentration	Subsurface Free Liquids Average Concentration
Molybdenum (dissolved)	mg/L	0.0142	0.025
Molybdenum (total)	mg/L	0.016	0.0255
Nickel (dissolved) 2008 WD	mg/L	< 0.00061	0.0031
Nickel (dissolved) 6020 WD	mg/L	< 0.00059	0.004
Nickel (total)	mg/L	0.0009	0.004
Nitrate as N	mg/L	< 0.10	0.29
Nitrite as N	mg/L	< 0.10	0.09
Oil & grease	mg/L	< 5.3	4.8
Oxidation/Reduction Potential	mg/L	158.8	123
pH*	SU	8.0	7.3
Phenols	mg/L	< 0.050	< 0.050
Phosphorus	mg/L	< 0.31	0.8
Potassium (dissolved)	mg/L	7.19	9.70
Potassium (total recoverable)	mg/L	7.64	9.77
Radium - 226	mg/L	0.711	0.687
Radium - 228	mg/L	1.80	1.11
Radium (total)	mg/L	2.51	1.80
Selenium (total)	mg/L	< 0.00058	0.001
Silica	mg/L	4.35	23.9
Silver (dissolved)	mg/L	< 0.0005	0.0004
Silver (total)	mg/L	< 0.0005	< 0.0005
Sodium (total recoverable)	mg/L	74.0	77.9
Specific Conductance	mg/L	799	1015
Sulfate	mg/L	247	262
Sulfide (total)	mg/L	0.057	0.05
Thallium (dissolved)	mg/L	< 0.001	0.0007
Thallium (total)	mg/L	< 0.001	0.0007
Total dissolved solids	mg/L	563	710
Total Organic Carbon	mg/L	3.8	1.4
Total suspended solids	mg/L	19.8	47.5
Zinc (dissolved)	mg/L	< 0.01	< 0.01
Zinc (total)	mg/L	< 0.01	0.01

*Used https://calstormcompliance.com/ph-averaging-tool

Appendix B: List of Chemical Additives, Waste Streams and Sorbent Materials

Chemical Additives
Ammonia Hydroxide
Coal Dust Suppression Products*
Aqueous Ammonia
Anodamine
Potassium Iodide
Mill Scale

* Only a very small percentage of these chemicals would enter the ash pond. A high majority of the product would be consumed in the combustion process. Varying products may be used. While the products are comprised of different ingredients (e.g., lignosulfonates, acrylic and vinyl polymers, petroleum distillates), they all share the same inherent properties in that they adhere to solids for stabilization purposes and are not readily washed away during rainfall events.

Waste Streams and Sorbent Materials*
Bottom Ash and Economizer Ash sluice water
Air Heater Ash water
Tunnel Ground Water Sump
Coal Pile Runoff
Slag Tank Cooling Water
Intake Pump House Sump
Ammonia Storage Tank Sump
Building low Volume Wastewater
Condensate Storage Area and Overflows
Station Basement Sumps
Stormwater Sources
Boiler Drain Water

*No sorbent materials

DYNEGY

Safety Data Sheet

Section 1
Identification of the Substance and of the Supplier

1.1 Product Identifier

Product Name/Identification:	ASTM Bottom Ash
Synonyms:	Ash; Ashes; Ash residues; Ashes, residues, bottom; Bottom ash; Bottom ash residues; Coal Fly Ash; Pozzolan; Waste solids.
Formula:	UVCB Substance

1.2 Relevant Identified Uses of the Substance or Mixture and Uses Advices Against

Relevant Identified Uses:	Component of wallboard, concrete, roofing material, bricks, cement kiln feed.
Uses Advised Against:	None known.

1.3 Details of the Supplier of the SDS

Manufacturer/Supplier:	Dynegy, Inc.
Street Address:	601 Travis Street, Suite 1400
City, State and Zip Code:	Houston, TX 77002
Customer Service Telephone:	800-633-4704

Section 2
Hazards Identification

2.1 Classification of the Substance

GHS Classification(s) according to OSHA Hazard Communication Standard (29 CFR 1910.1200):

- Eye Irritant, Category 2A
- STOT-SE, Category 3 (Respiratory Irritation)
- Carcinogen, Category 1A
- STOT-RE, Category 1 (Lungs)
- Toxic to Reproduction, Category 2

2.2 Label Elements

Labelling according to 29 CFR 1910.1200 Appendices A, B and C*	
Hazard Pictogram(s):	
Signal word:	**DANGER**
Hazard Statement(s):	*Causes serious eye irritation.* *May cause respiratory irritation.* *May cause damage to lungs after repeated/prolonged exposure via inhalation.* *May cause cancer of the lung.* *Suspected of damaging fertility or the unborn child.*
Precautionary Statement(s):	*Obtain special instructions before use.* *Do not handle until all safety precautions have been read and understood.* *Avoid breathing dust.* *Wash thoroughly after handling.* *Do not eat drink or smoke when using this product.* *Wear protective gloves/protective clothing/eye protection/face protection.* *Use outdoors or in a well-ventilated area.* *If exposed or concerned: Get medical advice/attention.* *Store in a secure area.* *Dispose of product in accordance with local/national regulations.*

** Fly ash and other coal combustion products (CCPs) are UVCB substances (unknown or variable composition or biological). Various CCPs, noted as ashes/ash residuals; Ashes, residues, bottom; Bottom ash; Bottom ash residues; Waste solids, ashes under TSCA are defined as: "The residuum from the burning of a combination of carbonaceous materials. The following elements may be present as oxides: aluminum, calcium, iron, magnesium, nickel, phosphorus, potassium, silicon, sulfur, titanium, and vanadium." Ashes including fly ash and fluidized bed combustion ash are identified by CAS number 68131-74-8. The exact composition of the ash is dependent on the fuel source and flue additives composed of many constituents. The classification of the final substance is dependent on the presence of specific identified oxides as well as other trace elements.*

2.3 Other Hazards

Listed Carcinogens:

-Respirable Crystalline Silica

IARC: [Yes] **NTP:** [Yes] **OSHA:** [Yes] **Other:** **(ACGIH)** [Yes]

Section 3
Composition/Information on Ingredients

Substance	*CAS No.*	*Percentage (%)*	*GHS Classification*
Crystalline Silica	*14808-60-7*	*20 - 40%*	*Repeat Dose STOT, Category 1* *Carcinogen, Category 1A*
Silica, crystalline respirable (RCS)	*14808-60-7*	*See Footnote 1*	*Repeat Dose STOT, Category 1* *Carcinogen. Category 1A*
Aluminosilicates[2]	*Various, see Footnote 2*	*10 - 60%*	*Single Exposure STOT, Category 3*
Calcium oxide (CaO)	*1305-78-8*	*10 - 30%*	*Skin Irritant, Category 2* *Eye Irritant, Category 1* *Single Exposure STOT, Category 3*
Iron oxide	*1309-37-1*	*1 - 10%*	*Not Classified*
Manganese dioxide (MnO_2)	*1313-13-9*	*<2%*	*Skin Irritant, Category 2* *Eye Irritant, Category 2B*
Magnesium oxide	*1309-48-4*	*2 - 10%*	*Not Classified*
Phosphorus pentoxide (P_2O_5)	*1314-56-3*	*≤2%*	*Skin Irritant, Category 2* *Eye Irritant, Category 2B*
Sodium oxide	*1313-59-3*	*1 - 10%*	*Not Classified*
Potassium oxide (K_2O)	*12136-45-7*	*≤1%*	*Skin Irritant Category 2* *Eye Irritant Category 2B*
Titanium dioxide (TiO_2)	*13463-67-7*	*<3%*	*Not Classified*

[1]*The percentage of respirable crystalline silica has not been determined. Therefore, a GHS classification of Carcinogen 1A has been assigned.*

[2]*Aluminosilicates (CAS# 1327-36-2) may be in the form of mullite (CAS# 1302-93-8); aluminosilicate glass; pozzolans (CAS# 71243-67-9); or calcium aluminosilicates such as tricalcium aluminate (C3A), or calcium sulfoaluminate (C4A3S). The form is dependent on the source of the coal and or the process used to create the CCP. Pulverized coal combustion would be more likely to create high levels of pozzolans. Aluminosilicates may have inclusions of calcium, titanium, iron, potassium, phosphorus, magnesium and other metal oxides.*

Section 4
First Aid Measures

4.1 Description of First Aid Measures

Inhalation:	If product is inhaled and irritation of the nose or coughing occurs, remove person to fresh air. Get medical advice/attention if respiratory symptoms persist.
Skin Contact:	If skin exposure occurs, wash with soap and water.
Eye Contact:	If product gets into the eye, rinse copiously with water for several minutes. Remove contact lenses, if present and easy to do. Seek medical attention/advice if irritation occurs or persists.
Ingestion:	No specific first aid measures are required.

4.2 Most Important Health Effects, Both Acute and Delayed

Acute Effects: Direct exposure may cause respiratory irritation, eye irritation and skin irritation. The product dust can dry and irritate the skin and cause dermatitis and can irritate eyes and skin through mechanical abrasion.

Chronic Effects: Chronic exposure may cause lung damage from repeated exposure. Prolonged inhalation of respirable crystalline silica above certain concentrations may cause lung diseases, including silicosis and lung cancer.

4.3 Indication of Any Immediate Medical Attention and Special Treatment Needed

Seek first aid or call a doctor or Poison Control Center if contact with eyes occurs and irritation remains after rinsing. Get medical advice if inhalation occurs and respiratory symptoms persist.

Section 5
Firefighting Measures

5.1 Extinguishing Media

Suitable Extinguishing Media:	Product is not flammable. Use extinguishing media appropriate for surrounding fire.
Unsuitable Extinguishing Media:	Not applicable, the product is not flammable.

5.2 Special Hazards Arising from the Substance or Mixture

Hazardous Combustion Products:	None known.

5.3 Advice for Firefighters

Special Protective Equipment and Precautions for Firefighters:	As with any fire, wear self-contained breathing apparatus (NIOSH approved or equivalent) and full protective gear.

Section 6
Accidental Release Measures

6.1 Personal Precautions, Protective Equipment and Emergency Procedures

Personal precautions/Protective Equipment:	See Section 8.2.2 Individual Protective Measures. For concentrations exceeding Occupational Exposure Levels (OELs), use a self-contained breathing apparatus (SCBA).
Emergency procedures:	Use scooping, water spraying/flushing/misting or ventilated vacuum cleaning systems to clean up spills. Do not use pressurized air.

6.2 Environmental Precautions

Environmental precautions:	Prevent contamination of drains or waterways and dispose according to local and national regulations.

6.3 Methods and Material for Containment and Cleaning Up

Methods and materials for containment and cleaning up:	Do not use brooms or compressed air to clean surfaces. Use dust collection vacuum and extraction systems. Large spills of dry product should be removed by a vacuum system. Dampened material should be removed by mechanical means and recycled or disposed of according to local and national regulations.

See Sections 8 and 13 for additional information on exposure controls and disposal.

Section 7
Handling and Storage

7.1 Precautions for Safe Handling

Practice good housekeeping. Use adequate exhaust ventilation, dust collection and/or water mist to maintain airborne dust concentrations below permissible exposure limits (note: respirable crystalline silica dust may be in the air without a visible dust cloud).

Do not permit dust to collect on walls, floors, sills, ledges, machinery, or equipment. Maintain and test ventilation and dust collection equipment. In cases of insufficient ventilation, wear a NIOSH approved respirator for silica dust when handling or disposing dust from this product. Avoid contact with skin and eyes. Wash or vacuum clothing that has become dusty. Avoid eating, smoking, or drinking while handling the material.

7.2 Conditions for Safe Storage, Including any Incompatibilities

Minimize dust produced during loading and unloading.

Section 8
Exposure Controls/Personal Protection

8.1 Control Parameters

OCCUPATIONAL EXPOSURE LIMITS					
SUBSTANCE		OSHA PEL TWA (mg/m^3)	NIOSH REL TWA (mg/m^3)	ACGIH TLV TWA (mg/m^3)	CA - OSHA PEL (mg/m^3)
Calcium oxide		5	2	2	2
Particulates Not Otherwise Regulated	Total	15	15	10	10
	Respirable	5	5	3	5
Respirable Crystalline Silica	Respirable	0.05	0.05	0.025	0.05
Manganese dioxide (as manganese compounds)	Total	5 (Ceiling)	1 3 (STEL)	0.1	0.2
	Respirable	-	-	0.02	-

8.2 Exposure Controls

8.2.1 Engineering Controls

Provide ventilation to maintain the ambient workplace atmosphere below the occupational exposure limit(s). Use general and local exhaust ventilation and dust collection systems as necessary to minimize exposure.

8.2.2 Personal Protective Equipment (PPE)

Respiratory protection:	Wear a NIOSH approved particulate respirator if exposure to airborne particulates is unavoidable and where occupational exposure limits may be exceeded. If airborne exposures are anticipated to exceed applicable PELs or TLVs, a self-contained breathing apparatus or airline respirator is recommended.
Eye and face protection:	If eye contact is possible, wear protective glasses with side shields. Avoid contact lenses.
Hand and skin protection:	Wear gloves and protective clothing. Wash hands with soap and water after contact with material.

Section 9
Physical and Chemical Properties

9.1 Information on Basic Physical and Chemical Properties

Property: Value	Property: Value
Appearance (physical state, color, etc.): Fine tan/ gray particulate	**Upper/lower flammability or explosive limits:** Not applicable
Odor: Odorless[1]	**Vapor Pressure (Pa):** Not applicable
Odor threshold: Not applicable	**Vapor Density:** Not applicable
pH (25 °C) (in water): 8 - 11	**Specific gravity or relative density:** 2.2 – 2.9
Melting point/freezing point (°C): Not applicable	**Water Solubility:** Slight
Initial boiling point and boiling range (°C): Not applicable	**Partition coefficient: n-octane/water:** Not determined
Flash point (°C): Not determined	**Auto ignition temperature (°C):** Not applicable
Evaporation rate: Not applicable	**Decomposition temperature (°C):** Not determined
Flammability (solid, gas): Not combustible	**Viscosity:** Not applicable

[1] The use of urea or aqueous ammonia injected into the flue gas to reduce nitrogen oxides (NOx) emissions may result in the presence of ammonium sulfate or ammonium bisulfate in the ash at less than 0.1%. When ash containing these substances becomes wet under high pH (>9), free ammonia gas may be released resulting in objectionable/nuisance ammonia odor and potential exposure to ammonia gas especially in confined spaces.

Section 10
Stability and Reactivity

10.1 Reactivity:	The material is an inert, inorganic material primarily composed of elemental oxides.
10.2 Chemical stability:	The material is stable under normal use conditions.
10.3 Possibility of hazardous reactions:	The material is a relatively stable, inert material; however, when ash containing ammonia becomes wet under high pH (>9), free ammonia gas may be released resulting in an objectionable/nuisance ammonia odor and potential exposure to ammonia gas especially in confined spaces. Polymerization will not occur.
10.4 Conditions to avoid:	Product can become airborne in moderate winds. Dry material should be stored in silos. Materials stored out of doors should be covered or maintained in a damp condition.
10.5 Incompatible materials:	None known.
10. 6 Hazardous decomposition products:	None known.

Section 11
Toxicological Information

11.1 Information on Toxicological Effects

Endpoint	Data
Acute oral toxicity	LD50 > 2000 mg/kg
Acute dermal toxicity	LD50 > 2000 mg/kg
Acute inhalation toxicity	LD50 > 5.0 mg/L
Skin corrosion/irritation	Does not meet the classification criteria but may cause slight skin irritation. Product dust can dry the skin which can result in irritation.
Eye damage/irritation	Causes serious eye irritation. Positive scores for conjunctiva irritation and chemosis in 2/3 animals based on average of 24, 48 and 72-hour scores with irritation clearing within 21 days; no corneal or iritis effects observed.
Respiratory/skin sensitization	Not a respiratory or dermal sensitizer.
Germ cell mutagenicity	Not mutagenic in in-vitro and in-vivo assays with or without metabolic activation.
Carcinogenicity	Not available. Respirable crystalline silica has been identified as a carcinogen by OSHA, NTP, ACGIH and IARC.
Reproductive toxicity	No developmental toxicity was observed in available animal studies. Reproductive studies on CCPs showed either no reproductive effects, or some effects on male and female reproductive organs and parameters but without a clear dose response.
STOT-SE	CCPs when present as a nuisance dust may result in respiratory irritation.
STOT-RE	In a 180-day inhalation study with fly ash dust, no effects were observed at the highest dose tested. NOEC = 4.2 mg/m^3; it is not possible to assess the level at which toxicologically significant effects may occur. Repeated inhalation exposures to high levels of respirable crystalline silica may result in lung damage (i.e., silicosis).
Aspiration Hazard	Not applicable based product form.

Section 12
Ecological Information

12.1 Toxicity

Fly Ash (CAS# 68131-74-8)	
Toxicity to Fish	LC50 > 100 mg/L
Toxicity to Aquatic Invertebrates	Data indicates that the test substance is not toxic to *Daphnia magna* (EC50 undetermined)
Toxicity to Aquatic Algae and Plants	EC50 = 10 mg/L
Calcium oxide CAS# 1305-78-8	
Toxicity to Fish	LC50 = 50.6 mg/L The findings were closely related to the pH of the test solutions; therefore, pH is considered to be the main reason for the effects.
Toxicity to Aquatic Invertebrates	EC50 = 49.1 mg/L The findings were closely related to the pH of the test solutions; therefore, pH is considered to be the main reason for the effects.
Toxicity to Aquatic Algae and Plants	NOEC =48 mg/L @ 72 hours based on $Ca(OH)_2$ The initial pH of the test medium was not directly related to the biologically relevant effects. The formation of precipitates is likely the result of the reaction between CO_2 dissolved in the medium.

12.2 Persistence and Degradability

Not relevant for inorganic materials.

12.3 Bioaccumulative Potential

This material does not contain any compounds that would bioaccumulate up the food chain.

12.4 Mobility in Soil

No data available.

12.5 Results of PBT and vPvB Assessment

This material does not contain any compounds classified as “persistent, bioaccumulative or toxic” nor as “very persistent/very bioaccumulative”.

12.6 Other Adverse Effects

None known.

Section 13
Disposal Considerations

See Sections 7 and 8 above for safe handling and use, including appropriate industrial hygiene practices.

Dispose of all waste product and containers in accordance with federal, state and local regulations.

Section 14
Transport Information

Regulatory entity: U.S. DOT	Shipping Name:	Not Regulated
	Hazard Class:	Not Regulated
	ID Number:	Not Regulated
	Packing Group:	Not Regulated

Section 15
Regulatory Information

15.1 Safety, Health and Environmental Regulations/Legislation Specific for the Mixture

- TSCA Inventory Status

  All components are listed on the TSCA Inventory.

- California Proposition 65

  The following substances are known to the State of California to be carcinogens and/or reproductive toxicants:

  - Respirable crystalline silica
  - Titanium dioxide

- State Right-to-Know (RTK)

Component	CAS	MA[1,2]	NJ[3,4]	PA[5]	RI[6]
Ammonium bisulfate	7803-63-6	No	Yes	No	No
Ammonium sulfate	7783-20-2	Yes	No	Yes	No
Calcium oxide	1305-78-8	Yes	Yes	Yes	No
Iron oxide	1309-37-1	Yes	Yes	Yes	No
Magnesium oxide	1309-48-4	No	Yes	No	No
Phosphorus pentoxide (or phosphorus oxide)	1314-56-3	Yes	Yes	Yes	No
Potassium oxide	12136-45-7	No	Yes	No	No
Silica-crystalline (SiO_2), quartz	14808-60-7	Yes	Yes	Yes	No
Sodium oxide	1313-59-3	No	Yes	No	No
Titanium dioxide	13463-67-7	Yes	Yes	Yes	Yes

[1] Massachusetts Department of Public Health, no date
[2] 189th General Court of The Commonwealth of Massachusetts, no date
[3] New Jersey Department of Health and Senior Services, 2010a
[4] New Jersey Department of Health, 2010b
[5] Pennsylvania Code, 1986
[6] Rhode Island Department of Labor and Training, no date

Section 16
Other Information, Including Date of Preparation or Last Revision

16.1 Indication of Changes

Date of preparation or last revision: February 23, 2018

16.2 Abbreviations and Acronyms

- ACGIH: American Conference of Industrial Hygienists
- CA: California
- CAS: Chemical Abstract Services
- CCP: Coal Combustion Product
- CFR: Code of Federal Regulations
- EPA: Environmental Protection Agency
- GHS: Globally Harmonized System of Classification and Labelling
- IARC: International Agency for Research on Cancer
- LC50: Concentration resulting in the mortality of 50 % of an animal population
- LD50: Dose resulting in the mortality of 50 % of an animal population
- MA: Massachusetts
- NA: Not Applicable
- NJ: New Jersey
- NOEC: No observed effect concentration
- NIOSH: National Institute of Occupational Safety and Health
- NOx: Nitrogen oxides
- NTP: US National Toxicology Program
- OEL: Occupational Exposure Limit
- OSHA: Occupational Safety and Health Administration
- PA: Pennsylvania
- PBT: Persistent, Toxic and Bioaccumulative
- PEL: Permissible exposure limit
- PPE: Personal Protective Equipment
- REL: Recommended exposure limit
- RI: Rhode Island
- RCS: Respirable Crystalline Silica
- RTK: Right-to-Know
- SCBA: Self-contained breathing apparatus
- SDS: Safety Data Sheet
- STEL: Short-term exposure limit
- STOT-RE: Specific target organ toxicity-repeated exposure
- STOT-SE: Specific target organ toxicity-single exposure
- TLV: Threshold limit value
- TSCA: Toxic Substances Control Act
- TWA: Time-weighted average
- UEL: Upper explosive limit
- UVCB: Unknown or Variable Composition/Biological
- U.S.: United States
- U.S. DOT: United States of Department of Transportation

16.3 Other Hazards

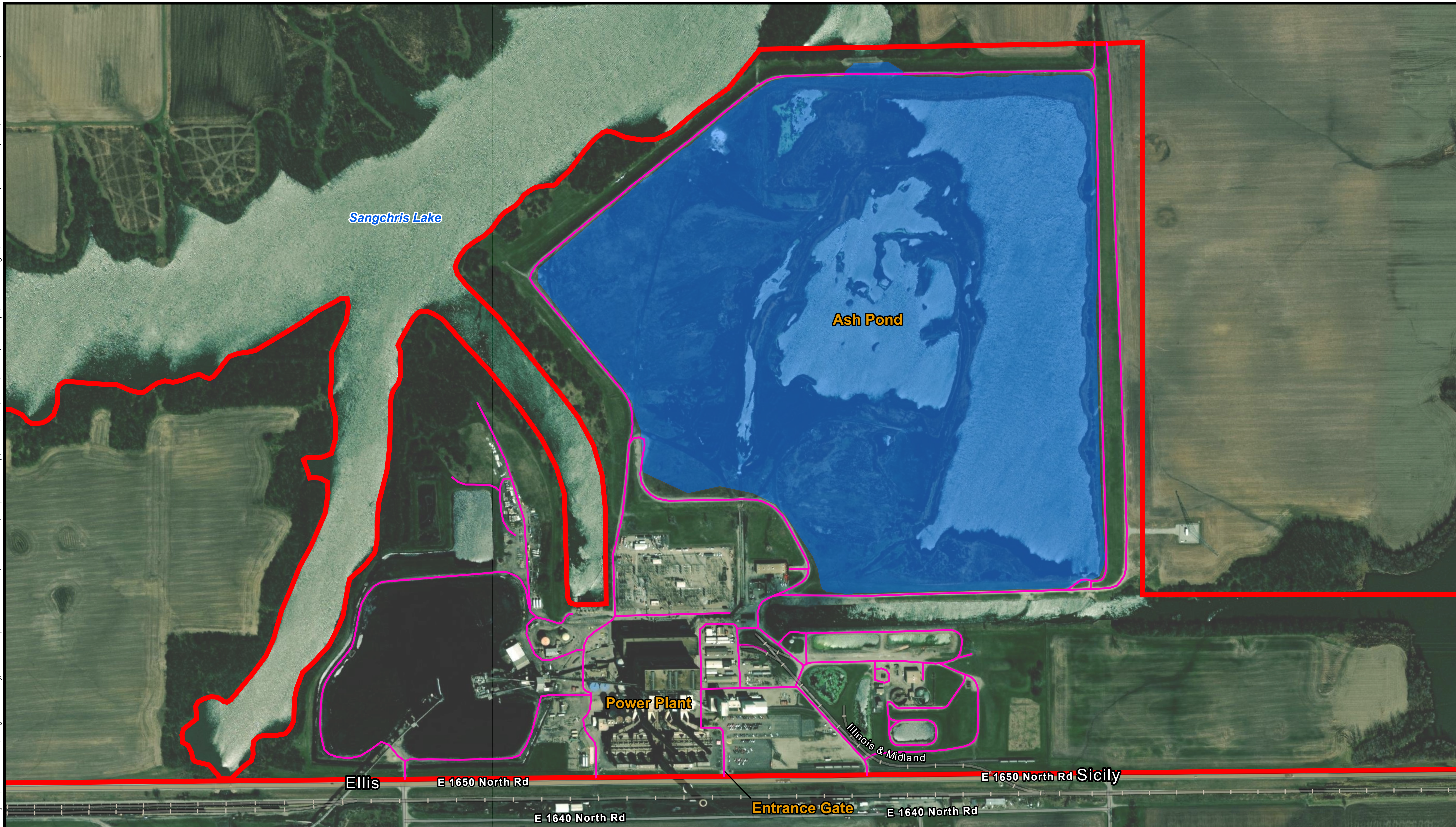
Hazardous Materials Identification System (HMIS) Degree of hazard (0= low, 4 = extreme)							
Health:	2*	**Flammability:**	0	**Physical Hazards:**	0	**Personal protection:****	

** Chronic Health Effects*
****** *Appropriate personal protection is defined by the activity to be performed.*
See Section 8 for additional information.

DISCLAIMER:

This SDS has been prepared in accordance with the Hazard Communication Rule 29 CFR 1910.1200. Information herein is based on data considered to be accurate as of date prepared. No warranty or representation, express or implied, is made as to the accuracy or completeness of this data and safety information. No responsibility can be assumed for any damage or injury resulting from abnormal use, failure to adhere to recommended practices, or from any hazards inherent in the nature of the product.

ATTACHMENT E: SITE PLAN MAP AND ON-SITE TRANSPORTATION PLAN 845.220(a)(4) AND 845.220(a)(2)(E)



- Internal Roads
- Kincaid Generation Property Boundary
- Existing CCR Pond

NORTH

500 250 0 500

Scale in Feet

BURNS McDONNELL

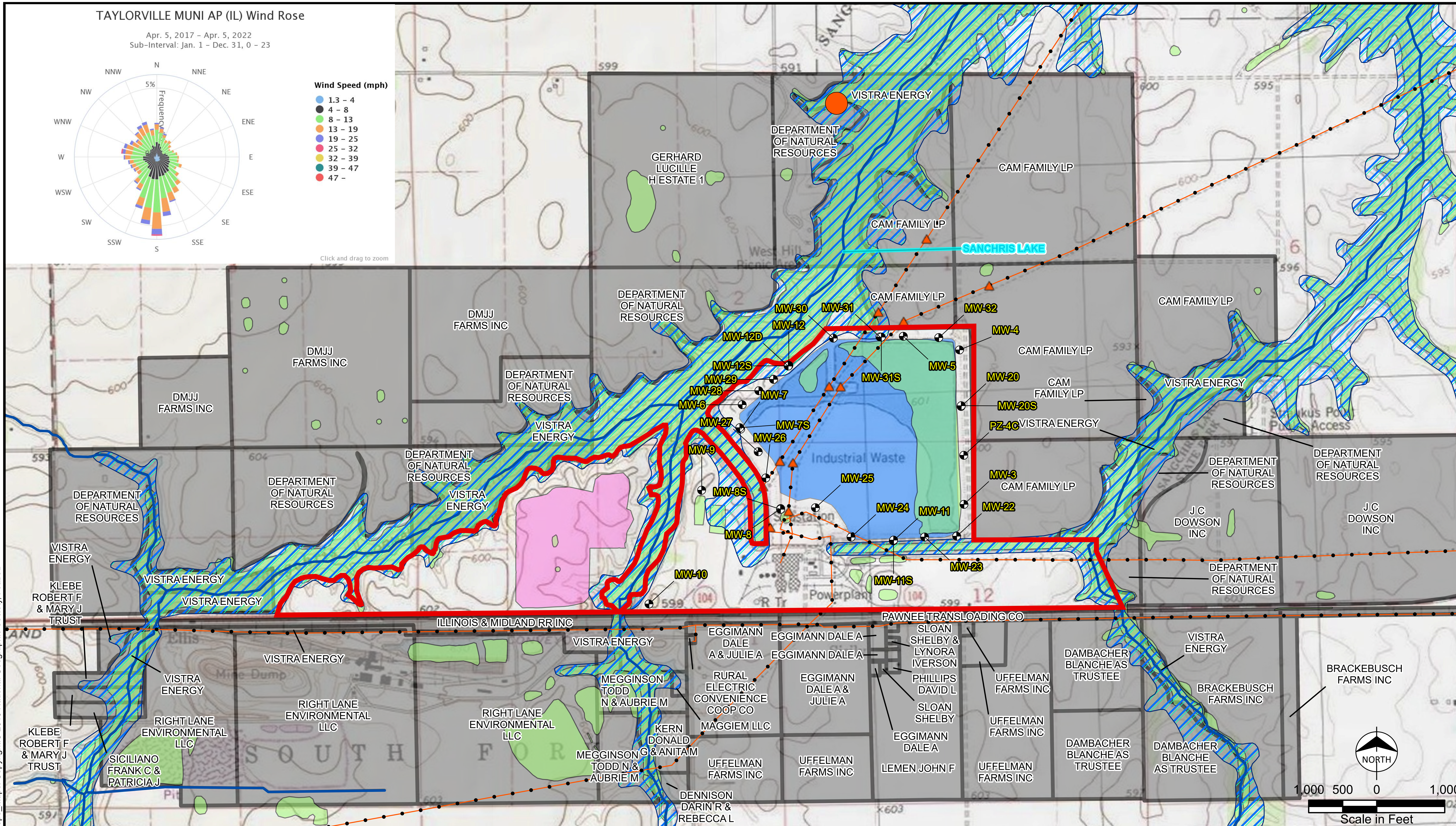
Attachment E
Site Plan Map and
On-Site Transportation Plan
Kincaid - Ash Pond
Vistra Energy
Christian County, Illinois

Issued: 7/5/2022

Source: Esri, Burns & McDonnell, Vistra Energy

Path: Z:\Clients\ENS\VistraEnergy\132803_Prt845CnPermitStudies\Geospatial\DataFiles\ArcDocs\Figure X - NWI and FEMA Map.aprx belockwood 7/5/2022
Service Layer Credits: World Imagery: Maxar
Hybrid Reference Layer: Esri Community Maps Contributors, Sangamon County, Missouri Dept. of Conservation, Missouri DNR, © OpenStreetMap, Microsoft, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, US Census Bureau, USDA

ATTACHMENT F: SITE LOCATION MAP 845.220(a)(3)



- Monitoring Well
- Transmission Tower
- EIA Transmission Line
- NHD FLowline
- Kincaid Generation Property Boundary
- Adjacent Property Boundary
- Existing CCR Pond
- Proposed Landfill
- NWI Wetland
- FEMA 100-Year Floodplain
- Known Threatened or Endangered Species Habitat

NOTE
1. CCR unit limits and Site boundary locations are approximate.
2. Local utilities including, but not limited to, service electric lines, gas lines, water and sewer lines, telecommunication lines, plant utilities, and/or private utilities are not shown on this figure and shall be verified in the field prior to any site work.
3. There are no Nature Preserves or Land and Water Reserves within the project area or 1,000m of the project area.
4. There are no historic and archaeological sites within the project area or 1,000m of the project area.
5. The Kirtland's Snake (Clonophis kirtlandii) is a threatened/endangered species of nonvenomous snake that has an identified habitat approximately 940 meters north of the existing ash pond, opposite of Sangchris Lake.

BURNS McDONNELL

Attachment F
Site Location Map
Kincaid - Ash Pond
Vistra Energy
Christian County, Illinois

Path: Z:\Clients\ENS\VistraEnergy\132803_Prt845CnPermit\Studies\Geospatial\DataFiles\ArcDocs\Figure X - NWI and FEMA Map.aprx belockwood 7/5/2022
Service Layer Credits: USA_Topo_Maps: Copyright:© 2013 National Geographic Society, i-cubed

Source: Esri, Burns & McDonnell, Vistra Energy, FEMA, NWI, NHD, USGS, IDNR

Issued: 7/5/2022

ATTACHMENT G: FINAL CLOSURE PLAN AND PROPOSED CLOSURE SCHEDULE (INCLUDING CLOSURE ALTERNATIVES ANALYSIS) 845.210, 845.220(a)(5-6), 845.720(b), 845.220(d)(2)

CCR SURFACE IMPOUNDMENT FINAL CLOSURE PLAN KINCAID POWER PLANT ASH POND (IEPA ID W0218140002-01)

Kincaid, Illinois

Kincaid Generation, L.L.C.

IEPA Part 845 Kincaid Ash Pond Construction Permit Application

Project No. 132803

Revision A
7/28/2022

CCR SURFACE IMPOUNDMENT FINAL CLOSURE PLAN KINCAID POWER PLANT ASH POND (IEPA ID W0218140002-01) Kincaid, Illinois

prepared for

Kincaid Generation, L.L.C.
IEPA Part 845 Kincaid Ash Pond Construction Permit Application
Kincaid, Illinois

Project No. 132803

Revision A
7/28/2022

prepared by

Burns & McDonnell Engineering Company, Inc.
St. Louis, Missouri

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LIST OF TABLES

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LIST OF ABBREVIATIONS

Abbreviation	**Term/Phrase/Name**
Burns & McDonnell	Burns & McDonnell Engineering Company, Inc.
BMP	Best Management Practice
CAA	Closure Alternatives Analysis
CBR	Closure by Removal
CCR	Coal Combustion Residual
C.F.R.	Code of Federal Regulations
CIP	Closure-in-Place
CMP	Corrugated Metal pipe
cm/sec	Centimeters per second
ComEd	Commonwealth Edison Company
CY	Cubic Yards
DSP	Dam Safety Program
HELP	Hydrologic Evaluation of Landfill Performance
ft	Feet
IDNR	Illinois Department of Natural Resources
IEPA	Illinois Environmental Protection Agency
in/yr	Inches of water per year
Inc.	Incorporated
KAP	Kincaid Ash Pond
KPP	Kincaid Power Plant
kVA	Kilovolt-Ampere

Abbreviation	Term/Phrase/Name
LLDPE	Linear low-density polyethylene
L.L.C.	Limited Liability Company
MWac	Megawatts AC
MWdc	Megawatts DC
NPDES	National Pollutant Discharge Elimination System
PLS	Pure Live Seed
PV	Photovoltaic
OWR	Office of Water Resources
Rev.	Revision
RCP	Reinforced Concrete Pipe
SF	Square foot
SWPPP	Storm Water Pollution Prevention Plan
TOC	Table of Content
WPC	Water Pollution Control
WWTP	Wastewater Treatment Plant
%	Percent

1.0 INTRODUCTION

Kincaid Generation, L.L.C. is the operator of the coal-fired Kincaid Power Plant (KPP) located in Christian County near Kincaid, Illinois. One Coal Combustion Residuals (CCR) surface impoundment, the Kincaid Ash Pond (KAP) is present at the KPP. The KAP has an Illinois Environmental Protection Agency (IEPA) identification number of W0218140002-01.

This Final Closure Plan was developed in accordance with 35 Ill. Admin. Code 845, Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments (Part 845). Closure of the KAP is scheduled to be completed no later than October 31, 2028. As part of the closure effort, a new photovoltaic (PV) solar power facility will be installed on top of the closed KAP. The PV facility will have a rated power of approximately 29 megawatts AC (MWac) and an installed power of approximately 34 megawatts DC (MWdc). Interconnection of the solar facility will occur at the existing Kincaid substation.

1.1 Selected Closure Method

Section 845.720(b)(3): The final closure plan must identify the proposed selected closure method and must include the information required in subsection (a)(1) and the closure alternatives analysis specified in Section 845.710.

Based on the Closure Alternatives Analysis (CAA) completed for the KAP, a hybrid closure with a final cover system has been identified as the most appropriate closure method. All CCR in the northern portion of the impoundment will be removed and relocated to the southern portion of the impoundment which will be closed in accordance with Section 845.750. Under this hybrid approach, approximately 52% of the current CCR footprint within the impoundment will be removed. The CAA is provided in **Appendix A** and information developed to support the CAA is provided in **Appendix B**.

1.2 Organization of Final Closure Plan

This Final Closure Plan is organized in the following manner:

- **Section 2** includes the Final Closure Plan, as required by Section 875.720(a)(1);
- **Section 3** includes a summary of amendments of the Closure Plan;
- **Section 4** includes a discussion of how the closure using a final cover system will comply with the performance and design requirements of Sections 845.720 and 845.750;

- **Section 5** includes additional information regarding the closure;
- **Section 6** includes a Certification from a Qualified Professional Engineer; and
- **Section 7** includes reference documents used in the development of this Final Closure Plan.

2.0 FINAL CLOSURE PLAN

Section 845.720(a)(1): Content of the Preliminary Closure Plan. The owner or operator of a new CCR surface impoundment or an existing CCR surface impoundment not required to close under Section 845.700 must prepare a preliminary written closure plan that describes the steps necessary to close the CCR surface impoundment at any point during the active life of the CCR surface impoundment consistent with recognized and generally accepted engineering practices.

This section includes the final closure plan for the KAP, as required by Section 845.720(a)(1). Specific requirements of the closure plan and the relevant regulatory citations are included in the following sections.

2.1 Narrative Closure Description

Section 845.720(a)(1)(A): A narrative description of how the CCR surface impoundment will be closed in accordance with this Part.

The KAP will be closed in place by consolidating the CCR into a reduced footprint and covering the consolidated CCR with a final cover compliant with 40 C.F.R. § 257.102(d)(3) and Section 845.750(c). The remainder of the KAP footprint will be closed by removing all of the CCR and placing these CCR materials within the consolidated footprint. The KAP is an unlined CCR surface impoundment; however, the impoundment is underlain by lean clay overlying hard glacial till (lean sandy clay) and closure of the KAP will include constructing a final cover system that ties into existing, low permeability subsoils; existing, low permeability perimeter berm soils; or low permeability fill soils; thereby encapsulating CCR within the KAP on the top, bottom, and sides.

During the closure process, off-site CCR beneficial use opportunities will continue to be assessed. CCR consolidation and closure in place in combination with offsite beneficial use may result in a smaller onsite CCR footprint, for the purposes of final cover system design, and a reduced construction schedule.

Permit-level engineering drawings and material specifications for the closure are provided in **Appendix C**.

2.1.1 Water Management During Closure

The KAP currently operates as a closed-loop impoundment, whereby water is recirculated from the KAP back to the KPP for bottom ash sluicing. In addition to bottom ash sluice water, stormwater from the West Area Runoff Basin is also discharged to the KAP. During the initial phase of closure (Phase 1), a temporary operating pool, approximately 9.4 acres in size, will be constructed in the southeastern corner of the KAP using sheet pile or other vertical hydraulic barrier system. Ponded and subsurface free liquids generated during KAP closure activities will be transferred to the temporary operating pool. During Phase 1 closure, bottom ash sluice water recirculation will continue while free liquids are removed from the KAP and CCR from the northern portion of the KAP is removed and consolidated with CCR in the southern portion of KAP. The temporary operating pool is sized to accommodate West Area Runoff Basin discharges, including storm surges (Type II, 10-year, 24-hour event), while bottom ash discharges to the KAP and sluice water recirculation to the KPP continue; however, the West Area Runoff Basin discharge can also be routed to the onsite wastewater treatment plant (WWTP) for treatment and subsequent discharge via National Pollutant Discharge Elimination System (NPDES) Outfall B01. Sizing calculations for the temporary operating pool are provided in **Appendix D**.

Under normal circumstances, the West Area Runoff Basin discharge will be routed to the WWTP, providing the capacity needed for the KAP temporary operating pool to receive free liquids removed from the CCR during closure activities. However, in the event of a WWTP upset or large storm event, West Area Runoff Basin discharges can still be routed to the KAP temporary operating pool. This arrangement will also allow bottom ash sluice water recirculation to continue while free liquids are removed from the remainder of the KAP and CCR from the northern portion of the KAP is removed and consolidated with CCR in the southern portion of KAP. No other changes in waste streams are expected to occur during closure of the KAP.

Under certain circumstances (e.g., periods of high CCR unwaters/dewaters production), it may be necessary to transfer water from the KAP temporary operating pool to the WWTP for treatment and discharge via Outfall B01. Modifications to the existing WWTP may also be required to meet NPDES discharge permit requirements. Final NPDES discharge requirements will be established, and WWTP modification needs will be determined based on the results of a pending antidegradation study.

The KPP will be retired prior to the start of the second phase of KAP closure. Near the end of the second phase of closure, free liquids will be removed from the temporary operating pool and the pool will be filled in with CCR. The hydraulic barrier system used to create the temporary operating pool will not be removed but will be closed in place beneath the final cover system. Final CCR grading, general fill placement and grading, and cover system construction will be completed during the second phase of closure.

2.1.2 Phase 1 Closure

The initial phase of KAP closure with a final cover system will include the following tasks:

- Prepare the site for closure by establishing perimeter stormwater Best Management Practices (BMPs), as and if needed, at the construction limits of disturbance.

- Construct a temporary operating pool, approximately 9.4 acres in size, in the southeastern corner of the KAP using sheet pile or other vertical hydraulic barrier system.

- Modify the existing ash sluice pipelines and relocate the existing bottom ash sluice channel to convey CCR discharges from the existing ash sluice pipelines to the temporary operating pool.

- Unwater the KAP by pumping ponded free liquids to the temporary operating pool.

- Abandon existing geotechnical piezometers XPW-01 through XPW-04 that will not be utilized as post-closure instrumentation. Abandonment will be performed in accordance with Illinois monitoring well regulations.

- Establish a temporary dewatering and water management system within the KAP consisting of trenches and sumps to support passive (i.e., gravity) removal of free liquids and to collect contact stormwater during closure and maintain the KAP in an unwatered state. During construction, contact stormwater will be pumped to the temporary operating pool within the KAP. As discussed in Section 2.1.1, water collecting with the temporary operating pool will either be recirculated to the KPP or transferred to the onsite WWTP for treatment and subsequent discharge via NDPES Outfall B01.

- Remove all CCR from the northern portion of the KAP and consolidate it with CCR in the southern Closure-In-Place (CIP) portion of KAP. A new soil dike will be constructed along the northern boundary of the CIP portion of the KAP in accordance with the Illinois Department of Natural Resources Part 3702 Rules. To alleviate stability concerns for the new dike construction, any saturated soils underlying the proposed location of the new dike will be over excavated and replaced with compacted, low permeability soils. This includes any materials located in the former stream channels leading to Sangchris Lake.

- After CCR has been removed from the northern portion of the KAP, subsoils will be visually inspected for indications of CCR. If subsoils with the presence of CCR are observed, they will be removed and consolidated in the southern portion of the KAP. It is anticipated that up to 1 ft of subsoils may be removed; however, visual inspection will be conducted to confirm that all CCR is removed. CCR will be placed in lifts and compacted to provide a subgrade suitable for construction of a final cover system. Free liquids will be removed from the CCR to support construction activity and fill placement, using the water management system.

- Begin constructing a final cover system extending over the footprint of the KAP that contains consolidated CCR, and includes, from bottom to top:
    - A 40-mil linear low-density polyethylene (LLDPE) geomembrane, placed on a prepared subgrade with rocks no larger than one inch in diameter and other sharp objects removed prior to placement;
    - A nonwoven geotextile cushioning layer, to protect the geomembrane from rocks and/or sharp objects in the cover soil;
    - Based on a demonstration included as **Appendix E**, pursuant to Section 845.750(c)(2), final soil cover including an alternative 1.5 foot (ft) protective layer (i.e., cover soil) to protect the geomembrane and 0.5 ft of topsoil capable of supporting vegetation, for a total cover soil thickness of 2 ft.
    - The final cover system grades will be approximately 3-percent (%) over the majority of the KAP, with a 7% slope along the southern extent and 25% (4 horizontal to 1 vertical [4H:1V]) around the perimeter, to intersect existing grades or final grades where CCR has been removed.
    - The final cover system will include an anchor trench for the geosynthetic materials along the entire perimeter of the KAP to secure the final cover system into existing grades. The anchor trench will be placed beyond the final limits of CCR.
    - Existing groundwater monitoring wells MW-23 and MW-24 and existing piezometer P-002, will be retained and modified by extending the wells through the final cover system, sealing the penetration with a pipe boot, and constructing a new surface completion on top of the final cover.

2.1.3 Phase 2 Closure

The second phase of KAP closure with a final cover system will include the following tasks:

- Continue maintaining BMPs, the temporary operating pool and the temporary dewatering and water management system. The KPP will be retired prior to the start of Phase 2 closure activities; consequently, bottom ash discharges to the KAP and bottom ash sluice recirculation from the KAP will not occur during Phase 2.

- Abandon existing outflow structures and culverts connecting the KAP to Sangchris Lake and the Bottom Ash Sluice Recycle System. This will prevent unplanned discharges through these conduits under post-closure conditions. This will be accomplished by completing the following:

    - For the bottom ash sluice recycle intake structure, demolish the concrete intake structure and building, clean the interior of the 60-inch concrete reinforced pipe (RCP) [intake pipe] via pressure washing, and seal the RCP intake pipe. Following cleaning of the RCP, a plug will be inserted outside of the portion of the pipe that penetrates through the dike (approximately 50 ft south of the intake structure, north of the 90-degree bend), as shown on drawings provided in Attachment C of the Construction Permit Application. The entire extent of the RCP intake pipe, from the intake structure to the plug, will then be filled with cement-bentonite grout.

    - For the emergency overflow structure, demolish the concrete intake structure and catwalk, clean the interior of the 48-inch corrugated metal pipe (CMP) [outflow pipe] via pressure washing, and seal the outflow pipe by inserting a plug near the discharge end and filling the entire length with cement-bentonite grout.

- Complete removal of all CCR from the northern portion of the KAP and consolidation of this CCR in the southern portion of KAP. After CCR has been removed, subsoils will be visually inspected for indications of CCR. If subsoils with the presence of CCR are observed, they will be removed and consolidated in the southern portion of the KAP. It is anticipated that up to 1 ft of subsoils may be removed; however, visual inspection will be conducted to confirm that all CCR is removed. CCR will be placed in lifts and compacted to provide a subgrade suitable for construction of a final cover system. Free liquids will be removed from the CCR to support construction activity and fill placement, using the water management system.

    - In total, approximately 1,872,000 cubic yards (CY) of CCR will be removed from the northern portion of the KAP and placed in the consolidated footprint in the southern portion of the Site.

- There are a total of four (4) towers supporting 345-kilovolt transmission lines owned by Commonwealth Edison Company (ComEd), located within the footprint of the KAP. All four of the towers lie within the northern portion of the KAP where all CCR will be removed. Based on correspondence between ComEd and Kincaid Generation, L.L.C., each leg of each transmission tower is encased below grade in a concrete cylinder and is believed to be founded on subsurface materials lying below the CCR. The transmission lines will be relocated, raised, or otherwise modified, in coordination with ComEd, as and if needed to allow for construction access. If the towers are to remain in place during construction, proper safety protocols established by ComEd will be adhered to during the removal of CCR around the base of the transmission towers.

- Upon completion of the new dike for the CIP portion of the KAP, a section of the existing dike along the north boundary of the existing KAP will be breached to allow non-contact stormwater to flow by gravity into Sangchris Lake. A riprap-lined stormwater conveyance channel will be constructed through the opening of the dike to prevent erosion and sediment from entering the Lake.

- Clean, imported general fill will be placed and graded within the northern portion of the KAP Pond to promote positive stormwater drainage away from the CIP footprint to the conveyance channel and into Sangchris Lake.

- Complete construction of a final cover system extending over the entire footprint of the consolidated CCR footprint. The cover system will be constructed as described in Section 2.1.2.

- Remove free liquids from the temporary operating pool by discharging the contents through an NPDES-permitted outfall following treatment, as required.

- To minimize infiltration and prevent erosion, construct a post-closure non-contact stormwater management system consisting of cross-slope swales, riprap-lined letdown channels and perimeter ditches. These features will convey stormwater from the KAP final cover system to the northern portion of the KAP where CCR has been removed and to Sangchris Lake.

- In the southeast corner of the KAP, install five culvert pipes to convey stormwater from the perimeter ditches to the Sangchris Lake channel that runs parallel to the southern boundary of the KAP.

- Establish vegetation on the final cover system by:

- o Fertilizing the topsoil, as needed to support vegetation, based on agronomical soil tests;
- o Seeding the topsoil with a suitable grass seed for local climatic and soil conditions;
- o Providing temporary BMPs measures such as mulch, erosion control blankets, silt fences, and/or straw wattles, as necessary to reduce the potential for soil erosion until vegetation is established; and
- o Restoring the site, after vegetation is established and the site is stabilized, by removing stormwater BMPs and temporary stabilization measures that are no longer needed.
- o For select areas of the site, the vegetation shall include native pollinator plantings consistent with the Illinois Department of Natural Resources (IDNR) "Solar Site Pollinator Scorecard" (Solar Site Pollinator Scorecard, 2022). In the northern portion of the KAP, outside of the CIP area, the soils will be fertilized and planted with pollinator plants. If pollinators are proposed for the CIP area, the final grading plan shall be revised to increase the depth of the protective soil to accommodate the deeper roots of the pollinators. In accordance with the Pollinator Establishment Guidelines prepared by the IDNR, native prairie species will be planted approximately 1/8"-1/4" deep on bare firm ground free of weeds. A ratio of 25% Native Grasses to 75% wildflowers is preferred and on slopes with grades of 5% or less, with a minimum seeding rate of 20 seeds per square foot (SF) of Pure Live Seed (PLS). PLS is calculated by the following equation: PLS = % Purity X % Total Germination/100 (Illinois Department of Natural Resources, 2019).

  Long-term maintenance of the pollinators shall be performed in accordance with IDNR guidelines. The site should be checked for undesirable species such as woody plants or invasive species at least annually. During the first year, mowing at a height of 10" or greater 1-3 times during the growing season. Spot mowing and/or spot herbicide treatment will be performed to control noxious and undesirable weeds. After the first year, mowing will not take place during April 15th – October 1st.

2.2 Decontamination of CCR Surface Impoundment

Section 845.720(a)(1)(B): If closure of the CCR surface impoundment will be accomplished through removal of CCR from the CCR surface impoundment, a description of the procedures to remove the CCR and decontaminate the CCR surface impoundment in accordance with Section 845.740.

After all CCR has been removed from the northern portion of the KAP and consolidated with CCR in the southern portion of KAP, subsoils will be visually inspected for signs of CCR. If subsoils with the presence of CCR are observed, they will be removed and consolidated in the southern portion of the KAP.

It is anticipated that up to 1 ft of subsoils may be removed; however, visual inspection will be conducted to confirm that all CCR in the northern portion of the KAP is removed. The portion of the earthen berm along the northern boundary of the KAP that is removed to provide a stormwater conveyance will also be consolidated with CCR in the southern portion of the KAP. Decontamination of areas outside of the northern portion of the KAP will not be required because there have been no releases of CCR from the northern portion of the KAP and there is no containment system within the KAP.

2.3 Final Cover System

Section 845.720(a)(1)(C): If closure of the CCR surface impoundment will be accomplished by leaving CCR in place, a description of the final cover system, designed in accordance with Section 845.750, and the methods and procedures to be used to install the final cover. The closure plan must also discuss how the final cover system will achieve the performance standards specified in Section 845.750.

A description of the final cover system design, the methods and procedures used for installation, and how the final cover system will achieve the Section 845.750 performance standards is provided in **Section 4** of this Final Closure Plan.

2.4 Maximum CCR Inventory

Section 845.720(a)(1)(D): An estimate of the maximum inventory of CCR ever on-site over the active life of the CCR surface impoundment.

The KAP currently contains approximately 2,949,000 CY of CCR. Approximately 180,000 CY of additional bottom ash will be generated between the end of 2021 and the time CCR generation ceases at the KPP in July 2027, resulting in a maximum CCR capacity of approximately 3,129,000 CY.

2.5 Largest Surface Area Estimate

Section 845.720(a)(1)(E): An estimate of the largest area of the CCR surface impoundment ever requiring a final cover (see Section 845.750), at any time during the CCR surface impoundment's active life.

The largest surface area of the KAP, in plan-view, is approximately 172 acres (Ramboll, 2021). This is the current size of the KAP. As part of the closure plan, the CCR material will be consolidated in the southern portion of the KAP. The final cover will be placed over an area of approximately 84 acres, extending completely across the surface area of the consolidated CCR footprint and beyond the limits of CCR within the KAP. The geosynthetic components of the cover system will terminate in an anchor trench to prevent surface water from infiltrating under the cover system.

During the closure process, off-site CCR beneficial use opportunities will continue to be assessed. CCR consolidation and closure in place in combination with offsite beneficial use may result in a smaller onsite CCR footprint, for the purposes of final cover system design, and a reduced construction schedule.

2.6 Closure Completion Schedule

Section 845.720(a)(1)(F): A schedule for completing all activities necessary to satisfy the closure criteria in this Section, including an estimate of the year in which all closure activities for the CCR surface impoundment will be completed. The schedule should provide sufficient information to describe the sequential steps that will be taken to close the CCR surface impoundment, including identification of major milestones such as coordinating with and obtaining necessary approvals and permits from other agencies, the dewatering and stabilization phases of CCR surface impoundment closure, or installation of the final cover system, and the estimated timeframes to complete each step or phase of CCR surface impoundment closure.

All KAP closure activities are expected to be completed prior to October 2028. A milestone closure completion schedule has been prepared and is provided in **Table 2-1**. Key sequential phases and sub-tasks that will be completed as part of the closure will include:

Phase 1 – While the KPP is operational:

- Prepare the site for closure by establishing perimeter stormwater BMPs, as and if needed, at the construction limits of disturbance.
- Construct a temporary operating pool, approximately 9.4 acres in size, in the southeastern corner of the KAP using sheet pile or other vertical hydraulic barrier system. Relocate the existing bottom ash sluice channel to convey CCR discharges from the existing ash sluice pipelines to the temporary operating pool.
- Unwater the KAP by pumping ponded free liquid to the temporary operating pool.
- Abandon existing geotechnical piezometers XPW-01 through XP2-004 that will not be utilized as post-closure instrumentation. Abandonment will be performed in accordance with Illinois monitoring well regulations.
- Establish a temporary dewatering and water management system within the KAP consisting of trenches and sumps to support the passive (i.e., gravity) removal of free liquids from CCR for

stabilization and to collect contact stormwater during closure and maintain the KAP in an unwatered state.

- Remove all CCR from the northern portion of the KAP and consolidate it with CCR in the southern portion of KAP.

- Begin constructing a final cover system extending over the consolidated CCR footprint.

Phase 2 – After the KPP ceases operations on July 1, 2027:

- Continue maintaining BMPs, the temporary operating pool and the temporary dewatering and water management system. The KPP will be retired prior to the start of Phase 2 closure activities; consequently, bottom ash discharges to the KAP and bottom ash sluice recirculation from the KAP will not occur during Phase 2.

- Abandon existing outflow structures and culverts connecting the KAP to Sangchris Lake and the Bottom Ash Sluice Recycle System.

- Complete removal of all CCR from the northern portion of the KAP and consolidation of CCR in the southern portion of KAP.

- Open a section of the berm along the northern boundary of the KAP and construct a riprap-lined stormwater conveyance channel to allow non-contact stormwater to flow by gravity into Sangchris Lake.

- Place and grade clean, imported general fill within the northern portion of the KAP Pond to promote positive stormwater drainage to the conveyance channel and into Sangchris Lake.

- Complete construction of a final cover system extending over the entire consolidated CCR footprint.

- Remove free liquids from the temporary operating pool by discharging the contents through an NPDES-permitted outfall following treatment, as required.

- Construct a post-closure non-contact stormwater management system consisting of cross-slope swales, riprap-lined letdown channels and perimeter ditches to convey stormwater from the KAP final cover system to the northern portion of the KAP and Sangchris Lake.

- In the southeast corner of the KAP, install five culvert pipes to convey non-contact stormwater from perimeter ditches to the Sangchris Lake channel that runs parallel to the southern boundary of the KAP.
- Restore the site, after vegetation is established and the site is stabilized, by removing stormwater BMPs and temporary stabilization measures that are no longer needed.

Table 2-1: Closure Completion Milestone Schedule

Milestone	Timeframe (Preliminary Estimates)
Final Closure Plan Submittal	
Agency Coordination, Approvals, and Permitting • Obtain state permits, as needed, for free liquids removal, water discharge, land disturbance, and dam modifications.	8 to 12 months after final Closure Plan Approval
Final Design and Bid Process • Complete final design of the closure and select a construction contractor.	6 to 8 months after Agency Coordination, Approvals, and Permitting
Remove Free Liquids and Stabilize CCR, Install Final Cover System • Complete contractor mobilization, installation of stormwater BMPs, and unwatering of the KAP • Consolidate CCR material in the southeast footprint and grade to design contours • Abandon outfall structures, stabilize the KAP, and complete grading. • Install the final cover system and stormwater management features	20 to 26 months after necessary permits are issued
Site Restoration • Seed and stabilize the KAP. • Complete Contractor demobilization.	3 to 5 months
Timeframe to Complete Closure	39 to 54 months (prior to October 2028)

During the closure process, off-site CCR beneficial use opportunities will continue to be assessed. CCR consolidation and closure in place in combination with offsite beneficial use may result in a smaller onsite CCR footprint, for the purposes of final cover system design, and a reduced construction schedule.

Section 845.720(a)(1)(F) (Continued): When preparing the preliminary written closure plan, if the owner or operator of a CCR surface impoundment estimates that the time required to complete closure will exceed the timeframes specified in Section 845.760(a), the preliminary written closure plan must include the site-specific information, factors and considerations that would support any time extension sought under Section 845.760(b).

The time required to complete closure construction is not currently expected to exceed the timeframe specified in Section 845.760(a). Therefore, closure extensions for the KAP are not being sought at this time.

3.0 AMENDMENTS OF FINAL CLOSURE PLAN

Section 845.720(b)(4): *If a final written closure plan revision is necessary after closure activities have started for a CCR surface impoundment, the owner or operator must submit a request to modify the construction permit within 60 days following the triggering event.*

If revisions are required for this Final Closure Plan, the owner will submit a request to modify the construction permit within 60 days following the triggering event.

Table 3-1: CCR Final Closure Plan Revisions

Revision Number and Date	Pages or Section	Description of Revision	Professional Engineer Certifying Plan

4.0 CLOSURE WITH FINAL COVER SYSTEM

This section includes a description of the final closure with a final cover system that will be completed for the KAP surface impoundment, including principal design and construction features, material specifications, and a discussion of how each feature satisfies the requirements of Section 845.750. Drawings showing each design feature and material specifications are provided in **Appendix C**.

4.1 Minimization of Post-Closure Infiltration and Releases

Section 845.750(a)(1): *The owner or operator of a CCR surface impoundment must ensure that, at a minimum, the CCR surface impoundment is closed in a manner that will: Control, minimize or eliminate, to the maximum extent feasible, post-closure infiltration of liquids into the waste and releases of CCR, leachate, or contaminated run-off to the ground or surface waters or to the atmosphere.*

The proposed CIP design will control, minimize, or eliminate, as much as feasible, "post-closure infiltration of liquids" and releases of CCR, leachate, or contaminated runoff as interpreted by Illinois EPA in the Part 845 rulemaking.

Closure will, to the maximum extent feasible, minimize the post-closure infiltration of liquids into the retained CCR through the installation of a final cover system with the following design features and specifications:

- A 40-mil LLDPE geomembrane low-permeability layer will be placed on the prepared subgrade to minimize vertical infiltration into the surface impoundment. The geomembrane will be constructed on a subgrade that is free of sharp rocks or other debris and will be protected from damage by installing a geotextile cushion layer and a total of two feet of cover soil and topsoil over the top of the geomembrane.

- Surface stormwater will be routed off the top of the final cover by the construction of a free-draining, post-closure stormwater management system including swales, letdown channels and perimeter ditches. The stormwater management system will drain by gravity and preclude water impoundment on top of the final cover system, thereby minimizing post-closure infiltration into the CCR.

The need for a geocomposite drainage layer within the final cover system was evaluated for stability and infiltration. The geotechnical analyses documented in **Appendix F** demonstrate that a geocomposite drainage layer is not required for cover system stability purposes. The infiltration modeling results presented in Attachment B of the Part 845 Construction Permit Application demonstrate that a geocomposite drainage layer is not required for final cover system transmissivity purposes.

Releases of CCR leachate and/or contaminated run-off into the groundwater, surface waters, and/or atmosphere will be minimized, to the maximum extent feasible, as:

- The KAP is an unlined CCR surface impoundment; however, the impoundment is underlain by lean clay overlying hard, glacial till (lean sandy clay). Closure of the KAP will include constructing a final cover system that ties into existing, low permeability subsoils; existing, low permeability perimeter berm soils; or low permeability fill soils; thereby encapsulating CCR within the KAP on the top, bottom, and sides. This will minimize and control lateral migration of water into the unit and minimize any releases of CCR leachate into ground or surface waters, in addition to minimizing any lateral migration of CCR leachate out of the KAP.
    - The final cover system will tie into surrounding low permeability soils, by constructing a final cover anchor trench beyond the horizontal limits of the consolidated CCR. The final cover will therefore provide continuous encapsulation between the CCR and surrounding environment on the top, bottom, and sides of the CCR.
    - This continuous barrier will result in the CCR being physically isolated from the surrounding environment on all sides, including the groundwater, surface water, and atmosphere and therefore minimize the releases of CCR, leachate, or contaminated run-off into the ground, surface waters, and atmosphere.
- CCR leachate (e.g., pore water within the CCR) volumes will be minimized via the installation of the final cover system including a low-permeability geomembrane layer. The final cover system will minimize infiltration and therefore the amount of leachate within the CCR. As shown in the groundwater modeling results presented in Attachment B of the Part 845 Construction Permit Application, the CIP closure design will result in a 99% reduction in infiltration into the KAP, as compared to pre-closure conditions. The Groundwater Modeling Report also shows that the closure design will result in a 99% reduction in hydraulic flux out of the KAP, as compared to pre-closure conditions. Due to the reduction in the hydraulic flux out of the KAP, the mass flux of CCR constituents out of the KAP will also be controlled or minimized as much as feasible as a result of closure design.

- Releases of CCR leachate via the existing bottom ash sluice recycle intake structure and the emergency overflow structure will be prevented by removing the structures and sealing the associated pipes connecting the KAP to adjacent areas. Sealing will include cleaning the RCP and CMP pipes, and filling the pipes with cement-bentonite grout, thereby removing potential flow paths that could otherwise allow leachate to be released.

- Based on hydrogeological studies previously conducted by Ramboll, CCR consolidated within the KAP will be located above the uppermost aquifer (Ramboll, 2021).

- The groundwater modeling results presented in Attachment B of the Part 845 Construction Permit Application demonstrate that closure of the KAP by consolidation and construction of a final cover system will limit surface water infiltration and the potential release of CCR leachate, resulting in reductions of groundwater CCR constituent concentrations.

4.2 Preclusion of Future Impoundment

Section 845.750(a)(2): Preclude the probability of future impoundment of water, sediment, or slurry.

A final cover system will be installed over the area of consolidated CCR within the KAP. The final cover system will be sloped to positively drain away from the area of consolidated CCR, to the exterior of the KAP, and preclude future impoundment of water, sediment, or slurry. This will include final CCR grading and cover system construction at grades of approximately 3% over the majority of the area of consolidated CCR, with a 7% slope along the southern extent and 25% (4H:1V) grades around the perimeter, to intersect existing grades or final grades where CCR has been removed. Stormwater will be conveyed off the final cover system by stormwater swales that will flow by gravity into perimeter stormwater conveyance ditches via riprap-lined letdown channels. Riprap-lined letdown channels will also convey stormwater off the cover and into the northern portion of the KAP where CCR will be removed. In the southeast corner of the KAP, culvert pipes will be installed to convey stormwater from perimeter ditches to the Sangchris Lake channel that runs parallel to the southern boundary of the KAP.

Hydrologic and hydraulic calculations used to design the stormwater channels and other control features to preclude impoundment are provided in **Appendix G**.

4.3 Provisions for Preventing Instability, Sloughing and Movement

Section 845.750(a)(3): Include measures that provide for major slope stability to prevent the sloughing or movement of the final cover system during the closure and post-closure care period.

The perimeter berms of the KAP are constructed of compacted fill materials and are founded on clay overlying glacial till. A new berm will be constructed along the north and northwest perimeter of the area of consolidated CCR within the KAP. To alleviate stability concerns for the new dike construction, any saturated soils underlying the proposed location of the new dike will be over excavated and replaced with compacted, low permeability soils. Evaluations were performed to estimate the general stability of four perimeter berm sections that will be constructed or modified during closure construction. Long-term steady-state, end of construction and seismic stability evaluations were performed. The resulting factors of safety exceed typical regulatory minimum values for static and seismic loading conditions. Slope stability analyses are provided in **Appendix F**.

Sloughing and movement of the final cover system will be minimized by constructing the final cover system at relatively flat slopes, including 3% over most of the final cover, 7% along the southern extent, and 25% (4H:1V) around the perimeter, to intersect existing or final grades where CCR has been removed. The potential for sloughing and movement of the final cover system has been evaluated by performing a cover system stability check for the various interfaces within the final cover system. The resulting factors of safety exceed typical minimum values for static and seismic loading conditions. Veneer stability analyses are provided in **Appendix F**.

Existing information was reviewed to assess the potential for mine subsidence to impact stability of the KAP under post-closure conditions. Based on the review, potential movement associated with mine subsidence is not expected to affect the stability of the KAP under post-closure conditions. The results of the mine subsidence review are summarized in **Appendix F**.

4.4 Minimize the Need for Further Maintenance

<u>Section 845.750(a)(4)</u>: *Minimize the need for further maintenance of the CCR surface impoundment.*

Future maintenance needs will be minimized using the following design features:

- The final cover system will be installed at 3% slopes over most of the consolidated CCR area, with a 7% slope along the southern extent of the KAP, and 25% slopes (4H:1V) around the perimeter of the consolidated CCR area, to intersect existing grades or final grades where CCR has been removed.
    - The relatively flat 3% slopes will minimize erosion of the final cover soils and thereby minimize maintenance needs by reducing stormwater flow velocities relative to steeper slopes.

  - The relatively flat 3% slopes will also support routine mowing of vegetation of the final cover system by allowing tractor-based mowing equipment to operate on these slopes.

- The final cover, outside of stormwater conveyances, will be stabilized by placing topsoil, fertilizing the topsoil, establishing vegetation using suitable grass species.

  - The vegetation will minimize erosion of the final cover system by stabilizing the topsoil. The use of fertilizer and selection of a suitable grass species will minimize maintenance required to repair areas of poor vegetation establishment.

- Stormwater swales and perimeter ditches will be stabilized with erosion control blankets and straw wattles. Stormwater letdown channels and conveyance channels leading to Sangchris Lake will be armored with riprap erosion protection. Erosion control blankets and riprap will minimize post-closure erosion and associated maintenance for stormwater channels.

  - Calculations used to design the stormwater channel stabilization and riprap armoring were based on the 100-year, 24-hour, and 25-year, 24-hour storms. These calculations are provided in **Appendix G.**

4.5 Be Completed in Shortest Amount of Time

<u>Section 845.750(a)(5)</u>: Be completed in the shortest amount of time consistent with recognized and generally accepted engineering practices.

Closure construction is expected to be completed within an amount of time that is consistent with recognized and generally accepted timeframes required to permit, design, bid, and construct a CCR impoundment final closure system, with a consideration of other permits form multiple agencies that are also required for the project. An estimated closure construction schedule is provided in **Section 2.6**. It should be noted that this schedule may change based on contractor, equipment, and material availability and actual weather conditions at the time at which closure occurs.

4.6 Drainage and Stabilization

<u>Section 845.750(b)(1)</u>: Free liquids must be eliminated by removing liquid wastes or solidifying the remaining wastes and waste residues.

<u>Section 845.750(b)(2)</u>: Remaining wastes must be stabilized sufficiently to support the final cover system.

Prior to installing the final cover system, free liquids will be removed from the CCR within the KAP during both phases of closure. Engineering measures necessary to remove liquid waste that is readily separable under ambient temperature and pressure are being evaluated. The removal of free liquids will result in the stabilization of the remaining CCR and will therefore allow the final cover to be placed on a stable subgrade.

4.7 Final Cover System

Section 845.750(c): *If a CCR surface impoundment is closed by leaving CCR in place, the owner or operator must install a final cover system that is designed to minimize infiltration and erosion, and, at a minimum, meets the requirements of this subsection (c) unless the owner or operator demonstrates that another construction technique or material provides equivalent or superior performance to the requirements of this subsection (c) and is approved by the Agency. The final cover system must consist of a low permeability layer and a final protective layer. The design of the final cover system must be included in the preliminary and final written closure plans required by Section 845.720 and the construction permit application for closure submitted to the Agency.*

A final cover system has been designed consistent with the requirements of Section 845.720(c). The final cover will use a geomembrane as a low-permeability barrier with protective and vegetative soil covers overlying the geomembrane. The design of the final cover system is discussed in the proceeding sections.

During the closure process, off-site CCR beneficial use opportunities will continue to be assessed. CCR consolidation and closure in place in combination with offsite beneficial use may result in a smaller onsite CCR footprint, for the purposes of final cover system design, and a reduced construction schedule.

4.7.1 Low Permeability Layer – Geomembrane

Section 845.750(c)(1)(B): *A geomembrane constructed in accordance with the following standards: i) The geosynthetic membrane must have a minimum thickness of 40 mil (0.04 inches) and, in terms of hydraulic flux, must be equivalent or superior to a three-foot layer of soil with a hydraulic conductivity of 1 x 10-7 cm/sec; ii) The geomembrane must have strength to withstand the normal stresses imposed by the waste stabilization process; and (iii) The geomembrane must be placed over a prepared base free from sharp objects and other materials that may cause damage.*

The final cover system will include a 40-mil LLDPE geomembrane. Ramboll completed a Hydrologic Evaluation of Landfill Performance (HELP) (Tolaymat, T. & Krause, M., 2020) model of the final cover system that estimated a total infiltration rate of 0.0041 inches of water per year (in/yr).

The geomembrane will be installed on a prepared subgrade, after the underlying CCR has been stabilized. Therefore, additional normal stresses will not be imparted on the geomembrane due to the waste stabilization process. The subgrade (e.g., base) for the geomembrane will be visually inspected and sharp objects such as rocks or debris that may damage the geomembrane will be removed, prior to deployment of the geomembrane.

4.7.2 Final Protective Layer

Section 845.750(c)(2): *The final protective layer must meet the following requirements, unless the owner or operator demonstrates that another final protective layer construction technique or material provides equivalent or superior performance to the requirements of this subsection (c)(2) and is approved by the Agency.*

A) Cover the entire low permeability layer;

B) Be at least three feet thick, be sufficient to protect the low permeability layer from freezing, and minimize root penetration of the low permeability layer;

C) Consist of soil material capable of supporting vegetation;

D) Be placed as soon as possible after placement of the low permeability layer; and

E) Be covered with vegetation to minimize wind and water erosion.

A final protective layer will be placed over and extend slightly beyond the entire geomembrane low-permeability layer in plan. Based on the demonstration included in **Appendix E**, pursuant to Section 845.750(c)(2), the protective layer will include, from bottom to top, a nonwoven geotextile, a 1.5-ft thick cover soil layer, and a 0.5-ft thick topsoil layer, for a total thickness of 2 ft.

The nonwoven geotextile and 1.5-ft thick cover soil layer will protect the geomembrane from root penetration. Geomembranes are not susceptible to freeze damage. The geotextile and cover soil will be placed as soon as practical after the geomembrane has been deployed and both quality assurance and quality control testing has been performed on the geomembrane seams. The 0.5-ft thick topsoil layer will be fertilized, as necessary, to vegetate the final protective layer.

4.8 Certification

Section 845.750(c)(4): The owner or operator of the CCR surface impoundment must obtain and submit with its construction permit application for closure a written certification from a qualified professional engineer that the design of the final cover system meets the requirements of this Section.

The undersigned qualified professional engineer registered in Illinois certifies that the design of the final cover system meets the requirements of Section 845.750.

John R. Hesemann
Printed Name

[signature] 7/26/2022
Signature Date

062.058523	IL	11/30/2023
Registration Number	State	Expiration Date

JOHN ROBERT HESEMANN
062-058523
LICENSED PROFESSIONAL ENGINEER OF ILLINOIS
7/26/22

Affix Seal

4.9 Uses of CCR in Closure

Section 845.750(d): This subsection specifies the allowable uses of CCR in the closure of CCR surface impoundments closing under Section 845.700. Notwithstanding the prohibition on further placement in Section 845.700, CCR may be placed in these surface impoundments, but only for purposes of grading and contouring in the design and construction of the final cover system, if: 1) The CCR placed was generated at the facility and is located at the facility at the time closure was initiated; 2) CCR is placed entirely above the elevation of CCR in the surface impoundment, following dewatering and stabilization (see subsection (b)); 3) The CCR is placed entirely within the perimeter berms of the CCR surface impoundment; and 4) The final cover system is constructed with either: A) A slope not steeper than 5% grade after allowance for settlement; or B) At a steeper grade, if the Agency determines that the steeper slope is necessary, based on conditions at the site, to facilitate run-off and minimize erosion, and that side slopes are evaluated for erosion potential based on a stability analysis to evaluate possible erosion potential. The stability analysis, at a minimum, must evaluate the site geology; characterize soil shear *strength; construct a slope stability model; establish groundwater and seepage conditions, if any; select loading conditions; locate critical failure surface; and iterate until minimum factor of safety is achieved.*

CCR currently residing in the northern portion of the KAP will be relocated to southern portion of the KAP where it will be placed above the elevation of existing CCR in the surface impoundment, following the removal of free liquids and stabilization. This CCR was generated onsite and will be located at the facility at the time closure is initiated. The CCR will be placed entirely within the perimeter berms of the KAP.

As shown in the drawing package provided in **Appendix C**, final cover slopes will typically consist of 3% over the majority of the KAP, with a 7% slope along the southern extent and 25% (4H:1V) grades around the perimeter, to intersect existing grades or final grades where CCR has been removed. The 25% slopes will be required to connect stormwater swales to perimeter ditches via letdown channels. The perimeter ditches will route stormwater to the north, where it will be conveyed through the northern portion of the KAP, where CCR has been removed, to Sangchris Lake via a stormwater conveyance channel, or to the southeast corner of the KAP, where it will be conveyed to the Sangchris Lake channel that runs parallel to the southern boundary of the KAP. The flowlines of stormwater perimeter ditches within the limits of final cover will be sloped at 1%.

The stability of the 7% and 25% final cover slopes has been evaluated both for the final cover system itself (e.g., veneer stability) and the global stability of the slope. These calculations included characterizing soil shear strength based on site geology, constructing slope stability models, establishing groundwater seepage conditions, selecting loading conditions, locating the critical failure surface, and iterating until minimum factors of safety were calculated. These calculations are provided in **Attachment F**. Resulting factors of safety exceed typical minimum factors of safety for both global and veneer stability.

4.10 Proposed PV Solar Panel Array

Upon completion of the closure construction, a new PV solar power facility will be installed on top of the closed ash pond with a rated power of approximately 29 megawatts MWac and an installed power of approximately 34 megawatts MWdc. Interconnection of the solar facility will occur at the existing KPP substation.

The solar facility layout is proposed to include a 2-volt, fixed tilt ballasted system using FirstSolar Series 6 CuRe PV modules rated at 480 watts and 25 Sungrow 1,100-kilovolt-ampere (kVA) inverters. The layout includes PV modules, inverters and MV transformers, access roads, and entrances. Alternate PV module and inverter models may be installed, as approved by Engineer, to incorporate the most efficient technology available at the time of installation. The layout includes various 16-footwide access roads to connect for access to the solar facility entrances. Transmission line easements intersecting the KAP will be clear of the PV panels. The facility layout is shown on Drawing CG009 included in Appendix C.

The PV racking system and electrical equipment will be placed on concrete foundations placed directly on the protective soil layer. A thin layer of select aggregate may be placed beneath some of the concrete foundations for leveling purposes. The racks and equipment will be placed to avoid interference with existing monitoring devices or the stormwater management system. The final design of the solar PV facility may be revised based on site conditions and the available equipment technology at the time of installation.

The ballast blocks will be designed to minimize the additional load on the protective soil layer so it will not adversely impact the final cover system. The stormwater drainage system will not be significantly altered by the proposed solar PV facility. All PV electric components will be installed above grade or within the protective soil layer; the geomembrane will not be penetrated. If changes to the proposed closure design are required, a revised closure plan will be submitted to the IEPA for approval.

5.0 ADDITIONAL INFORMATION

The vertical infiltration of liquids and releases of CCR, and leachate, and contaminated run-off into and out of the KAP will be controlled, minimized or eliminated, to the maximum extent feasible, under post-closure conditions.

- Closure of the KAP will include constructing a final cover system that ties into existing, low permeability subsoils; existing, low permeability perimeter berm soils; or low permeability fill soils; thereby encapsulating CCR within the KAP on the top, bottom, and sides, as discussed in Section 4.0.
- Based on information presented by Ramboll (Ramboll, 2021), CCR within the KAP is expected to be perennially above the uppermost aquifer level following closure. Additionally, there will not be an intermittent, recurring, or sustained hydraulic connection between any portion of the CCR unit and the uppermost aquifer due to normal fluctuations in groundwater elevations, including the seasonal high-water table.

Based on available data, the top of the uppermost aquifer occurs at an elevation ranging from 580 - 583 ft above mean sea level (amsl). A review of existing boring and CPT logs, in addition to the historic topographic contours, indicates the base of CCR is between approximately 592 and 596 ft amsl within the CIP footprint, resulting in a range of separation distance between the top of the uppermost aquifer and the base of CCR of 9 to 16 ft. Following closure, the lowest elevation of CCR within the CIP footprint will be approximately 595 ft amsl, as shown in Sheet CG007 in Attachment D. The resulting separation distance between the top of the uppermost aquifer and the base of CCR will be approximately 12 to 16 ft.

6.0 CERTIFICATION FROM A QUALIFIED PROFESSIONAL ENGINEER

<u>Section 845.720(b)(5):</u> *The owner or operator of the CCR surface impoundment must obtain and submit with its construction permit application for closure a written certification from a qualified professional engineer that the final written closure plan meets the requirements of this Part.*

I, John R. Hesemann, being a Registered Professional Engineer in good standing in the State of Illinois, do hereby certify, to the best of my knowledge, information, and belief, that the information contained in this construction permit application has been prepared in accordance with the accepted practice of engineering and the requirements of Title 35, Subtitle G, Chapter I, Subchapter j, Section 845.720 of the Illinois Administrative Code.

John R. Hesemann
Printed Name

[signature] 7/26/2022
Signature Date

062.058523 IL 11/30/2023
Registration Number State Expiration Date

Affix Seal

7.0 REFERENCES

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Solar Site Pollinator Scorecard. (2022, July 25). Retrieved from Illinois Department of Natural Resources: https://www2.illinois.gov/dnr/conservation/pollinatorscorecard/pages/default.aspx

Tolaymat, T., & Krause, M. (2020). *Hydrologic Evaluation of Landfill Performance: 4.0 User Manual.* Washington, DC: EPA/600/B 20/219.

APPENDIX A - CLOSURE ALTERNATIVE ANALYSIS

Closure Alternatives Analysis for the Ash Pond at the Kincaid Power Plant Kincaid, Illinois

July 28, 2022

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Abbreviations

AACE	Association for the Advancement of Cost Engineering
BCU	Bedrock Confining Unit
BMP	Best Management Practice
CAA	Closure Alternatives Analysis
CBR-Offsite	Closure-by-Removal with Off-Site CCR Disposal
CCR	Coal Combustion Residual
CFR	Code of Federal Regulations
CIP	Closure-in-Place
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CY	Cubic Yard
EJ	Environmental Justice
FEMA	Federal Emergency Management Agency
GHG	Greenhouse Gas
GWPS	Groundwater Protection Standards
IAC	Illinois Administrative Code
IDNR	Illinois Department of Natural Resources
IEPA	Illinois Environmental Protection Agency
LCU	Lower Confining Unit
LLDPE	Linear Low-Density Polyethylene
N_2O	Nitrous Oxide
NID	National Inventory of Dams
NO_x	Nitrogen Oxides
NPDES	National Pollutant Discharge Elimination System
PM	Particulate Matter
PMP	Potential Migration Pathway
TVA	Tennessee Valley Authority
UA	Uppermost Aquifer
US DOT	United States Department of Transportation
USCU	Upper Semi-confining Unit
VOC	Volatile Organic Compound
WPC Permit	Water Pollution Control Construction and Operating Permit

Summary of Findings

Title 35, Part 845 of the Illinois Administrative Code (IAC; IEPA, 2021a) requires the development of a Closure Alternatives Analysis (CAA) prior to undertaking closure activities at certain surface impoundments containing coal combustion residuals (CCRs) in the State of Illinois. Pursuant to requirements under IAC Section 845.710, this report presents a CAA for the Ash Pond located on Kincaid Generation, LLC's Kincaid Power Plant property near the Village of Kincaid, Illinois. The goal of a CAA is to holistically evaluate potential closure scenarios with respect to a wide range of factors, including the efficiency, reliability, and ease of implementation of the closure scenario; its potential positive and negative short- and long-term impacts on human health and the environment; and its ability to address concerns raised by residents (IAC Part 845; IEPA, 2021a). Gradient evaluated two specific closure scenarios for the Ash Pond: Closure-in-Place (CIP) with CCR excavation and consolidation, as well as Closure-by-Removal with Off-Site CCR Disposal (CBR-Offsite). The CIP scenario entails excavating CCR from the northern portion of the Ash Pond, consolidating it into the southern portion, and then capping the CCR with a new cover system consisting of, from bottom to top, a geomembrane layer, a geotextile drainage layer, and 24 inches of low-permeability soil with a vegetated surface. The CBR-Offsite scenario entails excavating all of the CCR from the Ash Pond and transporting it to an off-Site landfill for disposal. Even though capping the entire Ash Pond (without any excavation or consolidation) would be an acceptable closure approach based on IAC Section 845.710 (IEPA, 2021a), it was not evaluated in this CAA. Kincaid Generation, LLC will also continue to evaluate potential opportunities for beneficial re-use of the CCR excavated from the Ash Pond as an alternative to disposal.

IAC Section 845.710(c)(2) requires CAAs to "[i]dentify whether the facility has an onsite landfill with remaining capacity that can legally accept CCR, and, if not, whether constructing an onsite landfill is possible" (IEPA, 2021a). There is no existing on-Site landfill on the Kincaid Power Plant property. Due to the planned redevelopment of the Site as a utility-scale solar generation and battery energy storage facility, there is not sufficient space available to construct an on-Site landfill.

Table S.1 summarizes the expected impacts of the CIP and CBR-Offsite closure scenarios with regard to each of the factors specified under IAC Section 845.710 (IEPA, 2021a). Based on this evaluation and the additional details provided in Section 2 of this report, CIP has been identified as the most appropriate closure scenario for the Ash Pond. Key benefits of the CIP scenario relative to the CBR-Offsite scenario include the more rapid redevelopment of the Site for installation of solar panels on the capped impoundment and reduced impacts to workers, community members, and the environment during construction (*e.g.*, fewer constructed-related accidents, lower energy demands, less air pollution and greenhouse gas [GHG] emissions, and reduced duration of traffic-related impacts). Moreover, the CIP scenario will meet the required closure schedule (*i.e.*, closure completed by October 2028) defined in IAC Section 845.700(d)(2)(C)(ii) (IEPA, 2021a), whereas the CBR-Offsite scenario will be unable to meet this required schedule.

Table S.1 Comparison of Proposed Closure Scenarios

Evaluation Factor (Report Section; IAC Part 845 Section)	Closure Scenario	
	CIP	**CBR-Offsite**
Closure Alternative Descriptions (Section 2.1; IAC Section 845.710(c))	The CCR in the Ash Pond would be excavated from the northern portion of the Ash Pond, consolidated into the southern portion, and then capped in place with a new cover system consisting of, from bottom to top, a geomembrane layer, a geotextile drainage layer, and 24 inches of low-permeability soil with a vegetated surface. During the closure process, we will continue to assess off-Site CCR beneficial use opportunities. Ash consolidation and closure in place, in combination with offsite beneficial use, may result in a smaller footprint for purposes of our ultimate cap design, along with a reduced construction schedule.	All CCR would be excavated from the Ash Pond and transported *via* truck to an off-Site landfill for disposal. Expansion of the off-Site landfill may be necessary in order to accept all of the CCR from the Ash Pond. Due to the planned redevelopment of the Site as a utility-scale solar energy generation and battery energy storage facility, there is not sufficient space available to construct an on-site landfill. This scenario meets the requirements of IAC Section 845.710(c)(2) (IEPA, 2021a), which requires an assessment be included in the CAA of whether the Site has an on-Site landfill with available capacity or whether an on-Site landfill can be constructed.
Type and Degree of Long-Term Management, Including Monitoring, Operation, and Maintenance (Section 2.2.3; IAC Section 845.710(b)(1)(C))	Monitoring would be performed for 30 years post-closure or until GWPSs are achieved, whichever is longer. Additionally, the final cover system for the Ash Pond would undergo 30 years of annual inspections, mowing, and maintenance.	Monitoring would be performed for 3 years post-closure or until GWPSs are achieved, whichever is longer.
Magnitude of Reduction of Existing Risks (Section 2.2.1; IAC Sections 845.710(b)(1)(A) and 845.710(b)(1)(F))	There are no current unacceptable risks to any human or ecological receptors associated with the Ash Pond. Because there are no current risks, and dissolved constituent concentrations would be expected to decline post-closure, no risks to human or ecological receptors would be expected post-closure.	There are no current unacceptable risks to any human or ecological receptors associated with the Ash Pond. Because there are no current risks, and dissolved constituent concentrations would be expected to decline post-closure, no risks to human or ecological receptors would be expected post-closure.
Likelihood of Future Releases of CCR (Section 2.2.2; IAC Sections 845.710(b)(1)(B) and 845.710(b)(1)(F))	During closure, there would be minimal risk of dike failure occurring at the Ash Pond (due to, for example, flooding or seismic activity) and minimal risk of dike overtopping during flood conditions. Post-closure, the risks of overtopping and dike failure would be even smaller than they are currently, due to the installation of a protective soil cover and new stormwater control structures. Dikes, final cover, and stormwater control features have been designed to withstand earthquakes and storm events.	During closure, there would be minimal risk of dike failure occurring at the Ash Pond (due to, *e.g.*, flooding or seismic activity) and minimal risk of dike overtopping during flood conditions. Following excavation, there would be no risk of CCR releases due to dike failure. Changing geochemical conditions during an extended excavation can be a mechanism that results in the mobilization and increased transport in groundwater for some constituents.
Worker Risks (Section 2.2.4.1; IAC Sections 845.710(b)(1)(D) and 845.710(b)(1)(F))	An estimated 0.016 worker fatalities and 2.5 worker injuries would be expected to occur due to on-Site activities under this closure scenario. An additional 0.014 worker fatalities and 1.01 worker injuries would be expected to occur off-Site due to vehicle accidents during hauling, labor and equipment mobilization and demobilization, and material deliveries. In total, 0.030 worker fatalities and 3.5 worker injuries would be expected to occur under this closure scenario. Overall, risks to workers would likely be higher under the CBR-Offsite scenario and lower under the CIP scenario.	An estimated 0.018 worker fatalities and 2.8 worker injuries would be expected to occur due to on-Site activities under this closure scenario. An additional 0.027 worker fatalities and 1.9 worker injuries would be expected to occur off-Site due to vehicle accidents during hauling, labor and equipment mobilization and demobilization, and material deliveries. In total, 0.046 worker fatalities and 4.7 worker injuries would be expected to occur under this closure scenario. Overall, risks to workers would likely be higher under the CBR-Offsite scenario and lower under the CIP scenario.
Community Risks (Section 2.2.4.2; IAC Sections 845.710(b)(1)(D) and 845.710(b)(1)(F))		
▪ *Off-Site Impacts on Nearby Residents and EJ Communities*	Off-Site impacts on nearby residents (including accidents, traffic, noise, and air pollution) would be less under the CIP closure scenario than under the CBR-Offsite scenario, because the former would require less off-Site vehicle and equipment travel miles than the CBR-Offsite scenario. In total, an estimated 0.012 fatalities and 0.58 injuries would be expected to occur among community members due to off-Site activities under this scenario. With regard to traffic impacts, a haul truck would be likely to pass a location near the Site every 4.6 minutes on average during working hours for approximately 500 working days under this closure scenario.	Off-Site impacts on nearby residents would be greater under the CBR-Offsite scenario than under the CIP closure scenario, because the former would require significantly more off-Site vehicle and equipment travel miles. In total, an estimated 0.047 fatalities and 1.7 injuries would be expected to occur among community members due to off-Site activities under this scenario. With regard to traffic impacts, a haul truck would be likely to pass a location near the Site every 1.7 minutes on average during working hours for approximately 2,140 working days under this closure scenario.
▪ *Impacts on Scenic, Historical, and Recreational Value*	Due to, for example, noise and visual disturbances, construction activities may have short-term negative impacts on the recreational use of Sangchris Lake and the greater Sangchris Lake State Recreation Area. Because the expected duration of construction activities is shorter under this closure scenario (2.1-2.8 years) compared to the CBR-Offsite scenario (8.9-11.5 years), short-term impacts on the scenic and recreational value of natural areas near the Site would likely be lesser under the CIP scenario than CBR-Offsite scenario. There are no historical sites in the vicinity of the Ash Pond or the proposed on-Site landfill location. Thus, no impacts on historical sites would be expected under any closure scenario.	Due to, for example, noise and visual disturbances, construction activities may have short-term negative impacts on the recreational use of Sangchris Lake and the greater Sangchris Lake State Recreation Area. Because the expected duration of construction activities is longer under the CBR-Offsite scenario (8.9-11.5 years) than under the CIP scenario (2.1-2.8 years), short-term impacts on the scenic and recreational value of natural areas near the Site would be greater under the CBR-Offsite scenario than under the CIP scenario There are no historical sites in the vicinity of the Ash Pond or the proposed on-Site landfill location. Thus, no impacts on historical sites would be expected under any closure scenario.
Environmental Risks (Section 2.2.4.3; IAC Sections 845.710(b)(1)(D) and 845.710(b)(1)(F))		

Evaluation Factor (Report Section; IAC Part 845 Section)	Closure Scenario	
	CIP	**CBR-Offsite**
▪ *Impacts on Greenhouse Gas Emissions and Energy Consumption*	Total energy demands and GHG emissions would be lower under the CIP closure scenario than under the CBR-Offsite scenario, because the total equipment and vehicle mileage required under the former would be lower than those required under the CBR closure scenarios. The CIP scenario would have an additional, unquantified carbon footprint due to the need to manufacture geomembranes for use in the final cover system. At the grid scale, construction of a solar facility at the Site and installation of a solar facility on the capped impoundment would put energy back on the grid and reduce reliance on non-renewable energy sources. The CIP scenario would result in more rapid redevelopment of the solar facility on the capped impoundment – and, hence, the more rapid realization of grid-scale solar energy benefits – than the CBR-Offsite scenario.	Total energy demands and GHG emissions would be higher under the CBR-Offsite scenario than under the CIP closure scenario, because the total equipment and vehicle mileage required under the former would be higher than those required under the CIP closure scenario. If the expansion of the off-Site landfill became necessary in order to accept all of the CCR from the Ash Pond, then the CBR-Offsite scenario would have an additional, unquantified carbon footprint due to the need to manufacture geomembranes for use in the expanded landfill liner. At the grid scale, construction of a solar facility at the Site would put energy back on the grid and reduce reliance on non-renewable energy sources.
▪ *Impacts on Natural Resources and Habitat*	Construction activities may have short-term negative impacts on species located near the Ash Pond, the off-Site borrow soil location, the on-Site landfill, and the off-Site landfill. Because the expected duration of construction activities is shorter under the CIP scenario (2.1-2.8 years) compared to the CBR-Offsite scenario (8.9-11.5 years), short-term impacts on natural resources and habitat would likely be lesser under the CIP than under the CBR-Offsite scenario.	Construction activities may have short-term negative impacts on species located near the Ash Pond, the off-Site borrow soil location, the on-Site landfill, and the off-Site landfill. Because the expected duration of construction activities is longer under the CBR-Offsite scenario (8.9-11.5 years) than it is under the CIP scenario (2.1-2.8 years), short-term impacts on natural resources and habitat would likely be greater under the CBR-Offsite scenario than under the CIP scenario.
Time Until Groundwater Protection Standards Are Achieved (Section 2.2.5; IAC Sections 845.710(b)(1)(E) and 845.710(d)(2 and 3))	Groundwater modeling was performed to evaluate future groundwater quality in the vicinity of the Ash Pond under each of the proposed closure alternatives (Ramboll, 2022). The modeling demonstrated that groundwater concentrations will decline below the GWPS for all constituents within 17 years after closure for all closure scenarios (Ramboll, 2022).	Groundwater modeling was performed to evaluate future groundwater quality in the vicinity of the Ash Pond under each of the proposed closure alternatives (Ramboll, 2022). The modeling demonstrated that groundwater concentrations will decline below the GWPS for all constituents within 17 years after closure for all closure scenarios (Ramboll, 2022). Additionally, changing geochemical conditions during an extended excavation can be a mechanism that results in the mobilization and increased transport in groundwater for some constituents. This may result in GWPS exceedance durations in excess of the model predictions.
Long-Term Reliability of the Engineering and Institutional Controls (Section 2.2.7; IAC Section 845.710(b)(1)(G))	CIP would be expected to be a reliable closure alternative over the long term.	CBR-Offsite would be expected to be a reliable closure alternative over the long term.
Potential Need for Future Corrective Action (Section 2.2.8; IAC Section 845.710(b)(1)(H))	Corrective action is expected to be necessary at the Site. An evaluation of potential corrective measures and corrective actions has not yet been completed, but will be conducted consistent with the requirements outlined in IAC Sections 845.660 and 845.670.	Corrective action is expected to be necessary at the Site. An evaluation of potential corrective measures and corrective actions has not yet been completed, but will be conducted consistent with the requirements outlined in IAC Sections 845.660 and 845.670.
Effectiveness of the Alternative in Controlling Future Releases (Section 2.3; IAC Section 845.710(b)(2)(A and B))	There are no current or future risks to any human or ecological receptors associated with the Ash Pond. During closure, there would be minimal risk of dike failure occurring and minimal risk of dike overtopping during flood conditions. Post-closure, the risks of overtopping and dike failure would be even lower than they are currently, due to the installation of a protective soil cover and new stormwater control structures. Dikes, final cover, and stormwater control features have been designed to withstand earthquakes and storm events.	There are no current or future risks to any human or ecological receptors associated with the Ash Pond. During closure, there would be minimal risk of dike failure occurring and minimal risk of dike overtopping during flood conditions. Following excavation, there would be no risk of CCR releases due to dike failure.
Ease or Difficulty of Implementing the Alternative (Section 2.4; IAC Section 845.710(b)(3))		
▪ *Degree of Difficulty Associated with Construction*	CIP is a reliable and standard method for managing and closing waste impoundments. Dewatering saturated CCR to construct a stabilized final cover system subgrade may present challenges during closure; however, these challenges are common to most CCR surface impoundment closures and are commonly addressed *via* surface water management and dewatering techniques.	Relative to the CIP scenario, the CBR-Offsite scenario poses additional implementation difficulties due to the larger earthwork volumes and larger dewatering volumes involved. Hauling to an off-Site landfill would be required under the CBR scenario. Because the CCR would be hauled on public roads, it would require haul trucks with a smaller capacity (16.5 cubic yards *vs.* 34 cubic yards) and would also need to be dewatered to a greater extent than would be necessary under the CIP scenario. Off-Site landfilling would additionally require the development of a disposal plan and could raise issues related to the co-disposal of CCR and other non-hazardous wastes. The off-Site landfill may also need to be expanded to receive all of the CCR generated during excavation. Off-Site landfilling would additionally require the development of a disposal plan and could raise issues related to the co-disposal of CCR and other non-hazardous wastes. The off-Site landfill may also need to be expanded to receive all of the CCR generated during excavation.

Evaluation Factor (Report Section; IAC Part 845 Section)	Closure Scenario	
	CIP	**CBR-Offsite**
▪ *Expected Operational Reliability*	Operational reliability would be expected under all closure scenarios.	Operational reliability would be expected under all closure scenarios.
▪ *Need for Permits and Approvals*	Permits required under all of the closure scenarios would include a modification to the existing NPDES permit, a construction permit from the IDNR Dam Safety Program to allow the embankment and spillways of the Ash Pond to be modified as part of closure, a construction stormwater permit through IEPA, and a joint water pollution control construction and operating permit (WPC permit).	Permits required under all of the closure scenarios would include a modification to the existing NPDES permit, a construction permit from the IDNR Dam Safety Program to allow the embankment and spillways of the Ash Pond to be modified as part of closure, a construction stormwater permit through IEPA, and a WPC permit. Additional permits and approvals may be required under the CBR-Offsite scenario if the off-Site landfill must be expanded to receive all of the CCR from the Ash Pond.
▪ *Availability of Equipment and Specialists*	CIP and CBR rely on common construction equipment and materials and typically do not require the use of specialists. However, global supply chains have been disrupted due to the COVID-19 pandemic, resulting in shortages in the availability of construction equipment and parts. There may be delays in construction under all of the closure scenarios if supply chain resilience does not improve by the time construction begins. Due to the smaller earthwork volumes involved and a lesser need for construction equipment under the CIP scenario than under the CBR-Offsite, shortages may cause fewer challenges under the CIP scenario than under the CBR-Offsite scenario.	CIP and CBR rely on common construction equipment and materials and typically do not require the use of specialists. However, global supply chains have been disrupted due to the COVID-19 pandemic, resulting in shortages in the availability of construction equipment and parts. There may be delays in construction under all of the closure scenarios if supply chain resilience does not improve by the time construction begins. Due to the larger earthwork volumes involved and a greater need for construction equipment under the CBR-Offsite than under the CIP scenario, shortages may cause greater challenges under the CBR-Offsite scenario than under the CIP scenario. The current shortage of truck drivers may be particularly impactful under the CBR-Offsite scenario, due to the large volumes of borrow soil and CCR to be hauled to and from the Site under this scenario.
▪ *Available Capacity and Location of Treatment, Storage, and Disposal Services*	Under the CIP scenario, all of the CCR currently within the Ash Pond would be stored within the existing footprint of the impoundment. Treatment would consist of unwatering the Ash Pond at the start of construction, performing limited dewatering to stabilize the CCR subgrade, and managing stormwater inflow. Water from unwatering and dewatering the Ash Pond would be discharged in accordance with the NPDES permit for the facility.	The capacity remaining at the chosen off-Site landfill (the Five Oaks Landfill in Taylorville, Illinois) would be sufficient to receive all of the CCR in the Ash Pond. However, due to the relatively short period over which CCR would be received at the landfill, vertical and/or lateral expansions of the landfill may become necessary. Additionally, the landfill operators may need to develop a disposal plan to account for the increased volume of material that would be received and CCR waste's unique characteristics. If expansion of the chosen off-Site landfill were found to be impractical or infeasible, then an alternative landfill located farther from the Site would need to be identified. Two likely alternatives to the Five Oaks Landfill are the Sangamon Valley Landfill in Springfield, Illinois, and Litchfield-Hillsboro Landfill in Litchfield, Illinois. Due to insufficient capacity, both landfills would require expansion if selected. Water from unwatering and dewatering the Ash Pond would be discharged in accordance with the NPDES permit for the facility.
Impact of Alternative on Waters of the State (Section 2.5; IAC Section 845.710(d)(4))	No current or future exceedances of any screening benchmarks for surface water would be expected under any closure scenario.	No current or future exceedances of any screening benchmarks for surface water would be expected under any closure scenario.
Potential Modes of Transportation Associated with CBR (Section 2.1; IAC Section 845.710(c)(1)	This factor is not relevant for the CIP scenario.	IAC Section 845.710(c)(1) requires that CBR alternatives consider multiple methods for transporting CCR off-site, including rail, barge, and trucks. Burns & McDonnell evaluated the feasibility of transporting CCR to the off-Site landfill *via* rail or barge and found that neither option is viable at this Site. Truck transport has been identified as the preferred option for transporting CCR to the off-Site landfill under this closure scenario. The local availability and use of natural gas-powered trucks, or other low-pollution trucks, will be evaluated prior to the start of construction.
Concerns of Residents Associated with Alternatives (Section 2.6; IAC Section 845.710(b)(4))	Despite the preference for CBR that has been expressed by nonprofits in the region, CIP would effectively address residents' concerns regarding potential impacts to groundwater and surface water quality at the Site. Relative to the two CBR scenarios, the CIP scenario also presents less risks to nearby residents in the form of accidents, traffic, noise, and air pollution. Under the CIP scenario, the Site could be more rapidly redeveloped for installation of a solar facility on the capped impoundment than under the CBR-Offsite scenario. A public meeting was held on June 15, 2022, pursuant to requirements under IAC Section 845.710(e). Questions raised by attendees were addressed at the meeting; subsequently, a written summary of the questions and responses was prepared.	Despite the preference for CBR that has been expressed by nonprofits in the region, the CBR-Offsite scenario has potential disadvantages with regard to potential community concerns. Relative to the CIP scenario, the CBR-Offsite scenario presents greater risks to nearby residents in the form of accidents, traffic, noise, and air pollution. A public meeting was held on June 15, 2022, pursuant to requirements under IAC Section 845.710(e). Questions raised by attendees were addressed at the meeting; subsequently, a written summary of the questions and responses was prepared.

Notes:
CAA = Closure Alternatives Analysis; CBR = Closure-by-Removal; CBR-Offsite = Closure-by-Removal with Off-Site CCR Disposal; CCR = Coal Combustion Residual; CIP = Closure-in-Place; EJ = Environmental Justice; GHG = Greenhouse Gas; GWPS = Groundwater Protection Standard; IAC = Illinois Administrative Code; IDNR = Illinois Department of Natural Resources; IEPA = Illinois Environmental Protection Agency; NPDES = National Pollutant Discharge Elimination System.

1 Introduction

1.1 Site Description and History

1.1.1 Site Location and History

Kincaid Generation, LLC's Kincaid Power Plant is an electric power generating facility with coal-fired units located approximately 4 miles west of the Village of Kincaid, Illinois, along the shores of Sangchris Lake. From 1914 until 1994, the Peabody Coal Company undertook underground shaft mining below and surrounding the single coal combustion residual (CCR)-containing impoundment at the Site – the Kincaid Ash Pond. Mining operations on the property have since ceased (Ramboll, 2021). The Kincaid Power Plant began operating in 1967 and will be retired by the end of 2027 (Moore, 2020; Ramboll, 2021; Power-technology.com, 2021).

1.1.2 CCR Impoundment

The Kincaid Power Plant produces and stores CCRs as a part of its operations. The Kincaid Ash Pond (Vistra ID No. CCR Unit 141, Illinois Environmental Protection Agency [IEPA] ID No. W0218140002-01, and National Inventory of Dams [NID] ID No. IL50706), which is the only CCR-containing impoundment at the Site, is the subject of this report.

The Ash Pond (Figure 1.1) is a 172-acre unlined surface impoundment that was constructed in 1964-1965 for the management of both CCR and non-CCR waste streams (AECOM, 2016a; Ramboll, 2021). The Ash Pond has been in continuous operation since 1967 (Ramboll, 2021). Currently, it receives sluiced bottom ash *via* eight sluice pipes, which discharge into the southwest side of the basin. A third-party recycling company periodically recovers a portion of the ash from the Ash Pond for beneficial re-use (AECOM, 2016b). After the Kincaid Power Plant is retired in 2027, the Ash Pond will no longer receive sluiced ash. The closure of the Ash Pond will be done in phases, beginning when the power plant is retired; the final closure of the Ash Pond is expected to be completed in 2028 (Appendix B).

During normal operating conditions, outflows from the Ash Pond are either conveyed back to the Kincaid Power Plant *via* a concrete recycle pipe for re-use in plant processes or are diverted to an on-Site wastewater treatment plant. Effluent from the wastewater treatment plant is conveyed into the discharge flume that runs along the southern boundary of the pond (Figure 1.1), which is permitted to discharge to the eastern lobe of Sangchris Lake *via* a National Pollutant Discharge Elimination System (NPDES)-permitted outfall (Geosyntec, 2021; IEPA, 2021b).

Figure 1.1 Site Location Map. Adapted from Geosyntec (2021, Figure 2).

1.1.3 Surface Water Hydrology

The Kincaid Ash Pond is located within the Sangchris Lake Watershed (Hydrologic Unit Code 071300070402) and directly borders a portion of Sangchris Lake to the northwest (Figure 1.1; AECOM, 2016a; Ramboll, 2021). Sangchris Lake is the cooling pond for the Kincaid Power Plant. It was formed in 1964 by damming Clear Creek, a tributary to the south fork of the Sangamon River (Ramboll, 2021). As described above (Section 1.1.2), the Ash Pond discharges decanted water either directly or indirectly (*e.g.*, *via* the on-Site wastewater treatment plant) to the discharge flume along the southern boundary of the pond, which connects to the eastern lobe of Sangchris Lake (AECOM, 2016a,b; Geosyntec, 2021; IEPA, 2021b; Ramboll, 2021).

Sangchris Lake is listed on the 2018 Illinois Section 303(d) List as being impaired for fish consumption due to mercury. In addition, Sangchris Lake is impaired for aesthetic quality due to total phosphorus and total suspended solids (IEPA, 2016, 2019a).

In addition to Sangchris Lake, there are also several unnamed freshwater ponds located on the property to the south of the Ash Pond (Figure 1.2; Ramboll, 2021; US FWS, 2021).

A total of 33 surface water samples were collected from locations along Sangchris Lake adjacent to the Site in October 2021 (Golder Associates Inc., 2021). These data are summarized in Gradient's human health and ecological risk assessment for the Site, which is provided as Appendix A of this report.

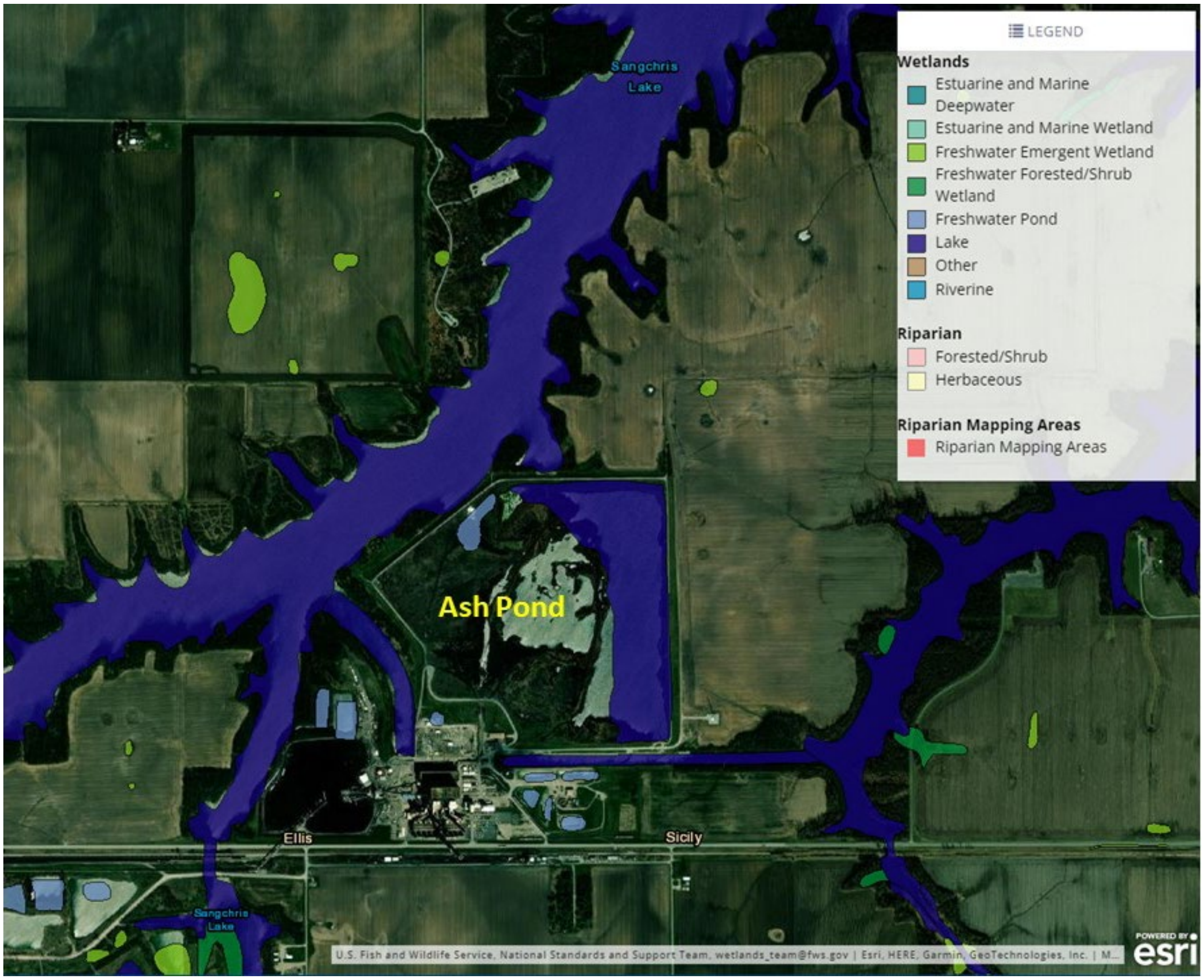

Figure 1.2 Wetlands and Surface Water Bodies in the Vicinity of the Kincaid Ash Pond. Adapted from US FWS (2021).

1.1.4 Hydrogeology

The geology underlying the Site in the vicinity of the Ash Pond consists of several distinct hydrostratigraphic units (Ramboll, 2021):

- **Upper Semi-confining Unit (USCU):** The USCU consists of low-permeability clay, with some silt and minor sand, silt layers, and some discontinuous lenses of sand. The higher-permeability sand lenses located within this unit have been identified as potential migration pathways (PMPs). The USCU includes the lithologic layers identified as the Cahokia Formation.
- **Uppermost Aquifer (UA):** The UA is a thin (generally less than 4 feet thick) unit comprised of moderately permeable sand, silty sand, and clayey sand and gravel. The UA includes the clays and silts of the Upper Cahokia Formation and the sands and gravels of the Lower Cahokia Formation. Groundwater flow through the UA is the primary pathway for contaminant migration at the Site.

- **Lower Confining Unit (LCU):** The LCU, which underlies the UA, is comprised of low-permeability silt and clay with minor sand, silt layers, and occasional discontinuous lenses of sand. The LCU includes the lithologic layers identified as the Vandalia Till.
- **Bedrock Confining Unit (BCU):** The BCU, which is comprised of interbedded shale and limestone of the Pennsylvanian Age Bond Formation, underlies the entire Ash Pond and acts as an aquitard due to its low hydraulic conductivity.

Groundwater within the UA flows northwest toward Sangchris Lake. In the vicinity of the Ash Pond, groundwater within the USCU similarly appears to flow predominantly north/northwest towards the western lobe of Sangchris Lake. However, there is also a component of groundwater flow to the south and east towards the discharge flume that runs along the southern boundary of the Ash Pond, which flows into the eastern lobe of Sangchris Lake (Ramboll, 2021).

The "Hydrogeologic Site Characterization Report" prepared by Ramboll as part of the operating permit for the Ash Pond includes an evaluation of groundwater data collected from Ash Pond monitoring wells between 2015 and 2021 (Ramboll, 2021).

1.1.5 Site Vicinity

The Kincaid Power Plant property is located in a primarily rural area. It is bounded by the lobes of Sangchris Lake to the north and east, and by Route 104 to the south. The Ash Pond overlies two abandoned underground coal mines, the Peabody No. 8 Mine (active from 1914 to 1954) and the Peabody No. 10 Mine (active from 1951 to 1994) (AECOM, 2016b; Ramboll, 2021).

Scenic, recreational, and historical areas near the Site include the Sangchris Lake State Recreation Area and the Abraham Lincoln National Heritage Area (Ramboll, 2021). The Sangchris Lake State Recreation Area, which surrounds the Site to the north and east, is used for boating, fishing, camping, hunting, hiking, and picnicking (IDNR, 2022). The Abraham Lincoln National Heritage Area is a Category III Natural Historic Site that spans 43 counties and 17 million acres in Central Illinois (Looking for Lincoln Heritage Coalition, 2022; Ramboll, 2021). Although the Kincaid Power Plant property is located within the greater Abraham Lincoln National Heritage Area, the nearest site with known historic relevance inside of the greater heritage area (the Great Eastern Stagecoach, exhibit on the "Looking for Lincoln Story Trail") lies over 6 miles from the Site, in Edinburg, Illinois (Looking for Lincoln Heritage Coalition, 2022; Ramboll, 2021). Based on a review of the Illinois Department of Natural Resources (IDNR) Historic Preservation Division database and the Illinois State Archaeological Survey database, there are no historic sites located within 1,000 meters of the Ash Pond (Ramboll, 2021).

1.2 IAC Part 845 Regulatory Review and Requirements

Title 35, Part 845 of the Illinois Administrative Code (IAC; IEPA, 2021a) requires the development of a Closure Alternatives Analysis (CAA) prior to undertaking closure activities at certain CCR-containing surface impoundments in the State of Illinois. Section 2 of this report presents a CAA for the Ash Pond pursuant to requirements under IAC Section 845.710. The goal of a CAA is to holistically evaluate each potential closure scenario with respect to a wide range of factors, including the efficiency, reliability, and ease of implementation of the closure scenario; its potential positive and negative short- and long-term impacts on human health and the environment; and its ability to address concerns raised by residents (IEPA, 2021a). A CAA is a decision-making tool that is designed to aid in the selection of an optimal closure alternative for the impoundments at a site.

2 Closure Alternatives Analysis

2.1 Closure Alternative Descriptions (IAC Section 845.710(c))

This section of the report presents a CAA for the Ash Pond pursuant to requirements under IAC Section 845.710 (IEPA, 2021a). The two closure scenarios evaluated in this CAA are Closure-in-Place (CIP) with CCR consolidation and Closure-by-Removal with Off-Site CCR Disposal (CBR-Offsite). Under the CIP scenario, the CCR in the Ash Pond would be consolidated in the southern portion of the Ash Pond and then capped with a new cover system. Under the CBR-Offsite scenario, all of the CCR would be excavated from the Ash Pond and hauled to an off-Site landfill. Kincaid Generation, LLC will also continue to evaluate potential opportunities for beneficial re-use of the CCR excavated from the Ash Pond as an alternative to disposal.

IAC Section 845.710(c)(2) requires CAAs to "[i]dentify whether the facility has an onsite landfill with remaining capacity that can legally accept CCR, and, if not, whether constructing an onsite landfill is possible" (IEPA, 2021a). There is no existing on-Site landfill on the Kincaid Power Plant property. Due to the planned redevelopment of the Site as a utility-scale solar generation and battery energy storage facility, there is not sufficient space available to construct an on-Site landfill.

Sections 2.1.1 and 2.1.2 provide detailed descriptions of the CIP and CBR-Offsite closure scenarios. These scenarios are based on closure documents and analyses provided to Gradient by Burns & McDonnell, which are attached to this report as Appendix B.

2.1.1 Closure-in-Place (CIP)

Under the CIP scenario, CCR would be excavated from the northern portion of the Ash Pond, consolidated into the southern portion, and then capped in place with a final cover system. This scenario includes the following work elements (Appendix B):

- Dewatering and unwatering to remove liquids from the Ash Pond *via* pumping and the construction of drilled sumps, engineered trenches, and/or horizontal wells. Water would be treated, as necessary, and discharged to Sangchris Lake *via* an NPDES-permitted outfall.
- Excavation of CCR from the northern portion of the Ash Pond and relocation into the southern portion of the Ash Pond, followed by contouring and grading to manage stormwater. The excavation and consolidation of CCRs will result in CCRs being separated vertically from underlying groundwater during the simulated post-closure conditions (Ramboll, 2022).
- Construction of a new soil berm with an east-west orientation, in order to separate the consolidated CCR area from the clean-closed area to the north.
- Installation of a hydraulic cut-off wall (sheet piling) along the north and west berms of the consolidated footprint area in order to maintain an operating pool during the operation of the Kincaid Power Plant. This operating pool would also receive dewatering fluids during the CCR excavation and consolidation. After the Kincaid Power Plant has been retired, and prior to the installation of the final cover system, any free water remaining within the consolidated area would be removed *via* pumping.

- Construction of an alternative cover system consisting of a 40-mil linear low-density polyethylene (LLDPE) geomembrane layer, a geotextile drainage layer, and 24 inches of protective soil cover suitable for supporting vegetative growth. An alternative cover performance demonstration has been submitted to IEPA for approval pursuant to IAC Section 845.750(c)(2) (Geosyntec, 2022). A solar facility atop the cover system is currently being designed. Components of the vegetative cover may change as details of the solar facility are finalized. However, any changes to the cover are expected to be protective of human health and the environment and meet the requirements of Section 845.750(c).
- Long-term (post-closure) monitoring and maintenance, including at least 30 years of groundwater monitoring at the impoundment, or until such time as groundwater protection standards (GWPSs) are achieved. Additionally, 30 years of post-closure care would be undertaken for the final cover system, including annual cap inspections, mowing, and maintenance.

This CIP plan meets all closure requirements of IAC Section 845.750 (IEPA, 2021a). Key closure elements that address the Part 845 closure requirements are summarized below. Further details are provided in the Closure Plan (Burns & McDonnell Engineering Company, Inc., 2022).

- An alternative cover system would be installed over the CCR that remains in the Ash Pond. The cover, consisting of a 40-mil LLDPE geomembrane low-permeability layer, a geotextile drainage layer, and 24 inches of soil, would minimize the vertical infiltration of precipitation into the basin (IAC Section 845.750(a)(1)) (Geosyntec, 2022). A solar facility atop the cover system is currently being designed. Components of the vegetative cover may change as details of the solar facility are finalized. However, any changes are expected to be protective of human health and the environment and meet the requirements of Section 845.750(c).
- The final cover system would be gently sloped to direct surface water away from the Ash Pond. Beyond the final cover system, channels would direct surface water away from the Ash Pond to existing Site drainages (IAC Section 845.750(a)(2)).
- Impounded water would be removed from the Ash Pond and managed in accordance with the NPDES permit for the facility (IAC Sections 845.750(b)(1) and 845.750(b)(2)).
- Free liquids in the CCR would be eliminated by removing liquid wastes or solidifying the remaining wastes. Engineered trenches would facilitate gravity drainage of liquid wastes in the CCR and direct the liquid wastes to sumps. Other engineering measures, such as drilled sumps and/or horizontal wells, may also be considered to facilitate removal of liquid wastes and stabilization of wastes. Liquid wastes will be managed in accordance with the NPDES permit for the Site (IAC Sections 845.750(b)(1) and 845.750(b)(2)).
- The proposed CIP design will control, minimize, or eliminate as much as feasible post-closure infiltration of liquids and releases of CCR, leachate, or contaminated runoff as interpreted by IEPA in the Part 845 rulemaking. Specifically, CIP will result in a reduction of infiltration into the Ash Pond by 99.8% compared to pre-closure conditions (Ramboll, 2022). Additionally, CIP will result in a reduction of hydraulic flux out of the Ash Pond by 99.8% compared to pre-closure conditions (Ramboll, 2022). Due to the reduction in the hydraulic flux out of the Ash Pond, the mass flux out of the Ash Pond will also be controlled or minimized as much as feasible as a result of CIP.

Furthermore, during the closure process, we will continue to assess off-Site CCR beneficial use opportunities. Ash consolidation and closure in place in combination with offsite beneficial use may result in a smaller footprint for purposes of our ultimate cap design along with a reduced construction schedule.

Approximately 1,872,000 cubic yards (CY) of CCR would be relocated south of the berm under this scenario (an assumed travel distance of 0.5 miles; Appendix B). Construction of the new berm and the final cover system would require an additional 542,000 CY of soil to be hauled to the Site from an off-Site borrow area, as well as existing berms and dikes on the Kincaid Power Plant property. It is expected that a suitable off-Site borrow location can be identified within 5 miles of the Site (Appendix B). Borrow soil would be hauled to the Site using haul trucks with an assumed capacity of 16.5 CY each (Appendix B).

Under the CIP scenario, the expected overall duration of construction and earthwork activities is approximately 2.1-2.8 years (or 25-34 months; Appendix B). The CIP scenario is expected to meet the required closure schedule (*i.e.*, closure completed by October 2028) defined in IAC Section 845.700(d)(2)(C)(ii) (IEPA, 2021a). Key parameters for the CIP scenario are shown in Table 2.1.

Table 2.1 Key Parameters for the Closure-in-Place (CIP) Scenario

Parameter	Value
Surface Area of Ash Pond	172 acres
Surface Area of Final Cover System	84 acres
Volume of CCR to be Relocated	1,872,000 CY
Travel Distance for Relocation of CCR	0.5 miles
Required Volume of Borrow Soil	542,000 CY
Distance to the Borrow Site	5 miles
Duration of Construction	2.1-2.8 years
Labor Hours	
Total On-Site Labor	213,000 hours
Total Off-Site Labor	4,000 hours
30% Contingency	652,000 hours
Total Labor Hours:	282,000 hours
Vehicle and Equipment Travel Miles	
Vehicles On-Site	53,300 miles
Equipment On-Site	500,000 miles
On-Site Haul Trucks (Unloaded + Loaded)	55,100 miles
Labor Mobilization	1,520,000 miles
Equipment Mobilization (Unloaded + Loaded)	51,500 miles
Off-Site Haul Trucks (Unloaded + Loaded)	328,000 miles
Material Deliveries (Unloaded + Loaded)	176,000 miles
Total On-Site Vehicle and Equipment Travel Miles:	608,000 miles
Total Off-Site Vehicle and Equipment Travel Miles:	2,080,000 miles
Total Vehicle and Equipment Travel Miles:	2,690,000 miles

Notes:
CCR = Coal Combustion Residual; CY = Cubic Yard.
Source: Appendix B.

2.1.2 Closure-by-Removal with Off-Site CCR Disposal (CBR-Offsite)

Under the CBR-Offsite scenario, all of the CCR would be excavated from the Ash Pond and transported to an off-Site landfill for disposal. Evaluation of landfill capacity and permitted use must be taken into consideration for each landfill considered for off-Site disposal. For example, a municipal landfill is often designed and permitted to accept waste from the local community at a specific rate. The landfill owner relies on this information to determine the remaining life of a landfill and determine when it will be necessary to expand or close the landfill. Due to the lengthy permitting and construction process, a landfill would need to continue accepting current waste streams and ash for a significant period of time to be a viable option, assuming the landfill owner and state approve. Furthermore, given the volume of ash that would need to be transported, it is important to evaluate impacts to communities that will be affected by the increase in truck traffic to and from the landfill. The nearest operating landfill to meet these criteria is the Five Oaks Landfill in Taylorville, Illinois (890 East 1500 North Road), which is located approximately 7.5 miles from the Site by road (Appendix B). CCR would be hauled to the off-Site landfill using haul trucks with a capacity of 16.5 CY, a smaller capacity than that of the haul trucks that would haul CCR to the on-Site landfill (34 CY), due to restrictions placed on the size of trucks that can be used on public roadways. As is described below in Section 2.4.5, while the Five Oaks Landfill currently has adequate capacity to accept all of the excavated CCR form the Ash Pond, due to the timing over which the CCR is expected to be received, lateral or vertical expansions of the landfill may be required.

IAC Section 845.710(c)(1) requires CBR alternatives to consider multiple methods for transporting CCR off-site, including rail, barge, and trucks. Burns & McDonnell evaluated the feasibility of transporting CCR to the off-Site landfill *via* rail and barge, summarized below (Appendix B).

- Rail transportation of CCR is unlikely to be a viable option because of the need to design, permit, and construct additional rail lines and loading infrastructure (Appendix B). Additionally, the existing rail lines would have to be shared with other users, which may cause delays. Furthermore, loading and unloading facilities at the power plant and the landfill may need to be upgraded and/or replaced (Appendix B). For this alternative, trucks would still be needed to haul CCR to and from the terminals, and additional CCR exposures could occur during the loading and unloading of CCR into trucks and rail cars.
- Barge transport to the Five Oaks Landfill is not a viable option, because the Kincaid Power Plant property does not have barge loading capabilities and is also not connected to a reasonably close navigable waterway that leads to the landfill (Appendix B).

This CAA assumes transport of CCR to the off-Site landfill under this closure scenario by truck; however, rail transportation, if it is determined to be viable during the on-going evaluations, is not expected to change the conclusions in this CAA. Transport *via* truck would not require the construction of additional loading or unloading infrastructure and would not result in project delays due to permitting and coordination with other parties. The existing travel routes from the Site to the off-Site landfill are suitable for CCR transport *via* truck (Appendix B). The local availability and use of natural gas-powered trucks, or other low-pollution trucks, will be evaluated prior to the start of construction.

This scenario includes the following work elements (Appendix B):

- Dewatering and unwatering to remove liquids from the Ash Pond *via* pumping and passive dewatering methods. Water would be treated, as necessary, and discharged to Sangchris Lake *via* an NPDES-permitted outfall.an NPDES-permitted outfall.
- Excavation of CCR and at least 1 additional foot of underlying soils from the Ash Pond and transportation of these materials to the off-Site landfill.
- Backfilling as necessary to allow post-closure, non-contact stormwater to gravity flow into Sangchris Lake.

- Site restoration, including the placement of 6 inches of topsoil along the side slopes and bottom of the Ash Pond and revegetation with native grasses.
- Monitoring for 3 years post-closure or until such time as GWPSs are achieved, whichever is longer.

In total, approximately 2,950,000 CY of CCR would be excavated from the Ash Pond under this scenario. Backfilling of the Ash Pond and Site restoration would require an additional 3,260,000 CY of soil to be hauled to the Site from an off-Site borrow area, as well as existing berms and dikes on the Kincaid Power Plant property. A suitable borrow location is assumed to be located within 5 miles of the Site. A haul truck capacity of 16.5 CY each is assumed for the off-Site transport of borrow soil and CCR (Appendix B).

The overall duration of construction and earthwork activities under this closure scenario is approximately 8.9-11.5 years (or 107-138 months; Appendix B). As discussed previously, there would be a potential delay in the start of excavation activities under this scenario, due to the fact that agency coordination, approvals, and permitting are expected to take longer under this scenario than under the CIP scenario (8-12 months for CIP *vs.* 12-18 months for CBR-Offsite). The CBR-Offsite scenario will not meet the required closure schedule (*i.e.*, closure completed by October 2028) defined in IAC Section 845.700(d)(2)(C)(ii) (IEPA, 2021a). Key parameters for the CBR-Offsite scenario are shown in Table 2.2.

Table 2.2 Key Parameters for the Closure-by-Removal with Off-Site CCR Disposal (CBR-Offsite) Scenario

Parameter	Value
Surface Area of Ash Pond	172 acres
Hauled Volume of CCR	2,950,000 CY
Distance to the Off-Site Landfill	7.5 miles
Hauled Volume of Borrow Soil	3,260,000 CY
Distance to the Borrow Site	5 miles
Duration of Construction	8.9 to 11.5 years
Labor Hours	
Total On-Site Labor	241,000 hours
Total Off-Site Labor	23,400 hours
30% Contingency	79,400 hours
Total Labor Hours:	344,000 hours
Vehicle and Equipment Travel Miles	
Vehicles On-Site	99,200 miles
Equipment On-Site	2,140,000 miles
On-Site Haul Trucks (Unloaded + Loaded)	0 miles
Labor Mobilization	2,410,000 miles
Equipment Mobilization (Unloaded + Loaded)	96,000 miles
Off-Site Haul Trucks (Unloaded + Loaded)	2,870,000 miles
Material Deliveries (Unloaded + Loaded)	0 miles
Total On-Site Vehicle and Equipment Travel:	2,240,000 miles
Total Off-Site Vehicle and Equipment Travel:	5,380,000 miles
Total Vehicle and Equipment Travel:	7,620,000 miles

Notes:
CCR = Coal Combustion Residual; CY = Cubic Yard.
Source: Appendix B.

2.2 Long- and Short-Term Effectiveness of the Closure Alternative (IAC Section 845.710(b)(1))

2.2.1 Magnitude of Reduction of Existing Risks (IAC Section 845.710(b)(1)(A))

This section of the report addresses the potential risks to human and ecological receptors due to exposure to CCR-associated constituents in groundwater or surface water. Gradient has performed a human health and ecological risk assessment for the Site (included as Appendix A of this report), which provides a detailed evaluation of the magnitude of existing risks to human and ecological receptors associated with the Ash Pond. This report concluded that there are no current unacceptable risks to any human or ecological receptors associated with the Ash Pond. Because there are no current risks to any human or ecological receptors, and dissolved constituent concentrations would be expected to decline post-closure, no post-closure risks would be expected under any of the closure scenarios. Thus, there would be no current risk or future risk under any of the closure scenarios, and the magnitude of reduction of existing risks would be the same under all of the closure scenarios.

2.2.2 Likelihood of Future Releases of CCR (IAC Section 845.710(b)(1)(B))

This section of the report quantifies the risk of future releases of CCR that may occur during dike failure and storm-related events.

Storm-Related Releases and Dike Failure During Flood Conditions

Based on the effective Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map for the Site, the Ash Pond is not located within the 100-year flood zone for Sangchris Lake (FEMA, 2011). Engineering analyses show that the risk of overtopping occurring during flood conditions is also minimal under current conditions. Specifically, AECOM evaluated the risk of flood overtopping occurring at the Ash Pond and found that the impoundment can adequately manage flow during peak discharge from even a 1,000-year storm event, thus preventing overtopping (AECOM, 2016b; Geosyntec, 2021). Additionally, engineering analyses show that the Ash Pond dikes are expected to remain stable under static, seismic, and flood conditions (AECOM, 2016c; Geosyntec, 2021). Prior to closure (*i.e.*, under current conditions), the risk of dike failure occurring during floods or other storm-related events is therefore minimal. Post-closure, the risks of overtopping and dike failure occurring due to floods or other storm-related events would be even lower than they are currently. Under the CIP scenario, a new cover system would be installed, which would include 24 inches of soil and a geomembrane liner, as well as new stormwater control structures. Relative to current conditions, this cover system would provide increased protection against berm and surface erosion, groundwater infiltration, and other adverse effects that could potentially trigger a dike slope failure event. Under the CBR-Offsite scenario, all of the CCR in the Ash Pond would be excavated and relocated, eliminating the risk of a CCR release occurring post-closure. In summary, there is minimal current or future risk of sudden CCR releases occurring under any closure scenario either during or following closure.

Dike Failure Due to Seismicity

Sites in Illinois may be subject to seismic risks arising from the Wabash Valley Seismic Zone and the New Madrid Seismic Zone (IEMA, 2020). Although the Kincaid Power Plant property is located within a seismic impact zone, all structural components of the Ash Pond have been designed to resist the maximum horizontal acceleration in lithified earth material for the Site. The Ash Pond therefore meets the seismic safety requirements of 40 Code of Federal Regulations (CFR) Section 257.63(a) and IAC Section 845.330(a), and the overall risk of dike failure due to seismicity is expected to be low (Haley & Aldrich, Inc., 2018a; Burns & McDonnell, 2021). Additionally, the Ash Pond does not lie within 200 feet of an active fault or fault damage zone at which displacement has occurred within the current geological epoch (*i.e.*, within the last ~11,650 years; Haley & Aldrich, Inc., 2018b). The nearest known fault is the Sicily Fault, which is located about 2 miles east of the Ash Pond. The Sicily Fault does not have known recent activity (Haley & Aldrich, Inc., 2018b). Thus, the risk of dike failure occurring during or following closure activities due to seismic activity is expected to be low at the Ash Pond.

Risks of Future Releases of CCR at the On-Site Landfill

The effective FEMA Flood Insurance Rate Map for the Site demonstrates that the proposed on-Site landfill location does not lie within the 100-year flood zone for Sangchris Lake (Appendix B; FEMA, 2011). Additionally, although the Kincaid Power Plant property is located within a seismic impact zone, all structural components of the new on-Site landfill will be designed to meet the seismic safety requirements of 40 CFR Section 257.63(a) and IAC Section 845.330(a). Thus, the overall risk of CCR escaping the on-Site landfill during flooding or seismic conditions is low. Flooding risks and seismic risks at the off-Site landfill were not evaluated, because the off-Site landfill has previously been constructed and permitted and is already in operation. We assume that the off-Site landfill would operate in compliance with all state and federal regulations designed to minimize the threat of waste releases, including under seismic and flood conditions.

2.2.3 Type and Degree of Long-Term Management, Including Monitoring, Operation, and Maintenance (IAC Section 845.710(b)(1)(C))

The long-term operation and management plans for the Ash Pond under each closure scenario are described in Section 2.1 (Closure Alternatives Descriptions). In summary, under the CIP scenario, the Ash Pond would undergo monitoring for 30 years post-closure, or until such time as GWPSs are achieved. Under the CBR-Offsite scenario, the Ash Pond would undergo monitoring for 3 years post-closure, or until such time as GWPSs are achieved. The post-closure care plan for the CIP scenario would additionally include annual inspections, mowing, and maintenance of the final cover system.

2.2.4 Short-Term Risks to the Community or the Environment During Implementation of Closure (IAC Section 845.710(b)(1)(D))

2.2.4.1 Worker Risks

Best practices would be employed during construction in order to ensure worker safety and comply with all relevant regulations, permit requirements, and safety plans. However, it is impossible to completely eliminate the risk of accidents occurring during construction activities, both on and off Site. On-Site accidents include injuries and deaths arising from the use of heavy equipment and/or earthmoving operations during construction activities. Off-Site accidents include injuries and deaths due to vehicle accidents during labor and equipment mobilization/demobilization, material deliveries, and the hauling of borrow soil and CCR.

As shown in Tables 2.1 through 2.3, Burns & McDonnell estimates that the CIP scenario would require 213,000 on-Site labor hours (Appendix B). The CBR-Offsite scenario would require approximately 241,000 on-Site labor hours. The United States Bureau of Labor Statistics (US DOL, 2020a,b) provides estimates of the hourly fatality and injury rates for construction workers. Based on the accident rates reported by United States Bureau of Labor Statistics and the on-Site labor hours reported in Appendix B, we estimate that approximately 2.5 worker injuries and 0.016 worker fatalities would occur on-Site under the CIP scenario; approximately 2.8 worker injuries and 0.018 worker fatalities would occur on-Site under the CBR-Offsite scenario (Table 2.3). The rate of on-Site worker accidents is therefore expected to be higher under the CBR-Offsite scenario and lower under the CIP scenario.

Table 2.3 Expected Number of On-Site Worker Accidents Under Each Closure Scenario

Closure Scenario	Injuries	Fatalities
CIP	2.5	0.016
CBR-Offsite	2.8	0.018

Notes:
CBR-Offsite = Closure-by-Removal with Off-Site CCR Disposal; CIP = Closure-in-Place.

Off-Site, a greater number of haul truck miles, labor and equipment mobilization/demobilization miles, and material delivery miles would be required under the CBR-Offsite scenario than would be required under the CIP scenario (Tables 2.1 and 2.2). For example, under the CBR-Offsite scenario, 5,380,000 haul truck miles would be required, and, under the CIP scenario, only 2,080,000 haul truck miles would be required (Appendix B). The United States Department of Transportation (US DOT, 2020) provides estimates of the expected number of fatalities and injuries "per vehicle mile driven" for drivers and passengers of large trucks and passenger vehicles. Table 2.4 shows the expected number of off-Site accidents under each closure scenario due to all categories of off-Site vehicle usage. For these calculations, it was assumed that labor mobilization/demobilization would rely upon passenger vehicles (cars or light trucks, including pickups, vans, and sport utility vehicles) and that hauling, equipment mobilization/demobilization, and material deliveries would rely upon large trucks. Based on US DOT's accident statistics and the mileage estimates in Appendix B, an estimated 1.01 worker injuries and 0.014 worker fatalities would be expected to occur due to off-Site activities under the CIP scenario; an estimated 1.9 worker injuries and 0.027 worker fatalities would be expected to occur due to off-Site activities under the CBR-Offsite scenario.

Table 2.4 Expected Number of Off-Site Worker Accidents Under Each Closure Scenario

Off-Site Vehicle Use Category	CIP		CBR-Offsite	
	Injuries	Fatalities	Injuries	Fatalities
Hauling	0.042	9.53×10^{-4}	0.37	0.0083
Labor Mobilization/ Demobilization	0.94	0.012	1.5	0.019
Equipment Mobilization/ Demobilization	0.0066	0.00015	0.012	0.00028
Material Deliveries	0.023	0.00051	0	0
Total:	1.01	0.014	1.9	0.027

Notes:
CBR-Offsite = Closure-by-Removal with Off-Site CCR Disposal; CIP = Closure-in-Place.

Overall, taking into account accidents occurring both on- and off-Site, 3.5 worker injuries and 0.030 worker fatalities would be expected to occur under the CIP scenario; 4.7 worker injuries and 0.046 worker fatalities would be expected to occur under the CBR-Offsite scenario.

In summary, risks to workers due to accidents would be expected to be greater under the CBR-Offsite scenario than under the CIP scenario. Differences in worker risks between the two scenarios would largely be driven by off-Site activities.

2.2.4.2 Community Risks

Accidents

Vehicle accidents that occur off-Site can result in injuries or fatalities among community members, as well as workers. Based on the accident statistics reported by US DOT (2020) and the off-Site travel mileages reported in Appendix B, off-Site vehicle accidents could result in an estimated 0.58 injuries and 0.012 fatalities among community members (*i.e.*, people involved in haul truck accidents that are neither haul truck drivers nor passengers, including pedestrians, drivers of other vehicles, *etc*.) under the CIP scenario (Table 2.5). Under the CBR-Offsite scenario, off-Site vehicle accidents could result in an estimated 1.7 community injuries and 0.047 community fatalities.

Table 2.5 Expected Number of Community Accidents Under Each Closure Scenario

Off-Site Vehicle Use Category	CIP		CBR-Offsite	
	Injuries	Fatalities	Injuries	Fatalities
Hauling	0.12	0.0044	1.06	0.038
Labor Mobilization/ Demobilization	0.38	0.0048	0.60	0.0076
Equipment Mobilization/ Demobilization	0.019	0.00069	0.035	0.0013
Material Deliveries	0.06	0.0024	0	0
Total:	0.58	0.012	1.7	0.047

Notes:
CBR-Offsite = Closure-by-Removal with Off-Site CCR Disposal; CIP = Closure-in-Place.

Traffic

Haul routes would be expected to use major arterial roads and highways wherever possible, which would reduce the incidence of traffic. However, the heavy use of local roads for construction operations may result in traffic near the Site, the off-Site landfill, and the borrow area. Traffic could potentially cause travel delays on local roads and also cause damage to local roadways. It could also cause delays in the redevelopment of the Site for the installation of a solar facility on the capped impoundment.

Traffic may increase temporarily around the Site under all closure scenarios due to the daily arrival and departure of the workforce, equipment mobilization/demobilization, and material deliveries. However, these impacts would be expected to largely occur at the beginning or end of each work day (for the arrival/departure of the work force), at the beginning or end of the construction period (for equipment mobilization/demobilization), and at specific times throughout the construction period (for material deliveries). These impacts would therefore likely be less disruptive to community members than the constant and steady movement of haul trucks to and from the Site due to CCR hauling and borrow soil hauling. Under the CBR-Offsite scenario, hauling-related construction activities would be expected to take approximately 2,140 working days and require approximately 377,000 truckloads (179,000 truckloads of CCR and 198,000 truckloads of borrow soil; Appendix B). Assuming 10-hour working days, a haul truck would need to pass a given location near the Site once every 1.7 minutes on average under this closure scenario. Off-Site traffic demands due to hauling are expected to be lesser under the CIP scenarios than under the CBR-Offsite scenario, because no off-Site hauling of CCR would be required. The CIP scenario requires approximately 33,000 truckloads to transport borrow soil to the Site, which corresponds with a haul truck passing a given location near the Site once every 4.6 minutes on average for the approximately 500 working days duration of hauling-related construction activities.

Noise

Construction generates a great deal of noise, both in the vicinity of the Site and along haul routes. In a closure impact analysis performed by the Tennessee Valley Authority (TVA, 2015), the authors found that "typical noise levels from construction equipment used for closure are expected to be 85 dBA [decibels] or less when measured at 50 ft. These types of noise levels would diminish with distance…at a rate of approximately 6 dBA per each doubling of distance and therefore would be expected to attenuate to the recommended EPA noise guideline of 55 dBA at 1,500 ft." As identified in Google Street View (Google LLC, 2022), there is at least one residence and one business (HARSCO Minerals, Pawnee Plant) located within 1,500 feet of the Ash Pond along County Road 1640 N. to the south of the Site. This residence and this business may be adversely impacted by noise pollution under all of the closure scenarios. Recreators and wildlife along Sangchris Lake or within the greater Sangchris Lake State Recreation Area could also be temporarily impacted by construction noise under all of the closure scenarios. For example, one of the picnicking pavilions within the Sangchris Lake State Recreation Area (the West Hill Picnic Area) is located just over 1,500 feet north of the Ash Pond on the opposite bank of Sangchris Lake (Google LLC, 2022; Ramboll, 2021). The duration of noise impacts in the vicinity of the Ash Pond would be longer under the CBR-Offsite scenario than under the CIP scenario, because the expected duration of construction is longer under the former scenario than under the latter scenario (2.1-2.8 years under the CIP scenario *vs*. 8.9-11.5 years under the CBR-Offsite scenario).

In addition to impacts in the immediate vicinity of planned construction areas at the Site, local roads near the Site, the off-Site landfill (under the CBR-Offsite scenario only), and the off-Site borrow area (under all of the closure scenarios) may also experience noise pollution due to high volumes of truck traffic. As described above (Traffic), the construction schedule for the CBR-Offsite scenario requires haul trucks to pass by a given location every 1.7 minutes on average for 10 hours each day for approximately 2,140 working days, and the construction schedule for the CIP scenario requires haul trucks to pass a given location every 4.6 minutes on average for 10 hours each day for approximately 500 working days. Dump trucks generate significant noise pollution, with noise levels of approximately 88 decibels or higher expected within a 50-foot radius of the truck (Exponent, 2018). This noise level is similar to the noise level of a gas-powered lawnmower or leaf blower (CDC, 2019). Decibel levels above 80 can damage hearing after 2 hours of exposure (CDC, 2019).

In addition to haul truck impacts, noise pollution may also arise from the daily arrival and departure of the workforce, equipment mobilization/demobilization, and material deliveries. These impacts would be expected to largely occur at the beginning or end of each work day (for the arrival/departure of the work force), at the beginning or end of the construction period (for equipment mobilization/demobilization), and at specific times throughout the construction period (for material deliveries). These impacts would therefore likely be less disruptive to community members than the constant and steady movement of haul trucks to and from the Site. In summary, noise impacts are likely to be greater under the CBR-Offsite scenario than under the CIP scenario due to the need for off-Site hauling.

Air Quality

Construction can adversely impact air quality. Air pollution can occur both on-Site and off-Site (*e.g.*, along haul routes), potentially impacting workers as well as community members. With regard to construction activities, two categories of air pollution are of particular concern: equipment emissions and fugitive dust. The equipment emissions of greatest concern are those found in diesel exhaust. Most construction equipment is diesel-powered, including the dump trucks that would be used to haul material to and from the Site. Diesel exhaust contains numerous air pollutants, including nitrogen oxides (NO_x), particulate matter (PM), carbon monoxide (CO), and volatile organic compounds (VOCs) (Hesterberg *et al*., 2009; Mauderly and Garshick, 2009). Fugitive dust, another major air pollutant at construction sites, is generated by earthmoving operations and other soil- and CCR-handling activities. Along haul routes, an additional source of fugitive dust is road dust along unpaved dirt roads. Careful planning and the use of Best Management Practices (BMPs) such as wet suppression are used to minimize and control fugitive dust during construction activities; however, it is not possible to prevent dust generation entirely.

On-Site, emissions would be higher under the CBR-Offsite scenario than under the CIP scenario, due to the greater amount of on-Site vehicle and equipment travel miles required under these scenarios (608,000 total on-Site travel miles under the CIP scenario *vs*. 2,240,000 total on-Site travel miles under the CBR-Offsite scenario; Tables 2.1 and 2.2). Off-Site, emissions would similarly be higher under the CBR-Offsite scenarios than under the CIP scenario, due to the greater amount of off-Site vehicle and equipment travel miles required under these scenarios (2,080,000 total off-Site travel miles under the CIP scenario *vs.* 5,380,000 total off-Site travel miles under the CBR-Offsite scenario).

Environmental Justice

The State of Illinois defines environmental justice (EJ) communities to be those communities with a minority population above twice the state average and/or a total population below twice the state poverty rate (IEPA, 2019b).

As shown in a map of EJ communities throughout the state (IEPA, 2019b), the outer perimeter of the 1-mile buffer zone for the nearest EJ community lies over 10 miles northwest of the Site, near Springfield, Illinois (Figure 2.1). As described above (Noise), significant noise impacts due to construction are expected to be limited to potential receptors located within 1,500 feet (or 0.28 miles) of the Site. Similarly, the air quality impacts of construction are expected to be limited to potential receptors located within 1,000 feet (or 0.19 miles) of the Site (CARB, 2005; BAAQMD, 2017). Along heavily trafficked roadways, air quality impacts are expected to be limited to potential receptors located within 600 feet (or 0.11 miles) of the roadway (US EPA, 2014). The EJ community near Springfield is therefore unlikely to be directly impacted by on-Site air emissions, noise pollution, or other negative impacts arising at the Site. However, this community could potentially be impacted by off-Site impacts, including CCR hauling (under the CBR-Offsite scenario only), borrow soil hauling (under all of the closure scenarios), labor and equipment mobilization/demobilization, and material deliveries. Off-Site impacts due to labor and equipment mobilization/demobilization and material deliveries would be expected to be diffuse (*i.e.,* to span a wide range of transport routes originating over a wide area). Additionally, these impacts would be expected to largely occur at the beginning or end of each work day (for the arrival/departure of the work force), at the beginning or end of the construction period (for equipment mobilization/demobilization), and at specific times throughout the construction period (for material deliveries). Hauling, in contrast, would rely on a single transport route used continuously throughout the entire excavation period. Off-Site hauling is therefore more likely to have a significant impact on EJ communities than other types of off-Site vehicle use.

Two types of off-Site hauling are evaluated in this report: CCR hauling and borrow soil hauling. Overall, haul truck impacts on EJ communities due to borrow soil hauling are expected to be small, because borrow soil would be sourced from within 5 miles of the Site, and there are no EJ communities within 5 miles of the Site. A review of the Illinois map of EJ communities reveals that the preferred off-Site landfill (the Five Oaks Landfill in Taylorville, Illinois) is similarly not located near any EJ communities. Finally, based on the haul route suggested by Google Maps (Google LLC, 2022), transport of CCR to the off-Site landfill is unlikely to require CCR hauling through any EJ communities (Figure 2.1). In summary, no impacts on EJ communities are expected at the Kincaid Site under any closure scenario.

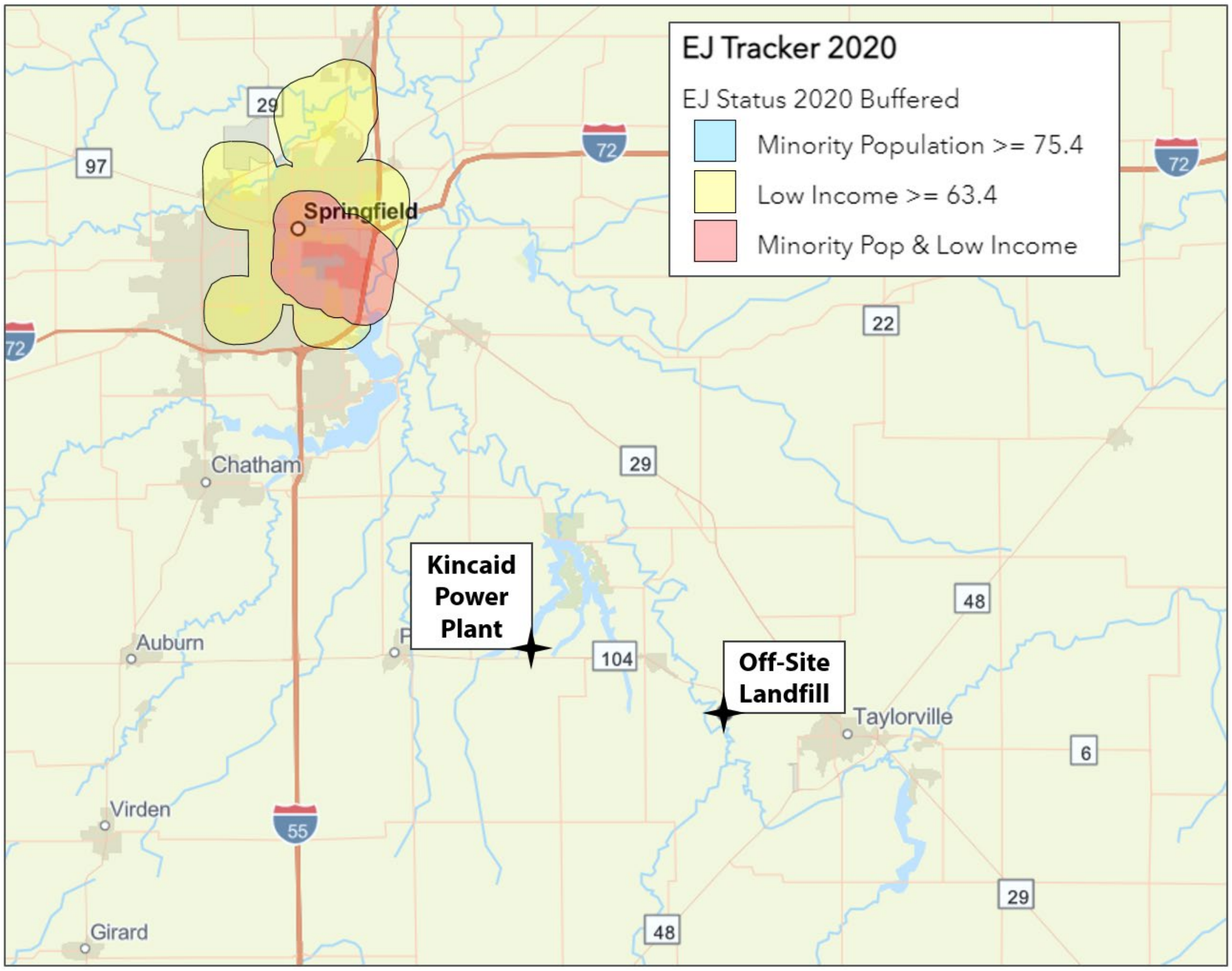

Figure 2.1 Environmental Justice Communities in the Vicinity of the Site and the Off-Site Landfill. Adapted from IEPA (2019b).

Scenic, Historical, and Recreational Value

During construction activities, negative impacts on scenic and recreational value may occur along Sangchris Lake and within the greater Sangchris Lake State Recreation Area. Noise impacts were described above. In addition, construction activities at the Ash Pond may be visible to recreators using these scenic and recreational areas, potentially interfering with the enjoyment of the view of the lake. The expected duration of construction activities is longer under the CBR-Offsite scenario than under the CIP scenario (8.9-11.5 years under the CBR-Offsite scenario *vs*. 2.1-2.8 years under the CIP scenario). It is therefore anticipated that short-term impacts on the scenic and recreational value of natural areas near the Site would be greater under the CBR-Offsite scenario than under the CIP scenario.

Based on a review of the IDNR Historic Preservation Division database and the Illinois State Archaeological Survey database, there are no historic sites located within 1,000 meters of the Ash Pond or the proposed on-Site landfill location (Ramboll, 2021).

2.2.4.3 Environmental Risks

Greenhouse Gas Emissions

In addition to the air pollutants listed above in Section 2.2.4.2, construction equipment emits greenhouse gases (GHGs), including carbon dioxide (CO_2) and possibly nitrous oxide (N_2O). The potential impact of each closure scenario on GHG emissions is proportional to the potential impact of each closure scenario on other emissions from construction vehicles and equipment, as described above in Section 2.2.4.2. In summary, GHG emissions from construction equipment and vehicles would be higher under the CBR-Offsite scenario than under the CIP scenario, because the total on-Site and off-Site vehicle and equipment travel miles required under the CBR-Offsite scenario (7,620,000 miles total vehicle and equipment travel miles) are greater than those required under the CIP scenario (2,690,000 total vehicle and equipment travel miles) (Tables 2.1 and 2.2).

We did not quantify the carbon footprint of the approximately 84 acres of 40-mil LLDPE geomembrane liner required for the final Ash Pond cover system under the CIP scenario. The carbon footprint of this geomembrane (*i.e.*, the fossil fuel emissions required to manufacture it) is an additional source of GHG emissions at the Site under the CIP scenario. The potential expansion of the off-Site landfill under the CBR-Offsite scenario would have additional, unquantified carbon footprints due to the manufacture of geomembranes used in the expanded or newly constructed landfill liners.

Energy Consumption

Energy consumption at a construction site is synonymous with fossil fuel consumption, because the energy to power construction vehicles and equipment comes from the burning of fossil fuels. Fossil fuel demands considered in this analysis include the burning of diesel fuel during construction activities and the carbon footprint of manufacturing geomembrane textiles. Because GHG emission impacts and energy consumption impacts both arise from the same sources at construction sites, the trends discussed above with respect to GHG emissions also apply to the evaluation of energy demands. Specifically, the energy demands of construction equipment and vehicles would be higher under the CBR-Offsite scenario than under the CIP scenario. We did not quantify the energy demands of the geomembranes required for the construction of the final cover system under the CIP scenario or, potentially, the geomembranes required for expansion of the off-Site landfill under the CBR-Offsite scenario.

The Kincaid Site is slated for redevelopment as a utility-scale solar power generating facility and a battery energy storage facility. The installation of the utility-scale solar-power-generating facility and a battery energy storage facility will provide additional tax revenue to the local community, create jobs, increase the reliability of the electrical grid, and support Illinois's path toward 100% clean energy by 2050. Because the CIP scenario requires less construction activities than the CBR-Offsite scenario and would be completed over a shorter time period, the CIP scenario would be expected to result in fewer delays to redevelopment of a solar facility on the capped impoundment – hence, the more rapid realization of grid-scale solar energy benefits – than the CBR-Offsite scenario.

Natural Resources and Habitat

During closure, major construction activities such as the excavation of the Ash Pond, the excavation of the borrow area, the construction of the on-Site landfill, and, potentially, the expansion of the off-Site landfill may require the destruction of some existing habitat atop portions of these construction areas, resulting in negative impacts to natural resources and habitat within the footprint of these areas. Construction may also have indirect negative impacts on the natural resources and habitat in the immediate vicinity of these locations by causing alarm and escape behavior in nearby wildlife (*e.g*., due to noise disturbances). Finally, although erosion prevention and sediment control measures will be undertaken under all of the closure scenarios, it is possible that limited negative short-term impacts could occur to sensitive aquatic species in Sangchris Lake and other minor surface water bodies located adjacent to construction areas on the Site due to sediment runoff during construction. The duration of time over which various short-term negative habitat impacts might occur due to construction would be longer under the CBR-Offsite scenario than under the CIP scenario, due to the longer expected duration of construction activities under the former scenario (2.1-2.8 years under the CIP scenario *vs*. 8.9-11.5 years under the CBR-Offsite scenario). Thus, negative short-term impacts to natural resources and habitat due to closure activities would likely be greater under the CBR-Offsite scenario than under the CIP scenario.

In addition to the short-term habitat impacts described above, closure of the Ash Pond may also result in long-term shifts in the habitat types overlying the major construction locations associated with the closure (the Ash Pond, the borrow area, and the off-Site landfill). This assessment does not make any value judgments regarding the relative value of the habitat types currently overlying these locations and the habitat types that could potentially overlie these locations post-closure under the various closure scenarios.

According to the IDNR Natural Heritage Database, there are three threatened species and two endangered species within Christian County (Ramboll, 2021). To our knowledge, however, no threatened or endangered species have been identified at the Site. Based on the information that is currently available, we do not expect construction activities to have negative impacts on any threatened or endangered species.

2.2.5 Time Until Groundwater Protection Standards Are Achieved (IAC Sections 845.710(b)(1)(E) and 845.710(d)(2 and 3))

The time horizon over which GWPSs would be exceeded at the Site is immaterial from a risk perspective, because there is no unacceptable risk associated with exceedances of a GWPS at the Site (see Section 2.2.1). Nonetheless, pursuant to requirements under IAC Section 845.710, this section of the text describes the time required to achieve GWPSs at the Site.

As described in Section 1.1.4 (Hydrogeology), groundwater within the UA flows northwest towards Sangchris Lake. In the vicinity of the Ash Pond, groundwater within the USCU similarly appears to flow predominantly north/northwest towards the western lobe of Sangchris Lake. However, there is also a component of groundwater flow to the south and east towards the discharge flume that runs along the southern boundary of the Ash Pond, which flows into the eastern lobe of Sangchris Lake. This suggests that there is a groundwater divide beneath the Ash Pond, such that groundwater flows towards both the western and eastern lobes of Sangchris Lake (Ramboll, 2021).

Groundwater elevations in the vicinity of the Ash Pond are primarily controlled by water levels in Sangchris Lake and the Ash Pond. Surface water levels in Sangchris Lake are not expected to fluctuate in the vicinity of the Ash Pond, because the lake is controlled by a dam (Ramboll, 2021).

Groundwater modeling was performed to evaluate future groundwater quality in the vicinity of the Ash Pond under each of the proposed closure alternatives (Ramboll, 2022). The modeling demonstrated that that groundwater concentrations will decline below the GWPS for all constituents within 17 years after closure for all closure scenarios, including CIP and CBR-Offsite (Ramboll, 2022). For all closure scenarios, constituents that exceed GWPS are predicted to remain in close proximity to the Ash Pond, and/or within current plume extents, as the plumes recede over time (Ramboll, 2022). Because the estimated duration of construction activities for the CBR-Offsite scenario is so much longer than the duration of construction activities for CIP (2.1-2.8 years for CIP compared to 8.9-11.5 years for CBR-Offsite; Section 2.1), CIP may actually achieve the GWPSs faster the CBR-Offsite scenario.

Additionally, changing geochemical conditions during an extended excavation associated with the CBR-Offsite scenario can be a mechanism that results in the mobilization and increased transport in groundwater for some constituents. This may result in GWPS exceedance durations in excess of the model predictions for the CBR-Offsite scenario.

2.2.6 Potential for Exposure of Humans and Environmental Receptors to Remaining Wastes, Considering the Potential Threat to Human Health and the Environment Associated with Excavation, Transportation, Re-disposal, Containment, or Changes in Groundwater Flow (IAC Section 845.710(b)(1)(F))

Section 2.2.1 evaluates potential risks to human and ecological receptors arising from the leaching of CCR-associated constituents into groundwater during closure activities and following the closure of the Ash Pond. Section 2.2.2 evaluates the potential for CCR releases to occur due to dike failure or overtopping during floods or other storm-related events. In summary, there is no current or future risk to any human or ecological receptors associated with the Ash Pond. Additionally, there is minimal current or future risk of overtopping occurring at the embankments due to flood conditions at the Site. Dike failure due to, *e.g.*, seismic activity and storm-related events is also exceedingly unlikely.

Section 2.2.4 evaluates several potential risks to human health and the environment during closure activities, including risks of accidents occurring among workers; risks to nearby residents and EJ communities related to accidents, traffic, noise, and air pollution; and risks to natural resources and wildlife. The findings from this section of the text are summarized in Table S.1 (Summary of Findings).

2.2.7 Long-Term Reliability of the Engineering and Institutional Controls (IAC Section 845.710(b)(1)(G))

Post-closure, there is minimal risk of engineering or institutional failures leading to sudden releases of CCR from the Ash Pond under the CIP scenario. There is no post-closure risk of engineering or institutional failures under the CBR-Offsite scenario (see Section 2.2.2 above). Additionally, there are no current or future unacceptable risks to any human or ecological receptors under any of the closure scenarios (see Section 2.2.1 above). Moreover, reliable engineering and institutional controls (*e.g.*, a bottom liner, a leachate management system, and groundwater monitoring) would be implemented at the off-Site landfill under the CBR-Offsite scenario. All of the evaluated closure scenarios are therefore reliable with respect to long-term engineering and institutional controls.

2.2.8 Potential Need for Future Corrective Action Associated with the Closure (IAC Section 845.710(b)(1)(H))

Corrective action is expected to be necessary at the Site. An evaluation of potential corrective measures and corrective actions has not yet been completed, but will be conducted consistent with the requirements outlined in IAC Sections 845.660 and 845.670.

2.3 Effectiveness of the Closure Alternative in Controlling Future Releases (IAC Section 845.710(b)(2))

2.3.1 Extent to Which Containment Practices Will Reduce Further Releases (IAC Section 845.710(b)(2)(A))

The CCR in the Ash Pond currently poses no unacceptable risks to human health or the environment (Section 2.2.1). Because current conditions do not present a risk to human health or the environment, and dissolved constituent concentrations would be expected to decline post-closure, there would also be no unacceptable risks to human health or the environment following closure, regardless of the closure scenario.

Section 2.2.2 discussed the potential for dike failure or overtopping to occur during or following closure activities, resulting in a sudden release of CCR. That analysis showed that there is minimal risk of sudden CCR releases occurring during or following closure under any of the closure scenarios.

2.3.2 Extent to Which Treatment Technologies May Be Used (IAC Section 845.710(b)(2)(B))

Under all three closure scenarios, water generated during the dewatering and unwatering of the Ash Pond would be treated, if necessary, prior to disposal. Following treatment, water from unwatering and dewatering would be discharged in accordance with the NPDES permit for the facility.

2.4 Ease or Difficulty of Implementing Closure Alternative (IAC Section 845.710(b)(3))

2.4.1 Degree of Difficulty Associated with Constructing the Closure Alternative

CIP using a final cover system is a reliable and standard method for managing and closing impoundments that relies on common construction activities. Dewatering saturated CCR to construct a stabilized final cover system subgrade can present challenges during closure; however, these challenges are common to most CCR surface impoundment closures and are commonly addressed *via* surface water management and dewatering techniques.

Excavation and landfilling of CCR is also a reliable and standard method for closing impoundments. However, relative to the CIP scenario, the CBR-Offsite scenario poses additional implementation difficulties due to the larger earthwork volumes and larger dewatering volumes involved. Under the CBR-Offsite scenario, hauling over public roads rather than private roads would require the use of lower-volume haul trucks, which would increase the number of trucks and trips required for CCR excavation and transport. Additionally, because the CBR-Offsite scenario would involve hauling CCR off-Site (*i.e.*, intrastate travel), a higher level of dewatering would be required under this scenario compared to the CIP scenario. As described in Section 2.2.4.2 (Community Risks), off-Site hauling may also have detrimental community impacts due to an increased incidence of vehicle accidents, traffic-related impacts, noise, and air pollution.

In addition to off-Site hauling, off-Site landfilling under the CBR-Offsite scenario may pose particular challenges. A disposal plan would need to be developed between Kincaid Generation, LLC and the owner/operator of the third-party landfill in order to outline acceptable waste conditions upon delivery, daily waste production rates, and the expected duration of the project. Off-Site landfilling may additionally raise issues related to the co-disposal of CCR and other non-hazardous wastes. Finally, the construction schedule for excavation may be negatively impacted if, during the course of closure, it is determined that the off-Site landfill must be expanded in order to receive all of the materials excavated from the Ash Pond.

2.4.2 Expected Operational Reliability of the Closure Alternative

There is no post-closure risk of operational failures leading to sudden releases of CCR from the Ash Pond under the CBR-Offsite scenario. There is minimal post-closure risk of sudden CCR releases occurring under the CIP scenario, because: (i) the final cover system will be constructed and maintained in accordance with all relevant state and federal safety regulations, and (ii) the dikes, final cover, and stormwater control features have all been designed to withstand earthquakes and storm events (see Section 2.2.2 above). Moreover, appropriate operational controls are expected to be implemented at the off-Site landfill under the CBR-Offsite scenario. As such, operational reliability would be expected under all of the closure scenarios.

2.4.3 Need to Coordinate with and Obtain Necessary Approvals and Permits from Other Agencies

Permits and approvals would be needed under all of the closure scenarios. Components of the three closure scenarios that would be expected to require a permit include:

- A modification to the existing NPDES permit through IEPA to allow the disposal of water generated from unwatering and dewatering operations *via* the existing NPDES-permitted outfall for the Site;
- A construction permit from the IDNR Office of Water Resources Dam Safety Program to allow the embankment and spillways of the Ash Pond to be modified as part of its closure;
- A construction stormwater permit through IEPA, including construction stormwater controls and other BMPs such as silt fences and other measures; and
- A joint water pollution control construction and operating permit (WPC permit).

Under the CBR-Offsite scenario, it may be necessary to expand the off-Site landfill. Additional permitting may be required under this scenario for the transport of the CCR and to expand the off-Site landfill. It may also be necessary to modify the operating plan for the off-Site landfill in order to accommodate the increased rate of filling of the landfill and the likely need for additional equipment and personnel to manage the receipt and disposal of the CCR.

2.4.4 Availability of Necessary Equipment and Specialists

CIP and CBR-Offsite are reliable and standard methods for managing waste that rely on common construction equipment and materials and typically do not require the use of specialists, outside of typical construction labor and equipment operators. However, global supply chains have been disrupted due to the COVID-19 pandemic, resulting in shortages in the availability of construction equipment and parts. There may be some shortages in construction equipment under all of the closure scenarios if supply chain resilience does not improve by the time construction begins. Alternatively, extended downtime may be required for equipment repairs and maintenance. A national shortage of truck drivers has also developed during the COVID-19 pandemic. Due to the larger earthwork volumes involved under the CBR-Offsite scenario than under the CIP scenario, shortages in construction equipment may cause greater challenges under the former than under the CIP scenario. The current shortage of truck drivers may be particularly impactful under the CBR-Offsite scenario, due to the large volume of CCR to be hauled from the Site under this scenario. If sufficient trucks and truck drivers are not available, the construction schedule at the Ash Pond may lengthen based on hauling-related delays.

The availability of critical materials such as metal, wood, and electronic chips has also been impacted by the COVID-19 pandemic. However, soil materials and geomembrane liner materials have generally been available during 2021 and early 2022 for landfill development and closure projects.

2.4.5 Available Capacity and Location of Needed Treatment, Storage, and Disposal Services

Under the CIP scenario, all of the CCR currently within the Ash Pond would be stored within the existing footprint of the Ash Pond. Treatment would consist of unwatering the Ash Pond at the start of construction, performing limited dewatering to stabilize the CCR subgrade, and managing stormwater inflow. Water from unwatering and dewatering the Ash Pond would be discharged in accordance with the NPDES permit for the facility. Under the CBR-Offsite scenario, water treatment would similarly consist of unwatering and dewatering the Ash Pond at the start of construction and discharging water from unwatering/dewatering in accordance with the NPDES permit for the facility. Due to the need for dewatering prior to CCR hauling, a higher volume of water would be expected to be generated during dewatering under the CBR-Offsite scenario than under the CIP scenario.

For the CBR-Offsite scenario, approximately 2,950,000 CY of CCR would be excavated from the Ash Pond and require disposal. For the CBR-Offsite scenario, the closest nearby third-party landfill with the ability to receive and dispose of CCR from the Site is the Five Oaks Landfill in Taylorville, Illinois (Appendix B). This facility has 7,050,000 CY of remaining capacity in its current permitted footprint. It receives 250,000 CY of waste annually and is located 7.5 miles from the Site by road (Appendix B; IEPA, 2021c). The Five Oaks Landfill therefore has sufficient capacity to receive CCR from the Ash Pond. However, closure of the Ash Pond would increase the annual waste receipt rate at the off-Site landfill. Due to the short timeframe over which CCR would be received at the landfill, vertical and/or lateral expansions of the landfill may become necessary. Additionally, the landfill operators may need to develop a disposal plan to account for the increased volume of material that would be received and CCR waste's unique characteristics. Elements of this disposal plan might include increasing daily operational capacity and procedures, expediting planned airspace construction, and potentially expediting the expansion of the landfill.

If disposal at the Five Oaks Landfill is impractical or infeasible, then an alternative landfill located farther from the Site would need to be identified. Two likely alternatives to the Five Oaks Landfill are the Sangamon Valley Landfill in Springfield, Illinois, and the Litchfield-Hillsboro Landfill in Litchfield, Illinois. The Sangamon Valley Landfill has 2,350,000 CY of remaining capacity in its current permitted footprint, receives 149,000 CY of waste annually, and is located 24.5 miles from the Site (IEPA, 2021c). The Litchfield-Hillsboro Landfill has 1,540,000 CY of remaining capacity in its current permitted footprint, receives 83,000 CY of waste annually, and is located 41.5 miles from the Site (IEPA, 2021c). Neither of these two alternative landfills has sufficient capacity for the volume of CCR to be excavated from the Ash Pond (2,950,000 CY) and would therefore require expansion if they were selected.

2.5 Impact of Closure Alternative on Waters of the State (IAC Section 845.710(d)(4))

As demonstrated in Gradient's human health and ecological risk assessment (Appendix A), modeled and measured surface water concentrations in Sangchris Lake are all below relevant human health and ecological screening benchmarks. Surface water concentrations of CCR-associated constituents would be expected to decline over time under all of the closure scenarios. Thus, no current or future exceedances of any human health or ecological screening benchmarks would be anticipated under any of the closure scenarios.

The lined landfills that would receive the CCR excavated from the Ash Pond under the CBR-Offsite scenario would be managed to ensure that no surface water impacts would occur in the vicinity of the landfill. In summary, no impacts on any waters of the state would be expected under any of the closure scenarios.

2.6 Concerns of Residents Associated with Closure Alternatives (IAC Section 845.710(b)(4))

Several nonprofits have raised concerns regarding the potential impacts of the coal ash impoundments at this Site and other sites throughout the region on groundwater and surface water quality, including Earthjustice, the Prairie Rivers Network, and the Sierra Club (Earthjustice *et al*., 2018; Sierra Club, 2014; Sierra Club and CIHCA, 2014). These parties generally prefer CBR to CIP, citing fears that allowing CCR to remain in place "allows the widespread groundwater contamination to continue indefinitely" (Earthjustice *et al*., 2018, p. 24). However, it is not the case that closing the Ash Pond at the Kincaid Site *via* CIP rather than CBR would result in undue risks to groundwater and surface water in the vicinity of the Site post-closure. As described in Sections 2.2.1 and 2.2.2, no current or future unacceptable risks to human or ecological receptors are associated with the Ash Pond under any of the closure scenarios. There is also minimal risk of future CCR releases occurring under any of the closure scenarios. Furthermore, groundwater modeling conducted at the Site demonstrated that groundwater concentrations will decline below the GWPS for all constituents at the same time for all closure scenarios (*i.e*., within 17 years after closure; Ramboll, 2022). All three closure scenarios are therefore responsive to residents' concerns regarding impacts to groundwater and surface water quality.

The CIP scenario has several advantages over the CBR-Offsite scenario with regard to likely community concerns. Notably, the CIP scenario presents fewer risks to workers and nearby residents during construction in the form of accidents, traffic-related impacts, noise, and air pollution (see Section 2.2.4 above). Closure would also be achieved more rapidly under the CIP scenario than under the CBR-Offsite scenario, due to the shorter expected duration of construction activities (2.1-2.8 years under the CIP scenario *vs.* 8.9-11.5 years under the CBR-Offsite scenario). Finally, because the CIP scenario would require less construction activity than the CBR-Offsite scenario and would also be completed over a shorter time period, the Site could be more rapidly redeveloped for the installation of a solar facility on the capped impoundment under the CIP scenario than under the CBR-Offsite scenario. Redevelopment of the Site for use in solar generation and battery energy storage would bring new jobs to the community and contribute positively to Illinois's growing renewable energy portfolio.

A public meeting was held on June 15, 2022, pursuant to requirements under IAC Section 845.710(e). Questions raised by attendees were addressed at the meeting; subsequently, a written summary of the questions and responses was prepared.

2.7 Class 4 Estimate (IAC Section 845.710(d)(1))

Analyses in the Final Closure Plan were prepared, consistent with Class 4 estimates, based on the Association for the Advancement of Cost Engineering (AACE) Classification Standard (or a comparable classification practice as provided in the AACE Classification Standard), as required by IAC Section 845.710 (IEPA, 2021a).

2.8 Summary

Table S.1 (Summary of Findings) summarizes the expected impacts of the CIP and CBR-Offsite closure scenarios with regard to each of the factors specified under IAC Section 845.710 (IEPA, 2021a). Based on this evaluation and the details provided in Section 2 above, CIP has been identified as the most appropriate closure scenario for the Ash Pond. Key benefits of the CIP scenario relative to the CBR-Offsite scenarios include the more rapid redevelopment of the Site for the installation of a solar facility on the capped impoundment and reduced impacts to workers, community members, and the environment during construction (*e.g.*, fewer constructed-related accidents, lower energy demands, less air pollution and GHG emissions, and reduced duration of traffic-related impacts). Moreover, the CIP scenario will meet the required closure schedule (*i.e.*, closure completed by October 2028) defined in IAC Section 845.700(d)(2)(C)(ii) (IEPA, 2021a), whereas the CCBR-Offsite scenario will be unable to meet this required schedule.

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Appendix A

Human Health and Ecological Risk Assessment

Human Health and Ecological Risk Assessment
Ash Pond
Kincaid Power Plant
Kincaid, Illinois

July 28, 2022

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Abbreviations

ADI	Acceptable Daily Intake
AP	Ash Pond
BCF	Bioconcentration Factor
BCG	Biota Concentration Guide
BCU	Bedrock Confining Unit
CCR	Coal Combustion Residuals
CEM	Conceptual Exposure Model
COI	Constituent of Interest
COPC	Constituent of Potential Concern
CSF	Cancer Slope Factor
CSM	Conceptual Site Model
ESV	Ecological Screening Value
GWPS	Groundwater Protection Standard
GWQS	Groundwater Quality Standards
HTC	Human Threshold Criteria
IEPA	Illinois Environmental Protection Agency
ILWATER	Illinois Water and Related Wells
ISGS	Illinois State Geological Survey
K_d	Equilibrium Partitioning Coefficient
KPP	Kincaid Power Plant
LCU	Lower Confining Unit
MCL	Maximum Contaminant Level
NID	National Inventory of Dams
NRWQC	National Recommended Water Quality Criteria
ORNL RAIS	Oak Ridge National Laboratory Risk Assessment Information System
pCi	PicoCuries
PMP	Potential Migration Pathway
PRG	Preliminary Remediation Goal
RfD	Reference Dose
RME	Reasonable Maximum Exposure
RSL	Regional Screening Level
SI	Surface Impoundment
SWQC	Surface Water Quality Criteria
UA	Uppermost Aquifer
US DOE	United States Department of Energy
US EPA	United States Environmental Protection Agency
USCU	Upper Semi-confining Unit
USGS	United States Geological Survey

1 Introduction

The Kincaid Power Plant (KPP, or "the Site") is an electric power generating facility with coal-fired units located approximately four miles west of the Village of Kincaid in Christian County, Illinois. The KPP is owned and operated by Kincaid Generation LLC. The KPP operates as a coal-fired power plant and has a single coal combustion residuals (CCR) management unit, the Ash Pond (AP) (Vistra Identification [ID] Number [No.] 141, Illinois Environmental Protection Agency [IEPA] ID No. W0218140002-01, and National Inventory of Dams [NID] No. IL50706 (Ramboll, 2021). The Kincaid AP, the subject of this report, is a 172-acre, unlined surface impoundment (SI) used to manage CCR and non-CCR waste streams at the KPP (Ramboll, 2021).

This report presents the results of an evaluation that characterizes potential risk to human and ecological receptors that may be exposed to CCR constituents in environmental media originating from the AP. This risk evaluation was performed to support the Closure Alternatives Assessment for the AP in accordance with requirements in Title 35 Part 845 of the Illinois Administrative Code (IEPA, 2021). Human and ecological risks were evaluated for Site-specific constituents of interest (COIs). The conceptual site model (CSM) assumed that Site-related COIs in groundwater may migrate to the adjacent Sangchris Lake and affect surface water and sediment in the vicinity of the Site.

Consistent with United States Environmental Protection Agency (US EPA) guidance (US EPA, 1989), this report used a tiered approach to evaluate potential risks, which included the following steps:

1. Identify complete exposure pathways and develop a conceptual exposure model (CEM).
2. Identify Site-related COIs: Constituents detected in groundwater were considered COIs if their maximum detected concentration over the period from 2015 to 2021 exceeded a groundwater protection standard (GWPS) identified in Part 845.600 (IEPA, 2021), or a relevant surface water quality standard (IEPA, 2019; US EPA Region IV, 2018).
3. Perform screening-level risk analysis: Compare maximum measured or modeled COI concentrations in surface water and sediment to conservative, health-protective benchmarks to determine constituents of potential concern (COPCs).
4. Perform refined risk analysis: If COPCs are identified, perform a refined analysis to evaluate potential risks associated with the COPCs.
5. Formulate risk conclusions and discuss any associated uncertainties.

This assessment relies on a conservative (*i.e.*, health-protective) approach and is consistent with the risk approaches outlined in US EPA guidance. Specifically, we considered evaluation criteria detailed in IEPA guidance documents (*e.g.*, IEPA, 2013, 2019), incorporating principles and assumptions consistent with the Federal CCR Rule (US EPA, 2015a) and US EPA's "Human and Ecological Risk Assessment of Coal Combustion Residuals" (US EPA, 2014a).

US EPA has established acceptable risk metrics. Risks above these US EPA-defined metrics are termed potentially "unacceptable risks." Based on the evaluation presented in this report, no unacceptable risks to human or ecological receptors resulting from CCR exposures associated with the AP were identified. This means that the risks from the Site are likely indistinguishable from normal background risks. Specific risk assessment results include the following:

- No completed exposure pathways were identified for any groundwater receptors; consequently, no risks were identified relating to the use of groundwater.
- No unacceptable risks were identified for recreators boating in Sangchris Lake adjacent to the Site.
- No unacceptable risks were identified for recreators exposed to sediment in Sangchris Lake adjacent to the Site.
- No unacceptable risks were identified for anglers consuming locally caught fish.
- No unacceptable risks were identified for ecological receptors exposed to surface water or sediment.
- No bioaccumulative ecological risks were identified.

It should be noted that this evaluation incorporates a number of conservative assumptions that tend to overestimate exposure and risk. Moreover, it should be noted that because current conditions do not present a risk to human health or the environment, there will also be no unacceptable risk to human health or the environment for future conditions when the AP is closed. For all future closure scenarios, potential releases of CCR-related constituents will decline over time and, consequently, potential exposures to CCR-related constituents in the environment will also decline.

2 Site Overview

2.1 Site Description

The KPP is located approximately four miles west of the Village of Kincaid in Christian County, Illinois. The KPP operates as a coal-fired power plant and has a single CCR management unit, the AP (Vistra ID No. 141, IEPA ID No. W0218140002-01, and NID No. IL50706). The Kincaid AP, the subject of this report, is a 172-acre, unlined SI used to manage CCR and non-CCR waste streams at the KPP (Ramboll, 2021).

The AP is located between two lobes of Sangchris Lake (Figure 2.1), which was formed in 1964 by damming Clear Creek, a tributary to the south fork of the Sangamon River. Sangchris Lake was created to provide a source of cooling water for the KPP. The western lobe of Sangchris Lake forms part of the western and the northern border of the AP and is connected to an intake flume for the KPP on the western edge of the AP. A discharge flume from the KPP forms the southern border of AP and is connected to the eastern lobe of Sangchris Lake. The KPP property is surrounded by the lobes of Sangchris Lake and Sangchris Lake State Park to the north and east, and a combination of undeveloped land and surface support facilities associated with the former Peabody Coal Company #10 mine to the south and west (Ramboll, 2021).

Figure 2.1 Site Location Map. Source: Ramboll (2021).

2.2 Geology/Hydrogeology

The geology underlying the Site in the vicinity of the KPP consists of unlithified deposits overlying a bedrock confining unit (BCU). The unlithified materials consist of three major hydrostratigraphic units: the upper semi-confining unit (USCU), the uppermost aquifer (UA), and the lower confining unit (LCU) (Ramboll, 2021). The USCU is primarily composed of low permeability clay and silt with some clayey sand and sandy clay intervals and high permeability sand lenses of the Cahokia Formation (Ramboll, 2021). The UA is composed of low permeability clays and silts of the Upper Cahokia Formation and the underlying moderate permeability sand and gravel layers of the Lower Cahokia Formation (Ramboll, 2021). At some locations, the UA also includes the interface with the underlying Vandalia Till (Ramboll, 2021). The LCU is composed of low permeability silt and clay with minor sand layers of the Vandalia Till (Ramboll, 2021). The BCU is composed of interbedded shale and limestone and underlies the entire footprint of the AP (Ramboll, 2021).

The discontinuous sand lenses within the USCU were designated as potential migration pathways (PMPs) because there is a high probability of contaminant transport through the high permeability sandy intervals (Ramboll, 2021). The USCU/PMP has a geometric mean horizontal hydraulic conductivity of 5.4×10^{-5} cm/s (Ramboll, 2021). The UA is generally less than 4 feet (ft) thick and has a geometric mean horizontal hydraulic conductivity of 4.14×10^{-5} cm/s (Ramboll, 2021). The UA is underlain by the confining units LCU and BCU.

Groundwater elevations within the AP are higher than the surface water elevations in Sangchris Lake (Ramboll, 2021). This groundwater mound (*i.e.*, piezometric maximum) due to the hydraulic influence of the AP facilitates a radial groundwater flow pattern from the AP towards two lobes of Sangchris Lake: a predominant groundwater flow in the north/northwest direction towards the western lobe of Sangchris Lake and a flow component in the south and southeast direction towards the eastern lobe of Sangchris Lake (Figure 2.2). The horizontal hydraulic gradient for the USCU/PMP averaged 0.010 ft/ft, which corresponds to an average groundwater flow velocity of 0.010 ft/day (Ramboll, 2021). The horizontal hydraulic gradient for the UA averaged 0.013 ft/ft, which corresponds to an average groundwater flow velocity of 0.0023 ft/day (Ramboll, 2021).

2.3 Conceptual Site Model

A CSM describes sources of contamination, the hydrogeological units, and the physical processes that control the transport of water and solutes. In this case, the CSM describes how groundwater underlying the KPP migrates and interacts with surface water and sediment in the adjacent Sangchris Lake. The CSM was developed using available hydrogeologic data specific to the KPP (Ramboll, 2021), including information on groundwater flow and surface water characteristics.

CCR-related constituents may migrate vertically downward beneath the KPP and into groundwater; these constituents may subsequently migrate with groundwater in the USCU/PMP and the UA and eventually flow into Sangchris Lake (Ramboll, 2021). Groundwater flow within the UA and the USCU/PMP is mostly in the horizontal direction because these units are underlain by confining layers (*i.e.*, LCU and BCU) that may inhibit vertical flow. After groundwater flows into the lake, dissolved constituents in groundwater may partition between sediments and surface water.

2.4 Groundwater Monitoring

A total of 32 wells have been used to monitor the groundwater quality near and downgradient of the AP. Of these, 23 wells are screened in the UA, 1 well is screened in the BCU, and 8 wells are screened in the USCU (Table 2.1).

The analyses presented in this report relied on all available data from the 32 wells collected between 2015 and 2021, which is the period subsequent to the promulgation of the Federal CCR Rule. Groundwater samples were analyzed for a suite of total metals, specified in Illinois CCR Rule Part 845.600 (IEPA, 2021).[1] A summary of the groundwater data used in this risk evaluation is presented in Table 2.2. The AP-related well locations used in this risk evaluation are shown in Figure 2.2. The use of groundwater data in this risk evaluation does not imply that detected constituents are associated with the AP or that they have been identified as potential groundwater exceedances.

Figure 2.2 Monitoring Well Locations. Source: Ramboll (2021, Figure 3-1).

[1] Samples were analyzed for a longer list of inorganic constituents, but these constituents were not evaluated in the risk evaluation.

Table 2.1 Groundwater Monitoring Wells Related to Kincaid Ash Pond

Well	Hydrogeologic Unit	Date Constructed	Screen Top Depth (ft bgs)	Screen Bottom Depth (ft bgs)	Well Depth (ft bgs)
MW-1	UA	04/20/2010	15	25	25
MW-2	UA	04/21/2010	10	20	20
MW-3	UA	04/15/2010	14	24	24
MW-4	UA	04/14/2010	12	22	22
MW-5	UA	04/22/2010	30	40	40
MW-6	UA	04/16/2010	10	20	20
MW-7	UA	04/16/2010	10	20	20
MW-7S	USCU	02/02/2021	6	11	11
MW-8	UA	04/13/2010	12	22	22
MW-8S	USCU	02/02/2021	4	7	7
MW-9	UA	04/19/2010	10	20	20
MW-10	UA	04/19/2010	10	20	20
MW-11	UA	06/17/2015	11	21	21
MW-11S	USCU	01/26/2021	4	8	8
MW-12	UA	07/23/2015	15	25	25
MW-12S	USCU	01/27/2021	5	9	9
MW-12D	BCU	01/26/2021	50	55	55
MW-20	UA	01/26/2021	14	24	24
MW-20S	USCU	01/26/2021	4	10	10
MW-22	UA	02/03/2021	15	19	19
MW-23	UA	02/02/2021	23	28	28
MW-24	UA	02/02/2021	27	32	32
MW-25	USCU	02/02/2021	9	14	14
MW-26	UA	02/02/2021	7	12	12
MW-27	USCU	02/02/2021	10	15	15
MW-28	UA	02/02/2021	12	22	22
MW-29	UA	02/01/2021	14	19	19
MW-30	UA	02/03/2021	35	40	40
MW-31	UA	02/03/2021	35	40	40
MW-31S	USCU	02/03/2021	25	30	30
MW-32	UA	02/03/2021	32	37	37
PZ-4C	UA	03/30/2016	15.5	20.5	20.5

Notes:
Source: Ramboll (2021).
BCU = Bedrock Confining Unit; bgs = Below Ground Surface; UA = Uppermost Aquifer; USCU = Upper Semi-confining Unit.
(a) No groundwater data were available for MW-11S. With the exception of the May 2021 sampling event, this monitoring well was dry during all sampling events (Ramboll, 2021).

Table 2.2 Groundwater Data Summary

Constituent	Samples with Constituent Detected	Samples Analyzed	Minimum Detected Value	Maximum Detected Value	Maximum Laboratory Detection Limit
Total Metals (mg/L)					
Antimony	5	396	0.0010	0.0016	0.0050
Arsenic	133	412	0.0010	0.18	0.025
Barium	411	412	0.020	2.7	0.0050
Beryllium	4	396	0.0012	0.010	0.0050
Boron	412	412	0.044	11	0.13
Cadmium	1	388	0.0017	0.0017	0.0050
Chromium	56	412	0.0015	0.35	0.0075
Cobalt	103	412	0.0010	0.14	0.0050
Lead	38	412	0.0010	0.25	0.0075
Lithium	175	289	0.0012	0.18	0.015
Mercury	2	398	0.00023	0.00048	0.00020
Molybdenum	121	289	0.0011	0.028	0.0075
Selenium	41	412	0.0010	0.021	0.040
Thallium	4	388	0.0021	0.0025	0.010
Radionuclides (pCi/L)					
Radium-226 + 228	386	386	0	9.3	2.0
Other (mg/L, unless otherwise noted)					
Chloride	368	412	1.0	245	50
Fluoride	421	422	0.11	0.78	0.20
Sulfate	385	412	10	929	500
Total Dissolved Solids	398	398	244	1,830	50

Notes:
Source: Ramboll (2021).
pCi/L = PicoCuries Per Liter.

2.5 Surface Water Monitoring

Golder collected a total of 33 surface water samples from Sangchris Lake in the vicinity of AP in October 2021 (Golder Associates Inc., 2021). The sample locations are shown in Figure 2.3, and the sampling results are summarized in Table 2.3.

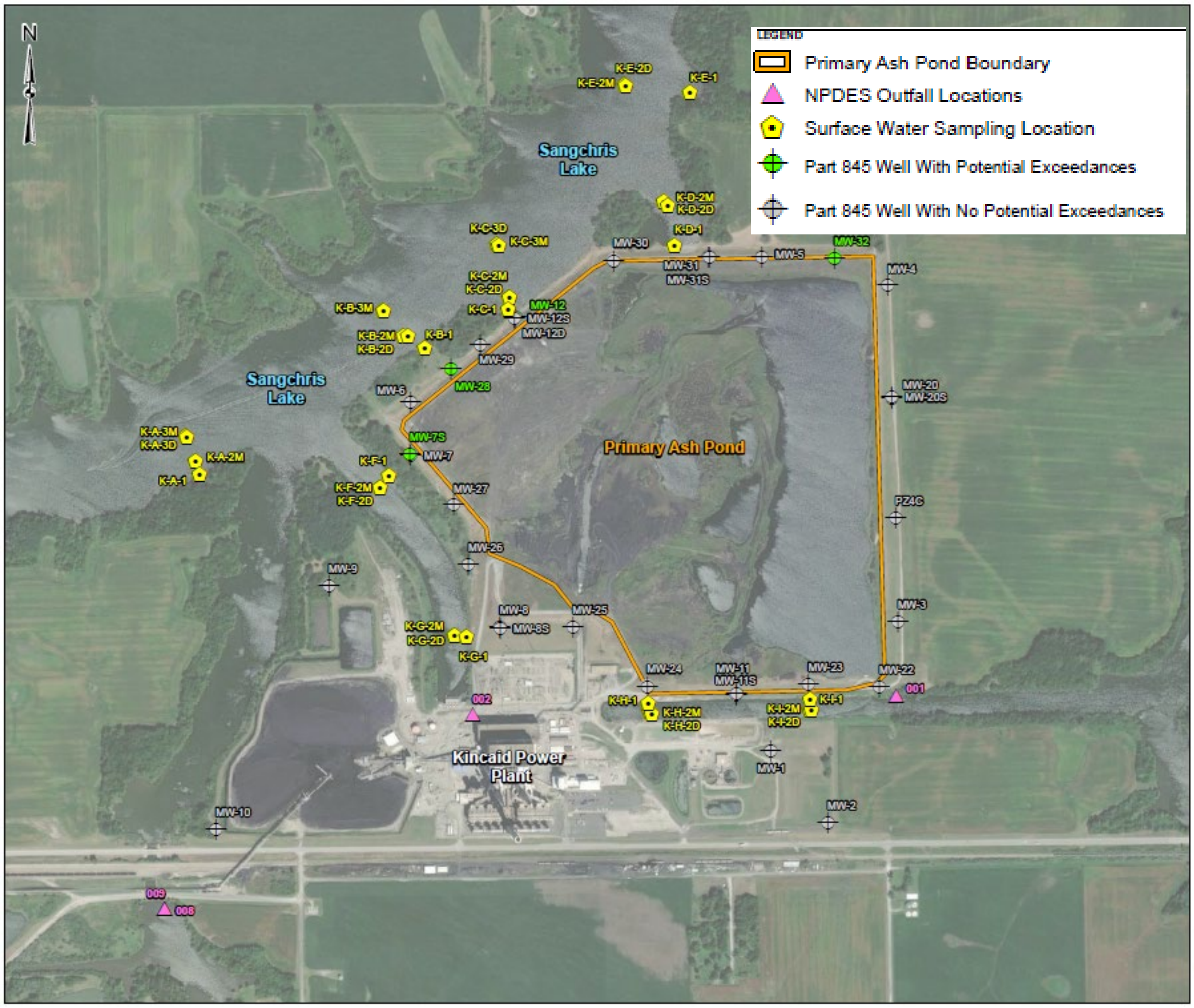

Figure 2.3 Surface Water Sampling Locations. Source: Golder Associates Inc. (2021).

Table 2.3 Surface Water Data Summary

Constituent	Samples with Constituent Detected	Samples Analyzed	Minimum Detected Value	Maximum Detected Value	Maximum Laboratory Detection Limit
Dissolved Metals (mg/L)					
Antimony	9	33	0.0012	0.0045	0.0010
Chromium	1	33	0.0024	0.0024	0.0015
Total Metals (mg/L)					
Arsenic	33	33	0.0023	0.0034	0.0010
Barium	33	33	0.063	0.084	0.0010
Beryllium	0	33	ND	ND	0.0010
Boron	33	33	0.035	0.065	0.025
Cadmium	0	33	ND	ND	0.0010
Calcium	33	33	29	34	0.10
Cobalt	0	33	ND	ND	0.0010
Iron	33	33	0.17	1.6	0.025
Lead	1	33	0.0011	0.0011	0.0010
Lithium	0	33	ND	ND	0.0030
Magnesium	33	33	18	20	0.050
Manganese	33	33	0.074	0.23	0.0020
Mercury	0	33	ND	ND	0.00020
Molybdenum	0	33	ND	ND	0.0015
Potassium	33	33	2.8	3.2	0.10
Selenium	0	33	ND	ND	0.0010
Sodium	33	33	12	13	0.050
Radionuclides (pCi/L)					
Radium-226 + 228	32	33	0.024	1.3	NA
Other (mg/L, unless otherwise noted)					
Chloride	33	33	20	21	1.0
Fluoride	33	33	0.35	0.36	0.10
Phosphorus	1	33	0.15	0.15	0.10
Sulfate	33	33	30	32	10
Total Dissolved Solids	33	33	162	218	20

Notes:

Source: Golder Associates Inc. (2021).

NA = Not Applicable; ND = Not Detected; pCi/L = PicoCuries Per Liter.

Surface water was analyzed for both total and dissolved metals. Only the total metals are reported here, because they are generally higher concentrations than dissolved metals. However, since antimony and chromium were not detected in the analysis for total metals, the results of the dissolved metals are reported for these two constituents only.

3 Risk Evaluation

3.1 Risk Evaluation Process

A risk evaluation was conducted to determine whether constituents present in groundwater underlying and downgradient of the AP have the potential to pose adverse health effects to human and ecological receptors. The risk evaluation is consistent with the principles of risk assessment established by US EPA and has considered evaluation criteria detailed in Illinois guidance documents (*e.g.*, IEPA [2013, 2019]).

The general risk evaluation approach is summarized in Figure 3.1 and discussed below.

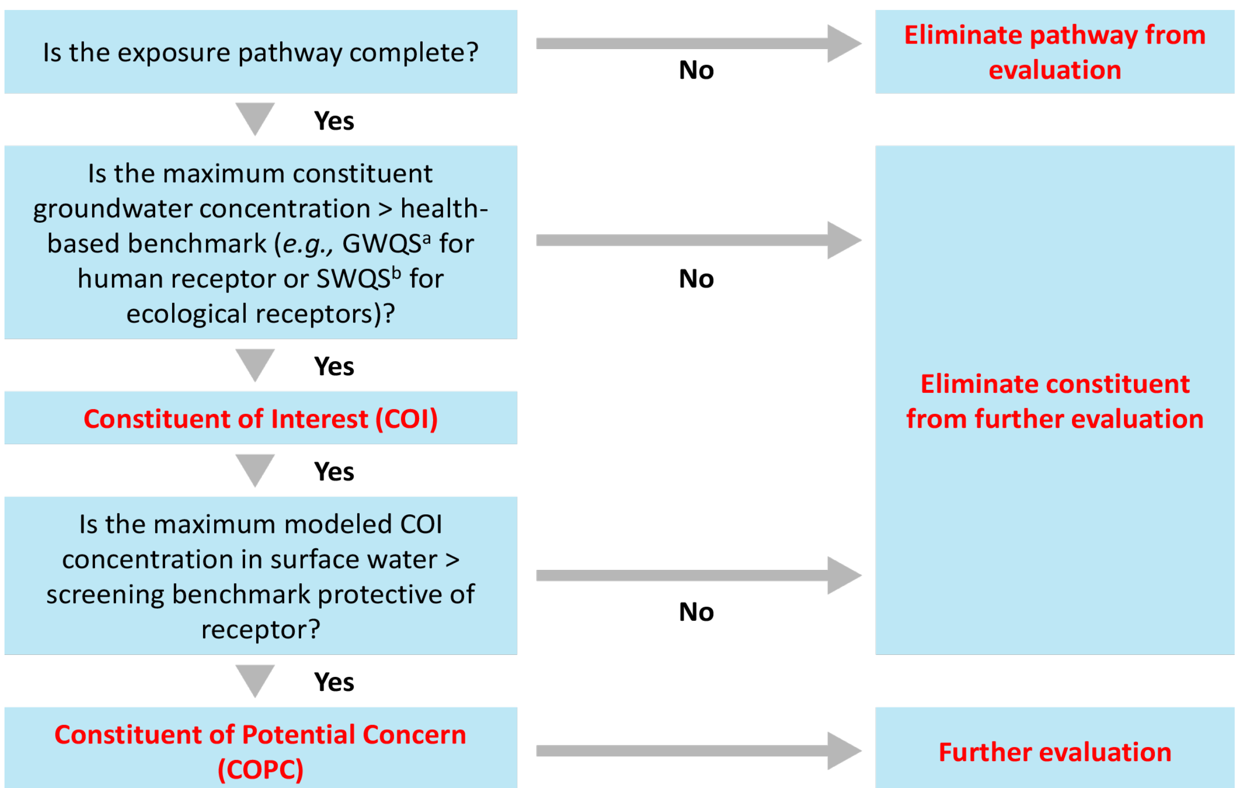

Figure 3.1 Overview of Risk Evaluation Methodology. GWQS = Groundwater Quality Standard; IEPA = Illinois Environmental Protection Agency; SWQS = Surface Water Quality Standard; US EPA = United States Environmental Protection Agency. (a) The IEPA Part 845 GWPS were used to identify COIs. (b) IEPA SWQS protective of chronic exposures to aquatic organisms were used to identify ecological COIs. In the absence of an SWQS, US EPA Region IV ecological screening values were used.

The first step in the risk evaluation was to develop the CEMs and identify complete exposure pathways. All potential receptors and exposure pathways based on groundwater use and surface water use in the vicinity of the Site were considered. Exposure pathways that are incomplete were excluded from the evaluation.

Groundwater data were used to identify COIs. COIs were identified as constituents with maximum concentrations in groundwater in excess of groundwater quality standards (GWQS)[2] for human receptors and surface water quality standards (SWQS) for ecological receptors. Based on the CSM (Section 2.3), some groundwater underlying the AP has the potential to interact with surface water in Sangchris Lake. Therefore, potential AP-related constituents in groundwater may potentially flow toward and flow into surface water in Sangchris Lake.

Surface water samples have been collected from Sangchris Lake adjacent to the Site; however, sediment samples have not been collected from the lake. Gradient modeled the potential migration of COIs from groundwater to surface water and sediment to evaluate potential risks to receptors (see Section 3.3.3).

Gradient modeled the COI concentrations in surface water and sediment based on the groundwater data from the AP-related wells. The measured and modeled COI concentrations in surface water and sediment were compared to conservative, generic risk-based screening benchmarks for human health and ecological receptors. These generic screening benchmarks rely on default assumptions with limited consideration of site-specific characteristics. Human health benchmarks are receptor-specific values calculated for each pathway and environmental medium that are designed to be protective of human health. Ecological benchmarks are medium-specific values designed to be protective of all potential ecological receptors exposed to surface water. Ecological and human health screening benchmarks are inherently conservative because they are intended to screen out chemicals that are of no concern with a high level of confidence. Therefore, a measured or modeled COI concentration exceeding a screening benchmark does not indicate an unacceptable risk, but only that further risk evaluation is warranted. COIs with maximum concentrations exceeding a conservative screening benchmark are identified as COPCs requiring further evaluation.

As described in more detail below, this evaluation relied on the screening assessment to demonstrate that constituents present in groundwater underlying the AP do not pose an unacceptable human health or ecological risk. That is, after the screening step, no COPCs were identified and further assessment was not warranted.

3.2 Human and Ecological Conceptual Exposure Models

A CEM provides an overview of the receptors and exposure pathways requiring risk evaluation. The CEM describes the source of the contamination, the mechanism that may lead to a release of contamination, the environmental media to which a receptor may be exposed, the route of exposure (exposure pathway), and the types of receptors that may be exposed to these environmental media.

3.2.1 Human Conceptual Exposure Model

The human CEM for the Site depicts the relationships between the off-Site environmental media potentially impacted by constituents in groundwater and human receptors that could be exposed to these media. Figure 3.2 presents a human CEM for the Site. It considers a human receptor who could be exposed to

[2] As discussed further in Section 3.3.2, GWQS are protective of human health and not necessarily of ecological receptors. While ecological receptors are not exposed to groundwater, groundwater can potentially enter into the adjacent surface water and impact ecological receptors. Therefore, two sets of COIs were identified: one for humans and another for ecological receptors.

COIs hypothetically released from the AP into groundwater, surface water, sediment, and fish. The following human receptors and exposure pathways were evaluated for inclusion in the Site-specific CEM.

- Residents – exposure to groundwater/surface water as drinking water
- Residents – exposure to groundwater/surface water used for irrigation
- Recreators in the lake adjacent to the Site:
  - Boaters – exposure to surface water and sediment while boating
  - Swimmers – exposure to surface water and sediment while swimming
  - Anglers – exposure to surface water and sediment and consumption of locally caught fish

All of these exposure pathways were considered to be complete, except for residential exposure to groundwater or surface water used for drinking water or irrigation, and swimming. Section 3.2.1.1 explains why the residential drinking water and irrigation pathways are incomplete, and Section 3.2.1.2 provides additional description of the recreational exposures. The permitted activities in Sangchris Lake do not include swimming, therefore this pathway was not evaluated (IDNR, 2022a).

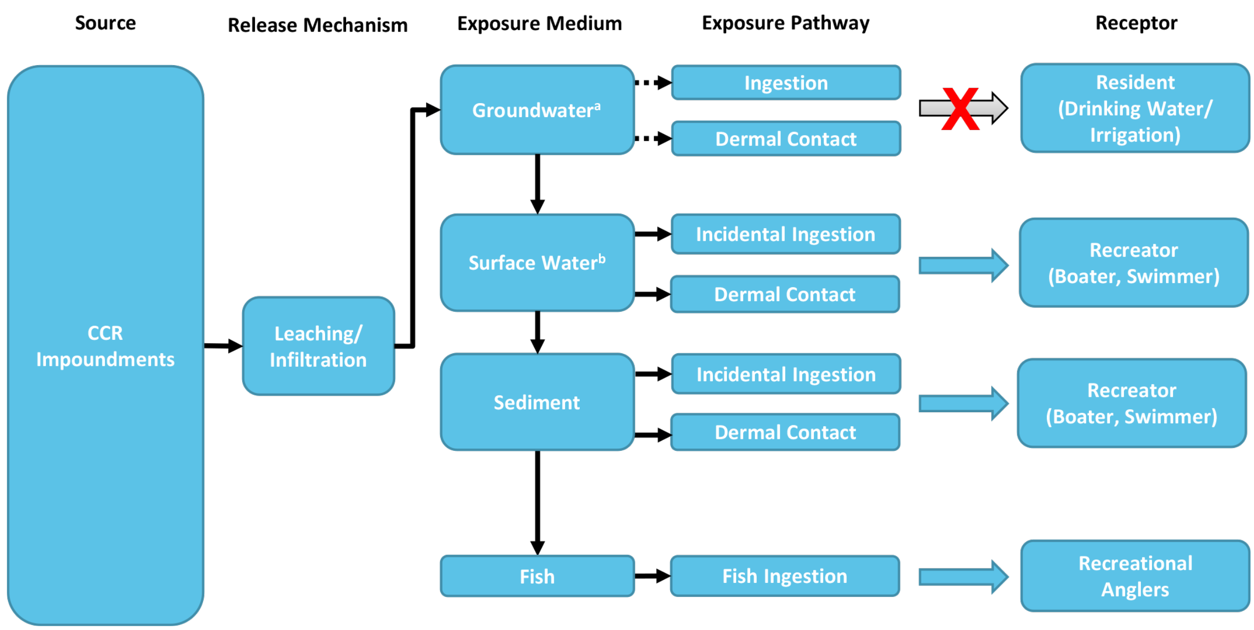

Figure 3.2 Human Conceptual Exposure Model. CCR = Coal Combustion Residuals. Dashed line/Red X = Incomplete or insignificant exposure pathway. (a) Groundwater in the vicinity of the Site is not used as a drinking water or irrigation source. (b) Surface water is not used as a drinking water source.

3.2.1.1 Groundwater or Surface Water as a Drinking Water/Irrigation Source

Groundwater as a source of drinking water and/or irrigation water is not a complete exposure pathway for CCR-related constituents originating from the KPP. As presented below, wells in the vicinity of the AP are either not used as a source of drinking water and/or irrigation water or are hydraulically separated from the AP.

Relying on federal and state databases, Ramboll completed a potable water well survey in 2021 (Ramboll, 2021). A total of nine wells were identified within a 1,000-meter radius of the AP during a comprehensive search of the Illinois State Geological Survey's (ISGS) Illinois Water and Related Wells (ILWATER) Map (ISGS, 2020). The wells that were identified included two wells that were identified as dry, one well identified as a municipal water supply well, two wells identified as private water wells, one well identified as a commercial well, and three coal mining or engineering related test wells (Ramboll, 2021, Figure 3.3). While there is no information available about the current use of these wells, they are either unlikely to be used as sources of drinking/irrigation water and/or are unlikely to be affected by potential CCR-related constituents originating from the AP. Wells that were identified in the Ramboll (2021) receptor survey are summarized below:

- The two dry wells and the coal mining test well are not used as sources of drinking or irrigation water and consequently are not shown on Figure 3.3. Moreover, the dry wells are located on opposite sides of Sangchris Lake from the AP (Ramboll, 2021); thus, there is no plausible mechanism by which they could be impacted by any potential constituents in groundwater associated with the AP. The coal mining test well, which was installed in 1911 (Ramboll, 2021) is located under the current location of Sangchris Lake (Ramboll, 2021).
- One private water well is shown on the KPP property (Ramboll, 2021). If this well exists, it likely is not used as source of drinking or irrigation water. The receptor survey also lists a private well (120212464000; Ramboll, 2021); this well is actually located south of the Town of Kincaid, far from the KPP property. Since these wells are either unlikely to be used as source of drinking/irrigation water or unaffected by potential CCR-related constituents originating from the AP they have not been shown on Figure 3.3.
- One private water well (#42) is shown within the boundaries of the AP (Ramboll, 2021; Figure 3.3). If this well actually exists, it is not used as source of drinking or irrigation water.
- There are two engineering test or test hole locations (#55 and #91). These are not likely to be used as sources of drinking or irrigation water. Moreover, the test holes are located on opposite sides of Sangchris Lake from the AP (Ramboll, 2021); thus, there is no plausible mechanism by which they could be impacted by any potential constituents in groundwater associated with the AP.
- There is one commercial well (#62) installed in 1980 by Commonwealth Edison (Ramboll, 2021, Figure 3.3). The well is located on the opposite side of Sangchris Lake from the AP; thus, there is no plausible mechanism by which it could be impacted by any potential constituents in groundwater associated with the AP.
- There is one municipal supply well (#98) installed in 1975 at Sangchris State Park. The well is located approximately 1,800 feet side-gradient of the AP along the edge of Sangchris Lake; given that there is a strong groundwater flow gradient toward the lake, it is unlikely that this well could be impacted by CCR-related constituents originating from the AP.

Additionally, as summarized below, there is no off-Site migration of CCR-related constituents in either shallow or deep groundwater and Sangchris Lake is not used as a public water supply.

- **There is no off-Site migration of CCR-related constituents in groundwater**. Groundwater from the AP flows toward two lobes of Sangchris Lake. Primary groundwater flow directions are to the north/northwest direction towards the western lobe of Sangchris Lake and to the south/southeast direction towards the eastern lobe of Sangchris Lake (Ramboll, 2021). Both lobes of Sangchris Lake in the vicinity of the AP are hydraulic boundaries that prevent shallow groundwater from flowing past or underneath them. Furthermore, Sangchris Lake is a regional "sink," which means that groundwater flows to Sangchris Lake but cannot flow past. Thus, there is no plausible mechanism by which potential constituents in groundwater associated with the AP could have impacted off-Site groundwater.
- **Sangchris Lake adjacent to AP is not used as a public water supply.** Sangchris Lake is a cooling water pond maintained by Kincaid Generation LLC, which restricts the use of the lake as a source of drinking water. Therefore, the human exposure pathway of surface water ingestion (as potable water) adjacent to the AP was not evaluated further.
- **The AP has a limited hydraulic connection to deep groundwater.** The confining units (*i.e.*, LCU and BCU) underlying the shallow water bearing units (*i.e.*, the UA and the USCU/PMP) form a hydraulic barrier between the KPP and deeper groundwater resources. Due to very low permeability of the LCU, downward migration of shallow groundwater is expected to be limited. Therefore, the likelihood of KPP AP-related impacts to deep groundwater is minimal.

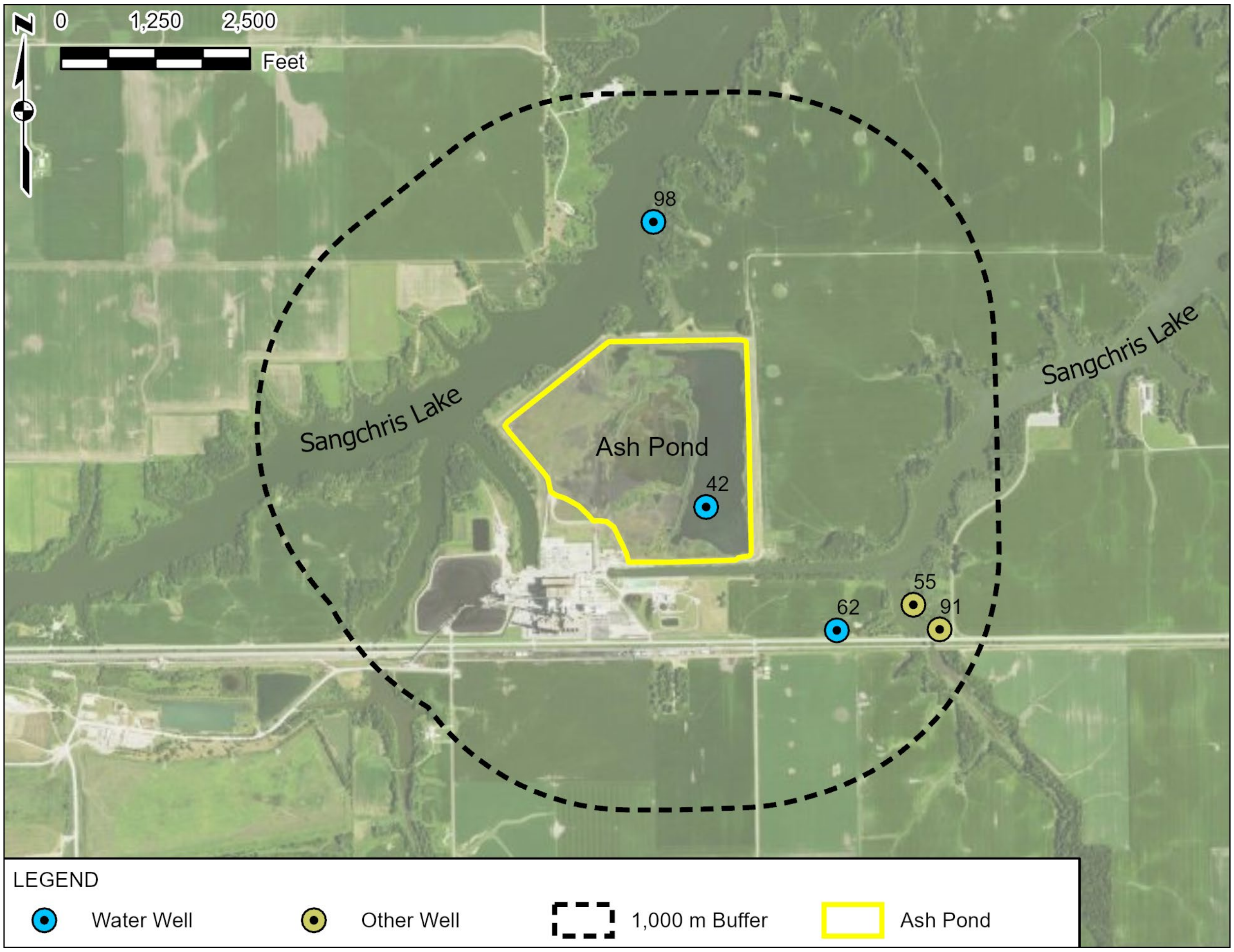

Figure 3.3 Water Wells Within 1,000 Meters of the KPP Ash Pond. KPP = Kincaid Power Plant. Reproduced from Ramboll (2021, Figure B-2).

3.2.1.2 Recreational Exposures

Sangchris Lake is located adjacent to the Site and portions of the lake are owned by Kincaid Generation LLC (Ramboll, 2021). Sangchris Lake State Park is located to the north of the Site (Ramboll, 2021), and the lake is used for recreational fishing (IDNR, 2022b). Recreational exposure to surface water and sediment may occur during activities such as boating or fishing in the lake. Recreational anglers may also consume locally caught fish from Sangchris Lake. Swimming is not listed as a permitted activity in Sangchris Lake (IDNR, 2022b).

3.2.2 Ecological Conceptual Exposure Model

The ecological CEM for the Site depicts the relationships between off-Site environmental media (surface water and sediment) potentially impacted by COIs in groundwater and ecological receptors that may be exposed to these media. The ecological risk evaluation considered both direct toxicity and secondary toxicity *via* bioaccumulation. Figure 3.4 presents the ecological CEM for the Site. The following ecological receptor groups and exposure pathways were considered:

- **Ecological Receptors Exposed to Surface Water:**
  - Aquatic plants, amphibians, reptiles, and fish.
- **Ecological Receptors Exposed to Sediment:**
  - Benthic invertebrates (*e.g.*, insects, crayfish, and mussels).
- **Ecological Receptors Exposed to Bioaccumulative COIs:**
  - Higher trophic-level wildlife (avian and mammalian) *via* direct exposures (surface water and sediment exposure) and secondary exposures through the consumption of prey (*e.g.*, plants, invertebrates, small mammals, and fish).

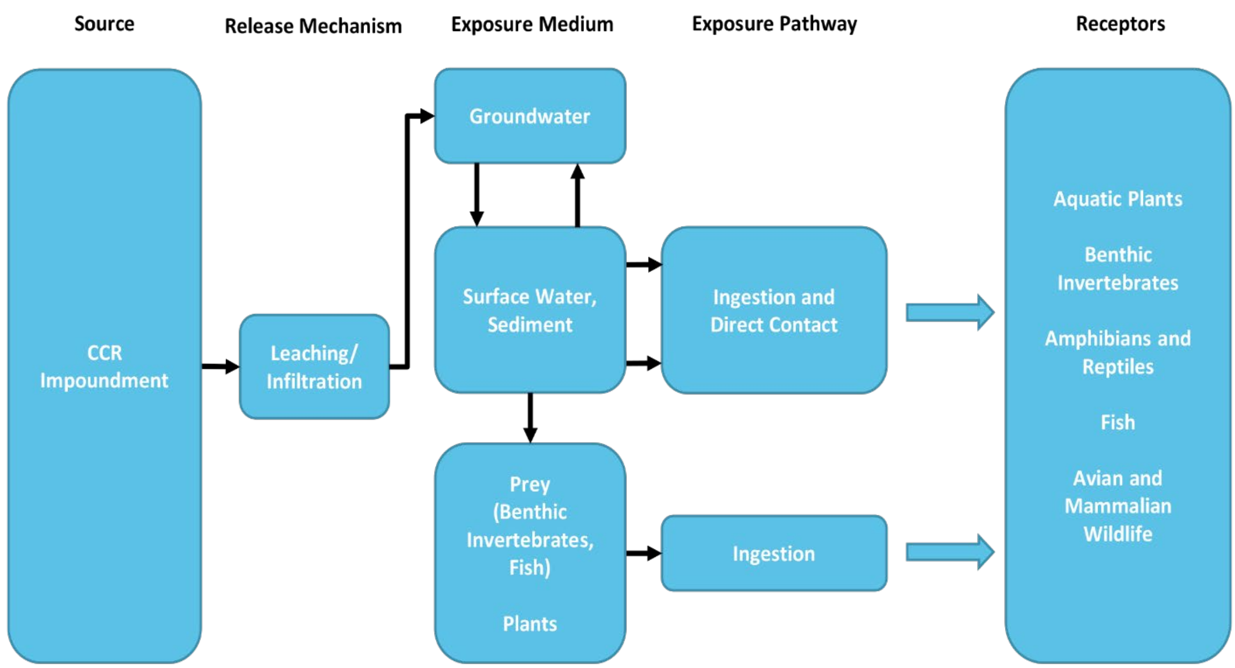

Figure 3.4 Ecological Conceptual Exposure Model. CCR = Coal Combustion Residuals.

3.3 Identification of Constituents of Interest

Risks were evaluated for COIs. A constituent was considered a COI if the maximum detected constituent concentration in groundwater exceeded a health-based benchmark. According to US EPA risk assessment guidance (US EPA, 1989), this screening step is designed to reduce the number of constituents carried through the risk evaluation that are anticipated to have a minimal contribution to the overall risk. Identified COIs are the constituents that are most likely to pose a risk concern in the surface water adjacent to the Site.

3.3.1 Human Health Constituents of Interest

For the human health risk evaluation, COIs were conservatively identified as constituents with maximum concentrations in groundwater above the GWPS listed in the Illinois CCR Rule Part 845.600 (IEPA, 2021).

Gradient used the maximum detected concentrations from groundwater samples collected from all of the AP-associated wells, regardless of hydrostratigraphic unit. The use of groundwater data in this risk evaluation does not imply that detected constituents are associated with the AP or that they have been identified as potential groundwater exceedances. Using this approach, 10 COIs (arsenic, barium, beryllium, boron, chromium, cobalt, lead, lithium, thallium, and radium-226+228) were identified for the human health risk evaluation *via* the surface water pathway (Table 3.1).

The water quality parameters that exceeded the GWPS included chloride, sulfate, and total dissolved solids; however, these constituents were not included in the risk evaluation because the GWPS are based on aesthetic quality. The US EPA secondary maximum contaminant levels (MCLs) for chloride, sulfate, and total dissolved solids are based on aesthetic quality. The secondary MCLs for chloride and sulfate (250 mg/L) are based on salty taste (US EPA, 2021a). The secondary MCL for total dissolved solids (500 mg/L) is based on hardness, deposits, colored water, staining, and salty taste (US EPA, 2021a). Given that these parameters are not likely to pose a human health risk concern in the event of exposure, they were not considered to be human health COIs.

Table 3.1 Human Health Constituents of Interest

Constituent[a]	Maximum Concentration	GWPS[b]	Human Health COI[c]
Total Metals (mg/L)			
Antimony	0.0016	0.0060	No
Arsenic	0.18	0.010	Yes
Barium	2.7	2.0	Yes
Beryllium	0.010	0.0040	Yes
Boron	11	2.0	Yes
Cadmium	0.0017	0.0050	No
Chromium	0.35	0.10	Yes
Cobalt	0.14	0.0060	Yes
Lead	0.25	0.0075	Yes
Lithium	0.18	0.040	Yes
Mercury	0.00048	0.0020	No
Molybdenum	0.028	0.10	No
Selenium	0.021	0.050	No
Thallium	0.0025	0.0020	Yes
Radionuclides (pCi/L)			
Radium-226 + 228	9.3	5.0	Yes
Other (mg/L, unless otherwise noted)			
Chloride	245	200	No[d]
Fluoride	0.78	4.0	No
Sulfate	929	400	No[d]
Total Dissolved Solids	1,830	1,200	No[d]

Notes:
COI = Constituent of Interest; GWPS = Groundwater Protection Standard; pCi/L = PicoCuries Per Liter.
Shaded = Compound identified as a COI.
(a) The constituents are those listed in the Illinois Part 845.600 GWPS (IEPA, 2021).
(b) The Illinois Part 845.600 GWPS (IEPA, 2021) were used to identify COIs.
(c) COIs are constituents for which the maximum concentration exceeds the groundwater standard.
(d) This constituent is not likely to pose a human health risk concern due to the absence of studies regarding toxicity to human health. Therefore, this constituent is not considered a COI.

3.3.2 Ecological Constituents of Interest

The Illinois GWPS, as defined in IEPA's guidance, were developed to protect human health, but not necessarily ecological receptors. While ecological receptors are not exposed to groundwater, groundwater can potentially migrate into the adjacent surface water and impact ecological receptors. Therefore, to identify ecological COIs, the maximum concentrations of constituents detected in groundwater were compared to ecological surface water benchmarks protective of aquatic life.

The surface water screening benchmarks for freshwater organisms were obtained from the following hierarchy of sources:

- IEPA (2019) surface water quality criteria (SWQC). IEPA SWQC are health-protective benchmarks for aquatic life exposed to surface water on a long-term basis (*i.e.*, chronic exposure). The SWQC for several metals are hardness-dependent (cadmium, chromium, copper, lead, manganese, nickel, and zinc). Screening benchmarks for these constituents were calculated assuming US EPA's default hardness of 100 mg/L (US EPA, 2022).[3]
- US EPA Region IV (2018) surface water Ecological Screening Values (ESVs) for hazardous waste sites.

Benchmarks from the United States Department of Energy's (US DOE) guidance document ("A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota") were used for radium (US DOE, 2019). US DOE (2019) presents benchmarks for radium-226 and radium-228 (4 and 3 picoCuries per liter [pCi/L], respectively). Given that radium concentrations are expressed as total radium (radium-226+228, *i.e.*, the sum of radium-226 and radium-228), Gradient used the lower of the two benchmarks (3 pCi/L for radium-228) to evaluate total radium concentrations.

Consistent with the human health risk evaluation, Gradient used the maximum detected concentrations from groundwater samples collected from all of the AP-associated wells (regardless of hydrostratigraphic unit) without considering spatial or temporal representativeness for ecological receptor exposures. The use of the maximum constituent concentrations in this evaluation is designed to conservatively identify COIs that warrant further investigation. Boron, cadmium, chromium, cobalt, lead, and radium-226+228 were identified as COIs for ecological receptors (Table 3.2).

[3] Hardness data were obtained from United States Geological Survey (USGS) monitoring station USGS-05575570, located at the north end of Sangchris Lake, 3.4 miles north of the AP (USGS *et al*., 2022). The available hardness data include 133 samples with a date range of 1980 to 1997. The hardness ranges from 140 to 330 mg/L, with an average of 231 mg/L. However, the US EPA (2022) default hardness of 100 mg/L was used. Use of a higher hardness value would result in less stringent screening values; thus, use of the US EPA default hardness is conservative.

Table 3.2 Ecological Constituents of Interest

Constituent[a]	Maximum Groundwater Concentration	Ecological Benchmark[b]	Basis	Ecological COI[c]
Total Metals (mg/L)				
Antimony	0.0016	0.19	US EPA R4 ESV	No
Arsenic	0.18	0.19	IEPA SWQC	No
Barium	2.7	5.0	IEPA SWQC	No
Beryllium	0.010	0.064	US EPA R4 ESV	No
Boron	11	7.6	IEPA SWQC	Yes
Cadmium	0.0017	0.0011	IEPA SWQC	Yes
Chromium	0.35	0.21	IEPA SWQC	Yes
Cobalt	0.14	0.019	US EPA R4 ESV	Yes
Lead	0.25	0.020	IEPA SWQC	Yes
Lithium	0.18	0.44	US EPA R4 ESV	No
Mercury	0.00048	0.0011	IEPA SWQC	No
Molybdenum	0.028	7.2	US EPA R4 ESV	No
Selenium	0.021	1.0	IEPA SWQC	No
Thallium	0.0025	0.0060	US EPA R4 ESV	No
Radionuclides (pCi/L)				
Radium-226 + 228	9.3	3.0	US DOE	Yes
Other (mg/L, unless otherwise noted)				
Chloride	245	500	IEPA SWQC	No
Fluoride	0.78	4.0	IEPA SWQC	No
Sulfate	929	NA	NA	NA
Total Dissolved Solids	1,830	NA	NA	NA

Notes:
COI = Constituent of Interest; ESV = Ecological Screening Value; GWPS = Groundwater Protection Standard; IEPA = Illinois Environmental Protection Agency; NA = Not Available; pCi/L = PicoCuries Per Liter; SWQC = Surface Water Quality Criteria; US DOE = United States Department of Energy; US EPA R4 = United States Environmental Protection Agency Region IV.
Shaded = Compound identified as a COI.
(a) The constituents are those listed in the Illinois Part 845.600 GWPS (IEPA, 2021).
(b) Ecological benchmarks are from the hierarchy of sources discussed in Section 3.3.2: IEPA SWQC (IEPA, 2019); US EPA Region IV "Ecological Risk Assessment Supplemental Guidance" (US EPA Region IV, 2018); and US DOE's guidance document, "A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota" (US DOE, 2019).
(c) Constituents with maximum detected concentrations exceeding a benchmark protective of surface water exposure are considered ecological COIs.

3.3.3 Surface Water and Sediment Modeling

Surface water sampling has been conducted in Sangchris Lake adjacent to the Site. To estimate the potential contribution to surface water (and sediment) from groundwater specifically associated with AP, Gradient modeled concentrations in Sangchris Lake surface water and sediment from groundwater flow into the lake for the detected human and ecological COIs. This is because the constituents detected in groundwater above an ecological- or health-based benchmark are most likely to pose a risk concern in the adjacent surface water. Gradient modeled human health and ecological COI concentrations in the surface water and sediment using a mass balance calculation based on the surface water and groundwater mixing. The model assumes a well-mixed groundwater-surface water location. The maximum detected concentrations in groundwater (regardless of well location) from 2015 to 2021 were conservatively used to model COI concentrations in surface water and sediment. The groundwater data were measured as total metals. Use of the total metals concentration for these COIs may overestimate surface water concentrations because dissolved concentrations, which are lower than total concentrations, represent the mobile fractions of constituents that could likely flow into and mix with surface water.

This modeling approach does not account for geochemical transformations that may occur during groundwater mixing with surface water. Gradient assumed that predicted surface water concentrations were influenced only by the physical mixing of groundwater as it enters the surface water, and were not further influenced by the geochemical reactions in the water and sediment, such as precipitation. In addition, the model only predicts surface water and sediment concentrations as a result of the potential migration of COI concentrations in AP-related groundwater and does not account for background concentrations in surface water or sediment.

For this evaluation, Gradient adapted a simplified and conservative form of US EPA's indirect exposure assessment methodology (US EPA, 1998) that was used in US EPA's coal combustion waste risk assessment (US EPA, 2014a). The model is a mass balance calculation based on surface water and groundwater mixing and the concept that the dissolved and sorbed concentrations can be related through an equilibrium partitioning coefficient (K_d). The model assumes a well-mixed groundwater-surface water location, with partitioning among total suspended solids, dissolved water column, sediment pore water, and solid sediments.

Sorption to soil and sediment is highly dependent on the surrounding geochemical conditions. To be conservative, we ignored the natural attenuation capacity of soil and sediment and estimated the surface water concentration based only on the physical mixing of groundwater and surface water (*i.e.*, dilution) at the point of entry of groundwater to the surface water.

The aquifer and surface water properties used to estimate the volume of groundwater flowing to Sangchris Lake and surface water concentrations are presented in Table 3.3. The COI concentrations in sediment were modeled using the COI-specific sediment-to-water partitioning coefficients and the sediment properties presented in Table 3.4. In the absence of Site-specific information for Sangchris Lake, Gradient used default assumptions (*e.g.*, depth of the upper benthic layer and bed sediment porosity) to model sediment concentrations. The modeled surface water and sediment concentrations are presented in Table 3.5. These modeled concentrations reflect conservative contributions from groundwater flow. A description of the modeling and the detailed results are presented in Appendix A.

Table 3.3 Groundwater and Surface Water Properties Used in Modeling

Parameter	Unit	Values	Notes/Source
Groundwater			
COI Concentration	mg/L	Constituent-specific	Maximum detected concentration in groundwater
Cross Section Area for the UA[a]	m^2	13,942	The sum of the maximum saturated thicknesses of the USCU/PMP and the UA (*i.e.*, approximately 6 meters) multiplied by the length of the AP intersecting Sangchris lake (*i.e.*, about 2,287 meters) (Ramboll, 2021).
Hydraulic Gradient	m/m	0.012	The average of hydraulic gradients for the UA and the USCU/PMP (Ramboll, 2021).
Average Hydraulic Conductivity	cm/s	4.59×10^{-5}	Average of the geometric mean horizontal hydraulic conductivities measured for the USCU/PMP (5×10^{-5} cm/s) and the UA (4×10^{-5} cm/s) (Ramboll, 2021).
Surface Water			
Surface Water Flow Rate in Sangchris Lake	L/yr	3.8×10^{10}	Mean surface water flow in Sangchris Lake (US EPA Region V, 1975; Larimore and Tranquilli, 1981).
Total Suspended Solids	mg/L	19	Average TSS concentration in Sangchris Lake.[b]
Depth of the Water Column	m	4.6	Mean depth of Sangchris Lake (Larimore and Tranquilli, 1981).
Suspended Sediment to Water Partition Coefficient	mg/L	Constituent-specific	Values based on US EPA (2014a)

Notes:

AP = Ash Pond; COI = Constituent of Interest; PMP = Potential Migration Pathway; TSS = Total Suspended Solids; UA = Uppermost Aquifer; US EPA = United States Environmental Protection Agency; USCU = Upper Semi-confining Unit; USGS = United States Geological Survey.

(a) Cross-sectional area represents the area through which groundwater flows from the UA into Sangchris Lake (*i.e.*, the groundwater flow area that intersects with Sangchris Lake).

(b) TSS data were obtained from USGS monitoring station USGS-05575570, located at the north end of Sangchris Lake, 3.4 miles north of the AP (USGS *et al*., 2022). The available TSS data include 160 samples with a date range of 1979 to 1997. The TSS ranges from 2 to 359 mg/L, with an average of 19 mg/L.

Table 3.4 Sediment Properties Used in Modeling

Parameter	Unit	Value	Notes/Source
Sediment			
Depth of Upper Benthic Layer	m	0.03	Default (US EPA, 2014a)
Depth of Water Body	m	4.63	Sum of depth of water column (4.6 m, depth of Sangchris Lake) (Larimore and Tranquilli, 1981) and depth of upper benthic layer (0.03 m) (US EPA, 2014a)
Bed Sediment Particle Concentration	g/cm^3	1	Default (US EPA, 2014a)
Bed Sediment Porosity	-	0.6	Default (US EPA, 2014a)
TSS Mass Per Unit Area	kg/m^2	0.0874	Depth of water column × TSS × conversion factors (10^{-6} kg/mg and 1,000 L/m^3)
Sediment Mass Per Unit Area	kg/m^2	30	Depth of upper benthic layer × bed sediment particulate concentration × conversion factors (0.001 kg/g, 10^6 cm^3/m^3)
Sediment to Water Partition Coefficients	mg/L	Constituent-specific	Values based on US EPA (2014a)

Notes:
TSS = Total Suspended Solids; US EPA = United States Environmental Protection Agency.

Table 3.5 Surface Water and Sediment Modeling Results

COI	Groundwater Concentration (mg/L or pCi/L)	Mass Discharge Rate (mg/yr or pCi/yr)	Total Water Column Concentration (mg/L or pCi/L)	Concentration Sorbed to Bottom Sediments (mg/kg or pCi/kg)
Total Metals				
Arsenic	0.18	4.2E+05	1.1E-05	2.4E-03
Barium	2.7	6.4E+06	1.7E-04	4.5E-02
Beryllium	0.010	2.5E+04	6.6E-07	3.2E-04
Boron	11	2.6E+07	7.0E-04	3.8E-03
Cadmium	0.0017	4.1E+03	1.1E-07	8.6E-05
Chromium	0.35	8.5E+05	2.2E-05	5.3E-01
Cobalt	0.14	3.4E+05	8.9E-06	5.1E-03
Lead	0.25	6.2E+05	1.6E-05	6.1E-02
Lithium	0.18	4.3E+05	1.1E-05	(a)
Thallium	0.0025	6.1E+03	1.6E-07	2.6E-06
Radionuclides				
Radium-226+228	9	2.2E+07	5.9E-04	3.8E+00

Notes:
COI = Constituent of Concern; K_d = Equilibrium Partitioning Coefficient; pCi/L = PicoCuries Per Liter; pCi/kg = PicoCuries Per Kilogram; pCi/yr = PicoCuries Per Year.
(a) Lithium does not readily sorb to soil or sediment particles; a K_d value of 0 was used for the modeling, therefore the sediment concentration was zero.

3.4 Human Health Risk Evaluation

The section below presents the results of the human health risk evaluation for recreators (boaters and anglers) in Sangchris Lake adjacent to the Site. Risks were assessed using the maximum measured or modeled COIs in surface water.

3.4.1 Recreators Exposed to Surface Water

Screening Exposures: Recreators could be exposed to surface water *via* incidental ingestion and dermal contact while boating. In addition, anglers could consume fish caught in Sangchris Lake. The maximum measured or modeled COI concentrations in surface water were used as conservative upper-end estimates of the COI concentrations to which a recreator might be exposed directly (incidental ingestion of COIs in surface water while boating) and indirectly (consumption of locally caught fish exposed to COIs in surface water).

Screening Benchmarks: Illinois surface water criteria (IEPA, 2019), known as human threshold criteria (HTC), are based on incidental exposure through contact or ingestion of small volumes of water while swimming or during other recreational activities, as well as the consumption of fish. The HTC values were calculated from the following equation (IEPA, 2019):

$$\text{HTC} = \frac{\text{ADI}}{\text{W} + (\text{F} \times \text{BCF})}$$

where:

HTC	=	Human health protection criterion in milligrams per liter (mg/L)
ADI	=	Acceptable daily intake (mg/day)
W	=	Water consumption rate (L/day)
F	=	Fish consumption rate (kg/day)
BCF	=	Bioconcentration factor (L/kg-tissue)

Illinois defines the acceptable daily intake (ADI) as the "maximum amount of a substance which, if ingested daily for a lifetime, results in no adverse effects to humans" (IEPA, 2019). US EPA defines its chronic reference dose (RfD) as an "estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure for a chronic duration (up to a lifetime) to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime" (US EPA, 2011a). Illinois lists methods to derive an ADI from the primary literature (IEPA, 2019). In accordance with Illinois guidance, Gradient derived an ADI by multiplying the MCL by the default water ingestion rate of 2 L/day (IEPA, 2019). In the absence of an MCL, Gradient applied the RfD used by US EPA to derive its Regional Screening Levels (RSLs) (US EPA, 2021b) as a conservative estimate of the ADI. The RfDs are given in mg/kg-day, while the ADIs are given in mg/day; thus, Gradient multiplied the RfD by a standard body weight of 70 kg to obtain the ADI in mg/day. The calculation of the HTC values is shown in Appendix B, Table B.1.

Gradient used bioconcentration factors (BCFs) from a hierarchy of sources. The primary BCFs were those that US EPA used to calculate the National Recommended Water Quality Criteria (NRWQC) for human health (US EPA, 2002). Other sources included BCFs used in the US EPA coal combustion ash risk assessment (US EPA, 2014a) and BCFs reported by Oak Ridge National Laboratory's Risk Assessment

Information System (ORNL RAIS) (ORNL, 2020).[4] Lithium did not have a BCF value available from any authoritative source; therefore, the water quality criterion for lithium was calculated assuming a BCF of 1. This is a conservative assumption, as lithium does not readily bioaccumulate in the aquatic environment (ECHA, 2020).

Illinois recommends a fish consumption rate of 0.020 kg/day (20 g/day) for an adult weighing 70 kg (IEPA, 2019). Illinois recommends a water consumption rate of 0.01 L/day for "incidental exposure through contact or ingestion of small volumes of water while swimming or during other recreational activities" (IEPA, 2019). Appendix B, Table B.1 presents the calculated HTC for fish consumption and water ingestion, and for fish consumption only.

The HTC for fish consumption for radium-226+228 was calculated as follows:

$$\mathrm{HTC} = \frac{\mathrm{TCR}}{(\mathrm{SF} \times \mathrm{BAF} \times \mathrm{F})}$$

where:

HTC = Human health protection criterion in picoCuries per liter (pCi/L)
TCR = Target cancer risk (1×10^{-5})
SF = Food ingestion slope factor (risk/pCi)
BAF = Bioaccumulation factor (L/kg-tissue)
F = Fish consumption rate (kg/day)

The food ingestion slope factor (lifetime excess total cancer risk per unit exposure, in risk/pCi) used to calculate the HTC was the highest value of those for radium-226 (Ra-226), radium-228 (Ra-228), and "Ra-228+D" (US EPA, 2001). According to US EPA (2001), "+D" indicates that "the risks from associated short-lived radioactive decay products (*i.e.,* those decay products with radioactive half-lives less than or equal to 6 months) are also included."

Screening Risk Evaluation: The maximum modeled and measured COI concentrations in surface water were compared to the calculated Illinois HTC values (Table 3.6). All surface water concentrations were below their respective benchmarks. The HTC values are protective of recreational exposure *via* water and/or fish ingestion and do not account for dermal exposures to COIs in surface water while boating. However, given that the measured and modeled COI surface water concentrations are orders of magnitude below an HTC protective of water and/or fish ingestion, dermal exposures to COIs are not expected to be a risk concern. Moreover, the dermal uptake of metals is considered to be minimal and only a small proportion of ingestion exposures. Thus, none of the COIs evaluated would be expected to pose an unacceptable risk to recreators exposed to surface water while boating or anglers consuming fish caught in Sangchris Lake.

[4] Although recommended by US EPA (2015c), US EPA EpiSuite 4.1 (US EPA, 2019) was not used as a source of BCFs because inorganic compounds are outside the estimation domain of the program.

Table 3.6 Risk Evaluation for Recreators Exposed to Surface Water

COI	Maximum Surface Water Concentration		HTC for Water and Fish	HTC for Water Only	HTC for Fish Only	COPC	
	Modeled	Measured[a]				Based on Modeled Concentrations	Based on Measured Concentrations
Total Metals (mg/L)							
Arsenic	1.1E-05	0.0034	0.022	2.0	0.023	No	No
Barium	1.7E-04	0.084	1.5	400	1.5	No	No
Beryllium	6.6E-07	ND	0.021	0.80	0.021	No	NA
Boron	7.0E-04	0.065	467	1,400	700	No	No
Chromium	2.2E-05	0.0024	0.61	20	0.63	No	No
Cobalt	8.9E-06	ND	0.0035	2.1	0.0035	No	NA
Lead	1.6E-05	0.0011	0.015	0.015	0.015	No	No
Lithium	1.1E-05	ND	4.7	14	7.0	No	NA
Thallium	1.6E-07	ND	0.0017	0.40	0.0017	No	NA
Radionuclides (pCi/L)							
Radium-226+228	5.9E-04	1.3	1,000	1,000	87,413	No	No

Notes:

COI = Constituent of Interest; COPC = Constituent of Potential Concern; HTC = Human Threshold Criteria; NA = Not Applicable; ND = Not Detected; pCi/L = PicoCuries Per Liter.

(a) Measured concentrations are listed only for the constituents identified as COIs. Measured surface water concentrations may be different from modeled concentrations because measured data include the effects of background and other industrial sources. Modeled concentrations only represent the potential effect on surface water quality resulting from the measured groundwater concentrations.

3.4.2 Recreators Exposed to Sediment

Recreational exposure to sediment may occur during boating activity in Sangchris Lake; exposure to sediment may occur through incidental ingestion and dermal contact.

Screening Exposures: COIs in impacted groundwater flowing to the river can sorb to sediments. In the absence of sediment data, sediment concentrations were modeled using maximum detected groundwater concentrations.

Screening Benchmarks: There are no established recreator RSLs that are protective of recreational exposures to sediment (US EPA, 2021c). Therefore, benchmarks that are protective of recreational exposures to sediment *via* incidental ingestion and dermal contact were calculated using US EPA's RSL guidance (US EPA, 2021c). These benchmarks were calculated using the recommended assumptions (*i.e.*, oral bioavailability, body weights, and averaging time) and toxicity reference values (*i.e.*, RfD and cancer slope factor [CSF]), with the following changes: recreators were assumed to be exposed to sediment while recreating 60 days per year (or 2 weekend days per week for 30 weeks per year, from April to October). The exposure duration was assumed for a child 6 years of age and an adult 20 years of age, per US EPA guidance (US EPA, 2014b). The daily recommended residential soil ingestion rates of 200 mg/day for a child and 100 mg/day for an adult are based on an all-day exposure to residential soils (US EPA, 2014b, 2011b). Since recreational exposures to sediment are assumed to occur for less than 4 hours per day, one-third of the daily residential soil ingestion (67 mg/day for a child and 33 mg/day for an adult) was used as a conservative assumption. For dermal exposures, recreators were assumed to be exposed to sediment on their lower legs and feet (1,026 cm^2 for the child and 3,026 cm^2 for the adult, based on the age-weighted surface areas reported in US EPA [2011b]). While other body parts may be exposed to sediment, the contact time is likely to be very short, as the sediment would wash off in the surface water. Gradient used US EPA's recommended adherence factor of 0.2 mg/cm^2 based on child exposure to wet soil (US EPA, 2004, 2014b), which was used in the US EPA RSL User's Guide for a child recreator exposed to soil or sediment (US EPA, 2021c). The sediment screening benchmarks were calculated based on a target hazard quotient of 1, or a target cancer risk of 1×10^{-5}. Appendix B, Table B.2 presents the calculation of screening benchmarks protective of recreational exposures to sediment. A recreator sediment screening benchmark for radium-226+228 was based on soil Preliminary Remediation Goals (PRGs) calculated for radium-226 and radium-228 using US EPA's PRG calculator (US EPA, 2020). The lower of the two values was used as the recreator sediment screening benchmark for radium-226+228 (Appendix B).

Screening Risk Evaluation: The modeled sediment concentrations were well below the recreational sediment screening benchmarks (Table 3.7). Therefore, exposure to sediment is not expected to pose an unacceptable risk to recreators in Sangchris Lake.

Table 3.7 Risk Evaluation for Recreators Exposed to Sediment

COI	Modeled Sediment Concentration (mg/kg)	Recreator Sediment Screening Benchmark (mg/kg)	COPC
Total Metals (mg/kg)			
Arsenic	2.4E-03	6.8E+01	No
Barium	4.5E-02	2.7E+05	No
Beryllium	3.2E-04	2.7E+03	No
Boron	3.8E-03	2.7E+05	No
Chromium	5.3E-01	2.1E+06	No
Cobalt	5.1E-03	4.1E+02	No
Lead	6.1E-02	4.0E+02	No
Lithium	(a)	2.7E+03	NA
Thallium	2.6E-06	1.4E+01	No
Radionuclides (pCi/kg)			
Radium-226+228	3.8E+00	7.9E+03	No

Notes:
COI = Constituent of Interest; COPC = Constituent of Potential Concern; K_d = Equilibrium Partitioning Coefficient; NA = Not Applicable; pCi/kg = PicoCuries Per Kilogram.
(a) Lithium does not readily sorb to soil or sediment particles; a K_d value of 0 was used for the modeling.

3.5 Ecological Risk Evaluation

Based on the ecological CEM (Figure 3.4), ecological receptors could be exposed to surface water and dietary items (*i.e.*, prey and plants) potentially impacted by identified COIs (*i.e.*, boron, cadmium, chromium, cobalt, lead, and radium-226+228).

3.5.1 Ecological Receptors Exposed to Surface Water

Screening Exposures: The ecological evaluation considered aquatic communities in Sangchris Lake potentially impacted by identified ecological COIs. Measured and modeled surface water concentrations were compared to risk-based ecological screening benchmarks.

Screening Benchmarks: Surface water screening benchmarks protective of aquatic life were obtained from the following hierarchy of sources:

- IEPA SWQC (IEPA, 2019), regulatory standards that are intended to protect aquatic life exposed to surface water on a long-term basis (*i.e.*, chronic exposure). For cadmium, the surface water benchmark is hardness-dependent and calculated using a default hardness of 100 mg/L (US EPA, 2022);[5]
- US EPA Region IV (2018) surface water ESVs for hazardous waste sites; and
- US DOE benchmarks from the guidance document, "A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota" (US DOE, 2019).

Risk Evaluation: The maximum measured and modeled COI concentrations in surface water were compared to the benchmarks protective of aquatic life (Table 3.8). The measured and modeled surface water concentrations for the COIs were below their respective benchmarks. Thus, none of the COIs evaluated are expected to pose an unacceptable risk to aquatic life in Sangchris Lake.

Table 3.8 Risk Evaluation for Ecological Receptors Exposed to Surface Water

COI	Maximum Surface Water Concentration		Ecological Freshwater Benchmark	Basis	COPC	
	Modeled	Measured			Based on Modeled Concentrations	Based on Measured Concentrations
Total Metals (mg/L)						
Boron	7.0E-04	6.5E-02	7.6	IEPA SWQC	No	No
Cadmium	1.1E-07	ND	0.0011	IEPA SWQC	No	NA
Chromium	2.2E-05	2.4E-03[a]	0.18[b]	IEPA SWQC	No	No
Cobalt	8.9E-06	ND	0.019	US EPA R4 ESV	No	NA
Lead	1.6E-05	1.1E-03	0.020	IEPA SWQC	No	No
Radionuclides (pCi/L)						
Radium-226+228	5.9E-04	1.3E+00	3.0	US DOE	No	No

Notes:
COI = Constituent of Interest; COPC = Constituent of Potential Concern; ESV = Ecological Screening Value; IEPA = Illinois Environmental Protection Agency; NA = Not Applicable; ND = Not Detected; pCi/L = PicoCuries Per Liter; SWQC = Surface Water Quality Criteria; US DOE = United States Department of Energy; US EPA R4 = United States Environmental Protection Agency Region IV.
(a) Chromium was not detected in the total metals analysis, but had one detect in the dissolved metals analysis. Therefore, the chromium concentration shown in this table is for dissolved metals.
(b) IEPA SWQC for dissolved chromium.

[5] Conservatisms associated with using a default hardness value are discussed in Section 3.6.

3.5.2 Ecological Receptors Exposed to Sediment

Screening Exposures: COIs in impacted groundwater flowing to Sangchris Lake can sorb to sediments *via* chemical partitioning. In the absence of sediment data, sediment concentrations were modeled using maximum detected groundwater concentrations. Therefore, the modeled COI sediment concentrations reflect the potential maximum Site-related sediment concentration from groundwater discharge.

Screening Benchmarks: Sediment screening benchmarks were obtained from US EPA Region IV (2018). The majority of the sediment ESVs are based on threshold effect concentrations from MacDonald *et al.* (2000), which provides consensus values that identify concentrations below which harmful effects on sediment-dwelling organisms are unlikely to be observed. In the absence of an ESV for radium-226+228, a sediment screening value of 90,000 pCi/kg was used, based on the biota concentration guide (BCG) for radium-228 (US DOE, 2019).[6] The benchmarks used in this evaluation are listed in Table 3.9.

Screening Risk Results: The maximum modeled COI sediment concentrations were below their respective sediment screening benchmarks (Table 3.9). The modeled sediment concentrations attributed to potential contributions from Site groundwater for all COIs were less than or equal to 1% of the sediment screening benchmark. Therefore, the modeled sediment concentrations attributed to potential contributions from Site groundwater are not expected to significantly contribute to ecological exposures in Sangchris Lake adjacent to the Site.

Table 3.9 Risk Evaluation for Ecological Receptors Exposed to Sediment

COI	Modeled Sediment Concentration	ESV[a]	COPC	% of Benchmark
Total Metals (mg/kg)				
Boron	3.8E-03	38[b]	No	0.01%
Cadmium	8.6E-05	0.99	No	0.009%
Chromium	5.3E-01	43	No	1.2%
Cobalt	5.1E-03	50	No	0.01%
Lead	6.1E-02	35.8	No	0.2%
Radionuclides (pCi/kg)				
Radium-226+228	3.8E+00	90,000[c]	No	0.004%

Notes:
COI = Constituent of Interest; COPC = Constituent of Potential Concern; ESV = Ecological Screening Value; NOEC = No Observed Effect Concentration; pCi/g = PicoCuries Per Gram; pCi/kg = PicoCuries Per Kilogram; US DOE = United States Department of Energy; US EPA = United States Environmental Protection Agency.
(a) ESV is from US EPA Region IV (2018).
(b) NOEC of 38 mg/kg was used as a conservative benchmark for boron in the absence of an ESV (ECHA, 2019).
(c) ESV is from US DOE (2019); value converted from 90 pCi/g to 90,000 pCi/kg.

3.5.3 Ecological Receptors Exposed to Bioaccumulative Constituents of Interest

Screening Exposures: COIs with bioaccumulative properties can impact higher-trophic-level wildlife exposed to these COIs *via* direct exposures (surface water and sediment exposure) and secondary exposures through the consumption of dietary items (*e.g.*, plants, invertebrates, small mammals, and fish).

[6] US DOE (2019) reported the BCG for sediment as 90 pCi/g for Ra-228 and 100 pCi/g for Ra-226; the lower of the two values was used for Ra-226+228, and converted to pCi/kg.

Screening Benchmark: US EPA Region IV (2018) and IEPA SWQC (IEPA, 2019) guidance documents were used to identify constituents with potential bioaccumulative effects.

Risk Evaluation: The ecological COIs (*i.e.*, boron, cadmium, chromium, cobalt, lead, and radium-226+228) were not identified as having potential bioaccumulative effects. Therefore, these COIs are not considered to pose an ecological risk *via* bioaccumulation.

3.6 Uncertainties and Conservatisms

A number of uncertainties and their potential impact on the risk evaluation are discussed below. Wherever possible, conservative assumptions were used in an effort to minimize uncertainties and overestimate rather than underestimate risks.

Exposure Estimates:

- The risk evaluation included the Illinois Part 845.600 constituents detected in groundwater samples (above GWPS) collected from wells associated with the AP. However, it is possible that not all of the detected constituents are related specifically to the AP.
- The human health and ecological risk characterizations were based on the maximum measured or modeled COI concentrations, rather than on averages. Thus, the variability in exposure concentrations was not considered. Assuming continuous exposure to the maximum concentration overestimates human and ecological exposures, given that receptors are mobile and concentrations change over time. For example, US EPA guidance states that risks should be estimated using average exposure concentrations as represented by the 95% upper confidence limit on the mean (US EPA, 1992). Given that exposure estimates based on the maximum concentrations did not exceed risk benchmarks, Gradient has greater confidence that there is no risk concern.
- Only constituents detected in groundwater were used to identify COIs and model COI concentrations in surface water and sediment. For the constituents that were not detected in the AP groundwater, the detection limits were below the Illinois Part 845.600 GWPS and thus do not require further evaluation.
- COI concentrations in surface water were modeled using the maximum detected total COI concentrations in groundwater. Modeling surface water concentrations using total metal concentrations may overestimate surface water concentrations because dissolved concentrations, which are lower than total concentrations, represent the mobile fractions of constituents that could likely flow into and mix with surface water.
- The COIs identified in this evaluation also occur naturally in the environment. Contributions to exposure from natural or other non-AP-related sources were not considered in the evaluation of modeled concentrations; only exposure contributions potentially attributable to Site groundwater mixing with surface water were evaluated. While not quantified, exposures from potential AP-related groundwater contributions are likely to represent only a small fraction of the overall human and ecological exposure to COIs that also have natural or non-AP-related sources.
- Screening benchmarks for human health were developed using exposure inputs based on US EPA's recommended values for reasonable maximum exposure (RME) assessments (US EPA, 2014b). RME is defined as "the highest exposure that is reasonably expected to occur at a site but that is still within the range of possible exposures" (US EPA, 2004). US EPA states the "intent of the RME is to estimate a conservative exposure case (*i.e.*, well above the average case) that is still within the range of possible exposures" (US EPA, 1989). US EPA also notes this high-end exposure "is the highest dose estimated to be experienced by some individuals, commonly stated

as approximately equal to the 90th percentile exposure category for individuals" (US EPA, 2015b). Thus, most individuals will have lower exposures than those presented in this risk assessment.

Toxicity Benchmarks:

- Screening-level ecological benchmarks were compiled from IEPA and US EPA guidance and designed to be protective of the majority of Site conditions, leaving the option for Site-specific refinement. In some cases, these benchmarks may not be representative of the Site-specific conditions or receptors found at the Site, or may not accurately reflect concentration-response relationships encountered at the Site. For example, the ecological benchmark for cadmium is hardness-dependent. However, hardness data are not available for Sangchris Lake; therefore, Gradient relied on US EPA's default hardness of 100 mg/L. Use of a higher hardness value would increase the cadmium SWQC because benchmarks become less stringent with higher levels of hardness. Regardless of the hardness, the maximum modeled cadmium concentration is orders of magnitude below the SWQC.
- In addition, for the ecological evaluation, Gradient conservatively assumed all constituents to be 100% bioavailable. Modeled COI concentrations in surface water are considered total COI concentrations. In addition, the measured surface water data used in this report represent total concentrations. US EPA recommends using dissolved metals as a measure of exposure to ecological receptors because it represents the bioavailable fraction of metal in water (US EPA, 1993). Therefore, the modeled surface water COI concentrations may be an overestimation of exposure concentrations to ecological receptors.
- In general, it is important to appreciate that the human health toxicity factors used in this risk evaluation are developed to account for uncertainties, such that safe exposure levels used as benchmarks are often many times lower (even orders of magnitude lower) than the levels that cause effects which have been observed in human or animal studies. For example, toxicity factors incorporate a 10-fold safety factor to protect sensitive subpopulations. This means that a risk exceedance does not necessarily equate to actual harm.

4 Summary and Conclusions

A screening-level risk evaluation was performed for potential Site-related constituents in groundwater at the KPP in Kincaid, Illinois. The CSM developed for the Site indicates that groundwater beneath the AP flows into Sangchris Lake adjacent to the Site and may potentially impact surface water and sediment.

CEMs were developed for human and ecological receptors. The complete exposure pathways for humans include recreators (boaters) in Sangchris Lake who are exposed to surface water and sediment, and anglers who consume locally caught fish. Based on the local hydrogeology, residential exposure to groundwater used for drinking water or irrigation is not a complete pathway and was not evaluated. The complete exposure pathways for ecological receptors include aquatic life (including aquatic and marsh plants, amphibians, reptiles, and fish) exposed to surface water; benthic invertebrates exposed to sediment; and avian and mammalian wildlife exposed to bioaccumulative COIs in surface water, sediment, and dietary items.

Groundwater data collected from 2015 to 2021 were used to estimate exposures. Surface water data collected from Sangchris Lake in 2021 were also evaluated. For groundwater constituents retained as COIs, surface water and sediment concentrations were modeled using the maximum detected groundwater concentration. Surface water and sediment exposure estimates were screened against benchmarks protective of human health and ecological receptors for this risk evaluation.

US EPA has established acceptable risk metrics. Risks above these US EPA-defined metrics are termed potentially "unacceptable risks." Based on the evaluation presented in this report, no unacceptable risks to human or ecological receptors resulting from CCR exposures associated with the AP were identified. This means that the risks from the Site are likely indistinguishable from normal background risks. Specific risk assessment results include the following:

- For recreators exposed to surface water, all COIs were below the conservative risk-based screening benchmarks. Therefore, none of the COIs evaluated in surface water are expected to pose an unacceptable risk to recreators in Sangchris Lake adjacent to the Site.
- For recreators exposed to sediment *via* incidental ingestion and dermal contact, the modeled sediment concentrations were below health-protective sediment benchmarks. Therefore, the modeled sediment concentrations are not expected to pose an unacceptable risk to recreators exposed to sediment in Sangchris Lake adjacent to the Site.
- For anglers consuming locally caught fish, the modeled concentrations of all COIs in surface water (as well as the measured data) were below conservative benchmarks protective of fish consumption. Therefore, none of the COIs evaluated are expected to pose an unacceptable risk to recreators consuming fish caught in Sangchris Lake.
- Ecological receptors exposed to surface water include aquatic and marsh plants, amphibians, reptiles, and fish. The risk evaluation showed that none of the modeled or measured COIs in surface water exceeded protective screening benchmarks. Ecological receptors exposed to sediment include benthic invertebrates. The modeled sediment COIs did not exceed the conservative screening benchmarks; therefore, none of the COIs evaluated in sediment are expected to pose an unacceptable risk to ecological receptors.

- Ecological receptors were also evaluated for exposure to bioaccumulative COIs. This evaluation considered higher-trophic-level wildlife with direct exposure to surface water and sediment and secondary exposure through the consumption of dietary items (*e.g.*, plants, invertebrates, small mammals, and fish). None of the ecological COIs were identified as having potential bioaccumulative effects. Overall, this evaluation demonstrated that none of the COIs evaluated are expected to pose an unacceptable risk to ecological receptors.

It should be noted that this evaluation incorporates a number of conservative assumptions that tend to overestimate exposure and risk. The risk evaluation was based on the maximum detected COI concentration for each constituent; however, US EPA guidance states that risks should be based on a representative average concentration such as the 95% upper confidence limit on the mean. Thus, using the maximum concentration tends to overestimate exposure. Although the COIs identified in this evaluation also occur naturally in the environment, the contributions to exposure from natural background sources and nearby industry were not considered; thus, CCR-related exposures were likely overestimated. In addition, exposure estimates assumed 100% metal bioavailability, which likely results in overestimates of exposure and risks. Further, exposure estimates were based on inputs to evaluate the "reasonable maximum exposure"; thus, most individuals will have lower exposures than those estimated in this risk assessment.

Finally, it should be noted that because current conditions do not present a risk to human health or the environment, there will also be no unacceptable risk to human health or the environment for future conditions when the AP is closed. For all future closure scenarios, potential releases of CCR-related constituents will decline over time and, consequently, potential exposures to CCR-related constituents in the environment will also decline.

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Appendix A

Surface Water and Sediment Modeling

Gradient modeled concentrations in Sangchris Lake surface water and sediment based on available groundwater data. First, Gradient estimated the flow rate of constituents of interest (COIs) that may flow into Sangchris Lake *via* groundwater. Then, Gradient adapted United States Environmental Protection Agency's (US EPA) indirect exposure assessment methodology (US EPA, 1998) in order to model surface water and sediment water concentrations in Sangchris Lake.

Model Overview

Groundwater flow into Sangchris Lake is represented by a one-dimensional steady-state model. In this model, the groundwater plume migrates horizontally in the uppermost aquifer (UA) and the upper semi-confining unit (USCU) (*i.e.*, potential migration pathway [PMP]) prior to discharging into Sangchris Lake. The groundwater flow entering the lake is the flow going through a cross-sectional area with a length equal to the length of the lake adjacent to the Ash Pond (AP) with potential coal combustion residuals (CCR)-related impacts and a height equal to the maximum saturated thicknesses of the UA and the PMP/USCU. It was assumed that groundwater flowing through the shallow water bearing zones (*i.e.*, the UA and the USCU/PMP) may flow into Sangchris Lake.

Groundwater flow entering Sangchris Lake mixes with the surface water in the lake. The COIs entering the lake *via* groundwater can dissolve into the water column, sorb to suspended sediments, or sorb to benthic sediments. Using US EPA's indirect exposure assessment methodology (US EPA, 1998), the model evaluates the surface water and sediment concentrations at a location downstream of the groundwater discharge, assuming a well-mixed water column.

Groundwater Discharge Rate

The groundwater discharge rate was evaluated using conservative assumptions. Gradient conservatively assumed that the groundwater concentrations were uniformly equal to the maximum detected concentration for each individual COI. Gradient ignored adsorption by subsurface soil and assumed that groundwater flowing through the shallow aquifers discharges into the lake.

For each groundwater unit, the groundwater flow rate into Sangchris Lake was derived using Darcy's Law:

$$Q = K \times i \times A$$

where:

Q = Groundwater flow rate (m^3/s)
K = Hydraulic conductivity (m/s)
i = Hydraulic gradient (m/m)
A = Cross-sectional area (m^2)

For each COI, the mass discharge rate into the lake was then calculated by:

$$m_c = C_c \times Q \times CF$$

where:

m_c = Mass discharge rate of the COI (mg/year)
C_c = Maximum groundwater concentration of the COI (mg/L)
Q = Groundwater flow rate (m^3/s)
CF = Conversion factors: 1,000 L/m^3; 31,557,600 s/year

The values of the aquifer parameters used for these calculations are provided in Table A.1. The calculated mass discharge rates were then used as inputs for the surface water and sediment partitioning model.

The cross-sectional area for the shallow water bearing units (*i.e.*, the UA and the USCU/PMP) was 13,942 m^2. The length of the discharge zone was estimated to be approximately 2,287 m. The height of the discharge zone was assumed to be the sum of the thicknesses of the USCU/PMP and the UA (*i.e.*, approximately 6 m) (Ramboll, 2021). The length of the groundwater discharge zone was estimated using Google Earth Pro (Google LLC, 2022).

The hydraulic gradient was 0.012 m/m, based on the average of the horizontal hydraulic gradients determined for the UA (0.015, 0.008, and 0.015 m/m) and the USCU/PMP (*i.e.*, 0.01 m/m) (Ramboll, 2021).

The hydraulic conductivity was 0.000046 cm/s, based on the average of the geometric mean horizontal hydraulic conductivity measured for the USCU/PMP (0.0000504 cm/s) and the UA (0.0000414 cm/s) (Ramboll, 2021).

Surface Water and Sediment Concentration

Groundwater that flows into Sangchris Lake will be diluted in the surface water flow. Constituents transported by groundwater into the surface water migrate into the water column and the bed sediments. The surface water model Gradient used to estimate the surface water and sediment concentrations is a steady-state model described in US EPA's indirect exposure assessment methodology (US EPA, 1998), and also used in US EPA's "Human and Ecological Risk Assessment of Coal Combustion Residuals" (US EPA, 2014). This model describes the partitioning of constituents between surface water, suspended sediments, and benthic sediments based on equilibrium partition coefficients. It estimates the concentrations of constituents in surface water, suspended sediments, and benthic sediments at steady-state equilibrium at a theoretical location downstream of the discharge point after complete mixing of the water column. In the analysis, Gradient used the partitioning coefficients given in Table J-1 of the US EPA CCR Risk Assessment for all COIs (US EPA, 2014). The partition coefficients are presented in Table A.2.

To be conservative, Gradient assumed that the constituents were not affected by dissipation or degradation once they entered the water body. The total water body concentration of the COI was calculated as (US EPA, 1998):

$$C_{wtot} = \frac{m_c}{V_f \times f_{water}}$$

where:

C_{wtot}	=	Total water body concentration of the constituent (mg/L)
m_c	=	Mass discharge rate of the COI (mg/year)
V_f	=	Water body annual flow (L/year)
f_{water}	=	Fraction of COI in the water column (unitless)

A mean flow rate of about 43 cubic feet per second (cfs) was determined for Sangchris Lake in 1975, almost ten years after the lake was formed by damming Clear Creek (US EPA Region V, 1975; Larimore and Tranquilli, 1981). The surface water parameters are presented in Table A.3.

The fraction of COIs in the water column was calculated for each COI using the sediment/water and suspended solids/water partition coefficients (US EPA, 2014, Table J-1). The fraction of COIs in the water column is defined as (US EPA, 2014):

$$f_{water} = \frac{(1 + [K_{dsw} \times TSS \times 0.000001]) \times \frac{d_w}{d_z}}{\left([1 + (K_{dsw} \times TSS \times 0.000001)] \times \frac{d_w}{d_z}\right) + ([bsp + K_{dbs} \times bsc] \times \frac{d_b}{d_z})}$$

where:

K_{dsw}	=	Suspended sediment-water partition coefficient (mL/g)
K_{dbs}	=	Sediment-water partition coefficient (mL/g)
TSS	=	Total suspended solids in the surface water body (mg/L), set equal to a representative average concentration of 19 mg/L for Sangchris Lake (USGS *et al.*, 2022)
0.000001	=	Units conversion factor
d_w	=	Depth of the water column (m). The depth of the water column was estimated as 4.6 m (Larimore and Tranquilli, 1981)
d_b	=	Depth of the upper benthic layer (m), set equal to 0.03 m (US EPA, 2014)
$d_z = d_w + d_b$	=	Depth of the water body (m) = 4.63 m
bsp	=	Bed sediment porosity (unitless), set equal to 0.6 (US EPA, 2014)
bsc	=	Bed sediment particle concentration (g/cm^3), set equal to 1.0 g/cm^3 (US EPA, 2014)

The fraction of COIs dissolved in the water column (f_d) is calculated as (US EPA, 2014):

$$f_d = \frac{1}{1 + K_{dsw} \times TSS \times 0.000001}$$

The values of the fraction of COIs in the water column and other calculated parameters are presented in Table A.4.

The total water column concentration (C_{wcTot}) of the COIs, comprising both the dissolved and suspended sediment phases, is then calculated as (US EPA, 2014):

$$C_{wcTot} = C_{wtot} \times f_{water} \times \frac{d_z}{d_w}$$

Finally, the dissolved water column concentration (C_{dw}) for the COIs is calculated as (US EPA, 2014):

$$C_{dw} = f_d \times C_{wcTot}$$

The dissolved water column concentration was then used to calculate the concentration of COIs sorbed to suspended solids in the water column (US EPA, 1998):

$$C_{sw} = C_{dw} \times K_{dsw}$$

where:

C_{sw}	=	Concentration sorbed to suspended solids (mg/kg)
C_{dw}	=	Concentration dissolved in the water column (mg/L)
K_{dsw}	=	Suspended solids/water partition coefficient (mL/g)

In the same way, using the total water body concentration and the fraction of COIs in the benthic sediments, the model derives the total concentration in benthic sediments (US EPA, 2014, Table J-1-12):

$$C_{bstot} = f_{benth} \times C_{wtot} \times \frac{d_z}{d_b}$$

where:

C_{bstot}	=	Total concentration in bed sediment (mg/L or g/m^3)
C_{wtot}	=	Total water body concentration of the constituent (mg/L)
f_{benth}	=	Fraction of contaminant in benthic sediments (unitless)
d_b	=	Depth of the upper benthic layer (m)
$d_z = d_w + d_b$	=	Depth of the water body (m)

This value can be used to calculate dry weight sediment concentration as follows:

$$C_{sed-dw} = \frac{C_{bstot}}{bsc}$$

where:

C_{sed-dw}	=	Dry weight sediment concentration (mg/kg)
C_{bstot}	=	Total sediment concentration (mg/L)
bsc	=	Bed sediment bulk density (default value of 1 g/cm^3 from US EPA [2014])

The total sediment concentration is composed of the concentration dissolved in the bed sediment pore water (equal to the concentration dissolved in the water column) and the concentration sorbed to benthic sediments (US EPA, 1998).

The concentration sorbed to benthic sediments was calculated from (US EPA, 1998):

$$C_{sb} = C_{dbs} \times K_{dbs}$$

where:

C_{sb}	=	Concentration sorbed to bottom sediments (mg/kg)
C_{dbs}	=	Concentration dissolved in the sediment pore water (mg/L)
K_{dbs}	=	Sediments/water partition coefficient (mL/kg)

For each COI, the modeled total water column concentration, the modeled dry weight sediment concentration, and the modeled concentration sorbed to sediment are presented in Table A.5.

Table A.1 Parameters Used to Estimate Groundwater Discharge to Surface Water

Groundwater Unit	Parameter	Name	Value	Unit
UA and USCU/PMP	A	Cross-Sectional Area[a]	13,942	m^2
UA and PMP	i	Hydraulic Gradient[b]	0.012	m/m
UA and PMP	K	Hydraulic Conductivity[c]	0.000046	cm/s

Notes:
Source: Hydraulic gradient and hydraulic conductivity values from Ramboll (2021).
Cross-sectional area was estimated from Ramboll (2021).
PMP = Potential Migration Pathway; UA = Uppermost Aquifer; USCU = Upper Semi-Confined Unit.
(a) The sum of the thicknesses of the USCU/PMP and the UA (*i.e.*, approximately 6 m) multiplied by the length of the ash pond intersecting Sangchris lake (*i.e.*, about 2,287 m).
(b) The average of the horizontal hydraulic gradients determined for the UA (0.015, 0.008, and 0.015 m/m) and the USCU/PMP (*i.e.*, 0.01 m/m).
(c) The average of the geometric mean horizontal hydraulic conductivities measured for the USCU/PMP (0.0000504 cm/s) and the UA (0.0000414 cm/s).

Table A.2 Partition Coefficients

Constituent	Sediment-Water, Mean, K_{dbs}		Suspended Sediment-Water, Mean, K_{dsw}	
	Value (log_{10}) (mL/g)	Value (mL/g)	Value (log_{10}) (mL/g)	Value (mL/g)
Metals				
Arsenic	2.4	2.51E+02	3.9	7.94E+03
Barium	2.5	3.16E+02	4.0	1.00E+04
Beryllium	2.8	6.31E+02	4.2	1.58E+04
Boron	0.8	6.31E+00	3.9	7.94E+03
Cadmium	3.3	2.00E+03	4.9	7.94E+04
Chromium	4.9	7.94E+04	5.1	1.26E+05
Cobalt	3.1	1.26E+03	4.8	6.31E+04
Lead	4.6	3.98E+04	5.7	5.01E+05
Lithium	-	0	-	0
Thallium	1.3	2.00E+01	4.1	1.26E+04
Radionuclides				
Radium-226+228	-	7.40E+03	-	7.40E+03

Notes:
Source: US EPA (2014).
K_d = Equilibrium Partition Coefficient.
Lithium does not readily sorb to soils and sediments. Consequently, sediment concentrations were not modeled for this constituent (K_d was assumed to be 0).

Table A.3 Surface Water Parameters

Parameter	Name	Value	Unit
TSS	Total Suspended Solids	19	mg/L
V_{fx}	Surface Water Flow Rate	3.82×10^{10}	L/yr
d_b	Depth of Upper Benthic Layer (default)	0.03	m
d_w	Depth of Water Column	4.6	m
d_z	Depth of Water Body	4.63	m
bsc	Bed Sediment Bulk Density (default)	1	g/cm^3
bsp	Bed Sediment Porosity (default)	0.6	-
M_{TSS}	TSS Mass per Unit Area[a]	0.0874	kg/m^2
M_S	Sediment Mass per Unit Area[b]	30	kg/m^2

Notes:
Source of default values: US EPA (2014).
(a) Determined by multiplying total suspended solids, TSS by the depth of water column, d_w.
(b) Determined by multiplying depth of upper benthic layer, d_b, with sediment bed particle concentration of 1 g/cc.

Table A.4 Calculated Parameters

COI	Fraction of Constituent in the Water Column f_{water}	Fraction of Constituent in the Benthic Sediments $f_{benthic}$	Fraction of Constituent Dissolved in the Water Column $f_{dissolved}$
Arsenic	0.412	0.588	0.869
Barium	0.339	0.661	0.943
Beryllium	0.210	0.790	0.913
Boron	0.959	0.041	0.955
Cadmium	0.1616	0.8384	0.3985
Chromium	0.0065	0.9935	0.2948
Cobalt	0.211	0.789	0.455
Lead	0.039	0.961	0.095
Lithium	0.996	0.004	
Thallium	0.902	0.098	0.807
Radionuclides			
Radium-226+228	0.023	0.977	0.877

Note:
COI = Constituent of Interest.

Table A.5 Surface Water and Sediment Modeling Results

COI	Groundwater Concentration (mg/L or pCi/L)	Mass Discharge Rate (mg/yr or pCi/yr)	Total Water Column Concentration (mg/L or pCi/L)	Concentration Sorbed to Bottom Sediments (mg/kg or pCi/kg)
Total Metals				
Arsenic	0.18	4.2E+05	1.1E-05	2.4E-03
Barium	2.7	6.4E+06	1.7E-04	4.5E-02
Beryllium	0.010	2.5E+04	6.6E-07	3.2E-04
Boron	11	2.6E+07	7.0E-04	3.8E-03
Cadmium	0.0017	4.1E+03	1.1E-07	8.6E-05
Chromium	0.35	8.5E+05	2.2E-05	5.3E-01
Cobalt	0.14	3.4E+05	8.9E-06	5.1E-03
Lead	0.25	6.2E+05	1.6E-05	6.1E-02
Lithium	0.18	4.3E+05	1.1E-05	(a)
Thallium	0.0025	6.1E+03	1.6E-07	2.6E-06
Radionuclides				
Radium-226+228	9.25	2.2E+07	5.9E-04	3.8E+00

Notes:
COI = Constituent of Concern; K_d = Equilibrium Partition Coefficient; pCi/L = PicoCuries Per Liter; pCi/kg = PicoCuries Per Kilogram.
(a) Lithium does not readily sorb to soil or sediment particles; a K_d value of 0 was used for the modeling.

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Appendix B

Screening Benchmarks

Table B.1 Calculated Water Quality Standards Protective of Incidental Ingestion and Fish Consumption

Human Health COI	BCF[a] (L/kg-tissue)	Basis	MCL (mg/L)	RfD (mg/kg-day)	ADI[b] (mg/day)	Human Threshold Criteria		
						Water & Fish (mg/L)	Water Only (mg/L)	Fish Only (mg/L)
Total Metals								
Arsenic	44	NRWQC (2002)	0.010	0.00030	0.020	0.022	2.0	0.023
Barium	130	US EPA (2014)	2.0	0.20	4.0	1.5	400	1.5
Beryllium	19	NRWQC (2002)	0.0040	0.0020	0.0080	0.021	0.80	0.021
Boron	1	(c)	NC	0.20	14	467	1,400	700
Chromium	16	NRWQC (2002)	0.10	1.5	0.20	0.61	20	0.63
Cobalt	300	ORNL (2020)	NC	0.00030	0.021	0.0035	2.1	0.0035
Lead	46	US EPA (2014)	0.015	NC	0.030	0.015	0.015	0.015
Lithium	1	(c)	NC	0.002	0.14	4.7	14	7.0
Thallium	116	NRWQC (2002)	0.0020	0.000010	0.0040	0.0017	0.40	0.0017
Human Health COI	**BAF (L/kg-tissue)**		**MCL (pCi/L)**	**ADI (pCi/day)**	**Food Ingestion Slope Factor[d] (risk/pCi)**	**Human Threshold Criteria**		
	SW-Fish	**Basis**				**Water & Fish (pCi/L)**	**Water Only (pCi/L)**	**Fish Only (pCi/L)**
Radium-226+228	4.0	ORNL (2020)	5	10	1.43E-09	1,000	1,000	87,413

Notes:

ADI = Acceptable Daily Intake; BAF = Bioaccumulation Factor; BCF = Bioconcentration Factor; COI = Constituent of Interest; IEPA = Illinois Environmental Protection Agency; MCL = Maximum Contaminant Level; NC = No Criterion Available; NRWQC = National Recommended Water Quality Criteria; ORNL = Oak Ridge National Laboratory; pCi = PicoCurie; Ra = Radium; RfD = Reference Dose; US EPA = United States Environmental Protection Agency.

(a) BCFs from the following hierarchy of sources:
- NRWQC (US EPA, 2002). National Recommended Water Quality Criteria: 2002. Human Health Criteria Calculation Matrix.
- US EPA (2014a). Human and Ecological Risk Assessment of Coal Combustion Residuals.
- ORNL RAIS (ORNL, 2020). Risk Assessment Information System (RAIS) Toxicity Values and Chemical Parameters.

(b) ADI based on the MCL is calculated as the MCL (mg/L) multiplied by a water ingestion rate of 2 L/day. In the absence of an MCL, the ADI was calculated as the RfD (mg/kg-day) multiplied by the body weight (70 kg).

(c) BCF of 1 was used as a conservative assumption, due to lack of published BCF.

(d) Food ingestion slope factors for Ra-226+D and Ra-228+D were compared and the higher factor (Ra-228+D) was selected. The "+D" indicates that the risks from "associated short-lived radioactive decay products are also included" (US EPA, 2001).

Equations from IEPA (2019):

Consumption of Water and Fish

$$HTC = \frac{ADI}{W + (F \times BCF)}$$

Incidental Consumption of Water Only

$$HTC = \frac{ADI}{W}$$

Consumption of Fish Only

$$HTC = \frac{ADI}{F \times BCF}$$

Where:

Human Threshold Criteria (HTC)	Chemical-specific	mg/L
Acceptable Daily Intake (ADI)	Chemical-specific	mg/day
Fish Consumption Rate (F)	0.02	kg/day
Bioconcentration Factor (BCF)/ Bioaccumulation Factor (BAF)	Chemical-specific	L/kg-tissue
Water Consumption Rate (W)	0.01	L/day
Body Weight	70	kg
Target Cancer Risk (TCR)	1.0E-05	

Radium-226+228

$$HTC = \frac{TCR}{(SF \times BAF \times F)}$$

Table B.2 Recreator Exposure to Sediment

COI	Relative Bioavailability (unitless)	Dermal Absorption Fraction (unitless)	Cancer: TRV: CSF $(mg/kg\text{-}day)^{-1}$	Cancer: TRV: Dermal CSF $(mg/kg\text{-}day)^{-1}$	Cancer: Child + Adult: Incidental Ingestion SL (mg/kg)	Cancer: Child + Adult: Dermal Contact SL (mg/kg)	Cancer SL (mg/kg)	Non-Cancer: TRV: RfD (mg/kg-day)	Non-Cancer: TRV: Dermal RfD (mg/kg-day)	Non-Cancer: Child: Incidental Ingestion SL (mg/kg)	Non-Cancer: Child: Dermal Contact SL (mg/kg)	Non-Cancer: Adult: Incidental Ingestion SL (mg/kg)	Non-Cancer: Adult: Dermal Contact SL (mg/kg)	Non-cancer SL (mg/kg): Child	Non-cancer SL (mg/kg): Adult	Recreator RSL Sediment (mg/kg)	Basis[a]
Total Metals																	
Arsenic	1	3.0E-02	1.5E+00	1.5E+00	8.1E+01	4.1E+02	6.8E+01	3.0E-04	3.0E-04	4.1E+02	4.4E+03	4.4E+03	8.0E+03	3.8E+02	2.8E+03	6.8E+01	c
Barium	1	NA	NC	NC	NC	NC	NC	2.0E-01	1.4E-02	2.7E+05	NA	2.9E+06	NA	2.7E+05	2.9E+06	2.7E+05	nc
Beryllium	1	NA	NC	NC	NC	NC	NC	2.0E-03	1.4E-05	2.7E+03	NA	2.9E+04	NA	2.7E+03	2.9E+04	2.7E+03	nc
Boron	1	NA	NC	NC	NC	NC	NC	2.0E-01	2.0E-01	2.7E+05	NA	2.9E+06	NA	2.7E+05	2.9E+06	2.7E+05	nc
Chromium	1	NA	NC	NC	NC	NC	NC	1.5E+00	2.0E-02	2.1E+06	NA	2.2E+07	NA	2.1E+06	2.2E+07	2.1E+06	nc
Cobalt	1	NA	NC	NC	NC	NC	NC	3.0E-04	3.0E-04	4.1E+02	NA	4.4E+03	NA	4.1E+02	4.4E+03	4.1E+02	nc
Lead	1	NA	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	4.0E+02	L
Lithium	1	NA	NC	NC	NC	NC	NC	2.0E-03	2.0E-03	2.7E+03	NA	2.9E+04	NA	2.7E+03	2.9E+04	2.7E+03	nc
Thallium	1	NA	NC	NC	NC	NC	NC	1.0E-05	1.0E-05	1.4E+01	NA	1.5E+02	NA	1.4E+01	1.5E+02	1.4E+01	nc
Radionuclides																**Total Soil PRG (pCi/kg)**	
Radium-226+228																7.9E+03	

Notes:

COI = Constituent of Interest; CSF = Cancer Slope Factor; NC = No Criterion Available; pCi = PicoCurie; PRG = Preliminary Remediation Goal; RfD = Reference Dose; RSL = Regional Screening Level; SL = Screening Level; TRV = Toxicity Reference Value; US EPA = United States Environmental Protection Agency.

(a) Screening benchmark defined as the lower of the Screening Levels for cancer and non-cancer. The basis of the benchmark presented as c = based on cancer endpoint, nc = based on non-cancer endpoint, or L = based on blood lead levels.

Equations for Screening Benchmark and Screening Levels:

$$\text{Screening Benchmark} = \frac{1}{\frac{1}{SL_{ing}} + \frac{1}{SL_{derm}}}$$

$$\text{Non-cancer } SL_{ing} = \frac{THQ * RfD}{Intake} \qquad \text{Cancer } SL_{ing} = \frac{TR}{Intake * CSF}$$

$$\text{Non-cancer } SL_{derm} = \frac{THQ * RfD}{Intake * ABS} \qquad \text{Cancer } SL_{derm} = \frac{TR}{Intake * ABS * CSF}$$

Where:

Target Risk (TR)	1E-05	
Target Hazard Quotient (THQ)	1	
Reference Dose (RfD)	Chemical-specific	mg/kg-day
Dermal Absorption Fraction (ABS)	Chemical-specific	
Cancer Slope Factor (CSF)	Chemical-specific	mg/kg
Incidental Ingestions Screening Level (SL_{ing})	Chemical-specific	mg/kg
Dermal Contact Screening Level (SL_{derm})	Chemical-specific	mg/kg

Sediment – Ingestion (Chemical)

Intake Factor (IF) = $\frac{IR \times EF \times ED \times CF}{BW \times AT}$ =		Non-Cancer: Child	Non-Cancer: Adult	Cancer: Child	Cancer: Adult	Basis
		7.3E-07	6.8E-08	6.3E-08	2.0E-08	
IR	Ingestion Rate (mg/day)	67	33	67	33	One-third of US EPA residential soil ingestion rate (Professional Judgment)
EF	Sediment Exposure Frequency (days/year)	60	60	60	60	2 days/week between April and October when air temperature > 70°F (Professional Judgment)
ED	Exposure Duration (years)	6	20	6	20	Default value for Resident (US EPA, 2021b)
CF	Conversion Factor (kg/mg)	0.000001	0.000001	0.000001	0.000001	
BW	Body Weight (kg)	15	80	15	80	Default value for Resident (US EPA, 2021b)
AT	Averaging Time (days)	2,190	7,300	25,550	25,550	Default value for Resident (US EPA, 2021b)

Sediment – Dermal Contact (Chemical)

Intake Factor (IF) = $\frac{SA \times AF \times EF \times ED \times CF}{BW \times AT}$ =		Non-Cancer: Child	Non-Cancer: Adult	Cancer: Child	Cancer: Adult	Basis
		2.2E-06	1.2E-06	1.9E-07	3.6E-07	
SA	Surface Area Exposed to Sediment (cm^2/day)	1,026	3,026	1,026	3,026	Age weighted SA for lower legs and feet (US EPA, 2011b)
AF	Sediment Skin Adherence Factor (mg/cm^2)	0.2	0.2	0.2	0.2	Age weighted AF for children exposed to sediment (US EPA, 2011b)
EF	Sediment Exposure Frequency (days/year)	60	60	60	60	2 days/week between April and October when air temperature > 70°F (Professional Judgment)
ED	Exposure Duration (years)	6	20	6	20	Default value for Resident (US EPA, 2021b)
CF	Conversion Factor (kg/mg)	0.000001	0.000001	0.000001	0.000001	
BW	Body Weight (kg)	15	80	15	80	Default value for Resident (US EPA, 2021b)
AT	Averaging Time (days)	2,190	7,300	25,550	25,550	Default value for Resident (US EPA, 2021b)

Table B.3.1 Recreator PRGs for Soil, Input Values

Variable	Recreator Soil Default Value	Form-Input Value
A (PEF Dispersion Constant)	16.2302	16.8653
B (PEF Dispersion Constant)	18.7762	18.7848
City (Climate Zone)	Default	Chicago, IL (7)
C (PEF Dispersion Constant)	216.108	215.0624
Cover layer thickness for GSF (gamma shielding factor) cm	0 cm	0 cm
$CF_{rec\text{-}fowl}$ (fowl contaminated fraction) unitless	1	1
$CF_{rec\text{-}game}$ (game contaminated fraction) unitless	1	1
ED_{rec} (exposure duration - recreator) yr		26
EF_{rec} (exposure frequency - recreator) day/yr		60
$f_{p\text{-}fowl}$ (fowl on-site fraction) unitless	1	1
$f_{p\text{-}game}$ (land game on-site fraction) unitless	1	1
$f_{s\text{-}fowl}$ (fraction of year fowl is on site) unitless	1	1
$f_{s\text{-}game}$ (fraction of year land game is on site) unitless	1	1
$MLF_{pasture}$ (pasture plant mass loading factor) unitless	0.25	0.25
t_{rec} (time - recreator) yr		26
TR (target risk) unitless	0.000001	0.000001
F(x) (function dependent on U_m/U_t) unitless	0.194	0.182
PEF (particulate emission factor) m^3/kg	1,359,344,438	1,560,521,177
Q/C_{wind} (g/m^2-s per kg/m^3)	93.77	98.431
A_s (acres)	0.5	0.5
Site area for ACF (area correction factor) m^2	1,000,000 m^2	1,000 m^2
ED_{rec} (exposure duration - recreator) yr		26
$ED_{rec\text{-}a}$ (exposure duration - recreator adult) yr		20
$ED_{resc\text{-}c}$ (exposure duration - recreator child) yr		6
EF_{rec} (exposure frequency - recreator) day/yr		60
$EF_{rec\text{-}a}$ (exposure frequency - recreator adult) day/yr		60
$EF_{rec\text{-}c}$ (exposure frequency - recreator child) day/yr		60
ET_{rec} (exposure time - recreator) hr/day		8
$ET_{rec\text{-}a}$ (exposure time - recreator) hr/day		8
$ET_{rec\text{-}c}$ (exposure time - recreator) hr/day		8
$IFA_{rec\text{-}adj}$ (age-adjusted inhalation rate - recreator) m^3		9,200
$IFS_{rec\text{-}adj}$ (age-adjusted soil intake rate - recreator) mg		63,720
$IRA_{rec\text{-}a}$ (inhalation rate - recreator adult) m^3/day	20	20
$IRA_{rec\text{-}c}$ (inhalation rate - recreator child) m^3/day	10	10
$IRS_{rec\text{-}a}$ (soil intake rate - recreator adult) mg/day	100	33
$IRS_{rec\text{-}c}$ (soil intake rate - recreator child) mg/day	200	67
t_{rec} (time - recreator) yr		26
TR (target risk) unitless	0.000001	0.000001
U_m (mean annual wind speed) m/s	4.69	4.65
U_t (equivalent threshold value)	11.32	11.32
V (fraction of vegetative cover) unitless	0.5	0.5

Notes:

IL = Illinois; PRG = Preliminary Remediation Goal; yr = Year.

Table B.3.2 Recreator PRGs for Soil, Ra-226

Isotope	ICRP Lung Absorption Type	Soil Ingestion Slope Factor (risk/pCi)	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/yr per pCi/g)	Food Ingestion Slope Factor (risk/pCi)	Lambda (1/yr)	Half-life (yr)	1,000 m^2 Soil Volume Area Correction Factor	0 cm Soil Volume Gamma Shielding Factor	Particulate Emission Factor (m^3/kg)	Dry Soil-to-Plant Transfer Factor (pCi/g-fresh plant per pCi/g-dry soil)	Beef Transfer Factor (pCi/kg per pCi/d)	Poultry Transfer Factor (pCi/kg per pCi/d)	Ingestion PRG TR = 1.0E-06 (pCi/g)	Inhalation PRG TR = 1.0E-06 (pCi/g)	External Exposure PRG TR = 1.0E-06 (pCi/g)	Total PRG TR = 1.0E-06 (pCi/g)	Total PRG TR = 1.0E-06 (mg/kg)	Total PRG TR = 1.0E-06 (pCi/kg)
Ra-226	S	6.77E-10	2.82E-08	2.50E-08	5.14E-10	4.33E-04	1.60E+03	6.85E-01	1.00E+00	1.56E+09	1.95E-02	1.70E-03	-	2.32E+01	6.02E+03	4.10E+01	1.48E+01	1.50E-05	1.48E+04

Notes:

d = Day; ICRP = International Commission on Radiological Protection; pCi = PicoCurie; PRG = Preliminary Remediation Goal; Ra = Radium; S = Slow; TR = Target Risk; yr = Year.

Table B.3.3 Recreator PRGs for Soil, Ra-228

Isotope	ICRP Lung Absorption Type	Soil Ingestion Slope Factor (risk/pCi)	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/yr per pCi/g)	Food Ingestion Slope Factor (risk/pCi)	Lambda (1/yr)	Half-life (yr)	1,000 m^2 Soil Volume Area Correction Factor	0 cm Soil Volume Gamma Shielding Factor	Particulate Emission Factor (m^3/kg)	Dry Soil-to-Plant Transfer Factor (pCi/g-fresh plant per pCi/g-dry soil)	Beef Transfer Factor (pCi/kg per pCi/d)	Poultry Transfer Factor (pCi/kg per pCi/d)	Ingestion PRG TR = 1.0E-06 (pCi/g)	Inhalation PRG TR = 1.0E-06 (pCi/g)	External Exposure PRG TR = 1.0E-06 (pCi/g)	Total PRG TR = 1.0E-06 (pCi/g)	Total PRG TR = 1.0E-06 (mg/kg)	Total PRG TR = 1.0E-06 (pCi/kg)
Ra-228	S	1.98E-09	4.37E-08	3.43E-11	1.42E-09	1.21E-01	5.75E+00	1.00E+00	1.00E+00	1.56E+09	1.95E-02	1.70E-03	-	7.93E+00	3.89E+03	2.04E+04	7.91E+00	2.90E-08	7.91E+03

Notes:

d = Day; ICRP = International Commission on Radiological Protection; pCi = PicoCurie; PRG = Preliminary Remediation Goal; Ra = Radium; S = Slow; TR = Target Risk; yr = Year.

APPENDIX B - SUPPORTING INFORMATION FOR CLOSURE ALTERNATIVES ANALYSIS

Kincaid Power Plant Closure Alternatives Analysis Supporting Information Report 199 IL-104, Kincaid, IL 62540

Vistra Energy

Project No. 132803

August 2022

Kincaid Power Plant Closure Alternatives Analysis Supporting Information Report 199 IL-104, Kincaid, IL 62540

prepared for

Vistra Energy

Project No. 132803

August 2022

prepared by

Burns & McDonnell Engineering Company, Inc.
St Louis, Missouri

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1.0 INTRODUCTION

Kincaid Generation, LLC is the owner of the coal-fired Kincaid Power Plant (KPP), located in Christian County, Illinois. Kincaid is an active power plant and will remain active until 2027, at which time electricity production will cease and it will become inactive. Closure of the Kincaid Ash Pond (KAP) will take place in phases and upon shut down of the power plant in 2027, with final closure complete in fall of 2028.

This supplemental information was developed for the closure alternatives analysis, performed by others, as required in accordance with 35 Illinois Administrative Code 845, Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments (Part 845). Closure of the KAP will be performed under the relevant Illinois Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments (Part 845) [1] and the United States Environmental Protection Agency (USEPA) CCR Rule [2].

Part 845 requires a Closure Alternatives Analysis (CAA) to be completed, pursuant to the requirements of Section 854.710, to support the Closure Plan prepared pursuant to Section 845.720. The CAA for the Kincaid Ash Pond will be performed by Gradient Corporation (Gradient). Burns & McDonnell has prepared this Closure Alternatives Analysis Supporting Information Report (Report) to provide information to Gradient to support its preparation of the CAA.

1.1 Report Contents

The following information is contained within this report:

- **Section 1** includes the Introduction and Background.
- **Section 2** includes information related to closure-by-removal (CBR) including:
  - An evaluation of potential offsite landfills to receive the CCR for CBR-Offsite, and
  - A feasibility evaluation of CCR transportation for CBR-Offsite using over-the-road trucks, rail, and barging.
- **Section 3** includes an overview of the planned construction for closure-in-place (CIP) and CBR-Offsite.
- **Section 4** includes a project schedule for CIP and CBR-Offsite.
- **Section 5** includes estimates for construction material quantities, labor, vehicle miles, and equipment miles, for CIP and CBR-Offsite.

2.0 CLOSURE BY REMOVAL INFORMATION

Section 845.710(c)(1) requires the evaluation of complete removal of CCR (e.g., CBR), and Section 845.710(d)(2) requires the CAA to identify if the Power Plant has a landfill that can accept the CCR, or if constructing an onsite landfill is feasible. Additionally, Section 845.710(c)(1) requires the evaluation of multiple modes of transportation of CCR, including rail, barge, and truck. This section includes an evaluation of onsite landfill options, potential offsite landfills, and potential methods for transporting CCR to offsite landfills.

2.1 Potential Closure by Removal – Onsite Landfill Options

2.1.1 Existing Kincaid CCR Landfill

There is no existing onsite landfill at the Kincaid Power Plant.

2.1.2 Feasibility of New Onsite CCR Landfill Construction

Due to the planned redevelopment of the Site as a utility-scale solar generation and battery energy storage facility, there is not sufficient space available to construct a landfill.

2.2 Potential Closure by Removal – Offsite Landfill Options

Potential offsite landfills suitable for disposing of the approximately 2,950,000 CY of CCR within the KAP were evaluated using IEPA's online Illinois Disposal Capacity Report. The closest landfills to the site, by road miles, were determined to be the Waste Management Five Oaks Landfill located in Taylorville, Illinois, the Republic Services Sangamon Valley Landfill in Springfield, Illinois, and the Republic Services Envotech Landfill in Litchfield, Illinois.

The Five Oaks Landfill is the preferred landfill since it is located nearest the Kincaid Power Plant, thereby resulting in reduced hauling mileage. All the landfills have sufficient remining permitted capacity to receive the approximate 2,950,000 CY volume of CCR; however, as of the date of this report, the landfills have not been contacted to confirm that they would be willing to accept the CCR. Information on the potentially suitable landfills is provided in **Table 1** [3] and the location of each landfill relative to the Kincaid Power Plant is provided in **Figure 1.**

2.3 Potential Closure by Removal – Offsite Transportation Methods

Section 845.710(c)(1) requires multiple methods of transporting removed CCR to be considered for a CBR closure alternative. These methods include rail, barge, and truck. An evaluation of each method is included within this section. **Figure 1** shows the truck routes for all three landfills as well as the rail lines for the

Five Oaks Landfill and Sangamon Landfill.

2.3.1 Transport by Truck

The Kincaid Power Plant is located along Illinois Route 104 (IL-104), a suitable roadway for receiving truck hauling traffic. Potential travel routes between the KAP and the proposed landfills described below are shown on **Figure 1** although actual travel routes may vary.

Waste Management Five Oaks Landfill

The Five Oaks Landfill is accessible from the Site via IL-104. IL-104 is a state-maintained Class II truck route with five bridges between the Site and the Five Oaks landfill. IL-104 passes through Kincaid, Illinois.

Republic Services Sangamon Valley Landfill

The Sangamon Valley Landfill is accessible from the Site via several routes, all of which are state-maintained Class I and Class II truck routes. The proposed route to the landfill would take IL-104 west to Interstate 55, north and around Springfield, IL.

Republic Services Envotech Landfill

The Envotech Landfill is accessible from the Site via several routes, all of which are state-maintained Class I and Class II truck routes. The proposed route to the landfill would take IL-104 west to Interstate 55, south through Litchfield, IL.

Potential travel routes between the Kincaid Power Plant and the potential landfill disposal sites are shown on **Figure 1**, although actual travel routes may vary. Transporting CCR by truck will not require the construction of additional loading or unloading infrastructure at either the receiving landfill or Kincaid. However, improvements would be required for the ingress/egress at the Kincaid Plant. The entrance to the facility would need to be widened and a traffic signal or at a minimum, a turning lane added to safely enter and exit the facility. CCR would be loaded into trucks using heavy equipment at the KAP. CCR will then be unloaded at the receiving landfill by the truck directly. Slight project delays related to coordination with other entities (i.e., Christian County, State of Illinois, etc.), design, and permitting are likely to occur. However, transporting CCR by truck is a viable and the preferred option for the Kincaid Power Plant.

2.3.2 Transport by Rail

Waste Management Five Oaks Landfill

The Five Oaks Landfill is owned and operated by Waste Management. Located at 890 E 1500 North Rd. Taylorville, IL, the landfill is approximately seven miles southeast of the Kincaid Power Plant. An Illinois & Midland Railroad line (IMRR) is located immediately south of the Kincaid Power Plant as shown on

Figure 1. IMRR predominantly ships coal but offers other cargo transportation options [4]. The IMRR line runs parallel to the Five Oaks landfill property with a spur leading into the Five Oaks Landfill property along the eastern side. A cursory search using Google Maps and Street View suggests this spur is overgrown and not currently in use. It is assumed that maintenance and clean-up would be required as well as leasing or purchasing of the spur to make the IMRR a viable option. No evaluation of the cost of constructing the infrastructure required for bulk loading and unloading has been included in the assessment of the site.

Republic Services Sangamon Valley Landfill

The Sangamon Valley Landfill is owned and operated by Republic Services. Located at 2565 Sandhill Rd. in Springfield, IL, the landfill is approximately thirty miles northwest of the Kincaid Power Plant. The rail line nearest the Sangamon Valley Landfill is located several hundred feet west of the landfill as shown on **Figure 1**. This line is owned by Union Pacific (UP) and operated by Amtrak according to the U.S. Department of Transportation Federal Railroad Administration Safety Map. There are no spurs leading to the Sangamon Valley landfill and therefore not a viable hauling option unless additional tracks are constructed. No evaluation of bulk loading and unloading has been included in the assessment of the site.

Republic Services Envotech Landfill

The Envotech Valley Landfill is owned and operated by Republic Services. Located at 2565 Sandhill Rd. in Springfield, IL, the landfill is approximately thirty miles northwest of the Kincaid Power Plant. There are no railroad lines located near the Envotech Landfill.

Transporting CCR by rail is unlikely to be a viable option due to the need to design, permit, and construct additional rail lines and loading infrastructure, the potential need to share use of the rail lines, and the need to upgrade or replace the unloading infrastructure at the landfill.

2.3.3 Transport by Barge

The Kincaid Power Plant is located along Lake Sangchris but does not have barge loading capabilities and is not connected to a reasonably close navigable waterway that leads to a landfill. Therefore, barging is not a viable option for transporting CCR to an offsite landfill for disposal.

3.0 CLOSURE DESCRIPTION NARRATIVES

Section 845.720(a)(1)(A) requires narrative description of CCR impoundment closures to be prepared describing how it will be closed in accordance with Part 845. Narrative descriptions for two closure alternatives – closure by removal (CBR) and close in-place (CIP) – have been prepared for the Kincaid Ash Pond (KAP) and are presented below. The designs for these options are conceptual in nature and only a cursory desktop review of location restrictions, such as wetlands and floodplains, was performed. In depth evaluations, investigations and designs will need to be performed for the final alternative chosen.

3.1 Closure in Place (CIP)

Under the CIP scenario, the CCR in the KAP will be consolidated into a reduced footprint, graded, and capped with a new cover system. A description of the CIP alternative for the KAP is as follows:

- The KAP will be unwatered/dewatered by pumping free water (ponded and subsurface) to the onsite wastewater treatment system (WWTS) for treatment and subsequent discharge through NPDES Outfall B01.
- CCR will be relocated to the southern portion of the impoundment, contoured, and graded to promote stormwater management.
- A new soil berm with an east-west orientation will be constructed to separate the consolidated CIP CCR area from the "clean-closed" area to the north.
- All CCR from the area north of the constructed berm will be excavated and placed/consolidated in an approximately 84-acre area located south of the new berm.
- A hydraulic cut-off wall (sheet piling) will be installed along the interior of the north and west berms of the consolidated footprint area to maintain an operating pool in the southeast corner of the CIP area during operation of the Kincaid Power Plant. This operating pool will also receive dewatering fluids during CCR excavation and consolidation activities. The free water (ponded and subsurface) will be pumped from within the consolidated area after the plant has ceased operation and prior to installation of the cap system.
- The consolidated CCR will be contoured and graded to promote stormwater management.
- An alternative final cover system will be constructed over the consolidated CCR. The cover system will consist of a 40-mil linear low-density polyethylene (LLDPE) geomembrane layer, a geotextile cushion layer, and twenty-four inches of protective soil cover suitable for supporting vegetative growth.
- The final cover system will be crowned to direct surface water away from the facility. Beyond the limits of the final cover system, channels will direct surface water to existing site drainages.

- The development of a solar facility and/or battery storage within the project area is currently under consideration.

3.2 Closure by Removal (CBR) Offsite

A description of the CBR alternative for the KAP is as follows:

- The KAP will be unwatered/dewatered by pumping free water (ponded and subsurface) to the onsite WWTS for treatment and subsequent dischargethrough NPDES Outfall B01.
- CCR will be removed from the KAP using mass mechanical excavation techniques. An estimated 2,950,000 cubic yards (CY) of CCR material will be excavated and removed from the KAP. Most of the CCR material is bottom ash and is antiCIPated to require very little dewatering. The CCR material that contains fly ash and economizer ash will be dewatered with the use of dewatering trenches or other forms of passive dewatering (i.e., rim ditching or windrowing) to result in CCR conditioned for the appropriate conveyance method. Dewatering flows will be pumped to the WWTS for treatment and subsequent discharge through NPDES Outfall B01.
- CCR will be loaded into over-the-road dump trucks and hauled to the offsite receiving landfill.
- The KAP does not have a liner system to remove, but the underlying soils will be over excavated a minimum of 1-foot to remove all CCR from within the KAP.
- The KAP will be backfilled as necessary to promote positive drainage towards the north and through the breached dike, to allow post-closure, non-contact stormwater to gravity flow into Lake Sangchris. Backfill materials would include clean soil material excavated from an offsite borrow source.
- The KAP will be restored by placing six inches of topsoil on the bottom and side slopes of the KAP and establishing vegetation. Stormwater best management practices (BMPs) such as erosion control blankets and straw wattles will be used, as needed, to reduce erosion during vegetation establishment.
- After vegetation is established, BMPs will be removed.

4.0 CONSTRUCTION SCHEDULES

Section 845.720(a)(1)(F) requires a schedule including all activities necessary to complete closure to be prepared. Schedules have been prepared for CIP and CBR-Offsite and are included within this section. Schedules were prepared using estimates of task durations based on Burns & McDonnell's experience, typical weather conditions at the site, and expected construction rates relative to estimated construction quantities.

4.1 CIP

The proposed closure completion schedule for CIP is provided in **Table 2**.

4.2 CBR Offsite

The proposed closure completion schedule for CBR-Offsite is provided in **Table 2**.

5.0 MATERIAL, QUANTITY, LABOR, AND MILEAGE ESTIMATES

5.1 Quantity Estimates

Section 845.720(d)(1) requires an analysis be prepared for each alternative in accordance with the Class 4 standards of the Association for the Advancement of Cost Engineering (AACE) [5]. Analyses for both CIP and CBR-Offsite were prepared in accordance with the AACE Class 4 standards, utilizing the following approach:

- Major construction components and line-items were identified, in accordance with the narrative closure description (**Section 3**).

  Construction quantities were estimated based on volume estimates, area estimates, and proposed construction schedules (**Section 4**).

- Soil fill was assumed to come from offsite borrow sources located within 5-miles of the KPP on average. Soil borrow is available from existing berms and dikes on site as well.

- A contingency of 30% was applied for the analysis, based on the level of design and quantity estimate prepared as part of this Report.

5.2 Labor and Mileage Estimates

In addition to construction quantity estimates, Gradient also utilized Burns & McDonnell's estimates of construction labor hours, equipment usage, haul truck mileage, daily labor mobilization vehicle mileage, material delivery mileage, and onsite vehicle mobilization mileage. These estimates were prepared using the following approach:

- For line items where RSMeans [6] was utilized, the corresponding RSMeans crew size, equipment description, and daily output were utilized to estimate the total number of man-hours and equipment hours.

- For line items where RSMeans data was unavailable, the crew size, equipment description, and daily output were estimated based on Burns & McDonnell's experience.

- Daily labor mobilization miles were estimated assuming an average one-way commute of thirty-five miles for each individual working onsite. The number of working days were estimated from the construction schedules (**Section 4**).

- Estimates of haul truck mileage were based on the assumed round-trip haul distance and dump truck size. Offroad haul trucks were estimated to be 34CY and on road haul trucks were estimated to be 16.5CY. All dump trucks were assumed to be filled to capacity.

- Estimates of material delivery miles were prepared based on Burns & McDonnell's experience.

6.0 REFERENCES

[1] Illinois Environmental Protection Agency, "35 Ill. Adm. Code Part 845, Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments," Springfield, IL, Accessed January 2022.

[2] United Stated Environmental Protection Agency, "40 CFR Parts 257 and 261, Hazardous and Solid Waste Management System, Disposal of Coal Combustion Residuals from Electric Utilities, Final Rule, 2015," Accessed January 2022.

[3] Illinois Environmental Protection Agency, "Thirty Fourth Annual Landfill Capacity Report - 2020," Accessed February 2022.

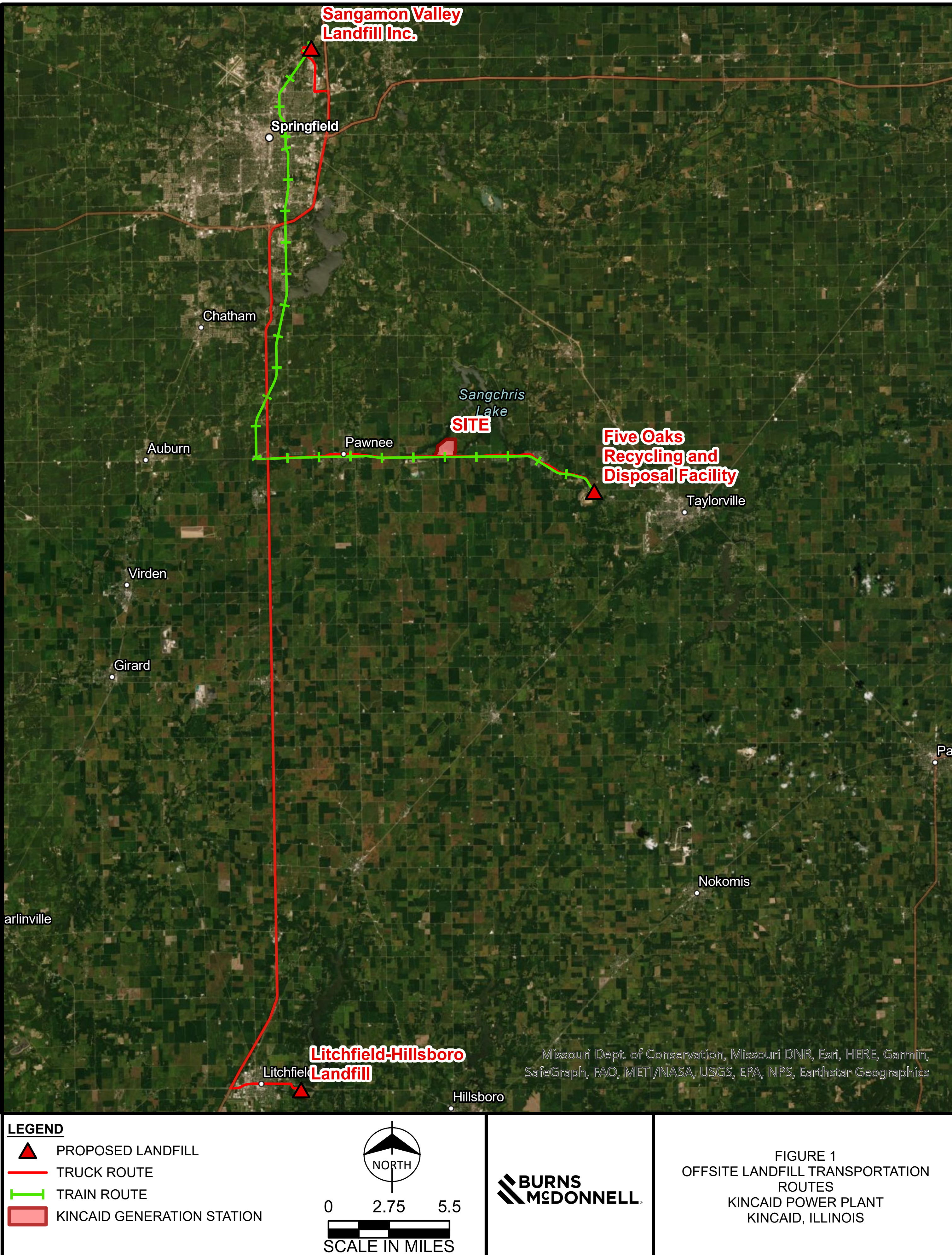
[4] Genesee & Wyoming, "Illinois & Midland Railroad (IMRR)", Accessed February 2022.

https://www.gwrr.com/imrr/

[5] AACE International. 2005. COST ESTIMATE CLASSIFICATION SYSTEM – AS APPLIED IN ENGINEERING, PROCUREMENT, AND CONSTRUCTION FOR THE PROCESS INDUSTRIES: TCM Framework: 7.3 – Cost Estimating and Budgeting (AACE International Recommended Practice No. 18R-97). Accessed March 2022.

[6] RSMeans, "Heavy Construction Costs with RSMeans Data," Gordian, 2022.

FIGURES



BURNS McDONNELL

FIGURE 1
OFFSITE LANDFILL TRANSPORTATION ROUTES
KINCAID POWER PLANT
KINCAID, ILLINOIS

TABLES

Table 1 - Off-Site Landfill Information

Landfill Name:	Owner:	Location:	One-way Distance From Site:	5-yr Average Disposal Volume (CY):	Remaining Site Capacity (CY)
Five Oaks Recycling and Disposal Facility	Waste Management	Taylorville, IL	7.5	249664	7051864
Sangamon Valley Landfill Inc.	Republic Services	Springfield, IL	24.5	148,706	2,348,775
Litchfield-Hillsboro Landfill	Republic Services	Litchifield, IL	41.5	82,620	1,535,189

Notes
CY - Cubic Yards

1. Table information collected from the IEPA 2020 Landfill Capacity Report
https://www2.illinois.gov/epa/topics/waste-management/landfills/landfill-capacity/Pages/2020.aspx

Table 2 - Closure Schedules

Milestone	Timeframe	
	Closure in Place	Closure by Removal to Off-Site Landfill
Agency Coordination, Approvals, Permitting Obtain state permits, as needed, for dewatering/unwatering, water discharge, land disturbance, and outlet modifications	8 to 12 months after final Closure Plan Approval	12 to 18 months after final Closure Plan Approval
Final Design and Bid Process* Complete final design of the closure and select a construction contractor	6 to 8 months after Agency Coordination, Approvals, and Permitting	6 to 12 months after Agency Coordination, Approvals, and Permitting
Close CCR Unit Complete Contractor mobilization, installation of stormwater control measures for construction Complete dewatering and unwatering Complete Mass Excavation of CCR and decontamination of Ash Pond Install final cover system (closure in place only) Winter weather delays are assumed between November and March of each construction year	20 to 26 months after necessary permits are issued	102 to 130 months after necessary permits are issued
Final Grading	3 to 5 months	3 to 5 months
Site Restoration Seed and stabilize the Ash Pond Complete Contractor demobilization	2 to 3 months after grading is complete	2 to 3 months after grading is complete
Timeframe to Complete Closure	**39 to 54 months**	**125 to 168 months**

Notes

*Assume final design and bidding is concurrent with final approvals and permitting

Table 3a: Material Quantity Estimate - Consolidate Closure in Place

Item No.	Item	Crew	Worker Type	Workers (#)	Equipment Type	Equipment (#)	Daily Output	Labor Hours	Equipment Hours	Units	Quantity	RS Means Code
1	**Pre-Construction**											
	Mobilization and Demobilization									LS	1	
2	**Site Preparation**											
	Site Preparation: Clearing and Grubbing	B7	Operator x 1 Laborer x 5	6	Brush Chipper x 1 Crawler Loader x 1 Chainsaws x 2	4	1	1,032	688	AC	17.2	311110100020
	Grub Stumps and Remove	B30	Truck Driver x 2 Laborer x 6	3	Excavator X1 Dump Truck X 2	3	2	258	258	AC	17.2	311110100150
	Construction Soil Erosion and Sediment Controls	B62	Operator x 1 Laborer x 2	3	Skid Steer x 1	1	650	508	169	LF	11,000	312514161000
	Construction Facilities - Office Trailer	-	-	-	-	-	-	-	-	LS	1	15213200400
	Construction Facilities - Storage Trailers (2)	-	-	-	-	-	-	-	-	LS	2	152132000200
	Construction Facilities - Portable Toilets (4)	-	-	-	-	-	-	-	-	MO	25	15433406410
	Dust Control	B59	Truck Driver x 1	1	Water Truck x 1	1	1	5,400	5,400	DAY	540	312323202510
	Haul Road Maintenance	B86A	Operator x 1	1	Grader x 1	1	1	2,160	2,160	DAY	216	312323202600
3	**Dewatering, Unwatering, and Stormwater Management**											
	Unwatering, Dewatering, and Stormwater Management for the Ash Pond	B10K	Operator x 1 Laborer x 0.5	1.5	Pump x 1	1	1	9,150	6,100	DAY	610	312319201100
	Additional Pump				Pump x 1	1	1	0	6,100	DAY	610	312319201120
	Dewatering Sumps Installation	B6	Operator x 1 Laborer x 2	3	Backhoe x 1	1	1	60	20	EA	2	330561101210
4	**Closure**											
	Creation of a Soil Berm											
	Excavation of on-site soil	B14J								CY	5,556	
	Hauling material to southern portion of site	B34F	Truck Driver x 1	1	Dump Truck x 1	1	680.00	82	82	CY	5,556	312323206470
	Spreading of Material	B10B	Operator x 1 Laborer x 0.5	1.5	Dozer x 1	1	1,000.00	83	56	CY	5,556	312323170020
	Compaction of Material	B10Y	Operator x 1 Laborer x 0.5	1.5	Vibratory Roller x 1	1	2,300.00	36	24	CY	5,556	312323235020
	Excavation and Loading of Material	B14J	Operator x 1 Laborer x 0.5	1.5	Front End Loader x 1	1	3,800.00	612	408	CY	155,000	312316435400
	Hauling and stockpiling Material	B34C	Truck Driver x 1	1	Dump Truck x 1	1	215.00	7,209	7,209	CY	155,000	312323203266
	Double Handling of Soil									CY	155,000	
	Spreading of Material	B10B	Operator x 1 Laborer x 0.5	1.5	Dozer x 1	1	1,000.00	2,325	1,550	CY	155,000	312323170020
	Finish grading material	B11L	Operator x 1 Laborer x 1	2	Grader x 1	1	1.84	40	20	CY	4	312216103300
	Hydraulic cut-off wall											
	Drive sheet piling along north and west berms of consolidated footprint area	B40	Pile Driver x 5 Operator x 3	8	Crane x 1 Vibratory Hammer x 1	2	22.12	5,425	1,356	LF	1,500	314116101900

Relocate Sluice Channel											
Excavate new sluice channel	B11M	Operator x 1 Laborer x 1	2	Backhoe Loader x 1	1	200	2,700	1,350	CY	27,000	312316130060
Excavation of Ash Material											
Excavation of ash material	B14J	Operator x 1 Laborer x 0.5	1.5	Front End Loader x 1	1	1,900.00	14,779	9,853	CY	1,872,000	312316432500
Hauling material to southern portion of site	B34F	Truck Driver x 1	1	Dump Truck x 1	1	528.00	35,455	35,455	CY	1,872,000	312323206470
Spreading of Material	B10B	Operator x 1 Laborer x 0.5	1.5	Dozer x 1	1	1,000.00	28,080	18,720	CY	1,872,000	312323170020
Compaction of Material	B10Y	Operator x 1 Laborer x 0.5	1.5	Vibratory Roller x 1	1	2,300.00	12,209	8,139	CY	1,872,000	312323235020
Fine grading of CCR surface	B11L	Operator x 1 Laborer x 1	2	Grader x 1	1	1.84	914	457	AC	84	312216103300
Piezometer and Monitoring Well Install	C18	Laborer x 1.125	1.125	Concrete Cart x 1	1	1.00	45	40	EA	4	
5 Pond Capping											
Geomembrane, 40-mil LLDPE	B63B	Operator x 1 Laborer x 3	4	Skid Steer x 1	1	0.3	10,136	2,534	AC	84	
Geotextile, 8-oz.	2 Clab	Laborer x 2	2		5	0.5	3,379	8,447	AC	84	
Anchor Trench	B11C	Operator x 1 Laborer x 1	2	Excavator x 1	1	150	1,067	533	LF	8,000	312316130050
Placement of Protective Cover Soil (offsite source)											
Excavation and Loading of Material	B14J	Operator x 1 Laborer x 0.5	1.5	Front End Loader x 1	1	3,800.00	824	549	CY	208,804	312316435400
Hauling and stockpiling Material	B34C	Truck Driver x 1	1	Dump Truck x 1	1	215.00	9,712	9,712	CY	208,804	312323203266
Double Handling of Soil									CY	208,804	
Spreading of Material	B10B	Operator x 1 Laborer x 0.5	1.5	Dozer x 1	1	1,000.00	3,132	2,088	CY	208,804	312323170020
Finish grading material	B11L	Operator x 1 Laborer x 1	2	Grader x 1	1	1.84	911	456	AC	84	312216103300
Placement of Vegetative Soil (offsite source)											
Excavation and Loading of Material	B12D	Operator x 1 Laborer x 1	2	Excavator x 1	1	2,040.00	682	341	CY	69,601	312316420305
Hauling and Stockpiling Material	B34C	Truck Driver x 1	1	Dump Truck x 1	1	215.00	3,237	3,237	CY	69,601	312323203266
Double Handling of Soil									CY	69,601	
Spreading of Material	B10B	Operator x 1 Laborer x 0.5	1.5	Dozer x 1	1	1,000.00	1,044	696	CY	69,601	312323170020
Finish grading material	B11L	Operator x 1 Laborer x 1	2	Grader x 1	1	1.84	911	456	AC	84	312216103300
Installation of drainage channels (ditches)									CY	13,000	
Erosion Control Blanket	2 Clab	Laborer x 2	2	-	0	1000	1,444	0	SY	72,222	312514160120
Installation of drainage letdowns											
Riprap	B30	Operator x 1 Truck Driver x 2	3	Excavator x 1 Dump Trucks x 2	3	100	1,600	1,600	SY	5,333	313713100200
Geotextile, 10 oz.	2 Clab	Laborer x 2	2			2,400	44	0	SY	5,333	313219161510

6 Stormwater and Perimeter											
Removal of Outlet Structure	B14A	Operator x 1 Laborer x 0.5	1.5	Excavator x 1	1	0.10	150	100	LS	1	
Removal of Outlet Pipes	B14A	Operator x 1 Laborer x 0.5	1.5	Excavator x 1	1	0.20	75	50	LS	1	
Installation of permanent stormwater culverts, riprap aprons, and outlets	B14A	Operator x 1 Laborer x 0.5	1.5	Excavator x 1	1	0.10	150	100	LS	1	
Establish Access Roads											
Gravel for Access Road	B32	Operator x 3 Laborer x 1	4	Grader x 1 Roller x 1 Dozer x 1	3	6,000	30	23	CY	4,500	321123230370
Geotextile, 10 oz.	2 Clab	Laborer x 2	2			2,400	111	0	SY	13,350	313219161510
Placement of Soil For Positive Drainage (off-site source)											
Excavation and Hauling Material	B34F	Truck Driver x 1	1	Dump Truck x 1	1	680.00	1,596	1,596	CY	108,500	312323206470
Spreading of Material	B10B	Operator x 1 Laborer x 0.5	1.5	Dozer x 1	1	1,000.00	1,628	1,085	CY	108,500	312323170020
Compaction of Material	B10Y	Operator x 1 Laborer x 0.5	1.5	Vibratory Roller x 1	1	2,300.00	708	472	CY	108,500	312323235020
Finish grading material	B11L	Operator x 1 Laborer x 1	2	Grader x 1	1	1.84	957	479	AC	88	312216103300
Seed, fertilize, and maintain vegetated surfaces	B65/B66	Operator x 1	1	Loader-Backhoe x 1	1	1.5	1,333	1,333	AC	200	329219130020, 320190130120, 329113160650
7 Engineering and Construction Support											
Final Closure Design, Local Permitting Support, and Bid Support	**BMcD**	Engineering Staff x 4	4	-	0	0.01	4,000	0	LS	1	
Engineering Support and CQA during Construction	**BMcD**	CQA Staff x 3 Engineering Staff x 1	4	Truck x 3	3	0.001	40,000	30,000	LS	1	
							Labor Hours: 217,423	**Equipment Hours: 171,499**			

Notes

1. RS Means used as reference - adjusted based on project size, location, type. Year - 2022, Location - Effingham, IL

2. Grey crews were established based on BMcD relevant project experience.

6. Quantities were developed through conceptual figures and are considered estimates at this stage.

7. It is assumed that no additional dewatering of the bottom ash is required beyond pumping through the sumps.

8. It is assumed that power will be provided by Owner

9. It is assumed that unwatering discharge will be processed through the on-site WWTP and discharged through the NPDES outfall.

12. Unwatering/Dewatering is based on a single pump with a backup pump.

This Engineer's Opinion of Probable Cost is based primarily on our experience and judgement as a professional consultant combined with information from past experience, vendors, and published sources. Since Burns & McDonnell has no control over weather, cost and availability of labor, material and equipment, labor productivity, construction contractor's procedures and methods, unavoidable delays, construction contractor's methods of determining prices, economic conditions, government regulations and laws (including the interpretation thereof), competitive bidding or market conditions and other factors affecting such opinions or projections; consequently, the final project costs will vary from the opinions of costs presented in this study and funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Table 3b: Labor, Equipment, and Mileage Estimate - Closure in Place - Totals

Item	Quantity	Assumptions
Labor Total Hours	217,423	10-hr days
Duration of Onsite Construction in Days	500	Working days, 25 months on-site, 20-working days per month average
Average Daily Crew Size	43	Crew Members
Daily Labor Mobilization Miles	1,521,958	Average of 70 miles round trip per day
Vehicles Miles Onsite	53,333	2 mile round trip from gate to parking 5 miles per day for CQA tech and Construction Supervisor 10% Contingency for site visitors (client and engineering support)
Equipment Mobilization Miles - Unloaded	25,725	Average of 300 miles one way for equipment hauling Average 1 load of equipment 2,000 Equipment working hours
Equipment Mobilization Miles - Loaded	25,725	Average of 300 miles one way for equipment hauling Average 1 load of equipment per working week
Daily Equipment Miles Onsite	500,000	Average of ~20 crew members running equipment Assume 50 miles per piece of equipment (average 5 mph, 10-hrs per day)
Onsite Haul Truck Miles - Unloaded	27,529	34 CY Haul Truck 1 mile cycle
Onsite Haul Truck Miles - Loaded	27,529	34 CY Haul Truck 1 mile cycle
Offsite Haul Truck Miles - Unloaded	164,214	16.5 CY Dump Truck 10 mi cycle
Offsite Haul Truck Miles - Loaded	164,214	16.5 CY Dump Truck 10 mile cycle
Material Delivery Miles - Unloaded	88,197	Assume geosynthetic source ~850-miles from site (possibly South Carolina) 60 extra trips for piping, seed, fertilizer, mulch, straw wattles, and concrete - source 1000 miles away average
Material Delivery Miles - Loaded	88,197	Assume geosynthetic source ~850-miles from site (possibly South Carolina) 60 extra trips for piping, seed, fertilizer, mulch, straw wattles, and concrete - source 1000 miles away average
Estimated Total	**2,686,621**	**miles**

Table 4a: Material Quantity Estimate - Offsite Landfill

Item No.	Item	Crew	Worker Type	Workers (#)	Equipment Type	Equipment (#)	Daily Output	Labor Hours	Equipment Hours	Units	Quantity	RS Means Code
1	**Pre-Construction**											
	Mobilization and Demobilization									LS	1	
2	**Site Preparation**											
	Site Preparation: Clearing and Grubbing	B7	Operator x 1 Laborer x 5	6	Brush Chipper x 1 Crawler Loader x 1 Chainsaws x 2	4	1	1,032	688	AC	17.2	311110100020
	Grub Stumps and Remove	B30	Truck Driver x 2 Laborer x 6	3	Excavator X1 Dump Truck X 2	3	2	258	258	AC	17.2	311110100150
	Construction Soil Erosion and Sediment Controls	B62	Operator x 1 Laborer x 2	3	Skid Steer x 1	1	650	508	169	LF	11,000	312514161000
	Construction Facilities - Office Trailer	-	-	-	-	-	-	-	-	LS	1	15213200400
	Construction Facilities - Storage Trailers (2)	-	-	-	-	-	-	-	-	LS	2	152132000200
	Construction Facilities - Portable Toilets (4)	-	-	-	-	-	-	-	-	MO	29	15433406410
	Dust Control	B59	Truck Driver x 1	1	Water Truck x 1	1	1	6,300	6,300	DAY	630	312323202510
	Haul Road Maintenance	B86A	Operator x 1	1	Grader x 1	1	1	2,520	2,520	DAY	252	312323202600
3	**Dewatering, Unwatering, and Stormwater Management**											
	Unwatering, Dewatering, and Stormwater Management for the Primary Ash Pond	B10K	Operator x 1 Laborer x 0.5	1.5	Pump x 1	1	1	13,275	8,850	DAY	885	312309201100
	Additional Pump				Pump x 1	1	1	0	8,850	DAY	885	312319201120
	Dewatering Sumps Installation	B6	Operator x 1 Laborer x 2	3	Backhoe x 1	1	1	60	20	EA	2	330561101210
4	**Excavation and Disposal**											
	Excavation of Ash Material											
	Excavation of ash material	B14J	Operator x 1 Laborer x 0.5	1.5	Front End Loader x 1	1	3,800.00	11,641	7,761	CY	2,949,000	312316432500
	Hauling material offsite	B34C	Truck Driver x 1	1	Haul Truck x 1	1	165	178,727	178,727	CY	2,949,000	312323203298
	Offsite Disposal Fee	-	-	-	-	-	-	-	-	CY	2,949,000	
5	**Ash Pond Closure**											
	Removal of Outlet Structure	B14A	Operator x 1 Laborer x 0.5	1.5	Excavator x 1	1	0.10	150	100	LS	1	
	Removal of Outlet Pipe	B14A	Operator x 1 Laborer x 0.5	1.5	Excavator x 1	1	0.20	75	50	LS	1	
	Placement of Soil For Positive Drainage											
	Excavation and Loading of Material	B12D	Operator x 1 Laborer x 1	2	Excavator x 1	1	2,040.00	3,088	1,544	CY	315,000	312316420305
	Hauling Material	B34C	Truck Driver x 1	1	Dump Truck x 1	1	215.00	14,651	14,651	CY	315,000	312323203266
	Spreading of Material	B10B	Operator x 1 Laborer x 0.5	1.5	Dozer x 1	1	1,000.00	4,725	3,150	CY	315,000	312323170020
	Finish grading material	B11L	Operator x 1 Laborer x 1	2	Grader x 1	1	1.84	1,871	935	AC	172	312216103300
	Installation of permanent stormwater culvert, riprap apron, and outlet	B14A	Operator x 1 Laborer x 0.5	1.5	Excavator x 1	1	0.10	150	100	LS	1	

6 Perimeter											
Establish Access Roads											
Gravel for Access Road	B32	Operator x 3 Laborer x 1	4	Grader x 1 Roller x 1 Dozer x 1	3	6,000	30	23	CY	4,500	321123230370
Geotextile, 10 oz.	2 Clab	Laborer x 2	2			2,400	111	0	SY	13,350	313219161510
Seed, fertilize, and maintain vegetated surfaces	B65, B66	Operator x 2, Truck Driver x 1, Laborer x 1	4	Loader-Backhoe x 1, Power Mulcher x 1, Truck x 1	3	0	1,500	1500	AC	200	329219130020, 320190130120, 329113160650
7 Engineering and Construction Support											
Final Closure Design, Local Permitting Support, and Bid Support	**BMcD**	Engineering Staff x 4	4	-	0	0.01	4,000	0	LS	1	
Engineering Support and CQA during Construction	**BMcD**	CQA Staff x 1 Engineering Staff x 1	2	Truck x 1	1	0.001	20,000	10,000	LS	1	

	Labor Hours:	Equipment Hours:
	264,672	**246,196**
Contingency (30%)	**344,074**	**320,055**

Notes

1. RS Means used as reference - adjusted based on project size, location, type. Year - 2022, Location - Effingham, IL

2. Grey crews were established based on BMcD relevant project experience.

6. Quantities were developed through conceptual figures and are considered estimates at this stage.

7. It is assumed that no additional dewatering of the bottom ash is required beyond pumping through the sumps.

8. It is assumed that power will be provided by Owner

9. It is assumed that unwatering discharge will be processed through the on-site WWTP and discharged through the NPDES outfall.

12. Tipping Fees based on 2021 EREF Report for MSW landfills in Illinois

13. Unwatering/Dewatering is based on a single pump with a backup pump.

This Engineer's Opinion of Probable Cost is based primarily on our experience and judgement as a professional consultant combined with information from past experience, vendors, and published sources. Since Burns & McDonnell has no control over weather, cost and availability of labor, material and equipment, labor productivity, construction contractor's procedures and methods, unavoidable delays, construction contractor's methods of determining prices, economic conditions, government regulations and laws (including the interpretation thereof), competitive bidding or market conditions and other factors affecting such opinions or projections; consequently, the final project costs will vary from the opinions of costs presented in this study and funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Table 4b: Labor, Equipment, and Mileage Estimate - Closure by Removal -Offsite Landfill- Totals

Item	Quantity	Assumptions
Labor Total Hours	344,074	10-hr days
Duration of Onsite Construction in Days	1,540	Working days, 77 months on-site, 20-working days per month average
Average Daily Crew Size	22	Crew Members
Daily Labor Mobilization Miles	2,408,517	Average of 70 miles round trip per day
Vehicles Miles Onsite	92,636	2 mile round trip from gate to parking 5 miles per day for CQA tech and Construction Supervisor 10% Contingency for site visitors (client and engineering support)
Equipment Mobilization Miles - Unloaded	48,008	Average of 300 miles one way for equipment hauling Average 1 load of equipment 2,000 Equipment working hours
Equipment Mobilization Miles - Loaded	48,008	Average of 300 miles one way for equipment hauling Average 1 load of equipment per working week
Daily Equipment Miles Onsite	1,540,000	Average of ~20 crew members running equipment Assume 50 miles per piece of equipment (average 5 mph, 10-hrs per day)
Onsite Haul Truck Miles - Unloaded	0	34 CY Haul Truck 1 mile cycle
Onsite Haul Truck Miles - Loaded	0	34 CY Haul Truck 1 mile cycle
Offsite Haul Truck Miles - Unloaded	1,435,909	16.5 CY Dump Truck 15 mile cycle for CCR, 10-mile cycle for soils
Offsite Haul Truck Miles - Loaded	1,435,909	16.5 CY Dump Truck 15 mile cycle for CCR, 10-mile cycle for soils
Estimated Total	**7,008,987**	**miles**

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APPENDIX C - FINAL CLOSURE PLANS AND MATERIAL SPECIFICATIONS

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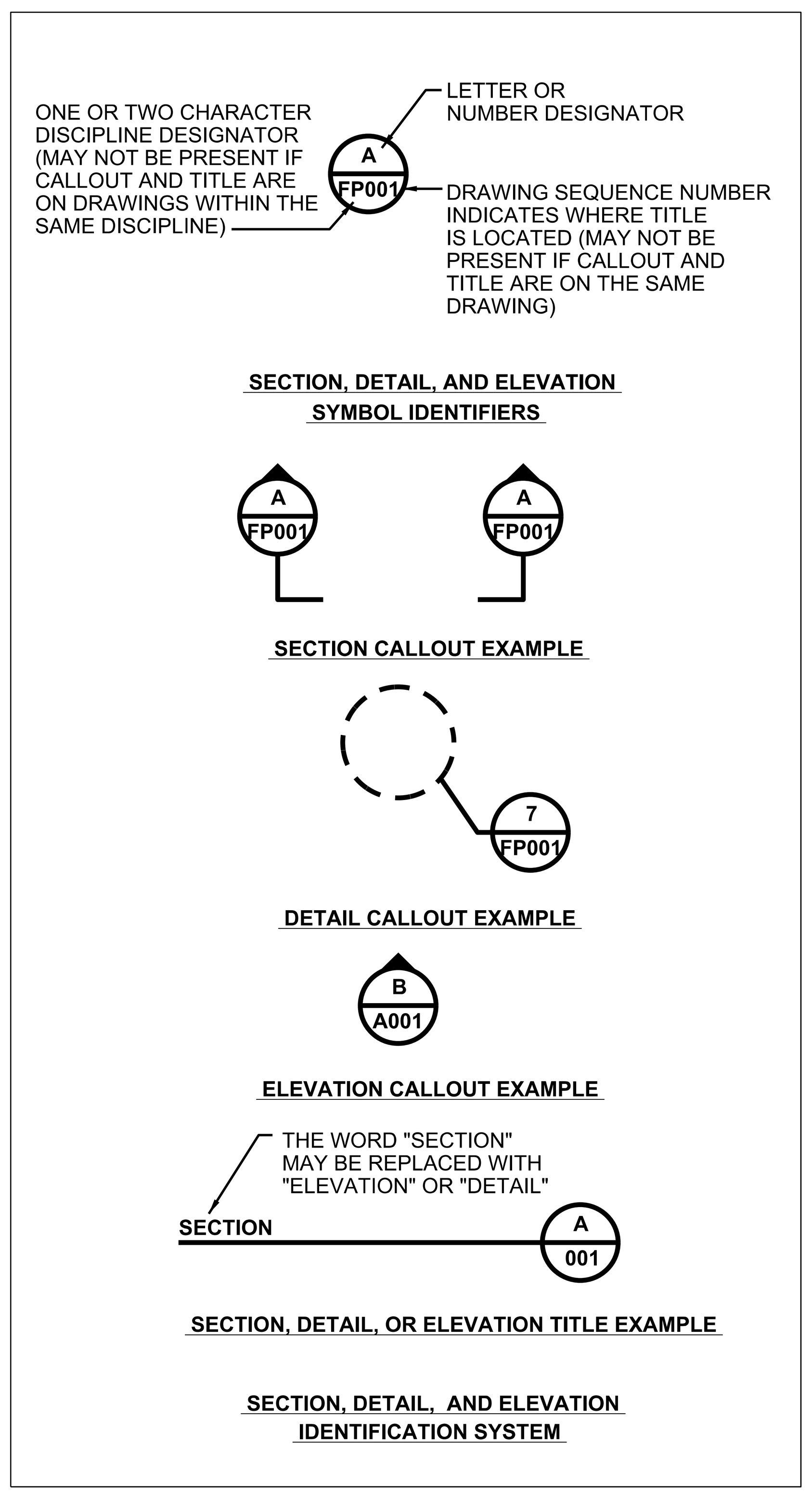
KINCAID ASH POND
SOUTH FORK TOWNSHIP, ILLINOIS

AUGUST 2022

BMCD PROJECT # 132803

Contract Drawings



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B	07/06/22	RNO	MDB	ISSUED FOR OWNER REVIEW	E	07/28/22	RNO	MDB	ISSUED FOR OWNER REVIEW
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KINCAID ASH POND

Cover - Index

LEGEND

NEW		EXISTING
	RAILROAD	
	ROADS	
750	CONTOURS	750
	✳TOP OF SLOPE / ✳TOE OF SLOPE	
	SWALE	
	FLOWLINE	
ST ST-1 ST	STORM SEWER	ST ST
ST ST-2 ST	STORM SEWER W/END SECTIONS	ST ST
CB-1	STORM SEWER	
	DEMOLITION	
	CRUSHED ROCK	
	RIPRAP	
	CONCRETE	
	ASPHALT	
	TOPSOIL & SEED	
	FENCES	
	SILT FENCE	
℄	PROPERTY LINE	℄
	GUARDRAIL	
	STRUCTURES	
	SURVEY MONUMENTS	BM
	MONITORING WELLS	MW-XX
	PROPOSED LIMIT OF FINAL COVER/ ANCHOR TRENCH ALIGNMENT	

✳ TOP OR TOE OF SLOPE TO MATCH EXIST. GRADE UNLESS AN ELEVATION OR SLOPE IS INDICATED.

ALL SYMBOLS ARE STANDARD WITHOUT RESPECT TO CONTRACTS.

ABBREVIATIONS

ABBREVIATION	TERM	ABBREVIATION	TERM
@	AT	M.O.	MID-ORDINATE
AHD	AHEAD	MW	MONITORING WELL
ASPH	ASPHALT	N	NORTH
AUX	AUXILIARY	NO	NUMBER
BK	BACK	OD	OUTSIDE DIAMETER
BLDG	BUILDING	OPNG	OPENING
BM	BENCHMARK	±	PLUS OR MINUS
BOT	BOTTOM	PC	POINT OF CURVE
CB	CATCH BASIN	PCC	PORTLAND CEMENT CONCRETE
C TO C	CENTER TO CENTER	PI	POINT OF INTERSECTION
CL	CENTERLINE	PL	PROPERTY LINE
CHDPE	CORRUGATED HIGH DENSITY POLYETHYLENE	PT	POINT OF TANGENT
CJ	CONSTRUCTION JOINT	P.R.C.	POINT OF REVERSE CURVE
CMAP	CORRUGATED METAL ARCH PIPE	P.V.C.	POINT OF VERTICAL CURVE
CMP	CORRUGATED METAL PIPE	P.V.I.	POINT OF VERTICAL INTERSECTION
CONC	CONCRETE	P.V.R.C.	POINT OF VERTICAL REVERSE CURVE
CPT	CORRUGATED POLYETHYLENE TUBING	P.V.T.	POINT OF VERTICAL TANGENT
DBL	DOUBLE	PZ	PIEZOMETER
DET	DETAIL	R	RADIUS
DI	DROP INLET	RD	ROAD
DIA	DIAMETER	RPT	RADIUS POINT
DWG	DRAWING	RCP	REINFORCED CONCRETE PIPE
ECB	EXISTING CATCH BASIN	RR	RAILROAD
EDB	ELECTRICAL DUCT BANK	RT	RIGHT
E	EAST	ROW	RIGHT-OF-WAY
EF	EACH FACE	S	SOUTH
EJ	EXPANSION JOINT	SLP	SLOPE
EL	ELEVATION	SHLDR	SHOULDER
EMH	ELECTRICAL MANHOLE	STD	STANDARD
EQN	EQUATION	ST	STORM SEWER
EXIST	EXISTING	STA	STATION
EW	EACH WAY	SWG	SWING
FBD	FLAT BOTTOM DITCH	T&B	TOP AND BOTTOM
FLL	FLOWLINE	TEMP	TEMPORARY
FO	FIBER OPTIC	TOA	TOP OF ASPHALT
GA	GAGE	TOC	TOP OF CONCRETE
GALV	GALVANIZED	TO GRATING	TOP OF GRATING
HDPE	HIGH DENSITY POLYETHYLENE	TOM	TOP OF MANHOLE
HORIZ	HORIZONTAL	TOP	TOP OF PAVEMENT
HP	HIGH POINT	TOR	TOP OF RAIL
HWY	HIGHWAY	TOSB	TOP OF SUBBALLAST
ID	INSIDE DIAMETER	TOSG	TOP OF SUBGRADE
IF	INSIDE FACE	TYP	TYPICAL
INTSCT	INTERSECTION	UON	UNLESS OTHERWISE NOTED
INVT EL	INVERT ELEVATION	VC	VERTICAL CURVE
L	LONG	VERT	VERTICAL
LCP	LEACHATE COLLECTION PIPE	W	WEST
LT	LEFT	W/	WITH
MAX	MAXIMUM	W/O	WITH OUT
MH	MANHOLE	WWF	WELDED WIRE FABRIC
MIN	MINIMUM	XPW	EXISTING POTABLE WATER WELL
MISC	MISCELLANEOUS		

NOTES:

1. ALL ABBREVIATIONS ARE BURNS & McDONNELL STANDARDS WITHOUT RESPECT TO CONTRACTS.
2. ABBREVIATIONS ARE APPLICABLE TO ALL DWGS.

GENERAL NOTES:

1. SURVEY COORDINATES ARE BASED ON ILLINOIS STATE PLANE NAD83 WEST ZONE, AND DATUM BASED ON NAVD88.

VICINITY MAP
NOT TO SCALE

NORTH

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KINCAID ASH POND
LEGEND, ABBREVIATIONS, VICINITY MAP & GENERAL NOTES

project 132803 | contract 8110

drawing CS001 — rev. E

sheet 1 of 1 sheets

file 132803CS001.DGN

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KINCAID ASH POND
EXISTING CONDITIONS PLAN

project: 132803
contract: 8110
drawing: **CS002**
rev.: **E**
sheet 1 of 1 sheets
file 135946CS002.DGN

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NOTES:

1. UTILITY EASEMENT DELINEATION DESCRIPTION CAN BE FOUND ON DOCUMENT NO. 1998R1245.
2. EXISTING CONTOURS SHOWN ARE FROM TOPOGRAPHY AND BATHYMETRY SURVEY PROVIDED BY INGENAE DATED 2/226/2021.
3. EXISTING TRANSMISSION LINES WILL BE RELOCATED, RAISED, OR MODIFIED TO ALLOW FOR CONSTRUCTION ACCESS.
4. THIS DRAWING REPRESENTS THE CONFIGURATION OF THE 84-ACRE CLOSE-IN-PLACE CONFIGURATION, BUT DOES NOT FULLY DEPICT THE INTERIM CONDITIONS NEEDED TO ACHIEVE THIS CONFIGURATION. THE PHASE 2 GRADING PLAN (SEE DWG CG002) REPRESENTS THE FINAL CLOSE-IN-PLACE CONFIGURATION, INCLUDING THE TOTAL QUANTITY OF CCR MATERIAL TO BE CONSOLIDATED WITHIN THE 84-ACRE CLOSE-IN-PLACE AREA.
5. AREA OF POTENTIALLY SATURATED CCR. SATURATED CCR UNDER LOW PERMEABILITY DIKE WILL BE REMOVED AND REPLACED WITH LOW PERMEABLE SOIL.

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KINCAID ASH POND
CONSOLIDATED GRADING PLAN
PHASE 1

project: 132803
contract: 8110
drawing: CG001 — rev. E
sheet 1 of 1 sheets
file 135946CG001.DGN

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NOTES:

1. ASSUMED BOTTOM OF CCR SURFACE BASED ON TOPOGRAPHIC SURFACE FILE BOA_v5A.DWG PROVIDED BY RAMBOLL ON MARCH 14, 2022.
2. UTILITY EASEMENT DELINEATION DESCRIPTION CAN BE FOUND ON DOCUMENT NO. 1998R1245.
3. EXISTING CONTOURS SHOWN ARE FROM TOPOGRAPHY AND BATHYMETRY SURVEY PROVIDED BY INGENAE DATED 2/26/2021.
4. EXISTING PIPES THROUGH DIKES TO BE ABANDONED IN PLACE AND FILLED WITH NON-SHRINK GROUT.
5. SHEET PILING INSTALLED IN INITIAL PHASE TO REMAIN IN PLACE.
6. EXISTING TRANSMISSION LINES WILL BE RELOCATED, RAISED, OR MODIFIED TO ALLOW FOR CONSTRUCTION ACCESS.
7. AREA OF POTENTIALLY SATURATED CCR. SATURATED CCR UNDER COMPACTED LOW PERMEABLE SOIL DIKE WILL BE REMOVED AND REPLACED WITH LOW PERMEABLE SOIL.

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CONSOLIDATED GRADING PLAN
PHASE 2

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drawing CG002 — rev. E
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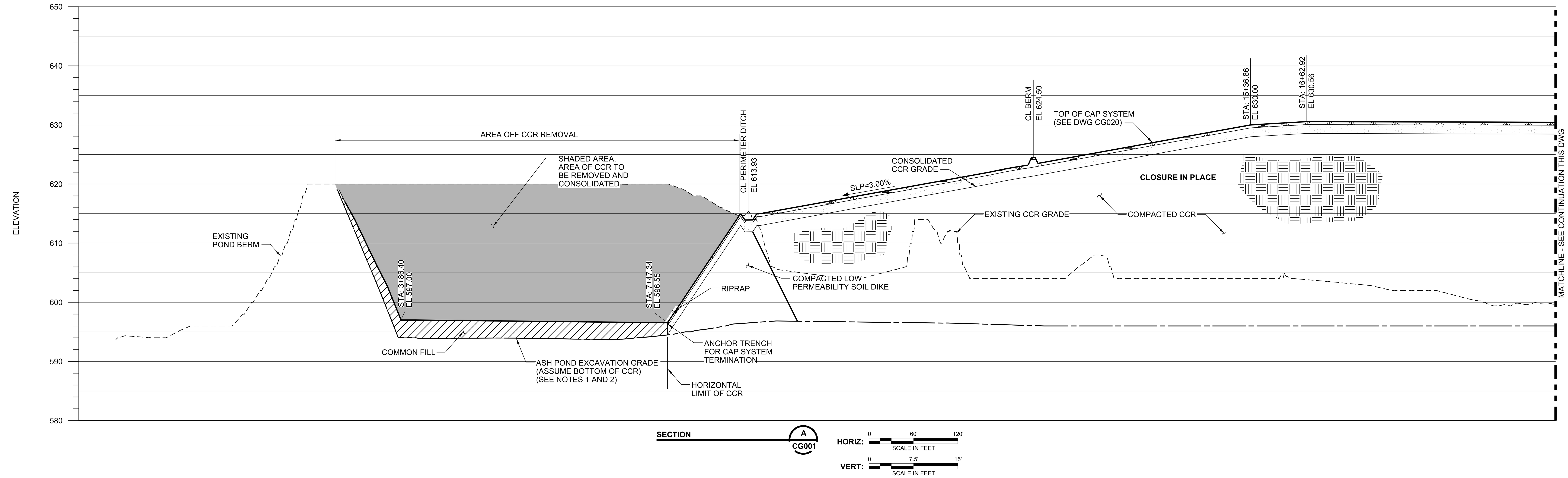
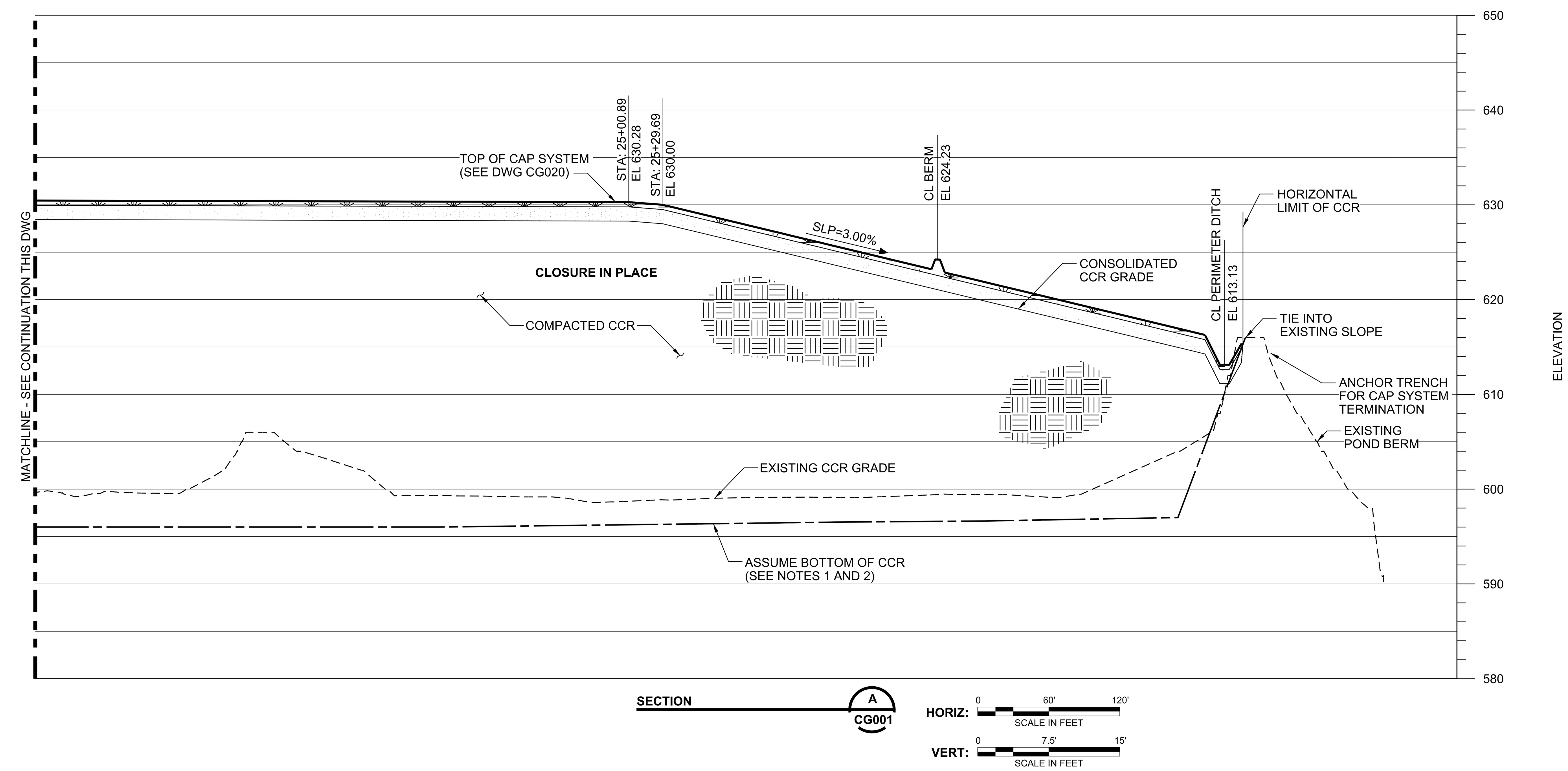
file 135946CG002.DGN





NOTES:

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2. VERTICAL EXCAVATION LIMITS SHOWN DO NOT ACCOUNT FOR OVER-EXCAVATION OF SUBSOILS.

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KINCAID ASH POND
CONSOLIDATED GRADING SECTIONS
PHASE 1
SHEET 1

project: 132803 — contract: 8110

drawing: **CG003** — rev. **E**

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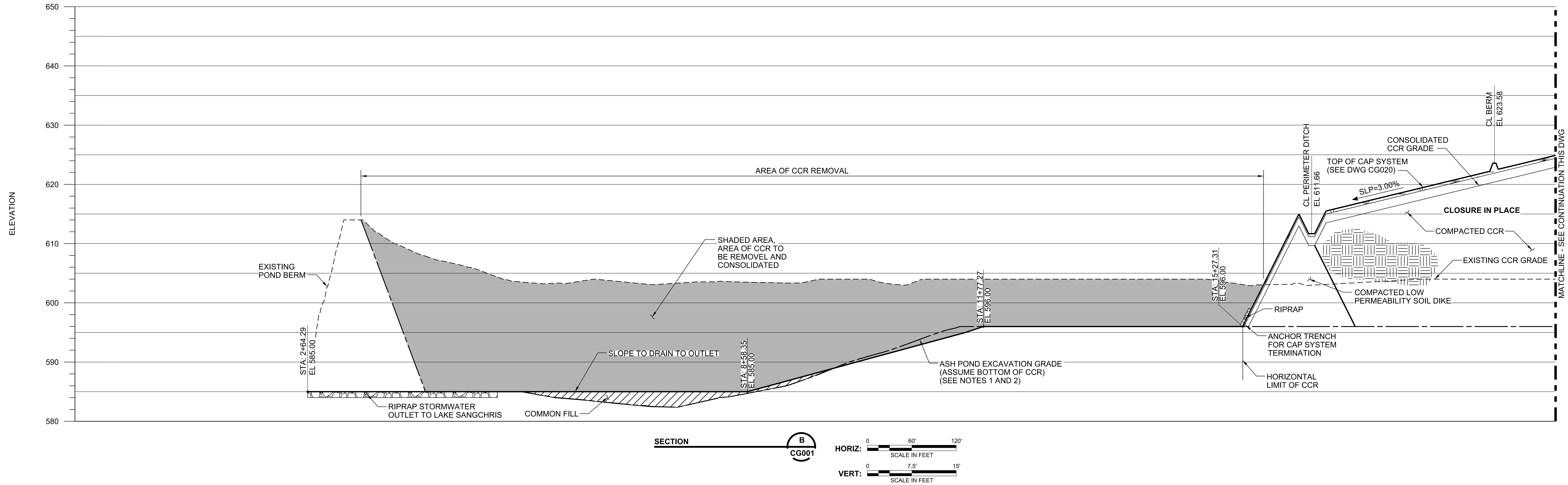

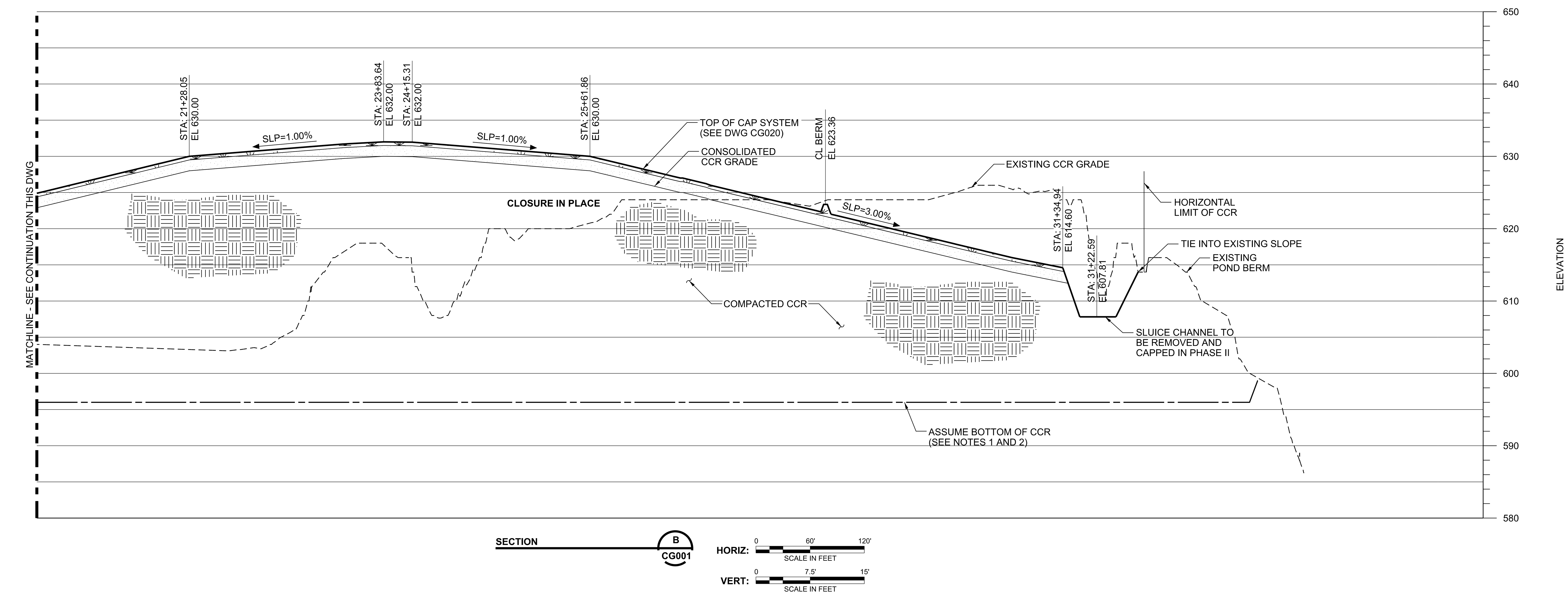

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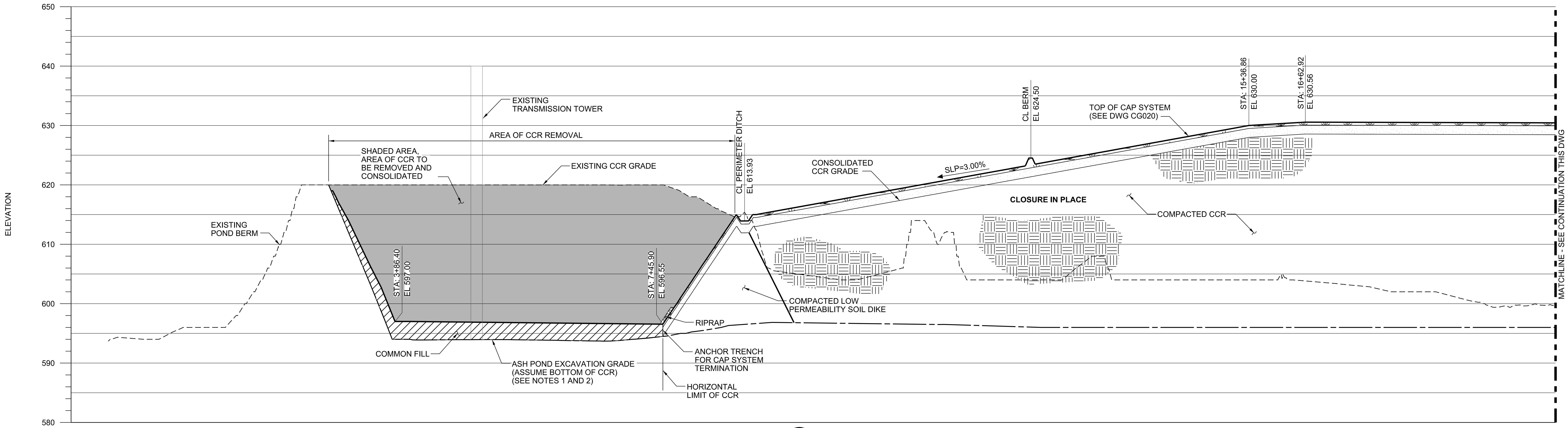

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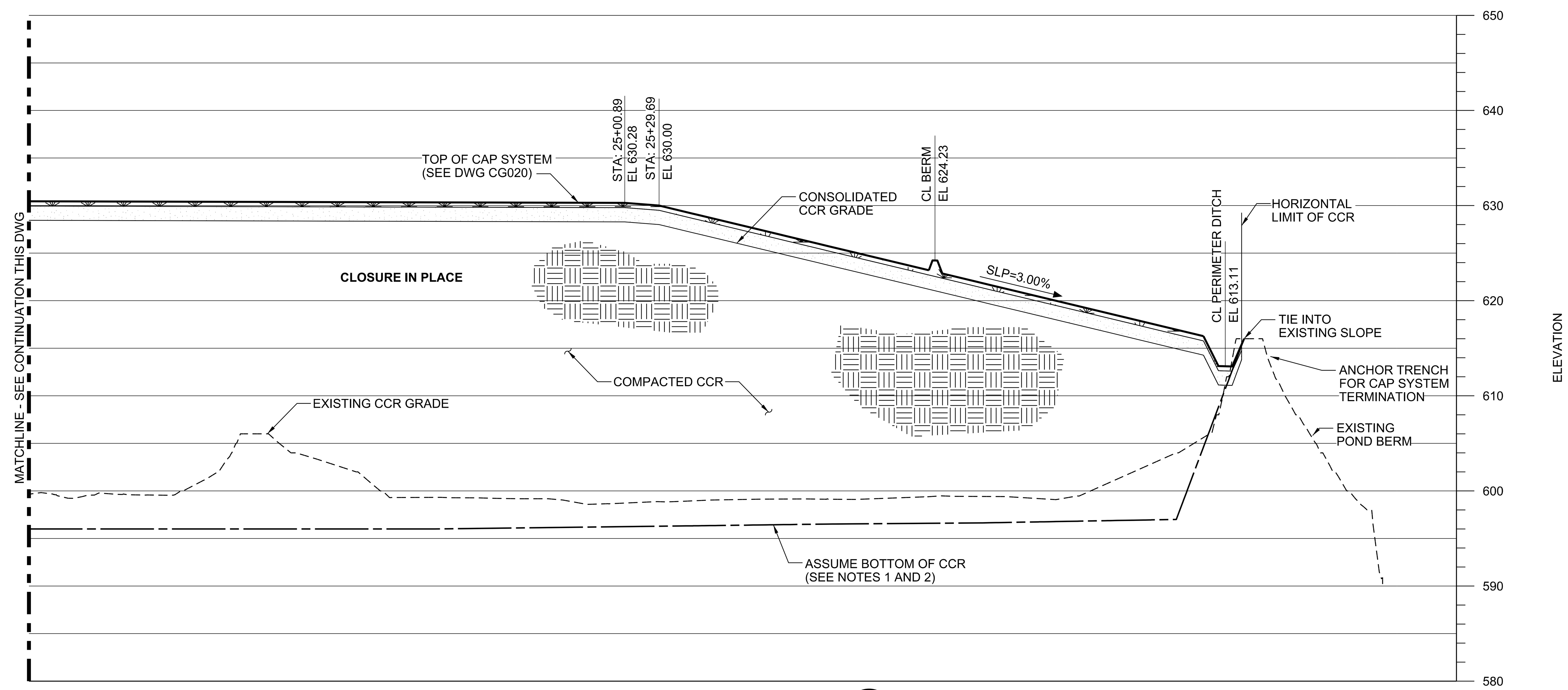
HORIZ: 0 60' 120' SCALE IN FEET

VERT: 0 7.5' 15' SCALE IN FEET



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CONSOLIDATED GRADING SECTIONS
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SHEET 1

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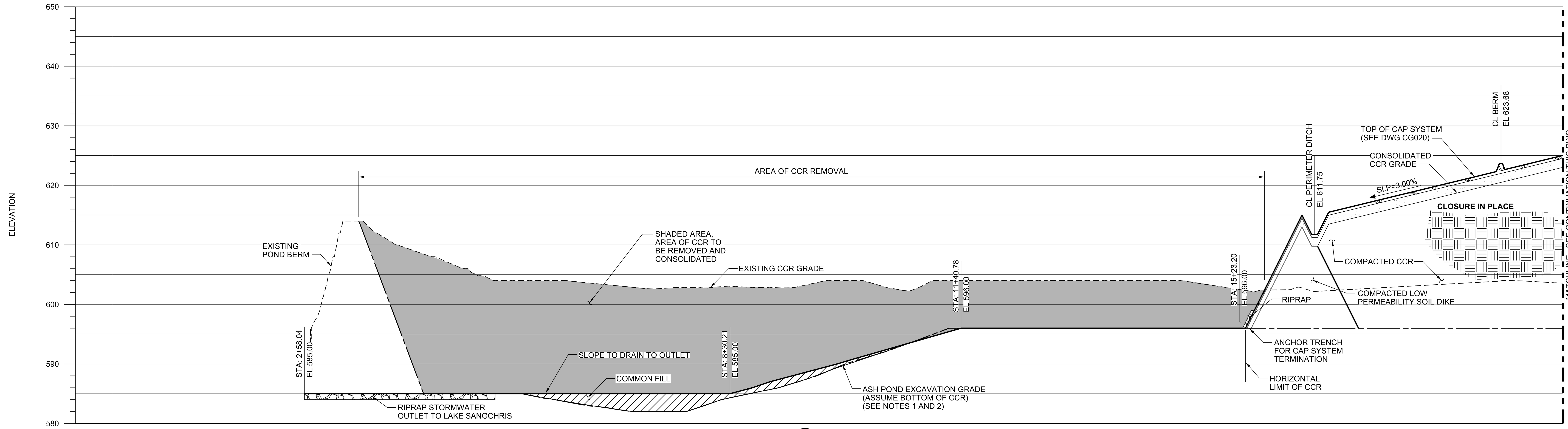

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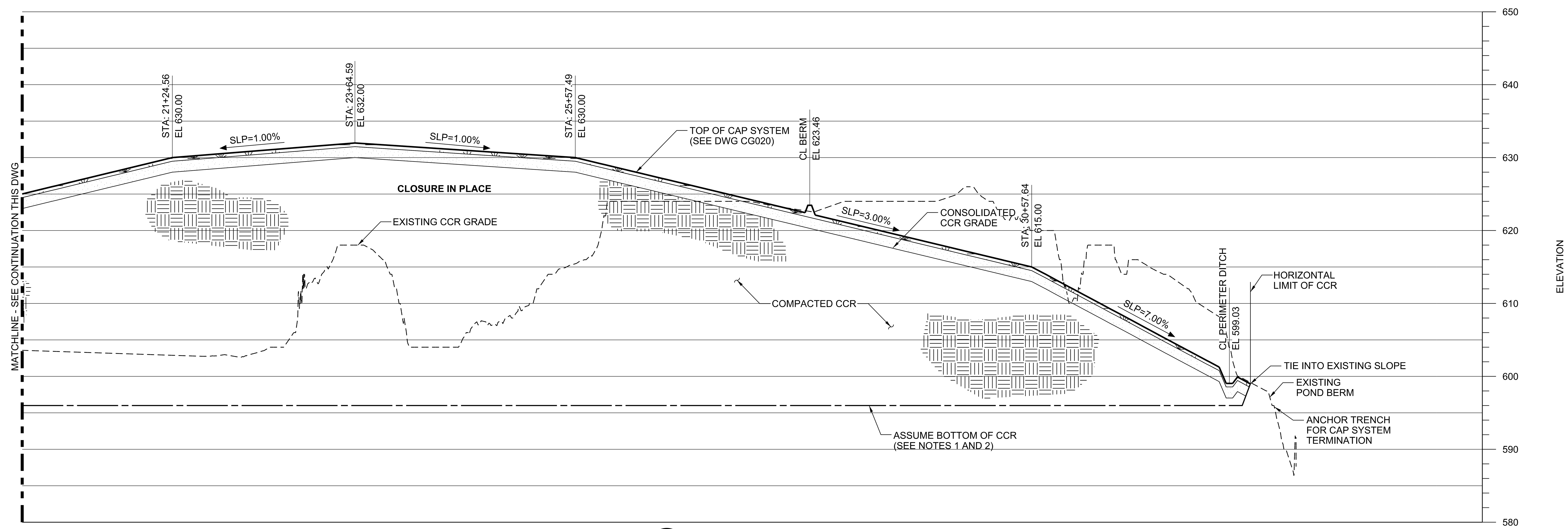

SECTION D / CG002

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CONSOLIDATED GRADING SECTIONS
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SHEET 2

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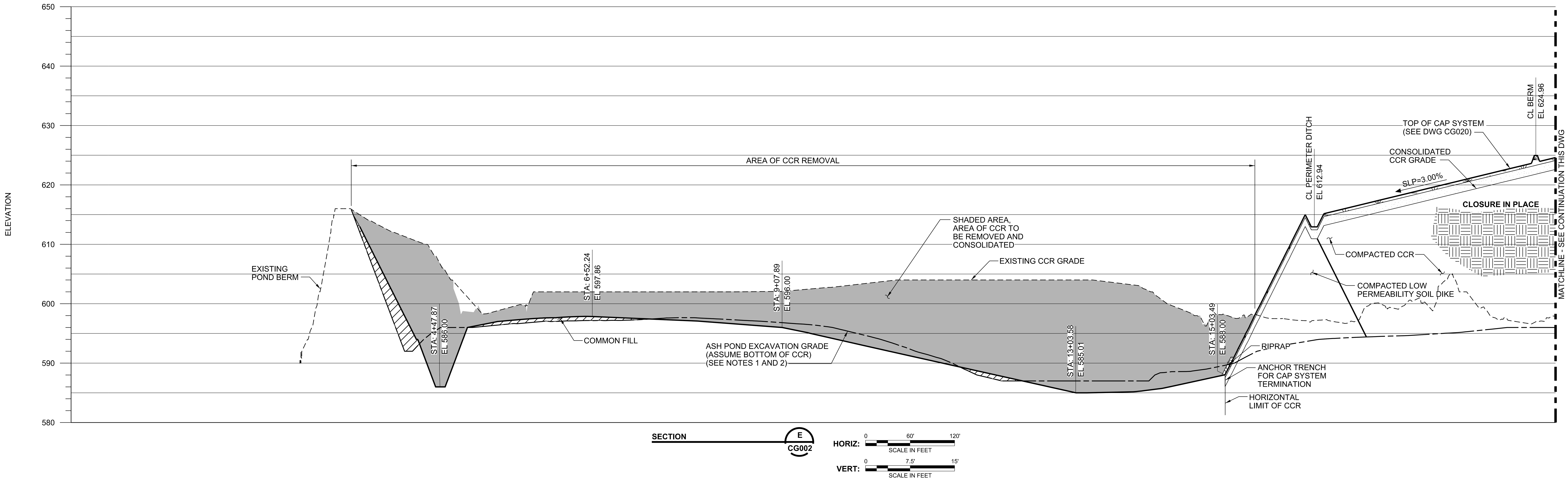

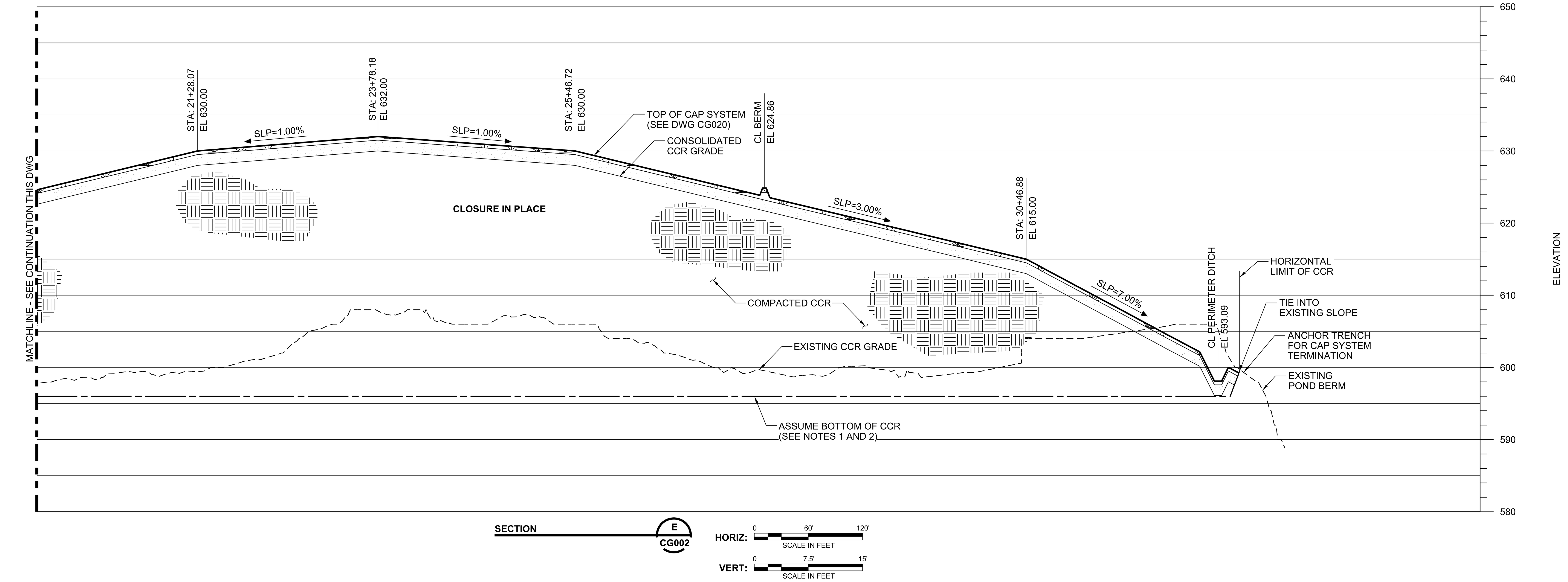

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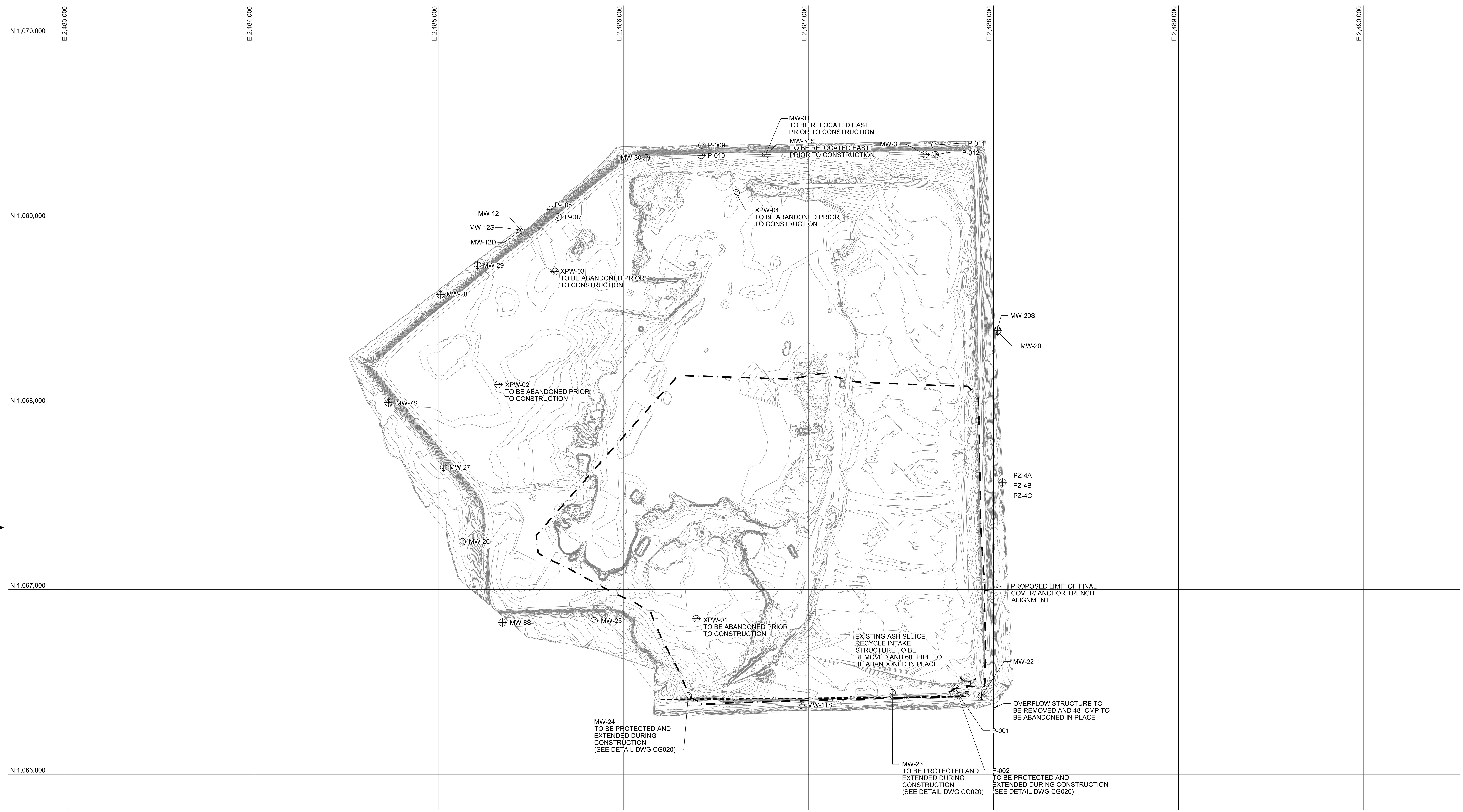

NOTES:

1. EXISTING CONTOURS SHOWN ARE FROM TOPOGRAPHY AND BATHYMETRY SURVEY PROVIDED BY INGENAE DATED 2/226/2021.
2. ADDITIONAL WELLS MAY BE ADDED OR ABANDONED IN FINAL DESIGN.
3. UNLESS OTHERWISE NOTED, ALL EXISTING WELLS AND PIEZOMETERS SHALL BE PRESERVED AND PROTECTED DURING CONSTRUCTION.

NORTH

0 200' 400'
SCALE IN FEET

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no.	date	by	ckd	description
E	07/28/22	RNO	MDB	ISSUED FOR PERMIT
D	07/20/22	RNO	MDB	ISSUED FOR OWNER REVIEW
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A	05/03/22	RNO	MDB	ISSUED FOR OWNER REVIEW

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Firm Reg. No. 184.001310-0006

designed R. OWENS
detailed S. NICHOLS

Luminant

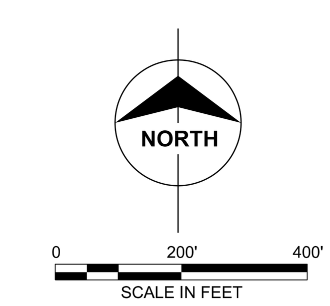
SOUTH FORK TOWNSHIP, ILLINOIS

KINCAID ASH POND
OUTFALL AND WELL ABANDONMENT PLAN

project 132803 | contract 8110
drawing **CG008** rev. **E**
sheet 1 of 1 sheets
file 135946CG008.DGN

PV Plant: Kincaid CCR Pond
Location: Illinois, United States
UTM convergence: -1.5897 °
Altitude: 602.62 ft
Suitable area: 96.6 acre
Perimeter fence: 2.6 mi

Rated Power: 28.5 MW
Peak Power: 33.6 MW
Ratio DC/AC: 1.18
Inverter output power factor: 0.900
Structure: Generic - 2V
PV Module: First Solar FS-6480A-C April2021 (69960 units)
Inverter: Sungrow SG1100UD (25 units)
Power Station: 1265.0 kVA, 0.63/34.5kV
Number of power stations: 25
Pitch distance: 22.09 ft
Modules per string: 5
Fixed structure tilt: 20.0 °



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no.	date	by	ckd	description
B	07/28/22	RNO	MDB	ISSUED FOR PERMIT
A	07/20/22	RNO	MDB	ISSUED FOR OWNER REVIEW

no.	date	by	ckd	description

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Firm Reg. No. 184.001310-0006

designed: R. OWENS
detailed: S. NICHOLS

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SOUTH FORK TOWNSHIP, ILLINOIS

KINCAID ASH POND
PROPOSED PANEL LAYOUT PLAN

project: 132803
contract: 8110
drawing: **CG009 — B** rev.
sheet 1 of 1 sheets
file 135946CG009.DGN

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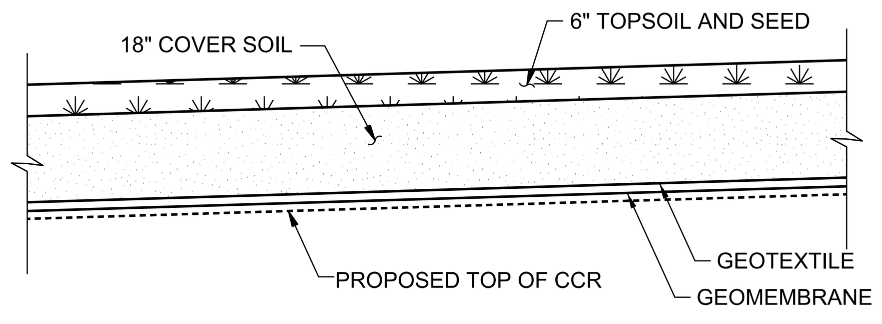
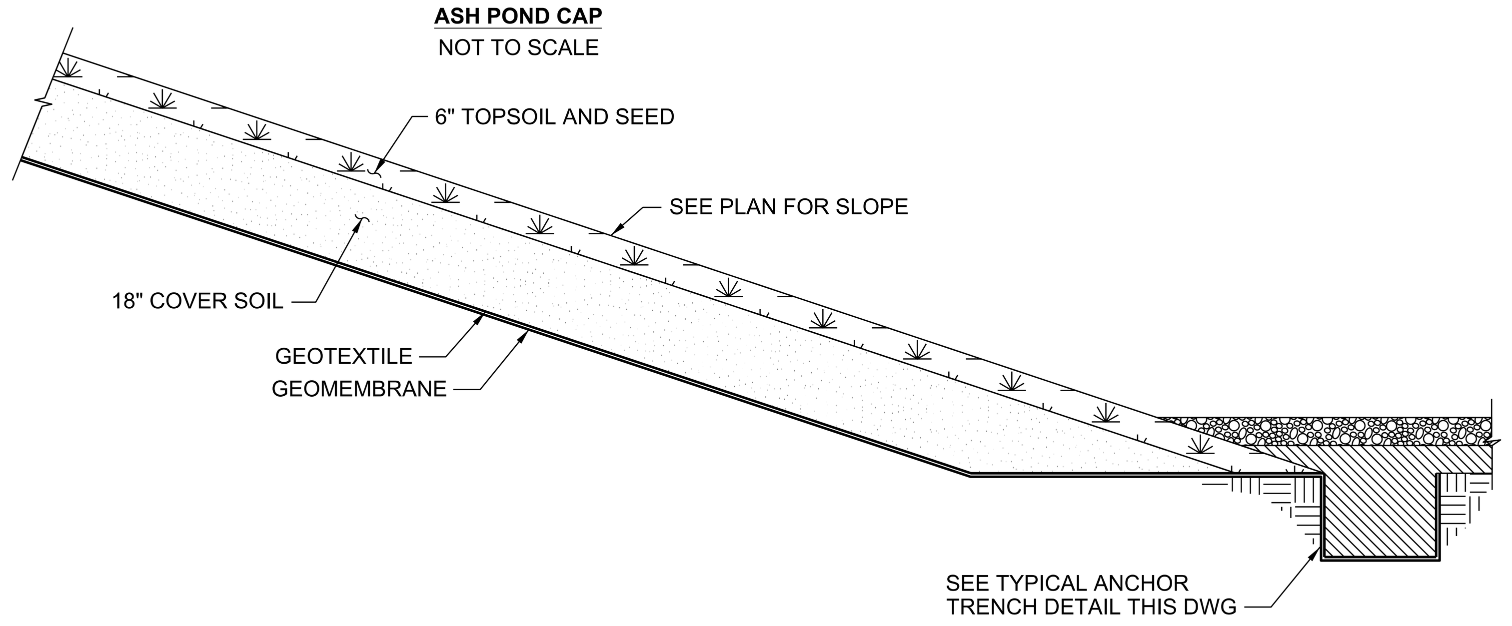
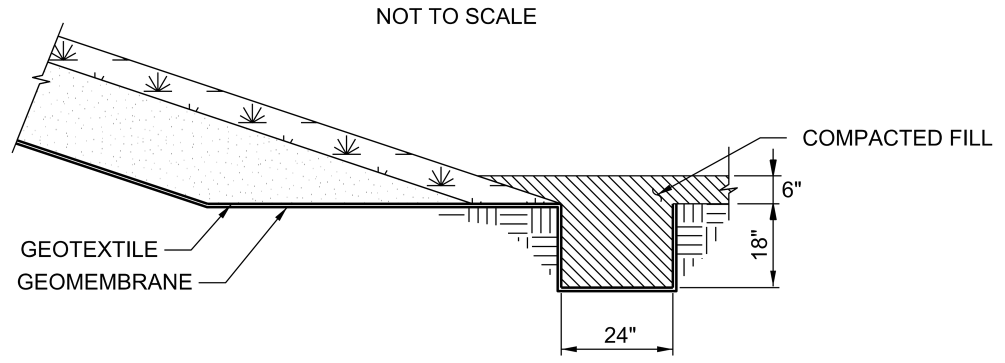


ASH POND CAP
NOT TO SCALE

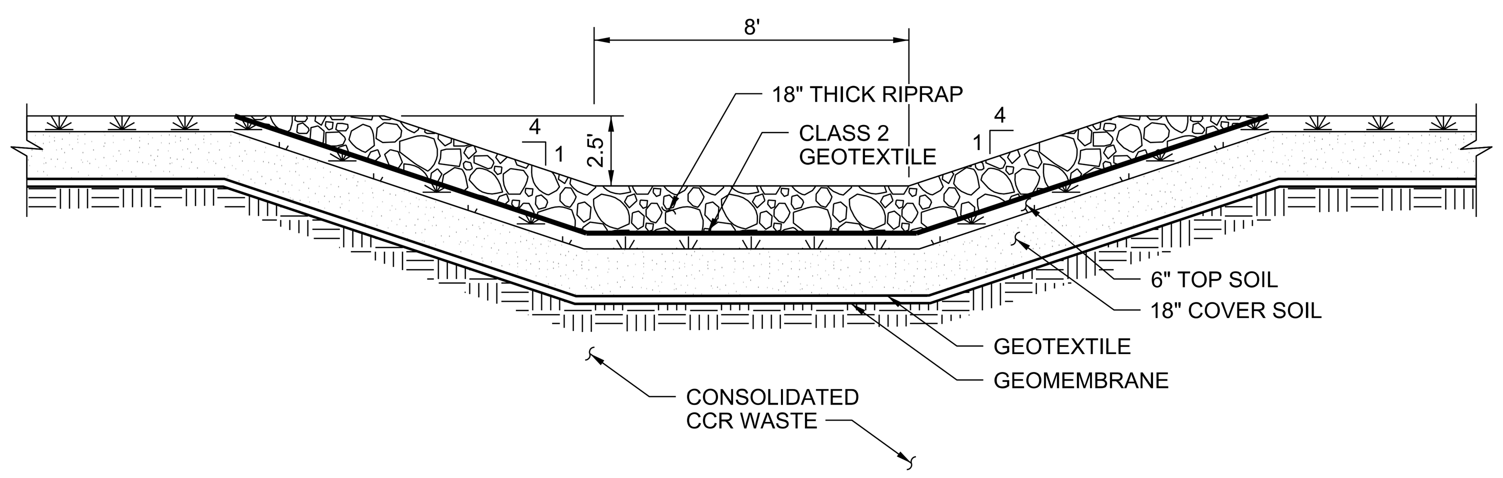


ASH POND CAP SYSTEM
NOT TO SCALE

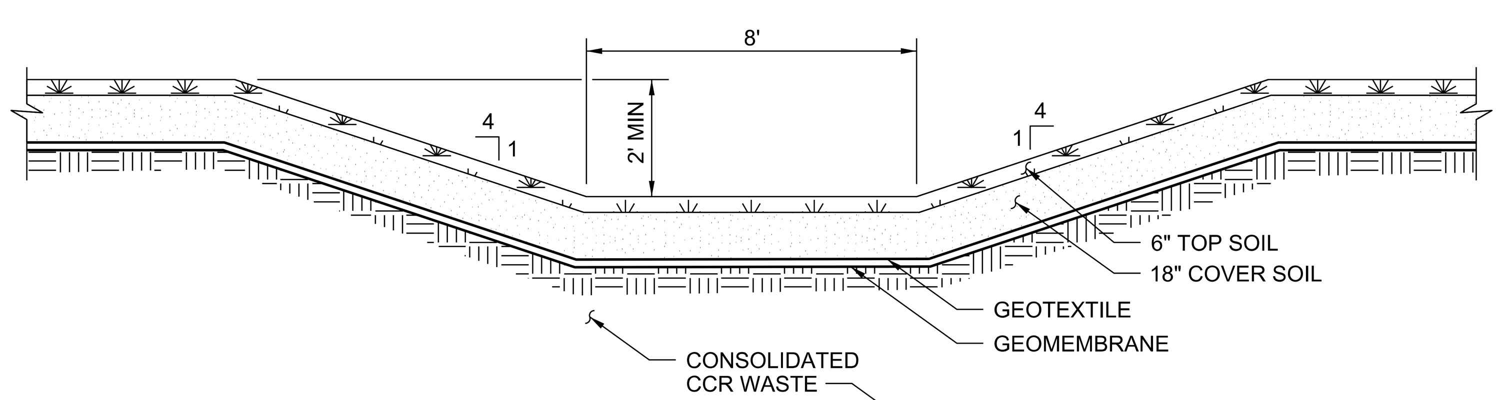


TYPICAL ANCHOR TRENCH DETAIL
NOT TO SCALE

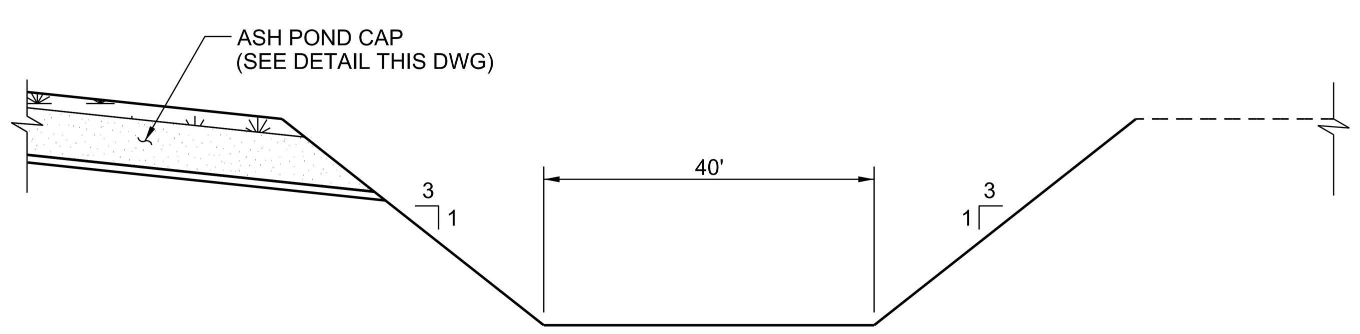
DETAIL (1)
NOT TO SCALE



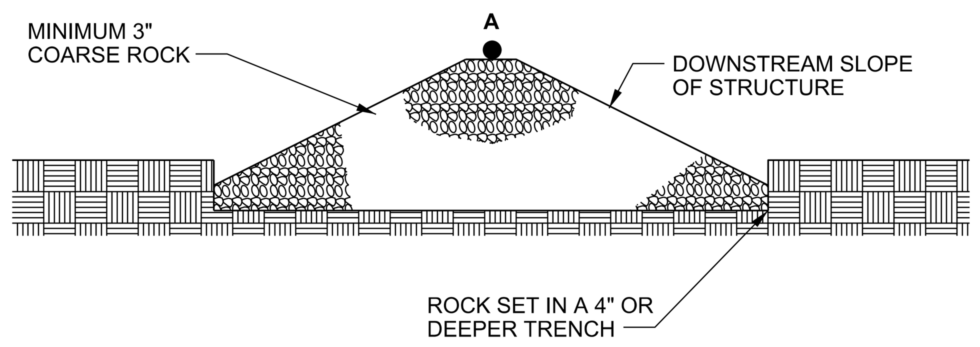
RIPRAP LETDOWN CHANNEL
NOT TO SCALE



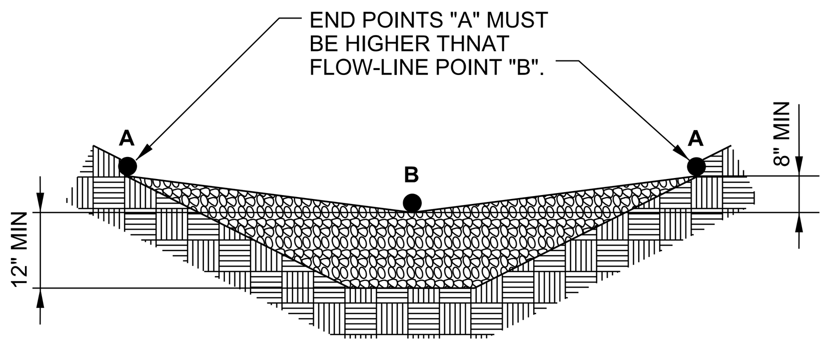
PERIMETER DITCH
NOT TO SCALE



TYPICAL SLUICE CHANNEL
NOT TO SCALE

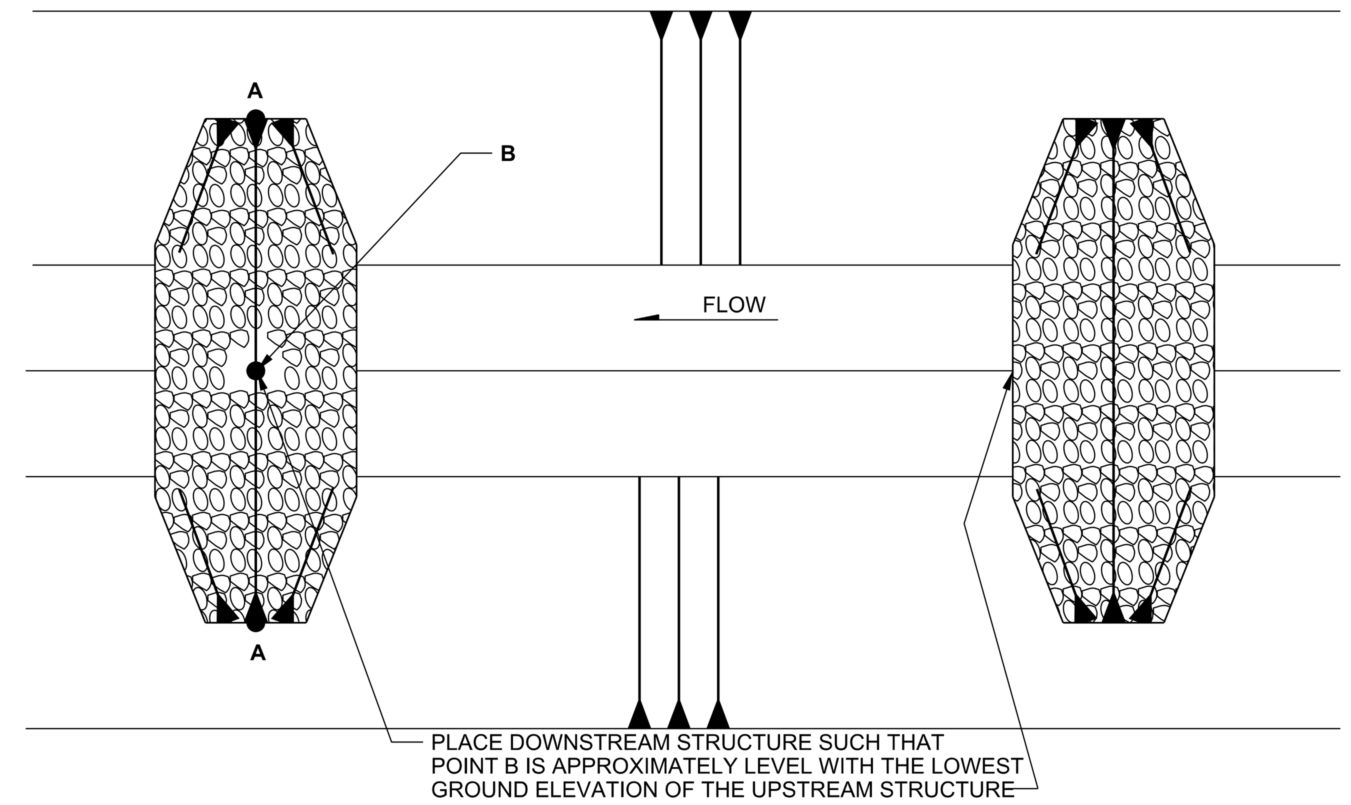


ROCK CHECK DAM IN DITCH SIDE VIEW
NOT TO SCALE

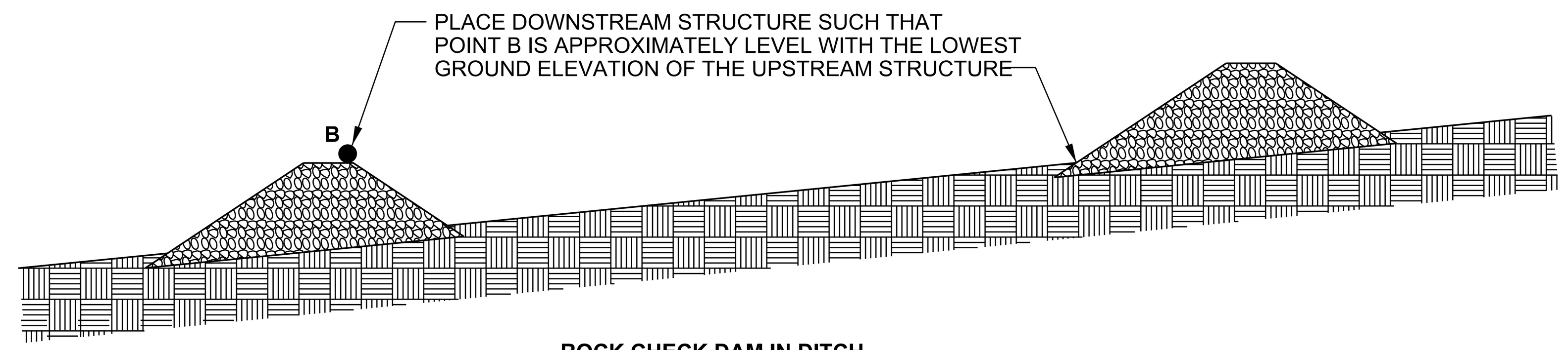


ROCK CHECK DAM IN DITCH FRONT VIEW
NOT TO SCALE

D50 OF ROCK (MM)	SUGGESTED ROCK DIAMETER AND FLOW DEPTHS DOWNSTREAM FACE OF STRUCTURE					
	35%	30%	25%	20%	15%	10%
	MAXIMUM FLOW DEPTH ON ROCK (MM)					
75	150	180	200	250	330	500
150	300	360	400	500	660	1000

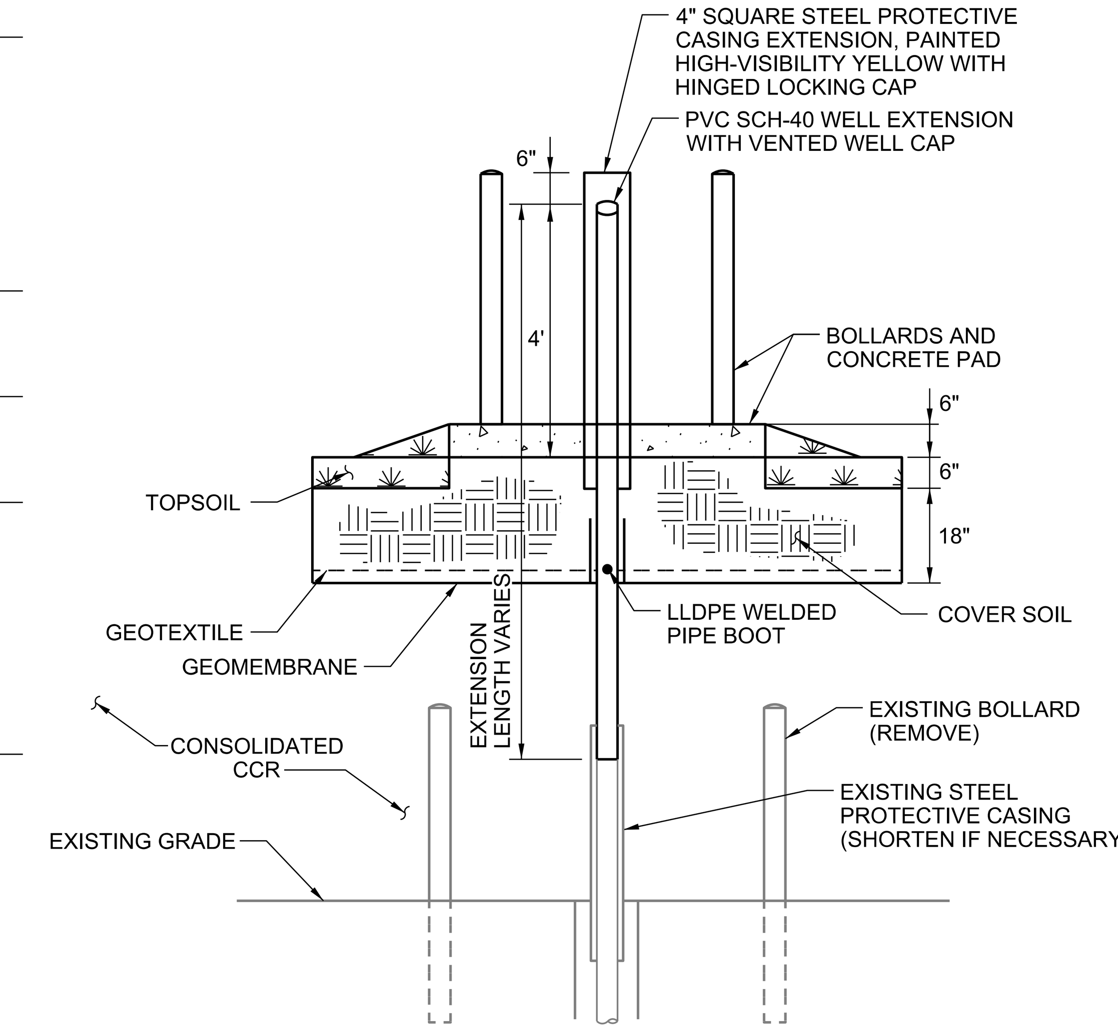


ROCK CHECK DAM IN DITCH PLAN VIEW
NOT TO SCALE

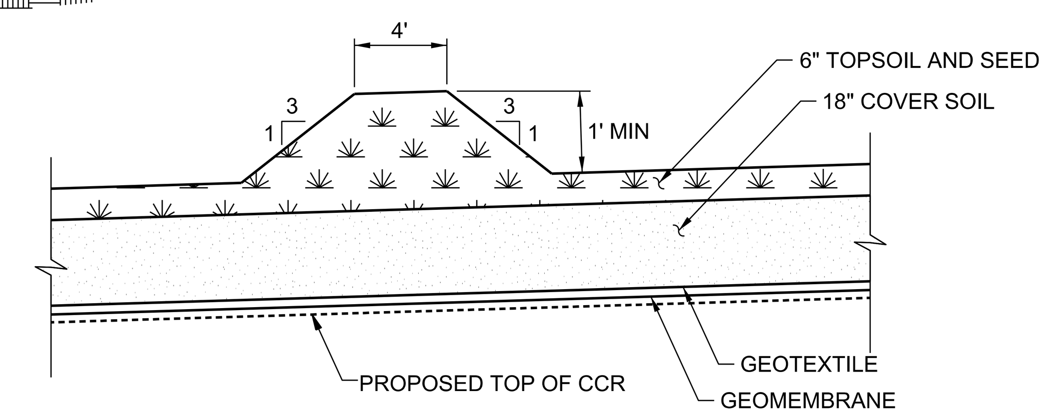


ROCK CHECK DAM IN DITCH FLOWLINE PROFILE
NOT TO SCALE

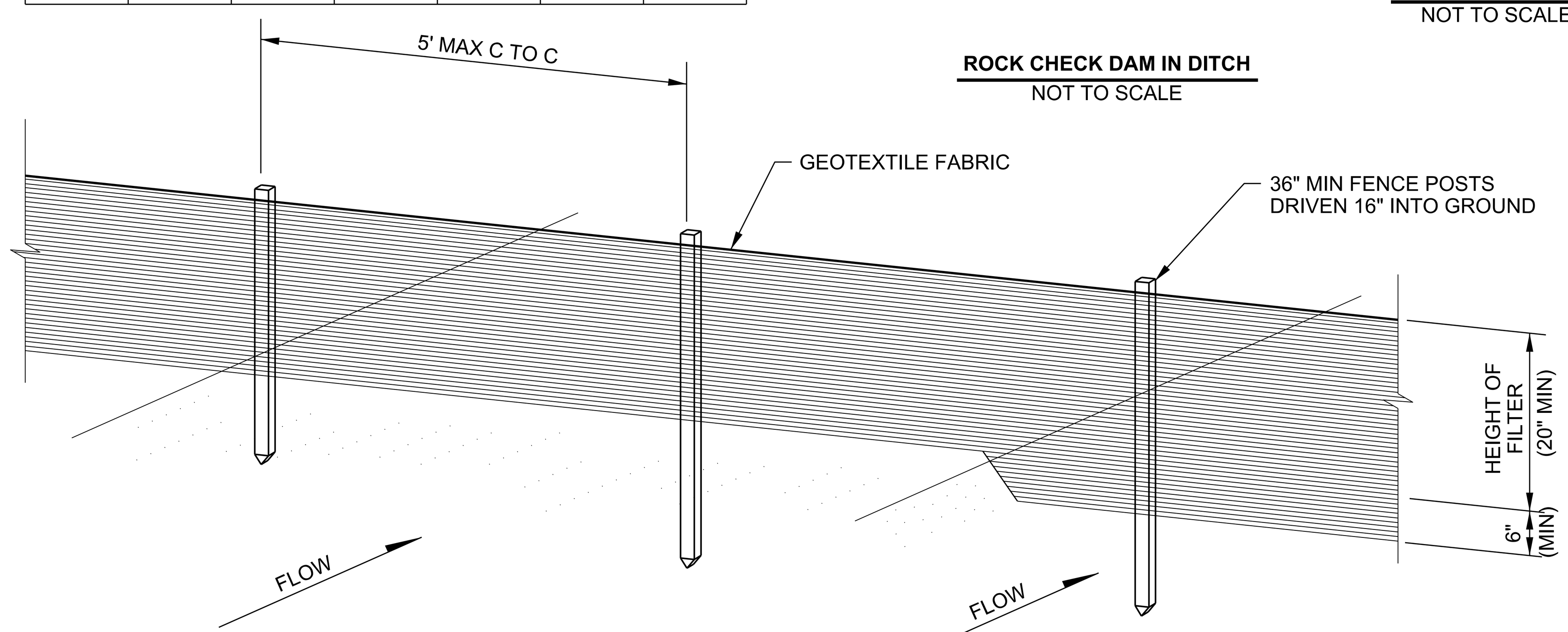
ROCK CHECK DAM IN DITCH
NOT TO SCALE



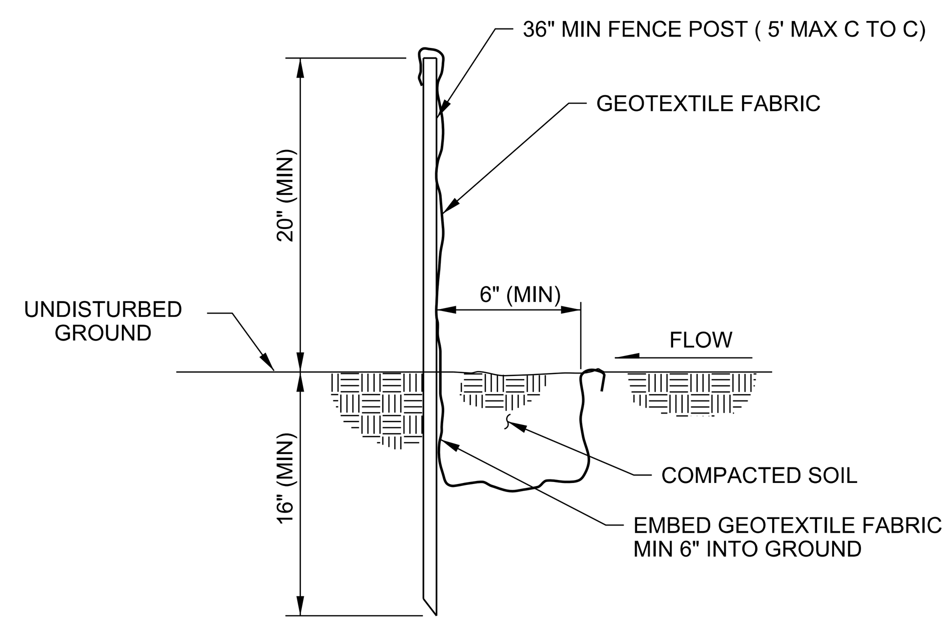
MONITORING WELL EXTENSION
NOT TO SCALE



TYPICAL CAP SYSTEM STORMWATER BERM
NOT TO SCALE



PERSPECTIVE VIEW



SILT FENCE TRENCH INSTALLATION DETAIL
NOT TO SCALE

CONSTRUCTION NOTES FOR FABRICATED SILT FENCE

1. GEOTEXTILE FABRIC TO BE FASTENED SECURELY TO TO FENCE POSTS WITH STAPLES.
2. WHEN TWO SECTIONS OF GEOTEXTILE FABRIC ADJOIN EACH OTHER THEY SHALL BE OVER-LAPPED BY SIX INCHES AND FOLDED.
3. MAINTENANCE SHALL BE PERFORMED AS NEEDED AND MATERIAL REMOVED WHEN "BULGES" DEVELOP IN THE SILT FENCE.

POSTS: STEEL EITHER "T" OR "U" TYPE OR 2" HARDWOOD.

GEOTEXTILE FABRIC: FILTER X, MIRAFI 100X, STABILINKA T140N OR APPROVED EQUAL.

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E	07/28/22	RNO	MDB	ISSUED FOR PERMIT
D	07/20/22	RNO	MDB	ISSUED FOR OWNER REVIEW
C	07/11/22	RNO	MDB	ISSUED FOR OWNER REVIEW
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KINCAID ASH POND
DETAILS

project 132803 | contract 8110
drawing CG020 — rev. E
sheet 1 of 1 sheets
file 132803CG020.DGN

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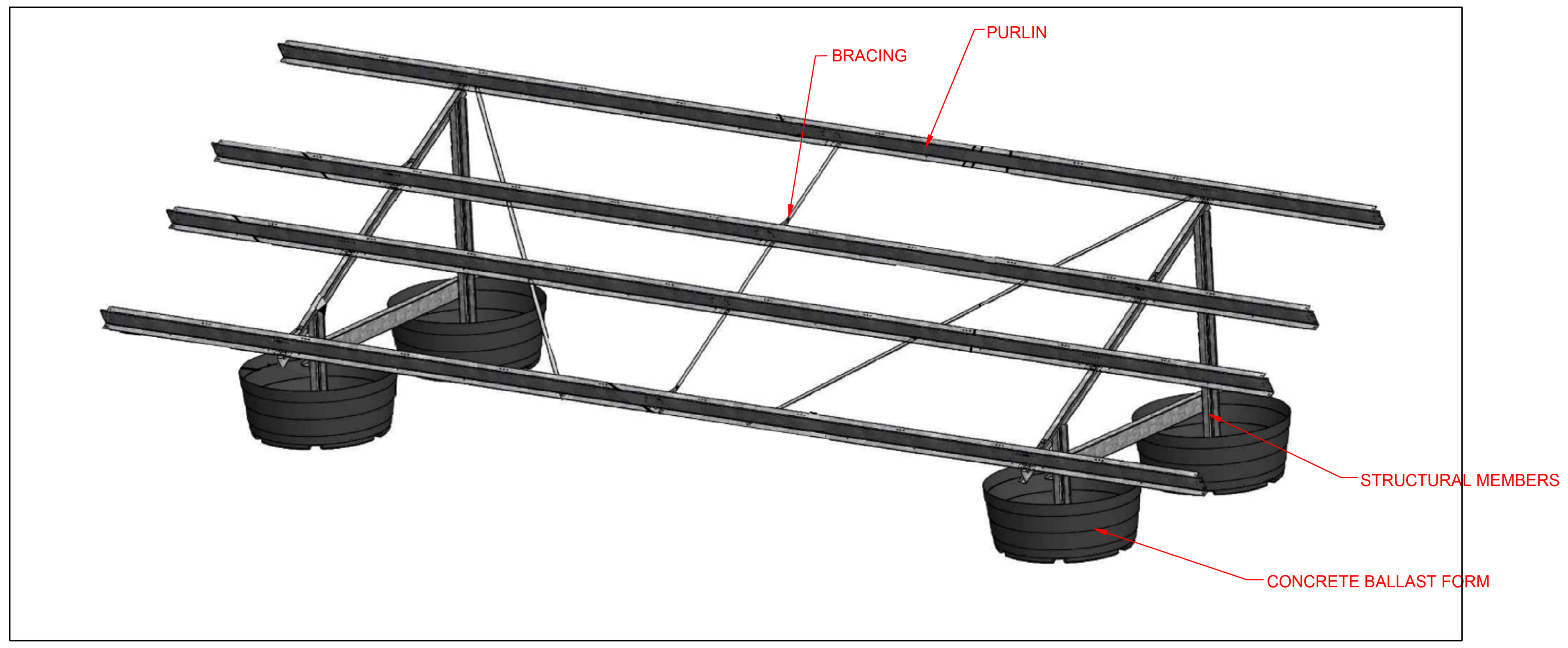
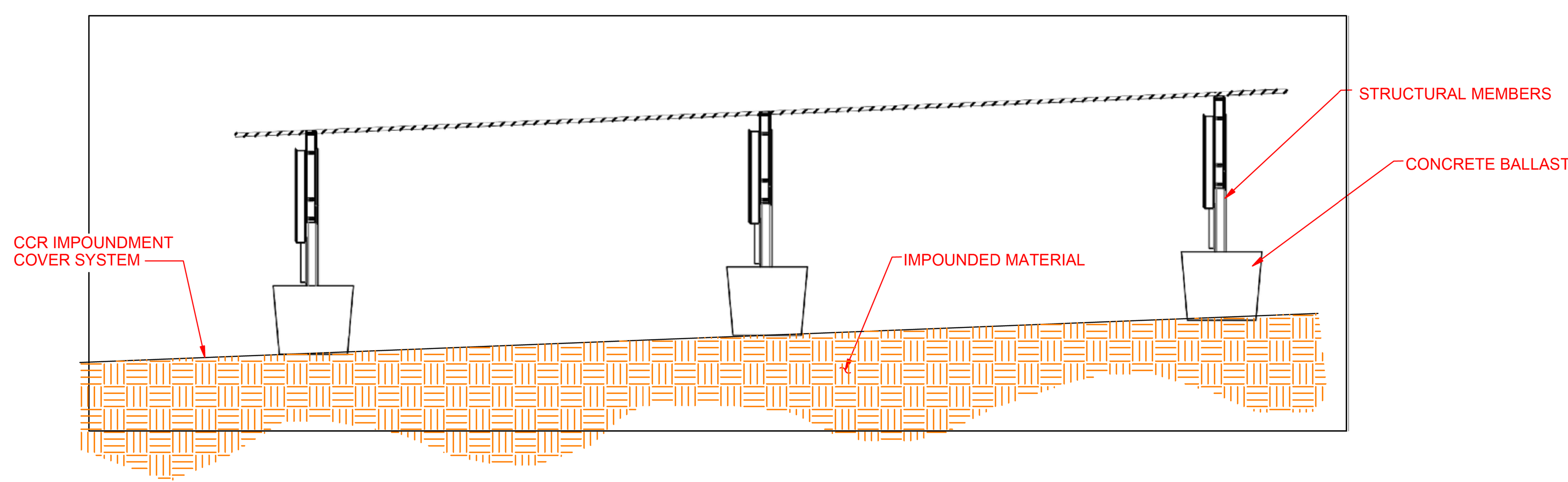


DETAIL 1 - TYP. FIXED TILT BALLAST RACKING
NOT TO SCALE

DETAIL 3 - TYP. SOLAR MODULE
NOT TO SCALE



DETAIL 2 - PROFILE VIEW OF BALLAST ON CAP
NOT TO SCALE

no.	date	by	ckd	description
A	07/28/22	RNO	MDB	ISSUED FOR OWNER PERMIT

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SOUTH FORK TOWNSHIP, ILLINOIS

KINCAID ASH POND
SOLAR DETAILS

project 132803 | contract 8110
drawing **CG021** — rev. **A**
sheet 1 of 1 sheets
file 132803CG021.DGN

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APPENDIX D - SIZING CALCULATIONS FOR TEMPORARY OPERATING POOL

Memorandum

BURNS McDONNELL

Date: 5/04/2022

Subject: Kincaid Ash Pond – Temporary Operating Pool Sizing Calculations
Part 845 Construction Permit Application

The Kincaid Ash Pond (KAP) currently operates as a closed-loop impoundment, whereby water is recirculated from the KAP back to the Kincaid Power Plant (KPP) for bottom ash sluicing. In addition to bottom ash sluice water, stormwater from the West Area Runoff Basin is also discharged to the KAP. Under these conditions, the normal operating level within the 172-acre[1] surface impoundment ranges from approximately 601.80 to 602.50 feet above mean sea level (ft amsl); however, a maximum pool elevation of 603.3 feet may be used during winter conditions to alleviate problems with freezing that may affect flow into the recycle intake structure[2]. During closure, it is assumed that bottom ash sluice water recirculation will continue while the KAP is unwatered/dewatered and CCR from the northern portion of the KAP is removed and consolidated with CCR in the southern portion of KAP.

During the initial phase of KAP closure, a temporary operating pool, approximately 9.4-acres in size, will be constructed in the southeastern corner of the KAP using sheet pile or other vertical hydraulic barrier system. Ponded and subsurface free waters generated during KAP closure activities will be transferred to this temporary operating pool. Under normal circumstances, the West Area Runoff Basin discharge, currently routed to the KAP, will be routed to the wastewater treatment plant (WWTP) for treatment and subsequent discharge via National Pollutant Discharge Elimination System (NPDES) Outfall B01. This will provide the additional capacity needed for the KAP temporary operating pool to receive CCR unwatering/dewatering fluids generated during closure activities. However, in the event of a WWTP upset or large storm event, it may be necessary for West Area Runoff Basin discharges to be temporarily routed to the KAP temporary operating pool. The calculations summarized herein were performed to verify that the 9.4-acre temporary operating pool can accommodate the West Area Runoff Basin discharge during a Type II, 10-year, 24-hour storm event.

Governing Assumptions

- The operating level in the KAP temporary operating pool prior to start of the storm event is assumed to be 601.80 ft amsl.
    - It is assumed that the 10-year, 24-storm event will not occur during winter conditions when a higher operating elevation (603.30 ft amsl) would be required to alleviate problems associated with freezing. In addition, based on discussions

---

[1] Ramboll. (2021). *Hydrogeologic Site Characterization Report, Kincaid Power Plant Ash Pond.* Milwaukee.

[2] Geosyntec Consultants. (2021). *USEPA CCR Rule and IEPA Part 845 Rule Applicability Cross-Reference, 2021 USEPA CCR Rule Periodic Certification Report, Ash Pond, Kincaid Power Plant, Kincaid, Illinois.* Chesterfield.

with KPP operations personnel, it will be possible for the KAP to operate at a minimum pool elevation (601.80 ft amsl) during closure activities.

- The maximum allowable operating level in the KAP temporary operating pool is assumed to be 603.50 ft amsl. This will provide approximately 1 ft of freeboard in the operating pool, assuming a maximum KAP berm elevation of 604.50 ft amsl.[1]
- Unwatering/dewatering discharges from the KAP to the temporary operating pool will cease during the storm event.

Storm Surge Capacity Calculations

- As shown in the attached calculations performed using HydroCAD® 10.00-24, the West Area Runoff Basin discharge to KAP associated with a Type II, 10-year, 24-hour storm event consist of the following[3]:
    - Surface runoff from the western portion of the KPP: 242,000 cubic ft (cu. ft)
    - KPP coal pile runoff: 175,000 cu. ft
    - Total volume: 417,000 cu. ft
- Maximum KAP temporary operating pool depth to accommodate storm surge = 1.7 ft
    - 604.50 ft amsl– 601.80 ft amsl – 1.00 ft freeboard = 1.7 ft
- Area bound by 601.80 ft amsl contour and proposed sheet pile wall within KAP = 8.16 acres (355,000 sq. ft)
    - Note: the total footprint of the temporary operating pool is approximately 9.4 acres, based on the area bound by the 605 ft amsl contour and proposed sheet pile wall; however, 8.16 acres is the estimated wetted area available for additional stormwater capacity based on the 601.8 ft amsl contour.
- Direct precipitation to 9.4-acre temporary operating pool = 148,000 cu. ft[4]
    - Note: the total footprint of the temporary operating pool (approximately 9.4 acres, based on the area bound by the 605 ft amsl contour and proposed sheet pile wall) was used to estimate the volume of direct precipitation into the temporary operating pool during a storm event.
- Total available volume to accommodate storm surge:
    - 1.7 ft * 355,000 sq. ft – 148,000 cu. ft = 456,000 cu. ft (> 417,000 cu. ft storm surge volume)

As shown above, the KAP temporary operating pool should accommodate West Area Runoff Basin discharges during a 10-year, 24-hour storm, if required, provided the water level in the KAP is maintained at 601.80 ft amsl or lower, depending on operational needs. The temporary

---

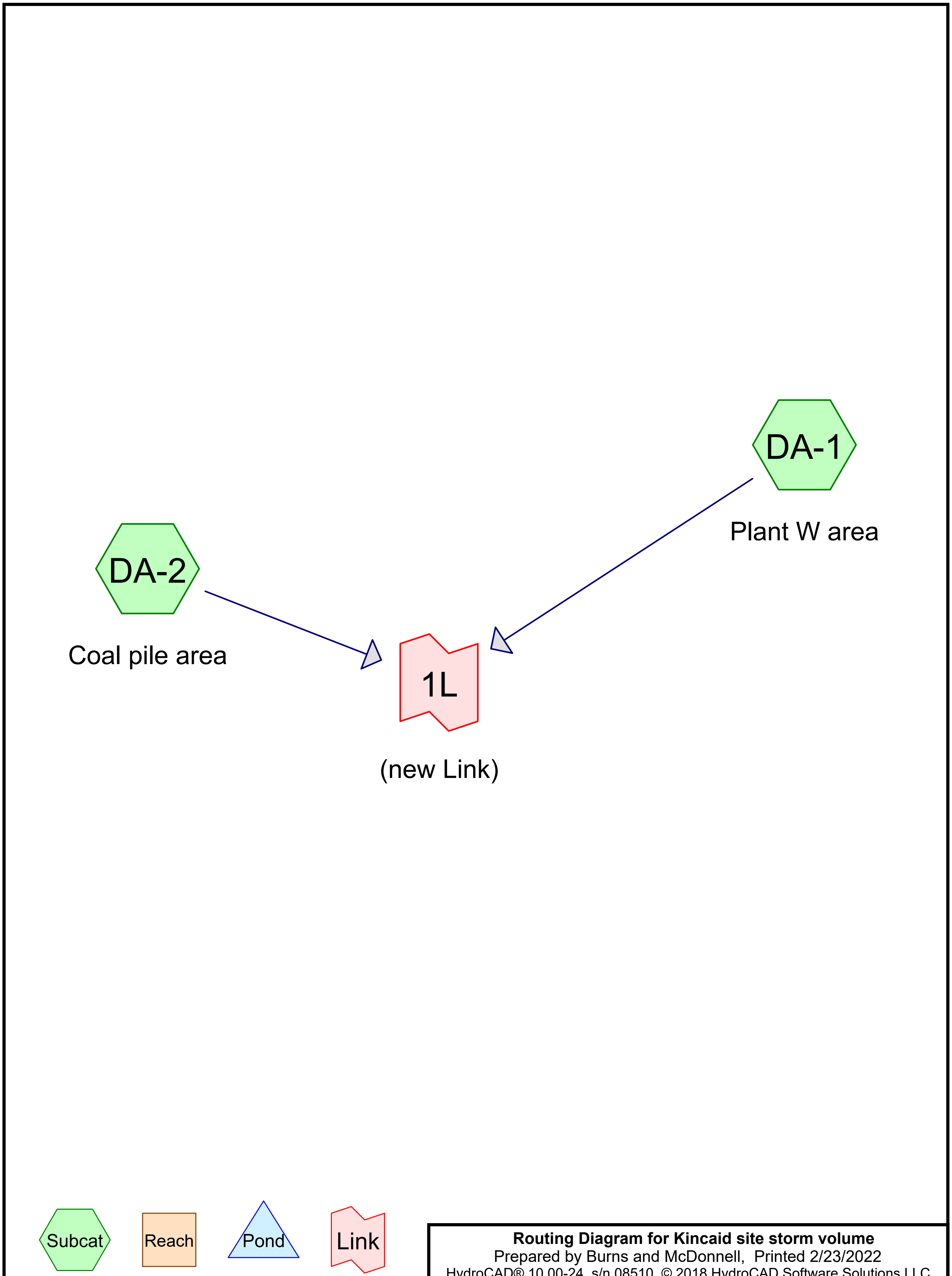
[3] Both stormwater runoff sources collect in the West Area Runoff Basin prior to discharge to the KAP.
[4] 4.36 inches over 9.4 acres = 0.36 ft * 408,000 sq. ft = 148,000 cu. ft

operating pool should accommodate approximately 50-percent of the West Area Runoff Basin discharge during a 10-year, 24-hour storm, if the water level in the KAP is maintained at 602.50 ft amsl (the high end of the current operating level range). Under this scenario, the remaining volume will be allowed to discharge from the temporary operating pool, via an opening (i.e., a weir system) in the sheet pile wall, into the area of the KAP undergoing closure. This water will be pumped back into the temporary operating pool when unwatering/dewatering operations resume following the storm event.

JRH/jrh

Attachments

cc: Ron Hager
Robert Owens



Routing Diagram for Kincaid site storm volume
Prepared by Burns and McDonnell, Printed 2/23/2022
HydroCAD® 10.00-24 s/n 08510 © 2018 HydroCAD Software Solutions LLC

Area Listing (all nodes)

Area (acres)	CN	Description (subcatchment-numbers)
1.349	74	>75% Grass cover, Good, HSG C (DA-1)
20.570	80	Coal pile area, HSG C (DA-2)
10.190	96	Gravel surface, HSG C (DA-1)
6.047	98	Roofs, HSG C (DA-1)
38.157	**87**	**TOTAL AREA**

Soil Listing (all nodes)

Area (acres)	Soil Group	Subcatchment Numbers
0.000	HSG A	
0.000	HSG B	
38.157	HSG C	DA-1, DA-2
0.000	HSG D	
0.000	Other	
38.157		**TOTAL AREA**

Ground Covers (all nodes)

HSG-A (acres)	HSG-B (acres)	HSG-C (acres)	HSG-D (acres)	Other (acres)	Total (acres)	Ground Cover	Subcatchment Numbers
0.000	0.000	1.349	0.000	0.000	1.349	>75% Grass cover, Good	DA-1
0.000	0.000	20.570	0.000	0.000	20.570	Coal pile area	DA-2
0.000	0.000	10.190	0.000	0.000	10.190	Gravel surface	DA-1
0.000	0.000	6.047	0.000	0.000	6.047	Roofs	DA-1
0.000	**0.000**	**38.157**	**0.000**	**0.000**	**38.157**	**TOTAL AREA**	

Summary for Subcatchment DA-1: Plant W area

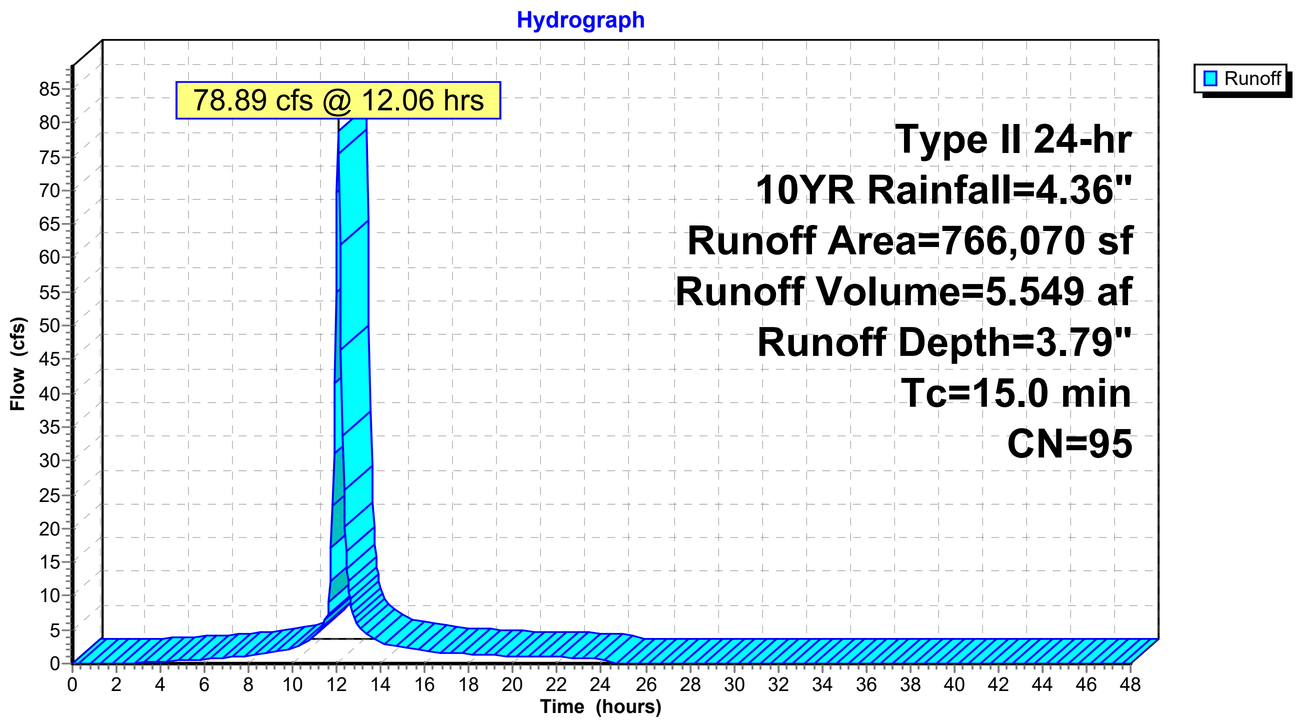
Runoff = 78.89 cfs @ 12.06 hrs, Volume= 5.549 af, Depth= 3.79"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 10YR Rainfall=4.36"

Area (sf)	CN	Description
443,884	96	Gravel surface, HSG C
263,417	98	Roofs, HSG C
58,769	74	>75% Grass cover, Good, HSG C
766,070	95	Weighted Average
502,653		65.61% Pervious Area
263,417		34.39% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment DA-1: Plant W area



Summary for Subcatchment DA-2: Coal pile area

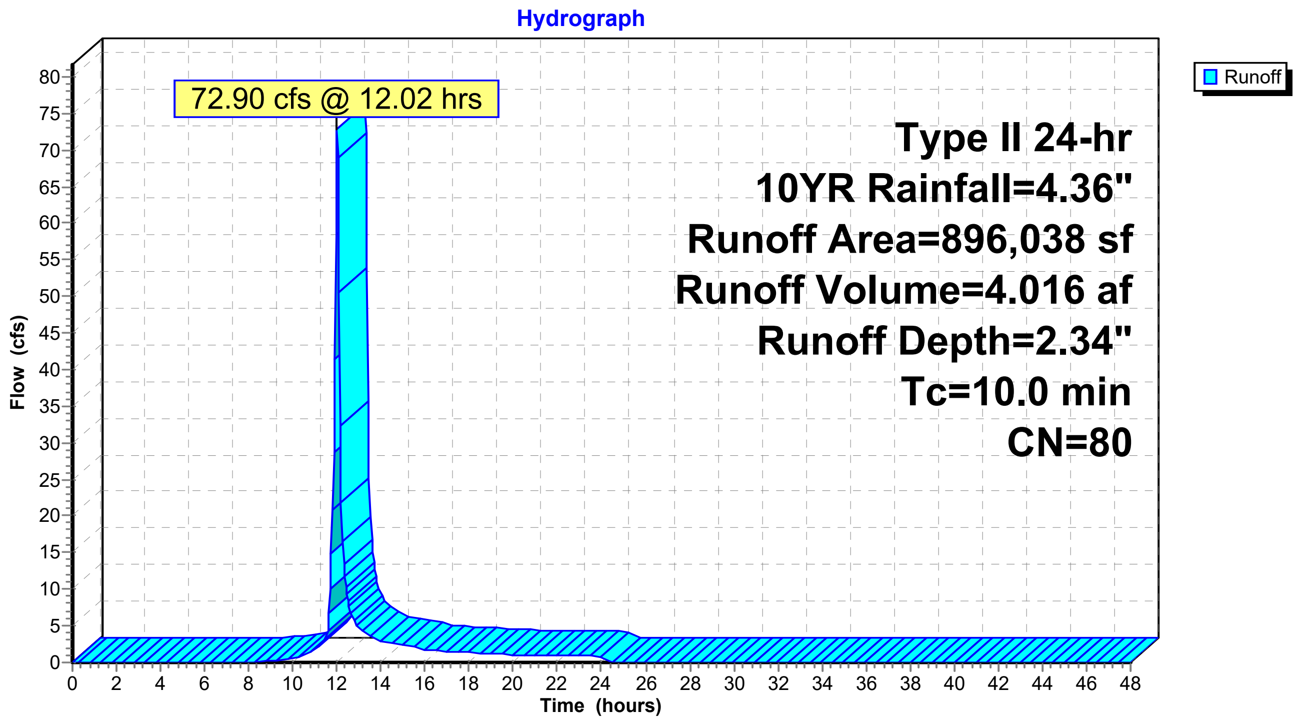
Runoff = 72.90 cfs @ 12.02 hrs, Volume= 4.016 af, Depth= 2.34"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 10YR Rainfall=4.36"

	Area (sf)	CN	Description
*	896,038	80	Coal pile area, HSG C
	896,038		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.0					**Direct Entry,**

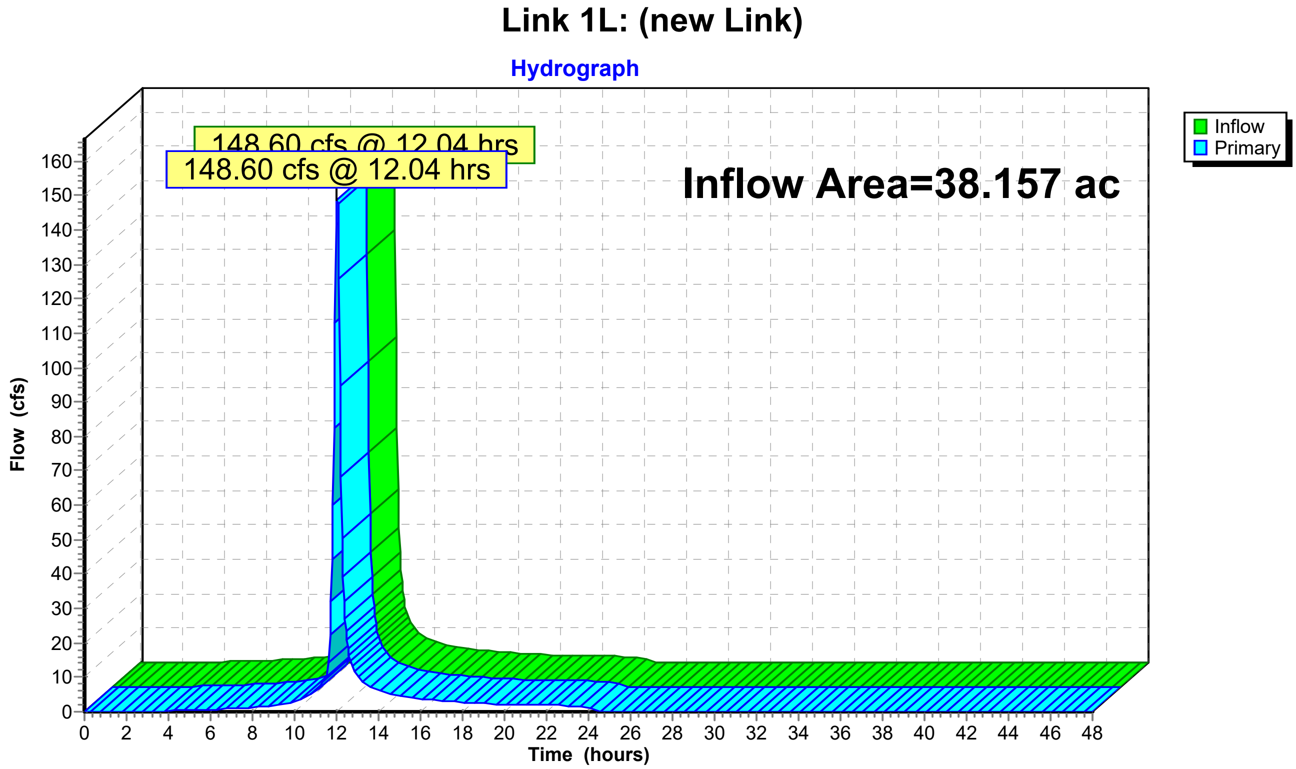
Subcatchment DA-2: Coal pile area



Summary for Link 1L: (new Link)

Inflow Area =	38.157 ac,	15.85% Impervious,	Inflow Depth = 3.01"	for 10YR event
Inflow =	148.60 cfs @	12.04 hrs, Volume=	9.565 af	
Primary =	148.60 cfs @	12.04 hrs, Volume=	9.565 af,	Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs



Summary for Link 1L: (new Link)

Inflow Area = 38.157 ac, 15.85% Impervious, Inflow Depth = 3.01" for 10YR event
Inflow = 148.60 cfs @ 12.04 hrs, Volume= 9.565 af
Primary = 148.60 cfs @ 12.04 hrs, Volume= 9.565 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

APPENDIX E - ALTERNATIVE FINAL PROTECTIVE LAYER EQUIVALENCY DEMONSTRATION

Geosyntec consultants

134 N. La Salle Street, Suite 300
Chicago, Illinois 60602
PH 312.658.0500
FAX 312.658.0576
www.geosyntec.com

Technical Memorandum

Date:	July 25, 2022
To:	Victor Modeer, P.E., DGE, Vistra on behalf of Kincaid Generation, L.L.C.
Copies to:	Phil Morris, Rhys Fuller, Vistra on behalf of Kincaid Generation, L.L.C.
From:	John Seymour, P.E., Geosyntec Consultants (Geosyntec) Lucas Carr, P.E., Geosyntec
Subject:	Proposed Alternative Final Protective Layer Equivalency Demonstration Kincaid Ash Pond, Kincaid Power Plant Kincaid, Illinois Geosyntec Project: GLP8025

PROPOSAL

An alternative final protective layer is proposed by Kincaid Generation, L.L.C. (KG) for the Kincaid Ash Pond (KAP) surface impoundment that will be closed-in-place at the Kincaid Power Plant (KPP). The closure will be in accordance with Illinois Administrative Code (IAC) Part 845 Rule [1] (Part 845). Overall, the proposal will meet the requirements of Section 845.750 c) 2).

This Technical Memorandum presents a demonstration that a 2-foot-thick alternative final protective layer consisting of an 18-inch-thick soil layer and a 6-inch layer of topsoil provide equivalent or superior performance to the default protective layer set forth in Section 845.750 c) 2). The alternative final protective layer works in combination with an underlying low permeability (geomembrane) layer in place of the default three-foot thick, low permeability compacted earth layer required by Section 845.750 c) 1) A). In addition, a cushion layer consisting of a geotextile is placed on top of the geomembrane prior to installation of the final protective layer. The combination of the above materials comprises the final "alternative final cover system".

A discussion of how the closure, including the proposed alternative final cover system discussed herein, meets the performance standards is contained in the Closure Plan [2], which includes the Closure Alternatives Assessment required by Section 845.710.

REQUIREMENTS OF SECTION 845

Section 845.750 provides requirements for both the final protective layer and underlying low permeability layer. They work in tandem to provide protection of groundwater and surface exposure conditions. A principal intention of the low permeability layer is to reduce the infiltration of liquid through the final cover system and into the CCR waste mass during post-closure conditions, in accordance with Section 845.720 (a), which states in part:

> *The owner or operator of a CCR surface impoundment must ensure that, at a minimum, the CCR surface impoundment is closed in a manner that will*:
>
> *1) Control, minimize or eliminate, to the maximum extent feasible, post-closure infiltration of liquids into the waste and releases of CCR, leachate or contaminated run-off to the ground or surface waters or to the atmosphere;*

Specific default requirements for the final cover system are included in Section 845.750(c), which requires the final cover system to have either: 1) a three-foot thick soil low permeability compacted earth layer overlain by a three-foot-thick final protective layer (final protective layer), or 2) a geomembrane low permeability layer with a three-foot-thick final protective layer.

The specific Section 845.750 (c) (2) design requirements for the final protective layer are as follows (emphasis added):

> *Standards for the Final Protective Layer: The final protective layer must meet the following requirements,* ***unless the owner or operator demonstrates that another final protective layer construction technique or material provides equivalent or superior performance to the requirements of this subsection (c)(2****) and is approved by the Agency.*

Therefore, Section 845.750 (c) (2) specifically allows the use of an alternate final protective layer as long as it provides an equivalent or superior performance to the default standards set forth in Section 845.750(c)(2), which are as follows:

> *A) Cover the entire low permeability layer;*
>
> *B) Be at least three feet thick, be sufficient to protect the low permeability layer from freezing, and minimize root penetration of the low permeability layer;*
>
> *C) Consist of soil material capable of supporting vegetation;*
>
> *D) Be placed as soon as possible after placement of the low permeability layer; and*
>
> *E) Be covered with vegetation to minimize wind and water erosion.*

The alternate design is only requesting an alternate to Section 845.740(c)(2)(B) related to the thickness of the of the final protective layer.

PROPOSED FINAL COVER SYSTEM SUMMARY

The proposed final cover systems will include:

- A low permeability layer consisting of a linear low-density polyethylene (LLDPE) geomembrane that is at least 40-mil in thickness, placed on a smooth CCR subgrade;
- A geotextile cushion; and
- A final protective layer consisting of 18 inches of protective cover soil with a 6-inch layer of topsoil capable of supporting vegetation.

The final protective layer will meet all Section 845.750(c)(2) criteria, will not need any supplemental engineering measures, and will be designed by a qualified professional engineer licensed in Illinois.

The concepts of the alternative cover system are illustrated on **Figure 1**.

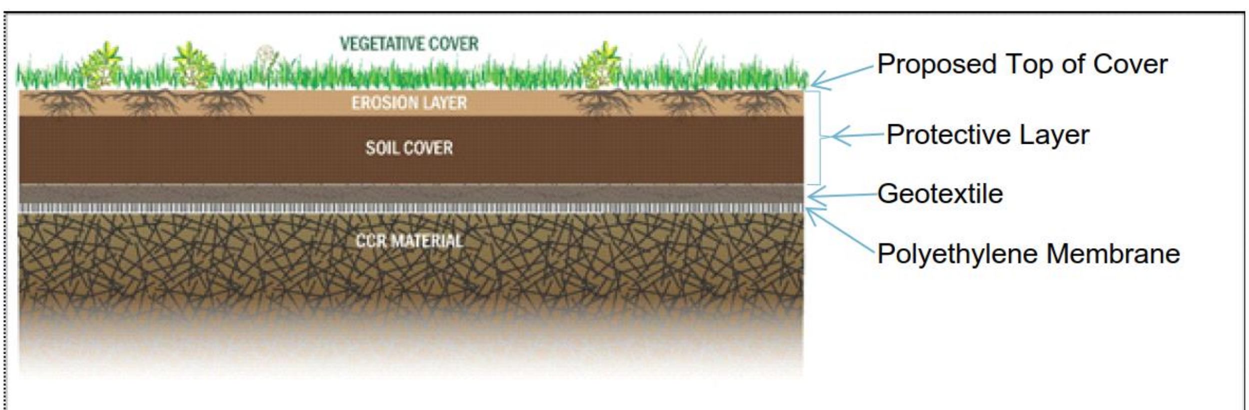


Figure 1: Proposed Alternative Final Cover System

The KPP Site is slated for re-development as a utility-scale solar facility if closure-in-place (CIP) is approved. A solar facility atop the cover system is currently being designed. Components of the vegetative cover may change as details of the solar facility are finalized. This will be discussed further under "Additional Considerations."

DEMONSTRATION

The proposed alternate final protective layer will address the five requirements of Section 845.750 (c)(2)(A) to (E), as described in this section.

Section 845.750(c)(2)(A) Cover the entire low permeability layer

The final protective layer will horizontally cover the entire low-permeability layer, as indicated in the drawings in Appendix C of the Closure Plan [2].

Therefore, the use of the two-foot-thick final protective layer will meet the minimum requirements of Section 845 750(c)(2)(A) because it will completely cover the low-permeability layer.

Section 845.750(c)(2)(B) Be sufficient to protect the low permeability layer from freezing, and minimize root penetration of the low permeability layer

The existing Part 845, which has the same requirements as Part 814 (closure rule for landfills), requires a three-foot-thick final protective layer to protect the underlying low permeability layer from freeze-thaw effects and root penetration. However, when a geomembrane is used as the low permeability layer it does not need these protections since it is not subject to the same impacts (i.e., causing an increase in hydraulic conductivity) as a compacted earth layer as discussed in more detail below.

A geomembrane low permeability layer will be used for the KPP KAP. Geomembranes have the following characteristics:

- Geomembranes do not have pores that can contain water and are therefore not susceptible to freeze-thaw damage that may reduce their performance as a low permeability layer and/or lead to degradation of the geomembrane.
    - In fact, geomembrane panel strength and stiffness both increase with decreasing temperatures ([3], [4]). In 1996, the United States Bureau of Reclamation [5] (USBR) performed testing of both geomembrane panels and seams subjected to up to 500 freeze-thaw cycles, in both constrained and unconstrained conditions, with temperature cycles as severe as +30º C to -20º C.
    - The testing showed no changes in the strength of the geomembrane panels or seams.

The USBR concluded that *"…there is simply "no change" in tensile behavior of geomembrane sheets or their seams after freeze-thaw cycling"*.

- In 2013, the Geosynthetic Institute, upon reviewing the results of the USBR and other studies, concluded that *"the essential question often raised in this regard, i.e., "will freeze-thaw conditions affect geomembrane sheets or their seam behavior," is answered with a resounding "NO""* [6].

- Geomembranes are not susceptible to grass plant root penetration because the geomembranes do not provide organic nutrients to plant roots and do not have pores or other areas where roots can enter the geomembrane.
  - Consequently, geomembranes are not a hospitable material that would either encourage root penetration or allow root penetration. Additionally, the geomembrane will be covered with a or geocomposite drainage layer with a geotextile filter on top, which will provide an additional barrier to root penetration.

U.S. EPA research [7] states that *"…a typical minimum thickness of the cover soil is 0.45 to 0.6 m…" (18 to 24 inches) thick "… for cover systems with hydraulic barriers"* (low permeability layer). This is particularly appropriate when using a geomembrane low permeability which is not susceptible to any impact from freezing. U.S. EPA research also states that cover thickness design for root penetration into the low permeability layer is only a concern for compacted clay layers or geosynthetic clay barriers. This is when using an appropriate design of cover vegetation.

Therefore, the use of the two-foot-thick final protective layer will provide equivalent or superior performance to the requirements of Section 845.750 (c) (2) (B) when coupled with a geotextile cushion and a geomembrane low permeability layer, as geomembranes are not susceptible to freeze-thaw damage or root penetration as compared to a low permeability compacted earth layer.

Section 845.750(c)(2)(C) Consist of soil material capable of supporting vegetation.

The uppermost six inches of the final protective layer will consist of topsoil that is capable of supporting vegetation, which is the same requirement as the default (three-foot thick) final protective layer. This is also consistent with the Federal CCR Rule, which requires a six-inch-thick "erosion" (topsoil) layer. Research [7] and Geosyntec's experience indicate topsoil layers are designed to have shallow-rooted grasses and most shallow-rooted grasses do not typically penetrate more than six inches into the subsurface. Shallow-rooted grasses will be specified based on recommendations from specialists at nurseries in the location of KPP and Illinois Department of Transportation guidelines. The topsoil layer will be fertilized and/or amended, as necessary, on a site-specific basis based on agronomical soil testing, to provide a growing medium for the vegetation that provides the required levels of nutrients and water storage during drought conditions.

Grass species will also be selected on a site-specific basis to minimize long-term vegetation maintenance, based on the climatic conditions at each site and the soil types. Vegetation will be established by applying seed and mulch and watering to establish the vegetation. Temporary erosion control measures will also be used during vegetation establishment to protect the topsoil layer from erosion. These measures may include erosion control blankets (ECBs), silt fences, hydroseeding, and/or other methods. The Post-Closure Care Plan includes the commitment to maintain the vegetation of the surface for the closed KPP KAP within the Construction Permit Application [8].

The 18-inches of the protective layer below the topsoil will consist of a soil type suitable for retaining moisture to provide additional support for vegetation during times of drought, and to support any grass species with roots that exceed six inches. Such soil types may include sandy clay loam, silty loam, silts, silty clays, lean clays, sandy clays, and/or sandy silts.

Therefore, the use of the two-foot-thick protective layer will meet the requirements of Section 845.750(c)(2)(C), as the final protective layer will utilize soil capable of supporting vegetation.

Section 845.750(c)(2)(D) Be placed as soon as possible after placement of the low permeability layer

The KPP KAP Closure Plan (Section 4.7.2 [2]) states that the geotextile and cover soil "…will be placed as soon as practical after the geomembrane has been deployed and both quality assurance and quality control testing has been performed on the geomembrane seams."

The use of a two-foot-thick protective layer will allow the final protective layer to be placed on top of the low permeability layer and vegetation to be established on top of the final protective layer sooner than if a three-foot thick final protective layer is used. This is due to the 33% reduction in earthwork volumes associated with the thinner 2-ft-thick final protective layer.

Therefore, the use of the two-foot-thick final protective layer will exceed the minimum requirements of Section 845.750(c)(2)(D), by allowing the protective layer to be installed sooner than when using a three-foot-thick protective layer.

Section 845.750(c)(2)(E) Be covered with vegetation to minimize wind and water erosion.

Vegetation will be established to cover the final protective after placement and fertilization, if needed, as noted in the discussion regarding Section 4.7.2 of the Closure Plan [2]. Additionally, the following design and engineering features, construction techniques, and maintenance procedures will be used to reduce the potential for wind and water erosion under both long-term conditions and during vegetation establishment.

- Design and Engineering Features
    - Final cover system slopes will be installed at relatively gentle grades (e.g., typically 3% slopes or flatter). The use of gentle grades will reduce water runoff velocities and therefore reduce the potential for water erosion of the final cover soils.
    - A stormwater management system consisting of channels, ditches, and letdowns is included in the drawings within the Closure Plan [2] and will be designed to collect stormwater in a controlled manner and route it off the final cover system which will minimize infiltration into the CCR waste mass. The stormwater management system will minimize the overland flow distance between stormwater channels. Channels will be lined with an appropriate material, based on estimated stormwater velocities, to limit water erosion.
- Construction Techniques
    - The final protective layer is typically the most susceptible to wind and water erosion in the period between the placement of the protective layer and the establishment of vegetation. To reduce the potential for both wind and water erosion during this time, the following approaches will be utilized:
        - Temporary erosion and sediment controls (ESCs) will be installed to reduce the potential for erosion, such as erosion control blankets (ECBs), silt socks (e.g., straw wattles), silt fences, and other methods. These ESCs will be regularly inspected and maintained until vegetation is established.
        - The entire surface of the final protective layer will be stabilized during seeding and until vegetation is established. Coverings may consist of straw mulch, hydroseeding binder, ECBs, or engineering growing media.
        - The final protective layer will be regularly inspected and maintained during vegetation establishment. Any areas that become eroded by wind and water will be repaired until vegetation is established to a suitable level over the surface of the final cover.

- Maintenance Procedures
  - During the post-closure care period, vegetation established on the final protective cover layer will be regularly maintained using a written and IEPA-approved maintenance program. The program will consist of regular mowing and inspections. Any bare areas or areas of erosion will be repaired by seeding and stabilizing the area, and observing the area until vegetation becomes re-established.
  - The final cover slopes will be relatively gentle (3% or flatter); these slopes experience less erosion in general, especially less than typical landfill covers sloped at predominately 25 to 33%. Typically, after three to five years, it is Geosyntec's experience that the cover vegetation becomes fully stabilized and experiences less erosion.

In conclusion, the use of the two-foot-thick final protective layer will exceed the minimum requirements of Section 845 750 c) 2) E), using a robust program to support the establishment of protective vegetation, prevent and address any erosion that may occur during vegetation establishment, and monitor and maintain the vegetation during post-closure conditions.

ADDITIONAL CONSIDERATIONS

Infiltration Analysis

The use of the proposed two-foot-thick final protective layer, when coupled with a geomembrane low permeability layer, will also meet the criteria contained within Section 845.750 (a) (1). Section 845.750 (a) (1) provides the following requirement:

> *Section 845.750(a)(1) Control, minimize or eliminate, to the maximum extent feasible, post-closure infiltration of liquids into the waste and releases of CCR, leachate, or contaminated run-off to the ground or surface waters or to the atmosphere;*

Section 845.750(a)(1) is an important overall measure of the effectiveness of the final cover system because it requires control of post-closure infiltration of liquids through the final cover and into the waste and releases of CCR.

An infiltration analysis was performed to by Ramboll, within the KPP KAP Construction Permit Application [8], to estimate post-closure liquid infiltration rates through both the default and the proposed alternate final cover systems at the KPP KAP. The infiltration analysis used the Hydrologic Evaluation of Landfill Performance (HELP) software promulgated by the USEPA [9]. The HELP model estimates the infiltration rates from the top of the cover, through the final protective layer and through the low permeability layer (either a geomembrane or the three-foot thick compacted earth layer). The results are included in **Appendix A**. The resulting estimated infiltration rates are provided in **Table 1**.

Table 1 – KPP KAP Final Cover Systems for Infiltration Analysis

Description	Low Permeability Layer[1]	Final Protective Layer	Infiltration Rate[2]
Proposed Alternative Final Cover System	40-mil Linear Low-Density Polyethylene (LLDPE) Geomembrane	2 ft of cover material, including, from bottom to top, a 10 oz nonwoven geotextile, 1.5 ft of sandy silty clay and 0.5 ft of silty clay loam	0.92 in/yr
Default Cover with Geomembrane Barrier	40-mil LLDPE Geomembrane	3 ft of cover material, including, from bottom to top, a 10 oz nonwoven geotextile, 2.5 ft of sandy silty clay and 0.5 ft of silty clay loam	1.62 in/yr
Default Cover with Compacted Earth Layer	3-ft thick compacted earth layer (1×10-7 cm/sec)	3 ft of cover material, including, from bottom to top, 2.5 ft of sandy silty clay and 0.5 ft of silty clay loam	1.95 in/yr

The KPP KAP analysis indicated that the performance of the proposed alternative final cover system with a geomembrane and a two-foot-thick final protective cover exceeds the performance offered by the default final cover system utilizing a geomembrane with the default three-foot-thick protective layer and cushion layer, with the infiltration rate reduced by a factor of 1.8.

Furthermore, the proposed alternate final cover system performance exceeds the performance of a final cover system using a three-foot-thick compacted earthen low permeability layer and a three-foot-thick final protective layer (a total cover thickness of six feet) by reducing infiltration by a factor of 2.1.

[1] All HELP run versions used a pinhole density of 1 hole per acre, installation defects of 1 hole/acre, and construction quality as "good".
[2] Infiltration is out the bottom of the low permeability layer.

Post-Closure Construction of Solar Panel Electrical Generating System

The KPP Site is slated for re-development as a utility-scale solar facility if closure-in-place (CIP) is approved. A solar facility atop the cover system is currently being designed. Components of the vegetative cover may change as details of the solar facility are finalized. The system will be designed, installed, and operated such that the closure performance standards will be maintained at an equivalent level as proposed in the KPP KAP Closure Plan [2].

For example, the panels are expected to be supported by concrete slab ballast foundations that will replace portions of the erosion (topsoil) layer and not cause excessive settlement of the cover and will reduce the amount of infiltration. The ballast foundations will not penetrate the geomembrane low-permeability layer to reduce the potential for defects that could otherwise increase infiltration. The space around the panel foundations will be replaced with an alternative to shallow rooted vegetation and will include stormwater runoff and erosion materials that will meet the erosion control standards of Section 845.750 and may also include forbs (herbaceous flowering plants).

Environmental and Societal Benefits

The use of the proposed two-foot-thick final protective layer will provide the following additional environmental and societal benefits, relative to the default three-foot-thick final protective layer:

- The final cover system earthwork quantities will be reduced by 33%. This will result in a corresponding 33% reduction in the amount of offsite soil fill that needs to be excavated, hauled to the construction location, and placed. This provides multiple benefits, such as:
    - Reduced disruption to offsite areas caused by the excavation of fill materials and corresponding disturbance to the natural environment.
    - Reduced haul truck traffic on local roadways, thereby reducing traffic impacts, roadway damage, air pollution, and carbon emissions.
    - Reduced earthwork effort during installation of the final cover system, thereby reducing air pollution and carbon emissions.
- Construction of the alternate final cover system can be completed faster than the default final cover, providing multiple benefits, such as:
    - Initiation of the reduction of infiltration at a sooner date than with the default final cover system.
    - Ceasing construction-related impacts to offsite residents (e.g., air pollution, carbon

emissions) at a sooner date than otherwise possible.

- The installation of a solar panel electrical generating system will provide green energy to the community and reduce the maintenance associated with the shallow rooted vegetation.

SUMMARY

The proposed alternate final protective layer will:

- Provide equivalent or superior performance to the requirements of Section 845.750 (c)(2).
- Have a geotextile cushion layer, which is not required by Section 845.750, over the geomembrane that adds physical protection for the geomembrane.
- Have a lower infiltration rate than the infiltration through the default soil final cover system.
- Meet or exceed the same criteria for long term performance and all other requirements of Section 845.750(c)(2).
- Provide other benefits by reducing the amount of final cover earthwork by 33% for the KPP KAP.
- A solar panel electrical generating system will provide green energy to the community and reduce the maintenance of the cover.

REFERENCES

[1] Illinois Environmental Protection Agency, "35 Ill. Adm. Code Part 845, Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments," Springfield, IL, 2021.

[2] Burns & McDonnell Engineering Company, Inc., "Final Closure Plan, Kincaid Power Plant Ash Pond, Kincaid Ash Pond," St. Louis, MO, 2022.

[3] A. L. Rollin, J. Lafleur, M. Marcotte, O. Dascal and Z. Akber, "Selection Criteria for the Use of Geomembranes in Dams and Dykes in Northern Climate," in *Proceedings of the International Conference on Geomembranes*, Denver, Colorado, 1945.

[4] D. E. Thorton and P. Blackall, "Report EPA-3-76-13: Field Evaluation of Plastic Film Liners for Petroleum Storage Areas in the Mackenzie Delta," Canadian Environmental Protection Service, 1976.

[5] A. I. Comer and Y. G. Hsuan, "Report R-96-03: Freeze-Thaw Cycling and Cold Temperature Effects on Geomembrane Sheets and Seams," U.S. Bureau of Reclamation, 1996.

[6] Y. G. Hsuan, R. M. Koerner and A. I. Comer, "GSI White Paper #28: Cold Temperature and Freeze-Thaw Cycling Behavior of Geomembranes and their Seams," Geosynthetic Institute, Folsom, Pennsylvania, 2013.

[7] United States Environmental Protection Agency, "(Draft) Technical Guidance For RCRA/CERCLA Final Covers," Office of Solid Waste and Emergency Response, Washington D.C., 2004.

[8] Burns & McDonnell Engineering Company, Inc., "CCR Surface Impoundment Construction Permit Applicaiton, Kincaid Power Plant, Ash Pond," St. Louis, Missouri, 2022.

[9] T. Tolaymat and M. Krause, "Hydrologic Evaluation of Landfill Performance: HELP 4.0 User Manual," United States Environmental Protection Agency, Washington, DC, 2020.

APPENDIX A: HELP MODEL OUTPUT

A-1: KPP KAP- 2-FT FINAL PROTECTIVE COVER SOIL

A-2: KPP KAP-3-FT FINAL PROTECTIVE COVER SOIL

A-3: KPP KAP-3-FT COMPACTED EARTH LAYER, 3-FT FINAL PROTECTIVE COVER SOIL

APPENDIX A-1

KPP KAP- 2-FT FINAL PROTECTIVE COVER SOIL

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title:	KIN AP CIP Cons	**Simulated On:**	6/21/2022 14:01

Layer 1
Type 1 - Vertical Percolation Layer (Cover Soil)
SiCL - Silty Clay Loam
Material Texture Number 12

Thickness	=	6	inches
Porosity	=	0.471	vol/vol
Field Capacity	=	0.342	vol/vol
Wilting Point	=	0.21	vol/vol
Initial Soil Water Content	=	0.4116	vol/vol
Effective Sat. Hyd. Conductivity	=	4.20E-05	cm/sec

Layer 2
Type 1 - Vertical Percolation Layer
Sandy Silty Clay
Material Texture Number 43

Thickness	=	18	inches
Porosity	=	0.4	vol/vol
Field Capacity	=	0.35	vol/vol
Wilting Point	=	0.3	vol/vol
Initial Soil Water Content	=	0.4	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-05	cm/sec

Layer 3
Type 2 - Lateral Drainage Layer
10 oz Nonwoven Geotextile
Material Texture Number 123

Thickness	=	0.11	inches
Porosity	=	0.85	vol/vol
Field Capacity	=	0.01	vol/vol
Wilting Point	=	0.005	vol/vol
Initial Soil Water Content	=	0.85	vol/vol
Effective Sat. Hyd. Conductivity	=	3.00E-01	cm/sec
Slope	=	2.5	%
Drainage Length	=	800	ft

Layer 4

Type 4 - Flexible Membrane Liner
LDPE Membrane
Material Texture Number 36

Thickness	=	0.04	inches
Effective Sat. Hyd. Conductivity	=	4.00E-13	cm/sec
FML Pinhole Density	=	1	Holes/Acre
FML Installation Defects	=	1	Holes/Acre
FML Placement Quality	=	3	Good

Layer 5

Type 1 - Vertical Percolation Layer (Waste)
Electric Plant Coal Bottom Ash
Material Texture Number 83

Thickness	=	372	inches
Porosity	=	0.578	vol/vol
Field Capacity	=	0.076	vol/vol
Wilting Point	=	0.025	vol/vol
Initial Soil Water Content	=	0.0791	vol/vol
Effective Sat. Hyd. Conductivity	=	1.40E-03	cm/sec

Layer 6

Type 1 - Vertical Percolation Layer
Silty CLay
Material Texture Number 44

Thickness	=	84	inches
Porosity	=	0.479	vol/vol
Field Capacity	=	0.371	vol/vol
Wilting Point	=	0.251	vol/vol
Initial Soil Water Content	=	0.371	vol/vol
Effective Sat. Hyd. Conductivity	=	1.20E-07	cm/sec

Note: Initial moisture content of the layers and snow water were computed as nearly steady-state values by HELP.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	87.2	
Fraction of Area Allowing Runoff	=	100	%
Area projected on a horizontal plane	=	84	acres
Evaporative Zone Depth	=	18	inches
Initial Water in Evaporative Zone	=	7.27	inches
Upper Limit of Evaporative Storage	=	7.626	inches
Lower Limit of Evaporative Storage	=	4.86	inches
Initial Snow Water	=	0	inches

Initial Water in Layer Materials	=	70.336	inches
Total Initial Water	=	70.336	inches
Total Subsurface Inflow	=	0	inches/year

Note: SCS Runoff Curve Number was calculated by HELP.

Evapotranspiration and Weather Data

Station Latitude	=	39.59	Degrees
Maximum Leaf Area Index	=	4.5	
Start of Growing Season (Julian Date)	=	102	days
End of Growing Season (Julian Date)	=	292	days
Average Wind Speed	=	10	mph
Average 1st Quarter Relative Humidity	=	72	%
Average 2nd Quarter Relative Humidity	=	66	%
Average 3rd Quarter Relative Humidity	=	73	%
Average 4th Quarter Relative Humidity	=	65	%

Note: Evapotranspiration data was obtained for Kincaid, Illinois

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
2.696568	2.105836	2.602577	3.411672	4.852763	3.801581
3.335953	3.024381	2.885088	4.052491	3.627085	2.799647

Note: Precipitation was simulated based on HELP V4 weather simulation for:
Lat/Long: 39.591502215865/-89.496388435364

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
34.7	35.6	45.8	59.9	73	79.3
83.1	80.3	71.1	62	47.6	36.4

Note: Temperature was simulated based on HELP V4 weather simulation for:
Lat/Long: 39.591502215865/-89.496388435364
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 39.591502215865/-89.496388435364

Average Annual Totals Summary

Title: KIN AP
Simulated on: 6/21/2022 14:03

	Average Annual Totals for Years 1 - 30*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	39.20	[3.42]	11,951,535.3	100.00
Runoff	6.862	[2.069]	2,092,482.9	17.51
Evapotranspiration	29.792	[3.16]	9,084,143.3	76.01
Subprofile1				
Lateral drainage collected from Layer 3	1.6178	[0.1841]	493,301.7	4.13
Percolation/leakage through Layer 4	0.916182	[0.203854]	279,362.3	2.34
Average Head on Top of Layer 4	7.6738	[1.8164]	---	---
Subprofile2				
Percolation/leakage through Layer 6	0.004092	[0.002049]	1,247.6	0.01
Water storage				
Change in water storage	0.9195	[0.7973]	280,359.8	2.35

* Note: Average inches are converted to volume based on the user-specified area.

Peak Values Summary

Title: KIN AP
Simulated on: 6/21/2022 14:03

	Peak Values for Years 1 - 30*	
	(inches)	(cubic feet)
Precipitation	3.09	943,327.1
Runoff	2.383	726,691.5
Subprofile1		
Drainage collected from Layer 3	0.0061	1,859.3
Percolation/leakage through Layer 4	0.007377	2,249.5
Average head on Layer 4	24.1098	---
Maximum head on Layer 4	36.7387	---
Location of maximum head in Layer 3	190.10 (feet from drain)	
Subprofile2		
Percolation/leakage through Layer 6	0.000037	11.4
Other Parameters		
Snow water	3.1704	966,725.5
Maximum vegetation soil water	0.4237 (vol/vol)	
Minimum vegetation soil water	0.2700 (vol/vol)	

Final Water Storage in Landfill Profile at End of Simulation Period

Title: KIN AP
Simulated on: 6/21/2022 14:03
Simulation period: 30 years

	Final Water Storage	
Layer	(inches)	(vol/vol)
1	2.6406	0.4401
2	7.0827	0.3935
3	0.0935	0.8500
4	0.0000	0.0000
5	55.1918	0.1484
6	32.7438	0.3898
Snow water	0.1673	---

APPENDIX A-2

KPP KAP- 3-FT FINAL PROTECTIVE COVER SOIL

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: KIN AP Default **Simulated On:** 6/21/2022 14:12

Layer 1

Type 1 - Vertical Percolation Layer (Cover Soil)
SiCL - Silty Clay Loam
Material Texture Number 12

Thickness	=	6	inches
Porosity	=	0.471	vol/vol
Field Capacity	=	0.342	vol/vol
Wilting Point	=	0.21	vol/vol
Initial Soil Water Content	=	0.4084	vol/vol
Effective Sat. Hyd. Conductivity	=	4.20E-05	cm/sec

Layer 2

Type 1 - Vertical Percolation Layer
Sandy Silty Clay
Material Texture Number 43

Thickness	=	30	inches
Porosity	=	0.4	vol/vol
Field Capacity	=	0.35	vol/vol
Wilting Point	=	0.3	vol/vol
Initial Soil Water Content	=	0.4	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-05	cm/sec

Layer 3

Type 2 - Lateral Drainage Layer
10 oz Nonwoven Geotextile
Material Texture Number 123

Thickness	=	0.11	inches
Porosity	=	0.85	vol/vol
Field Capacity	=	0.01	vol/vol
Wilting Point	=	0.005	vol/vol
Initial Soil Water Content	=	0.85	vol/vol
Effective Sat. Hyd. Conductivity	=	3.00E-01	cm/sec
Slope	=	2.5	%
Drainage Length	=	800	ft

Layer 4

Type 4 - Flexible Membrane Liner
LDPE Membrane
Material Texture Number 36

Thickness	=	0.04	inches
Effective Sat. Hyd. Conductivity	=	4.00E-13	cm/sec
FML Pinhole Density	=	1	Holes/Acre
FML Installation Defects	=	1	Holes/Acre
FML Placement Quality	=	3	Good

Layer 5

Type 1 - Vertical Percolation Layer (Waste)
Electric Plant Coal Bottom Ash
Material Texture Number 83

Thickness	=	372	inches
Porosity	=	0.578	vol/vol
Field Capacity	=	0.076	vol/vol
Wilting Point	=	0.025	vol/vol
Initial Soil Water Content	=	0.0797	vol/vol
Effective Sat. Hyd. Conductivity	=	1.40E-03	cm/sec

Layer 6

Type 1 - Vertical Percolation Layer
Silty CLay
Material Texture Number 44

Thickness	=	84	inches
Porosity	=	0.479	vol/vol
Field Capacity	=	0.371	vol/vol
Wilting Point	=	0.251	vol/vol
Initial Soil Water Content	=	0.371	vol/vol
Effective Sat. Hyd. Conductivity	=	1.20E-07	cm/sec

Note: Initial moisture content of the layers and snow water were computed as nearly steady-state values by HELP.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	87.2	
Fraction of Area Allowing Runoff	=	100	%
Area projected on a horizontal plane	=	84	acres
Evaporative Zone Depth	=	18	inches
Initial Water in Evaporative Zone	=	7.251	inches
Upper Limit of Evaporative Storage	=	7.626	inches
Lower Limit of Evaporative Storage	=	4.86	inches
Initial Snow Water	=	0	inches

Initial Water in Layer Materials	=	75.348	inches
Total Initial Water	=	75.348	inches
Total Subsurface Inflow	=	0	inches/year

Note: SCS Runoff Curve Number was calculated by HELP.

Evapotranspiration and Weather Data

Station Latitude	=	39.59	Degrees
Maximum Leaf Area Index	=	4.5	
Start of Growing Season (Julian Date)	=	102	days
End of Growing Season (Julian Date)	=	292	days
Average Wind Speed	=	10	mph
Average 1st Quarter Relative Humidity	=	72	%
Average 2nd Quarter Relative Humidity	=	66	%
Average 3rd Quarter Relative Humidity	=	73	%
Average 4th Quarter Relative Humidity	=	65	%

Note: Evapotranspiration data was obtained for Kincaid, Illinois

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
2.696568	2.105836	2.602577	3.411672	4.852763	3.801581
3.335953	3.024381	2.885088	4.052491	3.627085	2.799647

Note: Precipitation was simulated based on HELP V4 weather simulation for:
Lat/Long: 39.591502215865/-89.496388435364

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
34.7	35.6	45.8	59.9	73	79.3
83.1	80.3	71.1	62	47.6	36.4

Note: Temperature was simulated based on HELP V4 weather simulation for:
Lat/Long: 39.591502215865/-89.496388435364
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 39.591502215865/-89.496388435364

Average Annual Totals Summary

Title: KIN AP
Simulated on: 6/21/2022 14:14

	Average Annual Totals for Years 1 - 30*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	39.20	[3.42]	11,951,535.3	100.00
Runoff	6.106	[1.913]	1,861,774.0	15.58
Evapotranspiration	29.580	[3.068]	9,019,391.9	75.47
Subprofile1				
Lateral drainage collected from Layer 3	1.8831	[0.1399]	574,191.0	4.80
Percolation/leakage through Layer 4	1.623706	[0.315807]	495,100.4	4.14
Average Head on Top of Layer 4	14.2217	[2.89]	---	---
Subprofile2				
Percolation/leakage through Layer 6	0.229644	[0.509881]	70,022.9	0.59
Water storage				
Change in water storage	1.3976	[1.1065]	426,155.4	3.57

* Note: Average inches are converted to volume based on the user-specified area.

Peak Values Summary

Title: KIN AP
Simulated on: 6/21/2022 14:15

	Peak Values for Years 1 - 30*	
	(inches)	(cubic feet)
Precipitation	3.09	943,327.1
Runoff	2.367	721,828.5
Subprofile1		
Drainage collected from Layer 3	0.0061	1,865.8
Percolation/leakage through Layer 4	0.010880	3,317.7
Average head on Layer 4	36.1098	---
Maximum head on Layer 4	51.4651	---
Location of maximum head in Layer 3	229.55	(feet from drain)
Subprofile2		
Percolation/leakage through Layer 6	0.007879	2,402.3
Other Parameters		
Snow water	3.1704	966,725.5
Maximum vegetation soil water	0.4237	(vol/vol)
Minimum vegetation soil water	0.2700	(vol/vol)

Final Water Storage in Landfill Profile at End of Simulation Period

Title: KIN AP
Simulated on: 6/21/2022 14:15
Simulation period: 30 years

	Final Water Storage	
Layer	(inches)	(vol/vol)
1	2.5567	0.4261
2	11.8327	0.3944
3	0.0935	0.8500
4	0.0000	0.0000
5	62.6261	0.1683
6	40.0001	0.4762
Snow water	0.1673	---

APPENDIX A-3

KPP KAP-3-FT COMPACTED EARTH LAYER, 3-FT FINAL PROTECTIVE COVER SOIL

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title:	KIN AP Earth	**Simulated On:**	6/21/2022 14:26

Layer 1
Type 1 - Vertical Percolation Layer (Cover Soil)
SiCL - Silty Clay Loam
Material Texture Number 12

Thickness	=	6	inches
Porosity	=	0.471	vol/vol
Field Capacity	=	0.342	vol/vol
Wilting Point	=	0.21	vol/vol
Initial Soil Water Content	=	0.4175	vol/vol
Effective Sat. Hyd. Conductivity	=	4.20E-05	cm/sec

Layer 2
Type 1 - Vertical Percolation Layer
Sandy Silty Clay
Material Texture Number 43

Thickness	=	30	inches
Porosity	=	0.4	vol/vol
Field Capacity	=	0.35	vol/vol
Wilting Point	=	0.3	vol/vol
Initial Soil Water Content	=	0.4	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-05	cm/sec

Layer 3
Type 3 - Barrier Soil Liner
Liner Soil (High)
Material Texture Number 16

Thickness	=	36	inches
Porosity	=	0.427	vol/vol
Field Capacity	=	0.418	vol/vol
Wilting Point	=	0.367	vol/vol
Initial Soil Water Content	=	0.427	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-07	cm/sec

Layer 4
Type 1 - Vertical Percolation Layer (Waste)
Electric Plant Coal Bottom Ash

Material Texture Number 83

Thickness	=	372	inches
Porosity	=	0.578	vol/vol
Field Capacity	=	0.076	vol/vol
Wilting Point	=	0.025	vol/vol
Initial Soil Water Content	=	0.0813	vol/vol
Effective Sat. Hyd. Conductivity	=	1.40E-03	cm/sec

Layer 5

Type 1 - Vertical Percolation Layer

Silty CLay

Material Texture Number 44

Thickness	=	84	inches
Porosity	=	0.479	vol/vol
Field Capacity	=	0.371	vol/vol
Wilting Point	=	0.251	vol/vol
Initial Soil Water Content	=	0.371	vol/vol
Effective Sat. Hyd. Conductivity	=	1.20E-07	cm/sec

Note: Initial moisture content of the layers and snow water were computed as nearly steady-state values by HELP.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	87.2	
Fraction of Area Allowing Runoff	=	100	%
Area projected on a horizontal plane	=	84	acres
Evaporative Zone Depth	=	18	inches
Initial Water in Evaporative Zone	=	7.305	inches
Upper Limit of Evaporative Storage	=	7.626	inches
Lower Limit of Evaporative Storage	=	4.86	inches
Initial Snow Water	=	0	inches
Initial Water in Layer Materials	=	91.288	inches
Total Initial Water	=	91.288	inches
Total Subsurface Inflow	=	0	inches/year

Note: SCS Runoff Curve Number was calculated by HELP.

Evapotranspiration and Weather Data

Station Latitude	=	39.59	Degrees
Maximum Leaf Area Index	=	4.5	
Start of Growing Season (Julian Date)	=	102	days
End of Growing Season (Julian Date)	=	292	days

Average Wind Speed	=	10 mph
Average 1st Quarter Relative Humidity	=	72 %
Average 2nd Quarter Relative Humidity	=	66 %
Average 3rd Quarter Relative Humidity	=	73 %
Average 4th Quarter Relative Humidity	=	65 %

Note: Evapotranspiration data was obtained for Kincaid, Illinois

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
2.696568	2.105836	2.602577	3.411672	4.852763	3.801581
3.335953	3.024381	2.885088	4.052491	3.627085	2.799647

Note: Precipitation was simulated based on HELP V4 weather simulation for:
Lat/Long: 39.591502215865/-89.496388435364

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
34.7	35.6	45.8	59.9	73	79.3
83.1	80.3	71.1	62	47.6	36.4

Note: Temperature was simulated based on HELP V4 weather simulation for:
Lat/Long: 39.591502215865/-89.496388435364
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 39.591502215865/-89.496388435364

Average Annual Totals Summary

Title: KIN AP
Simulated on: 6/21/2022 14:28

	Average Annual Totals for Years 1 - 30*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	39.20	[3.42]	11,951,535.3	100.00
Runoff	7.233	[2.095]	2,205,494.3	18.45
Evapotranspiration	29.999	[3.242]	9,147,310.1	76.54
Subprofile1				
Percolation/leakage through Layer 3	1.951622	[0.078786]	595,088.6	4.98
Average Head on Top of Layer 3	20.5532	[2.2902]	---	---
Subprofile2				
Percolation/leakage through Layer 5	0.495501	[0.837159]	151,088.1	1.26
Water storage				
Change in water storage	1.4681	[1.0967]	447,642.8	3.75

* Note: Average inches are converted to volume based on the user-specified area.

Peak Values Summary

Title: KIN AP
Simulated on: 6/21/2022 14:28

	Peak Values for Years 1 - 30*	
	(inches)	(cubic feet)
Precipitation	3.09	943,327.1
Runoff	2.413	735,658.3
Subprofile1		
Percolation/leakage through Layer 3	0.006803	2,074.4
Average head on Layer 3	35.9998	
Subprofile2		
Percolation/leakage through Layer 5	0.008760	2,671.2
Other Parameters		
Snow water	3.1704	966,725.5
Maximum vegetation soil water	0.4237 (vol/vol)	
Minimum vegetation soil water	0.2700 (vol/vol)	

Final Water Storage in Landfill Profile at End of Simulation Period

Title: KIN AP
Simulated on: 6/21/2022 14:28
Simulation period: 30 years

	Final Water Storage	
Layer	(inches)	(vol/vol)
1	2.7721	0.4620
2	11.9240	0.3975
3	15.3720	0.4270
4	64.8616	0.1744
5	40.2328	0.4790
Snow water	0.1673	---

APPENDIX F - GEOTECHNICAL DESIGN OF SLOPES AND FINAL COVER SYSTEM

Project Description

The Kincaid Power Station (Kincaid) is owned and operated by Vistra Energy in Kincaid, Illinois. As part of the permitting for closure of the coal combustion residuals (CCR) pond, evaluations were performed to estimate the general stability of the proposed closure plan. Long term, steady-state (LTSS), end of construction (EOC), and seismic stability evaluations were performed. A stability evaluation of the proposed cover system was also completed.

The approximate surface area of the impoundment is 172 acres. A site layout is shown below in Figure 1 and an aerial view is included in Appendix A. Construction plans involve placing CCR from the northern portion of the pond in the southern portion of the pond. A new soil embankment will be built to separate the areas closed by removal and closed in place. The CCR will be placed at slopes between 3 and 7-percent. A geosynthetic cover system will also be installed. Additional details on the cover system are included in the Cover Stability Check section.

Previous work at the site by others included a subsurface investigation to support an evaluation of the perimeter embankments. Historical drawings and data from the previous subsurface investigation were relied upon to help understand subsurface material properties and develop cross sections. Historical groundwater data from piezometers installed around the pond was used to understand the piezometric surface.

Calculated factors of safety indicate adequate stability for the proposed closure plan.

Figure 1 Vistra Kincaid CCR Pond

Subsurface Information

A subsurface investigation was completed by AECOM in 2015. The investigation included 12 borings, 12 piezometers, and 39 CPTs within and around the pond. Laboratory testing was completed on selected samples and included strength testing, hydraulic conductivity, consolidation testing and index testing. Natural subsurface materials observed at the site consisted of 6 to 22 feet of soft to very stiff lean clay overlying hard glacial till (lean sandy clay). Borings were terminated in the hard glacial till. The existing embankments around the pond were constructed with compacted lean clay material and are between 10 and 25 feet high.

Three different soil types were identified from the borings: Embankment Fill, Natural Clay and Glacial Till. These soil groups were used in modeling subsurface conditions for the stability evaluations.

The elevations of the existing embankment crests range from 605 to 620 feet. The phreatic surface within the embankments is controlled by the water levels within the pond and Sangchris Lake located northwest of the site. Existing information notes normal operating water level within the pond was at an elevation of 603-feet which is slightly higher than piezometric surfaces indicated in existing data.

Cross Sections

Design cross sections are included in Appendix C. Three cross sections across the pond were developed in AutoCAD using borings and sections from drawings provided by the civil engineer (included in Appendix B). Sections show final grades of the CCR material excavated from the north section of the pond and the new embankment, existing embankments and cover system planned for the consolidated CCR. The new embankment will have a 4:1 slope and crest width of 20 to 25 feet. The consolidated CCR material will generally be sloped between 3 and 7-percent. Steeper grades will be located around the toe of the cap to facilitate the installation of perimeter ditches, with a maximum slope of 4:1. The nearest borings were drawn to scale on the appropriate section to approximate soil stratigraphy and material type.

The new embankment dividing the north and south areas of the pond was assumed to be constructed with similar material as the existing embankments. Groundwater was modeled based on the normal pond operating level of 603-feet. Ponded water was not included in the northern area of the pond. After reviewing all three sections, the north side of Section E was found to control the stability evaluations based on the height of embankment and subsurface materials. Section E extends north to south across the pond and crosses the tallest point of the future embankment.

Material Properties

The 2015 investigation included lab testing for particle size, water content, Atterberg limits, and unit weights. To understand the overall characteristics of soils, test results for each soil type denoted above were reviewed as a group. These results were used to estimate design properties for the materials.

Additionally, laboratory test results on undisturbed samples from the 2015 investigation were reviewed to calculate material strength properties. Direct shear tests and consolidated undrained with pore pressure measurement (CU-bar) triaxial tests were performed on multiple samples. Effective and total strength envelopes were calculated for each soil group based on these results.

Total and effective strength parameters calculated from strength testing for each material are outlined below. Strength parameters for CCR were estimated based on experience.

Table 1 Total and Effective Stress Envelopes for Subsurface Materials at Vistra Kincaid

Material	**Unit Weight (pcf)**	**φ (deg)**	**c (psf)**
CCR - Effective	80	25	0
Embankment CL - Total	120	17	592
Embankment CL - Effective	120	35	188
Native CL - Total	115	19	280
Native CL - Effective	115	33	113
Till (CL) - Total	130	20	1000
Till (CL) - Effective	130	38	500
* Strength parameters for Till (CL) material conservatively based on blow counts and relationships observed between total + effective strength envelopes in overburden material.			

Stability Evaluations and Factors of Safety
Stability evaluations were performed for the closure plan based on site-specific conditions using the computer program UTexas 4 (UTexas). Long-term, steady state (LTSS), end of construction (EOC), and seismic stability evaluations were performed. These models served to evaluate the expected conditions that apply to the closure plan final conditions.

The following minimum factors of safety were required for each of the evaluated conditions:

- Long-term, steady state: 1.5
- End of construction: 1.3
- Seismic: 1.0

These values are in line with published values by the U.S. Army Corps of Engineers and Duncan and Wright's *Soil Strength and Slope Stability*.

Stability Inputs
The LTSS analysis evaluated the closure plan stability considering expected daily operating conditions after construction efforts have been completed. In the LTSS model, the new embankment has been constructed and CCR has been moved from the north to south section of the pond for enough time to allow dissipation of any excess pore pressures. The normal daily operating water level was used for the LTSS evaluation to represent long-term groundwater conditions. For LTSS loading, all materials are modeled with drained strengths (effective stress envelopes).

For the EOC analysis, the stability of the closure plan was evaluated for anticipated undrained loading conditions directly after construction of the new embankment and placement of CCR. Undrained strengths of the cohesive materials underlying the pond were used because immediately following construction, excess pore pressure will not yet have had time to dissipate. Shear strengths of each material were estimated based on the effective stress of the material before any construction activities and the total strength envelope. For the new embankment fill, an undrained shear strength of 1000 psf was used based on NAVFAC references for shear strength parameters of compacted lean clay.

The seismic analysis required a two-stage evaluation in UTexas. A total strength envelope was used to model cohesive soils given the loading is relatively quick and thus undrained. Per UTexas guidance and discussions in Duncan and Wright, the total strength envelope measured from triaxial testing must be converted to a "d" and "ψ" envelope. These values are input as part of the UTexas second stage properties for seismic computations. A peak ground acceleration value of 0.11g was applied based on USGS data for the site location. The daily operations water level was used for the seismic evaluation.

A "fixed grid" method within UTexas was utilized for all analyses. In this method, circular shear surfaces are searched through a specified point with the center of the failure surface circle being limited to a specified box based on slope geometry. Different exit points were analyzed to understand variation of the safety factors for different shear surfaces. Most exit points were either at the embankment crest or toe. Each length of the search box was subdivided into 15 different segments leading to a total of 225 shear surfaces analyzed for each stability analysis.

Minimum slide surface weights were included in the evaluations. This was included to prevent UTEXAS from calculating unpractical, thin shear surfaces. (An infinite slope calculation is better to evaluate surface stability like this). Additionally, larger shear surfaces encompassing the entire height of the embankment are considered more representative of possible instabilities.

Results

Inputs and outputs for stability evaluations are included in Appendix D for the controlling section. Results from the stability analyses for Section E, North are listed below in Table 2:

Table 2 Mass Stability Factors of Safety for Section E, North

Section	Stability Analysis Type	Factor of Safety
Section E, North	Long-Term, Steady State	2.1
	End of Construction	1.4
	Seismic	1.4

Calculated safety factors met minimum requirements for LTSS, EOC, and seismic evaluations.

Cover Stability Check

A cover stability check was performed using a spreadsheet solution for the proposed cover system consisting of a 40mil LLDPE underlying 2.0-feet of compacted soil. The most conservative (steepest) slope for the system will be located around the edges of the proposed cap to facilitate the installation of perimeter ditches. This slope is 25% (14.0 degrees) and was used for calculations.

The cover system was checked with both smooth and textured geomembrane material. The interface between the overlying fill and geomembrane was checked in addition to the interface between the geomembrane and underlying CCR. Interface shear strength values from the GRI reference "Direct Shear Database of Geosynthetic-to-Geosynthetic and Geosynthetic-to-Soil Interfaces" were used. This reference is included in Appendix E along with example calculations.

Equations calculating the safety factor for a subaerial slope with a defined pore water pressure were used from Soil Strength and Slope Stability by Duncan and Wright. This reference is included in Appendix E.

Since the geomembrane cuts off movement of water, the considerations for pore pressures above and below the geomembrane will vary. Above the geomembrane, pore pressures from precipitation will be present. A fully saturated cover was evaluated for the interface between the overlying fill and geomembrane. This represents the worst case condition as the porewater pressure increases the driving forces and decreases the factor of safety. The minimum calculated safety factor in this evaluation of the proposed system is 2.8.

For interfaces beneath the geomembrane, saturation from precipitation is not possible given the hydraulic barrier from the geomembrane. Calculations were performed using a minimal water height of 0.01-ft. The minimum calculated safety factor in this evaluation of the proposed system is 2.0.

All safety factors calculated were greater than minimum required safety factor of 1.5.

Mine Subsidence

Mining of coal deposits beneath the pond have been previously performed. Existing reports performed by others were reviewed to understand previous subsidence at the site and possible future subsidence.

Subsidence was previously observed along the west and north embankments of the pond. This subsidence was between 2 and 3.5 feet and was generally observed to be a "bowl" shaped depression. Given the known information related to the coal depth, coal thickness and mining approach, this type of subsidence at the ground surface is expected. Further movement in the areas of previous subsidence are expected to be less than 6-inches.

Mining was also performed beneath the east embankment. At the time of the preparation of the previous report, no indications of subsidence had been observed in this area. However, if future subsidence is to occur, it is expected to be similar to other subsidence at the site in magnitude and shape.

Since the movement associated with these mine collapses at the site are large features with gradual movement, it is not expected to have any effect on stability of the proposed closure plan.

The existing report is included in Appendix G.

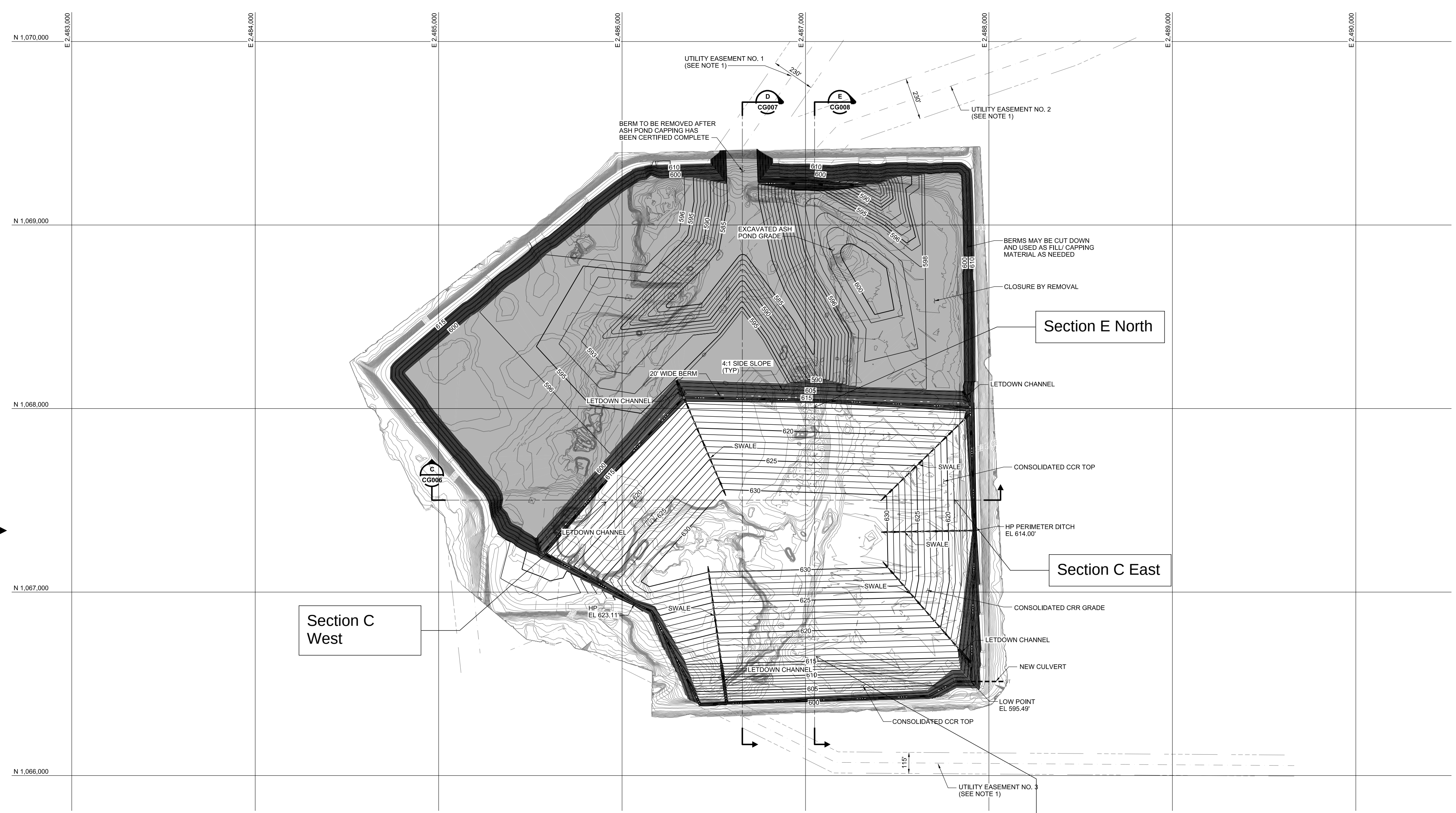
Attachments

Appendix A: Vistra Kincaid Site Location
Appendix B: Proposed Closure Plan Drawings
Appendix C: Cross Sections
Appendix D: Section E, North UTEXAS Results
Appendix E: Cover Stability Calculations
Appendix F: Geotechnical Reference Information
Appendix G: Existing Mine Subsidence Report

Appendix A: Vistra Kincaid Site Location


Kincaid Ash Pond
Kincaid Power Station

Appendix B: Proposed Closure Plan Drawings



NOTES:

1. ASSUMED BOTTOM OF CCR SURFACE BASED ON TOPOGRAPHIC SURFACE FILE BOA_v5A.DWG PROVIDED BY RAMBOLL ON MARCH 14, 2022.
2. UTILITY EASEMENT DELINEATION DESCRIPTION CAN BE FOUND ON DOCUMENT NO. 1998R1245.
3. EXISTING CONTOURS SHOWN ARE FROM TOPOGRAPHY AND BATHYMETRY SURVEY PROVIDED BY INGENAE DATED 2/226/2021.
4. EXISTING PIPES THROUGH DIKES TO BE ABANDONED IN PLACE AND FILLED WITH NON-SHRINK GROUT.
5. SHEET PILING INSTALLED IN INITIAL PHASE TO REMAIN IN PLACE.

PRELIMINARY - NOT FOR CONSTRUCTION

no.	date	by	ckd	description
A	04/20/22	RNO		ISSUED FOR OWNER REVIEW

BURNS McDONNELL
9400 WARD PARKWAY
KANSAS CITY, MO 64114
816-333-9400
Burns & McDonnell Engineering Co, Inc.
Firm Reg. No. 184.001310-0006

designed R. OWENS
detailed S. NICHOLS

Luminant
SOUTH FORK TOWNSHIP, ILLINOIS

KINCAID ASH POND
CONSOLIDATED GRADING PLAN
PHASE 2

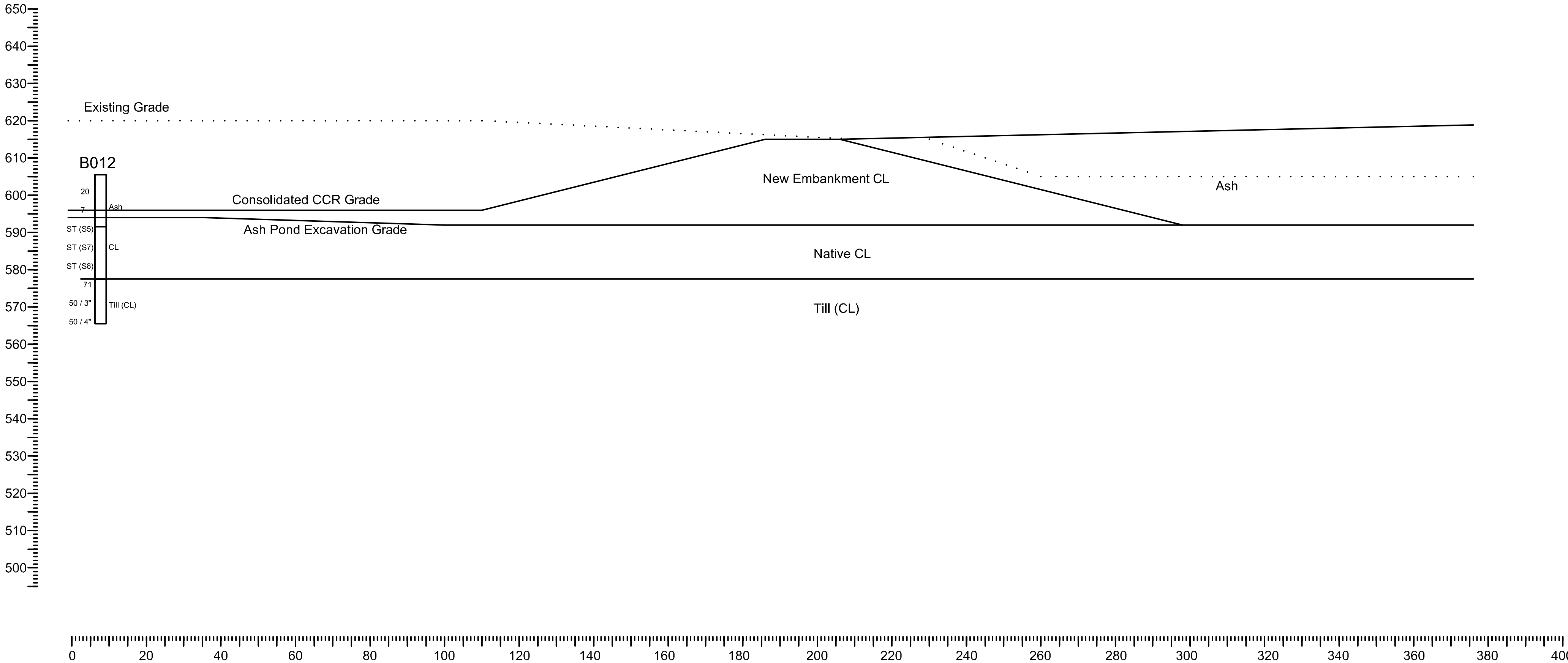
project 132803
contract 8110
drawing CG002 — rev. A
sheet 1 of 1 sheets
file 135946CG002.DGN

Z:\Clients\ENS\VistraEnergy\132803_Pt845CnPermit\Design\CADD\Dwgs\Dwgs\Contracts\132803CG002.dgn

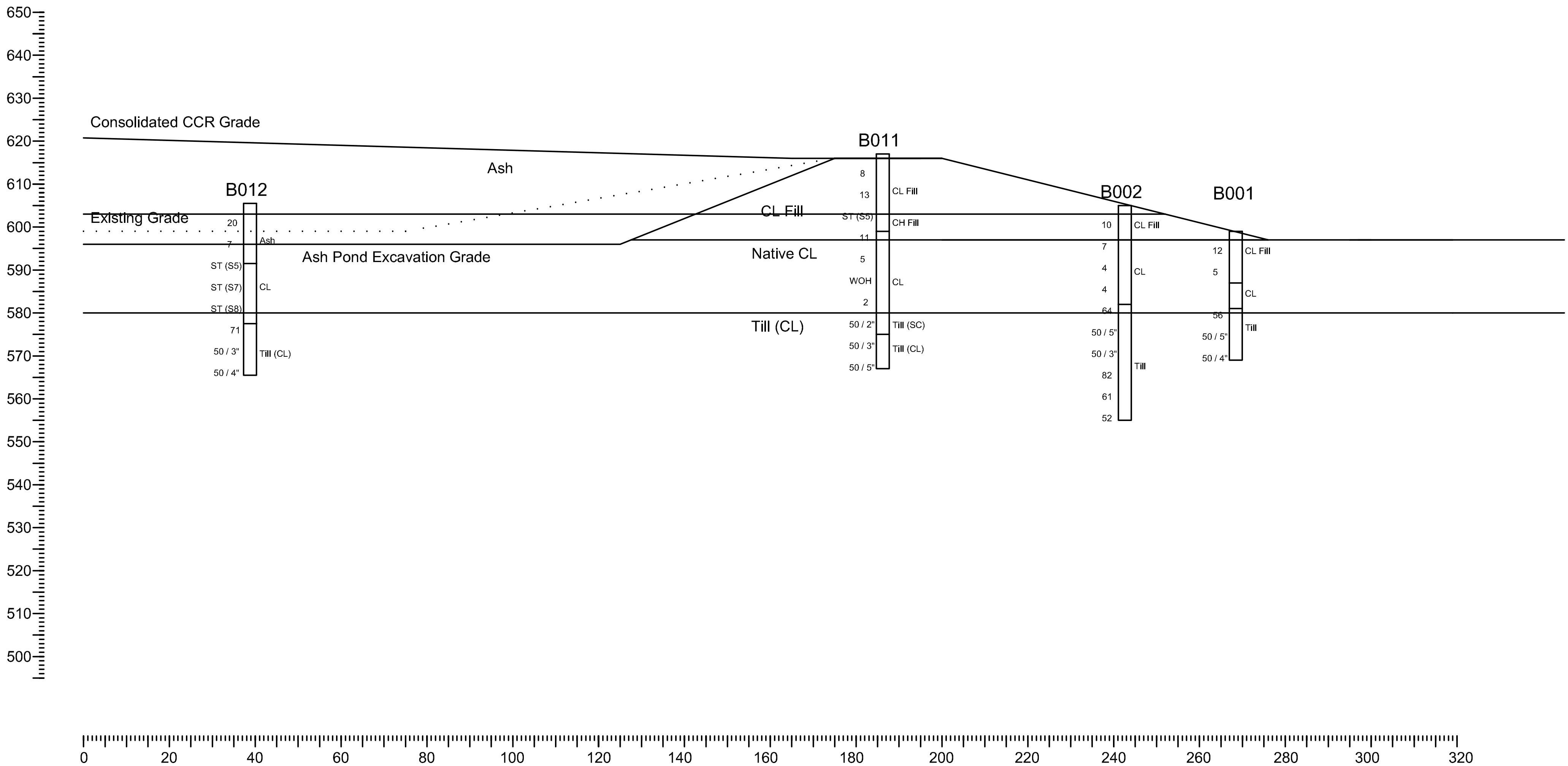
4/20/2022 sknichols 2:59:19 PM

Appendix C: Cross Sections

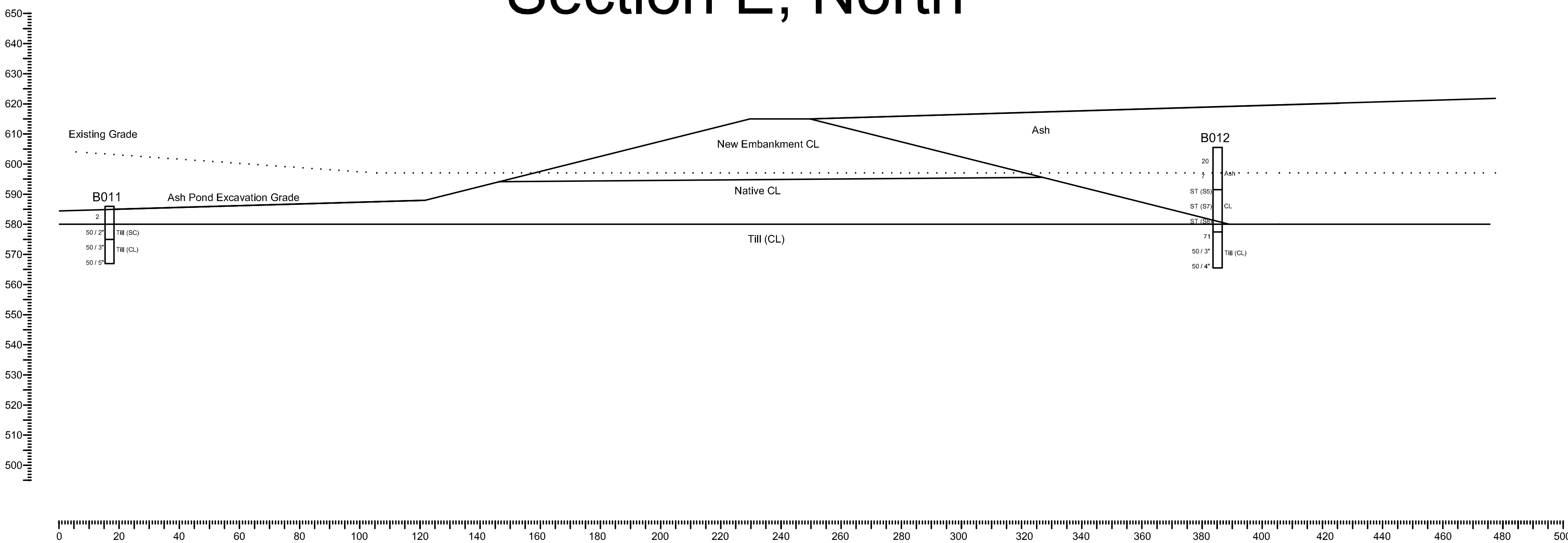
Section C, West



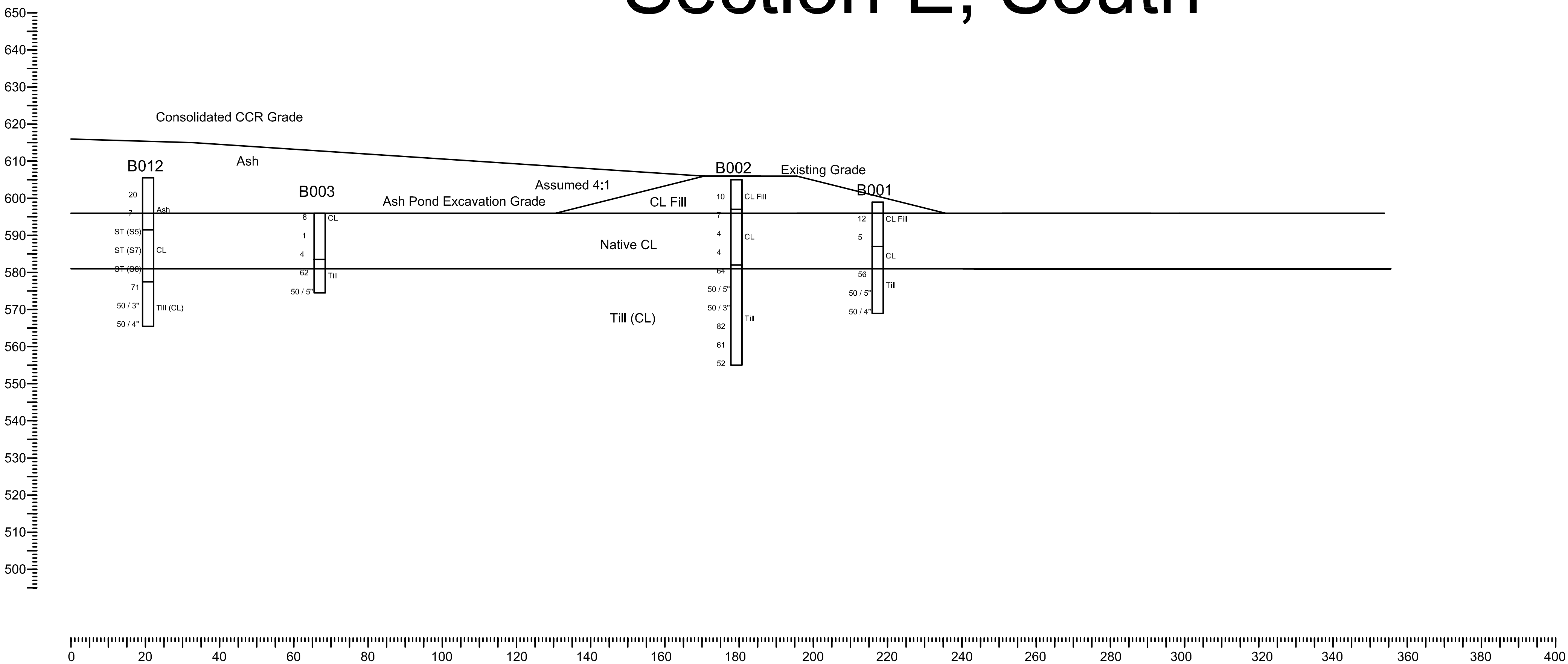
Section C, East



Section E, North



Section E, South



Appendix D: Section E, North UTEXAS Results

Section	Stability Analysis Type	Factor of Safety
Section E, North	Long-Term, Steady State	2.1
	End of Construction	1.4
	Seismic	1.4

Profile: Section E, North Case: LTSS File: Section E, North (LTSS)
Assumptions: LTSS for after construction has been completed

Unit Weight Average Effective Average Total Average

Fixed Grid Coordinates

x	y
100	620
100	750
230	750
230	620

Circle Exit
x 217 y 615
Tangent

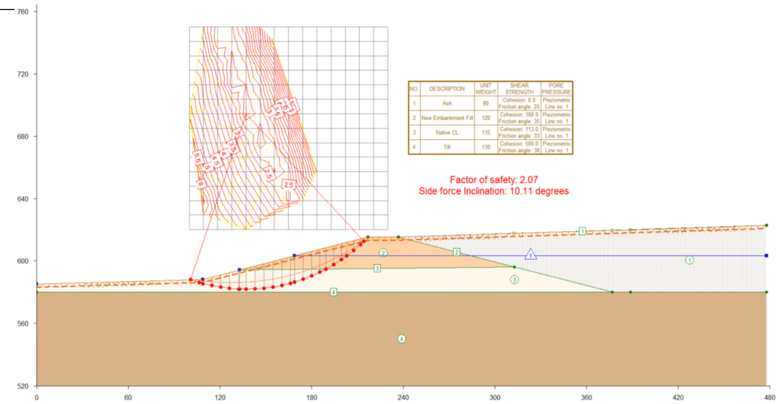
Search Grid Subdivisions
15
Crack Depth
2
Seismic Acceleration

Minimum Weight
10000

Results

Circles Attempted	Circles Completed	Circle Center x	Circle Center y	Circle Exit x	Circle Exit y
225	65	137	694	101	587

Factor of Safety	Errors
2.07	



Profile: Section E, North Case: EOC File: Section E, North (EOC)
Assumptions: End of construction. Cohesive soils modeled using cohesion only based on in-situ effective stresses before construction.

Unit Weight Average Effective Average Total Average

Embankment fill
c = 1000

Fixed Grid Coordinates

x	y
100	660
100	760
230	760
230	660

Circle Exit
x 109 y 588
Tangent

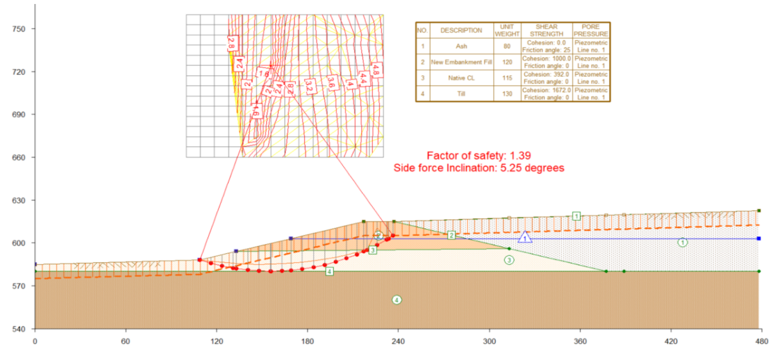
Search Grid Subdivisions
15
Crack Depth
10
Seismic Acceleration

Minimum Weight
10000

Results

Circles Attempted	Circles Completed	Circle Center x	Circle Center y	Circle Exit x	Circle Exit y
225	131	156	724	235	615

Factor of Safety	Errors
1.39	



Profile: Section E, North Case: Seismic File: Section E, North (Seismic)
Assumptions: End of construction. Cohesive soils modeled using cohesion only based on in-situ effective stresses before construction.

Unit Weight Average Effective Average Total Average

Fixed Grid Coordinates

x	y
100	640
100	750
190	750
190	640

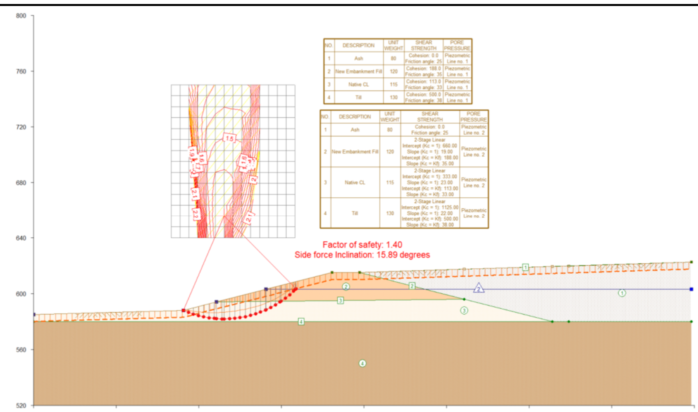
Circle Exit
x 109 y 588
Tangent

Search Grid Subdivisions
15
Crack Depth
5
Seismic Acceleration
0.11
Minimum Weight
10000

Results

Circles Attempted	Circles Completed	Circle Center x	Circle Center y	Circle Exit x	Circle Exit y
225	111	139	656	191	609

Factor of Safety	Errors
1.4	



Vistra Kincaid Pond

Cross-Section: E, North
Case: Long-Term, Steady State
Filename: Section E, North (LTSS)

UTEXAS4 Input File


```
GRAphics
HEAding follows -
Vistra Kincaid CCR - Section E, North (LTSS)
#132803

PROfile lines
   1 1 Ash
        237 615
        478 622.5

   2 2 New Embankment Fill
        133 594
        169 603
        217 615
        237 615
        313 596

   3 3 Native CL
         0 585
        109 588
        133 594
        313 596
        377 580

   4 4 Till
         0 580
        389 580
        478 580


MATerial properties
   1 Ash
      80 = unit weight
      Conventional Shear Strength
        0 25
      Piezometric Line
         1
   2 New Embankment Fill
      120 = unit weight
      Conventional Shear Strength
        188 35
      Piezometric Line
         1
   3 Native CL
      115 = unit weight
      Conventional Shear Strength
        113 33
      Piezometric Line
         1
   4 Till
      130 = unit weight
      Conventional Shear Strength
        500 38
      Piezometric Line
         1

PIEzometric line
     1 Piezometric Line
        0 585
        109 588
        133 594
        169 603
```

```
       478 603


LABel
Vistra Kincaid CCR - Section E, North (LTSS)
ANALYSIS/COMPUTATION
   Circular Search 2
     15 15
     100 620 100 750 230 750 230 620
     5 5
   Point
     217 615

      Minimum
        10000
     Crack
       2 D
     Short

COMpute
```

Vistra Kincaid Pond

Cross-Section: E, North
Case: Long-Term, Steady State
Filename: Section E, North (LTSS)

UTEXAS4 Input File


```
TABLE NO. 1
COMPUTER PROGRAM DESIGNATION: UTEXAS4
Originally Coded By Stephen G. Wright
Version No. 4.1.2.0 - Last Revision Date: 7/29/2020
(C) Copyright 1985-2020 S. G. Wright - All rights reserved
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* IMPLIED, CONCERNING THE ACCURACY, RELIABILITY, USEFULNESS      *
* OR ADAPTABILITY OF THIS SOFTWARE.                              *
******************************************************************
```

```
TABLE NO. 3
************************
* NEW PROFILE LINE DATA *
************************

----------------------------------------------------------
----- Profile Line No. 1 - Material Type (Number): 1 -----
----------------------------------------------------------
Description: Ash

Point        X           Y

   1      237.00      615.00
   2      478.00      622.50

----------------------------------------------------------
----- Profile Line No. 2 - Material Type (Number): 2 -----
----------------------------------------------------------
Description: New Embankment Fill

Point        X           Y

   1      133.00      594.00
   2      169.00      603.00
   3      217.00      615.00
   4      237.00      615.00
   5      313.00      596.00

----------------------------------------------------------
----- Profile Line No. 3 - Material Type (Number): 3 -----
----------------------------------------------------------
Description: Native CL

Point        X           Y

   1        0.00      585.00
   2      109.00      588.00
   3      133.00      594.00
   4      313.00      596.00
   5      377.00      580.00

----------------------------------------------------------
----- Profile Line No. 4 - Material Type (Number): 4 -----
----------------------------------------------------------
Description: Till

Point        X           Y

   1        0.00      580.00
   2      389.00      580.00
   3      478.00      580.00
```

```
TABLE NO. 4
*******************************************************************
* NEW MATERIAL PROPERTY DATA - CONVENTIONAL/FIRST-STAGE COMPUTATIONS *
*******************************************************************

-----------------------------------------------------------------
------------------- DATA FOR MATERIAL NUMBER 1 -------------------
-----------------------------------------------------------------
Description: Ash

Constant unit weight of soil (material): 80.0

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - 0.0
Friction angle - - - - - 25.00 (degrees)

Pore water pressures are defined by a piezometric line.
Piezometric line number: 1
Negative pore water pressures are NOT allowed - set to zero.

-----------------------------------------------------------------
------------------- DATA FOR MATERIAL NUMBER 2 -------------------
-----------------------------------------------------------------
Description: New Embankment Fill

Constant unit weight of soil (material): 120.0

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - 188.0
Friction angle - - - - - 35.00 (degrees)

Pore water pressures are defined by a piezometric line.
Piezometric line number: 1
Negative pore water pressures are NOT allowed - set to zero.

-----------------------------------------------------------------
------------------- DATA FOR MATERIAL NUMBER 3 -------------------
-----------------------------------------------------------------
Description: Native CL

Constant unit weight of soil (material): 115.0

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - 113.0
Friction angle - - - - - 33.00 (degrees)

Pore water pressures are defined by a piezometric line.
Piezometric line number: 1
Negative pore water pressures are NOT allowed - set to zero.

-----------------------------------------------------------------
------------------- DATA FOR MATERIAL NUMBER 4 -------------------
-----------------------------------------------------------------
Description: Till

Constant unit weight of soil (material): 130.0

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - 500.0
Friction angle - - - - - 38.00 (degrees)

Pore water pressures are defined by a piezometric line.
```

```
Piezometric line number: 1
Negative pore water pressures are NOT allowed - set to zero.
```

```
TABLE NO. 6
*******************************************************************
* NEW PIEZOMETRIC LINE DATA - CONVENTIONAL/FIRST-STAGE COMPUTATIONS *
*******************************************************************

--------------------------------------------------------
--------------- Piezometric Line Number 1 ---------------
--------------------------------------------------------
Description: Piezometric Line
Unit weight of fluid (water): 62.4

Point        X           Y

  1        0.00      585.00
  2      109.00      588.00
  3      133.00      594.00
  4      169.00      603.00
  5      478.00      603.00
```

```
TABLE NO. 16
*********************************
* NEW ANALYSIS/COMPUTATION DATA *
*********************************


Search will be conducted using a fixed grid.
Number of Points Across Grid: 15
Number of Points Up Grid: 15

Grid Corner
   Number           X              Y

     1           100.00         620.00
     2           100.00         750.00
     3           230.00         750.00
     4           230.00         620.00

----- Control Parameters for Finding "Critical" Radius -----
Initial number of subdivisions between maximum and minimum
radius for finding a critical radius/radii: 5

Minimum radius increment for terminating subdivision of radii: 5.000

The following criteria will be used for determining
the maximum and minimum radii:
     Point circles pass through - X: 217.00     Y: 615.00
Minimum weight required for computations to be performed: 10000

Depth of crack: 2.000
Automatic search output will be in short form.

--------------------------------------------------------------------------------
The following represent default values or values that were prevously defined:
Subtended angle for slice subdivision: 3.00(degrees)
There is no water in a crack.
Conventional (single-stage) computations will be performed.
Seismic coefficient: 0.000
Unit weight of water (or other fluid) in crack: 62.4
Search will be continued after the initial mode to find a most critical circle.
No restrictions exist on the lateral extent of the search.
No shear surfaces other than the most critical will be saved for display later.
Neither slope face was explicitly designated for analysis.
Radii for each grid point will be sorted in the order of increasing radius.
Critical circles for grid points will be output in the order of increasing factor of safety.
Standard sign convention used for direction of shear stress on shear surface.
Procedure of Analysis: Spencer

Iteration limit: 100
Force imbalance: 1.000000e-005 (fraction of total weight)
Moment imbalance: 1.000000e-005 (fraction of moment due to total weight)
Initial trial factor of safety: 3.000
Initial trial side force inclination: 17.189 (degrees)
Minimum (most negative) side force inclination allowed in Spencer's procedure: -10.00
```

```
TABLE NO. 26
*************************************
* NEW, COMPUTED SLOPE GEOMETRY DATA *
*************************************

These slope geometry were generated from the Profile Lines.
```

Point	X	Y
1	0.00	585.00
2	109.00	588.00
3	133.00	594.00
4	169.00	603.00
5	217.00	615.00
6	237.00	615.00
7	313.00	617.37
8	377.00	619.36
9	389.00	619.73
10	478.00	622.50

```
TABLE NO. 38
*************************************************
* FINAL SUMMARY OF COMPUTATIONS WITH FIXED-GRID *
*************************************************


Number of circles attempted: 225
Number of circles for which F calculated: 65
Circle with Lowest Factor of Safety:
     X coordinate for center: 137.14
     Y coordinate for center: 694.29
     Radius of circle: 112.532
Factor of safety: 2.068
Side force inclination: 10.11
Time Required for Computations: 1.0 seconds
```

```
TABLE NO. 43
************************************************************
* Coordinate, Weight, Strength and Pore Water Pressure     *
* Information for Individual Slices for Conventional       *
* Computations or First Stage of Multi-Stage Computations. *
* (Information is for the critical shear surface in the    *
* case of an automatic search.)                            *
************************************************************
```

Slice No.	X	Y	Slice Weight	Matl. No.	Cohesion	Friction Angle	Pore Pressure
	100.83	587.78					
1	103.64	586.90	617	3	113.0	33.00	59.6
	106.45	586.02					
2	107.73	585.68	671	3	113.0	33.00	142.9
	109.00	585.33					
3	111.87	584.67	2673	3	113.0	33.00	252.7
	114.74	584.01					
4	117.64	583.50	4447	3	113.0	33.00	415.9
	120.54	582.99					
5	123.47	582.63	6046	3	113.0	33.00	561.0
	126.39	582.27					
6	129.33	582.06	7447	3	113.0	33.00	687.5
	132.27	581.86					
7	132.63	581.84	1015	3	113.0	33.00	752.8
	133.00	581.83					
8	135.07	581.79	6073	3	113.0	33.00	794.1
	137.14	581.75					
9	140.09	581.83	9492	3	113.0	33.00	869.9
	143.03	581.91					
10	145.97	582.14	10292	3	113.0	33.00	942.4
	148.91	582.37					
11	151.83	582.75	10846	3	113.0	33.00	995.4
	154.75	583.14					
12	157.64	583.68	11152	3	113.0	33.00	1028.6
	160.54	584.21					
13	163.40	584.90	11210	3	113.0	33.00	1042.1
	166.27	585.59					
14	167.63	585.97	5355	3	113.0	33.00	1041.2
	169.00	586.36					
15	171.80	587.27	10853	3	113.0	33.00	981.9
	174.60	588.17					
16	177.36	589.23	10329	3	113.0	33.00	859.5
	180.11	590.28					
17	182.80	591.47	9593	3	113.0	33.00	719.2
	185.49	592.67					
18	187.45	593.65	6541	3	113.0	33.00	583.5
	189.41	594.63					
19	191.98	596.06	7829	2	188.0	35.00	432.9
	194.55	597.50					
20	197.04	599.07	6549	2	188.0	35.00	245.4
	199.54	600.64					
21	201.24	601.82	3783	2	188.0	35.00	73.8
	202.95	603.00					
22	205.29	604.78	4100	2	188.0	35.00	0.0
	207.64	606.57					
23	209.88	608.47	2560	2	188.0	35.00	0.0
	212.13	610.38					
24	213.18	611.34	683	2	188.0	35.00	0.0
	214.23	612.31					

No water in crack.

```
TABLE NO. 44
**********************************************************
* Seismic Forces and Forces Due to Distributed Loads for *
* Individual Slices for Conventional Computations or the *
* First Stage of Multi-Stage Computations.               *
* (Information is for the critical shear surface in the  *
* case of an automatic search.)                          *
**********************************************************

There are no seismic forces or forces due to distributed loads
for the current shear surface
```

```
TABLE NO. 47
*************************************************************
*  Information for the Iterative Solution for the Factor of  *
*  Safety and Side Force Inclination by Spencer's Procedure  *
*************************************************************
Allowable force imbalance for convergence:  2
Allowable moment imbalance for convergence: 243

        Trial     Trial
       Factor   Side Force     Force       Moment                 Delta
Iter-    of    Inclination   Imbalance   Imbalance    Delta-F     Theta
ation  Safety   (degrees)      (lbs.)    (ft.-lbs.)              (degrees)

   1   3.00000    17.1887   9.861e+003  -4.968e+006
First-order corrections to F and Theta ............   -1.2396    -1.5179
Reduced values - Deltas were too large ............   -0.5000    -0.6123

   2   2.50000    16.5765   5.072e+003  -2.529e+006
First-order corrections to F and Theta ............   -0.4598    -2.2470
Second-order corrections to F and Theta ...........   -0.4347    -5.6902
Reduced values - Deltas were too large ............   -0.2189    -2.8648

   3   2.28114    13.7117   2.690e+003  -1.382e+006
First-order corrections to F and Theta ............   -0.2139    -1.8553
Second-order corrections to F and Theta ...........   -0.2140    -3.4947
Reduced values - Deltas were too large ............   -0.1754    -2.8648

   4   2.10574    10.8469   5.070e+002  -2.669e+005
First-order corrections to F and Theta ............   -0.0378    -0.6351
Second-order corrections to F and Theta ...........   -0.0382    -0.7403

   5   2.06758    10.1066  -1.629e-001   9.968e+001
First-order corrections to F and Theta ............    0.0000    -0.0007
```

```
TABLE NO. 55
*********************************************************************
* Check of Computations by Spencer's Procedure (Results are for the *
* critical shear surface in the case of an automatic search.)       *
*********************************************************************

Summation of Horizontal Forces: 7.17648e-012

Summation of Vertical Forces: 1.13687e-011

Summation of Moments: -2.12780e-004

Mohr Coulomb Shear Force/Shear Strength Check Summation: 5.54223e-012
```

```
TABLE NO. 58
*********************************************************************
* Final Results for Stresses Along the Shear Surface                *
* (Results are for the critical shear surface in the case of a search.) *
*********************************************************************

SPENCER'S PROCEDURE USED TO COMPUTE THE FACTOR OF SAFETY
Factor of Safety: 2.068     Side Force Inclination:  10.11
```

-------- VALUES AT CENTER OF BASE OF SLICE --------

Slice No.	X-Center	Y-Center	Total Normal Stress	Effective Normal Stress	Shear Stress
1	103.64	586.90	161.2	101.6	86.6
2	107.73	585.68	330.2	187.4	113.5
3	111.87	584.67	548.6	295.9	147.6
4	117.64	583.50	862.6	446.7	195.0
5	123.47	582.63	1128.5	567.5	232.9
6	129.33	582.06	1348.9	661.3	262.4
7	132.63	581.84	1458.0	705.3	276.2
8	135.07	581.79	1527.0	732.9	284.8
9	140.09	581.83	1649.5	779.6	299.5
10	145.97	582.14	1758.6	816.2	311.0
11	151.83	582.75	1828.7	833.4	316.4
12	157.64	583.68	1861.4	832.8	316.2
13	163.40	584.90	1858.1	816.0	311.0
14	167.63	585.97	1836.6	795.4	304.5
15	171.80	587.27	1788.4	806.5	308.0
16	177.36	589.23	1696.6	837.1	317.6
17	182.80	591.47	1571.6	852.4	322.4
18	187.45	593.65	1438.7	855.2	323.3
19	191.98	596.06	1256.3	823.4	369.8
20	197.04	599.07	1035.5	790.1	358.5
21	201.24	601.82	828.4	754.6	346.5
22	205.29	604.78	616.2	616.2	299.6
23	209.88	608.47	369.2	369.2	216.0
24	213.18	611.34	181.9	181.9	152.5

```
TABLE NO. 59
*******************************************************************************
* Final Results for Side Forces and Stresses Between Slices                    *
* (Results are for the critical shear surface in the case of a search.)        *
*******************************************************************************
```

--------------- VALUES AT RIGHT SIDE OF SLICE ---------------

Slice No.	X-Right	Side Force	Y-Coord. of Side Force Location	Fraction of Height	Sigma at Top	Sigma at Bottom
1	106.45	782	587.40	0.722	939.9	-133.7
2	109.00	1307	587.07	0.651	919.8	44.3
3	114.74	2905	586.49	0.458	392.7	661.1
4	120.54	4949	586.07	0.391	213.4	1020.0
5	126.39	7154	585.89	0.360	110.3	1287.2
6	132.27	9281	585.94	0.342	37.6	1490.6
7	133.00	9530	585.97	0.340	29.8	1512.0
8	137.14	10846	586.15	0.331	-10.6	1618.5
9	143.03	12380	586.60	0.321	-59.4	1729.0
10	148.91	13410	587.27	0.314	-99.8	1791.7
11	154.75	13858	588.14	0.307	-132.0	1806.3
12	160.54	13689	589.24	0.301	-154.9	1771.6
13	166.27	12903	590.55	0.297	-166.2	1684.9
14	169.00	12313	591.27	0.295	-166.1	1622.9
15	174.60	10769	592.92	0.292	-160.5	1467.1
16	180.11	8914	594.77	0.290	-148.3	1280.9
17	185.49	6861	596.86	0.290	-122.2	1056.8
18	189.41	5286	598.62	0.296	-86.5	858.9
19	194.55	3554	601.00	0.295	-68.5	657.1
20	199.54	2070	603.59	0.296	-45.9	453.5
21	202.95	1281	605.48	0.292	-36.5	333.6
22	207.64	473	608.22	0.271	-28.6	181.6
23	212.13	30	611.16	0.228	-5.5	23.1
24	214.23	0	612.31	Below	-0.0	0.0

Read end-of-file on input while looking for another command word.
End of input data assumed - normal termination.

Vistra Kincaid Pond

Cross-Section: E, North
Case: End of Construction
Filename: Section E, North (EOC)

UTEXAS4 Input File


```
GRAphics
HEAding follows -
Vistra Kincaid CCR - Section E, North (EOC)
#132803

PROfile lines
   1 1 Ash
        237 615
        478 622.5

   2 2 New Embankment Fill
        133 594
        169 603
        217 615
        237 615
        313 596

   3 3 Native CL
         0 585
        109 588
        133 594
        313 596
        377 580

   4 4 Till
         0 580
        389 580
        478 580


MATerial properties
   1 Ash
      80 = unit weight
      Conventional Shear Strength
        0 25
      Piezometric Line
         1
   2 New Embankment Fill
      120 = unit weight
      Conventional Shear Strength
        1000 0
      Piezometric Line
         1
   3 Native CL
      115 = unit weight
      Conventional Shear Strength
        392 0
      Piezometric Line
         1
   4 Till
      130 = unit weight
      Conventional Shear Strength
        1672 0
      Piezometric Line
         1

PIEzometric line
     1 Piezometric Line
        0 585
        109 588
        133 594
        169 603
```

```
       478 603


LABel
Vistra Kincaid CCR - Section E, North (EOC)
ANALYSIS/COMPUTATION
   Circular Search 2
     15 15
     100 660 100 760 230 760 230 660
     5 5
   Point
     109 588

      Minimum
       10000
     Crack
      10 D
     Short

COMpute
```

```
TABLE NO. 1
COMPUTER PROGRAM DESIGNATION: UTEXAS4
Originally Coded By Stephen G. Wright
Version No. 4.1.2.0 - Last Revision Date: 7/29/2020
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* OR ADAPTABILITY OF THIS SOFTWARE.                             *
*****************************************************************
```

```
TABLE NO. 3
*************************
* NEW PROFILE LINE DATA *
*************************

----------------------------------------------------------
----- Profile Line No. 1 - Material Type (Number): 1 -----
----------------------------------------------------------
Description: Ash

Point        X           Y

   1      237.00      615.00
   2      478.00      622.50

----------------------------------------------------------
----- Profile Line No. 2 - Material Type (Number): 2 -----
----------------------------------------------------------
Description: New Embankment Fill

Point        X           Y

   1      133.00      594.00
   2      169.00      603.00
   3      217.00      615.00
   4      237.00      615.00
   5      313.00      596.00

----------------------------------------------------------
----- Profile Line No. 3 - Material Type (Number): 3 -----
----------------------------------------------------------
Description: Native CL

Point        X           Y

   1        0.00      585.00
   2      109.00      588.00
   3      133.00      594.00
   4      313.00      596.00
   5      377.00      580.00

----------------------------------------------------------
----- Profile Line No. 4 - Material Type (Number): 4 -----
----------------------------------------------------------
Description: Till

Point        X           Y

   1        0.00      580.00
   2      389.00      580.00
   3      478.00      580.00
```

```
TABLE NO. 4
**********************************************************************
* NEW MATERIAL PROPERTY DATA - CONVENTIONAL/FIRST-STAGE COMPUTATIONS *
**********************************************************************

------------------------------------------------------------------
------------------- DATA FOR MATERIAL NUMBER 1 -------------------
------------------------------------------------------------------
Description: Ash

Constant unit weight of soil (material): 80.0

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - - 0.0
Friction angle - - - - - 25.00 (degrees)

Pore water pressures are defined by a piezometric line.
Piezometric line number: 1
Negative pore water pressures are NOT allowed - set to zero.

------------------------------------------------------------------
------------------- DATA FOR MATERIAL NUMBER 2 -------------------
------------------------------------------------------------------
Description: New Embankment Fill

Constant unit weight of soil (material): 120.0

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - - 1000.0
Friction angle - - - - - 0.00 (degrees)

Pore water pressures are defined by a piezometric line.
Piezometric line number: 1
Negative pore water pressures are NOT allowed - set to zero.

------------------------------------------------------------------
------------------- DATA FOR MATERIAL NUMBER 3 -------------------
------------------------------------------------------------------
Description: Native CL

Constant unit weight of soil (material): 115.0

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - - 392.0
Friction angle - - - - - 0.00 (degrees)

Pore water pressures are defined by a piezometric line.
Piezometric line number: 1
Negative pore water pressures are NOT allowed - set to zero.

------------------------------------------------------------------
------------------- DATA FOR MATERIAL NUMBER 4 -------------------
------------------------------------------------------------------
Description: Till

Constant unit weight of soil (material): 130.0

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - - 1672.0
Friction angle - - - - - 0.00 (degrees)

Pore water pressures are defined by a piezometric line.
```

```
Piezometric line number: 1
Negative pore water pressures are NOT allowed - set to zero.
```

```
TABLE NO. 6
*******************************************************************
* NEW PIEZOMETRIC LINE DATA - CONVENTIONAL/FIRST-STAGE COMPUTATIONS *
*******************************************************************

---------------------------------------------------------
--------------- Piezometric Line Number 1 ---------------
---------------------------------------------------------
Description: Piezometric Line
Unit weight of fluid (water): 62.4

Point        X           Y

  1        0.00      585.00
  2      109.00      588.00
  3      133.00      594.00
  4      169.00      603.00
  5      478.00      603.00
```

```
TABLE NO. 16
*********************************
* NEW ANALYSIS/COMPUTATION DATA *
*********************************


Search will be conducted using a fixed grid.
Number of Points Across Grid: 15
Number of Points Up Grid: 15

Grid Corner
   Number           X              Y

     1           100.00         660.00
     2           100.00         760.00
     3           230.00         760.00
     4           230.00         660.00

----- Control Parameters for Finding "Critical" Radius -----
Initial number of subdivisions between maximum and minimum
radius for finding a critical radius/radii: 5

Minimum radius increment for terminating subdivision of radii: 5.000

The following criteria will be used for determining
the maximum and minimum radii:
     Point circles pass through - X: 109.00     Y: 588.00
Minimum weight required for computations to be performed: 10000

Depth of crack: 10.000
Automatic search output will be in short form.

--------------------------------------------------------------------------------
The following represent default values or values that were prevously defined:
Subtended angle for slice subdivision: 3.00(degrees)
There is no water in a crack.
Conventional (single-stage) computations will be performed.
Seismic coefficient: 0.000
Unit weight of water (or other fluid) in crack: 62.4
Search will be continued after the initial mode to find a most critical circle.
No restrictions exist on the lateral extent of the search.
No shear surfaces other than the most critical will be saved for display later.
Neither slope face was explicitly designated for analysis.
Radii for each grid point will be sorted in the order of increasing radius.
Critical circles for grid points will be output in the order of increasing factor of safety.
Standard sign convention used for direction of shear stress on shear surface.
Procedure of Analysis: Spencer

Iteration limit: 100
Force imbalance: 1.000000e-005 (fraction of total weight)
Moment imbalance: 1.000000e-005 (fraction of moment due to total weight)
Initial trial factor of safety: 3.000
Initial trial side force inclination: 17.189 (degrees)
Minimum (most negative) side force inclination allowed in Spencer's procedure: -10.00
```

```
TABLE NO. 26
*************************************
* NEW, COMPUTED SLOPE GEOMETRY DATA *
*************************************

These slope geometry were generated from the Profile Lines.

     Point       X           Y

        1        0.00      585.00
        2      109.00      588.00
        3      133.00      594.00
        4      169.00      603.00
        5      217.00      615.00
        6      237.00      615.00
        7      313.00      617.37
        8      377.00      619.36
        9      389.00      619.73
       10      478.00      622.50
```

```
TABLE NO. 38
*************************************************
* FINAL SUMMARY OF COMPUTATIONS WITH FIXED-GRID *
*************************************************


Number of circles attempted: 225
Number of circles for which F calculated: 131
Circle with Lowest Factor of Safety:
     X coordinate for center: 155.71
     Y coordinate for center: 724.29
     Radius of circle: 144.069
Factor of safety: 1.385
Side force inclination: 5.25
Time Required for Computations: 1.0 seconds
```

```
TABLE NO. 43
************************************************************
* Coordinate, Weight, Strength and Pore Water Pressure     *
* Information for Individual Slices for Conventional       *
* Computations or First Stage of Multi-Stage Computations. *
* (Information is for the critical shear surface in the    *
* case of an automatic search.)                            *
************************************************************
```

Slice No.	X	Y	Slice Weight	Matl. No.	Cohesion	Friction Angle	Pore Pressure
	109.00	588.00					
1	112.60	586.87	1679	3	392.0	0.00	126.6
	116.20	585.74					
2	119.85	584.80	4964	3	392.0	0.00	368.8
	123.50	583.86					
3	127.20	583.12	8020	3	392.0	0.00	588.6
	130.89	582.37					
4	131.95	582.19	2794	3	392.0	0.00	720.3
	133.00	582.02					
5	136.74	581.52	11567	3	392.0	0.00	837.0
	140.48	581.02					
6	144.24	580.72	14009	3	392.0	0.00	1003.7
	148.00	580.42					
7	151.77	580.32	16099	3	392.0	0.00	1146.4
	155.54	580.22					
8	155.62	580.22	405	3	392.0	0.00	1213.1
	155.71	580.22					
9	159.48	580.31	17846	3	392.0	0.00	1267.1
	163.25	580.41					
10	166.13	580.62	14539	3	392.0	0.00	1351.6
	169.00	580.83					
11	172.74	581.28	19873	3	392.0	0.00	1355.6
	176.49	581.72					
12	180.21	582.36	20453	3	392.0	0.00	1287.7
	183.92	583.00					
13	187.60	583.84	20620	3	392.0	0.00	1195.6
	191.28	584.67					
14	194.91	585.70	20381	3	392.0	0.00	1079.5
	198.54	586.73					
15	202.11	587.94	19751	3	392.0	0.00	939.6
	205.68	589.16					
16	209.18	590.56	18749	3	392.0	0.00	776.5
	212.68	591.96					
17	214.84	592.93	11119	3	392.0	0.00	628.4
	217.00	593.90					
18	218.10	594.43	5422	3	392.0	0.00	534.8
	219.20	594.96					
19	222.54	596.71	14666	2	1000.0	0.00	392.6
	225.88	598.46					
20	229.13	600.38	11385	2	1000.0	0.00	163.5
	232.37	602.30					
21	232.92	602.65	1629	2	1000.0	0.00	21.8
	233.47	603.00					
22	234.99	604.00	4006	2	1000.0	0.00	0.0
	236.50	605.00					

No water in crack.

```
TABLE NO. 44
**********************************************************
* Seismic Forces and Forces Due to Distributed Loads for *
* Individual Slices for Conventional Computations or the *
* First Stage of Multi-Stage Computations.               *
* (Information is for the critical shear surface in the  *
* case of an automatic search.)                          *
**********************************************************

There are no seismic forces or forces due to distributed loads
for the current shear surface
```

```
TABLE NO. 47
**************************************************************
*  Information for the Iterative Solution for the Factor of  *
*  Safety and Side Force Inclination by Spencer's Procedure  *
**************************************************************
Allowable force imbalance for convergence:  3
Allowable moment imbalance for convergence: 472

        Trial     Trial
       Factor   Side Force     Force       Moment                   Delta
Iter-    of     Inclination   Imbalance   Imbalance    Delta-F      Theta
ation  Safety   (degrees)      (lbs.)    (ft.-lbs.)               (degrees)

   1   3.00000    17.1887   2.372e+004  -1.172e+007
First-order corrections to F and Theta ............   -3.2039    -2.0048
Reduced values - Deltas were too large ............   -0.5000    -0.3129

   2   2.50000    16.8759   1.927e+004  -9.498e+006
First-order corrections to F and Theta ............   -1.8222    -2.3206
Reduced values - Deltas were too large ............   -0.5000    -0.6368

   3   2.00000    16.2391   1.264e+004  -6.180e+006
First-order corrections to F and Theta ............   -0.7852    -3.0426
Reduced values - Deltas were too large ............   -0.5000    -1.9374

   4   1.50000    14.3017   1.811e+003  -6.898e+005
First-order corrections to F and Theta ............   -0.1075    -6.5111
Reduced values - Deltas were too large ............   -0.0473    -2.8648

   5   1.45269    11.4369   9.633e+002  -3.443e+005
First-order corrections to F and Theta ............   -0.0646    -5.1680
Reduced values - Deltas were too large ............   -0.0358    -2.8648

   6   1.41688     8.5721   3.943e+002  -1.249e+005
First-order corrections to F and Theta ............   -0.0309    -3.0848
Reduced values - Deltas were too large ............   -0.0287    -2.8648

   7   1.38819     5.7073   1.936e+000   1.164e+004
First-order corrections to F and Theta ............   -0.0027    -0.4523
Second-order corrections to F and Theta ...........   -0.0027    -0.4529

   8   1.38549     5.2544   1.239e-003  -4.514e-001
First-order corrections to F and Theta ............   -0.0000    -0.0000
```

```
TABLE NO. 55
*********************************************************************
* Check of Computations by Spencer's Procedure (Results are for the *
* critical shear surface in the case of an automatic search.)       *
*********************************************************************

Summation of Horizontal Forces: 1.23919e-011

Summation of Vertical Forces: 3.48450e-011

Summation of Moments: -2.12691e-007

Mohr Coulomb Shear Force/Shear Strength Check Summation: 2.16005e-012

***** CAUTION ***** Forces Between Slices are NEGATIVE at Points
Along the UPPER one-half of the Shear Surface -
A Tension Crack may Be Needed

***** CAUTION ***** Some of the Forces Between Slices Act at Points
Above the Surface of the Slope or Below the Shear Surface -
Either a Tension Crack may be Needed or the SOLUTION MAY NOT
BE A VALID SOLUTION
```

```
TABLE NO. 58
*************************************************************************
* Final Results for Stresses Along the Shear Surface                   *
* (Results are for the critical shear surface in the case of a search.) *
*************************************************************************

SPENCER'S PROCEDURE USED TO COMPUTE THE FACTOR OF SAFETY
Factor of Safety: 1.385     Side Force Inclination:   5.25
```

-------- VALUES AT CENTER OF BASE OF SLICE --------					
Slice No.	X-Center	Y-Center	Total Normal Stress	Effective Normal Stress	Shear Stress
1	112.60	586.87	358.4	231.8	282.9
2	119.85	584.80	797.2	428.5	282.9
3	127.20	583.12	1190.0	601.4	282.9
4	131.95	582.19	1422.6	702.4	282.9
5	136.74	581.52	1630.6	793.6	282.9
6	144.24	580.72	1926.0	922.3	282.9
7	151.77	580.32	2174.4	1028.0	282.9
8	155.62	580.22	2288.9	1075.9	282.9
9	159.48	580.31	2379.7	1112.6	282.9
10	166.13	580.62	2519.2	1167.6	282.9
11	172.74	581.28	2617.1	1261.5	282.9
12	180.21	582.36	2686.3	1398.6	282.9
13	187.60	583.84	2708.6	1513.0	282.9
14	194.91	585.70	2684.3	1604.9	282.9
15	202.11	587.94	2614.0	1674.3	282.9
16	209.18	590.56	2498.1	1721.7	282.9
17	214.84	592.93	2374.2	1745.8	282.9
18	218.10	594.43	2256.3	1721.5	282.9
19	222.54	596.71	1796.8	1404.2	721.8
20	229.13	600.38	1321.2	1157.7	721.8
21	232.92	602.65	1030.0	1008.2	721.8
22	234.99	604.00	858.7	858.7	721.8

```
TABLE NO. 59
***********************************************************************
* Final Results for Side Forces and Stresses Between Slices           *
* (Results are for the critical shear surface in the case of a search.) *
***********************************************************************

       --------------- VALUES AT RIGHT SIDE OF SLICE ---------------
```

Slice No.	X-Right	Side Force	Y-Coord. of Side Force Location	Fraction of Height	Sigma at Top	Sigma at Bottom
1	116.20	2858	587.20	0.360	111.5	1291.1
2	123.50	6437	586.35	0.321	-62.6	1714.2
3	130.89	10322	585.69	0.299	-192.4	2043.8
4	133.00	11423	585.53	0.293	-227.1	2125.8
5	140.48	15175	585.14	0.278	-340.6	2376.4
6	148.00	18474	584.99	0.263	-446.2	2569.7
7	155.54	21068	585.06	0.250	-543.3	2704.2
8	155.71	21119	585.07	0.249	-545.5	2706.6
9	163.25	22789	585.39	0.235	-632.5	2778.5
10	169.00	23368	585.79	0.224	-690.4	2789.7
11	176.49	23152	586.52	0.207	-752.4	2744.2
12	183.92	21804	587.49	0.189	-793.2	2623.5
13	191.28	19351	588.67	0.167	-804.4	2417.3
14	198.54	15880	590.06	0.141	-772.6	2109.5
15	205.68	11532	591.63	0.108	-675.8	1673.8
16	212.68	6497	593.36	0.064	-476.1	1065.3
17	217.00	3088	594.46	0.026	-268.6	560.1
18	219.20	1320	594.83	Below	-133.7	264.8
19	225.88	-153	610.62	0.735	-22.1	3.8
20	232.37	-550	603.60	0.102	59.8	-146.1
21	233.47	-475	603.86	0.072	61.9	-140.7
22	236.50	0	605.00	Above	-0.0	0.0

```
Read end-of-file on input while looking for another command word.
End of input data assumed - normal termination.
```

Vistra Kincaid Pond

Cross-Section: E, North
Case: Seismic
Filename: Section E, North (Seismic)

UTEXAS4 Input File


```
GRAphics
HEAding follows -
Vistra Kincaid CCR - Section E, North (Seismic)
#132803

PROfile lines
   1 1 Ash
        237 615
        478 622.5

   2 2 New Embankment Fill
        133 594
        169 603
        217 615
        237 615
        313 596

   3 3 Native CL
         0 585
        109 588
        133 594
        313 596
        377 580

   4 4 Till
         0 580
        389 580
        478 580


MATerial properties
   1 Ash
      80 = unit weight
      Conventional Shear Strength
        0 25
      Piezometric Line
         1
   2 New Embankment Fill
      120 = unit weight
      Conventional Shear Strength
        188 35
      Piezometric Line
         1
   3 Native CL
      115 = unit weight
      Conventional Shear Strength
        113 33
      Piezometric Line
         1
   4 Till
      130 = unit weight
      Conventional Shear Strength
        500 38
      Piezometric Line
         1

PIEzometric line
     1 Piezometric Line
        0 585
       109 588
       133 594
       169 603
```

```
       478 603


SECond stage input activated
MATerial Properties
1 Ash
      80 = unit weight
      Conventional Shear Strength
        0 25
      Piezometric Line
         2
   2 New Embankment Fill
      120 = unit weight
      2-Stage Linear Strength Envelope
       660 19 188 35
      Piezometric Line
         2
   3 Native CL
      115 = unit weight
      2-Stage Linear Strength Envelope
       333 23 113 33
      Piezometric Line
         2
   4 Till
      130 = unit weight
      2-Stage Linear Strength Envelope
       1125 22 500 38
      Piezometric Line
         2

PIEzometric line
     2 Piezometric Line
        0 585
       109 588
       133 594
       169 603
       478 603


LABel
Vistra Kincaid CCR - Section E, North (Seismic)
ANALYSIS/COMPUTATION
   Circular Search 2
     15 15
     100 640 100 750 190 750 190 640
     5 5
   Point
     109 588

   Seismic
     0.11
   Crack
     5 D
   Two-Stage Computation
   Minimum
     10000
   Short

COMpute
```

```
TABLE NO. 1
COMPUTER PROGRAM DESIGNATION: UTEXAS4
Originally Coded By Stephen G. Wright
Version No. 4.1.2.0 - Last Revision Date: 7/29/2020
(C) Copyright 1985-2020 S. G. Wright - All rights reserved
***** SHINOAK SOFTWARE CONFIDENTIAL *****

This is a special pre-release beta-test version of the UTEXAS4 software.
It is provided for confidential use only on an approved non-disclosure basis.
Posession and use of this software is only permitted with the express, written
approval of Stephen G. Wright
***** SHINOAK SOFTWARE CONFIDENTIAL *****
******************************************************************
* RESULTS OF COMPUTATIONS PERFORMED USING THIS SOFTWARE          *
* SHOULD NOT BE USED FOR DESIGN PURPOSES UNLESS THEY HAVE        *
* BEEN VERIFIED BY INDEPENDENT ANALYSES, EXPERIMENTAL DATA       *
* OR FIELD EXPERIENCE. THE USER SHOULD UNDERSTAND THE ALGORITHMS *
* AND ANALYTICAL PROCEDURES USED IN THIS SOFTWARE AND MUST HAVE  *
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* IMPLIED, CONCERNING THE ACCURACY, RELIABILITY, USEFULNESS      *
* OR ADAPTABILITY OF THIS SOFTWARE.                              *
******************************************************************
```

```
TABLE NO. 3
************************
* NEW PROFILE LINE DATA *
************************

----------------------------------------------------------
----- Profile Line No. 1 - Material Type (Number): 1 -----
----------------------------------------------------------
Description: Ash

Point        X           Y

   1      237.00      615.00
   2      478.00      622.50

----------------------------------------------------------
----- Profile Line No. 2 - Material Type (Number): 2 -----
----------------------------------------------------------
Description: New Embankment Fill

Point        X           Y

   1      133.00      594.00
   2      169.00      603.00
   3      217.00      615.00
   4      237.00      615.00
   5      313.00      596.00

----------------------------------------------------------
----- Profile Line No. 3 - Material Type (Number): 3 -----
----------------------------------------------------------
Description: Native CL

Point        X           Y

   1        0.00      585.00
   2      109.00      588.00
   3      133.00      594.00
   4      313.00      596.00
   5      377.00      580.00

----------------------------------------------------------
----- Profile Line No. 4 - Material Type (Number): 4 -----
----------------------------------------------------------
Description: Till

Point        X           Y

   1        0.00      580.00
   2      389.00      580.00
   3      478.00      580.00
```

```
TABLE NO. 4
**********************************************************************
* NEW MATERIAL PROPERTY DATA - CONVENTIONAL/FIRST-STAGE COMPUTATIONS *
**********************************************************************

------------------------------------------------------------------
------------------- DATA FOR MATERIAL NUMBER 1 -------------------
------------------------------------------------------------------
Description: Ash

Constant unit weight of soil (material): 80.0

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - 0.0
Friction angle - - - - - 25.00 (degrees)

Pore water pressures are defined by a piezometric line.
Piezometric line number: 1
Negative pore water pressures are NOT allowed - set to zero.

------------------------------------------------------------------
------------------- DATA FOR MATERIAL NUMBER 2 -------------------
------------------------------------------------------------------
Description: New Embankment Fill

Constant unit weight of soil (material): 120.0

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - 188.0
Friction angle - - - - - 35.00 (degrees)

Pore water pressures are defined by a piezometric line.
Piezometric line number: 1
Negative pore water pressures are NOT allowed - set to zero.

------------------------------------------------------------------
------------------- DATA FOR MATERIAL NUMBER 3 -------------------
------------------------------------------------------------------
Description: Native CL

Constant unit weight of soil (material): 115.0

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - 113.0
Friction angle - - - - - 33.00 (degrees)

Pore water pressures are defined by a piezometric line.
Piezometric line number: 1
Negative pore water pressures are NOT allowed - set to zero.

------------------------------------------------------------------
------------------- DATA FOR MATERIAL NUMBER 4 -------------------
------------------------------------------------------------------
Description: Till

Constant unit weight of soil (material): 130.0

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - 500.0
Friction angle - - - - - 38.00 (degrees)
```

```
Pore water pressures are defined by a piezometric line.
Piezometric line number: 1
Negative pore water pressures are NOT allowed - set to zero.
```

```
TABLE NO. 6
*********************************************************************
* NEW PIEZOMETRIC LINE DATA - CONVENTIONAL/FIRST-STAGE COMPUTATIONS *
*********************************************************************

---------------------------------------------------------
--------------- Piezometric Line Number 1 ---------------
---------------------------------------------------------
Description: Piezometric Line
Unit weight of fluid (water): 62.4

Point        X           Y

  1        0.00      585.00
  2      109.00      588.00
  3      133.00      594.00
  4      169.00      603.00
  5      478.00      603.00
```

```
TABLE NO. 5
2222222222222222222222222222222222222222222222222222222222
2 NEW MATERIAL PROPERTY DATA - SECOND_STAGE COMPUTATIONS 2
2222222222222222222222222222222222222222222222222222222222

------------------------------------------------------------------
------------------- DATA FOR MATERIAL NUMBER 1 -------------------
------------------------------------------------------------------
Description: Ash

Constant unit weight of soil (material): 80.0

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - - 0.0
Friction angle - - - - - 25.00 (degrees)

Pore water pressures are defined by a piezometric line.
Piezometric line number: 2
Negative pore water pressures are NOT allowed - set to zero.

------------------------------------------------------------------
------------------- DATA FOR MATERIAL NUMBER 2 -------------------
------------------------------------------------------------------
Description: New Embankment Fill

Constant unit weight of soil (material): 120.0

---- 2-STAGE STRENGTHS FOR SECOND STAGE OF COMPUTATIONS

Kc = 1 ENVELOPE:
     Intercept of envelope ("d") - - - - - - - - - 660.0
     Slope of envelope ("psi") - - - - - - - - - - 19.00 (degrees)
Kc = Kf ENVELOPE:
     Intercept of envelope ("d") - - - - - - - - - 188.0
     Slope of envelope ("psi") - - - - - - - - - - 35.00 (degrees)

Pore water pressures are defined by a piezometric line.
Piezometric line number: 2
Negative pore water pressures are NOT allowed - set to zero.

------------------------------------------------------------------
------------------- DATA FOR MATERIAL NUMBER 3 -------------------
------------------------------------------------------------------
Description: Native CL

Constant unit weight of soil (material): 115.0

---- 2-STAGE STRENGTHS FOR SECOND STAGE OF COMPUTATIONS

Kc = 1 ENVELOPE:
     Intercept of envelope ("d") - - - - - - - - - 333.0
     Slope of envelope ("psi") - - - - - - - - - - 23.00 (degrees)
Kc = Kf ENVELOPE:
     Intercept of envelope ("d") - - - - - - - - - 113.0
     Slope of envelope ("psi") - - - - - - - - - - 33.00 (degrees)

Pore water pressures are defined by a piezometric line.
Piezometric line number: 2
Negative pore water pressures are NOT allowed - set to zero.

------------------------------------------------------------------
------------------- DATA FOR MATERIAL NUMBER 4 -------------------
```

```
-------------------------------------------------------------------
Description: Till

Constant unit weight of soil (material): 130.0

---- 2-STAGE STRENGTHS FOR SECOND STAGE OF COMPUTATIONS

Kc = 1 ENVELOPE:
     Intercept of envelope ("d") - - - - - - - - 1125.0
     Slope of envelope ("psi") - - - - - - - - - 22.00 (degrees)
Kc = Kf ENVELOPE:
     Intercept of envelope ("d") - - - - - - - - 500.0
     Slope of envelope ("psi") - - - - - - - - - 38.00 (degrees)

Pore water pressures are defined by a piezometric line.
Piezometric line number: 2
Negative pore water pressures are NOT allowed - set to zero.
```

```
TABLE NO. 7
22222222222222222222222222222222222222222222222222222222222222222222222
2 NEW PIEZOMETRIC LINE DATA - CONVENTIONAL/FIRST-STAGE COMPUTATIONS 2
22222222222222222222222222222222222222222222222222222222222222222222222

---------------------------------------------------------
--------------- Piezometric Line Number 2 ---------------
---------------------------------------------------------
Description: Piezometric Line
Unit weight of fluid (water): 62.4

Point        X           Y

  1        0.00      585.00
  2      109.00      588.00
  3      133.00      594.00
  4      169.00      603.00
  5      478.00      603.00
```

```
TABLE NO. 16
*********************************
* NEW ANALYSIS/COMPUTATION DATA *
*********************************


Search will be conducted using a fixed grid.
Number of Points Across Grid: 15
Number of Points Up Grid: 15

Grid Corner
   Number           X              Y

     1           100.00         640.00
     2           100.00         750.00
     3           190.00         750.00
     4           190.00         640.00

----- Control Parameters for Finding "Critical" Radius -----
Initial number of subdivisions between maximum and minimum
radius for finding a critical radius/radii: 5

Minimum radius increment for terminating subdivision of radii: 5.000

The following criteria will be used for determining
the maximum and minimum radii:
     Point circles pass through - X: 109.00     Y: 588.00
Seismic coefficient: 0.110
Seismic force acts at center of gravity.

Depth of crack: 5.000
Two-stage computations will be performed.
Minimum weight required for computations to be performed: 10000
Automatic search output will be in short form.

--------------------------------------------------------------------------------
The following represent default values or values that were prevously defined:
Subtended angle for slice subdivision: 3.00(degrees)
There is no water in a crack.
Unit weight of water (or other fluid) in crack: 62.4
Search will be continued after the initial mode to find a most critical circle.
No restrictions exist on the lateral extent of the search.
No shear surfaces other than the most critical will be saved for display later.
Neither slope face was explicitly designated for analysis.
Radii for each grid point will be sorted in the order of increasing radius.
Critical circles for grid points will be output in the order of increasing factor of safety.
Standard sign convention used for direction of shear stress on shear surface.
Procedure of Analysis: Spencer

Iteration limit: 100
Force imbalance: 1.000000e-005 (fraction of total weight)
Moment imbalance: 1.000000e-005 (fraction of moment due to total weight)
Initial trial factor of safety: 3.000
Initial trial side force inclination: 17.189 (degrees)
Minimum (most negative) side force inclination allowed in Spencer's procedure: -10.00
```

TABLE NO. 26
****
* NEW, COMPUTED SLOPE GEOMETRY DATA *
****

These slope geometry were generated from the Profile Lines.

Point	X	Y
1	0.00	585.00
2	109.00	588.00
3	133.00	594.00
4	169.00	603.00
5	217.00	615.00
6	237.00	615.00
7	313.00	617.37
8	377.00	619.36
9	389.00	619.73
10	478.00	622.50

```
TABLE NO. 38
*************************************************
* FINAL SUMMARY OF COMPUTATIONS WITH FIXED-GRID *
*************************************************


Number of circles attempted: 225
Number of circles for which F calculated: 111
Circle with Lowest Factor of Safety:
     X coordinate for center: 138.57
     Y coordinate for center: 655.71
     Radius of circle: 73.890
Factor of safety: 1.404
Side force inclination: 15.89
Time Required for Computations: 1.0 seconds
```

```
TABLE NO. 43
1111111111111111111111111111111111111111111111111111111111111
1 Coordinate, Weight, Strength and Pore Water Pressure     1
1 Information for Individual Slices for Conventional       1
1 Computations or First Stage of Multi-Stage Computations. 1
1 (Information is for the critical shear surface in the    1
1 case of an automatic search.)                            1
1111111111111111111111111111111111111111111111111111111111111
```

Slice No.	X	Y	Slice Weight	Matl. No.	Cohesion	Friction Angle	Pore Pressure
	109.00	588.00					
1	110.79	587.27	485	3	113.0	33.00	73.3
	112.58	586.55					
2	114.41	585.91	1446	3	113.0	33.00	214.7
	116.24	585.28					
3	118.10	584.74	2364	3	113.0	33.00	345.1
	119.96	584.21					
4	121.84	583.77	3224	3	113.0	33.00	464.3
	123.72	583.33					
5	125.63	582.99	4014	3	113.0	33.00	571.9
	127.53	582.65					
6	129.45	582.41	4723	3	113.0	33.00	667.6
	131.37	582.18					
7	132.19	582.11	2189	3	113.0	33.00	729.5
	133.00	582.03					
8	134.93	581.94	5582	3	113.0	33.00	782.7
	136.86	581.84					
9	137.72	581.83	2630	3	113.0	33.00	832.7
	138.57	581.82					
10	140.50	581.88	6261	3	113.0	33.00	873.7
	142.44	581.93					
11	144.37	582.08	6600	3	113.0	33.00	921.3
	146.30	582.23					
12	148.21	582.48	6827	3	113.0	33.00	956.1
	150.13	582.73					
13	152.03	583.09	6941	3	113.0	33.00	977.9
	153.93	583.44					
14	155.81	583.89	6943	3	113.0	33.00	986.7
	157.70	584.34					
15	159.55	584.89	6834	3	113.0	33.00	982.5
	161.40	585.44					
16	163.23	586.09	6619	3	113.0	33.00	965.3
	165.05	586.73					
17	166.84	587.47	6304	3	113.0	33.00	935.2
	168.63	588.21					
18	168.81	588.30	648	3	113.0	33.00	914.6
	169.00	588.38					
19	170.74	589.22	5848	3	113.0	33.00	859.7
	172.48	590.07					
20	174.18	591.00	5349	3	113.0	33.00	748.9
	175.87	591.93					
21	177.52	592.95	4778	3	113.0	33.00	627.1
	179.16	593.97					
22	179.57	594.25	1131	3	113.0	33.00	546.3
	179.99	594.52					
23	181.56	595.65	3961	2	188.0	35.00	458.8
	183.13	596.77					
24	184.64	597.98	3241	2	188.0	35.00	313.3
	186.16	599.19					
25	187.60	600.47	2493	2	188.0	35.00	157.9
	189.05	601.75					

26	189.70	602.38	904	2	188.0	35.00	38.9
	190.35	603.00					
27	190.58	603.23	282	2	188.0	35.00	0.0
	190.80	603.45					

No water in crack.

```
TABLE NO. 44
1111111111111111111111111111111111111111111111111111111111
1 Seismic Forces and Forces Due to Distributed Loads for 1
1 Individual Slices for Conventional Computations or the 1
1 First Stage of Multi-Stage Computations.              1
1 (Information is for the critical shear surface in the  1
1 case of an automatic search.)                          1
1111111111111111111111111111111111111111111111111111111111

There are no seismic forces or forces due to distributed loads
for the current shear surface
```

```
TABLE NO. 47
111111111111111111111111111111111111111111111111111111111111111
1  Information for the Iterative Solution for the Factor of  1
1  Safety and Side Force Inclination by Spencer's Procedure  1
1  Stage 1 of Multi-Stage Computations                       1
111111111111111111111111111111111111111111111111111111111111111
Allowable force imbalance for convergence:  1
Allowable moment imbalance for convergence: 167

        Trial     Trial
       Factor   Side Force     Force       Moment                   Delta
Iter-    of     Inclination   Imbalance   Imbalance    Delta-F      Theta
ation  Safety   (degrees)      (lbs.)    (ft.-lbs.)              (degrees)

   1   3.00000    17.1887   6.593e+003  -3.318e+006
First-order corrections to F and Theta ............   -1.2330    -1.7243
Reduced values - Deltas were too large ............   -0.5000    -0.6992

   2   2.50000    16.4895   3.356e+003  -1.669e+006
First-order corrections to F and Theta ............   -0.4686    -2.4821
Second-order corrections to F and Theta ...........   -0.4593    -5.5239
Reduced values - Deltas were too large ............   -0.2382    -2.8648

   3   2.26180    13.6247   1.749e+003  -8.944e+005
First-order corrections to F and Theta ............   -0.2168    -1.9899
Second-order corrections to F and Theta ...........   -0.2233    -3.3947
Reduced values - Deltas were too large ............   -0.1885    -2.8648

   4   2.07333    10.7599   2.865e+002  -1.496e+005
First-order corrections to F and Theta ............   -0.0347    -0.5923
Second-order corrections to F and Theta ...........   -0.0353    -0.6616

   5   2.03801    10.0983  -8.861e-002   5.587e+001
First-order corrections to F and Theta ............   -0.0000    -0.0006
```

```
TABLE NO. 48
22222222222222222222222222222222222222222222222222222222222
2 Detailed Information from Evaluation of Shear Strengths 2
2 for Stage 2 - Information is Only Given for Slices with 2
2 Two-Stage Shear Strengths (Strength Options 6 and 7).   2
2 (Information is for the critical shear surface in the   2
2 case of an automatic search.)                           2
22222222222222222222222222222222222222222222222222222222222
```

Slice No.	Effective Normal Stress at Consol.	Shear Stress at Consol.	Strength (Kc = 1)	Strength (Kc = Kf)	Kc	Kf
1	134.2	98.2	390.0	200.1	Strength from S envelope.	
2	289.5	147.7	455.9	301.0	Strength from S envelope.	
3	418.2	188.7	510.5	384.6	Strength from S envelope.	
4	523.6	222.3	555.2	453.0	Strength from S envelope.	
5	608.2	249.3	591.2	508.0	Strength from S envelope.	
6	674.2	270.3	619.2	550.8	Strength from S envelope.	
7	712.0	282.3	635.2	575.4	Strength from S envelope.	
8	741.9	291.8	647.9	594.8	Strength from S envelope.	
9	767.8	300.1	658.9	611.6	Strength from S envelope.	
10	784.1	305.3	665.8	622.2	Strength from S envelope.	
11	796.8	309.4	671.2	630.5	Strength from S envelope.	
12	797.3	309.5	671.4	630.8	Strength from S envelope.	
13	786.6	306.1	666.9	623.8	Strength from S envelope.	
14	765.5	299.4	658.0	610.1	Strength from S envelope.	
15	735.1	289.7	645.0	590.4	Strength from S envelope.	
16	696.2	277.3	628.5	565.1	Strength from S envelope.	
17	649.8	262.5	608.8	535.0	Strength from S envelope.	
18	622.3	253.7	597.2	517.1	Strength from S envelope.	
19	615.7	251.6	594.4	512.9	Strength from S envelope.	
20	604.4	248.0	589.6	505.5	Strength from S envelope.	
21	585.5	242.0	581.5	493.3	Strength from S envelope.	
22	571.2	237.5	575.5	483.9	Strength from S envelope.	
23	527.5	273.5	841.6	557.4	Strength from S envelope.	
24	484.7	258.8	826.9	527.4	Strength from S envelope.	
25	437.6	242.6	810.7	494.4	Strength from S envelope.	
26	401.9	230.3	798.4	469.4	Strength from S envelope.	
27	374.6	220.9	789.0	450.3	Strength from S envelope.	

```
TABLE NO. 49
2222222222222222222222222222222222222222222222222222222
2 Coordinate, Weight, Strength and Pore Water Pressure  2
2 Information for Individual Slices for Second         2
2 Stage of Multi-Stage Computations.                   2
2 (Information is for the critical shear surface in the 2
2 case of an automatic search.)                        2
2222222222222222222222222222222222222222222222222222222
```

Slice No.	X	Y	Slice Weight	Matl. No.	Cohesion	Friction Angle	Pore Pressure
	109.00	588.00					
1	110.79	587.27	485	3	200.1	0.00	0.0
	112.58	586.55					
2	114.41	585.91	1446	3	301.0	0.00	0.0
	116.24	585.28					
3	118.10	584.74	2364	3	384.6	0.00	0.0
	119.96	584.21					
4	121.84	583.77	3224	3	453.0	0.00	0.0
	123.72	583.33					
5	125.63	582.99	4014	3	508.0	0.00	0.0
	127.53	582.65					
6	129.45	582.41	4723	3	550.8	0.00	0.0
	131.37	582.18					
7	132.19	582.11	2189	3	575.4	0.00	0.0
	133.00	582.03					
8	134.93	581.94	5582	3	594.8	0.00	0.0
	136.86	581.84					
9	137.72	581.83	2630	3	611.6	0.00	0.0
	138.57	581.82					
10	140.50	581.88	6261	3	622.2	0.00	0.0
	142.44	581.93					
11	144.37	582.08	6600	3	630.5	0.00	0.0
	146.30	582.23					
12	148.21	582.48	6827	3	630.8	0.00	0.0
	150.13	582.73					
13	152.03	583.09	6941	3	623.8	0.00	0.0
	153.93	583.44					
14	155.81	583.89	6943	3	610.1	0.00	0.0
	157.70	584.34					
15	159.55	584.89	6834	3	590.4	0.00	0.0
	161.40	585.44					
16	163.23	586.09	6619	3	565.1	0.00	0.0
	165.05	586.73					
17	166.84	587.47	6304	3	535.0	0.00	0.0
	168.63	588.21					
18	168.81	588.30	648	3	517.1	0.00	0.0
	169.00	588.38					
19	170.74	589.22	5848	3	512.9	0.00	0.0
	172.48	590.07					
20	174.18	591.00	5349	3	505.5	0.00	0.0
	175.87	591.93					
21	177.52	592.95	4778	3	493.3	0.00	0.0
	179.16	593.97					
22	179.57	594.25	1131	3	483.9	0.00	0.0
	179.99	594.52					
23	181.56	595.65	3961	2	557.4	0.00	0.0
	183.13	596.77					
24	184.64	597.98	3241	2	527.4	0.00	0.0
	186.16	599.19					
25	187.60	600.47	2493	2	494.4	0.00	0.0
	189.05	601.75					

26	189.70	602.38	904	2	469.4	0.00	0.0
	190.35	603.00					
27	190.58	603.23	282	2	450.3	0.00	0.0
	190.80	603.45					

TABLE NO. 50

```
22222222222222222222222222222222222222222222222222222222222222222222222
2 Seismic Forces and Forces Due to Distributed Loads for Individual 2
2 Slices for the Second Stage of Multi-Stage Computations.          2
2 (Information is for the critical shear surface in the             2
2 case of an automatic search.)                                     2
22222222222222222222222222222222222222222222222222222222222222222222222
```

Slices No.	X	Seismic Force	Y for Seismic Force	FORCES DUE TO DISTRIBUTED LOADS Normal Force	Shear Force	X	Y
1	110.79	-53	587.86	0	0	110.79	588.45
2	114.41	-159	587.63	0	0	114.41	589.35
3	118.10	-260	587.51	0	0	118.10	590.27
4	121.84	-355	587.49	0	0	121.84	591.21
5	125.63	-442	587.57	0	0	125.63	592.16
6	129.45	-520	587.76	0	0	129.45	593.11
7	132.19	-241	587.95	0	0	132.19	593.80
8	134.93	-614	588.22	0	0	134.93	594.48
9	137.72	-289	588.53	0	0	137.72	595.18
10	140.50	-689	588.91	0	0	140.50	595.88
11	144.37	-726	589.51	0	0	144.37	596.84
12	148.21	-751	590.20	0	0	148.21	597.80
13	152.03	-764	590.99	0	0	152.03	598.76
14	155.81	-764	591.87	0	0	155.81	599.70
15	159.55	-752	592.85	0	0	159.55	600.64
16	163.23	-728	593.90	0	0	163.23	601.56
17	166.84	-693	595.05	0	0	166.84	602.46
18	168.81	-71	595.70	0	0	168.81	602.95
19	170.74	-643	596.40	0	0	170.74	603.44
20	174.18	-588	597.70	0	0	174.18	604.29
21	177.52	-526	599.07	0	0	177.52	605.13
22	179.57	-124	599.95	0	0	179.57	605.64
23	181.56	-436	600.89	0	0	181.56	606.14
24	184.64	-356	602.45	0	0	184.64	606.91
25	187.60	-274	604.06	0	0	187.60	607.65
26	189.70	-99	605.28	0	0	189.70	608.17
27	190.58	-31	605.81	0	0	190.58	608.39

```
TABLE NO. 51
222222222222222222222222222222222222222222222222222222222222222
2  Information for the Iterative Solution for the Factor of  2
2  Safety and Side Force Inclination by Spencer's Procedure  2
2  Second Stage of Multi-Stage Computations                 2
222222222222222222222222222222222222222222222222222222222222222
Allowable force imbalance for convergence:  1
Allowable moment imbalance for convergence: 167

        Trial     Trial
       Factor   Side Force     Force       Moment                   Delta
Iter-    of    Inclination   Imbalance   Imbalance    Delta-F       Theta
ation  Safety   (degrees)      (lbs.)    (ft.-lbs.)               (degrees)

   1   3.00000    17.1887   1.824e+004  -9.393e+006
First-order corrections to F and Theta ............   -3.3732    -0.1317
Reduced values - Deltas were too large ............   -0.5000    -0.0195

   2   2.50000    17.1692   1.499e+004  -7.721e+006
First-order corrections to F and Theta ............   -1.9267    -0.1545
Reduced values - Deltas were too large ............   -0.5000    -0.0401

   3   2.00000    17.1291   1.013e+004  -5.214e+006
First-order corrections to F and Theta ............   -0.8344    -0.2095
Reduced values - Deltas were too large ............   -0.5000    -0.1255

   4   1.50000    17.0036   2.032e+003  -1.038e+006
First-order corrections to F and Theta ............   -0.0981    -0.5612
Second-order corrections to F and Theta ...........   -0.0959    -1.0649

   5   1.40414    15.9387  -9.192e+000   5.388e+003
First-order corrections to F and Theta ............    0.0000    -0.0515
Second-order corrections to F and Theta ...........    0.0000    -0.0513

   6   1.40418    15.8873   7.674e-006  -1.712e-003
First-order corrections to F and Theta ............   -0.0000    -0.0000
```

```
TABLE NO. 55
*********************************************************************
* Check of Computations by Spencer's Procedure (Results are for the *
* critical shear surface in the case of an automatic search.)       *
*********************************************************************

Summation of Horizontal Forces: 9.89786e-012

Summation of Vertical Forces: 9.89075e-012

Summation of Moments: -1.70257e-009

Mohr Coulomb Shear Force/Shear Strength Check Summation: 4.54747e-013
```

TABLE NO. 58
****
* Final Results for Stresses Along the Shear Surface   *
* (Results are for the critical shear surface in the case of a search.) *
****

SPENCER'S PROCEDURE USED TO COMPUTE THE FACTOR OF SAFETY
Factor of Safety: 1.404   Side Force Inclination: 15.89

-------- VALUES AT CENTER OF BASE OF SLICE --------

Slice No.	X-Center	Y-Center	Total Normal Stress	Effective Normal Stress	Shear Stress
1	110.79	587.27	259.3	259.3	142.5
2	114.41	585.91	575.1	575.1	214.3
3	118.10	584.74	842.2	842.2	273.9
4	121.84	583.77	1066.3	1066.3	322.6
5	125.63	582.99	1251.7	1251.7	361.8
6	129.45	582.41	1401.9	1401.9	392.3
7	132.19	582.11	1491.4	1491.4	409.8
8	134.93	581.94	1563.0	1563.0	423.6
9	137.72	581.83	1626.4	1626.4	435.6
10	140.50	581.88	1670.5	1670.5	443.1
11	144.37	582.08	1712.0	1712.0	449.0
12	148.21	582.48	1728.4	1728.4	449.2
13	152.03	583.09	1721.1	1721.1	444.3
14	155.81	583.89	1691.7	1691.7	434.5
15	159.55	584.89	1641.5	1641.5	420.5
16	163.23	586.09	1572.0	1572.0	402.5
17	166.84	587.47	1484.3	1484.3	381.0
18	168.81	588.30	1431.1	1431.1	368.3
19	170.74	589.22	1366.0	1366.0	365.2
20	174.18	591.00	1239.2	1239.2	360.0
21	177.52	592.95	1096.6	1096.6	351.3
22	179.57	594.25	1001.6	1001.6	344.6
23	181.56	595.65	871.1	871.1	396.9
24	184.64	597.98	688.9	688.9	375.6
25	187.60	600.47	496.9	496.9	352.1
26	189.70	602.38	352.5	352.5	334.3
27	190.58	603.23	292.0	292.0	320.7

TABLE NO. 59
```
************************************************************************
* Final Results for Side Forces and Stresses Between Slices            *
* (Results are for the critical shear surface in the case of a search.) *
************************************************************************
```

--------------- VALUES AT RIGHT SIDE OF SLICE ---------------

Slice No.	X-Right	Side Force	Y-Coord. of Side Force Location	Fraction of Height	Sigma at Top	Sigma at Bottom
1	112.58	868	587.75	0.510	377.3	332.9
2	116.24	2274	587.21	0.425	265.9	699.6
3	119.96	4001	586.79	0.395	217.0	961.3
4	123.72	5867	586.49	0.379	184.3	1167.4
5	127.53	7723	586.33	0.369	158.4	1330.2
6	131.37	9444	586.31	0.362	136.0	1455.3
7	133.00	10107	586.33	0.359	127.0	1497.8
8	136.86	11479	586.49	0.354	106.1	1576.8
9	138.57	11985	586.60	0.352	96.8	1602.4
10	142.44	12875	586.95	0.348	75.8	1640.1
11	146.30	13380	587.42	0.344	55.1	1650.0
12	150.13	13483	588.03	0.340	35.0	1633.1
13	153.93	13185	588.76	0.337	16.0	1589.8
14	157.70	12502	589.62	0.333	-1.2	1520.2
15	161.40	11466	590.60	0.330	-15.7	1424.2
16	165.05	10125	591.72	0.327	-25.6	1300.2
17	168.63	8535	592.99	0.325	-28.0	1145.4
18	169.00	8354	593.13	0.325	-27.7	1126.9
19	172.48	6615	594.55	0.325	-22.5	944.3
20	175.87	4869	596.13	0.328	-11.6	744.1
21	179.16	3198	597.92	0.341	12.8	518.9
22	179.99	2790	598.44	0.349	23.1	455.0
23	183.13	1596	600.28	0.359	24.3	290.4
24	186.16	678	602.39	0.395	30.0	131.0
25	189.05	126	605.32	0.570	27.5	11.2
26	190.35	17	607.94	0.926	11.2	-4.9
27	190.80	-0	603.45	Below	0.0	-0.0

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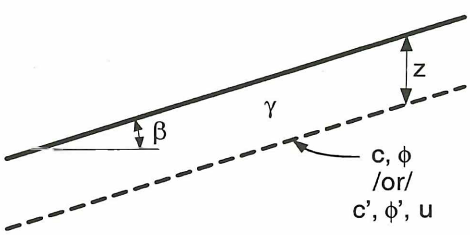
Appendix E: Cover Stability Calculations

$$F = \frac{c' + (\gamma z \cos^2 \beta - u) \tan \phi'}{\gamma z \cos \beta \sin \beta} \quad (6.17)$$

Equations for computing the factor of safety for an infinite slope are summarized in Figure 6.2 for both total stress and effective stress analyses and a variety of water and seepage conditions.

For a cohesionless (c, $c' = 0$) soil, the factor of safety calculated by an infinite slope analysis is independent of the depth, z, of the slip surface. For total stresses (or effective stresses with zero pore water pressure) the equation for the factor of safety becomes

$$F = \frac{\tan \phi}{\tan \beta} \quad (6.18)$$



Total Stresses: $s = c + \sigma \tan \phi$

Subaerial (not-submerged) slopes:

$$F = \frac{c}{\gamma z} \frac{2}{\sin(2\beta)} + (\cot \beta) \tan \phi$$

Submerged slopes ($\phi = 0$ only):

$$F = \frac{c}{(\gamma - \gamma_w) z} \frac{2}{\sin(2\beta)}$$

Total Stresses: $s = c' + \sigma' \tan \phi'$

General case (subaerial slope):

$$F = \frac{c'}{\gamma z} \frac{2}{\sin(2\beta)} + \left[\cot \beta - \frac{u}{\gamma z} (\cot \beta + \tan \beta) \right] \tan \phi'$$

Submerged slopes – no flow:

$$F = \frac{c'}{(\gamma - \gamma_w) z} \frac{2}{\sin(2\beta)} + [\cot \beta] \tan \phi'$$

Subaerial slope – seepage parallel to slope face:

$$F = \frac{c'}{\gamma z} \frac{2}{\sin(2\beta)} + \left[\cot \beta - \frac{\gamma_w}{\gamma} (\cot \beta) \right] \tan \phi'$$

Subaerial slope – horizontal seepage:

$$F = \frac{c'}{\gamma z} \frac{2}{\sin(2\beta)} + \left[\cot \beta - \frac{\gamma_w}{\gamma} (\cot \beta + \tan \beta) \right] \tan \phi'$$

Subaerial slope – pore water pressures defined by $r_u = \frac{u}{\gamma z}$:

$$F = \frac{c'}{\gamma z} \frac{2}{\sin(2\beta)} + [\cot \beta - r_u (\cot \beta + \tan \beta)] \tan \phi'$$

Figure 6.2 Summary of equations for computing the factor of safety for an infinite slope using both total stresses and effective stresses.

Similarly for effective stresses, if the pore water pressures are proportional to the depth of slide, the factor of safety is expressed by

$$F = [\cot \beta - r_u(\cot \beta + \tan \beta)] \tan \phi' \quad (6.19)$$

where r_u is the pore water pressure coefficient suggested by Bishop and Morgenstern (1960). The pore water pressure coefficient is defined as

$$r_u = \frac{u}{\gamma z} \quad (6.20)$$

Because the factor of safety for a cohesionless slope is independent of the depth of the slip surface, it is possible for a slip surface that is only infinitesimally deep to have the same factor of safety as that for deeper surfaces. Regardless of the lateral extent of the slope, a slip surface can develop that is shallow with respect to the lateral dimensions of the slope. Any slope will constitute an infinite slope as long as the soil is cohesionless. Therefore, the infinite slope analysis procedure is the appropriate procedure to use for any slope in cohesionless soil.[1]

The infinite slope analysis is also applicable to slopes in cohesive soils provided that a firmer stratum parallel to the face of the slope limits the depth of the failure surface. If such a stratum exists at a depth that is small compared to the lateral extent of the slope, an infinite slope analysis provides a suitable approximation for stability calculations.

The infinite slope equations were derived by considering equilibrium of forces in two mutually perpendicular directions and thus satisfy all force equilibrium requirements. Moment equilibrium was not considered explicitly; however, the forces on the two ends of the block are collinear and the normal force acts at the center of the block. Thus, moment equilibrium is satisfied, and the infinite slope procedure can be considered to fully satisfy all the requirements for static equilibrium.

[1] An exception to this may occur for soils with curved Mohr failure envelopes that pass through the origin. Although there is no strength at zero normal stress, and thus the soil might be termed *cohesionless*, the factor of safety depends on the depth of slide and the infinite slope analysis may not be appropriate. Also see the example of the Oroville Dam presented in Chapter 7.

132803
Vistra Kincaid
Liner Check

Subaerial - Defined r_u (FILL)

$$F = \frac{c'}{\gamma * z}\frac{2}{\sin(2b)} + [\cot(b) - r_u(\cot(b) + \tan(b))]\tan(\phi')$$

Height of fill (ft)	z	2	r_u	0.52		
Soil Unit Weight (pcf)	γ	120				
Water Unit Weight (pcf)	γw	62.4				
Slope angle (deg)	b	14	rad	0.244346	cot	4.01
Effective Cohesion (Fill)	c'	188				
Effective Friction Angle (Fill)	φ'	35				
Effective Friction Angle (Ash)	φ'	25				
Height of water (ft)	r_u	2				

		Granular	Cohesive
Effective Cohesion LLDPE (S) (kPa)	c'	0	12.4
Effective Cohesion LLDPE (S) (psf)	c'	0	259
Effective Friction Angle LLDPE (S) (deg)	φ'	27	11
Effective Cohesion LLDPE (T) (kPa)	c'	7.7	5.8
Effective Cohesion LLDPE (T) (psf)	c'	161	121
Effective Friction Angle LLDPE (T) (deg)	φ'	26	21

	$\frac{c'}{\gamma * z}\frac{2}{\sin(2b)}$	$+ [\cot(b) - r_u(\cot(b) + \tan(b))]$	$\tan(\phi')$	FoS
For Failure In On Interface with LLDPE (S, Cohesive)	4.60	1.80	0.19	4.9
For Failure In On Interface with LLDPE (T, Cohesive)	2.15	1.80	0.38	2.8

132803
Vistra Kincaid
Liner Check
Subaerial - Defined r_u (ASH)

$$F = \frac{c'}{\gamma * z}\frac{2}{\sin(2b)} + [\cot(b) - r_u(\cot(b) + \tan(b))]\tan(\phi')$$

Height of fill (ft)	z	2	r_u	0.0026		
Soil Unit Weight (pcf)	γ	120				
Water Unit Weight (pcf)	γw	62.4				
Slope angle (deg)	b	14	rad	0.244346	cot	4.01
Effective Cohesion (Fill)	c'	188				
Effective Friction Angle (Fill)	φ'	35				
Effective Friction Angle (Ash)	φ'	25				
Height of water (ft)	r_u	0.01				

		Granular	Cohesive
Effective Cohesion LLDPE (S) (kPa)	c'	0	12.4
Effective Cohesion LLDPE (S) (psf)	c'	0	259
Effective Friction Angle LLDPE (S) (deg)	φ'	27	11
Effective Cohesion LLDPE (T) (kPa)	c'	7.7	5.8
Effective Cohesion LLDPE (T) (psf)	c'	161	121
Effective Friction Angle LLDPE (T) (deg)	φ'	26	21

	$\frac{c'}{\gamma * z}\frac{2}{\sin(2b)}$	$+ [\cot(b) - r_u(\cot(b) + \tan(b))]$	$\tan(\phi')$	FoS
For Failure In On Interface with LLDPE (S, Ash)	0.00	4.00	0.51	2.0
For Failure In On Interface with LLDPE (T, Ash)	2.85	4.00	0.49	4.8

Appendix F: Geotechnical Reference Information


B010
B010
P010
P011
P012
P008
B007
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B007
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B011
B006
B006
B004
B004
B005
B012
B012
B003
P003
B003
B002
P002
B002

p-q Results - max obliquity

Boring	Material	Sample	Depth	σ_1'	σ_3'	σ_1	σ_3	p'	q'	p	q
B003	Native CL	S8	24 - 26	16.2	4.2	22.0	10.0	10.2	6.0	16.0	6.0
				33.7	10.0	43.8	20.0	21.8	11.9	31.9	11.9
				60.7	18.6	82.1	40.0	39.7	21.1	61.1	21.1
B004	Embankment CL	S8	19 - 21	25.2	4.7	28.5	8.0	15.0	10.2	18.2	10.2
				31.1	6.6	40.5	16.0	18.8	12.2	28.2	12.2
				47.2	12.8	66.4	32.0	30.0	17.2	49.2	17.2
B005	Native CL	S4	8 - 10	13.5	2.9	14.6	4.0	8.2	5.3	9.3	5.3
				18.8	5.2	21.6	8.0	12.0	6.8	14.8	6.8
				23.0	6.4	32.7	16.0	14.7	8.3	24.3	8.3
B007	Embankment CL	S6	16 - 18	23.1	4.6	26.0	7.5	13.8	9.3	16.8	9.3
				37.2	7.4	44.9	15.0	22.3	14.9	29.9	14.9
				51.4	10.5	70.9	30.0	30.9	20.4	50.4	20.4
B007	Native CL	S9	25 - 27	27.0	6.3	30.7	10.0	16.7	10.3	20.3	10.3
				39.3	10.4	48.9	20.0	24.8	14.5	34.5	14.5
				65.3	17.8	87.6	40.0	41.5	23.8	63.8	23.8
B008	Embankment CL	S4	8 -10	17.7	2.0	19.8	4.0	9.8	7.9	11.9	7.9
				30.2	3.7	34.5	8.0	17.0	13.3	21.3	13.3
				50.0	9.9	56.1	16.0	29.9	20.0	36.0	20.0
B010	Embankment CL	S6	18.5 - 20	14.1	3.5	18.1	7.5	8.8	5.3	12.8	5.3
				20.7	7.3	28.4	15.0	14.0	6.7	21.7	6.7
				36.4	14.6	51.8	30.0	25.5	10.9	40.9	10.9

p-q results - max obliquity

Material	Slope, α	Intercept, d (psi)	φ (deg)	cos(φ)	c (psi)	c (psf)	Sin(φ)	ψ (kc=1), deg	d (kc=1), psf
Embankment CL - Total	0.3003	3.9191	17.5	0.95	4.1	592	0.3003	16.7	564
Embankment CL - Effective	0.5746	1.0703	35.1	0.82	1.3	188	0.5746	29.9	154
Native CL - Total	0.3313	1.836	19.3	0.94	1.9	280	0.3313	18.3	264
Native CL - Effective	0.5377	0.6643	32.5	0.84	0.8	113	0.5377	28.3	96
Till (CL) - Total	0	0	0.0	1.00	0.0	0	0	0.0	0
Till (CL) - Effective	0	0	0.0	1.00	0.0	0	0	0.0	0

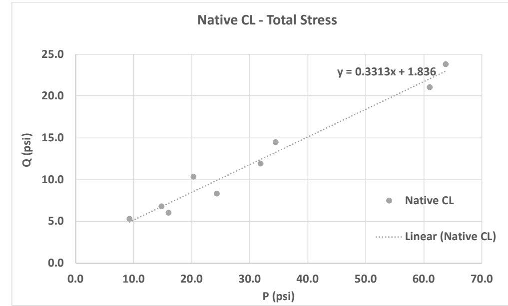
* No CU-bar strength testing performed on till materials

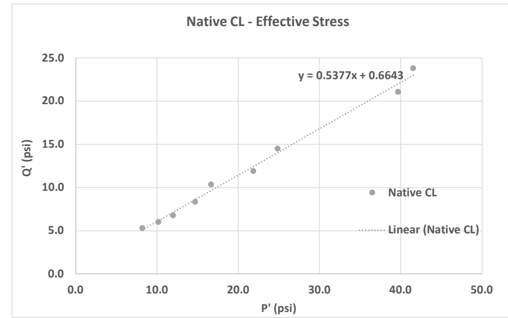
$$\phi = \arcsin(\tan\psi)$$

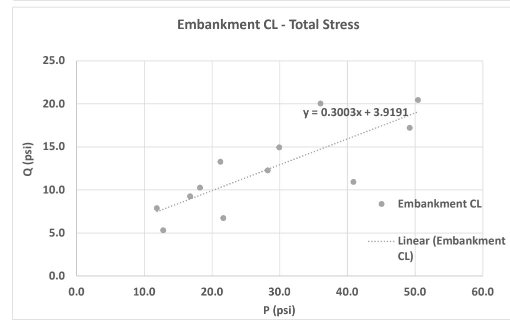
$$c = \frac{d}{\cos\phi}$$

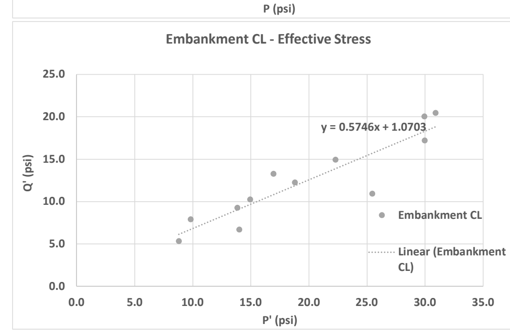
Summary for UTEXAS 4					
Material	Unit Weight (pcf)	φ (deg)	c (psf)	ψ (kc=1), deg	d (kc=1), psf
CCR - Effective	80	25	0	N/A	N/A
Embankment CL - Total	120	17	592	19	660
Embankment CL - Effective	120	35	188		
Native CL - Total	115	19	280	23	333
Native CL - Effective	115	33	113		
Till (CL) - Total	130	20	1000	22	1125
Till (CL) - Effective	130	38	500		

* Strength parameters for Till (CL) material conservatively based on blow counts and relationships observed between total + effective strength envelopes in overburden material.









Normal operating level of pond is 603.3-ft

Nearest Boring	PZ or VWP No.	Embankment	Ground Surface Elevation (ft NAVD88)	Location	PZ Type[1,2]	Total Depth[3] (feet)	Water Surface Elevation (feet)						Nearest Boring GSE (ft)
							8/23/15	10/7/15	10/30/15	11/23/15	12/23/15	Average	
B001	KIN-P001	Southeast	599.2	Toe	OSP	31.2	589.6	586.4	586.1	586.0	586.6	**587**	599.2
B002	KIN-P002	Southeast	605.2	Crest	OSP	22.0	600.2	599.5	599.1	599.2	599.5	**600**	605.2
B003	KIN-P003	South	623.3	Crest	OSP	47.2	601.5	601.3	601.1	601.5	601.8	**601**	624.5
B003	KIN-P004	South	601.7	Toe	VWP	19.0	N/M[4]	597.9	597.8	599.0	599.1	**598**	624.5
B004	KIN-P005	Southwest	619.0	Crest	OSP	42.4	593.4	593.0	592.7	592.8	593.7	**593**	621.3
B005	KIN-P006	Southwest	596.4	Toe	OSP	36.8	586.9	586.0	Dry	Dry	587.8	**587**	596.4
B007	KIN-P007	Northwest	618.9	Crest	OSP	32.1	595.2	594.9	594.7	594.8	595.2	**595**	621.5
B008	KIN-P008	Northwest	589.9	Toe	OSP	27.2	585.3	584.6	584.2	584.3	585.0	**585**	592.1
B009	KIN-P009	North	590.4	Toe	OSP	31.7	584.5	583.7	583.3	583.4	584.6	**584**	590.4
B010	KIN-P010	North	615.3	Crest	OSP	43.5	601.7	601.4	600.8	600.9	601.3	**601**	615.3
NE Corner	KIN-P011[5]	North	600.6	Toe	VWP	17.0	594.5	593.8	593.6	594.1	595.9	**594**	
NE Corner	KIN-P012[5]	North	617.6	Crest	VWP	20.0	606.2	600.8	600.2	598.8	598.9	**601**	

Notes:

1. OSP = open standpipe piezometer.
2. VWP = vibrating wire piezometer installed at locations not accessible with drill rig.
3. Total Depth = Approx. bottom of screen for standpipe piezometers, or installed depth for VWPs.
4. N/M = Not measured.
5. Coordinates and ground surface elevations of KIN-P011 and KIN-P012 are the same as KIN-C014 and KIN-C015, respectively, as KIN-P011 and KIN-C014 are collocated, and KIN-P012 and KIN-C015 are collocated.

Appendix G: Existing Mine Subsidence Report

AECOM
1001 Highlands Plaza Drive West
Suite 300
St. Louis, MO 63110-1337
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314 429 0100 tel
314 429 0462 fax

Memorandum

Confidential – Attorney Client Privileged

To	Jason Frierdich, PE	Page	1 of 11
cc	Jason Campbell, PE, Matt Ballance, PE, (Dynegy) Ron Hager (AECOM)		
Project:	Dynegy – Location Restrictions – §257.64(a),(b)(1)(3) of the USEPA CCR Rules		
Subject:	Kincaid and Coffeen Mine Subsidence at Ash Ponds		
From	Vic Modeer, PE, D.GE Tom Cooling, PE. D.GE William Prosser		
Date	December 6, 2016		

1.0 INTRODUCTION

The purpose of this memo is to review the information obtained to date of past instances of subsidence and the probability of future instances of surface subsidence due to the collapse or squeezing of abandoned underground coal mine workings below existing ash ponds located at the Coffeen and Kincaid Power Stations in Illinois. The respective location of the two stations within the West Central Mining Area of the Illinois Basin is shown in Figure 1. Coffeen is in southeastern Christian County and Kincaid is in northwest Christian County. The report discusses the probability of future surface subsidence at the ash ponds located at both of these locations.

The Illinois Department of Natural Resources (IDNR) has extensively recorded and documented mining activity in Illinois since the early 1900's. The Pennsylvanian Period coal deposits are widespread, extensively mined and have been a source of economic growth. The mining occurred beneath and resulted in surface subsidence impacts to cities, roadways and various types of facilities. Sind the early 1900's the IDNR along with insurance companies have also been thoroughly investigating and documenting subsidence impacts, correlating mining activities within coal measures to the resulting or potential subsidence and recommending successful measures to mitigate impacts.

This memorandum demonstrates that future mine subsidence at the Dynegy Coffeen Power Station (Coffeen) and Kincaid Power Station (Kincaid) Ash Ponds has a low probability of occurrence and if the unlikely subsidence should occur, will have minimal impacts. While historical subsidence occurred at Kincaid in 2014, there was no release of CCRs, no global instability occurred in the embankment dike, and the impacts of the subsidence were addressed through routine maintenance. Any future subsidence at Coffeen or Kincaid is unlikely to cause a release of CCR material and impacts can be addressed through procedures contained in Operations and Maintenance Manuals for both the CCR units at both stations, as required in the CCR Rule. This memorandum is in reference to §257.64(a),(b)(1)(3) of the USEPA CCR Rule.

2.0 COAL GEOLOGY

This memorandum deals with the three key coal units, the upper Danville (No. 7), the middle Herrin (No. 6) and the lower Springfield (No. 5) within the Coffeen and Kincaid study areas. The relative stratigraphic or vertical position of these coal bed units are outlined in the attached Figure 2. A subsurface profile of the coal beds running north and south is outlined in Figure 3. This profile includes the approximate locations of Coffeen and Kincaid. The spatial extents of the three respective coal beds, i.e. the Danville, the Herrin and the Springfield are shown on Figures 4, 5 and 6, respectively.

Based upon mine maps and records obtained from the Illinois Department of Natural Resources (IDNR), the shallowest coal bed, the Danville No. 7, has not been mined in the Coffeen and Kincaid study areas due to the relatively thin nature of this formation.

The middle-positioned coal unit, the Herrin No. 6, has been extensively mined at Coffeen and Kincaid. This important unit is the major coal-producing bed addressed in this report.

The lower-positioned Springfield No. 9 has not been mined in the Coffeen and Kincaid study areas, based upon IDNR records. Mining of the Springfield No. 9 has been confined to locations within Sangamon County immediately to the northwest. The closest Springfield No. 9 mining operation to the study area appears to be below the Interstate 55 corridor southeast of the City of Springfield.

3.0 SOURCES OF INFORMATION

3.1 DISCUSSION WITH IDNR - Robert Gibson, Interview

As part of this evaluation, a meeting was held with Mr. Robert Gibson the IDNR Supervisor[1*] of Abandoned Mined Land Reclamation Division on September 16, 2015. The key parts of Robert Gibson's personal communication deal with abandoned underground room and pillar mining below the Coffeen and Kincaid Stations exclusively, and his personal communication is summarized as follows:

Bob stated that there are two main types of surface subsidence or disruption, resulting from abandoned underground coal mine workings collapse with the room and pillar mining method in Central Illinois:

1) ***Pits*** *- Pits usually occur due to relatively shallow mines which are less than 200 feet deep. A pit typically extends to a depth of approximately 60 feet or less, has vertical*

[*] Robert "Bob" Gibson is a nationally recognized authority on coal mine subsidence. He is the Supervisor of the Emergency Section of the Abandoned Mines Land Reclamation Division for the Illinois Department of Natural Resources, and has been with the agency for more than 25 years. He helps local governmental entities and land owners deal with the immediate and long-term effects of mine subsidence. His ability to easily explain complex problems make him a popular expert sought out by both media and government agencies across the country.

Bob pioneered digital preservation methods of historical mine maps, and established engineering models to predict the intensity and duration of mine subsidence occurrences. He has presented his findings at numerous conferences and authored dozens of articles and publications.

sides, and can be treated as an erosional feature. Remediation of a pit consists of back-filling the opening of the pit.

2) ***Sags*** *- Sags are shallow, bowl-shaped depressions developed at the surface several hundreds of feet in diameter and typically 2 to 3 feet deep in the center. Sags are typically due to a failure of a historical underground room and pillar mined area. Sags are mostly a failure of the floor where remaining coal pillars actually punch through the floor causing the ceiling to sag. Trapped surface water resulting in sag ponds usually form in tilled fields and can accumulate a significant amount of surface water. Sags or sag ponds can be up to 1800 feet in diameter.*

3) ***Troughs*** *- Troughs are elongated sags due to the collapse of multiple pillars. Tension cracking occurs at the perimeter of the "bowl" and transitions from a neutral zone to a compressional zone in the middle. It is believed that the 2 to 3 feet depression at the surface is the typical expression of the collapse of an abandoned typical room and pillar coal mine with a height of approximately 7 to 8 feet at depths from 200 to 400 feet deep, i.e. the Herrin No. 6. At mine depths beyond 400 feet, there has been no recorded subsidence with the room and pillar method in the Herrin No 6 in Central Illinois.*

Bob also commented on the following:

Abandoned Mine Map Accuracy *- Abandoned mine maps available at IDNR have been found to be satisfactorily accurate for surface development planning.*

Time Frame Approximations *- Based upon surface settlement measurements, elapsed times for surface settlement to occur after the completion of underground room and pillar mining are highly variable and depend upon several factors. The main factor is the depth of the mine below the ground surface.*

Subsidence Case Study – Farmersville, IL*. The Herrin No. 6 coal seam with an average thickness of 7-feet and an average depth of approximately350-feet was mined below an area in Farmersville, Illinois. The underground mining pattern included high barrier pillars. Approximately 2-feet to 3-feet of sag type settlement has occurred along I-55 and is clearly visible today. No further settlement has been recorded by Illinois Department of Transportation since 1990. At a school building 1.3-feet of settlement occurred in 320 days. No further settlement has been recorded since the initial occurrence. No pit type subsidence has been observed or recorded over the approximately 2-mile stretch of Interstate 55.*

3.2 AECOM ADDITIONAL EXPERIENCE SUMMARY

The amount of literature available regarding surface subsidence in Central Illinois is extensive. Categorizing past abandoned coal mine surface subsidence and predicting future mine settlement is a challenging task deterministically because of the number of unknowns and the variables relative to the actual subsurface conditions and mining practices. An experiential method, based on the extensive IDNR and other studies is the most accurate approach for evaluating future subsidence in Illinois. The factors considered include but are not limited to:

1. Mine depth, thickness of the coal bed removed, mining pattern based on mine maps (i.e. room and pillar; barrier wall; long wall; total extraction), geology of the immediate roof and floor of the mine, geology between the surface and the mine, angle of draw (function of the latter factor), surface subsidence history within the study area with similar mining approaches, possible pillar robbing, time elapsed since mining ceased, and groundwater conditions are all factors that help determine the probability of subsidence as well as severity. A knowledge of as many factors as possible is important for evaluating the cause and potential impact of surface subsidence. The depth to the mine is the most important factor impacting surface subsidence.
2. The angle of draw (defined as the angle between the end of the underground mine workings and the point on the ground surface to which subsidence, due to that mine working, may extend). This angle usually ranges from 65 to 75 degrees to the horizontal in Illinois. The angle of draw's intersection with the surface usually determines the width or perimeter of the sag. At this point, tension cracking may occur on the surface.
3. Important factors include the geology and the condition of the mine roof and floor as well as the thickness of the coal mined. The floor usually consists mostly of shaley underclay with high volume change potential. The mine roof can be limestone and in some cases shale. A key factor in evaluating surface subsidence is knowledge of the roof and floor conditions. Literature on this coal measure states that for a typical mine approximately 300-feet deep with a room and pillar mining pattern developed in a 7-feet thickness of this coal bed will have a surface subsidence in a sag pattern of a maximum of 2-feet to 3-feet. This is also supported through the methods presented in References 2 through 5. Pit subsidence for mines at that depth is unlikely. It appears that the most common cause of sag type surface subsidence for mines approximately 300-feet deep with a room and pillar mining pattern is typically through one of the cases below:

    a. Remnant coal pillar failure due to spalling
    b. A punch of the coal pillar into softened underclay. Bearing capacity failure of the underclay occurs and a floor heave may result.
    c. Roof failure occurs less frequently in Illinois than floor failure. The presence of sags denotes a gradual settlement process most likely due to pillar punch rather than roof collapse.

3.3 Methods to Estimate Mine Subsidence in Illinois

The methods used to estimate the amount of expected mine subsidence in Illinois were taken from References 2 through 5.

4.0 SITE SPECIFIC DISCUSSION-EVALUATION – Coffeen Power Station

4.1 Coffeen Power Station

The existing ash pond layout at Coffeen Power Station is shown on Figure 7. Included are Coffeen Ash Ponds No. 1 and 2, the GMF Recycle Pond and the GMF Pond. This discussion deals solely with the documented presence of abandoned room and pillar coal mine workings within the Herrin No. 6 coal seam at a depth of about 500-feet to 510-feet with a thickness of 5.8 to 7.1 feet. As discussed in Section 2, there are no historic records of mining in the other coal seams present at the Coffeen Power Station.

4.2 Mine History

The Truax-Traer Coal Company performed the coal mining operation during the period from 1964 to 1970. At that time, the mine was known as the "Hillsboro" Mine. The Consolidation Coal Company took over the mining operation from 1971 to 1983 and renamed the mine "Consolidation No. 63, Hillsboro". An estimated 26,800,000 tons of coal were removed from the mine during the operational period with an extraction ratio of approximately 25% based on an estimate of volume removed from the recorded mine maps.

IDNR reports the following geologic problems encountered during the mining operations: *Roof problems were encountered, the problems characterized by slickensided or naturally occurring vertical planes developed during consolidation of the formation that cut through the roof shales and claystones. Floor heaving was slight, but had been a larger problem closer in time to the end of the mining operation.*

4.3 Discussion-Analysis

Figures 8 and 9 include overlays of the Hillsboro mine workings over the existing embankment dike structures under study. Figure 10 depicts only the original mine map for the area. The embankment dikes under study include, from south to north, for:

1. Ash Pond No. 1
2. Ash Pond No. 2
3. GMF Recycle Pond
4. GMF Pond

The "Hillsboro" mine described above underlies Ash Ponds No. 1 and 2. There is no undermining under the GMF Recycle Pond and the GMF Pond dikes. Figure 10 indicates that two narrow room and pillar mine drifts, each estimated to be about 100 feet wide, as part of the Clover Leaf Coal Company No. 4 Mine located to the north may have extended horizontally in close proximity to the north edge of the GMF Pond dike. It is the opinion of AECOM that these two small penetrations or incursions of the Clover Leaf Mine into the footprint of the GMF Gypsum Stack Embankment dike are unlikely impact or cause mine subsidence in the GMF Recycle Pond or the GMF Pond dikes.

AECOM personnel, based upon field inspections, indicated that there are no visibly apparent settlement areas along the crests of the dikes of the four ponds evaluated. Additionally, settlement areas were not noted in 2015 Weaver Consultants survey data for the four ponds, which was provided by Dynegy.

4.4 Conclusions - Coffeen Power Station

Based upon the results of the study, the opinion of AECOM is that there is unlikely to be future mine subsidence which could potentially cause a CCR release nor impacts the impoundments embankment dike stability for the following summarized reasons:

1. The deep (>500 feet) abandoned underground mine.
2. The low extraction ratio.
3. The lack of any evidence of previous settlement of the earthen containment structures under study.
4. The recorded heaving of the underclay, i.e. “pillar punch” during the mining operation, as a result there is a low probability of future significant subsidence of the embankment dikes forming the ponds which contain ash and other materials relative to the coal combustion process due to abandoned underground mining below the Coffeen Power Station.
5. Any future subsidence or settlements of the embankment dikes, if it were to occur, is expected to be relatively minor (e.g. 6 inches or less), and due to the depth of the mine, is expected to be of the “sag” type (Ref. 2 through 5). The documentation shows that subsidence of up to 6 inches will not cause instability in the embankment dikes nor a release of CCR waste.

5.0 SITE SPECIFIC DISCUSSION-EVALUATION - Kincaid Power Station

5.1 Kincaid Power Station

The study at the Kincaid Power Station is shown and outlined on the attached Figure 11. Some of the abandoned mine workings and openings located beneath the ash pond foot print area have been filled with fly ash and bottom ash. Details of the filling program are not available. Mine maps show that the area of the coal measure below the power station and southernmost embankment dike at the process water flume was not mine out or worked. An overlay of the Kincaid Ash Pond on the original Peabody No. 10 mine map is included as Figure 12.

This discussion deals solely with the documented presence of the abandoned coal mine workings below the Kincaid Ash Pond under study from the Herrin No. 6 coal bed at depths ranging from 300 to 380 feet in the Peabody Coal Co. Mine No. 10. As discussed in Section 2, there are no historic records of mining in the other coal seams present at the Kincaid Power Station. The recorded averaged thickness of the Herrin No. 6 coal bed is 6.5 to 7.5 feet. The coal averaged 6.5 feet thick under a limestone roof and 7.5 feet thick under the Anna Shale. The last reported mining was in 1994. The method of mining was panel room and pillar.

5.2 Mine History

The Peabody Coal Co. produced coal from this mine during the period of 1951 to 1994. IDNR reports numerous issues encountered during the mining period. During the mining period, the Anna

Shale roof tended to drop into the mine after extractions along slickensided joints, exposing a thin bed of the Brereton Shale under several feet of the water-bearing Anvil Rock Sandstone. As much as 35 feet of horizontal section of a roof fall consisting of silty shale and gray shale has been documented, and was likely caused by the presence of water in the Anvil Rock Sandstone. IDNR reports that the coal in the northern part of the mine which is within the area of this study was exceptionally hard with soft underclay.

5.3 Discussion-Analysis

The annual dam inspection reports for the Kincaid Ash Pond in 2013 and 2014 describe subsidence on the western embankment dike that was reported by the station staff to the inspection engineer in July of 2013. These reports are attached as References 8 and 9. Four areas of embankment dike crest surface subsidence were noted in the initial site visit by AECOM in 2015 of the embankment dike and are shown on Figure 13 of this report (Figure 1 from the AECOM report titled: *"Initial Site Visit CCR Unit Summary, Dynegy CCR Compliance Program",* dated June 17, 2015).

The areas of depression along the crests were photographed and documented by AECOM personnel during a site visit. Three of the subsidence areas are 2-feet to 3.5-feet deep extending in gentle bowl patterns along the embankment dike crests for a distance of approximately 500 to 600 feet. A fourth area is likely along the north embankment dike at the eastern section. These subsidence patterns are typical of a sag type for surface subsidence. These areas of subsidence are likely the result of a collapse in the mine workings due to roof collapse, pillar punch or pillar failure or a combination thereof which may be the result of a mining pattern and/or pillar pulling.

A visual-manual analysis was made between Figures 12 and 13 comparing the location of the four embankment dike subsidence areas observed in the field with the particular mining pattern below. Based upon IDNR publications, there are two mining patterns indicated below the subject ash pond: blind room and pillar panel (BRP) and room and pillar panel (RPP). The BRP mining pattern is indicated by the four prominent north-south trending drifts with checkerboard patterns of mining. These four BRP drifts in the mine underlying the ash pond are about 500 feet wide and are about 800 feet apart center to center. The percentage of coal extraction in BRP mining varies, but is generally less than 50% percent according to IDNR publications. A typical BRP mining pattern is depicted on page 4 of Reference 6.

Between the BRP mining pattern drifts, RPP mining has taken place. The pattern of mining is shown in Figure 12 and is less regular than the area of checkerboard BRP mining. Six barrier pillars are indicated running in an east-west direction. IDNR indicates that the percentage of coal extraction in RPP mining can approach 80 percent if the pillars are pulled. A typical RPP mining pattern is depicted also on page 4 of Reference 6.

The possibility of pillar-pulling and extraction ratios of up to 80 percent in the RPP mining area suggests a correlation between the location of the four embankment dike crest surface subsidence areas observed and the particular type of mining pattern below. The three areas of embankment dike crest settlement as indicated on Figure 13 are located over the areas of RPP mining patterns where the highest risk or probability of underground mine collapse could be expected.

Surficial embankment dike sloughing was recorded adjacent in at least two of the subsidence areas. However, the surficial sloughing is likely due to the relatively steep embankment side slopes (up to 1.4 horizontal to vertical) and is unlikely to be related to subsidence caused by the underground mine workings.

The south embankment dike is approximately 300-feet from the southern end of the mine workings. The depth of mining places the 20 degree to 25 degree angle of the draw's intersection with the surface north of the south embankment dike.

5.4 Conclusions –Kincaid Power Station

Based upon the results of our study and review, AECOM has made the following conclusions:

1. The three areas of embankment dike crest sag type settlement are positioned over the RPP areas where the expected highest probability of either roof collapse, pillar punch, pillar failure or a combination thereof occurring because of high extraction ratios, up to over 80 percent, due to pillar-pulling due to the following contributive factors:

    a. Mine records indicate an unstable roof at various locations;
    b. The mine is relatively shallow, i.e. 300 feet to 380 feet;
    c. Presence of water in the Anvil Rock Sandstone, and
    d. Soft underclay

2. Because of past subsidence in the RPP areas, AECOM believes there is a low probability of more than 6-inches of continued development of crest subsidence within the embankment dike areas positioned over the area of RPP mining pattern, Any future additional subsidence of the embankment dikes in the RPP areas in the western and central portions of the ash pond is expected to be very small, less than 6 inches and will likely be of the "sag" type.

3. There is an area of RPP mining below the eastern portion of the ash pond between the BRP area in the middle of the ash pond and the BRP underlying the eastern portion of the northernmost embankment dike. This area of embankment dike has not reported any subsidence, possibly because of the barrier pillar. There is an area of water ponding at the north toe of this area of embankment dike that has formed a wetland. This could be caused by sag subsidence. This area would have a high probability of 2-feet to 3-feet of subsidence if the barrier pillar had been pulled. This would be in the same manner as the RPP area beneath the western and central portions of the ash pond.

a. Any future subsidence of the embankment dike in the eastern RPP area is expected be on the order of 2-feet to 3-feet, to be of the "sag" type.
b. The subsidence in the western and central portions was adequately maintained using the Operations and Maintenance procedures in place during 2014.
c. This potential subsidence will not impact the southernmost embankment dike along the hot ditch due to mining terminating prior to reaching this area.
d. Any subsidence in the eastern portion will only impact the eastern portion of the north embankment dike. The potential 2-feet to 3-feet of subsidence is unlikely to cause embankment dike instability.
e. The 2-feet to 3-feet of subsidence is unlikely to cause a CCR release based on the observed post-subsidence condition of the western and central portions after experiencing subsidence, as well as the relatively high freeboard of the dikes in this area (over 15 feet).
f. The embankment dikes are inspected weekly and any noted subsidence should be repaired according to the Operations and Maintenance Manual.

4. In the areas of the BRP mining pattern, there is a low probability of future crest subsidence because of:

   a. Lower coal extraction percentages (50% or less)
   b. High coal pillar strength
   c. No coal pillar pulling
   d. The lack of appreciable amounts of observable crest settlement since at least 1994.
   e. Cessation of mining

6.0 Conclusion – Unstable Areas - USEPA CCR Rule §257.64(a), (b) (1) (3)

This memorandum has demonstrated that mine subsidence at the Coffeen Power Station Ash Ponds has a low probability of occurrence and if the subsidence should occur, the impact would be minimal. Any subsidence at Coffeen will be addressed through procedures contained in the Operations and Maintenance Manual as required in the CCR Rule.

This memorandum also demonstrated that subsidence has previously occurred at the Kincaid Power Station Ash Pond, there was no release and no instability caused in the embankment dike and these events were addressed through routine maintenance in 2014. In addition, any future subsidence at Kincaid is unlikely to cause a release of CCR material and will be addressed through the Operations and Maintenance Manual as required in the CCR Rule.

7.0 Limitations

The review and analysis in this memorandum is based on experience and documentation recorded from the late 19th century through the 2010's by the IDNR. Estimates of subsidence also were based on IDNR records and the cited references that have made analyses of subsidence in Illinois.

8.0 Closing

AECOM is pleased to support and work together with Dynegy on this important program. Please do not hesitate to call Vic 618-541-0878 (mobile) or Ron (office) 314-743-4239, if you have any questions or comments on this memorandum.

AECOM

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9. "Kincaid Station Ash Pond Dike Inspection," Hanson Engineers, October 12, 2015.
10. "CCR Unit Initial Site Visit Summary, Kincaid Ash Pond, AECOM, July 7, 2015.

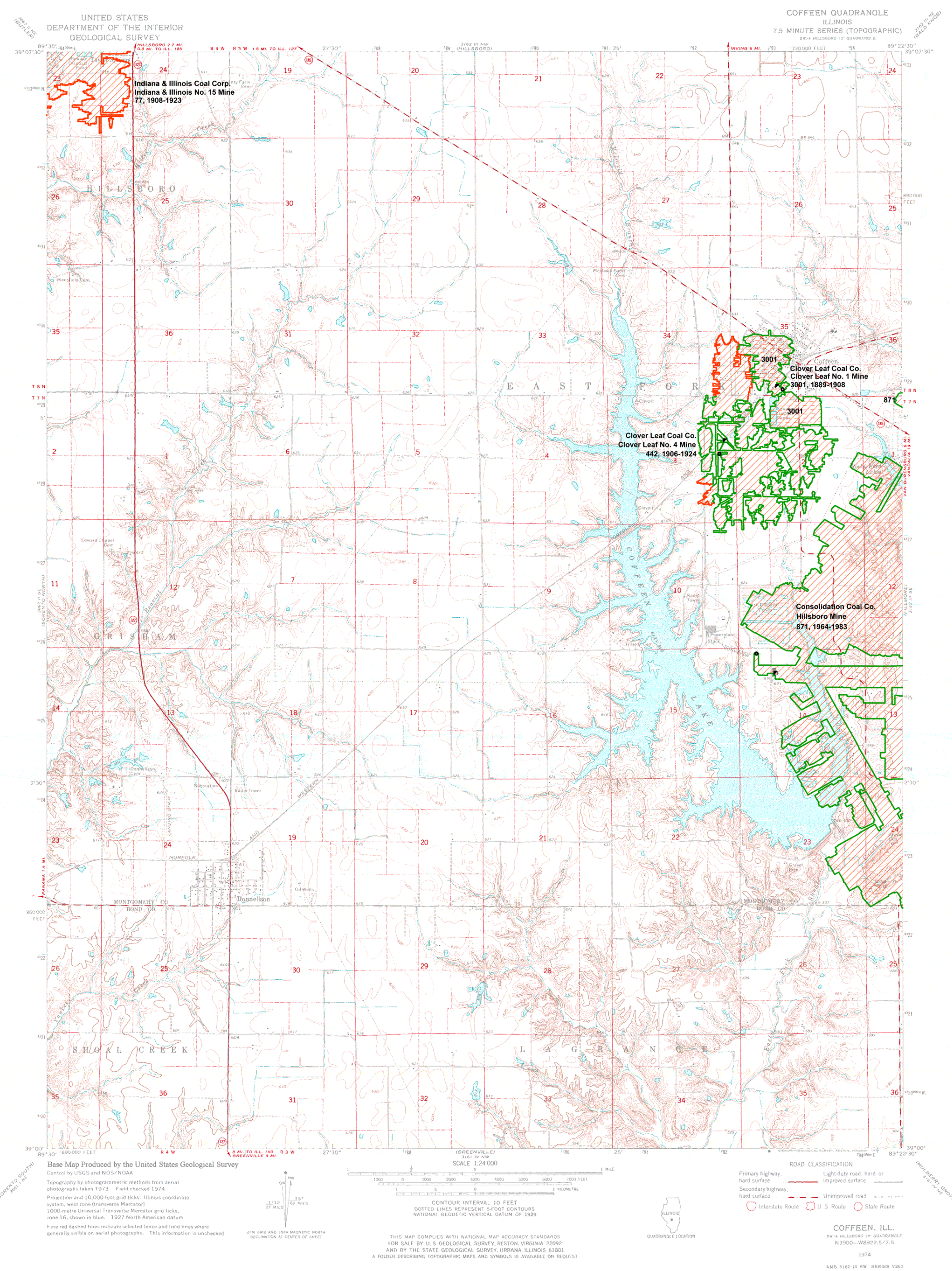
FIGURES:

Attorney Client Privileged

Reference 1

Coal Mines in Illinois
Coffeen Quadrangle

Montgomery & Bond Counties, Illinois



This map accompanies the Coal Mines Directory for the Coffeen Quadrangle. Consult the directory for a complete explanation of the information shown on this map.

Mining Method

- Room & Pillar (RP)
- Room & Pillar Basic (RPB)
- Modified Room & Pillar (MRP)
- Room & Pillar Panel (RPP)
- Blind Room & Pillar (BRP)
- Checkerboard Room & Pillar (CRP)
- High Extraction Retreat (HER)
- Longwall (LW)
- Underground, Method Unknown
- Strip Mine
- Auger Mine
- General Area of Mining

Source of Mine Outline

- Final Mine Map
- Not Final Mine Map
- Undated Mine Map
- Incomplete Mine Map
- Secondary Source Map

Tipple, Shaft, Slope, Drift Locations

- Strip Mine Tipple - Active
- Strip Mine Tipple - Abandoned
- Mine Shaft - Active
- Mine Shaft - Abandoned
- Mine Slope - Active
- Mine Slope - Abandoned
- Mine Drift - Active
- Mine Drift - Abandoned
- Air Shaft
- Uncertain Location
- Uncertain Type of Opening

Location

Mine Annotation
(space permiting)
Company
Mine Name
ISGS Index No., Years of Operation

Disclaimer

Please check the Coal Section at the Illinois State Geological Survey's web site at http://www.isgs.illinois.edu for the most up-to-date version of these products.

Note that each quadrangle scale mined-out area map requires the use of the associated text directory for full explanation of map features and mine attributes. Also note that some quadrangles have multiple seams of mining and therefore more than one map may be available for a particular quadrangle. Please take care to check for multiple maps, as extensive mining may exist in the other seams.

The maps and digital files used for these studies were compiled from data obtained from a variety of public and private sources and have varying degrees of completeness and accuracy. This compilation map presents reasonable interpretation of the geology of the area and is based on available data. Locations of some mine features may be offset by 500 feet or more due to errors in the original source maps, the compilation process, digitizing, or a combination of these factors. These data are not intended for use in site-specific screening or decision-making. Use of these documents does not eliminate the need for detailed studies to fully understand the geology of a specific site. The Illinois State Geological Survey, Institute of Natural Resource Sustainability, or the University of Illinois make no guarantee, expressed or implied, regarding the correctness of the interpretations presented in this data set and accept no liability for the consequences of decisions made by others on the basis of the information presented here.

These maps were designed for use at 1:24,000. Enlarging the map may reduce accuracy, as the original scale of the source maps used to compile the outlines shown varies from 1:400 to 1:150,000, and some mine locations are known only from text descriptions. See the accompanying mine directory for the original scale of the source map used for a specific mine to check accuracy of a given portion of the map. Areas with no mines shown may still be undermined; see the unlocated mines list at the back of each mine directory.

The image of the U.S.G.S. topographic base map was projected from the original UTM to Lambert Conformal Conic.

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Mine Outlines Compiled by
Jennifer M. Obrad

November 21, 2011

DIRECTORY OF COAL MINES IN ILLINOIS
7.5-MINUTE QUADRANGLE SERIES
COFFEEN QUADRANGLE
MONTGOMERY & BOND COUNTIES

Jennifer M. Obrad

2011

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Cover photo Track-mounted duckbill loading machine at a Peabody Coal Company mine, ca. 1915.

DISCLAIMER: The accuracy and completeness of mine maps and directories vary with the availability of reliable information. Maps and other information used to compile this mine map and directory were obtained from a variety of sources and the accuracy of some of the original information cannot be verified. Consequently, the Illinois State Geological Survey (ISGS) cannot guarantee the mine maps are free of errors and disclaims any responsibility for damages that may result from actions or decisions based on them.

The ISGS updates the maps and directories periodically, and welcomes any new information or corrections. Please contact the Coal Section of the ISGS at the address shown on the title page of this directory, or telephone (217) 244-4610.

CONTENTS

INTRODUCTION

Coal has been mined in 76 counties of Illinois. More than 7,400 coal mines have operated since commercial mining began in Illinois about 1810; fewer than 30 are currently active. To detail the extent and location of coal mining in Illinois, the Illinois State Geological Survey (ISGS) has compiled maps and directories of known coal mines. The ISGS offers maps at a scale of 1:100,000 and accompanying directories for each county in which coal mining is known to have occurred. Maps at a scale of 1:24,000 and accompanying directories, such as this, are available for selected quadrangles. Contact the ISGS for a list of these quadrangles.

These larger scale maps show the approximate positions of mines in relation to surface features such as roads and water bodies, and indicate the mining method used and the accuracy of the mine boundaries. The maps are useful for locating mine boundaries relative to specific properties and for assessing the potential for subsidence in an area. Mine boundaries compiled from final mine surveys are generally shown within 200 feet of their true position. As a result of poor cartographic quality and inaccuracies in the original mine surveys, boundaries of some older mines may be mislocated on the map by 500 feet or more. Original mine maps should be consulted in situations that require precise delineation of mine boundaries or internal workings of mined areas.

This directory serves as a key to the accompanying mine map and provides basic information on the coal mines in the quadrangle. The directory is composed of two parts. Part I explains the symbols and patterns used on the accompanying map and the summary data presented for each mine. Part II numerically lists the mines in the quadrangle and summarizes the geology and production history of each mine. Total production for the mine, not the portion in the quadrangle, is given.

MINING IN THE COFFEEN QUADRANGLE

Mining near Coffeen took place in the Herrin Coal, which ranged from 5.8 to 8 feet thick. The coal was deep, being 450 feet or more below the surface. The depth contributed to roof difficulties.

Mining began in the Coffeen Quadrangle in 1889, when Clover Leaf No. 1 Mine (mine index 3001) opened. After Clover Leaf No. 4 Mine (mine index 442) closed in 1924, a hiatus in mining activity continued until the Hillsboro Mine (mine index 871) opened in 1964. The Hillsboro Mine closed in 1983, leaving a great deal of coal remaining for future activity.

PART I EXPLANATION OF MAP AND MINE SUMMARY SHEET

INTERPRETING THE MAP

The map accompanying this directory shows the location of coal mines known to be present in the quadrangle. The map, corresponding to a U.S. Geological Survey (USGS) 7.5-minute quadrangle, covers an area bounded by lines of latitude and longitude 7.5-minutes apart. In Illinois, a quadrangle is approximately 6.5 miles east to west and 8.5 miles north to south, an area of about 56 square miles. The ISGS generally offers one map of mines per quadrangle. In some areas where extensive mining occurred in two or more overlapping seams, separate maps are compiled for mines in each seam to maintain readability of the map.

Mine Type and Mining Method
The mine type is indicated on the map by pattern color: green represents surface mines; red and yellow represent underground mines. The red patterns are used for areas of underground mining that are documented by a primary or secondary source map. A yellow pattern is used for cases where no map of the mine workings is available, but a general area of mining can be inferred from property maps or production figures. The patterns indicate the main mining methods used in underground mines. The methods are (1) room and pillar and (2) high extraction. The method used gives some indication of the amount and pattern of coal extraction within each mined area, and has some influence on the timing and type of subsidence that can occur over a mine.

The following discussion and illustrations of mining methods are based on Guither et al. (1984).

In room-and-pillar mines, coal is removed from haulage-ways (entries) and selected areas called rooms. Pillars of unmined coal are left between the rooms to support the roof. Depending on the size of rooms and pillars, the amount of coal removed from the production areas will range from 40% to 70%.

Room and Pillar - mining is divided into six categories:

- room-and-pillar basic (RPB, fig. 1A), an early method that did not follow a preset mining plan and therefore resulted in very irregular designs;
- modified room and pillar (MRP, fig. 1B);
- room-and-pillar panel (RPP, fig. 1C);
- blind room and pillar (BRP, fig. 1D);
- checkerboard room and pillar (CRP, fig. 1E);
- room and pillar (RP), a classification used when the specific type of room-and-pillar mining is unknown.

Blind and checkerboard are the most common types of room-and-pillar mining used in Illinois today. The knowledge of room-and-pillar mining methods gives a trained engineer information on the nature of subsidence that may occur. A more extensive discussion of subsidence can be found in Bauer et al. (1993).

High-extraction These mining methods are subdivided into high-extraction retreat (HER, Fig 1F) and longwall (LW, Fig 1G, 1H). In these methods, much of the coal is removed within well defined areas of the mine. Subsidence of the surface above these areas occurs within weeks. Once the subsidence activity ceases, the potential for further movement over these areas is low; however, subsidence may continue for several years after mining.

High-extraction retreat mining is a form of room-and-pillar mining that extracts most of the coal. Rooms and pillars are developed in the panels, and the pillars are then systematically removed (fig. 1F).

In early (pre-1960) longwall mines, mining advanced in multiple directions from a central shaft (fig. 1G). Large pillars of coal were left around the shaft, but all coal was removed beyond these pillars. Miners placed rock and wooden props and cribs in the mined-out areas to support the mine roof. The overlying rock gradually settled onto these supports, thus producing subsidence at the surface. In post-1959 longwall mines, room-and-pillar methods have been used to develop the main entries of the mine and panel areas. Modern longwall methods extract 100 percent of the coal in the panel areas (fig. 1H).

SOURCE MAPS

Mine outlines depicted on the map are, whenever possible, based on maps made from original mine surveys. The process of compiling and digitizing the quadrangle map may produce errors of less than 200 feet in the location of mine boundaries. Larger errors of 500 feet or more are possible for mines that have incomplete or inaccurate source maps.

Because of the extreme complexity of some mine maps, detailed features of mined areas have been omitted. The digitized mine boundary includes the exterior boundary of all rooms or entries that were at least 80 feet wide or protruded 500 feet from the main mining area. Unmined areas between mines are shown if they are at least 80 feet wide; unmined blocks of coal within mines are shown if they are at least 400 feet on each side. Original source maps should be consulted when precise information on mine boundaries or interior features is needed.

The mine summary sheet lists the source maps used to determine each mine outline. The completeness of map sources is indicated on the map by a line symbol at the mine boundary. Source maps are organized in five categories.

Final mine map The mine outline was digitized from an original map made from mine surveys conducted within a few months after production ceased. The date of the map and the last reported production are listed on the summary sheet.

Not a final map The mine is currently active or the mine outline was made from a map based on mine surveys conducted more than few months before production ceased. This implies the actual mined-out area is probably larger than the outline on the map. The mine summary sheet indicated the dates of source maps and the last reported production, as well as the approximate tonnage mined between these two dates (if the mine is abandoned). The summary sheet also lists the approximate acreage mined since the date of the map and, in some cases, indicates the area where additional mining may have taken place. This latter information is determined by locating on the map the active faces relative to probable boundaries of the mine property.

Undated map The source map was undated, so it may or may not be based on a final mine survey. When sufficient data are available, the probable acreage of the mined area is estimated from reported production, average seam thickness and a recovery rate comparable to other mines in the area. This information is listed in the summary sheet for the mine.

Incomplete map The source map did not show the entire mine. The summary sheet indicates the missing part of the mine map and the acreage of the unmapped area, which is estimated from the amount of coal known to have been produced from the mine.

Secondary source map The original mine map was not found so the outline shown was determined from secondary sources (e.g., outlines from small-scale regional maps published in other reports). The summary sheet describes the secondary sources.

POINTS AND LABELS

The locations of all known mine openings (shafts, slopes, and drifts) and surface mine tipples are plotted on the map. Tipples are areas where coal was cleaned, stockpiled, and loaded for shipping.

Only openings or tipples are plotted for mines without source maps. If the precise locations of these features are unknown, a special symbol is used to indicate the approximate location of the mine.

Each mine on the map is labeled with the names of the mine and operating company, ISGS mine index number, and years of operation (if known) if space permits. A seam designation is given on maps where more than one seam was mined. For a mine that operated under more than one name, only the most recent name is generally given. When a mine changed names or ownership shortly before closing, an earlier name is listed. All company and mine names are listed on the mine summary sheet in the directory, under the production history segment.

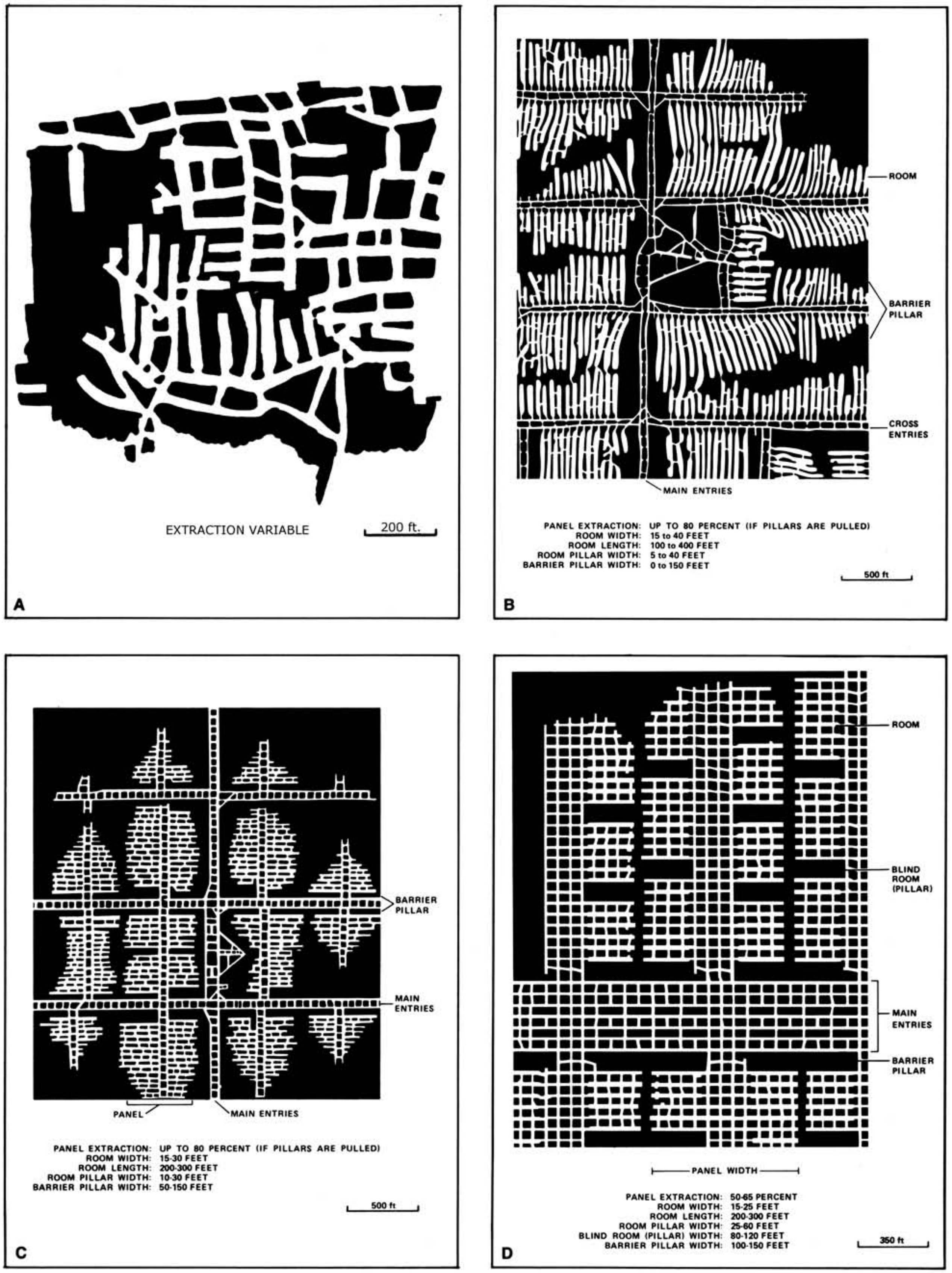

Figure 1 Mining methods: (A) room-and-pillar basic (RPB), (B) modified room and pillar (MRP), (C) room-and-pillar panel (RPP), (D) blind room and pillar (BRP).

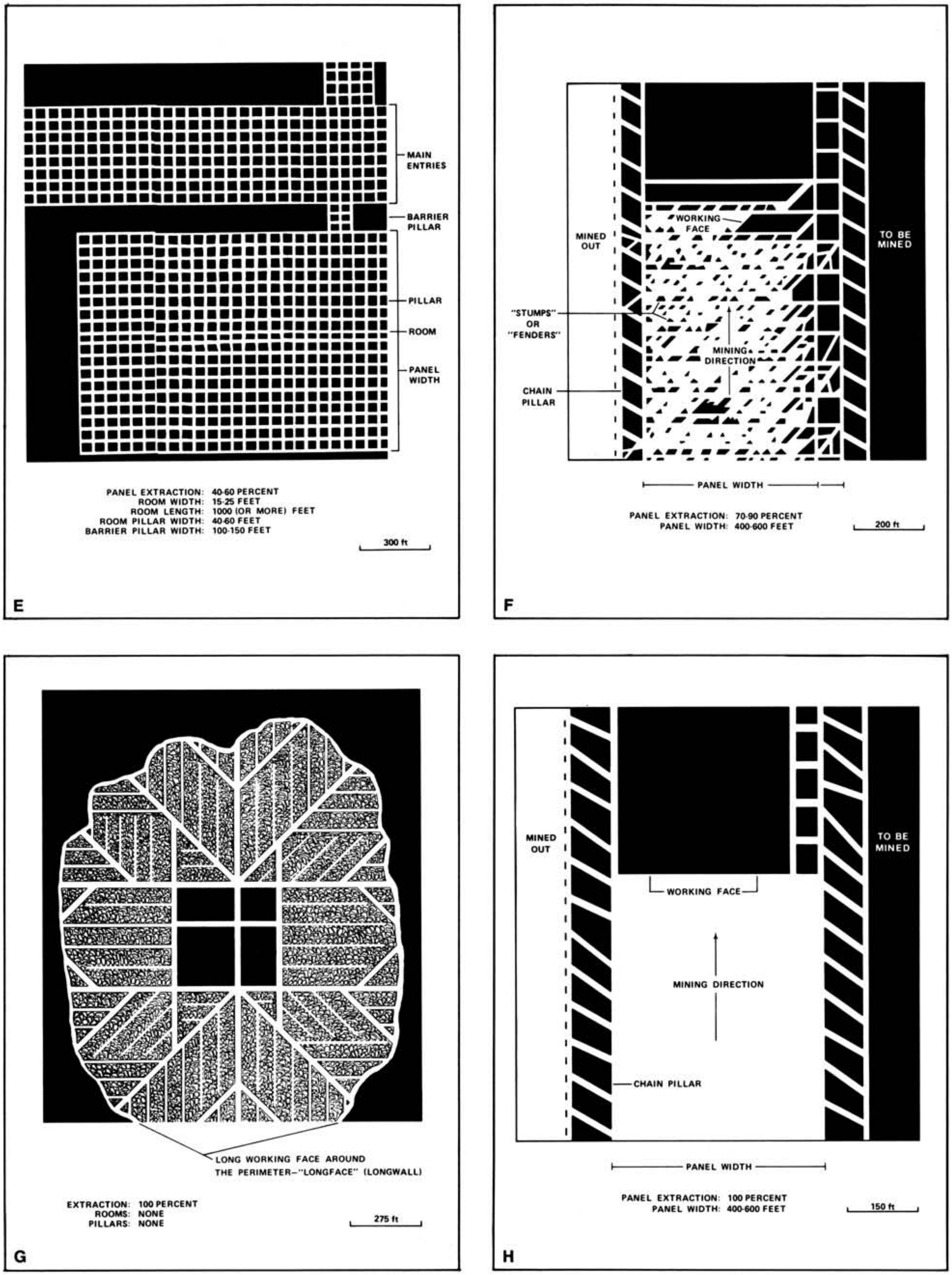

Figure 1 *(cont.)* Mining methods: (E) checkerboard room and pillar (CRP), (F) high extraction retreat (HER), (G) early (pre-1960) longwall, (H) post-1959 longwall

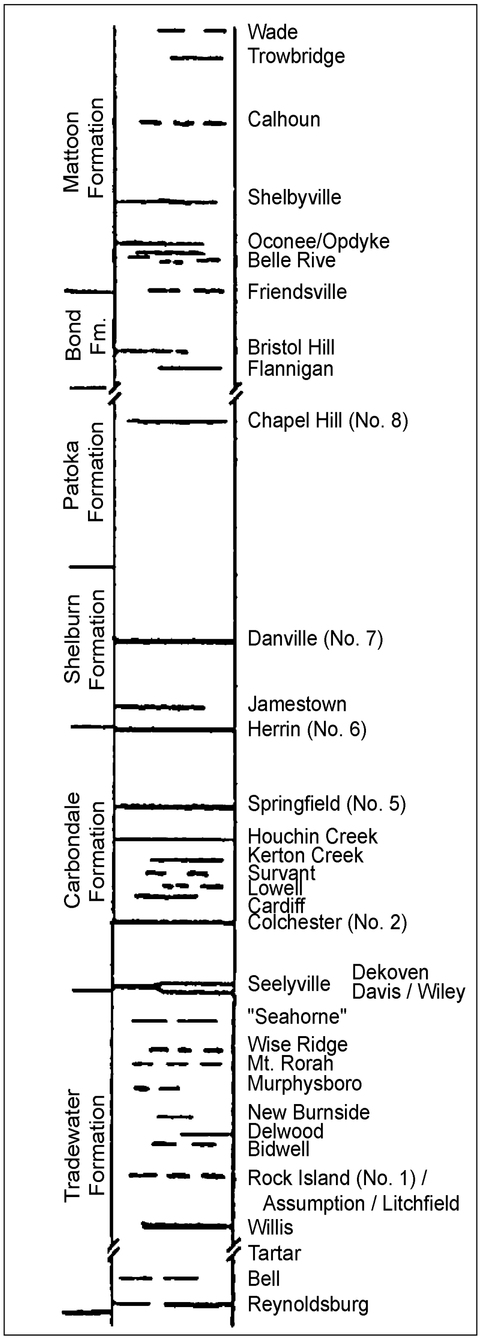

Figure 2 Generalized stratigraphic section, showing approximate vertical relations of coals in Illinois.

INTERPRETING A MINE SUMMARY SHEET

The mine summary sheet is arranged numerically by mine index number. Index numbers are shown on the map and in the mine listing. The mine summary sheet provides the following information (if available).

Company and mine name The last company or owner of the mine is used, unless no production was recorded for the last owner. In that case, the penultimate owner is listed. Mines often have no specific name; in these cases, the company name is also used as the mine name.

Type *Underground* denotes a subsurface mine in which the coal was reached through a shaft, slope, or a drift entry. *Surface* denotes a surface, open pit or strip mine.

Total mined-out acreage shown The total acreage of the mined area mapped, including any acreage mined on adjacent quadrangles, is calculated from the digitized outline of the mine. The acreage of large barrier pillars depicted on the map is excluded from the mined-out acreage. Small pillars not digitized are included in the acreage calculation. If the mine outline is not based on a final mine map, the acreage is followed by an estimate of additional acres that may have been mined. The estimate is determined from reported mine production, approximate thickness of the coal, and recovery rates calculated from nearby mines that used similar mining methods.

SHAFT, SLOPE, DRIFT OR TIPPLE LOCATIONS

Shaft, slope, drift, or tipple locations Locations of all known former entry points to underground mines or the location of coal cleaning, tipple, and shipping equipment used by the mine's facility are listed. The location is described in terms of county, township and range (Twp-Rge), section, and location within the section by quarters. NE SW NW, for instance, would describe the location in the northeast quarter of the southwest quarter of the northwest quarter. When sections are irregular in size, the quarters remain the same size and are oriented (or "registered") from the southeast corner of the section. Approximate footage from the section lines (FEL = from east line, FNL = from north line, for example) is given when that information is known; this indicates a surveyed location and is not derived from maps. Entry points are also plotted on the map and coded for the type of entry or tipple. A mine opening may have had many purposes during the life of the mine. Old hoist shafts are often later used for air and escape shafts; this information is included in the directory when known. The tipple for underground mines was generally located near the main shaft or slope. At surface mines, coal was sometimes hauled to a central tipple several miles from the mine pit.

GEOLOGY

Seam(s) mined The name of the coal seam(s) mined is listed, if known. If multiple seams were mined, they are all listed, although the mined-out area for each seam may be shown on separate maps. Figure 2 shows the stratigraphic section of the coal-bearing interval in Illinois, and the vertical relations among the coals.

Depth The depth to the top of the seam in the vicinity of the shaft is listed, if known. The depth is determined from notes made by geologists who visited the mine during its operation or from drill hole data in ISGS files. Depth generally varies little over the extent of a mine; however, reported depths for an individual mine may vary. Depth for surface-mined coals varies, and is usually represented as a range.

Thickness The approximate thickness of the mined seam is shown, if known. Thickness also comes from notes of geologists who visited the mine during its operation or from borehole data in ISGS files. Minimum, maximum, and average thicknesses are given when this information is available.

Mining method The principal mining method used at the mine (figs. 1A-H) is listed. See the mining methods section at the beginning of this directory for a discussion of this parameter.

Geologic problems reported Any known geologic problems, such as faults, water seepage, floor heaving, and unstable roof, encountered in the mine are reported. This information is from notes made by ISGS geologists who visited the mine, or from reports by mine inspectors published by the Illinois Department of Mines and Minerals, or from the source map(s). Geologic problems are not reported for active mines.

PRODUCTION HISTORY

Production history Tons of coal produced from the mine by each mine owner are totaled. When the source map used for the mine outline is not a final mine map, the tonnage produced since the date of the map is identified. For mines that extend into adjacent quadrangles, the tonnage reported includes areas mined in adjacent quadrangles.

SOURCE OF DATA

Source map This section lists information about the map(s) used to compile the mine outline and the locations of tipples and mine openings. In some cases more than one source map was used. For example, a map drawn before the mine closed may provide better information on original areas of the mine than a later map. When more than one map was used, the bibliography section explains what information was taken from each source.

Date The date of the most recent mine survey listed on the source map is reported.

Original scale The original scale of the source map is listed. Many maps are photo-reductions and are no longer at their original scale. The original scale gives some indication of the level of detail of the mine outline and the accuracy of the mine boundary relative to surface features. Generally, the larger the scale, the greater the accuracy and detail of the mine map. Mine outlines taken from source maps at scales smaller than 1:24,000 may be highly generalized and may well be inaccurately located with respect to surface features.

Digitized scale The scale of the digitized map is reported. The scale may be different from that of the original source map. In many cases the digitized map was made from a photo-reduction of the original source map, or the source map was not in a condition suitable for digitizing and the mine boundaries were transferred to another base map.

Map type Source maps are classified into five categories to indicate the probable completeness of the map. See discussion of source maps in the previous section.

Annotated bibliography Sources that provide information about the mine are listed, with the data taken from each source. Some commonly used sources are described below. Full bibliographic references are given for all other sources. Unless otherwise noted, all sources are available for public inspection at the ISGS.

Coal Reports Published since 1881, these reports contain tabular data on mine ownership, production, employment, and accidents. Some volumes include short descriptions made by mine inspectors of physical features and conditions in selected mines.

Directory of Illinois Coal Mines This source is a compilation of basic data about Illinois coal mines, originally gathered by ISGS staff in the early 1950s. Sources used for this directory are undocumented, but they are primarily Illinois Department of Mines and Minerals annual reports, ISGS mine notes, and coal company officials.

ENR Document 85/01, Guither, H. D., J. K. Hines, and R. A. Bauer, 1985 The Economic Effect of Underground Mining Upon Land Used for Illinois Agriculture: Illinois Department of Energy and Natural Resources Document 85/01, 185 p.

Microfilm map The U.S. Bureau of Mines maintains a microfilm archive of mine maps. A microfilm file for Illinois is available for public viewing at the ISGS.

Mine notes ISGS geologists have visited mines or contacted mine officials throughout the state since the early 1900s. Notes made during these visits range from brief descriptions of the mine location to long narratives (including sketches) of mining conditions and geology.

Federal Land Bank of St. Louis, Preliminary Reports on Subsidence Investigations Mining engineers working for the Federal Land Bank of St. Louis mapped areas of subsidence due to coal mining in the early 1930s. These reports often include county maps of mine properties with mined-out areas including shaft locations, as well as subsidence areas.

REFERENCES

Bauer, R. A., B. A. Trent, and P. B. Dumontelle, 1993, Mine Subsidence in Illinois: Facts for the Homeowner Considering Insurance, Illinois State Geological Survey, Environmental Geology Note 144, 16p.

Guither, H. D., J. K. Hines, and R. A. Bauer, 1985, The Economic Effects of Underground Mining Upon Land Used for Illinois Agriculture, Illinois Department of Energy and Natural Resources Document 85/01, 185p.

PART II DIRECTORY OF MINES IN THE COFFEEN QUADRANGLE

MINE SUMMARY SHEETS

A summary sheet on the geology and production history of each mine in the Coffeen Quadrangle is provided. These summary sheets are arranged numerically by mine index number. Consult Part I for a complete explanation of the data listed in the summary sheet.

Mine Index 77
Indiana & Illinois Coal Corporation, Indiana & Illinois No. 15 Mine

Type: Underground Total mined-out acreage shown: 441 Production indicates approximately 136 acres were mined after the map date.

SHAFT, SLOPE, DRIFT or TIPPLE LOCATIONS

Type	County	Township-Range	Section	Quarters-Footage
Main shaft (9'x16')	Montgomery	8N 4W	23	NW SE NE
Air shaft (9'x16')	Montgomery	8N 4W	23	NW SE NE

GEOLOGY

		Thickness (ft)			Mining
Seam(s) Mined	Depth (ft)	Min	Max	Ave	Method
Herrin	450-471			6.0-8.0	RPP

Geologic Problems Reported: The mine notes indicate this mine was filled with gas and that roof falls were a problem.

PRODUCTION HISTORY

Company	Mine Name	Years	Production (tons)
Montgomery County Coal Company	Taylor Spring	1908-1912	831,018
Peabody Coal Company	Peabody No. 15	1912-1915 *	692,431
C. & E. I. Coal Properties	C. & E. I. No. 15	1917-1918	279,360
Illinois Coal Properties	Illinois Coal Properties No. 15	1918-1919	247,616
Indiana & Illinois Coal Corporation **	Indiana & Illinois No. 15	1919-1921	490,881
Indiana & Illinois Coal Corporation	Indiana & Illinois No. 15	1921-1923	782,440 ***
			3,323,746

* Idle, temporarily abandoned 1915
** An April 1919 map indicates the mine was operated by Keller Coal Company, probably under a lease agreement.
*** Production after map date

Last reported production: October 1923

SOURCES OF DATA

Source Map	Date	Original Scale	Digitized Scale	Map Type
Microfilm, document 352595	2-15-1921	1:2400	1:3972	Not final

Annotated Bibliography (data source, brief description of information)

Coal Reports - Production, ownership, years of operation, seam, depth, thickness.
Directory of Illinois Coal Mines (Montgomery County) - Mine names, mine index, ownership, years of operation.
Mine notes (Montgomery County) - Mine type, shaft location, thickness, geologic problems.
Microfilm map, document 352595, reel 03139, frames 434-437 - Shaft locations, mine outline, mining method.

Mine Index 442
Clover Leaf Coal Company, Clover Leaf No. 4 Mine

Type: Underground   Total mined-out acreage shown: 399

SHAFT, SLOPE, DRIFT or TIPPLE LOCATIONS

Type	County	Township-Range	Section	Quarters-Footage
Main shaft (11'x22')	Montgomery	7N 3W	3	NE SE NE
Air shaft *	Montgomery	7N 3W	3	SW SE NE

* This air shaft was completed in 1913. The mine was connected to Clover Leaf No. 1 Mine (mine index 3001), which sufficed for the initial ventilation and escapeway.

GEOLOGY

		Thickness (ft)			Mining
Seam(s) Mined	Depth (ft)	Min	Max	Ave	Method
Herrin	510-544			6.0-8.0	RPP

Geologic Problems Reported: The roof was a massive black shale, with sandstone above. Rolls were present in the mine. The source map shows many unmined areas within the mine outline. The reason these areas were not mined is not specified in the mine notes or on the source map, but water-bearing sands above the roof shale could contribute to roof problems.

PRODUCTION HISTORY

Company	Mine Name	Years	Production (tons)
Clover Leaf Coal Mining Company	Clover Leaf No. 2	1906-1916	1,098,726
Coffeen Coal Mining Company	Coffeen No. 2	1916-1920	488,616
Clover Leaf Coal Company **	Clover Leaf No. 4	1920-1924 ***	251,515
			1,838,857

** According to the mine notes, Cosgrove Meehan Coal Company owned or operated the mine.
*** Idle 1922

Last reported production: March 1924

SOURCES OF DATA

Source Map	Date	Original Scale	Digitized Scale	Map Type
Microfilm, document 352580	7-1923	1:2400	1:4800	Not final
State archive, MSHA_412_04	7-14-1915	1:1200	1:1430	Not final
State archive, IL_2441_01	4-1924	1:2400	1:2400	Final

Annotated Bibliography (data source, brief description of information)

Coal Reports - Production, ownership, years of operation, mine type, depth, thickness.
Directory of Illinois Coal Mines (Montgomery County) - Mine names, mine index, ownership, years of operation.
Mine notes (Montgomery County) - Shaft location, seam, thickness, geologic problems.
Microfilm map, document 352580, reel 03139, frame 377 - Mine outline (southwest part of mine), geologic problems.
State Archive, MSHA_412, courtesy of Robert Gibson, IDNR - Mine outline (north half), mining method.
State Archive, IL_2441_01, courtesy of Robert Gibson, IDNR - Shaft locations, mine outline (south half), mining method.

Mine Index 871
Consolidation Coal Company, Hillsboro Mine (Consolidation No. 63 Mine)

Type: Underground   Total mined-out acreage shown: 4,841

SHAFT, SLOPE, DRIFT or TIPPLE LOCATIONS

Type	County	Township-Range	Section	Quarters-Footage
Man shaft	Montgomery	7N 3W	14	SW NE NW
Air shaft	Montgomery	7N 2W	18	SE NE NE
Hoist & air shaft	Montgomery	7N 3W	14	NE NW NW

GEOLOGY

Seam(s) Mined	Depth (ft)	Thickness (ft) Min	Max	Ave	Mining Method
Herrin	500-510			5.83-7.17	RPP

Geologic Problems Reported: Roof problems were widespread, the sites characterized by slickensided fault planes that cut irregularly through the roof shales and claystones. Small clay dikes were also associated with this small-scale faulting. Floor heaving was slight, but had been a larger problem in the past.

PRODUCTION HISTORY

Company	Mine Name	Years	Production (tons)
Truax-Traer Coal Company	Hillsboro	1964-1970	5,605,812
Consolidation Coal Company	Consolidation No. 63, Hillsboro	1971-1983	21,173,542
			26,779,354

Last reported production: July 1983

SOURCES OF DATA

Source Map	Date	Original Scale	Digitized Scale	Map Type
Company, Coal Section files	2-1-1983	1:12000	1:2170	Final *

* The map date is before mine closure, but the Coal Section has been assured that the workings shown on the map are indeed final. The mined area shown on the accompanying map is the approximate size expected for the reported production. This suggests that the mine outline is complete.

Annotated Bibliography (data source, brief description of information)

Coal Reports - Production, ownership, years of operation, mine type, depth, thickness.
Directory of Illinois Coal Mines (Montgomery County) - Mine names, mine index, ownership, years of operation.
Mine notes (Montgomery County) - Shaft location, seam, depth, thickness, geologic problems.
Company map, Coal Section files, 1983 Line Project - Shaft locations, mine outline, mining method.

Mine Index 3001
Clover Leaf Coal Company, Clover Leaf No. 1 Mine

Type: Underground   Total mined-out acreage shown: 137

SHAFT, SLOPE, DRIFT or TIPPLE LOCATIONS

Type	County	Township-Range	Section	Quarters-Footage
Main shaft	Montgomery	8N 3W	35	SW SE SW
Air shaft	Montgomery	8N 3W	35	SE SE SW

GEOLOGY

		Thickness (ft)			Mining
Seam(s) Mined	Depth (ft)	Min	Max	Ave	Method
Herrin	534-562			7.0-8.0	RP

Geologic Problems Reported:

PRODUCTION HISTORY

Company	Mine Name	Years	Production (tons)
Coffeen Coal & Coke Company	Coffeen	1889-1900	878,898
Coffeen Coal & Coke Company *	Coffeen	1900-1901	8,000
Clover Leaf Coal Company	Clover Leaf No. 1	1901-1908 **	484,939
			1,371,837

* Under management of Mitchell Coal & Coke Company
** Abandoned as a hoisting shaft, used as escapement for Clover Leaf No. 4 Mine (mine index 442)

Last reported production: 1908

SOURCES OF DATA

Source Map	Date	Original Scale	Digitized Scale	Map Type
Microfilm, document 352580	7-1923	1:2400	1:4800	Final
State archive, MSHA_412_04	7-14-1915	1:1200	1:1430	Final

Annotated Bibliography (data source, brief description of information)

Coal Reports - Production, ownership, years of operation, depth, thickness.
Directory of Illinois Coal Mines (Montgomery County) - Mine names, mine index, ownership, years of operation.
Mine notes (Montgomery County) - Mine type, shaft location, seam.
Microfilm map, document 352580, reel 03139, frame 377 - Mine outline (south half), mining method.
State Archive, MSHA_412, courtesy of Robert Gibson, IDNR - Shaft locations, mine outline (north half), mining method.

INDEX OF MINES IN THE COFFEEN QUADRANGLE

Attorney Client Privileged

Reference 2

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Behaviour of abandoned room and pillar mines in Illinois

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Summary

Little comprehensive information has been reported on the behaviour of room-and-pillar mines. The objective of this paper is to present case data on mine failures in the Illinois basin for use in practice. Presented are results of an ongoing study and details on the site characteristics of cases where sags have developed on the surface. Site data are reported to show the geologic, mining, and sag conditions that existed. Sags mainly develop from pillar, floor, or pillar–floor failure. The character of the sags depends upon the type of mine failure as well as the overburden response.

Preliminary results show that the statistical no-risk tributary pressure decreases over 300% as the mine age increases from about 2 to 100 years at a long-term value of approximately 300 psi (2070 kPa). As more information is collected and more analysis is done, the allowable tributary pressure can be determined for different site conditions.

A plot is also reported that depicts the relationship of the maximum subsidence to site conditions. It was found that the modified subsidence factor was heavily dependent upon the overburden rock thickness.

Keywords: Room and pillar mines; coal mining; abandoned mines; pillar strength.

Introduction

The Bureau of Mines and the State of Illinois are engaged in an ongoing cooperative effort to develop guidelines for underground coal mining methods to maximize coal recovery while minimizing the effects of subsidence on the surface. For room and pillar mining, in which no subsidence is anticipated, design guidelines are needed to minimize the amount of coal left behind for support while being adequate enough to prevent future subsidence. To develop adequate guidelines the structural contributions necessary from the roof, pillar, and floor must be determined for long-term performance of abandoned workings. Consideration of long-term stability is also important when it is necessary to estimate the stability of abandoned mines over which surface structures are proposed.

The objective of this paper is to present case data on mine failures in the Illinois Basin for use in practice. The paper presents in some detail the site characteristics where the sags have developed on the surface. The site data has been presented to show the geologic, mining, and sag conditions that existed.

The only practical avenues for which long-term stability design criteria can be developed are through:

(1) Empirical approaches – assessing the performance of existing room-and-pillar mines, or

(2) Analytical approaches – using mathematical or computer formulations which assertion of material and rock mass properties may be determined from lab and/or fields tests.

This paper deals with (1) above, but the necessity of case data can even be seen in (2), since verification or the predictability of (2) would require representative case data. Therefore, it would stand to reason to first identify the behaviour of case histories before pursuing a suitable model.

Case history data

The case history data used in this paper was acquired mainly from files of the Illinois State Geological Survey (ISGS), and some from the University of Illinois. The primary sources of the data were from field records and subsidence reports (Young, 1916; Herbert and Rutledge, 1927; Quade, 1934; Hunt, 1980; and Marino and Mahar, 1985).

The cases presented in this paper mainly exist in southern Illinois and some, in fact, exist in the same mine. About 75 cases were collected for this study, but the quality and extent of the data available varied. Complete data sets were considered to exist when they included:

(1) A representative geologic column,
(2) A mine map with the subsidence event superimposed,
(3) The number of years from coal extraction to surface subsidence,
(4) Maximum surface subsidence and,
(5) A subsidence of a sag variety (Bauer and Hunt, 1982).

Many cases did not contain information in one or two of these areas. However, because of the quantity of cases, a sufficient number of data points could be plotted even when the information was lacking in many other cases. Except for a few sites where exploratory work had been carried out to investigate the subsurface below the subsidence, little specific data was available on the mine floor conditions. Some data on floor conditions were obtained from nearby borehole logs and mine notes.

General characteristics of the case data can be discerned from the data shown in Fig. 1. From Fig. 1a it can be seen that the depth to the coal seam was well distributed from 100 to 400 ft (30.5 to 122 m). The overburden above the coal seams have soil thicknesses of 15 to 165 ft (4.6 to 50.3 m) with 50% between 15 to 50 ft (4.6 to 15.2 m) and 30% between 50 to 100 ft (15.2 to 122 m). Bedrock thicknesses in the overburdens range from 50 to 500 ft (15.2 to 152 m) with most in the range of 200 to 300 ft (61 to 91.5 m). For the case data the bedrock mainly consists, in volume, of shale and fine sandstone. In Illinois, however, there is little difference in the mechanical properties of the hard shale and the fine sandstone. Limestone probably makes up the third largest constituent in the overburden but when persistent and of sufficient thickness it can result in significant roof capacity.

Approximately 90% of the cases studied involve mines in the Herrin (No. 6) coal while the remaining 10% are in the Springfield (No. 5) seam. The seam thickness or mined height was

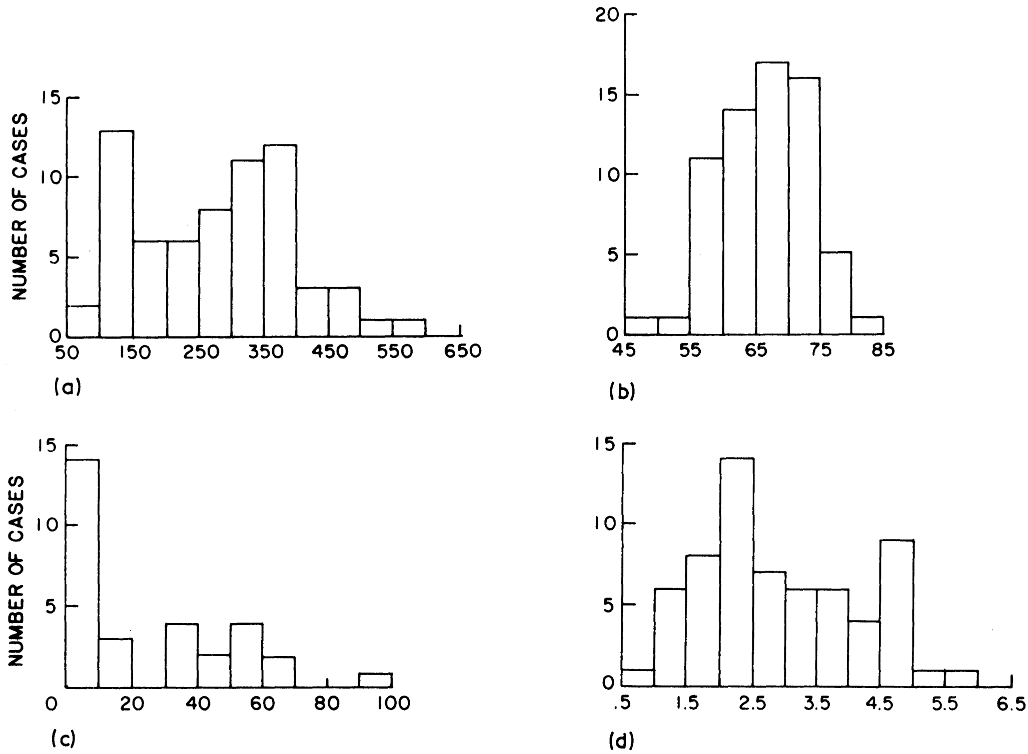

Fig. 1. Distributions of different site conditions for the case data: (a) mine depth in feet (1 ft = 0.3048 m), (b) percent extraction, (c) years to failure and (d) pillar width to height ratio

from 6.0 to 10.0 ft (1.8 to 3.0 m) and 5.0 to 6.5 ft (1.5 to 2.0 m) in the No. 6 and No. 5 coal seams, respectively.

Based on geologic logs and mine notes, it appears that in all cases the coal is underlain by underclay. Odom and Parham (1968) indicated that the Pennsylvanian age underclay units are the most persistent in the cyclothems in Illinois. Observations made at or near the sites show the underclay thickness to range from 0.5 to 14 ft (0.2 to 4.3 m) with about two-thirds of the thicknesses reported between 1 and 6 ft (0.3 to 1.8 m). The underclay is reported to be hard to soft with slickensides in most cases, and the mines frequently experienced heaving and/or squeezing. Squeezing was sometimes prevalent upon wetting the floor. The type of sedimentary rock beneath the underclay was variable, mainly consisting of a zone of nodular to continuous limestone up to several feet thick. Other materials found directly below the underclay are shales and sandstones. The shales were found to range up to 9.5 ft (2.9 m) thick. Sandstone was only found below the No. 5 coal in some cases.

Mine maps were available for over 90% of the cases. In the other cases the mining characteristics were determined from reports on the general layout of the rooms and pillars. The extraction ratios for the cases were fairly well distributed between 55 and 75% (Fig. 1b). The extraction ratio was typically determined directly from the mine plan beneath the sag. Also shown in Fig. 1 are the pillar width to height ratios in the failed abandoned workings, which range mainly from 1 to 5. In plan, the pillars are mainly rectangular shaped. Many of the cases collected involve old mines which operated in the first half of this century and which subsequently failed within 10 to 20 years after the time of extraction. Consequently, the mining pattern of many of the mines is the modified room-and-pillar type, with lesser quantities of irregular basic and checkerboard room-and-pillar layouts (Hunt, 1980).

The approximate time span to mine failure was determined from information available on the date of coal extraction and when the surface subsidence occurred. This calculation was possible in a number of cases and the distribution of years to failure, is shown in Fig. 1c. In estimating the years to failure, it is assumed that the time of progression of the subsidence through the overburden can be neglected.

For this study, only data on the maximum subsidence was used. In some cases this subsidence value was simply given in a report and in others it was actually determined from survey data. The maximum subsidence values given are approximate. Because the reported sags were unplanned, exact measurements were nearly impossible.

Modes of failure

Modes of failure and the associated subsidence in abandoned room and pillar mines in Illinois have been previously discussed in detail (Bauer and Hunt, 1982; Hunt, 1980; Marino and Mahar, 1985; Marino and Cording, 1985; Marino, 1986). Some of this information will be summarized herein.

There are three principal modes of failure which can lead to subsidence:

(1) Roof failure exclusively in rooms,
(2) Pillar crushing, and
(3) Pillar punching.

These types of failures may occur at any time.

Long-term roof failures in rooms occur with deterioration of the overburden rock. Surface subsidence only results from roof failure in the rooms in shallow mines less than 165 ft (50.3 m) deep, where there is insufficient bulking of caved materials (Hunt, 1980). The subsidence from roof failure is mainly manifested as steep sided pits and occasionally small sags. Thus, this failure mode probably represents a small portion of the cases because only sag subsidence data was collected. In Fig. 1 the distribution of overburden thickness (mine depth) for the sags included in this study are given.

Pillar crushing is the failure of the pillar as defined by the yield point due to increased stress. Where the roof and floor are firm, load bearing capacity of the coal pillar can be estimated by conventional pillar strength equations. However, a soft roof or floor may deform when loaded and subject the top and/or bottom of the pillar to lateral extension. This reduces the confinement stress in the pillar and consequently its load carrying capacity. This effect was measured and described by Greenwald *et al.* (1939), when a foot of underclay was present under test pillars vertically loaded to failure. Even harder floor, which behaves 'elastically' in the short term, can creep with time resulting in weakening of the pillar and possible crushing.

Subsidence from pillar crushing, when overburden bulking does not play a major role, are generally more abrupt than formation of sags resulting from pillar punching or floor failure (Marino and Cording, 1985). That is, most of the movement occurs in a shorter period of time and the sag flanks have more severe distortional characteristics.

Little data are available to verify the suitability of design methodology for failures resulting from pillar punching. The problem exists in performing long-term tests on the floor strata and other strata immediately beneath the coal. Pillars can lose floor bearing at any instant from the time of extraction to some later time when the floor yields from creep as well as when the failure is initiated or enhanced by changes of conditions in the mine, such as the addition of water and increased stress and disturbance from an adjacent mine collapse. Pillar punching (or floor squeeze) has been observed to occur almost a century later.

The sag subsidence from floor failure is generally time-dependent, taking years to subside at a slow rate, and usually contains a more gentle profile with less subsidence than from pillar crushing. The smaller vertical movements produce more gradual bending of the overburden rocks. The maximum subsidence observed at the surface is limited by the thickness of the soft material beneath the pillars in addition to the void space in the mine (minus the volume expansion in the overburden).

The major factors which affect the long-term stability of the pillar–floor system are:

(1) The initial pillar–floor safety factors,
(2) The presence of structural discontinuities in the coal measure strata,
(3) The creep properties of the floor materials and to a much lesser degree, those of the coal pillar,
(4) Water infiltration and floor softening,
(5) Various disturbances from adjacent mine collapses (Marino *et al.*, 1982).

In addition, the time at which mine failure by pillar crushing or pillar punching reaches the ground surface can also be impeded by intermittent bridging in the overburden.

Failure conditions

The first reported attempt to relate room-and-pillar mine collapse data to pillar stability was done by Salamon and Munro (1967). (This was the first of several papers that followed by Salamon, but the theory and data remained the same.) They used 27 cases where mine collapse occurred, a few to 32 years after extraction, and 98 cases of 'current' mine areas which have been stable for at least $1\frac{1}{2}$ years. It was assumed that all these 'current' cases would remain stable. For pillar failure Salamon and Munro considered the following fundamental equation to determine the safety factor, F.

$$F = \frac{KH^{\alpha}W^{\beta}}{P}$$

where K = strength of one cubic foot of coal, psi
α, β = appropriately chosen constants from case data
H = pillar height, in.
W = pillar width, in.
P = tributary pressure, psi

P, in psi, has been defined as:

$$P = \frac{d}{1-e}$$

where d = mine depth in ft (assuming $P = 1$ psi for $d = 1$ ft)
e = extraction ratio

This basic equation was taken from the equation developed by Greenwald *et al.* (1939), who conducted coal pillar tests. The final equation resulting from Salamon's and Munro's work contained values of $\alpha = -0.66$ and $\beta = 0.46$.

Bieniawski (1983) performed a case history investigation by studying 171 case histories featuring stable pillars from the United States and 20 case histories involving failed pillars in other countries. For each case Bieniawski determined the factor of safety. The factor of safety was determined by using a different pillar strength formula from Salamon and Munro and dividing the estimated strength by the tributary pressure. The pillar strength, σ_p, was estimated by Bieniawski (1969):

$$\sigma_p = \sigma_1(0.64 + 0.36W/H)$$

where σ_1 = the ultimate cubic coal strength, psi

From calculation of F for all the case histories, Bieniawski (1983) determined that F between 1.5 and 2.0 was appropriate for the US when using this pillar strength equation. The results of his analyses are illustrated in Fig. 2.

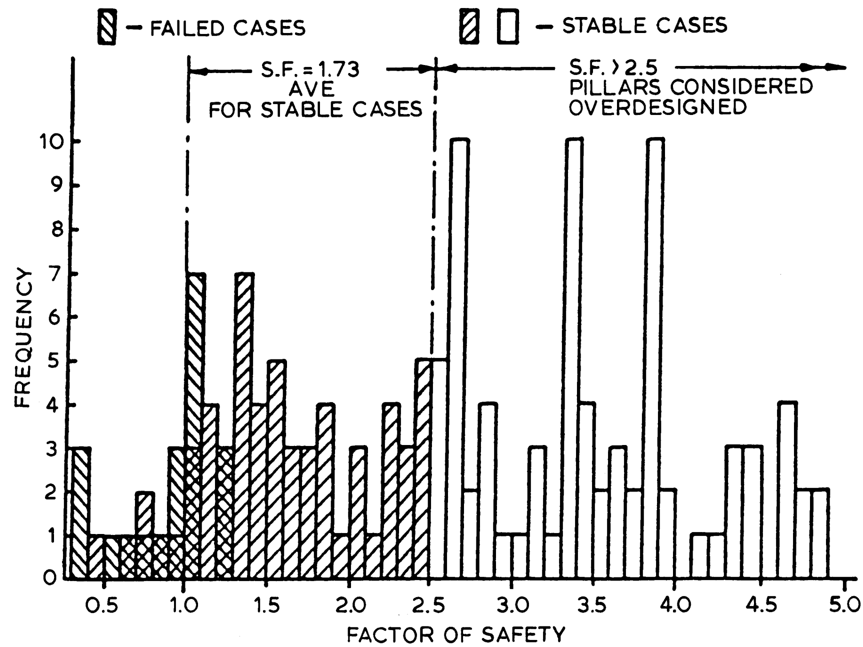

Fig 2. Histograms of safety factors for pillar strength formula summarized by Bieniawski (1969, 1983)

In the above two investigations neither considered any factor for time, i.e. all stable cases were assumed to remain stable and the years to failure of the failed cases were not included in the analysis. Or in other words, F does not significantly decrease with time (which is apparently a workable assumption if the majority of failures occur in the short term). Also, the above investigations only considered mine collapse from pillar failure (excluding definite roof fall cases). Mine stability depends upon the capacity of all the support elements and the applied overburden pressures.

In Illinois there is a definite decrease of the safety factor with time simply because a significant number of mines have collapsed decades after coal extraction. For the case histories collected, the tributary pressures, *P*, have been plotted against the years to failure, *YTF*, in Fig. 3. The distribution of *YTF* for these points is shown in Fig. 1c. The points in Fig. 3 show some scatter with a general downward trend with time. The scatter is probably mainly attributed to differing site conditions. Using the lower bound curve (the statistical no-risk curve, shown in Fig. 3) there is a decrease in the no-risk pressure from 1060 psi (7309 kPa) at 2 years to about 300 psi (2070 kPa) at 100 years. This converts to a drop in the 'no-risk' *P* of three-fold for that duration.

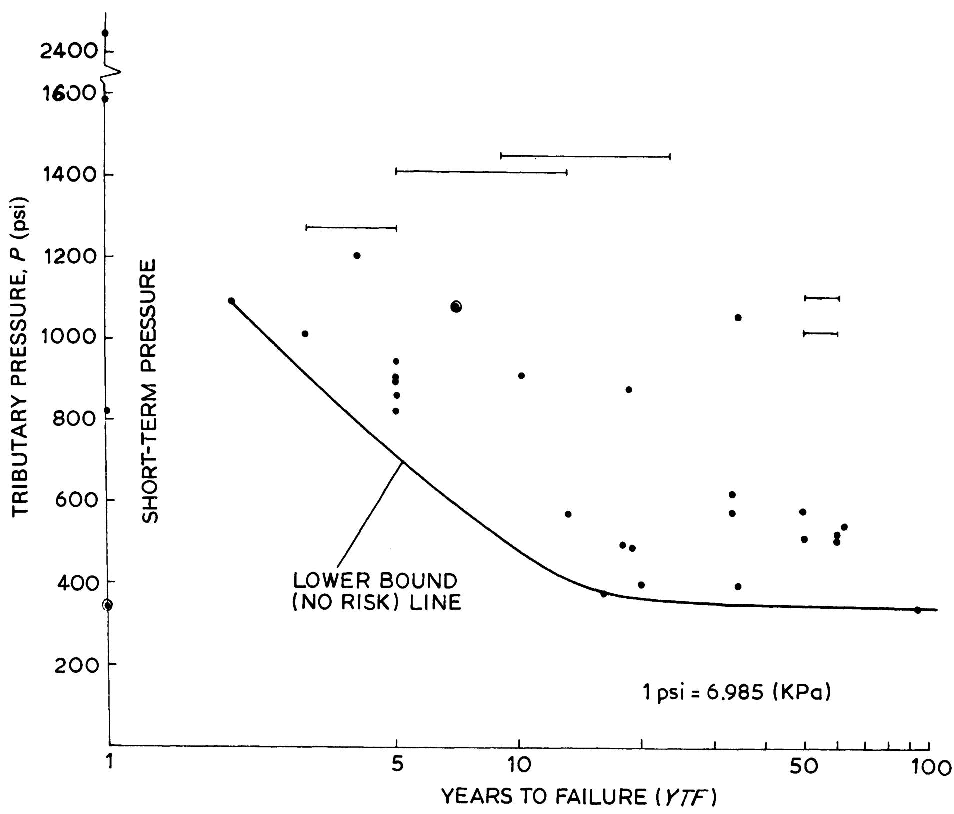

Fig. 3. Tributary pressure in pounds force per square inch (1 $lbf/in^2 = 0.1073\ MN/m^2$) against failure time for case data

The values at 1 year or less have been plotted at 1 year and are quite scattered. These scattered cases may not meet the average range of ground conditions for which that mine was designed or the pillars were severely robbed with the reported extraction ratios then being inaccurate.

Another interesting observation is that the overall pillar design of these mines does not appear to be significantly related to depth. Consequently, if sag subsidence occurs over a shallower mine, a floor squeeze is more likely since these mines generally have a higher pillar safety factor, thereby reducing the possibility of pillar failure.

Prediction of the subsidence potential and resulting surface damage are significant factors in room-and-pillar mine design. Estimating the maximum subsidence in conjunction with sag diameter is the most important prediction since they most directly relate to characteristics and the attendant damage. In Fig. 4, the modified subsidence factor, SF', is

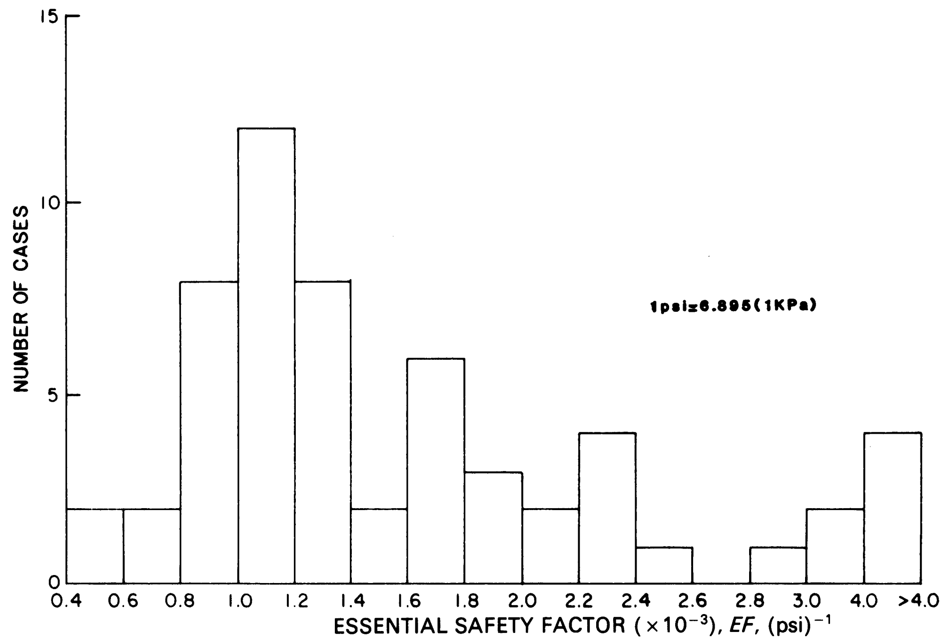

Fig. 4. Distribution of the essential safety factors for the case data

plotted against the 'essential safety factor', EF, for the case data. The definition of the modified subsidence factor is:

$$SF' = \frac{S_{max}}{He}$$

where S_{max} = the maximum sag subsidence
H = mining height
e = extraction ratio

Therefore, SF' is the conventional subsidence factor divided by the extraction ratio. The extraction ratio compensates for the volume of coal left in the abandoned workings. The essential safety factor, EF, is defined as:

$$EF = \frac{W^{0.5}}{H^{0.7}} \frac{(1-e)}{d}$$

where W = pillar width, in.
H = mining height, in.
e = extraction ratio
d = depth, ft
$\frac{W^{0.5}}{H^{0.7}}$ = an approximation of the function for pillar strength given by Greenwald *et al.* (1939), and Salamon and Munro (1967).

The purpose of computing the magnitude of *EF* is that it gives the relative susceptibility to pillar crushing. The distribution of *EF* for the case histories is shown in Fig. 5. The *EF* distribution of pillar stability shows much variation, indicating that other modes of failure must be considered in long-term stability analysis. This can especially be seen when comparing the distributions on Figs 2 and 4. As noted previously, pillar crushing can result in severe sags on the surface (when the volume expansion of the subsided rock overburden can be neglected). After this type of collapse, only limited void space is left between the roof and floor. As *EF* increases, however, the chances of pillar failure becomes respectively less. Therefore, the sag cases at relatively high *EF* values are probably from squeezes. This is not to say that floor failure or pillar failure induced by floor movement did not occur at lower *EF* values. Additionally, sag subsidence from roof failures may occur at any values but are more likely at low *EF* values where the overburden pressures are light.

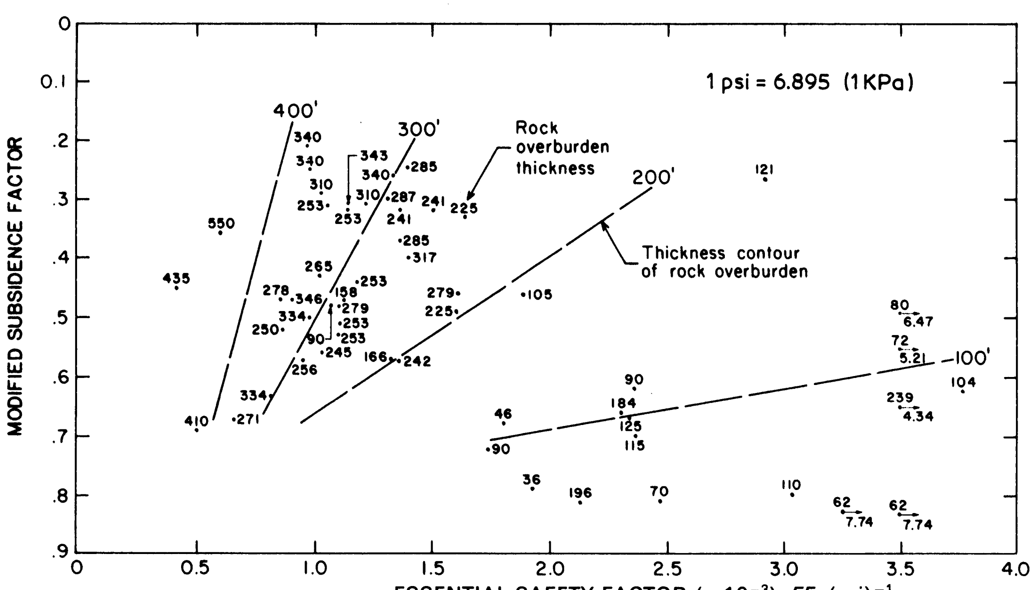

Fig. 5. Correlation of maximum subsidence with site characteristics for the case data

The increasing effect that the overburden thickness, R_x, has on SF' can be seen in Fig. 5 by the steepened trend of data with greater overburden thickness. Generally with the thicker rock overburden, the magnitude of SF' then becomes more increasingly a function of the character of the overburden. Towards the other end of the correlation on Fig. 5, for

EF values greater than 1.75×10^{-3} and for R_x less than 200 ft (61 m), there is more scatter and the *SF*′ values are generally higher than the rest of the data.

The significant dependence of *SF*′ on R_x is shown in Fig. 6 where the average modified subsidence factor, *SF*′, is depicted for different R_x intervals. It is very interesting that the *SF*′ value is about 1.8 times greater at $R_x = 35$ to 100 ft (10.7–30.5 m) than at 300–400 ft (91.5–122 m) range. These average *SF*′ values in Fig. 6 are conservative since the cases collected are the more obvious subsidences which could be observed on the surface. Thus, some of the more gentler subsidence cases may not be fully represented (particularly at the higher R_x ranges where the mine collapse is minimized at the ground surface).

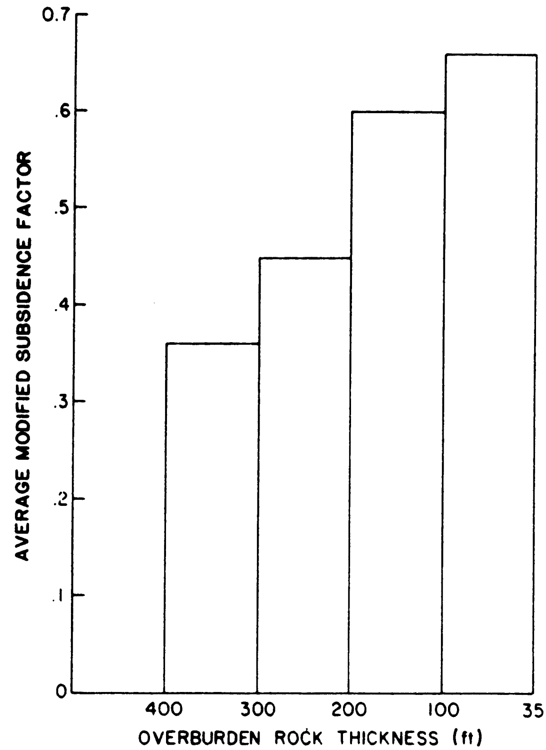

Fig. 6. The average modified subsidence factor for various ranges in overburden rock thickness for the case data. (Note 1 ft = 0.3048 m)

Summary and conclusions

The objective of this paper was to present results of the analysis of subsidence case history data on collapsed and abandoned mines in Illinois. Although the studying is incomplete some trends have been found and are given.

A general downward trend exists in the tributary pressure with the years to failure with some scatter. Using the lower bound no-risk line in Fig. 3, a reduction in the no-risk tributary pressure of more than 300% can be seen when the years to failure increases from 2 to 100. Mining and geologic characteristics corresponding to this time to failure trend have been preliminarily investigated but no salient correlation has been identified. As more data is collected and more analysis is done, the allowable tributary pressure can be determined for different site conditions.

There is a relationship between the maximum subsidence, S_{max}, and the site characteristics for the case histories. S_{max} is shown in the form of the subsidence factor divided by the extraction ratio, SF'. Although there is scatter in the data, it provides some general ranges for S_{max}. It can be seen that SF' is heavily dependent upon the overburden rock thickness, R_x. For example, the average SF' for cases of similar rock thicknesses incrementally increases from 0.36 for cases in the 300 to 400 ft (91.5 to 122 m) range to 0.66 for cases in the 35 to 100 ft (10.7 to 30.5 m) range.

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UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Subsidence Potential in Shale and Crystalline Rocks

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Subsidence Potential in Shale and Crystalline Rocks

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Abstract

This report presents a statistical summary of worldwide subsidence experience in shale and crystalline rocks, and includes an expanded bibliography of the most significant references on mining-induced subsidence in these rocks. No measurements have been reported in the literature of subsidence in "massive" shale and crystalline rocks (potential host rocks for radioactive-waste (radwaste) repositories). Predictions of the subsidence response of massive rock based on information gained from less uniform rocks will be subject to unknown but possibly large error.

Subsidence is controlled by a complex combination of mining and geologic factors. For example, as the percentage of shale in the rock mass decreases and the amount of sandstone increases, the angle of draw (and the area of potential surface subsidence) decreases. When limestone is present in the overlying rock the angle of draw can be three times less than for an equivalent amount of sandstone. In fractured crystalline rocks the angle of draw and the resulting surface deformation appear to be controlled not only by properties of the rock substance, as in shale, but also by preexisting joints. Faulting can limit or enlarge the draw angle in any rock formation. The data show that gross errors may occur when applying a subsidence model developed at one mine in one geologic environment to a mine at another location.

Control of subsidence with backfilling has been highly successful. In one case the subsidence predicted without backfill was nearly 20 times greater than that actually measured with backfill.

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Introduction

Modern industrial society produces increasingly larger amounts of highly toxic, long-lived chemical and radioactive-waste products. The attractiveness of proposals to place these hazardous materials in deep, geologically stable, storage sites depends on the stability of both the near- and far-field geologic environment. It is unreasonable to assume that any series of rooms and pillars will remain stable for many thousands of years. It is essential, therefore, to be able to predict and prepare for the deformation and failure of those pillars and for the resulting subsidence of the surface. The possibility that delayed subsidence will breach such a containment facility and allow surface water to enter can only be evaluated by considering the much shorter historical record of mining-induced subsidence.

No rock type has all of the desirable attributes for waste containment. However, crystalline rocks and thick shale sequences have been suggested as prime storage sites. Shale, a relatively weak rock, would inhibit the migration of hazardous wastes because of its tendency to deform plastically rather than by fracture. Pillars excavated in shale will, however, remain stable for a shorter time than pillars excavated in much stronger crystalline rocks (mainly granite and gneiss). Joints in rock masses provide a potential avenue for ground-water movement. In deep mines the water that enters through such joint systems in crystalline rocks must be pumped out. It is common practice to excavate shallow (100-150 m) storage caverns for liquified petroleum gas (LPG--butane and propane) in shales because of their ability to contain LPG under moderate pressures, <0.7 MPa (<100 lbf/in^2).

It is desirable to place storage facilities for critical materials in massive formations because predicting long-term rock mass response, while not simple, should be easier in massive formations than in more complex geologic environments. Alternating beds of different flat-lying or folded sedimentary rocks or folded, fractured, and injected metamorphic rock masses represent complex geologic environments which generally should be avoided.

The purpose of this report is to summarize and interpret the most relevant published subsidence information and to suggest the degree to which this information may be applied to predictions of subsidence in massive shale and crystalline rocks.

Mining background information

It is not possible to find mines operating in massive shale and crystalline rocks because there is no economic incentive, that is, no coal or other economic product to extract. Measurements of surface response to mining below shale and crystalline rocks are, therefore, virtually absent from the technical literature.

There are numerous statements concerning the importance of geology in the development of damaging subsidence effects. For example, Sopworth (1898, p. 165) suggested the following classification for beds overlying British coal deposits:

1. "Measures consisting of fairly equal proportions of rocky and argillaceous beds, and containing thick beds of sandstone." (Rocky probably means sand-size and coarser sediments.)

2. "Measures including a small proportion of rocky beds, say 15 percent, and only thin beds of sandstone." (Eighty-five percent argillaceous, 15 percent sandstone.)

3. "Variations between these two."

In the first case, according to Sopworth (1898, p. 165-166), the edge of the subsidence trough will follow or lie over the excavation and in the second case it will lie over the solid coal. (See fig. 1 for nomenclature.) In the third case it will vary between (1) and (2). The same year, Cooper (1898, p. 134) called attention to the absence of an angle of draw where the overlying beds include strong thick layers of limestone. As recently as 1976, Dunrud (1976, p. 1) stated, "Knowledge of geologic, topographic and socioeconomic conditions in prospective mining areas is vital to planning safe and efficient mining activities * * * ."

While no subsidence information exists for massive shale or massive crystalline rocks considerable data are available in the technical literature for layered sedimentary rocks overlying coal mines and for geologically complex crystalline rock masses above metal mines. The typical sedimentary sequence in coal deposits involves a cyclic deposition of different rock types (cyclothem) in which only one of the rock types is shale, although shale is the most abundant rock type at many locations. The typical geologic environment of a metalliferous ore deposit in crystalline rock, if indeed there is a typical deposit, includes folded and fractured rock masses. Faults, or dikes of different igneous rocks, frequently disrupt the continuity of the enclosing crystalline rock masses. In addition, the mining of thick (mining height greater than one-tenth the depth), irregular-shaped metalliferous orebodies frequently results in a prominent, steep-walled collapse depression at the surface. Such a collapse depression, which can be as much as tens to hundreds of feet in depth, is easy to measure and the measurement does not have to be very precise. The failure of pillars in a horizontal waste storage facility would not produce a steep-walled collapse depression or pit, but only a broad shallow downwarp of the ground surface, that is, trough subsidence, because there is no reason to use mining heights of one-tenth the depth, or greater. With one notable exception, no effort has been made to measure the more subtle, local, downward deflection of the surface, that is, trough subsidence, adjacent to a prominent collapse depression (Thomas, 1971).

Massive shale overburden represents, in effect, one extreme of rock type in the case of sedimentary lithology. Coal-mining subsidence-monitoring results involve different sequences of varying lithologies. Shale is typically a major proportion of the overlying sequence of strata. Bell (1975, p. 28) stated, "Argillaceous rocks account for about three-quarters of the thickness of a sequence of coal-bearing strata" in England. Kapp (1973, p. 7-8) on the other hand stated that, "There is approximately 70 percent of sandstones in the strata over the Kemira longwall panels" near Wollongong in Australia.

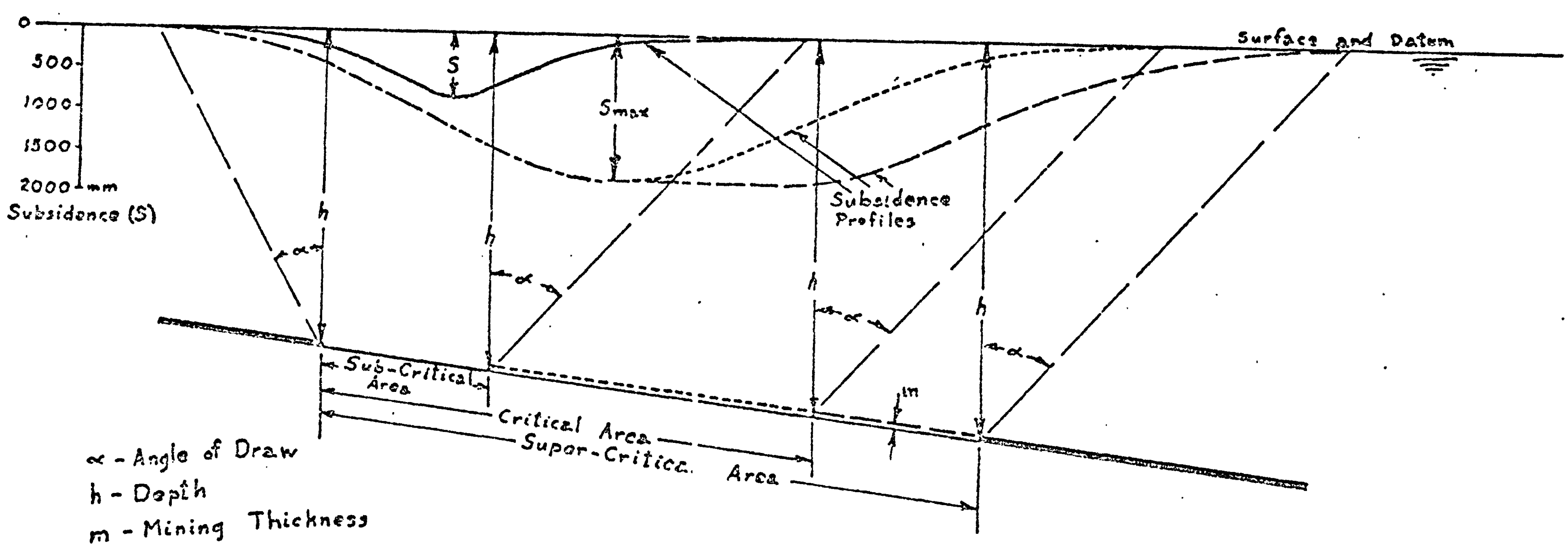

Figure 1.--Trough subsidence description. (Modified from National Coal Board, 1975.)

The limited number of subsidence-monitoring programs reported in the literature which also determined and reported the overlying lithology is indicated in table 1. It should not be assumed that lithology alone controls subsidence, nor for that matter that lithology is the only geologic factor that influences subsidence. Individual bed thickness, relative strength of the rock substance, and bedding cross-joint frequency probably have an effect on the amount of subsidence measured.

In regard to the prediction of subsidence, the extent of detectable subsidence outside the area of active mining is of as much interest as is depth of subsidence. The reach of subsidence effects outside the area of mining, generally referred to as the "angle of draw," appears to be highly variable. The angle of draw, the angle formed by the vertical line above the outer limit of mining and the lateral limit of detectable subsidence, has a special importance to land-use planning, because it indicates where the surface will be unaffected by mining-induced subsidence. The large variation in tabulated angles of draw is shown in table 2. The potential for error in applying an angle of draw measured from one country to another, or even within one country and (or) district is obviously considerable.

Subsidence over thin, tabular-bedded deposits

A tabular-bedded deposit can be considered thin when caving produced by collapse of the mine roof does not propagate to the surface and form a pitlike collapse depression. Schulte (1957, p. 193) reported on sinking a shaft from an upper coal seam to a fully extracted and caved longwall panel below. Schulte was unable to detect any damage to the rock exposed in the shaft walls more than nine seam thicknesses above the lower seam. He also found that the rubble from the collapsed roof had a height between three and four seam thicknesses above the former roof of the lower seam. Piggott and Eynon (1977, p. 763-765) mathematically examined the potential height of collapsed rock above rooms in room-and-pillar workings (figs. 2, 3). They concluded that the collapse height for a conservative 30-percent swell (bulking factor) for the rubble from the collapsed roof rock would result in a collapse height of 3.3-10 times the thickness of the mined seam. The smaller collapse height should develop in the case of rectangular (uniform) roof collapse and the larger collapse height in the case of adverse conical roof collapse, which occasionally develops above room intersections.

The subsidence effects resulting from failure of the pillars in a waste storage facility either in shale or in crystalline rock should be similar to that which would occur upon the extraction of a thin, tabular-bedded deposit. The surface depression that results is referred to as a subsidence trough. The standard symbols employed by the NCB (National Coal Board, 1975, p. 3) are presented in figure 1. The primary factors affecting the development of the trough in flat-lying tabular deposits like the Carboniferous coal measures of Great Britain are mining height and minimum mining width. Depth is a secondary factor, increasing the angle of draw distance, the extent of surface influence, and possibly the maximum subsidence. The similarity of subsidence measurements at different mines in Great Britain is indicated by the subsidence profiles in figure 4 (King and Whetton, 1957, p. 27).

Table 1.--Lithologies, mining conditions, and measured subsidence (supercritical condition)

Location and commodity	Lithologic percentages in overburden: Shale	Sandstone	Limestone	Depth (m)	Mining height (m)	Extraction (percent)	Maximum subsidence (percent of mining height)	References
Pennsylvania, coal.	50	22	28	98	1.7	83	40.0	Greenwald and others (1937).
Do---------	59	11	30	130	2.1	85	51.5	Maize and Greenwald (1939).
Do---------	78	13	9	108	1.6	90	50.0	Maize, Thomas, and Greenwald (1940).
Do---------	59	11	30	162	2.1	85	48.2	Maize, Thomas, and Greenwald (1941).
Do---------	59	11	30	91	2.1	85	46.3	Do.
New Mexico, coal.	63	37	0	104	3.0	100	69.0	Abel and Gentry (1978).
Great Britian, coal.	68	32	0	539	1.4	100	58.4	Sinclair (1950).
Do---------	63	29	8	793	1.8	100	65.2	Do.
Do---------	64	36	0	41	.6	100	84.0	Briggs and Ferguson (1933).
New Mexico, uranium.	86	14	0	152	3.0	36	7.0	C. H. Parrish (written commun., 1979).
California, borate.	17	83	0	118	42.1	100	73.9	Obert and Long (1962)1/.
Pennsylvania, coal.	48	52	0	60	1.8	86	57.9	Montz and Norris (1930).
Illinois, coal.	71	17	12	130	1.1	100	61.2	Herbert and Rutledge (1927).
Do---------	57	38	5	152	2.4	69	34.8	Do.
Illinois, shale.	64	4	32	119	7.6	51	15.2	Abel (1973); Fenix and Scisson, Inc. (1972).
New Mexico, potash.	40	(50 percent Salt Fm.)	102/	305	3.8	95	58.8	Miller and Pierson (1958).

1/Possibly subcritical, but presence of flat-bottomed subsidence trough indicates supercritical area.

2/Dolomite.

Table 2.--Angles of draw (from vertical) for coal mining in the United States and Europe

Country or district	Brauner (1973, p. 9)	Wardell (1959, p. 530)	Newhall and Plein (1934, p. 65)
Netherlands	35°-45°	35°-45°	---------------
Ruhr	30°-45°	--------------	---------------
Lower Rhine	------------	29°-39°	---------------
France	35°	--------------	---------------
Great Britain	25°-35°	28°-40°	---------------
United States of America (Pennsylvania).	20°	--------------	20°-25°
Poland	------------	19°-34°	---------------

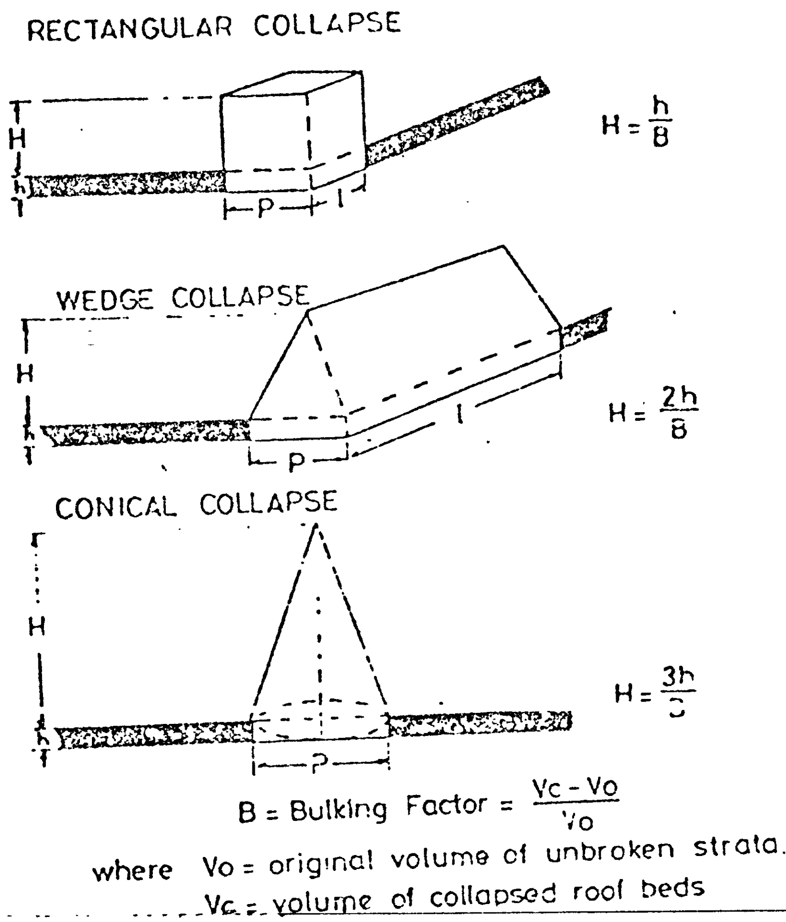

Figure 2.--Diagram showing notation for calculating maximum height of collapse (H) in relation to geometry of collapse. (Modified from Piggott and Eynon, 1977.)

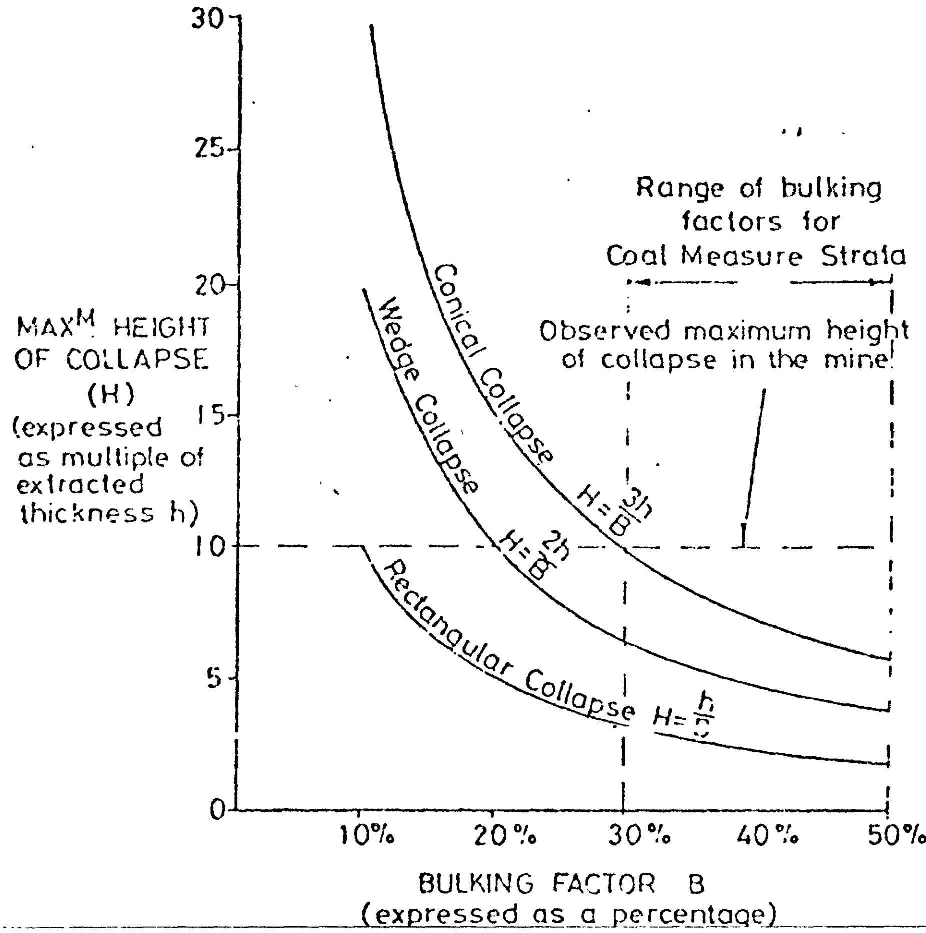

Figure 3.--Graph showing variation in maximum height of collapse for different modes of failure and bulking factors. (Modified from Piggott and Eynon, 1977.)

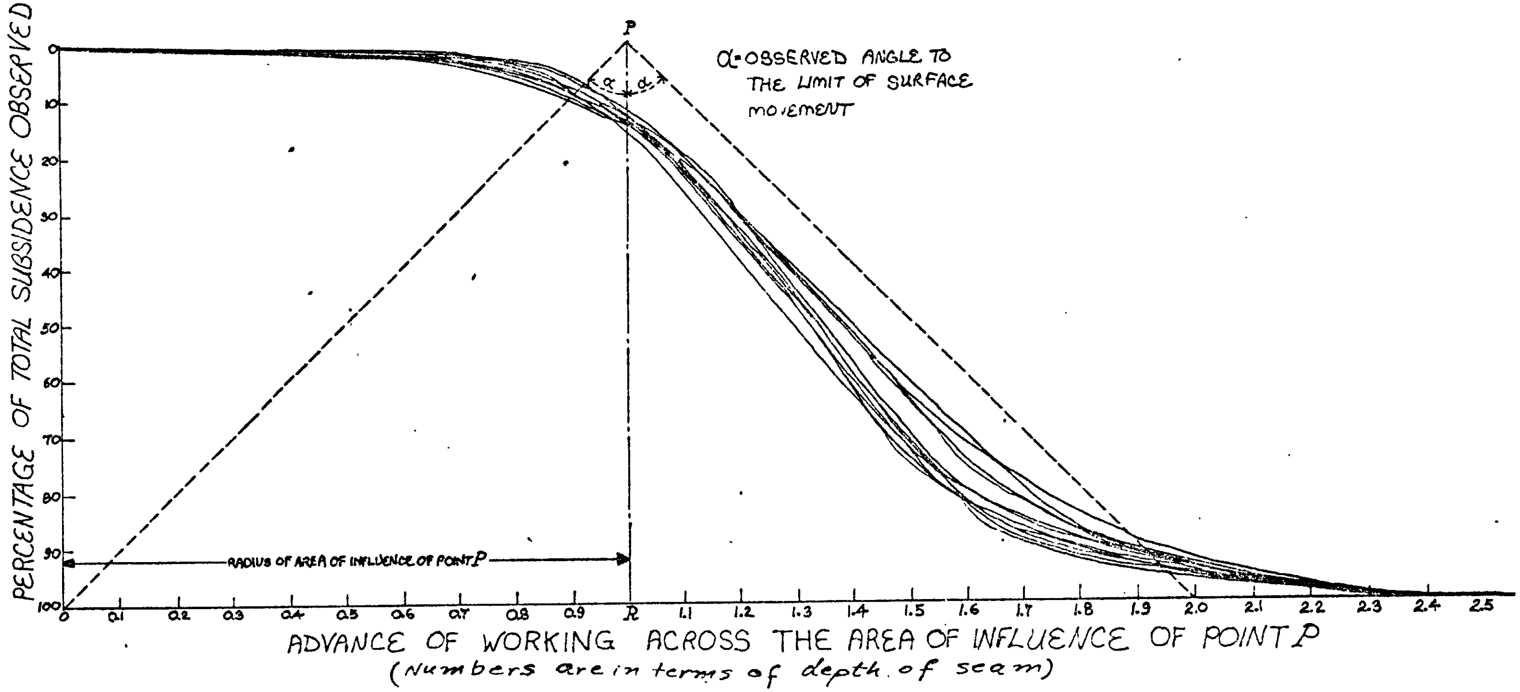

Figure 4.--A family of subsidence development curves from 11 British coal mines. (Modified from King and Whetton, 1957.)

The simplest mining geometry is produced by longwall extraction. In longwall coal mining the coal seam is completely extracted as a rectangular panel with a width of about 200 m and even a greater length. Leaving a portion of the coal seam as pillars, in the case of room-and-pillar mining, reduces the magnitude of subsidence, but does not change the general shape of the subsidence trough. The effect of pillars and (or) backfill on subsidence is discussed in a later section of this report.

Many investigators have assumed that the subsidence measured above one coal mine can be used to accurately predict subsidence that will result from mining at other locations. This is only grossly true (tables 1, 2). Obviously, geometric similarity among flat-lying tabular-bedded deposits is not the only control either on maximum subsidence or on angle of draw.

Data were collected from the literature to investigate the relationship between angle of draw and lithology, expressed in terms of the percentage of shale, sandstone, and limestone in the overlying strata. The data are presented in table 3. The proportions of the various lithologies, where not specifically reported, were calculated from drill hole logs. The percent of shale, sandstone, or limestone is by itself a relatively poor predictor of the angle of draw as shown in figures 5, 6, and 7. The statistical confidence that the angle of draw increases as the percent of shale in the overlying rock increases is only slightly better than 90 percent (fig. 5). Much lower confidence can be placed in the statement that the angle of draw decreases with increases either in sandstone (70 percent) or in limestone (65 percent) in the overlying rock (figs. 6, 7). However, a multiple linear regression evaluation of the sandstone and limestone percentages in the overlying strata indicates 98-percent confidence that the more complex relationship indicated in figure 8 is true. The indication is that limestone in the overlying rock causes as much as a threefold decrease in the angle of draw in comparison to an equivalent percentage of sandstone in the overburden. The student "t" statistical test for "goodness of fit" was used to determine these relationships.

More precise predictions of the complex interrelationship of geology and angle of draw require a more precise definition of the lithology, probably including bed thickness and jointing as well as rock type.

The dependence of maximum measured surface subsidence (S_{max}) on reported lithologies and mining conditions (table 1) is more complex than is the angle of draw relationship to lithologies alone. The assumed independent variables extracted from the literature were percent shale, percent sandstone, percent limestone, mining depth, mining height, and percent extraction.

The apparent dependence of maximum measured surface subsidence, as a percent of the mining height, on the lithologic percentages of shale, sandstone, and limestone is presented in figures 9-11. The calculated level of statistical confidence in an interrelationship, again using the student "t" test, between maximum subsidence and: (1) percent shale is 88 percent, (2) percent sandstone is 97 percent, and (3) percent limestone is 85 percent.

Table 3.--Angles of draw (from vertical) for mines in flat-bedded sedimentary rocks with respect to lithology of overburden

Location and commodity	Lithologic percentages in overburden			Angle of draw (degrees)	References
	Shale[1/]	Sandstone	Limestone		
Pennsylvania, coal.	50	22	28	18.0	Greenwald and others (1937).
Do	78	13	9	24.0	Maize, Thomas, and Greenwald (1940).
Do	59	11	30	9.0	Maize and Greenwald (1939).
Great Britain, coal.	12	88	0	0.0	English (1940).
New Mexico, coal.	63	37	0	15.0	Abel and Gentry (1978).
Great Britain, coal.	68	32	0	17.0	Sinclair (1950).
Do	63	29	8	12.0	Do.
Do	64	36	0	29.0	Briggs and Ferguson (1933).
New Mexico, uranium.	86	14	0	40.0	C. H. Parrish (written commun., 1979).
California, borate.	17	83	0	8.0 (avg.)	Obert and Long (1962).
Pennsylvania, coal.	48	52	0	18.0	Montz and Norris (1930).
India, coal	25	75	0	13.0	Kumar and Singh (1973).
Do	23	77	0	21.0	Do.
Do	57	43	0	28.0	Do.
Do	37	63	0	18.0	Do.
Do	35	65	0	17.0	Do.
Do	35	65	0	17.0	Do.
Do	23	77	0	17.0	Do.
Do	32	68	0	27.0	Do.
Illinois, coal	71	17	12	8.5	Herbert and Rutledge (1927).
Do	57	38	5	0.0	Do.
Arizona, copper	0	0	100	12.0	Trischka (1934)[2/].

1/Includes all argillaceous rocks.

2/Fault bounded on all four sides. Therefore, not employed in statistical analysis.

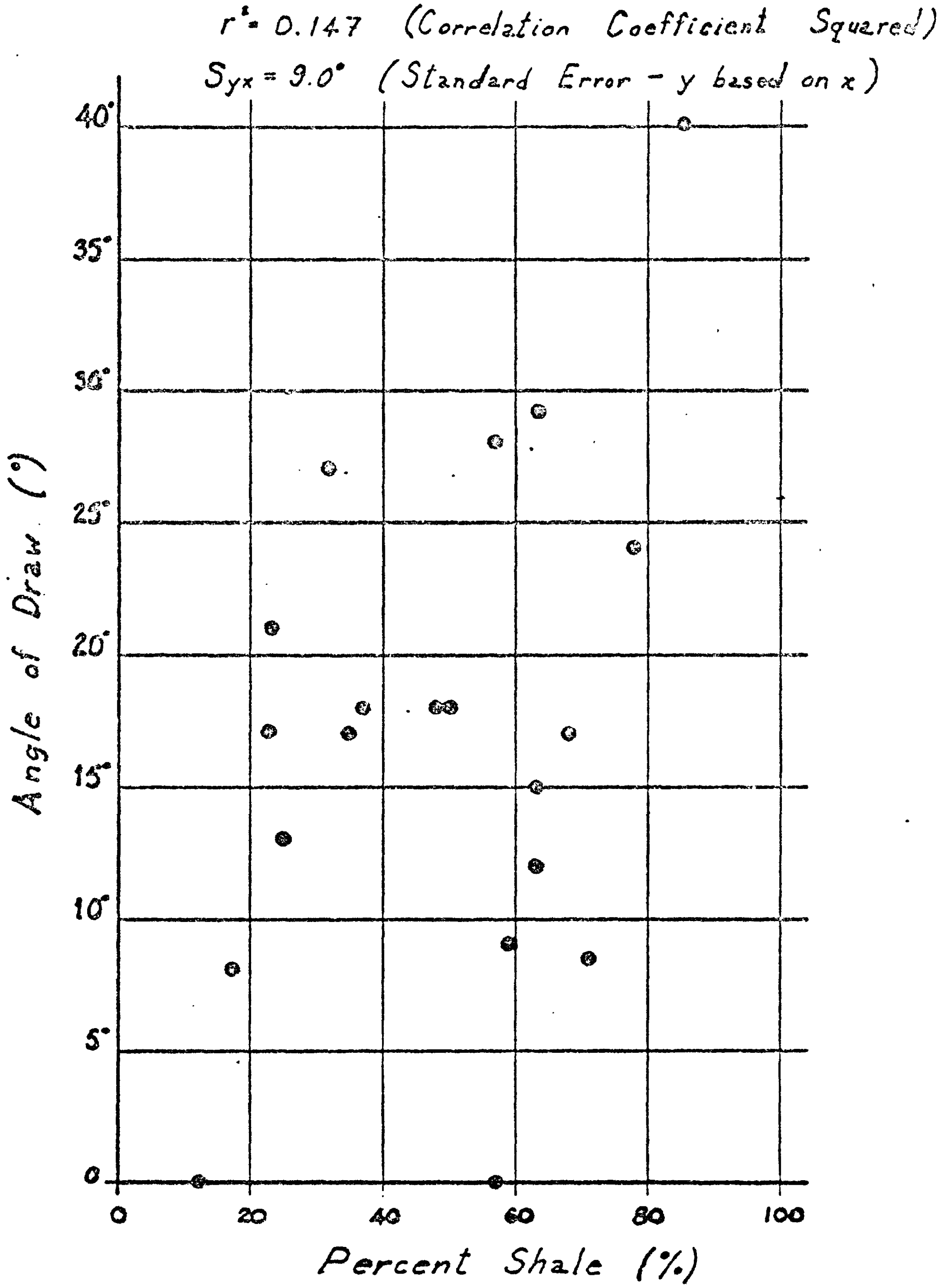

Figure 5. Reported angle of draw versus percent shale.

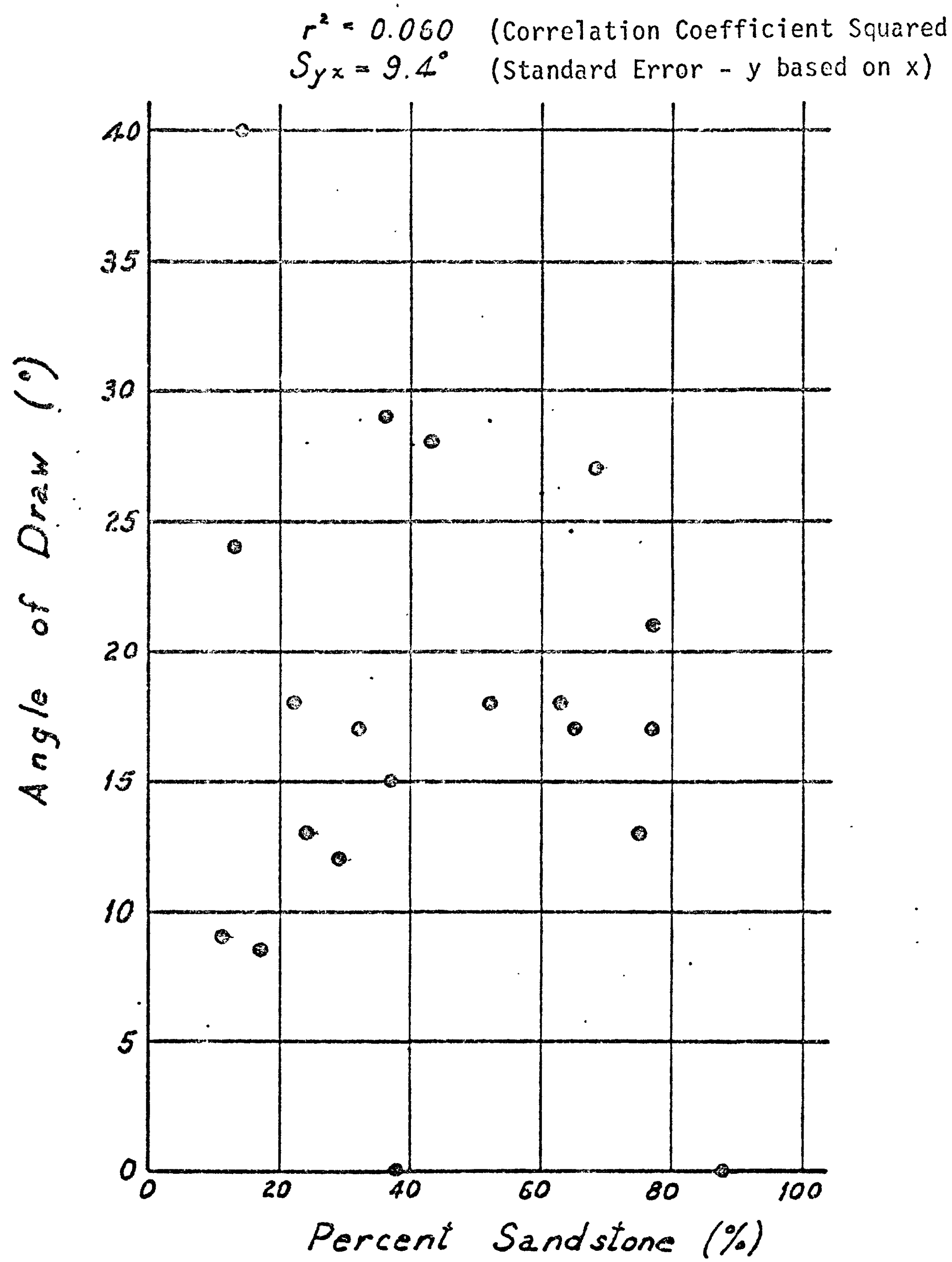

Figure 6. Reported angle of draw versus percent sandstone.

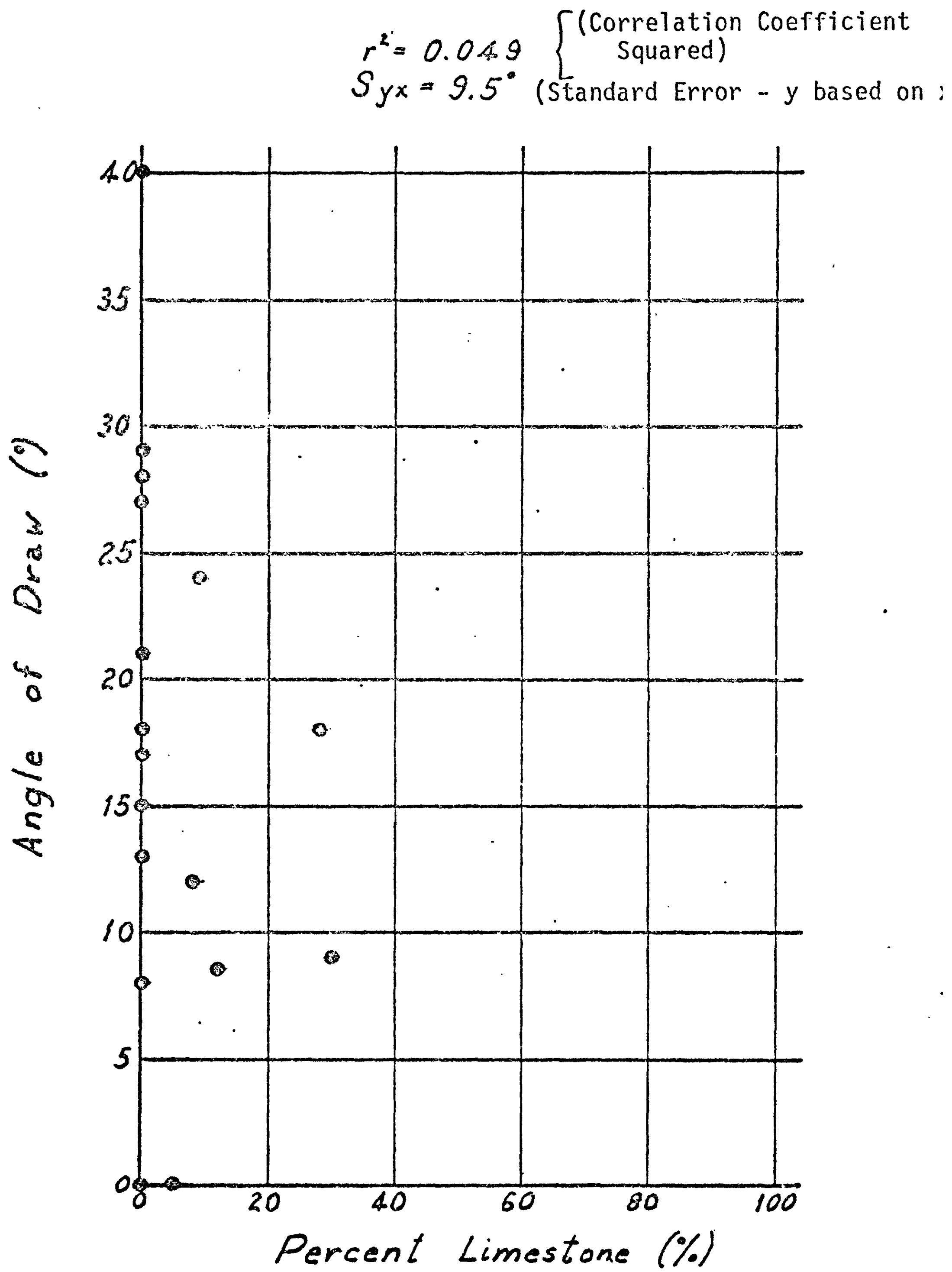

Figure 7. Reported angle of draw versus percent limestone.

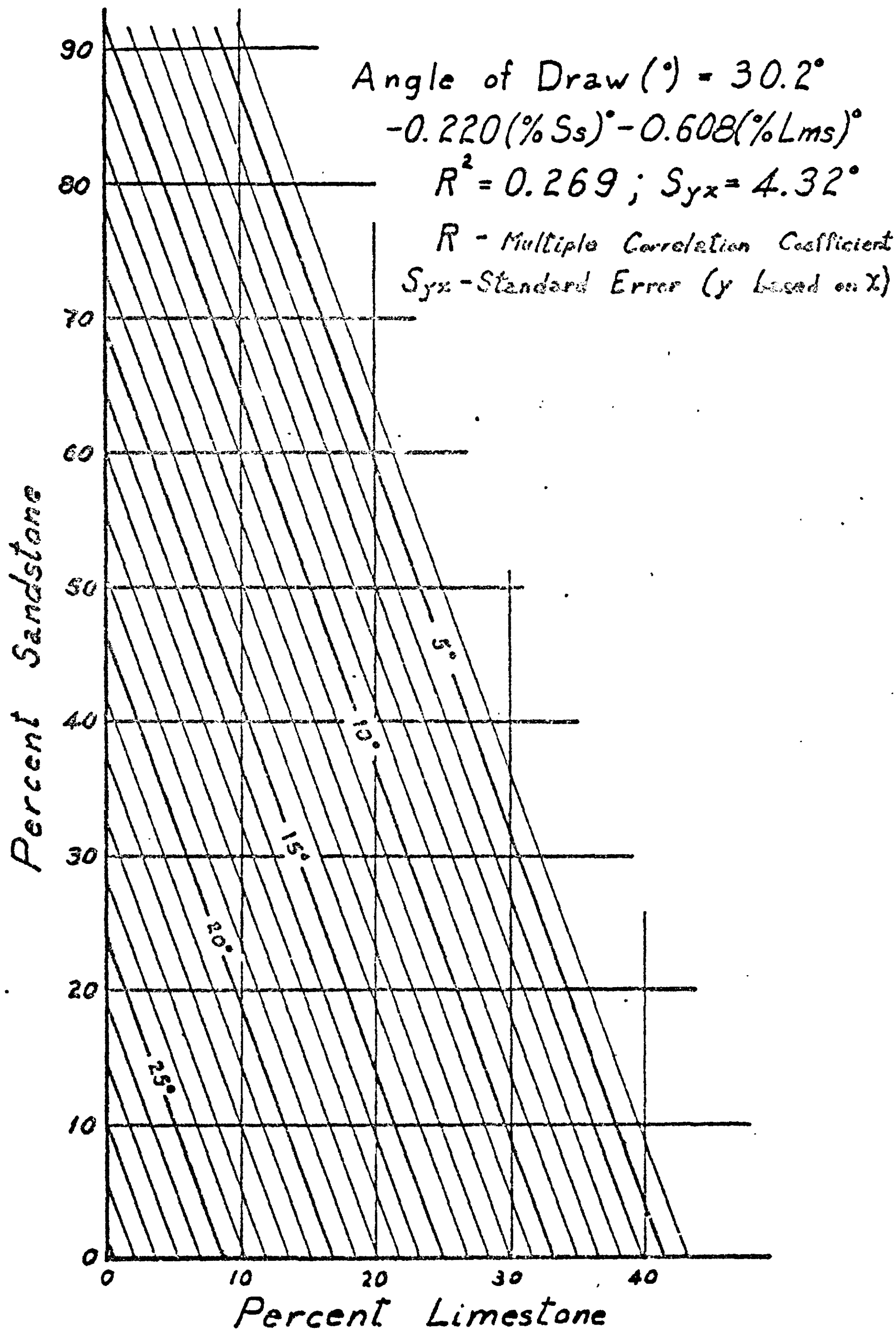

Figure 8. Reported angle of draw versus percent sandstone and limestone.

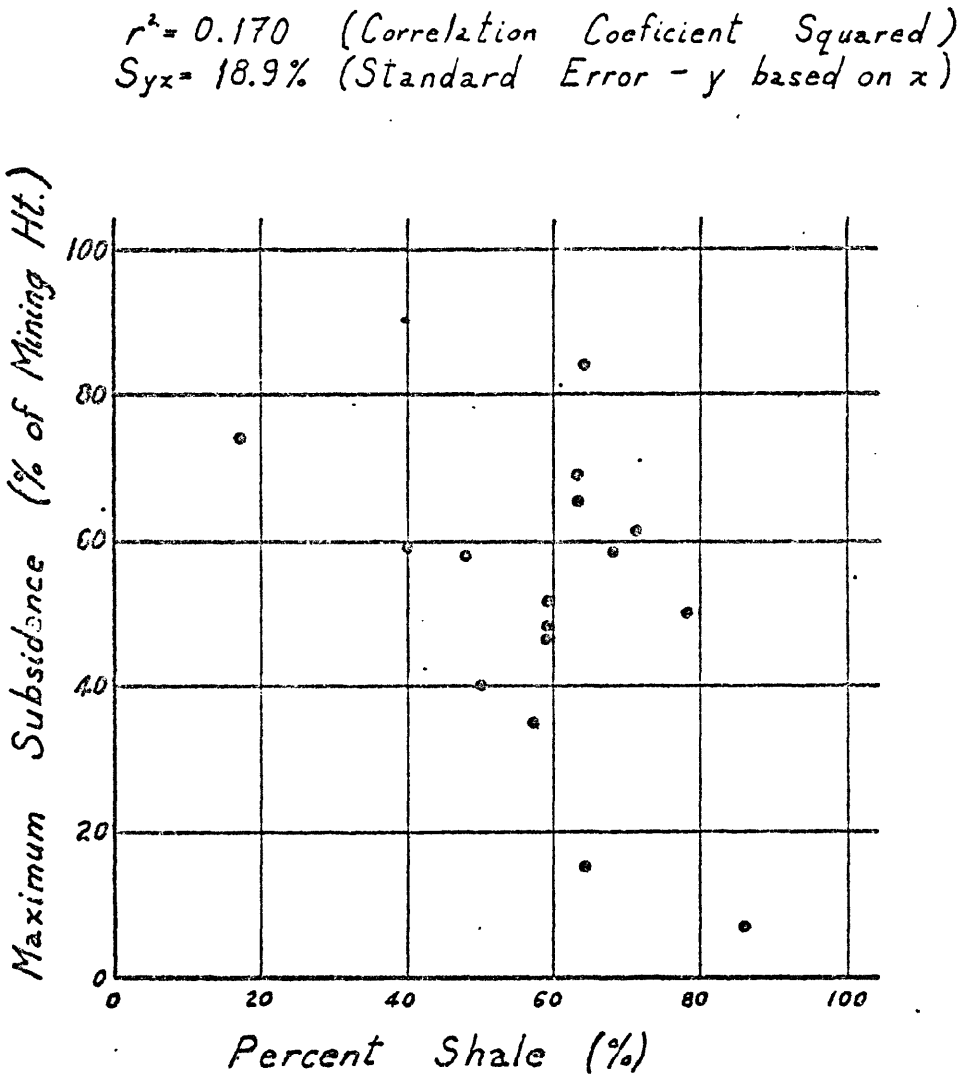

Figure 9. Reported maximum subsidence versus percent shale.

$r^2 = 0.312$ (Correlation Coefficient Squared

$S_{yx} = 17.2\%$ (Standard Error - y based on

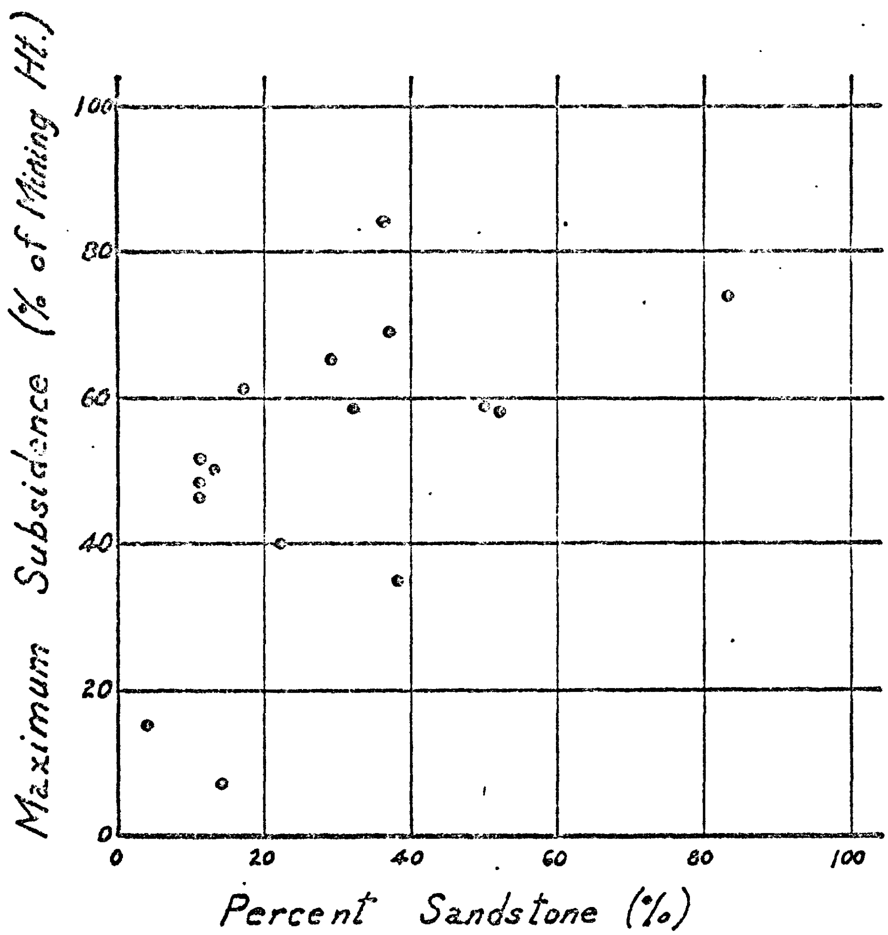

Figure 10. Reported maximum subsidence versus percent sandstone.

$r^2 = 0.146$ (Correlation Coefficient Squared)

$S_{yx} = 19.2\%$ (Standard Error - y based on x)

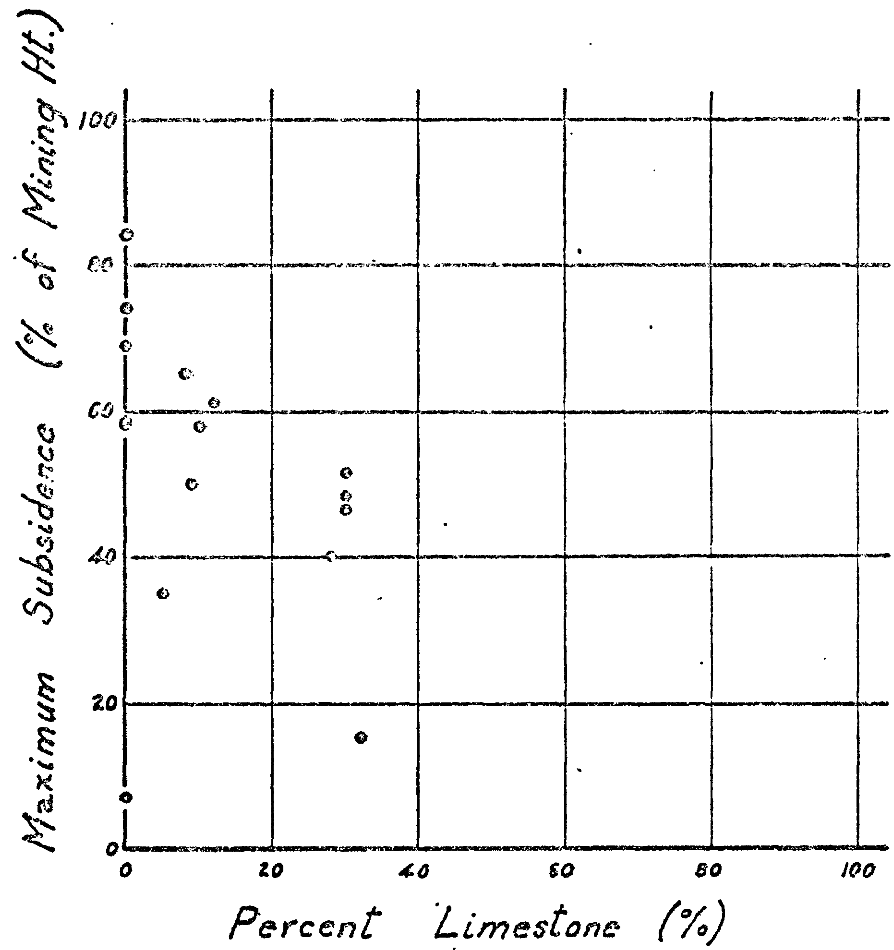

Figure 11. Reported maximum subsidence versus percent limestone.

The reported data on mining conditions indicate that there is probably no relationship between depth of mining and maximum measured subsidence (fig. 12). In fact, the calculated confidence level of about 40 percent is less than that for flipping a coin. The relationship between mining height and maximum measured subsidence involves one extreme outlying value (fig. 13), the results of which were reported by Obert and Long (1962) for a 42-m-high block of borate. This block was blasted down as a plug, which could make its inclusion in the statistical analysis questionable. Dropping the outlying value (fig. 14) increases the level of confidence in an interrelationship from 55 to 98 percent. The highest level of confidence, greater than 99 percent, of a relationship quite reasonably exists between the percent extraction and the maximum measured subsidence (fig. 15).

Subsidence over crystalline rocks

The crystalline rocks above many metalliferous orebodies are not ordinarily massive because they are commonly jointed and faulted. In addition, the typical igneous rock mass varies in rock composition, and may contain dikes, sills, and inclusions of country rock. These features generally would be undesirable in sites for underground storage or disposal of hazardous waste. Metalliferous orebodies generally have irregular geometries, varying in lateral and vertical dimensions. The thickness of ore withdrawn during mining in crystalline rocks is frequently sufficiently great to result in collapse of the surface. MacLennan (1929, p. 169) reported that a block cave stope broke through overlying massive Precambrian schist to the surface after 12.6 percent of the thickness of rock between the extraction level and the surface was removed. Thomas (1971, p. 5) reported that the upper surface of the monzonite rocks overlying one orebody was breached when 11 percent of the rock column had been withdrawn. Thomas (1971, p. 54) reported that withdrawal of about 10 percent of the same rock column above another orebody at a nearby location produced a similar breach.

The subsidence mechanism in the case of mineral extraction in crystalline rock is roughly as follows:

1. Collapse of rock progresses upward from the mining horizon (undercut level) as ore is withdrawn from below. The resulting column of caved and broken rock is confined above the area of extraction.

2. The ground surface does not begin to measurably subside until the collapse has so thinned the overlying intact rock that it cannot transfer the load of the overlying rock to the adjacent solid rock ribs. The overlying solid rock will then begin to deflect downward toward the collapsed rock below. Lateral movement of adjacent rock into the collapsed rubble column is resisted by the active pressure of the rubble (broken rock). In extreme cases, where the adjacent solid rock begins to move laterally into the rubble column, it is resisted by the passive pressure (resistance) exerted by the broken rock.

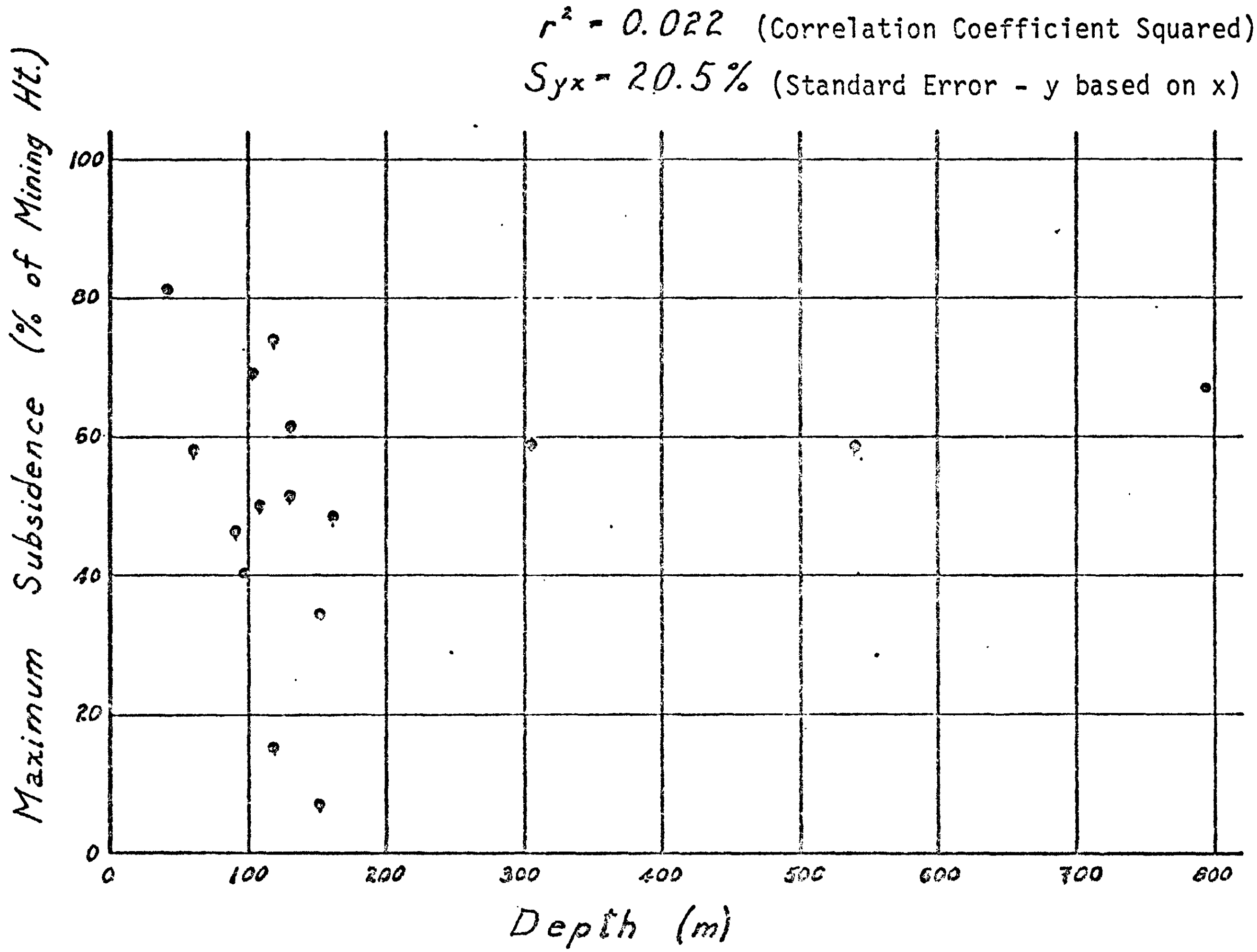

Figure 12. Reported maximum subsidence versus depth.

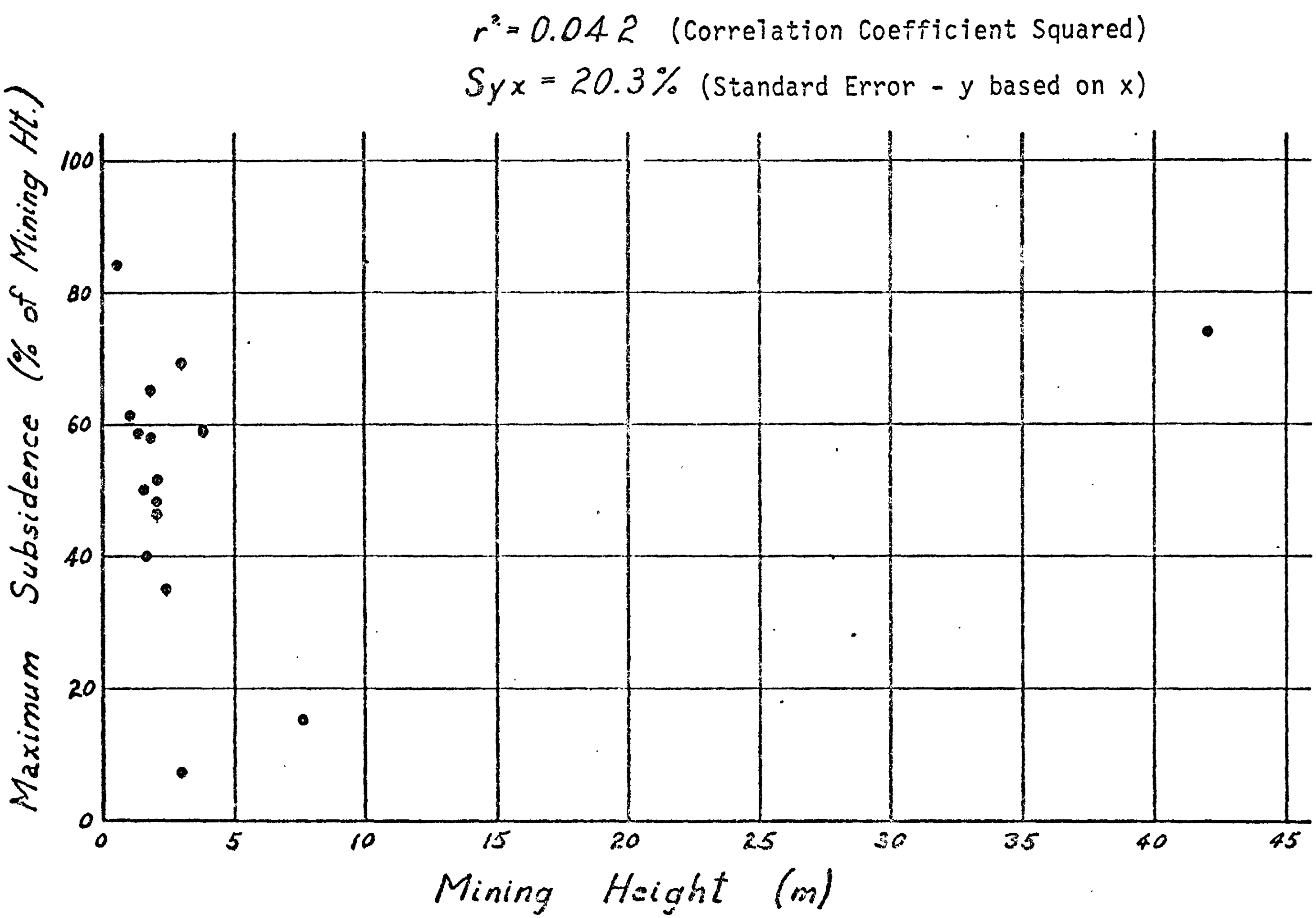

Figure 13. Reported maximum subsidence versus mining height (all data).

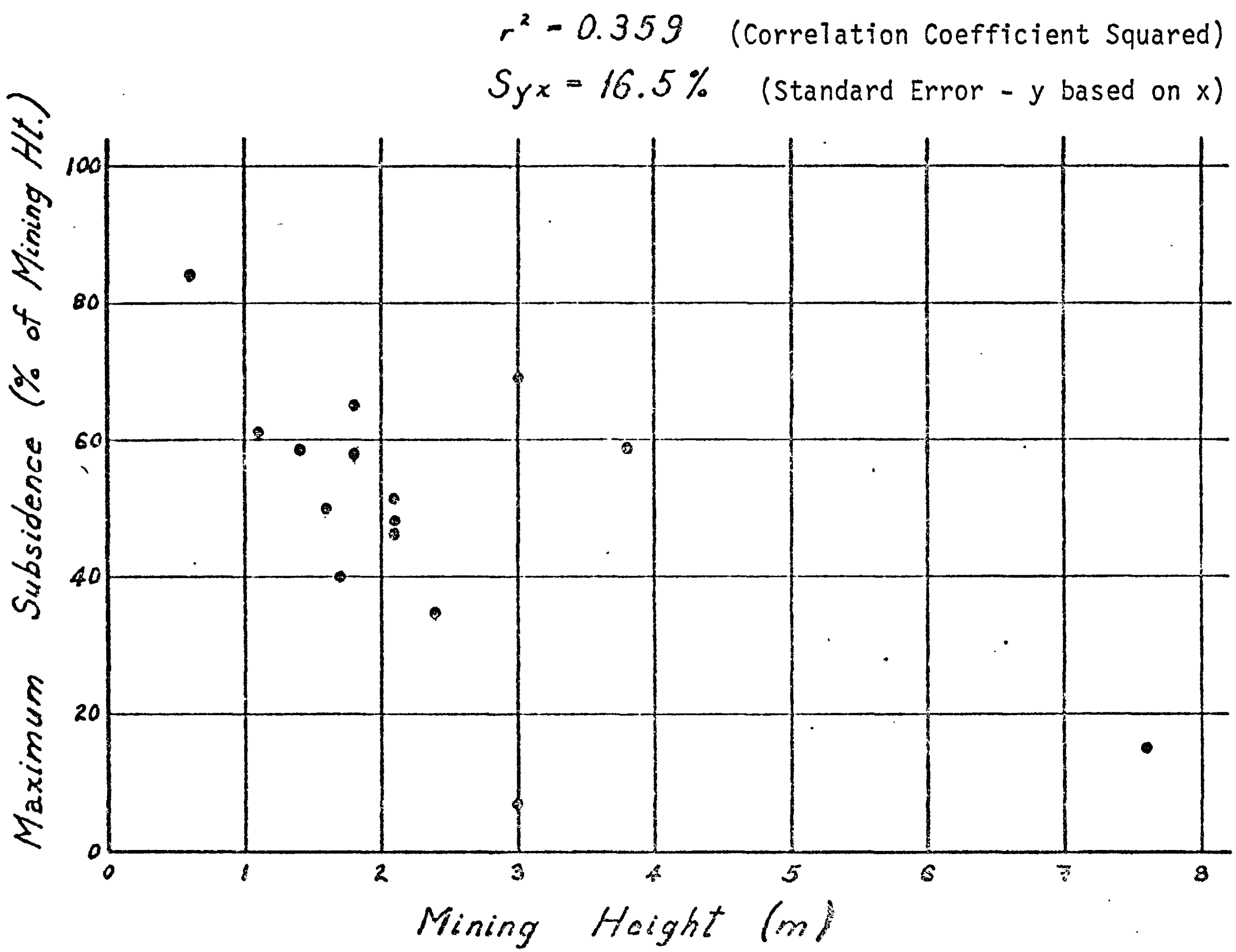

Figure 14. Reported maximum subsidence versus mining height (data outlier removed).

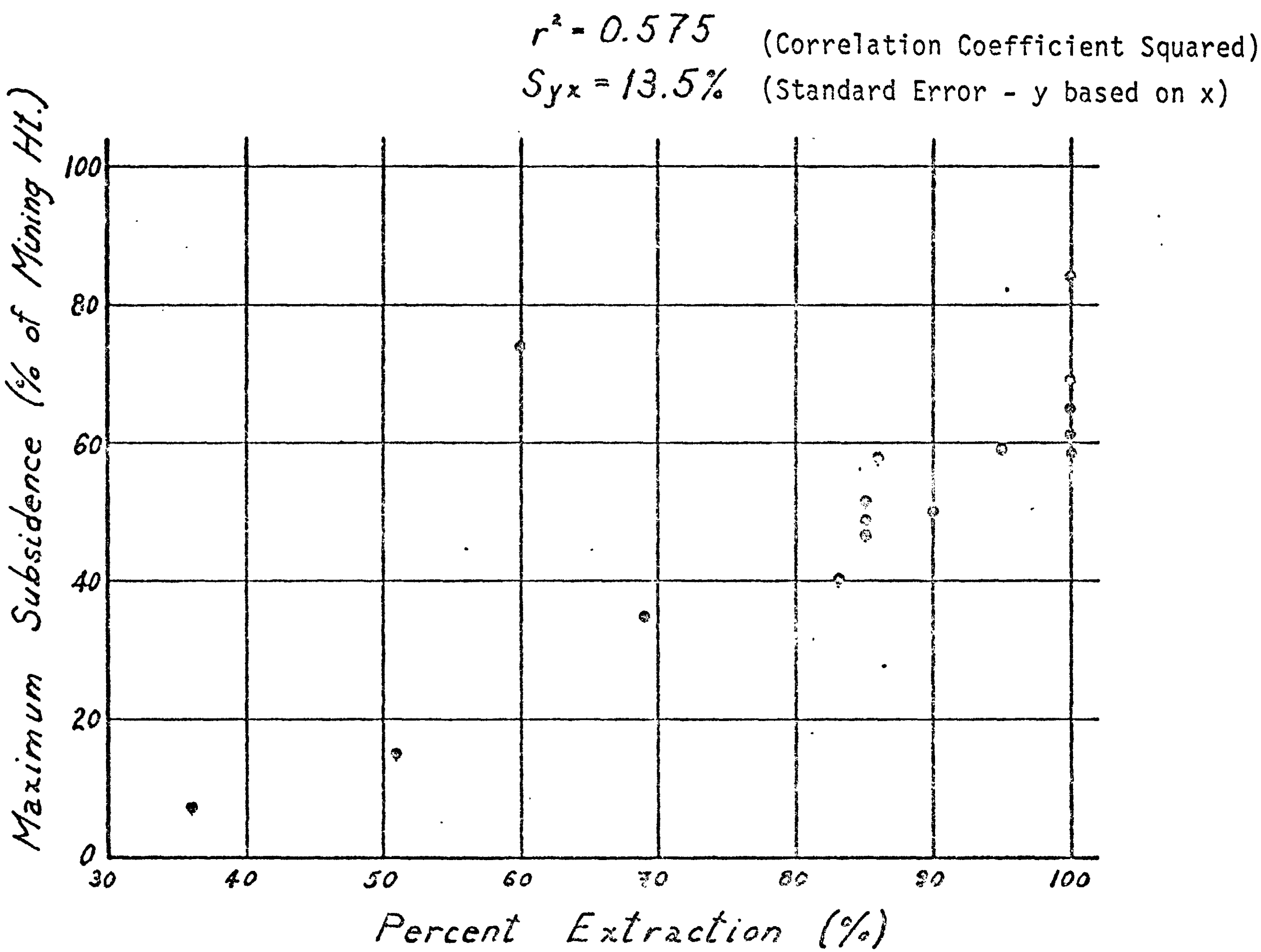

Figure 15. Reported maximum subsidence versus percent extraction.

3. Further extraction of caved ore from below results in increased sag (subsidence) of the ground surface above and adjacent to the area of extraction. The overlying intact rock is progressively thinned by the further upward migration of the broken rock, which causes intact rock to deflect onto the caved rock. The initial trough subsidence is similar in shape to the trough subsidence observed above coal mining (Thomas, 1971, p. 6, 16).

4. Continued extraction of ore will result in breaching of the surface. The initial breach is typically in the form of a circular pit, commonly referred to as a chimney. The chimney is roughly centered over the mining area, but may be offset a minor distance. Such an offset is probably the result of preferential collapse along geologic weaknesses in the rock mass.

5. If ore extraction continues, the surface breach will grow laterally near the surface where the broken rock, and the restraint it provides, has moved down the chimney. The rock adjacent to the subsided chimney either slides along geologic weaknesses, such as joints or faults, or topples into the evacuated upper part of the chimney.

6. The final, or ultimate, angle of draw is determined either by the place where the lowest angle of geologic weakness intersects both the ground surface and the mining horizon or by the place where the angle of repose of the broken rock mass is reached, whichever has the lower angle.

The presence of a fault in crystalline or sedimentary rock can terminate the angle of draw short of its normal value. In the case of crystalline rock a steeply dipping fault which lies outside the collapsing rock column can terminate the gradual increase of the angle of draw at the surface outcrop of the fault. In the case of trough subsidence and sedimentary rock (Lee, 1966) the subsidence curve is usually truncated by such a steeply dipping fault. In both cases, the ground surface abruptly drops across the fault, with the downthrown side toward the chimney or toward the center of the trough.

If a gently dipping fault intersects the collapsing rock column the lateral extent of surface subsidence can increase outward to the place where the fault intersects the ground surface. Whether or not this takes place depends primarily on the shear strength of the fault zone. Thomas (1971, p. 38-45) indicated the lateral extension of the subsidence pit to be about 1,000 ft along the San Manuel fault and beyond the draw limits measured on the other sides of the pit.

It is common practice to report both an initial and a final angle of draw for caving subsidence. The initial angle of draw is the extent of subsidence effects at the time the surface is breached. The final angle of draw includes the limit of measurable subsidence effects after mining has ceased. A negative initial angle of draw, that is, it extends inside the mining area, is frequently reported if precise survey measurements are not made. Such a negative angle of draw is the angle between the vertical and a line connecting the side of the chimney to the nearest side of the mining level. Reported initial and final angles of draw which breached the surface above metalliferous mines in crystalline rocks are tabulated in table 4. No information was found for initial angles of draw for trough subsidence where the extraction of thickness was limited and the surface was not breached by caving.

The progression of surface subsidence described above will end at any stage if extraction of rock from below stops, except where long-term consolidation of the collapsed rock has occurred. The ultimate extent of subsidence is controlled by "bedding and jointing which constitute the principal lines of weakness universally present in rock formations" and "may be considered the controlling factors in ground movement" (Crane, 1929, p. 6). "When rock formations are broken due to the removal of underground support, the movement occurs upon existing planes of weakness and not upon fresh breaks across the formations" (Crane, 1931, p. 3).

Both subsidence troughs and chimneys can occur either in crystalline or in sedimentary rocks and either above shallow coal mines or above shallow or deep metal mines. The differences are generally related to the lateral extent of surface subsidence effects. Lateral subsidence above crystalline rocks can extend farther because the dip of the joints can be flatter than the angle of draw observed for trough subsidence above bedded sediments. Typical bedding cross-joints are approximately perpendicular to the bedding planes. In flat-lying sediments, the bedding cross-joints do not define the extent of subsidence. In this case it is the flexure of the beds that determines the extent of subsidence. Typical subsidence in bedded sediments which are sufficiently deep that no collapsed chimneys result (about 10 times extraction thickness), does not extend beyond step 2 above.

Subsidence associated with pillar failure in room-and-pillar mining

Room-and-pillar mining is frequently used in areas where the surface must be protected from the effects of subsidence. In Pennsylvania this provision has been codified into law (Bituminous Mine Subsidence and Land Conservation Act, 1966). The assumption that subsidence can be eliminated by leaving pillars of sufficient size, however, is erroneous. The extraction of part of a tabular deposit, in this case coal in Pennsylvania, will increase the vertical stress in the remaining pillars. The pillars will shorten in response to the increase in stress. This pillar shortening will be transmitted to the surface, but its effect is normally so small as to be negligible and frequently undetectable. Prediction of the long-term stability of the pillars is a major problem for room-and-pillar mining. Pillar failures leading to sudden surface subsidence have occurred as long as 100 years after mining (Thornburn and Reid, 1977, p. 90).

Table 4.--Angles of draw (from vertical) reported for mines in crystalline rocks

Location and commodity	Angle of draw Initial	Angle of draw Final	Remarks	References
Missouri, iron---	--------	54°	Jasper and slates, joint and foliation controlled.	Crane (1929).
Do-------------	--------	10°	Jasper "master joint" controlled.	Do.
Do-------------	--------	$\leq$65°	Slates, foliation, and joint controlled.	Do.
Missouri, copper.	4°	24°	Joint (slip) influenced-------	Do.
Arizona, copper--	15°	40°	Porphyry and chlorite shist---	Mills (1934).
Do-------------	--------	$\leq$55°	Porphyry, joint controlled----	Do.
Do-------------	--------	$\leq$43°	Diorite, joint controlled-----	Do.
Colorado, molybdenum.	-2°-14°	$\leq$30°	Granite gneiss host, residual stress.	Vanderwilt (1949).
Arizona, copper.	-5°-32°	24°-45°	Porphyry host rock, joint and fault controlled.	Kantner (1934).
Do-------------	14°-40°	44°-48°	Schist and massive conglomerate, limited fault control.	Fletcher (1960).
Do-------------	17°		Monzonite porphyry 69 percent, gila conglomerate 31 percent.	Thomas (1971).
Do-------------	--------	5°-24°	Joint and fault controlled----	Do.
British Columbia, copper.	0°-5°	23°-36°	Joint with minor fault control, volcanics, and hanging wall gabbro.	Nelson and Fahrni (1950).

The monitoring of the surface above room-and-pillar mining operations is rarely undertaken; however, data are available from the few surface subsidence-monitoring programs over failed pillars (table 5). The subsidence reported is much less than that predicted by the widely used NCB (1975) model for longwall mining--the uniform extraction of a thickness of coal across a wide and long area. Knothe (1957, p. 214) reported a reduction of maximum subsidences to as little as one-thirty-fifth of the NCB longwall subsidence prediction for 50-percent extraction by room-and-pillar mining. This, no doubt, results from the fact that when pillars fail they crush and expand but do not flatten out uniformly. The shortened crushed pillars increase in load-carrying capacity in some proportion to their increase in cross-sectional area. Wilson (1972, p. 413) reported placing 166 MPa (24,000 lbf/in^2) on a cylinder of coal fragments whose width was 20 times its height. Likewise, solid coal pillars could never carry such a stress unless their width/height ratio was similarly large. The data presented in table 5 and shown graphically in figure 16 permit a statistical analysis based on the method presented by Wardell and Eynon (1968).

Backfill has been placed in room-and-pillar workings in some mines to reduce subsidence. This method has been highly successful as indicated by the results reported by Kumar and Singh (1973, p. 6-2, 6-3) and by the results in table 5 for the Jharia mine in India. The predicted percent of subsidence without backfill is nearly 20 times greater than that measured with backfill (fig. 17).

Accurate prediction of the reduction in subsidence effects resulting from backfilling around pillars commonly is not possible because uncontrolled or unreported factors, such as the completeness of filling and the compressibility of the fill are not accurately known. It is also necessary to determine the percent of swell of the failing pillar as it interacts against the fill material. Subsidence effects can be greatly reduced by backfilling, but subsidence cannot be eliminated.

Rate of subsidence

The time factor in mining-induced subsidence has been investigated in the past, mainly as it applies to coal mining. Young and Stoek (1916), for example, reached only one general conclusion: the deeper the seam the longer the duration of surface movement. Although this is a widely accepted finding the reasons behind it still are not completely understood.

Table 5.--Subsidence measured above room-and-pillar and partial extraction workings following pillar squeeze or failure

Location	Mining height (H) (m)	Pillar width (W) (m)	Extraction (R) (percent)	Depth (D) (m)	Average pillar stress (L_{max}) (MPa)	L_{max} (H/W)	Subsidence (H) (percent)	References
N. Staffs., G.B.	1.30	3.1	70	79	5.98	2.54	13.8	Wardell (1969).
Do-------	1.30	13.4	51	101	4.21	.41	2.2	Do.
Do-------	1.37	9.0	41	137/274	5.26/10.52	0.786/1.57	10.5	Wardell and Eynon (1968).
Cannock, G.B.	2.13	15.0	31	265	8.70	1.22	9.6	Do.
Franklin, Ill.	2.44	5.0	69	152	11.2	5.56	34.8	Herbert and Rutledge (1927).
Lick Creek, Ill.	7.62	12.0	51	122	5.63	3.15	15.2	Warm (1973).
J.J. No. 1, N. Mex.	3.1	12.0	36	152	5.38	1.34	6.9	C. H. Parrish (written commun., 1979).
Montoar 10, Pa. 1/	1.7	2.3	83	98	13.03	9.59	40.0	Greenwald and others (1937).
Crucible, Pa. 1/	2.1	1.5	85	129	19.51	26.6	51.5	Maize and Greenwald (1939).
Gibson, Pa. 1/	1.6	1.5	90	108	24.47	26.1	50.0	Maize, Thomas, and Greenwald (1940).
Crucible, Pa. 1/	2.1	1.5	85	162	24.47	33.2	48.2	Maize, Thomas, and Greenwald (1941).
Nemacolin, Pa. 1/	2.1	1.5	85	91	13.65	18.6	46.3	Do.
Carlsbad N. Mex.	3.89	5.5	95	305	137.88	97.7	58.8	Miller and Pierson (1958).
Jharia, India. 2/	10.5	61.0	57	165	8.67	1.49	.56	Kumar and Singh (1973).

1/Data partly determined from plans and sections presented.
2/Not used in statistical analysis because of hydraulic sand backfilling (stowing).

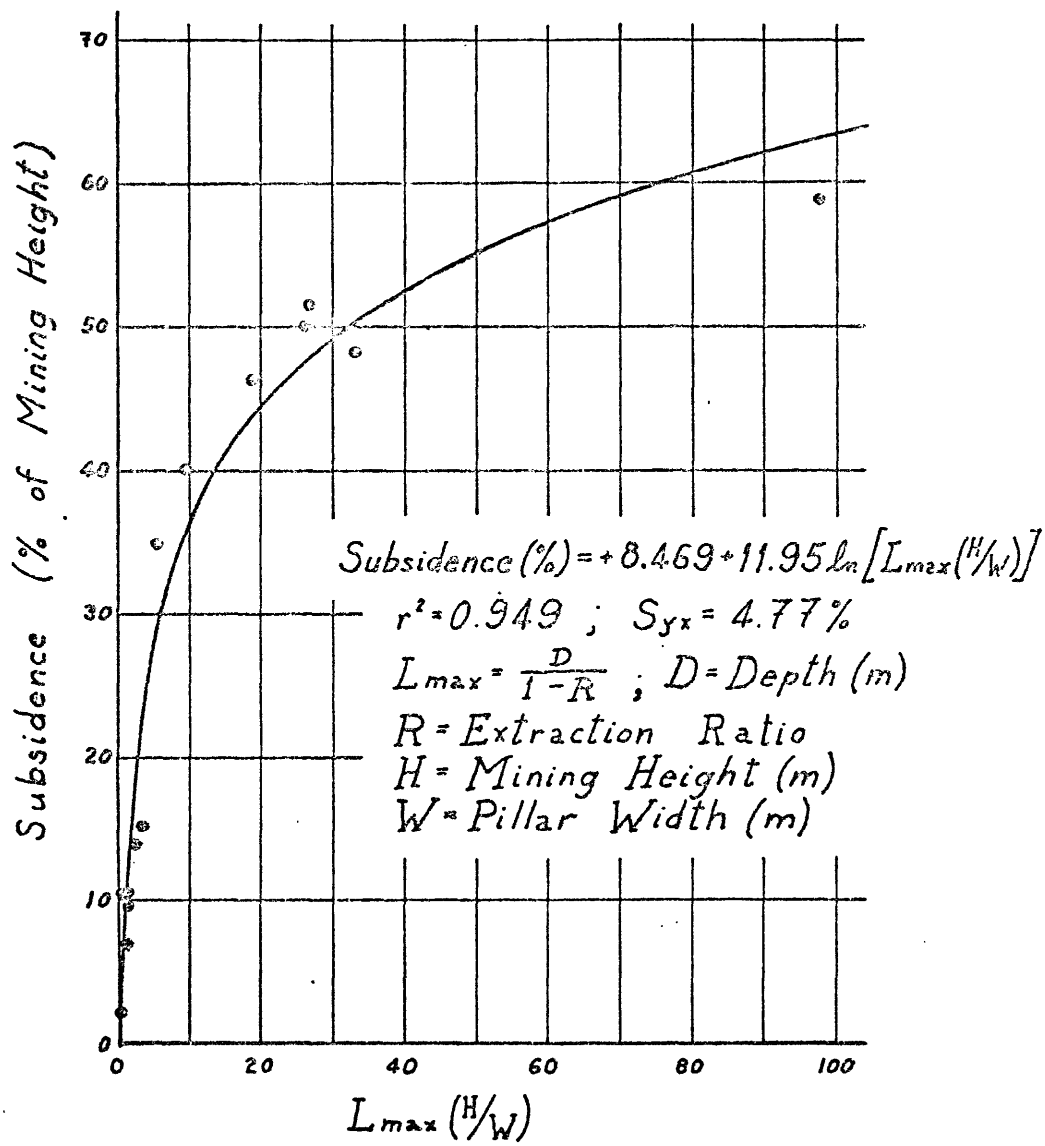

Figure 16.--Subsidence above room-and-pillar partial extraction workings following pillar squeeze or failure.

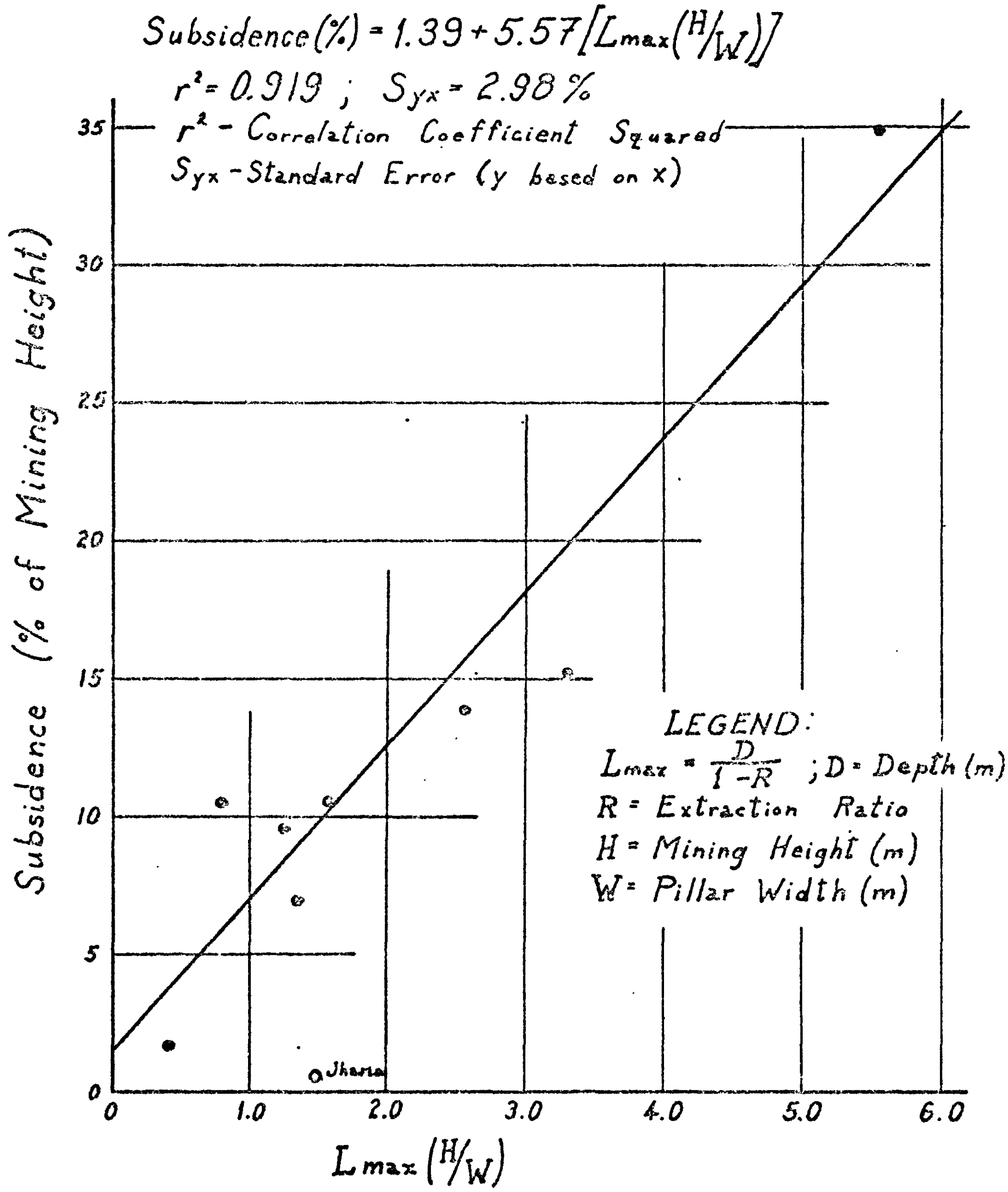

Figure 17.--Room-and-pillar subsidence accompanying pillar failure at low extraction.

Wardell (1953) showed that the subsidence of a point at the surface theoretically begins when a longwall face enters the "critical area" (fig. 3) and ceases when the face leaves the critical area. However, Wardell further showed that the surface point continues to subside (residual subsidence) for a variable period, perhaps months, but that on the average, 95 percent of the total subsidence occurs while the face is within the critical area. Most investigators suggest that rate of advance and depth of mining are the factors governing the rate of surface subsidence. In addition, a "development factor" which includes depth, mining height, and percent extraction (Orchard and Allen, 1974) has been proposed for mining-geometry influences. As stated earlier, in respect to the areal limits of subsidence, geological and geomechanical properties influence strain rates and modes of deformation. Orchard and Allen (1974) reported that, when the face advances out of the "critical area," further ground movements occur due to complex time-dependent stress redistribution processes in the overlying rocks.

The influence of depth of mining and face position on time-dependent subsidence becomes more important in the event of pillar failure in room-and-pillar mining than that in longwall mining. Pillar failure can be delayed, progressive, or sporadic.

Residual or delayed subsidence

Orchard and Allen (1974) noted that 9 percent of the total subsidence occurred during the 6 years after a 166-m-deep longwall face advance stopped at Peterlee, England. A thick dolomitic limestone apparently caused a delay and reduced the amount of subsidence. The same authors mention that a residual surface subsidence of 16 mm occurred 3 months after longwall mining of a 105-m-deep coal seam stopped in north Durham, England. Then, after a pause of 5 months during which there was no subsidence, a subsidence of 17 mm took place over the next 3 years. The delayed subsidence was 6.8 percent of the 3-year total. At this mine a 23-m-thick bed of sandstone apparently delayed surface deformation. A gradual lowering of the rock mass is associated with weak beds whereas violent, often delayed, collapse is associated with the sudden failure of strong roof rocks. According to Piggott and Eynon (1977), if there is at least one competent rock layer, which has a thickness of at least 1.75 times the appropriate opening span width, between the mine workings and the surface, the collapse process will be stopped by that competent bed.

Subsidence may be delayed either when the extraction percentage is decreased and pillars are left, or when backfilling is used. Similarly, Whetton and King (1961) found that the area of the underground workings also controls the timing and vertical extent of surface subsidence. Thus, roof deflection is proportional to roof span width and span width is proportional to surface subsidence; the greater the span width the more rapidly deformation will reach the surface.

Many accounts are recorded of severe surface deformations that occurred, often abruptly, long after mining ceased. With only a few exceptions, most of which are controlled by geological conditions such as those previously mentioned, the notable delayed residual subsidence has taken place in room-and-pillar mined areas rather than in longwall mined regions. In the former County of Lanark (Scotland) mining had been completed 118 years when a sudden collapse of sandstone beds occurred above workings only 16 m deep. At the surface structural damage to apartment buildings was so severe that the tenants were evacuated and several blocks of buildings were demolished (Thornburn and Reid, 1977). At Farmington, W. Va., intermittent episodes of subsidence occurred when 2- to 3-m-high coal pillars punched into the weak claystone mine floor (Gray, Bruhn, and Turka, 1977). Surface deformation that damaged dozens of homes and buildings began while the mine (85 m below the surface) was active. Subsidence movements continued for more than 4 years after mining stopped until the mine was backfilled with coal waste.

Summary and conclusions

Subsidence is the downward sinking of the ground surface due to the collapse of underground cavities, in the present case, mined cavities. The surface extent of subsidence is greater than the cavity length and width. Vertical movements predominate but lateral movements of both expansion and contraction also take place. In many areas maximum vertical subsidence is less than 50 percent of the mining height. Subsidence is a time-dependent deformation that may result from mine roof collapse, pillar failure, pillar punching, or various combinations of these mechanisms. Subsidence may be detected through rupture of utility pipelines, foundation displacements, or changed drainage patterns, more than 100 years after mining has ceased. Subsidence induced by longwall mining is much easier to predict and monitor than subsidence induced by partial extraction methods. The information presented here does, however, demonstrate that subsidence is controlled by the complex interaction of mining and geologic conditions and is time dependent, particularly in the case of room-and-pillar workings.

No measurements of subsidence effects have been made above room-and-pillar workings in massive shale and crystalline rocks. Therefore, predictions of subsidence from room-and-pillar excavation for waste storage facilities in these rocks based on information gained from less, perhaps much less, massive rocks will be subject to unknown error. Measurements in massive rocks will be needed to verify extrapolation of available subsidence measurements, mechanisms, and effects.

Perhaps reasonably accurate subsidence predictions can be made for deep waste storage chambers in more massive and less complex rock masses using one or more of the existing subsidence-prediction models for coal measure rocks. Accurate determination of geologic and excavation conditions, adequate monitoring, and careful analysis are required for a meaningful validation of such extrapolations.

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RECLAMATION AND ENFORCEMENT
TECHNICAL REPORT/1991

GUIDANCE MANUAL ON SUBSIDENCE CONTROL

U.S. Department of the Interior

Office of Surface Mining Reclamation and Enforcement

PB91-228403

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OFFICE OF SURFACE MINING RECLAMATION AND ENFORCEMENT
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Manual developed as an aid for the preparation of subsidence control plans for underground coal mining operations. Describes subsidence process, reviews available subsidence prediction methods, and describes techniques which is intended for information purposes only. Each mining area is unique and different states have different regulatory program requirements, consequently, clear communication between the state regulatory authority and the mine operator is needed that specific needs and requirements of the subsidence control regulations are understood and met.

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Final Report

Guidance Manual on Subsidence Control

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This report is based upon work done under contract by GAI Consultants, Inc., and the Office of Surface Mining.

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1.0 INTRODUCTION

This manual has been prepared as an aid in the preparation of subsidence control plans for underground coal mining operations. Most of the material in this manual was taken from the final report submitted to the Office of Surface Mining Reclamation and Enforcement by GAI Consultants, Inc., Monroeville, Pennsylvania. It describes the subsidence process, reviews available subsidence prediction methods, and describes subsidence control and prevention techniques. It is intended for information purposes only. Each mining area is unique and different States have different regulatory program requirements, consequently, clear communication between the State Regulatory Authority and the mine operator is needed in order that the specific needs and requirements of the subsidence control regulations are understood and met.

2.0 TYPES OF MINING

CONTENTS

2.1 Introduction

Almost all underground coal mining in the United States is conducted using one of three methods -- room-and-pillar (including pillar retreat), longwall, or shortwall. Major references on underground mining include, among others, Peng (1978); Peng and Chiang (1984); Hustrulid (1982); and Stefanko (1983).

2.2 Room-and-Pillar Mining

Room-and-pillar mining is the predominant method of coal extraction in the United States as it has been since coal was first mined in this country over 200 years ago. Mining patterns have evolved in the interim -- in the early years, primarily unevenly spaced, irregular pillars; by the turn of this century, regularly spaced, long narrow pillars; and since World War II, wider more nearly equidimensional pillars. Regardless of pillar configuration, the room-and-pillar method in its basic form consists of driving entries, rooms and cross-cuts into the coal seam to extract coal, while leaving pillars of coal to support the overburden. This procedure is called "developmental" mining. Movements of the ground surface during this period are nearly always imperceptible. In some districts, the developmental mining phase is followed by "pillar recovery", where the pillars are systematically extracted. Pillar extraction is invariably accompanied by subsidence of the round surface as the overburden sags into the mined-out area in response to the removal of mine level support. Where pillar extraction is not conducted and surface support is intended, the pillars must be designed to permanently support the ground surface.

The two broad categories of room-and-pillar mining are "conventional" and "continuous"--the distinction being based on differences in machinery and mining methods at the face. The following brief descriptions serve to illustrate the basic characteristics of each category. Details with regard to cutting and conveying the coal vary from mine to mine.

In "conventional" room-and-pillar mining, coal is recovered by first cutting a horizontal slot 10 to 12 feet deep at the bottom of the coal seam. The face is then pattern-drilled with blast holes designed to produce an 8- to 10-foot deep cut. After detonation of the explosives, the fragmented coal is loaded and transported out by one of various means (e.g., shuttle cars, belt) and the roof is supported in accordance with roof control plans. These operations are performed sequentially along a series of adjacent entries.

In "continuous" room-and-pillar mining, coal is recovered using a continuous miner, a machine that breaks the coal from the face through a mechanical action produced, variously, by means of a ripping head fitted with multi-bit chains; a boring head incorporating rotating arms fitted with bits; an augering head or, most often, a milling head. The coal cut from the solid is transported out by one or more various methods and the roof is supported in accordance with roof control plans.

For either method, temporary supports (hydraulic posts, screw jacks, or wood posts) are set in conjunction with coal extraction. Conventional expansion-anchor roof bolts are commonly used for roof support as are bolts secured by polyester resin.

During developmental mining, rooms are driven on regular spacings from the main entries to the far end of the mine panel. The rooms are connected by cross-cuts to form a pattern of coal pillars that is commonly orthogonal in plan (Figure 2.1). Cross-cuts are occasionally driven oblique to the entries to facilitate movements by mine equipment. Thirty to seventy percent of the coal may be extracted from the panel during development.

In some mining districts, this is all the coal recovered from a mine panel. More extensive mining may be undesirable or unfeasible. In some parts of Illinois, for example, partial extraction has been performed to avoid the development of subsidence troughs that would adversely affect surface drainage; and in parts of Ohio and northern West Virginia, partial extraction has been performed where strong limestone directly above mine level makes controlled roof breakage difficult and could lead to squeezes--a propagating failure of pillars and/or mine floor resulting from excessively high loads being transferred from the overburden. In other parts of Appalachia and Illinois, where the roof breaks in a controlled fashion, the recovery of coal pillars can increase the panel extraction to 80 to 95 percent.

During the pillar recovery operation, the pillars are systematically removed along a common front (the "break line", "pillar line", or "caving line") that sweeps across the panel from end to end. Pillars are generally recovered on retreat--that is, as mining progresses from the far end of the panel back towards the

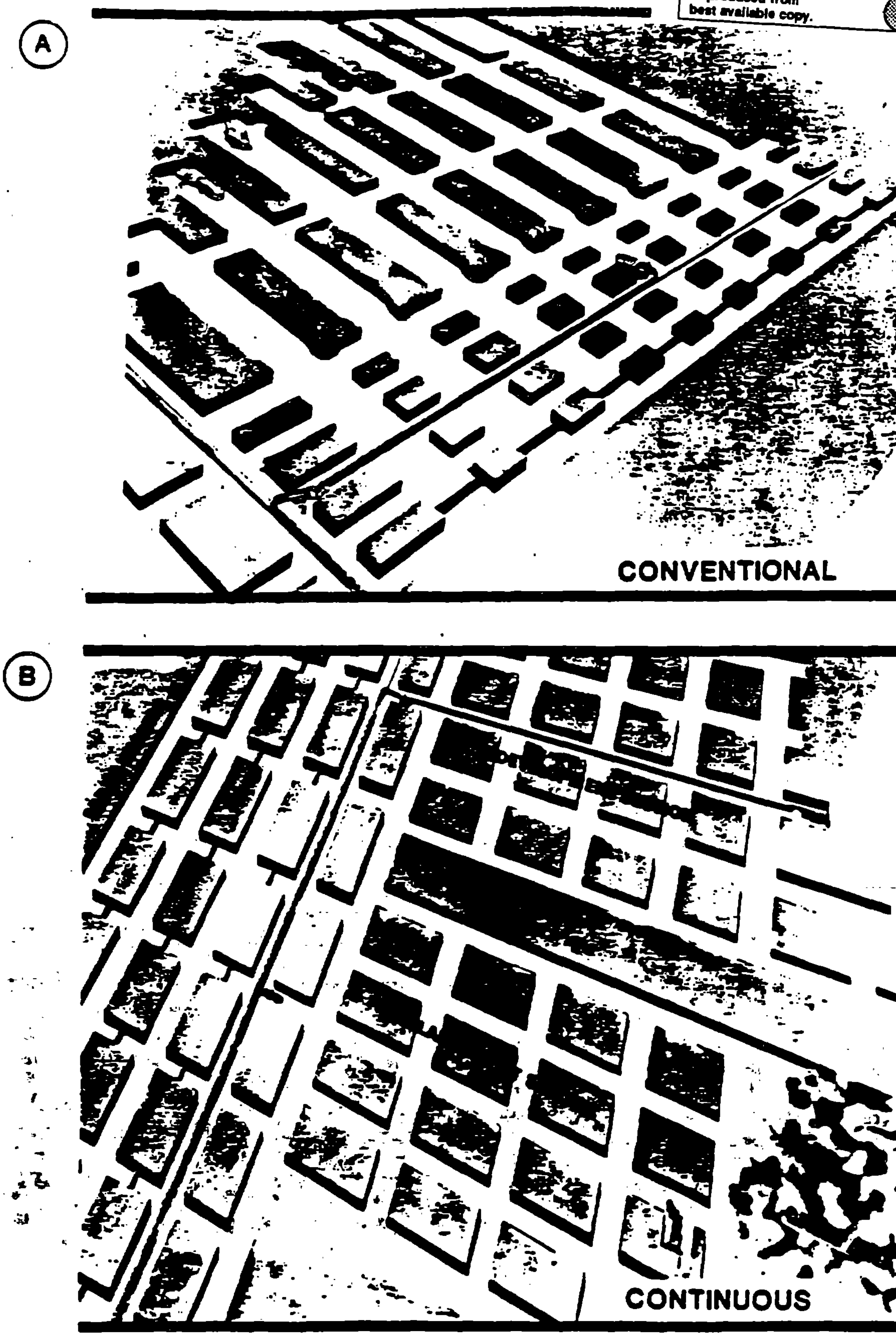

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FIGURE 2.1 ROOM-AND-PILLAR MINING

main entries—although in some systems pillars are also extracted on advance. Kauffman et al. (1981) summarizes a wide variety of pillar recovery methods on a district-by-district basis across the United States.

Pillars are commonly extracted by a "pocket-and-fender" ("split-and-fender") method or by an "open-end" method, the open-end method being more usual where conventional mining is practiced and the pocket-and-fender method where continuous mining is practiced. In a pocket-and-fender method, the pillar is subdivided into several blocks, which are then removed in sequential cuts or lifts, leaving only temporary, thin fenders (pillars) of coal for protection between the mining machine and the mined-out area. The fenders crush out as the roof caves and the overburden sags into the mine void. In an open-end method, pillars are extracted by taking successive cuts off the end of the unmined pillar nearest the gob, working back toward the as-yet unmined pillars. Other less common methods for recovering pillars include the "pocket-and-wing" and "outside lift" (Kauffman et al., 1981). For any of the methods, posts are set near the break line pillar cuts at the gob to prevent premature roof failure. The caving of the roof during pillar retreat and the accompanying downward adjustment of the overburden is similar to the caving mechanism that accompanies longwall mining, as is development of the subsidence trough at ground surface.

2.3 Longwall Mining

Longwall mining has a long history of use in Europe and has been tried at various times in the United States. In early attempts—some prior to 1900—labor costs associated with moving manual supports made the method uncompetitive relative to room-and-pillar mining. With the advent of powered supports in the United States in 1960, the method has received increasing attention, particularly over the past ten years. At present, longwall mining still accounts for only 5 to 10 percent of U.S. coal production, but is expected to challenge room-and-pillar mining in usage as the U.S. mining community becomes more accustomed to the method. Advantages claimed for longwall mining over room-and-pillar are (Stefanko, 1983): (1) greater continuity in operation and, hence, higher production; (2) greater percent extraction; (3) more flexibility in mining under poor roof conditions, at greater depths and in multiple seams; (4) better subsidence control; (5) improved safety from overhead support; and (6) associated benefits of no bolting at the face, rock dusting and certain ventilation controls. Recognized disadvantages are: (1) more pronounced delays; (2) higher moving costs; (3) higher capital costs for equipment; and, (4) difficulties in implementation where the roof and floor are too soft; where the roof is massive, or where the seam is of variable thicknesses; or the seam continuity is disrupted by gas wells or "want" areas, where the coal is absent locally.

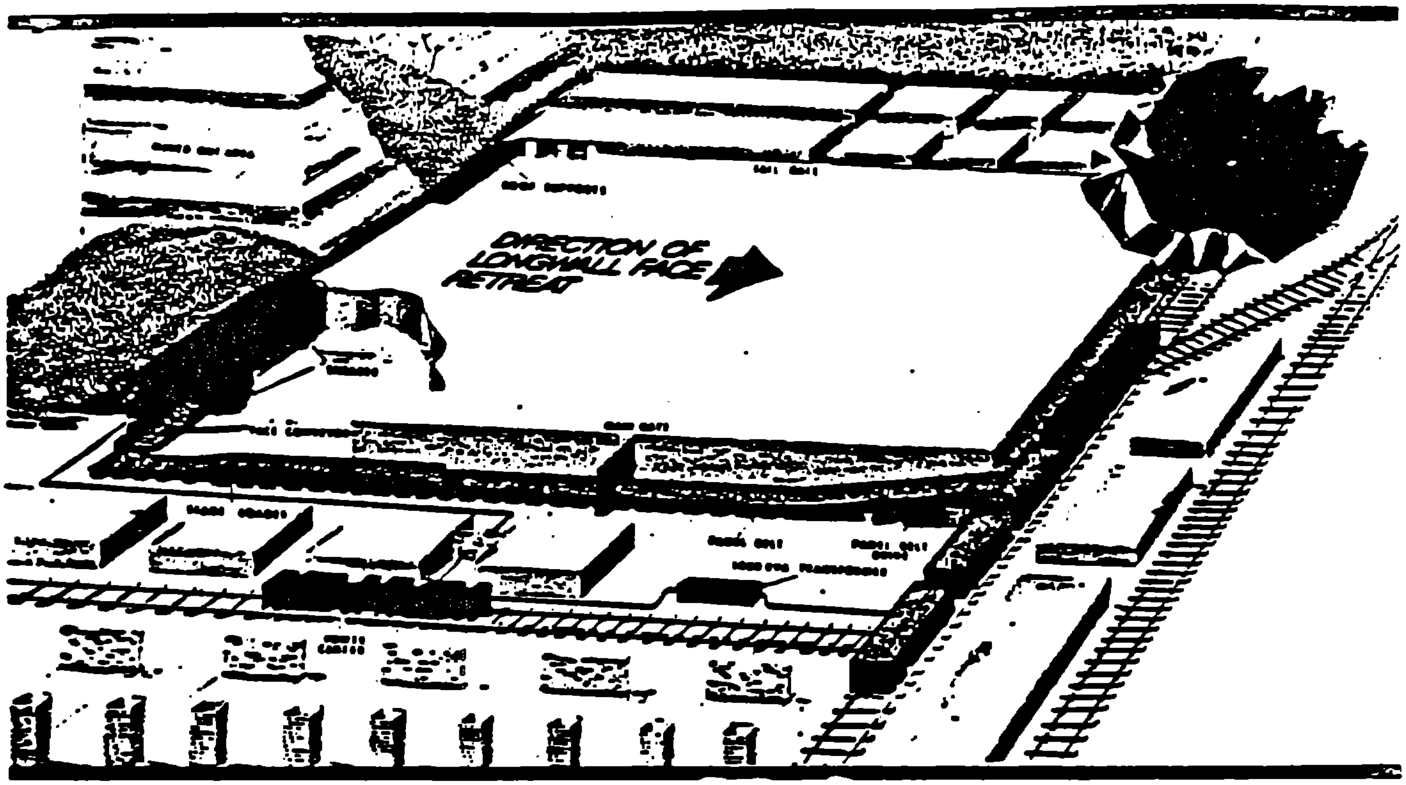
For reasons of safety, longwall mining in the United States is with few exceptions performed by the retreat method (Figure 2.2). Panel entries are developed in the initial stage of mining, after which the longwall face is established at the far end of the panel. From that location, the longwall progresses back towards the main entries. During retreat, a row of powered support units bears the weight of the roof at the face as the shearer passes from one side to the other of the block of coal being extracted. As the shearer passes, the supports are reset unit by unit to the new position of the cut face. The coal removed from the face is transported by conveyor to the panel entry and then to the main entries.

After mining has progressed some distance toward the main entries from the initial face position at the far end of the panel (a few feet to a few hundred feet depending on site conditions), the immediate roof becomes unstable and collapses to the mine floor. The collapse of this initial roof break zone is generally thought to extend to a height above the coal seam perhaps twice the mined thickness of coal and its first occurrence causes the initial transfer of weight onto the powered face supports. Caving of the immediate roof progresses systematically along the panel on concert with retreat of the face and repositioning of the powered supports. During this period, the ovelying strata slip, fracture and sag with the preponderance of overburden load being transferred by arching to the solid coal being mined (the front abutment), to the chain pillars bounding the panel on either side (the side abutments) and to the gob--the caved zone behind the supports (the rear abutment). As the mined-out area progressively increases in size, the overburden directly above the mined-out area comes to rest on the caved material, compressing it to some extent. Deflection of the overburden strata into the mined-out area produces a subsidence trough at ground surface.

At the present time, coal seams up to 15 feet in height are mined by the single slice technique described above. For thicker seams, a multiple slice technique can be used where an upper slice, or lift, is taken along the roof line of the coal using an advancing longwall-type system and a subsequent lower slice is taken along the floor line of the coal using a retreating longwall-type system. An intervening zone of coal several feet thick is left between the two slices; the lower slice, 11 feet thick; and the intervening zone, 6 feet thick. The lower retreat panel is sufficiently narrow that its bleeder entries lie beneath the mined-out area of the overlying advance panel, thereby moderating the load on the pillars protecting these entries.

2.4 Shortwall Mining

Shortwall mining with powered supports has been practiced in the United States since 1973. The shortwall method incorporates features of both the longwall and room-and-pillar methods and is often envisioned as being transition between the two in that it performs a longwall mining operation while employing continuous miners and



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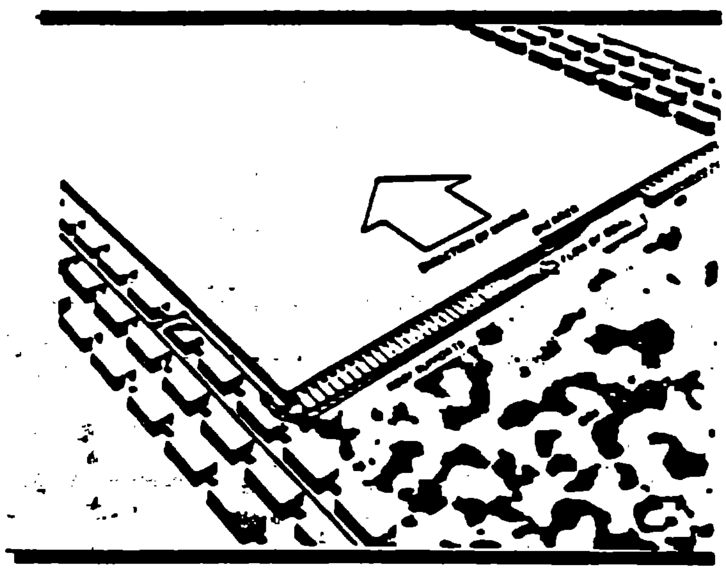

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FIGURE 2.2 LONGWALL MINING

shuttle cars retained from the room-and-pillar operations. Capital expenditures for implementing the system are moderated by the fact that face supports represent the principal acquisition.

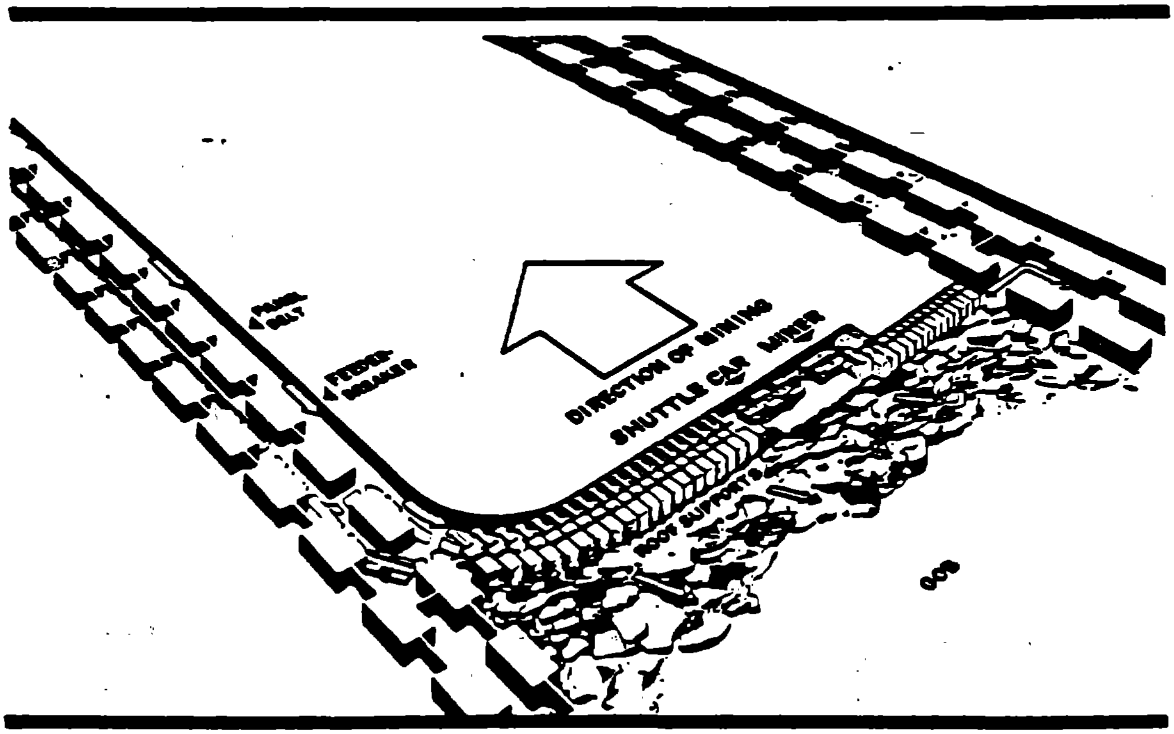
Figure 2.3 illustrates a shortwall layout. Shortwall production is claimed to compare favorably with longwall production when the relatively shorter panel-to-panel move time of the shortwall is taken into account.

In detail, the shortwall is somewhat different from longwall layouts. The shortwall is commonly one-quarter to one-third the width of a typical longwall. The depth of cut taken in a shortwall system is normally about three to four times the depth of a longwall cut. The greater depth of shortwall cut is the result of its employing a continuous miner for coal extraction. Owing to the large roof span that must be supported, shortwall supports are typicaly articulated and somewhat more costly than longwall supports. Shortwall mining, like longwall and room-and-pillar retreat mining, produces a trough at ground surfaces.

Geologic and site conditions may sometimes favor the use of a shortwall over a longwall system. The high, potentially dstructive pressures that would be delivered to longwall supports by massive, not easily broken, limestone and sandstone roof rock can sometimes be reduced to tolerable levels by use of a narrower shortwall face designed so that a greater proportion of the overburden weight is transferred to the abutments. The shortwall may also be more suitable than the longwall for mining in seams whose continuity is disrupted by gas wells or by areas where coal is absent.

2.5 Mining Types and Subsidence Control Methods

It is clear from these brief descriptions of mining types that a variety of technical and economic considerations govern the choice of mining method in a particular mine. Geologic factors include the thickness of the coal and partings and its depth below ground surface, as well as the mechanical properties of the mine roof, the floor, and the overburden strata. Safety concerns relate to roof and rib control, access, ventilation and water inflows.



COURTESY OF JOY MANUFACTURING COMPANY

FIGURE 2.3 SHORTWALL MINING

3.0 PLANNED VERSUS UNPLANNED SUBSIDENCE

CONTENTS

3.1 Definition of Terms

The term 'subsidence' as used in this report is defined as the settlement of the ground surface in response to underground coal mining. It is the inevitable result of high extraction mining practices and the occasional (relatively infrequent) results of partial extraction mining practices.

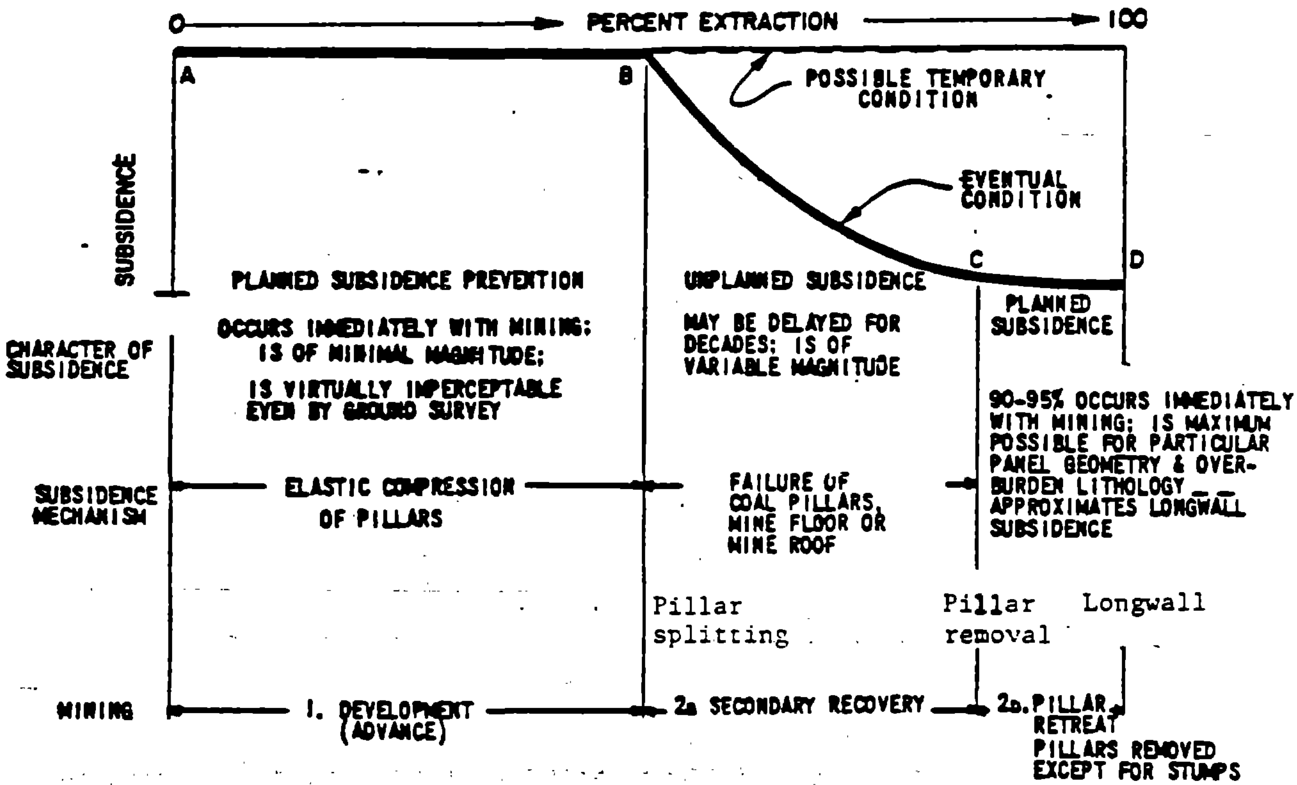
Planned subsidence represents lowering the ground surface in a predictable manner--predictable (within limits) as to a ral extent, amount of subsidence and amount of ground surface distrotion--as a result of appropriate mine design and mining procedures.

Unplanned subsidence represents lowering of the ground surface in a manner that cannot be predicted as to areal extent, amount of subsidence or amount of ground surface distrotion, as a result of failure at mine level of the overburden support system (coal pillars/mine roof/mine floor) or as a result of the action of other unanticipated causes, such as the piping of unconsolidated sediments into the mine void.

In either case, the geometry of the subsidence trough is governed in varying degrees by the thickness of the overburden strata, coal pillars and mine roof and floor, and the dimensions and geometry of the mined area.

3.2 Relationship Between Subsidence and Percent Extraction

The complete relationship between subsidence and percent extraction for a hypothetical mine panel is shown schematically in Figure 3.1. There, permanent ground support (and no subsidence) is denoted by the range A-B; impermanent ground support (and some subsidence given a sufficient period of time) by the range B-C; and essentially total withdrawal of support (and maximum subsidence), by the range C-D.



NOTE: Developmental mining (1) is followed either by limited Secondary Recovery (partial extraction Room-and-Pillar, 2a) or by complete Removal of Pillars (Longwall Retreat or Pillar Retreat, 2b).

The percent extraction at Point B depends upon site specific conditions.

FIGURE 3.1 SCHEMATIC OF RELATIONSHIP BETWEEN SUBSIDENCE AND PERCENT EXTRACTION FOR A ROOM-AND-PILLAR PANEL OF PARTICULAR GEOMETRY AND OVERBURDEN LITHOLOGY

Curve ABCD serves as a basis for the discussion that follows and is to be recognized as but one of a family of curves governed by panel geometry, overburden lithology, mine depth, and mining pattern.

When the percent extraction of coal from a mine panel is low to moderate (A-B), as is usual during developmental mining, the loads imposed upon the pillars by the overburden are generally small in relation to the size of the pillars. In this situation, subsidence of the ground surface is virtually nil and will remain so over the long term. Subsidence (such as it is) results primarily from elastic compression of the coal pillars. In contrast, when the percent extraction is high, approaching 100 percent, as is the case during longwall or room-and-pillar retreat mining (C-D), subsidence above the panel appraches the maximum possible for the particular panel geometry and overburden lithology and results primarily from the overburden sagging down into the mined-out area, coming to rest on and compressing the rubble from the now broken mine roof.

Where partial extraction room-and-pillar mining is practiced, an intermediate condition may exist (B-C). Here, the recovery of coal by such methods as slabbing or splitting pillars, although not attaining total extraction, may increase extraction to relatively high levels. If the panel has not been designed for permanent support, delayed subsidence of variable magnitude may eventually occur as a result of crushing of the coal pillars into the mine floor. The result could be unexpected damage to structures at ground surface or, in areas of flat terrain, the ponding of water above the mine panel.

With regard to what herein has been termed the intermediate range of extraction (B-C), Wardell (1958) and Wardell and Eynon (1968) present data supporting the concept that above a room-and-pillar panel where mine level failure or squeeze takes place, the maximum subsidence (expressed here as a proportion of mined height) is larger the greater the percent extraction, the smaller the pillars, the deeper the mine panel and the higher the average vertical stress in the panel abutments. Figure 3.2 presents their relationship, supplemented by data assembled by Abel and Lee (1980) from room-and-pillar mines in Pennsylvania, Illinois, New Mexico, and the United Kingdom.

Hasenfus (1984) and Karmis, et al., (1984 a, c) lend further support to the Wardell/Eynon relationship for eastern U.S. conditions, based on an examination of 60 cases studies of subsidence above room-and-pillar panels, primarily in Pennsylvania, West Virginia, and Alabama. They suggest that over the intermediate to high range of extraction, the amount of subsidence expressed as a proportion of mined height is larger the greater the percent extraction and the lesser the total thickness of hard rock in the overburden (Figure 3.3). They define "hard rock" as limestone and sandstone.

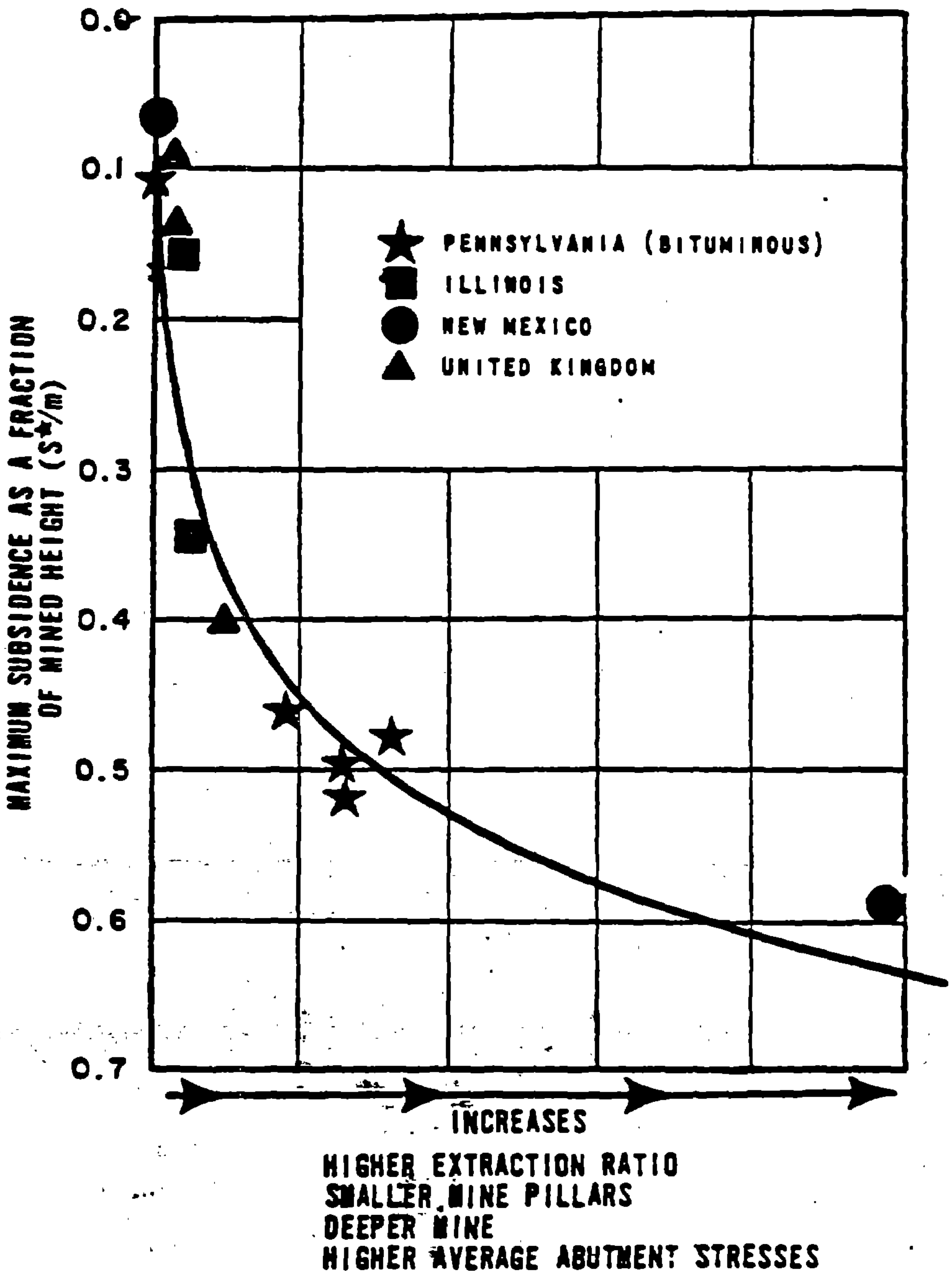
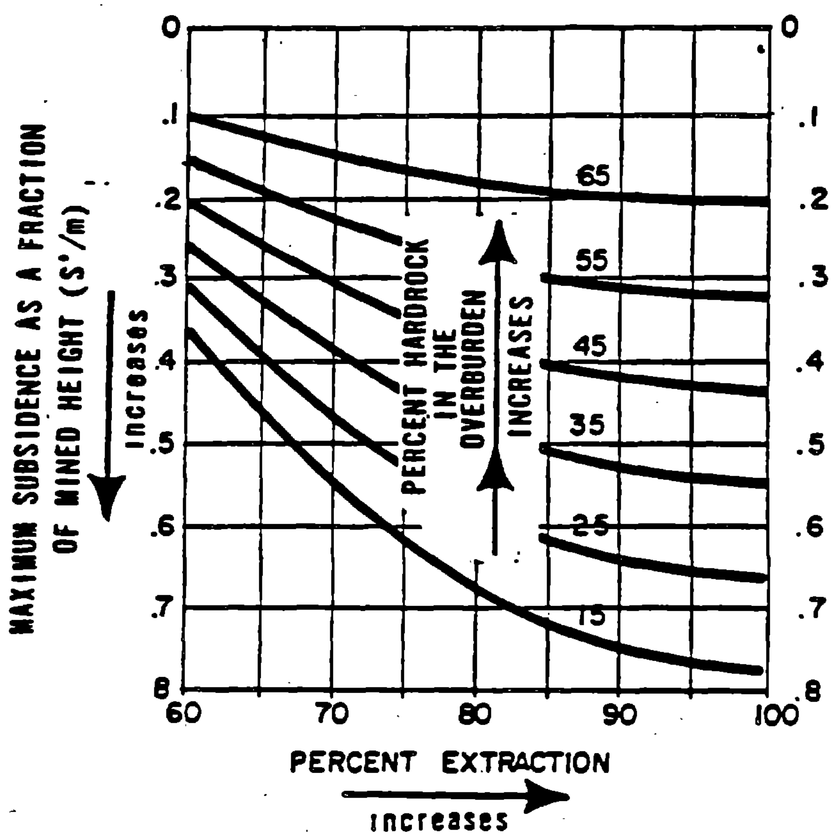


FIGURE 3.2 WARDELL / EYNON PLOT OF MAXIMUM SUBSIDENCE MEASURED ABOVE ROOM-AND-PILLAR MINES



NOTE:

1. HARDROCK INCLUDES BOTH SANDSTONE & LIMESTONE.
2. APPLICABLE TO MINE PANELS OF CRITICAL & SUPERCRITICAL DIMENSIONS ONLY. (DEFINED IN SECTION 4.4 2.2).
3. S'/m IS DEFINED AS THE SUBSIDENCE FACTOR IN SECTION 4.4.2.
4. BASED ON DATA FROM KARMIS, 1984a.

FIGURE 3.3 RELATIONSHIP BETWEEN SUBSIDENCE FACTOR, PERCENT EXTRACTION AND OVERBURDEN LITHOLOGY FOR ROOM-AND-PILLAR MINES IN THE EASTERN UNITED STATES

Even though the curves in Figure 3.3 provide a general sense of the amount of subsidence expected where room-and-pillar mining produces intermediate to high extraction, the curves give no indication of the time at which subsidence will occur (whether concurrent with mining or sometime after), nor to the precise location and geometry of the subsidence trough nor to the time-dependent nature of the subsidence process once it begins. These uncertainties arise primarily in association with the intermediate range of extraction because of the uncontrolled and often delayed nature of the failure process that produces subsidence under those circumstances.

Data compiled by Hunt (1980) for Illinois, where partial extraction room-and-pillar mining was conducted almost exclusively until about 20 years ago, illustrate that (1) the subsidence factor in cases of unplanned subsidence approaches and sometimes equals that above active mines where planned subsidence is practiced, and, (2) the associated ground slope, curvature and strain similarly approach the values for active mines. The numerous incidents of subsidence that sporadically occur each year above old mines in the Greater Pittsburgh Area -- many abandoned more than fifty years ago — further attest to the vagaries of ground movements above partial extraction mines.

3.3 Significance of the Subsidence-Percent Extraction Relationship

The implication of these data is that ground movements associated with unplanned subsidence can be as significant as those associated with planned subsidence. The difference is, with unplanned subsidence, one cannot be certain as to when or where the subsidence will occur. Thus, in order to meet the requirements of subsidence control, the intermediate range of extractions must generally be avoided in modern mining. One should design either for no subsidence (Zone A-B) by providing permanent pillar support or for the maximum subsidence attainable relative to panel geometry and overburden lithology (Zone C-D), by extracting virtually all of the coal and causing subsidence to take place concurrently with mining.

Section 4, "Planned Subsidence," which follows, identifies the parameters that are customarily used to characterize the subsidence trough and describes available methods to estimate these parameters prior to mining. Section 5, "Mining Methods to Deal with Subsidence" identifies design techniques that can be employed to achieve predictable subsidence or prevent subsidence.

4.0 PLANNED SUBSIDENCE

CONTENTS

4.1 Introduction

The determination of the effect of planned subsidences may contain the pre-mining estimates of the following:

1. The anticipated maximum subsidence—the largest ground surface settlement that is expected to accompany mining;

2. The anticipated size and location of the subsidence trough--a map outline of the area where mining-induced ground movements are expected to take place; and

3. The anticipated ground surface distortion—a cross sectional profile through the expected subsidence trough and estimates of the maximum ground slope, the maximum ground surface curvature and the maximum ground strain that are expected to accompany mining.

The occurrence of planned subsidence and the estimation of these parameters are discussed in the following three subsections:

- Development of the subsidence trough during mining (Sec. 4.2);

- Definitions of the principal parameters that characterize the subsidence trough (Sec. 4.3);

- o Available methods for making the required pre-mining estimates of maximum subsidence, anticipated size and location of the subsidence trough and anticipated ground surface distortion (Sec. 4.4); and

Examples illustrating the methods of estimation, which are interspersed throughout the chapter.

Further considerations of planned subsidence relating to the layout and the mining of panels to limit ground surface deformations are discussed in a later section of the manual (Section 5.2).

4.2 Development of the Subsidence Trough During Mining

4.2.1 Characteristic Profiles. A subsidence trough is a dish-shaped depression that develops above the mined-out area and progressively enlarges horizontally and vertically as coal support is systematically removed from beneath. A trough is generally characterized by stationary surface profiles in the longitudinal and transverse directions and by a non-stationary "dynamic" ground surface profile ("traveling wave") that accompanies the mine face in its passage from one end of the mine panel to the other (Figures 4.1 and 4.2).

A ground surface profile can be likened to a line drawn across the top surface of a deflecting plate. Increasing the span between the supports increases the deflection of the plate (and modifies the profile) until eventually the supports are so far apart that the underside of the plate comes into contact with the floor. Increasing the span still further results in a larger segment of the plate coming into contact with the floor but no greater deflection of the plate along the area of contact. In a similar way, increasing the size of a mined-out area produces more and more subsidence until critical panel dimensions are achieved beyond which the maximum subsidence (the maximum vertical deflection) does not increase. These concepts are discussed further in the following sections.

4.2.2. Vertical Movements

4.2.2.1. Longitudinal Profile. The longitudinal profile is drawn along the panel centerline where the ground movements in the direction of mining are most pronounced (greatest subsidence, slope, strain, curvature). The segment of the longitudinal profile draping over the forward abutment—that is, draping over the coal pillars beyond the face in the direction of mining—is termed the subsidence development and describes the vertical movement experienced by each point at ground surface as it is undermined. The subsidence development curve characteristically consists of three distinct segments (Figure 4.3A):

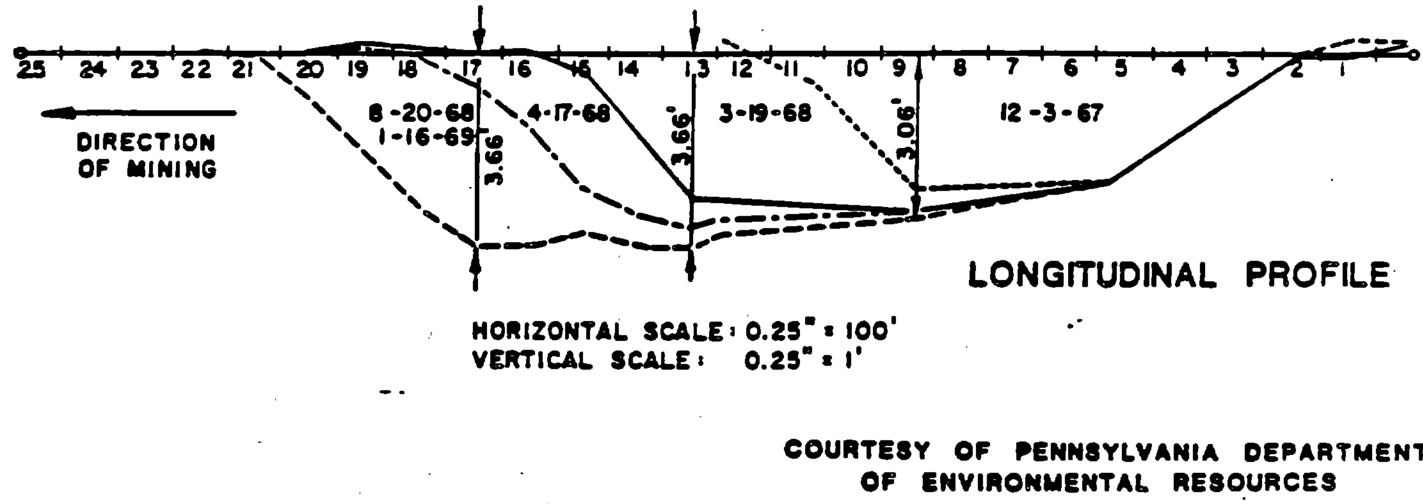


FIGURE 4.1 CROSS SECTION OF SUBSIDENCE TROUGH

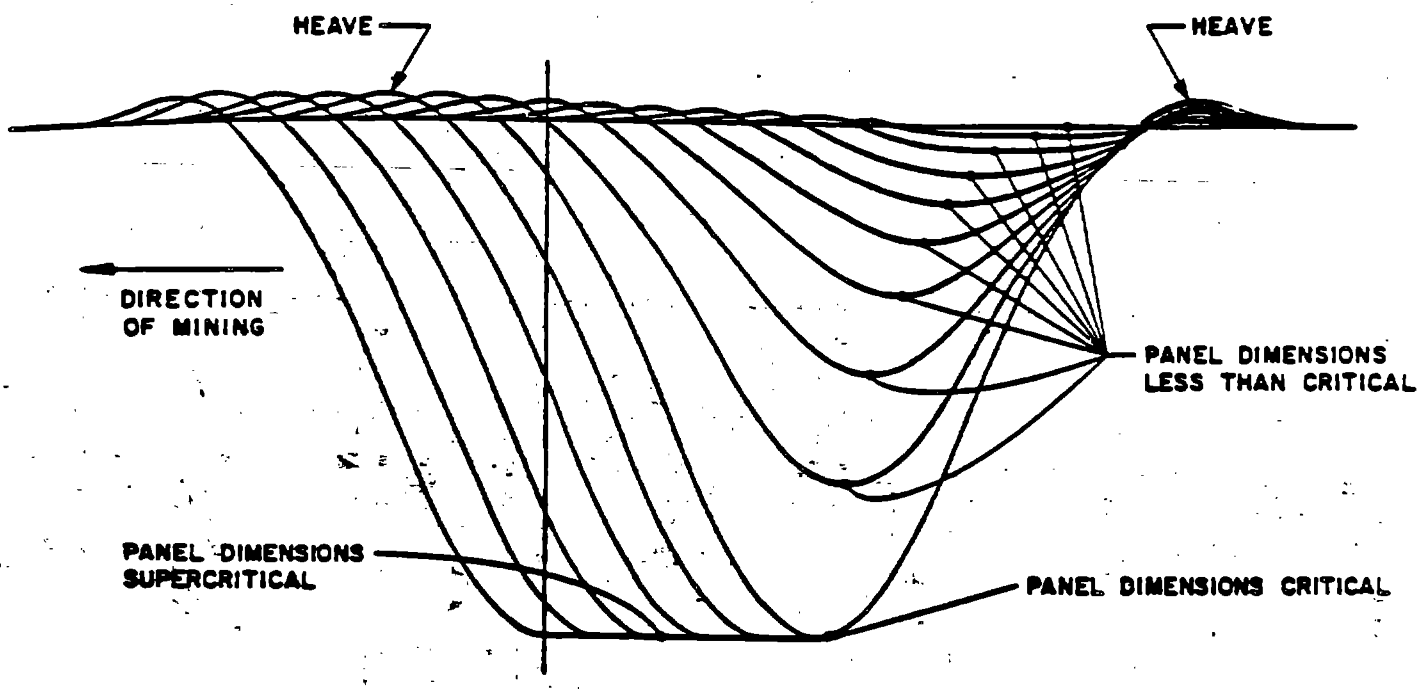
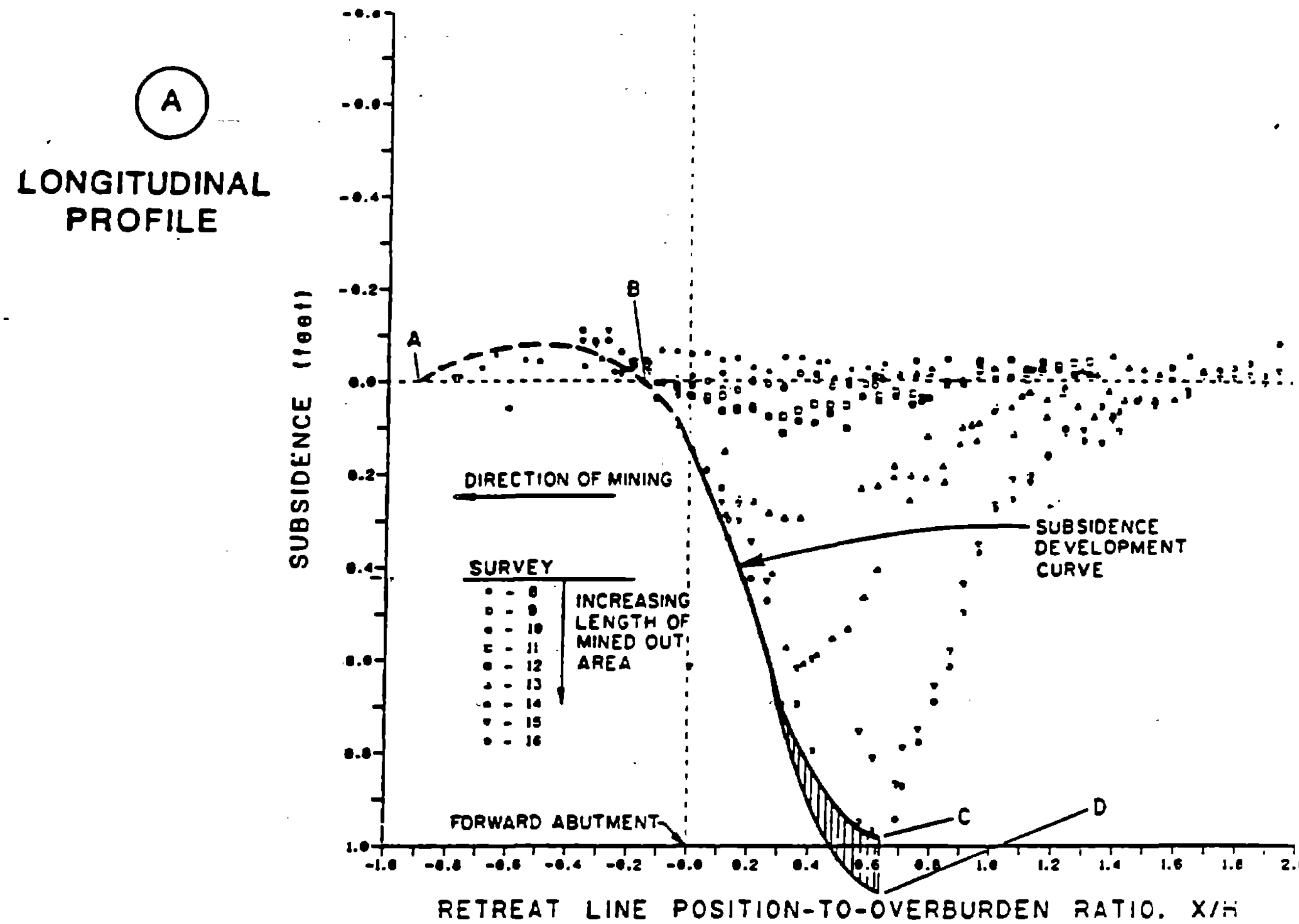


FIGURE 4.2 DYNAMIC GROUND SURFACE PROFILE



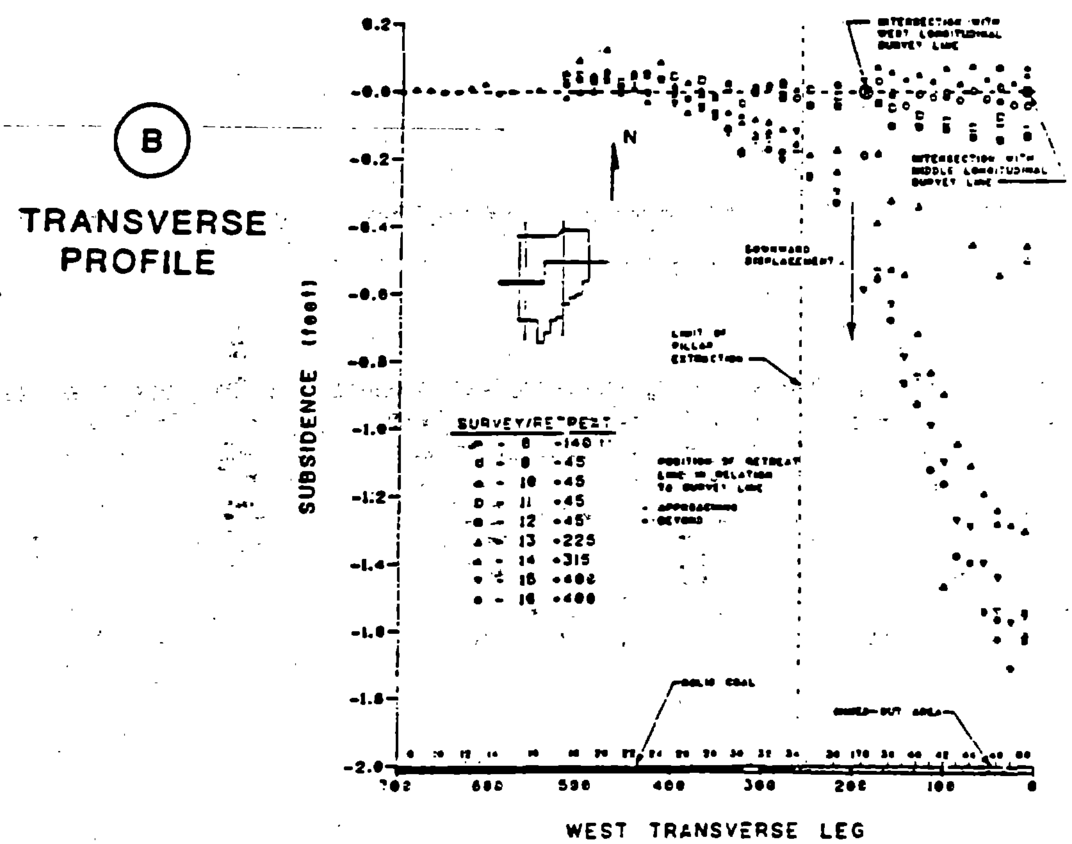


FIGURE 4.3 GROUND SURFACE PROFILES

- Heave zone (A-B);
- Subsidence zone (B-C);
- Residual Subsidence zone (B-C-D);

Consider a point on the ground surface. When the face has approached to within distance A of the point, the point begins to rise, or heave. The point continues to rise as the face draws nearer and reaches a maximum of an inch or two. As the face draws still closer, the point commences to move downward and achieves its pre-mining elevation once again when the face lies at a distance C from the point. The point has moved below its initial elevation by the time the face is directly beneath the point and continues to move downward in almost direct proportion to the distance the abutment has traveled beyond the point. The subsidence is nearly complete by the time the face has reached distance C from the point. Further movement C-D is residual—time-dependent creep deformations that take place after mining is finished. Residual movements can be influenced by changing conditions, such as flooding of the mine, which may alter the properties of the rock materials years after the completion of mining.

The shape of the subsidence development curve at any site is governed by the mechanical properties of the overburden and by the stiffness of the coal support at mine level. Figure 4.4 shows a subsidence development curve for a longwall panel.

The ground surface movements above the rear abutment, under ideal circumstances, are identical to those above the forward abutment. The ground surface heaves locally, if not generally. Long term creep and settlement may reduce the heave or eliminate it altogether.

4.2.2.2 Transverse Profile. The transverse profile is drawn across the short dimension of the panel, perpendicular to the longitudinal axis, and is often located along the panel bisector. It can be positioned nearer to the end of the panel, but no nearer than twice the overburden thickness if the profile is to be representative of the maximum ground surface deformation in the transverse direction.

Vertical ground movements along a transverse section often take place (but may not always be noticed) when the face is as far distant as 0.5 the thickness of the overburden 'H' from the section line. These initial, relatively subtle movements are generally associated with the passage of the heave zone at the leading edge of the traveling wave. More commonly, ground movements are not recognized until the face has approached to within 0.25H of the section line, at which point the ground surface begins subsiding below the original ground surface elevation. Movements then continue systematically downward as the face passes beneath and then beyond the section line

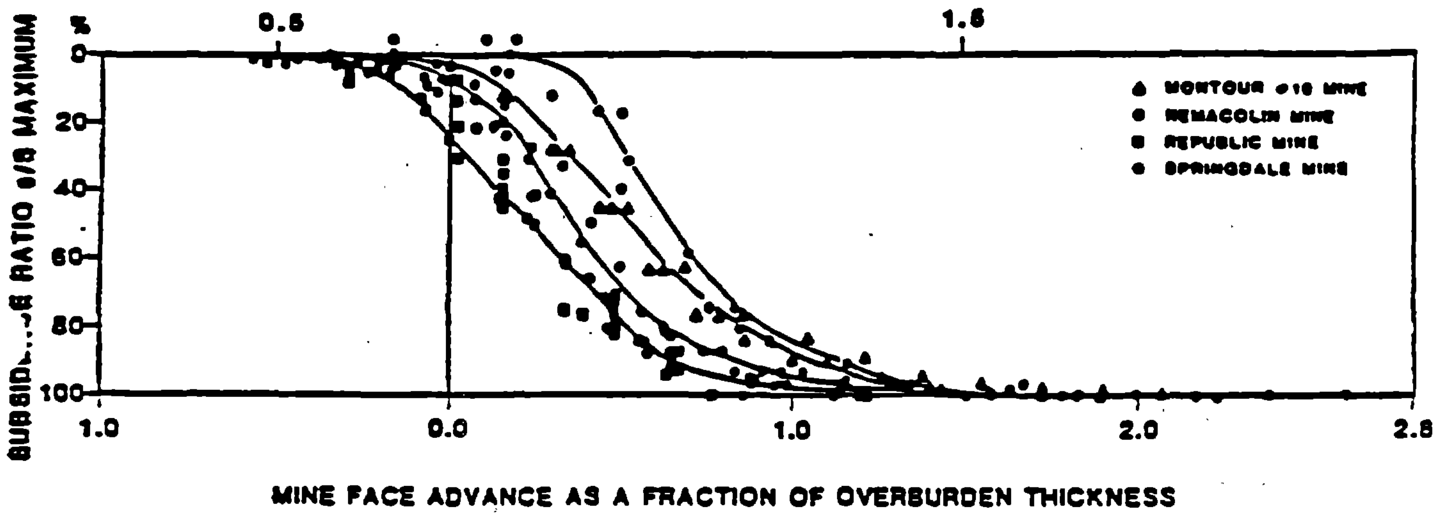


FIGURE 4.4 SUBSIDENCE DEVELOPMENT CURVES

(Figure 4.3B). The movements are generally complete when the face has passed 1.5H to 2H beyond the section line. (This is the rationale for locating the transverse profile line no closer than 2H to the end of a panel).

4.2.3 Horizontal Movements. The vertical motion of each point at ground surface is inevitably accompanied by horizontal movement. The pattern of horizontal movements, shown schematically in Figure 4.5, represents the migration of ground surface points towards the center of the subsidence as the face progresses across the panel. Ground around the the panel is said to be "drawn" toward the panel.

The horizontal movement at a particular point is commonly 10 to 40 percent of the corresponding vertical movement and is related to and can be estimated from the corresponding slope of the subsidence trough. Horizontal displacements in combination with ground slope, curvature and strain determined along longitudinal and transverse profiles are customarily used to assess the potential for mining-related damage to surface structures. The two-dimensional characterization of ground movements is, in fact, a dramatic simplification of a rather complex three-dimensional pattern of ground movements, that can produce twisting (racking) of surface structures. A representation of this three-dimensional pattern is presented in Figure 4.5. Current practice is not so sophisticated as to fully take these movements into account.

4.3 Definitions of Principal Parameters that Characterize the Subsidence Trough

The following parameters are commonly used to describe the geometry of a subsidence trough. All angles lie in a vertical plane normal to one of the edges of the mine panel (Figure 4.6). Ideally, the angles are constant for a particular mine panel and for a particular mine site. Generally, they are constant for neither.

a. Angle of Influence, α — the counterpart of the angle of draw that includes the heave zone bounding the subsidence trough; called the angle of advance influence when used in reference to the leading edge of the subsidence trough.

b. Angle of Draw, β — the angle with the vertical made by a straight line extending from the edge of the mined-out area to the nearest point at ground surface exhibiting no subsidence. This angle delineates the boundary of the subsidence trough, excluding any heave zone.

c. Angle of Break, δ — the angle with the vertical made by a straight line extending from the edge of the mined-out area to the point of maximum ground extension on the subsidence profile. (This term is somewhat archaic and is not often used).

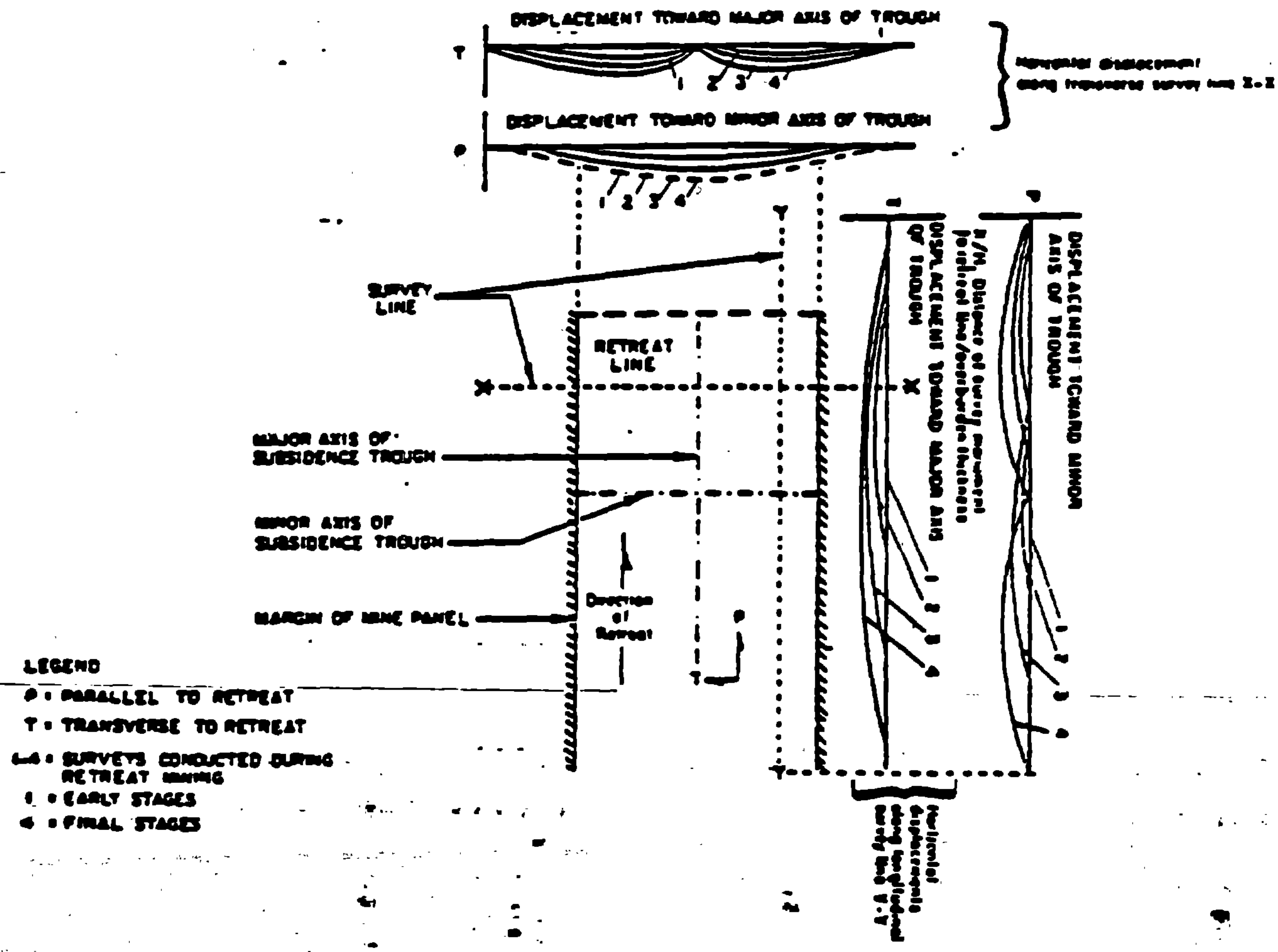
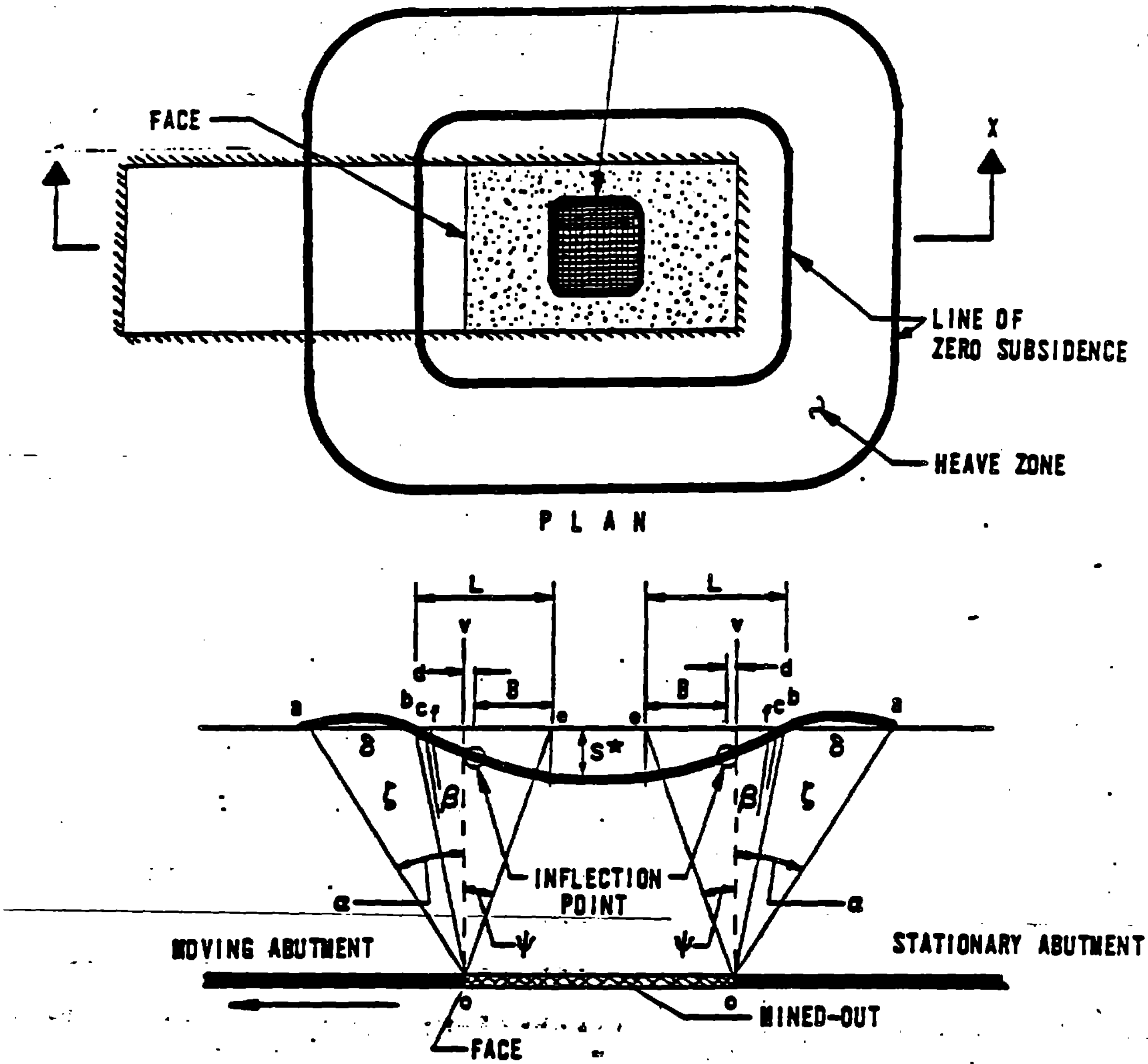


FIGURE 4.5 SCHEMATIC OF HORIZONTAL GROUND MOVEMENTS



α ANGLE OF ADVANCE INFLUENCE ∠aov

β ANGLE OF DRAW ∠bov

δ ANGLE OF BREAK ∠cov

ζ ANGLE OF DAMAGE ∠fov

ψ ANGLE OF COMPLETE MINING ∠eov

NOTE: IDEALLY THE PARAMETERS ARE CONSTANT AROUND THE PERIMETER OF THE TROUGH, OFTEN THEY ARE NOT.

S* MAXIMUM SUBSIDENCE ALONG PROFILE
= S_o, MAXIMUM POSSIBLE SUBSIDENCE FOR THE CASE SHOWN

B DISTANCE BETWEEN INFLECTION POINT AND NEAREST POINT OF MAXIMUM SUBSIDENCE.

d DISTANCE BETWEEN INFLECTION POIN AND EDGE OF MINE PANEL.

L DISTANCE BETWEEN EDGE OF TROUGH (ZERO SUBSIDENCE) AND NEAREST POINT OF MAXIMUM SUBSIDENCE.

FIGURE 4.6 PRINCIPAL PARAMETERS THAT CHARACTERIZE THE SUBSIDENCE TROUGH

d. Angle of Damage — the angle with the vertical made by a straight line extending from the edge of the mined-out area to the nearest point on the subsidence profile that separates the zone of mild ground movements from the zone of ground movements that could potentially damage a surface structure. This term must be used with caution since the amount of ground slope, ground curvature or ground strain that might cause damage varies between types of structures. (Without specification as to the type(s) of structure(s), the angle of damage value is ambiguous.)

e. Angle of Complete Mining, — the angle with the vertical made by a straight line extending from the edge of the mined-out area to the nearest point at ground surface exhibiting maximum subsidence. In some cases it equals the angle of draw, but more often is smaller.

f. Dimension B — the horizontal distance from the inflection point of the subsidence profile—the point where the curvature of the profile changes from concave up to concave down—to the nearest point of maximum subsidence on the subsidence profile. Used with the hyperbolic tangent profile function (Section 4.4.4.1).

g. Dimension d — the offset distance of the inflection point from the edge of the panel.

h. Dimension L — the horizontal distance between the lip of the trough (zero subsidence) and the point of maximum subsidence nearest the edge of the panel. In the case of a panel of critical or subcritical width, this represents the half-width of the subsidence trough.

4.4 Available Methods for Making the Required Pre-mining Estimates

4.4.1 Potential Limitations. We wish to point out at this juncture that the only meaningful approach to making pre-mining estimates of subsidence and related parameters is to employ empirical relationships based on subsidence data collected regionally or country-wide. Much of this section of the manual is devoted to describing such relationships, and the reader must be alert to their potential limitations:

- Whereas the mechanics of subsidence is essentially the same regardless of the geographic location of the mine, the quantity of available subsidence data varies widely from coal field to coal field. (The coal fields are shown in Figure 4.7.) By far the largest body of data relates to the eastern

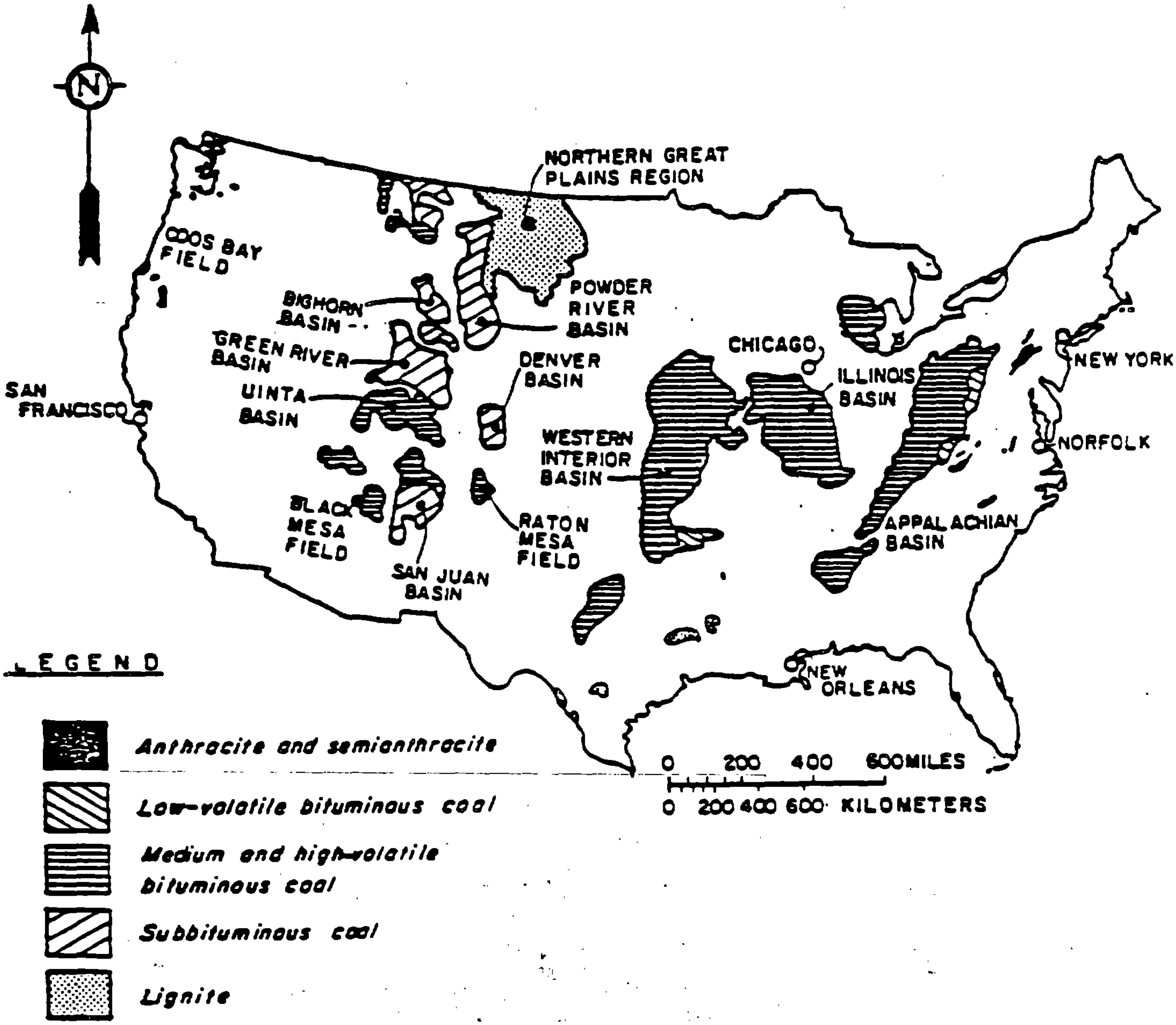


FIGURE 4.7 COAL FIELDS IN THE UNITED STATES (AFTER AVERITT, 1975)

coal fields (particularly the northern Appalachian); a lesser body to the Interior Coal Field (primarily the Illinois Basin); and a still lesser amount to the western coal fields. The information presented herein necessarily retains this geographical bias.

The user of this manual may, for lack of better information, be forced to estimate subsidence or other parameters using country-wide generalizations or relationships developed outside of his geographical area. The user is advised to state the basis for any estimates or calculations in his permit application.

- o Empirical relationships are generally simplified representations of complex connections between parameters. Published empirical relationships often fail to show the data on which they are based and may suggest a degree of exactness (and validity) that does not exist. The precision of any calculation discussed herein is certainly no better than two significant figures (if that—e.g., subsidence of 2.6 feet rather than 2.625 feet. And the uncertainty in any calculation is at least ten percent. One should view any calculated value in terms of a margin of uncertainty—e.g., subsidence of 2.6 feet +/- 10%).

  In general, the user of this manual is advised to compare answers from several methods wherever possible and to indicate a range of possible values for any parameter.

- o Site conditions may sometimes present complexities in the predictive process that are not addressed by the methods presented herein—for example, great variations in overburden thickness that may indicate pronounced non-uniformities in the subsidence profile. Such situations may require the attention of a subsidence specialist using methods not covered in this manual.

4.4.2 Maximum Subsidence. The ground surface settlement at the deepest point of the subsidence trough is customarily expressed in terms of the Subsidence Factor 'a' and the mined thickness of coal (the mine height) 'm':

$$S^{*} = a \cdot m \qquad (4.1)$$

where 'a' is dimensionless and ≤ 1, and 'm' is in dimensions of length (e.g. feet), as is the subsidence.

The Subsidence Factor is governed by the composition, strength and deformability of the overburden strata, the dimensions of the mined-out area, the thickness of the overburden, the degree of caving, the compressibility of the caved material and other factors. In the United States, the Subsidence Factor has not been found to exceed 0.85 and is generally less. The range of values attained by the Subsidence Factor in the United States is compared to that in the United Kingdom in Figure 4.8.

4.4.2.1 Effect on 'a' of Overburden Composition. The subsidence factor decreases in value with increase in the proportion of strong, stiff, "competent" rock units composing the overburden [Abel and Lee (1980), Karmis et al., (1981), Peng and Geng (1983), and Tandanand and Powell (1982)].

Values of the Subsidence Factor for 16 longwall panels in the Northern Appalachian Coal Field have been found to decrease with increase in 'n', where 'n' is the proportion by thickness of sandstone and limestone in the overburden (Tandanand and Powell, 1982):

$$a = 0.94 - 1.5n. \quad (4.2)$$

This expression is claimed to yield estimates within 25 percent of measured values of a. The mine panels included in the analysis ranged in width from 380 to 610 feet and in depth from 215 to 800 feet (0.513 < width-to-depth ratio, W/H < 2.09). Expressions for Subsidence Factor presented in the following subsections attempt to account explicitly for panel size and overburden composition.

4.4.2.2 Effect of Width-to-Depth Ration (W/H) on 'a'. The Subsidence Factor increases in value as the width and length of the panel increase relative to the mine depth. When the mine panel achieves or exceeds certain minimum ("critical") dimensions, which can be determined by the method presented in Subsection 4.4.3.2, a limiting maximum value of 'a' is attained. The Subsidence Factor under such conditions is governed primarily by the composition and properties of the overburden strata.

Figure 4.9 presents an empirical relationship between Subsidence Factor, the width-to-depth ratio of the mine panel and the combined percent sandstone and limestone ("hard rock") in the overburden based on 34 longwall cases from the Northern Appalachian Coal Field (Karmis, et al., 1983). The relationship does not explicitly account for panel length.

Figure 4.10A presents values of the Subsidence Factor documented for longwall, high extraction retreat (pillar retreat) and room-and-pillar cases in the Illinois sector of the Interior Coal Province (Hunt, 1980; Bauer and Hunt, 1981). Values of the Subsidence Factor for active mining--longwall and (pillar) retreat--represent primarily subcritical conditions and increase pronouncedly with increase in width-to-depth ratio. The width-to-depth ratio at which critical panel dimensions are achieved is not apparent. Because of the unreliability in using these data to estimate the Subsidence

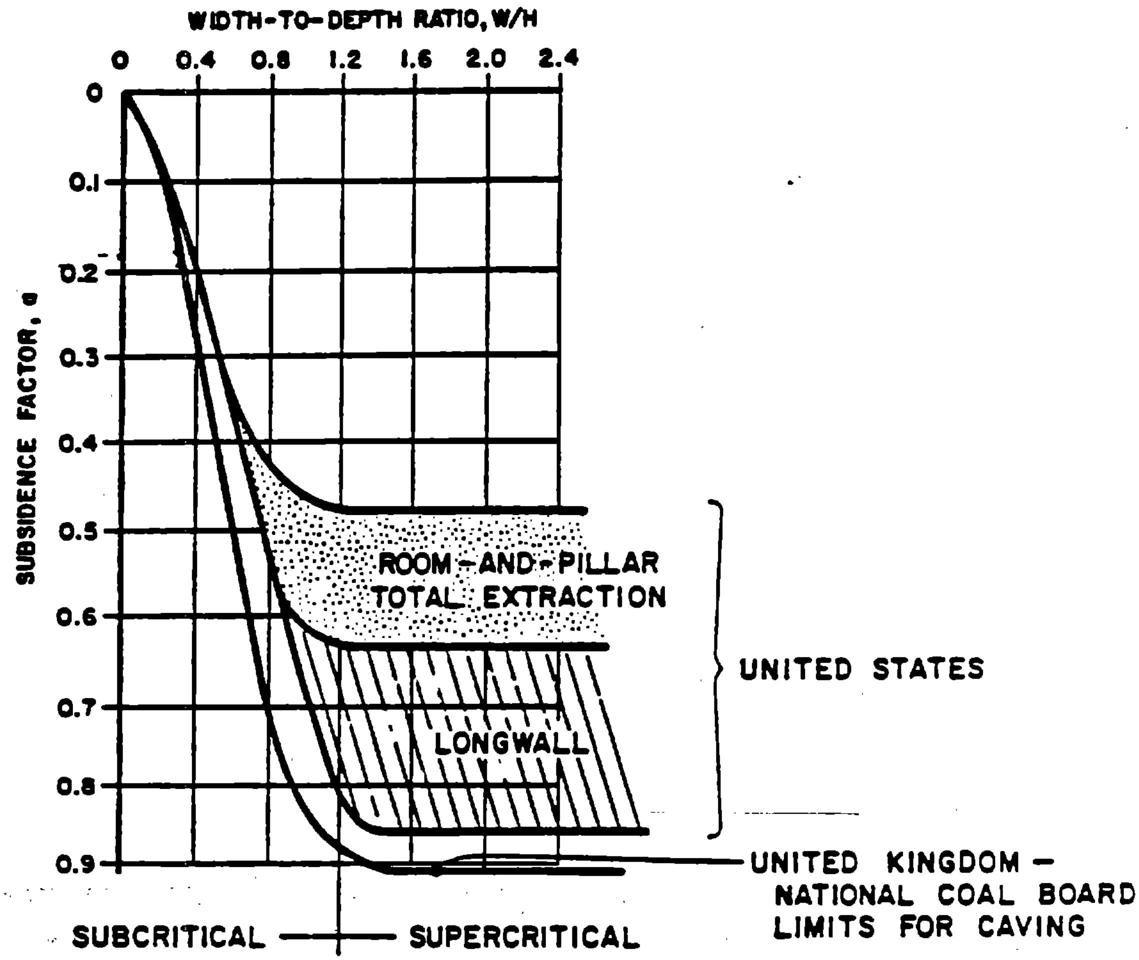


FIGURE 4.8 GENERAL RELATIONSHIP BETWEEN SUBSIDENCE FACTOR AND WIDTH-TO-DEPTH RATIO OF MINE PANEL

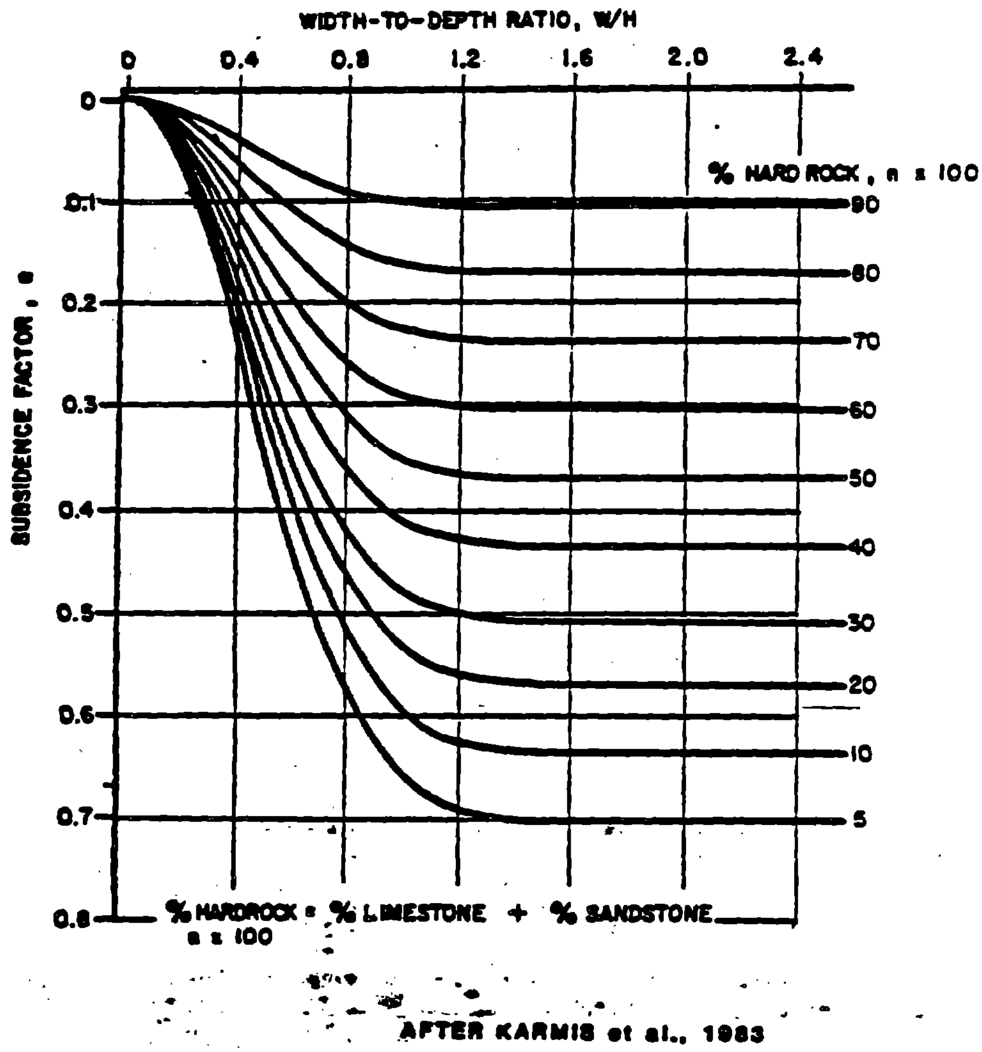


FIGURE 4.9 SUBSIDENCE FACTOR, AS A FUNCTION OF WIDTH-TO-DEPTH RATIO OF THE MINE PANEL AND THE PERCENT HARDROCK IN THE OVERBURDEN

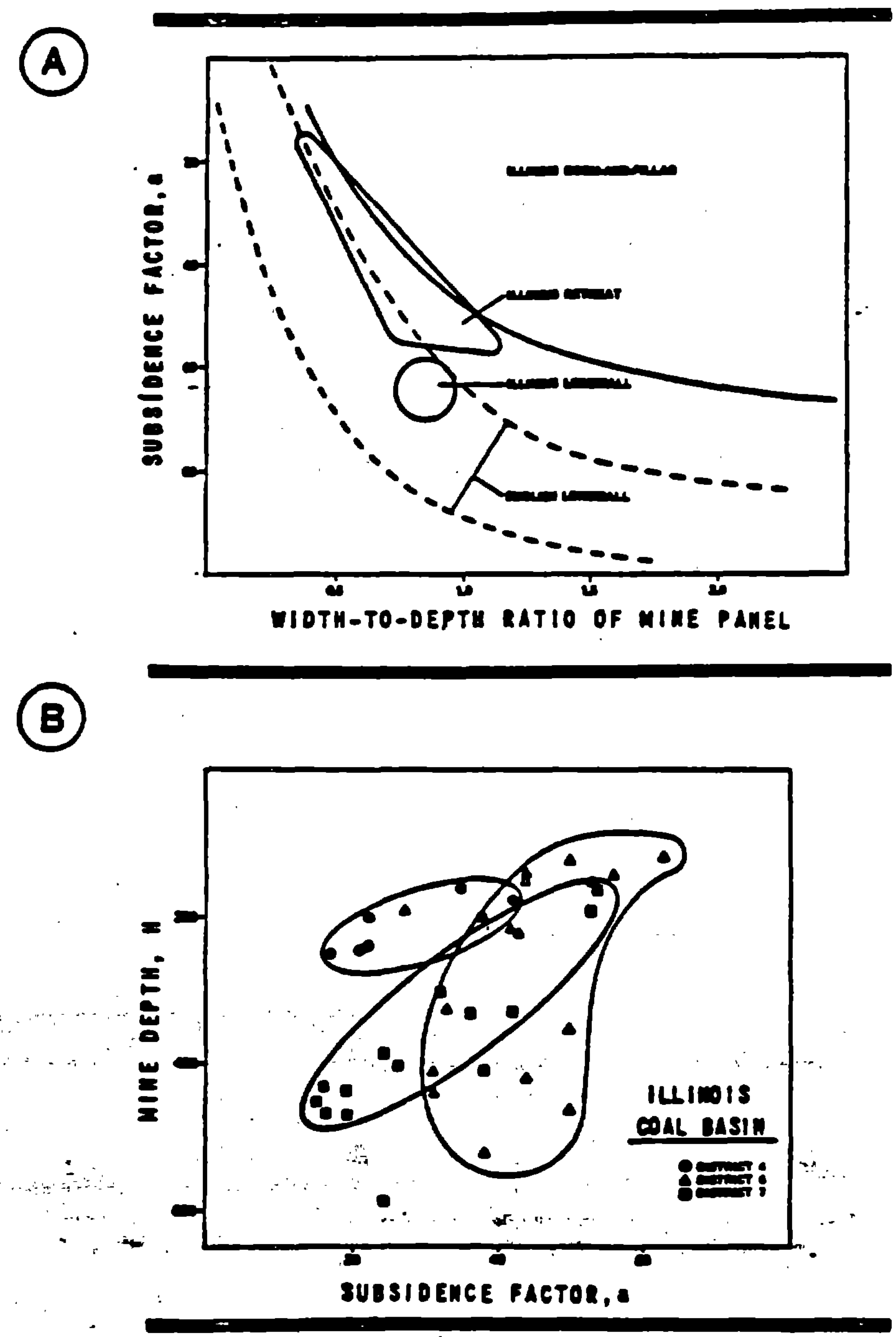


FIGURE 4.10 RELATIONSHIP BETWEEN SUBSIDENCE FACTOR AND WIDTH–TO–DEPTH RATIO OF THE MINE PANEL FOR ACTIVE/ABANDONED MINES IN THE INTERIOR COAL FIELD – ILLINOIS (AFTER BAUER AND HUNT, 1981)

Factor in Illinois for a particular width-to-depth ratio, the highest reasonable value of Subsidence Factor (e.g., a=0.7) should be assumed unless site specific information suggests otherwise.

Variations in overburden composition are thought responsible fr differences in the Subsidence Factor between mining districts in Illinois (Figure 4.10B). As in the Northern Appalachian Coal field, overburden with the greatest proportion of competent beds tends to exhibit the lowest values of Subsidence Factor, although the Illinois data are not specific in this regard.

4.4.2.3 Effect of both Width-to-Depth Ratio and Length-to-Depth Ratio on 'a'. The absolute maximum Subsidence Factor—the subsidence factor for critical and supercritical panel dimensions—can be estimated for site specific overburden composition from the following expression, based on an analysis by Peng and Geng (1983) of forty subsidences cases from the Northern Appalachian Coal Field:

$$a_o = 0.5\ (0.9 + P) \qquad (4.3)$$

where P is the Combined Strata Coefficient, reflecting the overall competence of the overburden on the basis of the weighted average rock strength,

$$P = \Sigma hQ/\Sigma h \qquad (4.4)$$

Q is the Stratum Property Coefficient (Figure 4.11) and h is the respective thickness of each stratum in the overburden. Note that the total overburden thickness $H = \Sigma h$.

Subsidence Factor a_o, when used in conjunction with Equation 4.1, yields what is sometimes called the "absolute maximum subsidence", which is designated as S_o.

For mine panels of subcritical length, subcritical width or both, the Subsidence Factor, and hence the maximum subsidence, is generally less than for panels of critical or supercritical dimensions, as reflected by the left-hand portion of the relationship between subsidence and panel width-to-depth ratio (Figures 4.8 and 4.9).

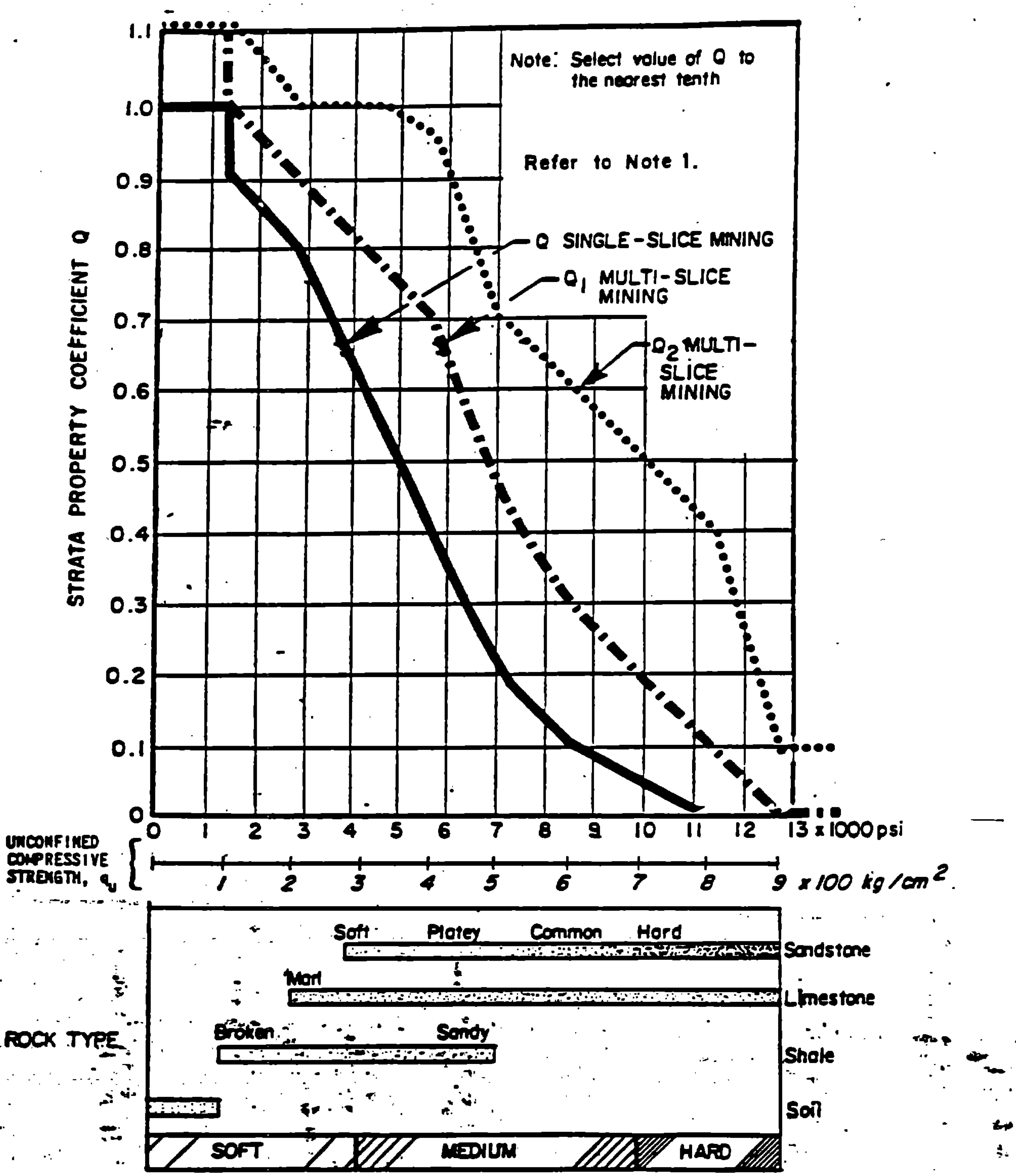
Peng and Geng (1983) propose the following expression for estimating maximum subsidence under subcritical conditions:

$$S^* = a'm \qquad (4.5a)$$

$$a' = a_o C \qquad (4.5b)$$

$$C = \sqrt{[(Ll/Lc)(Lw/Lc)]} \qquad (4.5c)$$

where a_o is the absolute maximum Subsidence Factor
a' is the Subsidence Factor adjusted for panel geometry



NOTE: 1. SECTION 2.2 DISTINGUISHES BETWEEN SINGLE-SLICE AND MULTIPLE-SLICE MINING. CONVENTIONAL LONGWALL MINING IS SINGLE-SLICE.

2. BASED ON DATA FROM PENG AND GENG, 1983.

3. USE OF THIS CHART IS ILLUSTRATED BY EXAMPLE 1, FIGURE 4.13.

FIGURE 4.11 STRATUM PROPERTY COEFFICIENT AS A FUNCTION OF ROCK TYPE AND STRENGTH

m is the mined thickness of coal
Ll is the length of the mined-out area
Lw is the width of the mined-out area, and
Lc is the critical dimension (for both width and length) required for absolute maximum subsidence (defined in Section 4.4.3.2); and
C is a parameter that is used to adjust the Subsidence Factor for panel geometry, with the condition that Ll/Lc and Lw/Lc $\leq$ 1. Values of C are presented graphically in Figure 4.12. For Lw/Lc > 0.65, the second of the two terms in brackets equals unity.

The use of Eq. 4.5 is illustrated in Example 1, Figure 4.13.

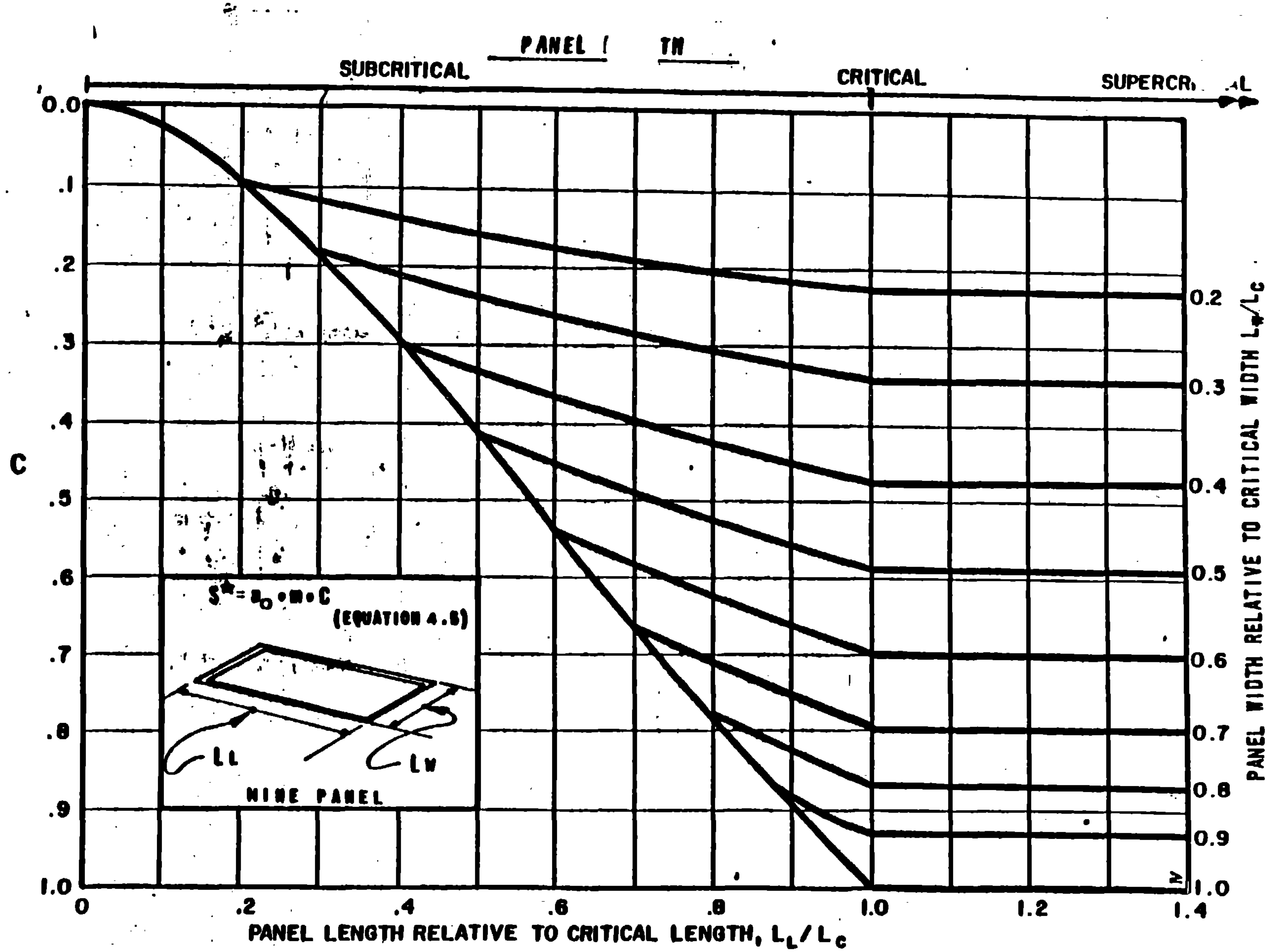
4.4.2.4 Other Factors Affecting 'a'. The subsidence factor for a given panel width increases somewhat with increasing depth, Kohli, et al. (1980). The effect is minor and is probably due to the compression of broken rock under the weight of the over burden. Possibly, some variation in the Subsidence Factor is also related to local variations in mine height (Munson and Eichfeld, 1980).

Subsidence above pillar retreat panels is sometimes found to be less than above longwall panels of similar dimensions, probably due to the presence of remnant pillar stumps within the room-and-pillar retreat panels and the somewhat more discontinuous manner in which the roof caves to the floor (Refer to Figure 4.8). An estimate of the Subsidence Factor for a room-and-pillar retreat mine that is based upon longwall relationships is expected to be conservative (that is, equal to or greater than the actual value).

4.4.3 Size and Location of the Subsidence Trough

4.4.3.1 General. A subsidence trough above an active mine encompasses the area that has been mined out as well as a border zone that may extend a distance of 20 to 50 percent of the overburden thickness beyond the margin of the mined-out area. The distance beyond the margin is delimited by the angle of draw which, in turn, is dictated by the mechanical properties of the overburden and the state of stress in the rock mass. The angle of draw may vary in size around the perimeter of the panel and may change with time. Once "critical" plan dimensions have been achieved, the trough becomes no deeper with further mining, except for residual movements. Methods for estimating critical panel dimensions and angle of draw are discussed below.

4.4.3.2 Critical Panel Dimensions. The mine panel has reached critical dimensions when a further increase in its width and length results in no increase in maximum subsidence within the trough. Of course, any further increase in dimensions of the mined-out area produces a corresponding increase in width and length of the trough



NOTE: 1. BASED ON EQUATION 4.6 PROPOSED BY PENG AND GENG, 1983.
2. USE OF THIS CHART IS ILLUSTRATED BY EXAMPLE 1, FIGURE 4.13.

FIGURE 4.12 RELATIONSHIP OF SUBSIDENCE TO WIDTH AND LENGTH OF MINE PANEL

Problem Total extraction mining (longwall or room-and-pillar retreat) is to be conducted in a 500-foot-wide, 1200-foot-long mine panel in a 6-foot seam located 600 feet below ground surface. The overburden consists of six units which are, in order, from ground surface to mine level: 5 feet of soil; 95 feet of sandy shale; 5 feet of limestone; 195 feet of sandstone; 100 feet of sandy shale; 175 feet of claystone; and 25 feet of carbonaceous shale. The laboratory uniaxial compressive strength of the claystone is on the order of 1200 psi; both shales, 5200 psi; the limestone, 8000 psi, the sandstone, 9000 psi; and the carbonaceous shale, 3500 psi. The strength of the soil is negligible.

o Estimate the maximum subsidence S* above the mine panel.

Solution:

1. Characterize the overburden in terms of the lithology (the rock composition).

   This is necessary because the Subsidence Factor is governed partially by lithology. Use the Combined Strata Coefficient, $P=\Sigma hQ/\Sigma h$ (Equation 4.4). The Stratum Property Coefficient Q for each overburden unit is determined from Figure 4.11 using the available laboratory strength data. (Oftentimes, in the absence of laboratory data, the stratum property coefficients are sufficiently well estimated from a visual classification of the rock core.)

   The Combined Strata Coefficient P is computed to be [(1x5 feet of soil) + (0.5x195 feet of shale) + (0.15x5 feet of limestone) + (0.1 x 195 feet of sandstone + (1 x 175 feet of claystone) + (0.7x25 feet of carbonaceous shale)]/600 feet = 315.25/600 feet = 0.53.

2. Compute the Absolute Maximum Subsidence Factor, a_o.

   From the value of P, the Absolute Maximum Subsidence Factor a_o is determined to be 0.72, using $a_o = 0.5(0.9+P)$, Equation 4.3. This subsidence factor applies to mine panels of critical and supercritical dimensions.

3. Compute the critical dimensions of the mine panel, Lc.

   The critical dimension Lc of the subject mine panel is found from Figure 4.14 to equal 840 feet. [Enter the figure with a_o=0.72 and exit with Lc/H=1.4. Multiply 1.4 by mine depth H=600 feet].

4. Compare the computed value of Lc with actual panel dimensions.

   The panel length Ll of 1200 feet exceeds Lc, while the panel width Lw of 500 feet does not. Thus, the subject mine panel is supercritical in length, but subcritical in width. Because of the subcritical panel width, the actual Subsidence Factor a' must be less than the Absolute Maximum Subsidence Factor a_o

5. Compute the Subsidence Factor, a'.

   Use Equation 4.5b and Figure 4.12. The respective ratios of width and length of the panel to the critical panel dimension are Lw/Lc=500/840=.60 and Ll/Lc =1200/840=1.43. Entering Figure 4.12 with these two ratios yields a C value of 0.7. From Equation 4.5b, $a' = a_o.C$ = 0.50.

   Since a' = 0.50 and the mine height m=6 feet, then the Maximum Subsidence S* equals a'.m = 0.50 x 6 = 3.0 feet

FIGURE 4.13 - EXAMPLE 1 - CALCULATION OF SUBSIDENCE FACTOR

This is the subsidence expected at the center of the subsidence trough. Subsidence elsewhere in the trough will be less and can be estimated from the ground surface profile (Section 4.4.4). As a point of interest, it will be noted that the particular conditions of the present problem also permit estimation of the maximum subsidence by way of Equation 4.2 and by Figure 4.9.

Alternate Solutions:

A. Consider Equation 4.2, ($a' = 0.94 - 1.5n$), an expression for the Subsidence Factor that accounts for the proportion of hard rock 'n' based on the combined thickness of sandstone and limestone. For the present case, W/H=0.83, which lies within the range of values on which Equation 4.2 is based, the value of n is computed to be [(195+5)/600]=0.333. The Subsidence Factor a' is then found to be [0.94-1.50(0.333)]=0.44. On this basis, the Maximum Subsidence S' is estimated to be 2.6 feet (Equation 4.1). This is within 15 percent of the value determined using Equation 4.5a.

B. Consider Figure 4.9 for another method of computing the maximum subsidence. For a W/H ratio of 0.83 and a % hard rock 'nx100' of 33.3, the Subsidence Factor a' is 0.40. On this basis, the Maximum Subsidence S' is estimated to be 2.4 feet (Equation 4.1). This is within 20 percent of the value determined using Equation 4.5a.

As an additional point of interest, it will be noted that, if the mine panel were of critical or supercritical dimensions, the maximum subsidence for the given geologic setting would be $S_o = a_o m = 4.3$ feet, about 40 percent more than expected for the subcritical mine panel considered in this example. It is clear that reducing the width of mine panel can significantly reduce the maximum subsidence. This is the basis of the narrow panel concept discussed in Section 5.2.2. Other methods are also available to limit subsidence. These are discussed in Chapter 5.

FIGURE 4.13 CONTINUED

and attendant vertical and horizontal movements in those portions of the trough where the maximum subsidence has not yet been achieved.

Past studies of U.S. subsidence data have suggested that critical panel dimensions in the Northern Appalachian Coal Field range between 1.11H (Chen and Peng, 1981) and 1.2H (Karmis et al., 1981), where H is the overburden thickness. This compares to 1.4H in the United Kingdom. More recent studies have recognized that critical panel dimensions are not constant, but, like the Subsidence Factor, depend upon overburden composition — the stronger and stiffer the overburden, the larger the critical panel dimensions. Peng and Geng (1983) suggest a near linear relationship between maximum Subsidence Factor a_0 and ratio of critical panel dimension to mine depth (Lc/H), as shown in Figure 4.14 for the Northern Appalachian Coal Field. Use of this relationship permits estimating the critical panel dimensions (critical width = critical length) on the basis of the mine depth H and the value of the Subsidence Factor a_0 computed from Equation 4.3. Critical panel dimensions have not been reported for other U.S. Coal Fields. In the absence of field data, the Peng-Geng pproach, being based on mechanical properties of the overburden, is expected to yield a reasonable first approximation of critical panel dimensions for other coal fields.

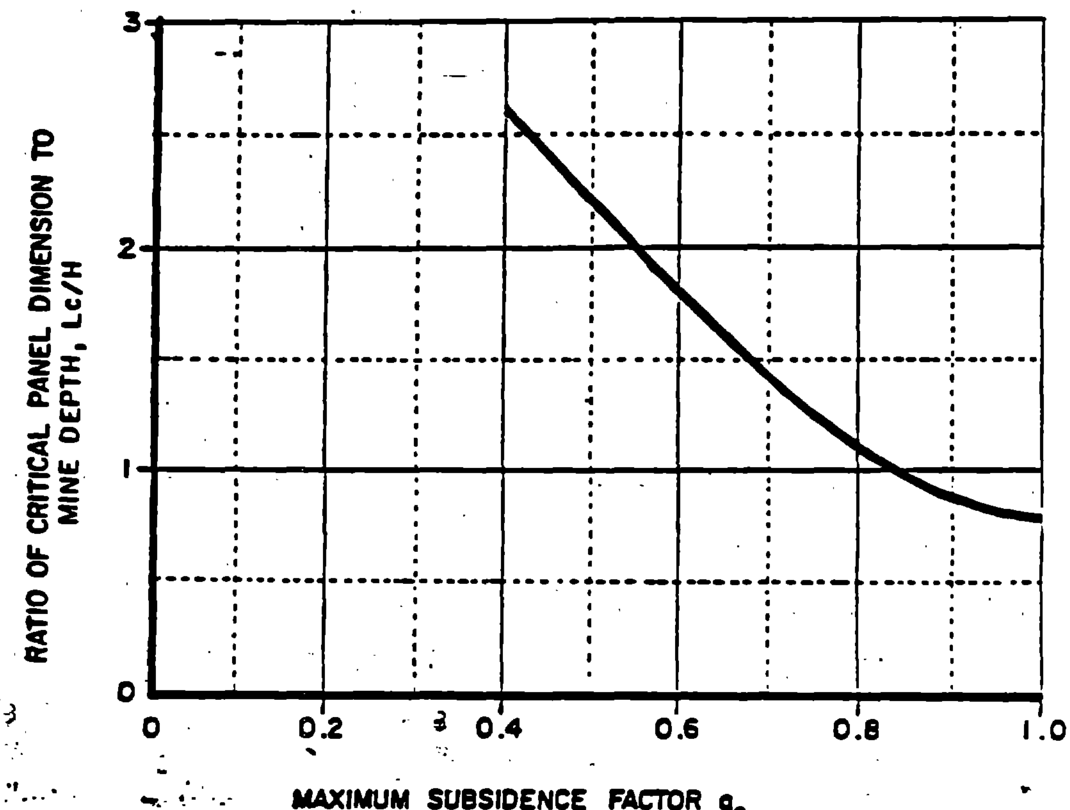
4.4.3.3 Angle of Drawer β. The angle of draw, unless stated otherwise, is determined from stationary subsidence profiles and in the United States has been found to range between 5 and 45 degrees, and most commonly between 10 and 35 degrees. No major distinction is apparent between angles of draw for longwall panels and those for room-and-pillar retreat.

Effect of Width-to-Depth Ratio on β. The angle of draw increases with increase in panel width-to-depth ratio and is customarily thought to reach a limiting value when critical panel dimensions are achieved (Karmis et al., 1983), Figure 4.15.

Effect of Overburden Compositon on β. Data world-wide suggest, in broad terms, that the thinner the soil mantle and the more competent the rock strata, the smaller is the angle of draw. Adamek and Jeran (1981) suggest that the bridging of competent strata in the upper interval of overburden may be responsible for angles of draw between 12 and 17 degrees in the Northern Appalachian Coal Field.

In estimating the angle of draw, Peng and Geng (1983) attempt to account for lithology of the overburden by way of the Subsidence Factor and also take into consideration overburden thickness and panel dimensions. For a panel whose length and width are critical or supercritical, they indicate the angle of draw in the Northern Appalachian Coal Field is given by

$$\beta o = 44 - 6a - 0.015H \tag{4.6}$$



NOTE:
a_0 is determined from equation 4.3, based on data from Peng & Geng, 1983.

FIGURE 4.14 RELATIONSHIP OF CRITICAL PANEL DIMENSION TO MAXIMUM SUBSIDENCE FACTOR AND MINE DEPTH

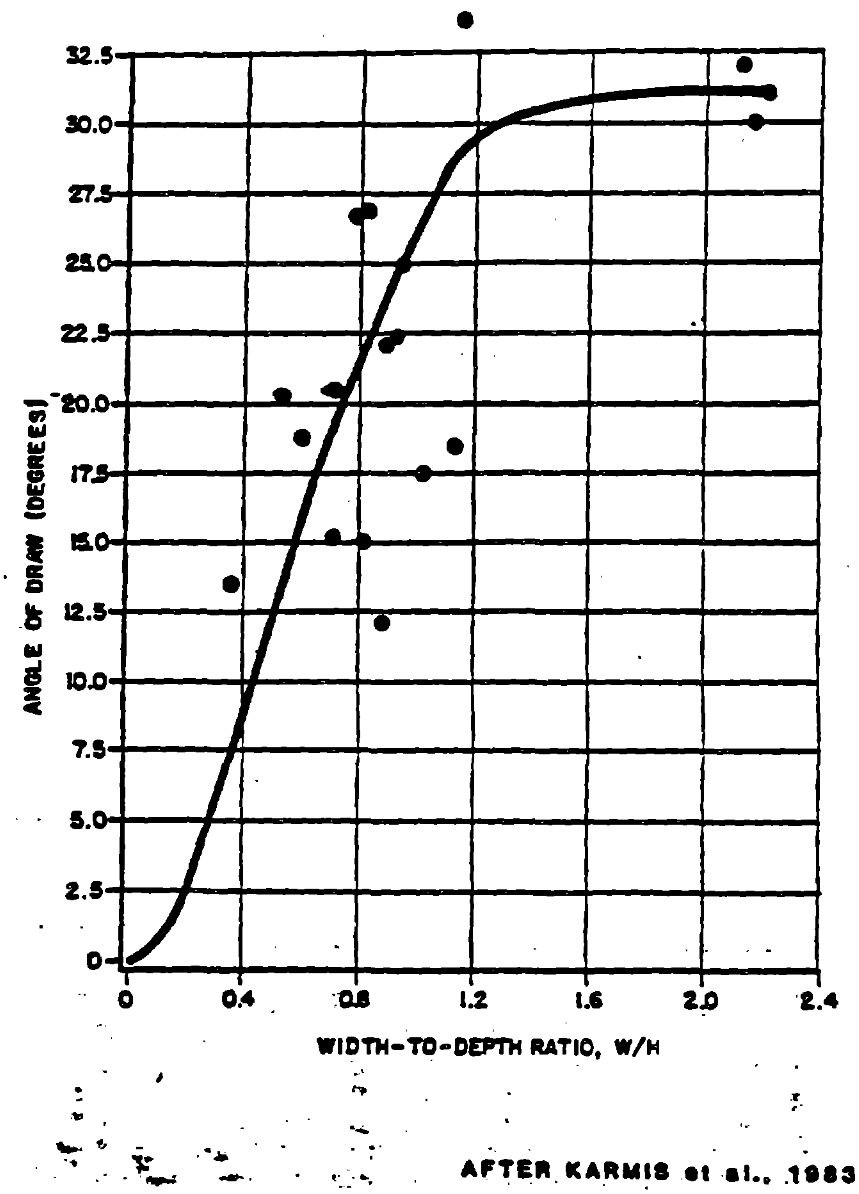


FIGURE 4.15 RELATIONSHIP OF ANGLE OF DRAW TO WIDTH-TO-DEPTH RATIO OF THE MINE PANEL

where 'a' is the Subsidence Factor, and 'H' is the overburden thickness.

For a panel whose length is critical or supercritical, but whose width is between 0.55 and 0.85 times the critical dimension, they indicate the angle of draw is given by

$$\beta = 38 - 6a - 0.015H \qquad (4.7)$$

Peng and Geng claim an uncertainty of 2 degrees (±) in estimates of angle of draw from Equations 4.6 and 4.7. (Be advised that both Equations 4.6 and 4.7 indicate that the angle of draw is larger the greater the competency of the rock. This is contrary to conventional wisdom. Care should be exercised in using these relationships to estimate angle of draw.)

In general, published data have not shown a strong correlation between angle of draw and lithology. Figure 4.16 is an example. The apparent absence of a trend may be due to one or more of the following factors: non-representative or poor information concerning lithology, poor measurements of angle of draw, failure to account for position of the strata in the rock sequence, failure to assess the weighted average overburden composition, failure to account for the dimensions of the mine panel, or failure to recognize that the angle of draw can vary with position around a panel even without significant variations in lithology.

With regard to the last point, Bruhn and Speck (1984) found the angle of draw to vary between 14 and 40 degrees at a single room-and-pillar retreat panel in northern West Virginia. With the benefit of direct observations at mine level, the variation could confidently be attributed to differences in support furnished by pillars around the perimeter of the mine panel. Floor heave and an associated loss of bearing capacity across a wide series of barrier and ventilation entry pillars along one side of the panel resulted in a large angle of draw in that area, whereas adequate bearing capacity along a narrow series of pillars on the opposite side of the panel resulted in a much smaller angle of draw. The writers suspect that much of the reported variation in angle of draw is due to differences in support along mine panel perimeters (including differences in the physical condition of any adjoining panel) and believe that no method for estimating angle of draw can be considered reliable that fails to account for panel boundary conditions. It follows that if pre-mining estimates of angle of draw are unreliable, then pre-mining estimates of the width or length of a prospective subsidence trough are similarly unreliable. This, in turn, lessens confidence in any estimate of the subsidence trough profile or derivative parameters for an area that is to be undermined. Conservatism in subsidence prediction is warranted.

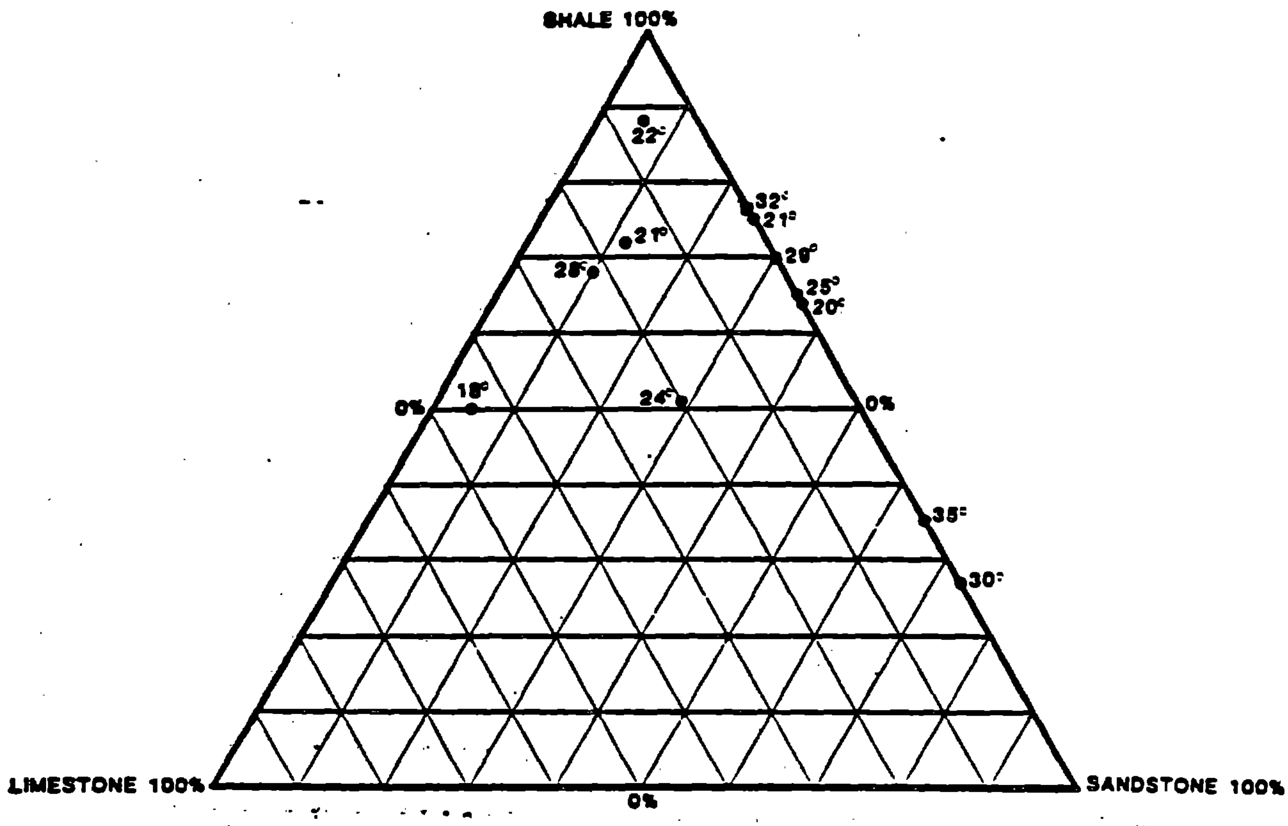


FIGURE 4.16 ANGLE OF DRAW COMPARED TO OVERBURDEN LITHOLOGY

4.4.4 Ground Surface Distortion

4.4.4.1 Ground Surface Profile. The ground surface settlement profile often resembles a broad inverted bell-shaped curve and commonly exhibits a heave zone around all or part of its perimeter. The profile furnishes a means for estimating the plan area of the subsidence trough as well as the geometric characteristics of the trough profile, which in turn, can be related to potential damage to structures at ground surface through relationships presented in a related eport entitled, "Development of Subsidence Damage Criteria", prepared for the OSMRE by Engineers International, Inc., 1985. A variety of analytical functions have been proposed in the United States and abroad to represent the subsidence profiles (Brauner, 1973).

For the Northern Appalachian Coal Field, Karmis, et al. (1983, 1984b) advocate use of a hyperbolic tangent function:

$$S(x) = 0.5 S^* [1-\tanh (Cx/B)] \qquad (4.8)$$

where x is the horizontal distance between a point on the profile and the origin, which is located at the inflection point—the point where the curvature changes from concave up to concave down;
- S^* is the maximum subsidence for the profile;
- B is the distance between the inflection point and the nearest point of maximum subsidence, S^*, and depends upon the W/H ratio of the panel, Table 4.1; and
- C is a constant equalling 1.4 for subcritical panels and 1.8 for critical.

Alternatively, the origin can be placed at the point of maximum subsidence nearest the edge of the panel, the same as for the exponential function discussed below. To do so, the parameter X/B in Table 1 should be replaced by (X-B)/B.

Chen and Peng (1981) prefer an exponential function of the type proposed by Martos (as reported by Brauner, 1973):

$$S(x) = 1/2\, S^* \left(1 - \tan h \frac{8.3X}{h}\right) \qquad (4.9)$$

where X is the horizontal distance from the inflection point which is also the origin point. X is positive towards rib and negative towards gob.
- S(x) is subsidence at a point X ft away from origin point.
- S^* is maximum subsidence
- h is mining depth.

Both the hyperbolic tangent and the exponential functions can be considered equally satisfactory frr sketching anticipated subsidence profiles for sites in the Northern Appalachian Coal Field and possibly elsewhere. For consistency in application, when using the hyperbolic tangent function, the maximum subsidence S* along a profile should be determined from Equation 4.1 with a subsidence factor from Figure 4.9, and when using the exponential function, S* should be determined from Equation 4.5 (or Figure 4.12) with a subsidence factor from Equation 4.3.

For the Interior Coal Province (specifically, the Old Ben No. 24 longwall panel near Benton, Illinois), Munson and Eichfeld (1980) conclude that a trigonometric (sine) function best fits the transverse subsidence profile. More general guidance concerning the geometric characteristics of subsidence troughs in the Illinois coal field is furnished by data from the Illinois Geological Survey (Figure 4.17). These data relate the Subsidence Factor to maximum profile slope and to average maximum profile curvature and identify locations on the profile corresponding to zero subsidence, maximum tensile curvature, maximum slope, maximum compressive curvature and maximum subsidence.

For the western coalfields, examples of subsidence profiles above longwall panels are given by Gentry (1976), Allgaier (1982) and Fejest (1986). These are not discussed in the context of profile functions, however.

Be aware of occasional local anomalies in the use of profile functions. Note, for example, that the hyperbolic tangent function indicates a finite horizontal displacement at the center of the trough — a physical impossibility. The exponential function correctly indicates zero displacement. Local anomalies cna probably be tolerated if th principal objective is to characterize the trough and compute order of magnitude estimates of dispalcement, strain, etc.

Any of the foregoing analytical methods can be used in two ways—(1) to sketch a smooth curve through existing subsidence data, or (2) to predict the subsidence profile in areas of future mining. For prediction, caution must be exercised due to the limited number of case studies in any locality that have been used to establish a norm. Success in prediction lies in determining proper values both of maximum subsidence along the profile and of the horizontal dimensional characteristics of the subsidence profile (B, d and L). Whereas a satisfactory estimate of maximum subsidence along the profile can be made using the relationships presented in Section 4.4.2, a comparable estimate of the horizontal dimensional characteristics of the trough can be difficult to achieve, largely because of uncertainties in estimating the angle of draw.

4.4.4.2 <u>Ground Surface Slope</u>. The slope of the ground surface i(X) at each point x along the subsidence profile is given by the first derivative with respect to X of the subsidence function S(X):

$$i(X) = S'(X) \tag{4.11}$$

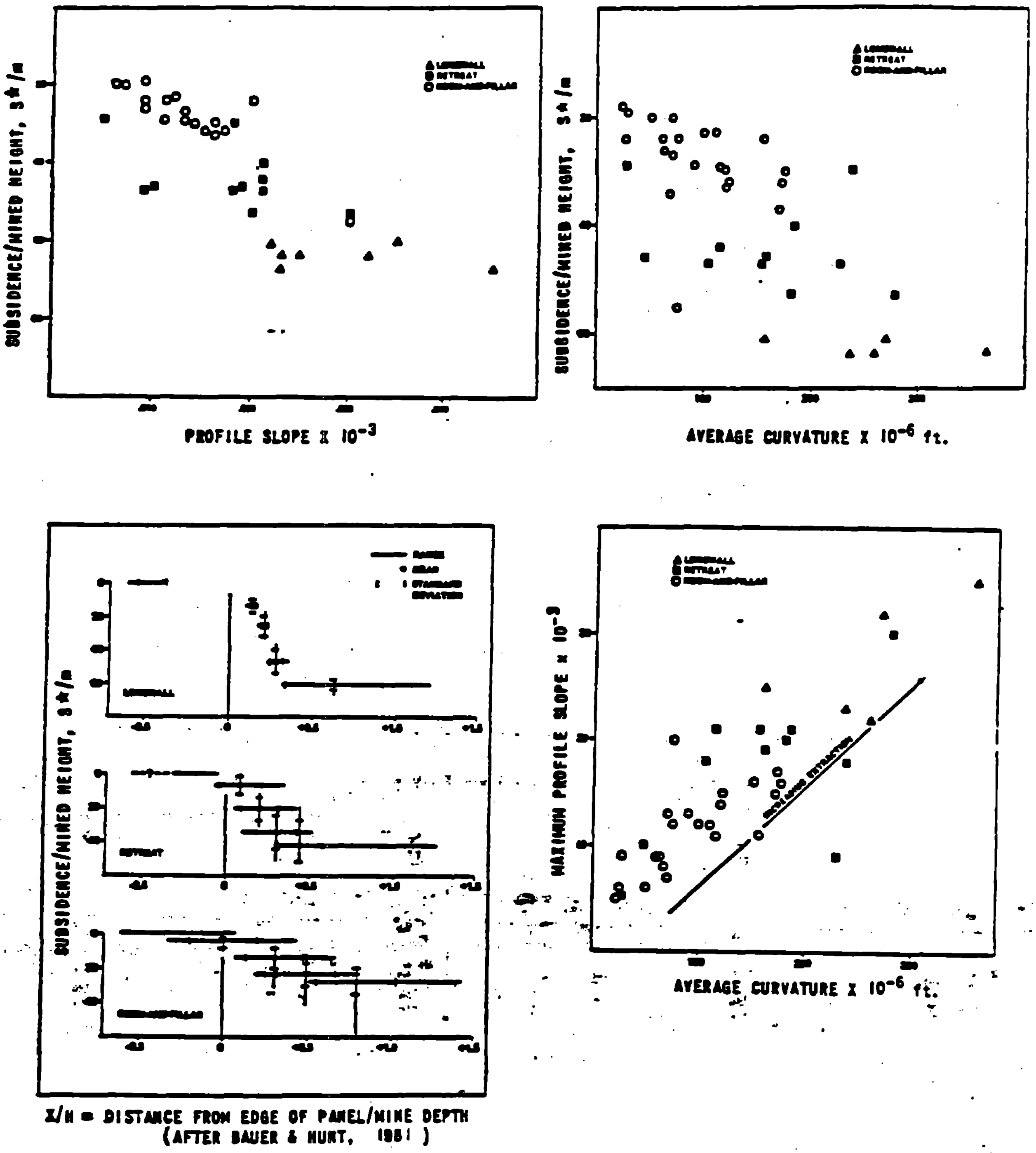


FIGURE 4.17 SUBSIDENCE PROFILE CHARACTERISTICS, INTERIOR COAL FIELD - ILLINOIS

Expressions for ground slope in terms of the hyperbolic tangent and the exponential functions are presented in Table 4.1, Column 3. Units: length/length (dimensionless).

4.4.4.3 Ground Surface Curvature. The curvature of the ground surface K(X) represents the rate of change of slope at each point X along the subsidence profile and is given by the second derivative with respect to X of the subsidence function S(X):

$$K(X) = S''(X) \tag{4.12}$$

Expressions for ground curvature in terms of the hyperbolic tangent and the exponential functions are presented in Table 4.1, Column 4. Units: 1/length.

4.4.4.4 Horizontal Ground Displacement. The horizontal movement u(X) of a point X on the subsidence profile is related to the ground slope i(X) at that point by an empirical constant J:

$$u(X) = Ji(X) \tag{4.13}$$

Expressions for horizontal ground displacement in terms of the hyperbolic tangent and the exponential functions are presented in Table 4.1, Column 5. Units: length.

4.4.4.5 Ground Strain (Horizontal Strain). The ground strain e(x) represents the amount of extension or compression (elongation or shortening) of the ground surface in the immediate vicinity of each ground surface point X relative to an original (pre-mining) gage length. By definition e(X) = L/L. Expressions for ground strain in terms of the hyperbolic tangent and the exponential functions are presented in Table 4.1, Column 6. Units: length/length (dimensionless).

Karmis, et al. (1984b), Figure 4.18, claim that, on average, the maximum ground strain at a subsidence site in the United States relates to maximum curvature according to

$$e_o = 0.92 \sqrt{Ko} \tag{4.14}$$

The uncertainty in strain values for the cases from which the relationship was developed is about 0.5 percent strain.

Example 2, Figure 4.19 illustrates the estimation of subsidence, ground slope, curvature and strain for a particular mine panel using the profile function method and the sketching of associated profiles. Several factors must be borne in mind when preparing plots and computing parameters using these functions:

1) The subsidence profile and associated parameters represent the configuration of the ground surface through the point of maximum

Table 4.1

PROFILE FUNCTION FACTORS

Hyperbolic Tangent Function
C = 1.4 Subcritical

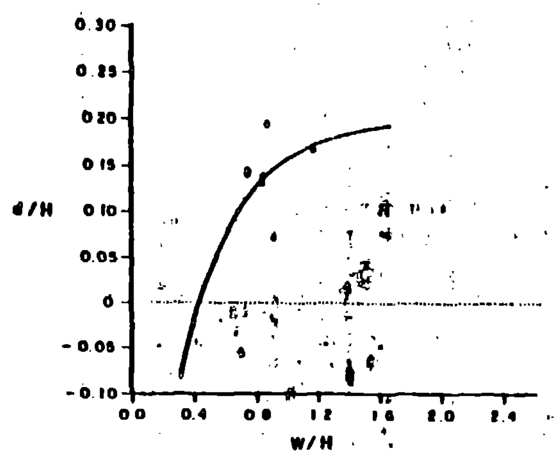
x/B	Subsidence A= S/S*	Slope A'= fB/S*	Curvature A''= kB²/S*	Horizontal Displacement cA'= u/S*	Strain cA''= eB/S*
-1.00	.943	-.151	-.375	.050	.125
-.95	.935	-.171	-.416	.057	.139
-.90	.926	-.193	-.460	.064	.153
-.85	.915	-.217	-.505	.072	.168
-.80	.904	-.243	-.551	.081	.184
-.75	.891	-.272	-.596	.091	.199
-.70	.877	-.303	-.639	.101	.213
-.65	.861	-.336	-.678	.112	.226
-.60	.843	-.371	-.712	.124	.237
-.55	.823	-.407	-.737	.136	.246
-.50	.802	-.444	-.752	.148	.251
-.45	.779	-.482	-.753	.161	.251
-.40	.754	-.519	-.739	.173	.246
-.35	.727	-.556	-.707	.185	.236
-.30	.698	-.590	-.655	.197	.218
-.25	.668	-.621	-.585	.207	.195
-.20	.636	-.648	-.495	.216	.165
-.15	.603	-.670	-.388	.223	.129
-.10	.570	-.686	-.267	.229	.089
-.05	.535	-.697	-.136	.232	.045
0.00	.500	-.700	0.000	.233	0.000
.05	.465	-.697	.136	.232	-.045
.10	.430	-.686	.267	.229	-.089
.15	.397	-.670	.386	.223	-.129
.20	.364	-.648	.495	.216	-.165
.25	.332	-.621	.585	.207	-.195
.30	.302	-.590	.655	.197	-.218
.35	.273	-.556	.707	.185	-.236
.40	.246	-.519	.739	.173	-.246
.45	.221	-.482	.753	.161	-.251
.50	.198	-.444	.752	.148	-.251
.55	.177	-.407	.737	.136	-.246
.60	.157	-.371	.712	.124	-.237
.65	.139	-.336	.678	.112	-.226
.70	.123	-.303	.639	.101	-.213
.75	.109	-.272	.596	.091	-.199
.80	.096	-.243	.551	.081	-.184
.85	.085	-.217	.505	.072	-.168
.90	.074	-.193	.460	.064	-.153
.95	.065	-.171	.416	.057	-.139
1.00	.057	-.151	.375	.050	-.125

Hyperbolic Tangent Function
C = 1.8 Critical

x/B	Subsidence A= S/S*	Slope A'= fB/S*	Curvature A''= kB²/S*	Horizontal Displacement cA'= u/S*	Strain cA''= eB/S*
-1.00	.973	-.093	-.318	.031	.106
-.95	.968	-.110	-.372	.037	.124
-.90	.962	-.131	-.435	.044	.145
-.85	.955	-.154	-.505	.051	.168
-.80	.947	-.181	-.583	.060	.194
-.75	.937	-.212	-.668	.071	.223
-.70	.926	-.248	-.760	.083	.253
-.65	.912	-.289	-.856	.096	.285
-.60	.897	-.334	-.953	.111	.318
-.55	.879	-.384	-1.046	.128	.349
-.50	.858	-.438	-1.130	.146	.337
-.45	.835	-.496	-1.197	.165	.399
-.40	.808	-.557	-1.238	.186	.413
-.35	.779	-.620	-1.245	.207	.415
-.30	.746	-.681	-1.209	.227	.403
-.25	.711	-.740	-1.124	.247	.375
-.20	.673	-.793	-.985	.264	.328
-.15	.632	-.837	-.795	.279	.265
-.10	.589	-.871	-.559	.290	.186
-.05	.545	-.893	-.288	.298	.096
0.00	.500	-.900	0.000	.300	0.000
.05	.455	-.893	.288	.298	-.096
.10	.411	-.871	.559	.290	-.186
.15	.368	-.837	.795	.279	-.265
.20	.327	-.793	.985	.264	-.328
.25	.289	-.740	1.124	.247	-.375
.30	.254	-.681	1.209	.227	-.403
.35	.221	-.620	1.245	.207	-.415
.40	.192	-.557	1.236	.186	-.413
.45	.165	-.496	1.197	.165	-.399
.50	.142	-.438	1.130	.146	-.377
.55	.121	-.384	1.046	.128	-.349
.60	.103	-.334	.953	.111	-.318
.65	.088	-.289	.856	.096	-.285
.70	.074	-.248	.760	.083	-.253
.75	.063	-.212	.668	.071	-.223
.80	.053	-.181	.583	.060	-.194
.85	.045	-.154	.505	.051	-.168
.90	.038	-.131	.435	.044	-.145
.95	.032	-.110	.372	.037	-.124
1.00	0.27	-.093	.318	.031	-.106

Origin at Inflection Point of Profile--the point where the curvature changes from concave up to concave down--located at distance d into the panel from the panel edge. Refer to Figure 4.6.

Hyperbolic Tangent Function



EXAMPLE:
SUBCRITICAL OR CRITICAL PANEL ($W \le L_c$)
GIVEN: PANEL WIDTH W = 500 FEET
MINE DEPTH H = 600 FEET

FOR W/H = 0.83, THE GRAPH INDICATES THAT d/H = 0.14.

THEREFORE d = 0.14 H = 84 FEET
$B = W/_2 - d$ = 166 FEET

FOR A SUPERCRITICAL PANEL, USE L_c AS THE PANEL WIDTH.

CHART FOR DETERMINING VALUE OF B FOR HYPERBOLIC TANGENT PROFILE FUNCTION

Table 4:1
(continued)

Exponential Function
a = 8.97
b = 2.03

X/L	Subsidence A= S/S*	Slope A'= iL/S*	Curvature A''= kL²/S*	Horizontal Displacement cA'= u/S*	Strain cA''= eL/S*
0.00	1.000	0.000	-18.000	0.000	-2.117
.05	.980	-.815	-16.117	-.096	-1.924
.10	.920	-1.563	-13.442	-.184	-1.605
.15	.826	-2.132	-9.140	-.251	-1.091
.20	.710	-2.465	-4.141	-.290	-.494
.25	.584	-2.550	.630	-.300	.075
.30	.459	-2.419	4.440	-.284	.530
.35	.345	-2.129	6.884	-.250	.822
.40	.248	-1.754	7.912	-.206	.945
.45	.170	-1.358	7.756	-.160	.926
.50	.111	-.992	6.800	-.117	.812
.55	.070	-.685	5.452	-.080	.651
.60	.042	-.447	4.046	-.053	.483
.65	.024	-.277	2.800	-.033	.334
.70	.013	-.163	1.816	-.019	.217
.75	.007	-.091	1.107	-.011	.132
.80	.003	-.048	.637	-.006	.076
.85	.002	-.024	.346	-.003	.041
.90	.001	-.012	.178	-.001	.021
.95	0.000	-.005	.086	-.001	.010
1.00	0.000	-.002	.040	0.000	.005

Origin is at the point of maximum subsidence nearest the edge of the panel.

In Figure 4.6, origin is located at a distance B+d into the panel from the panel edge.

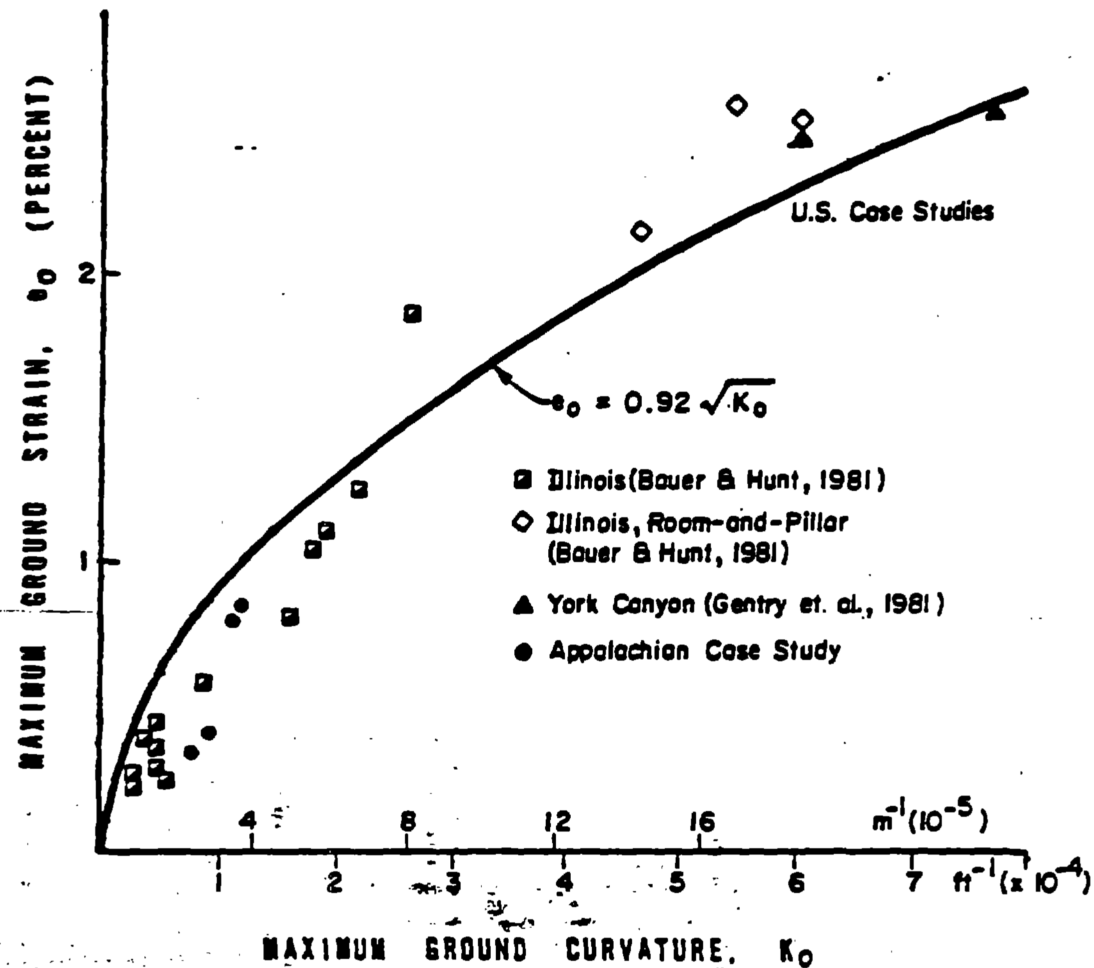


FIGURE 4.18 GENERAL RELATIONSHIP BETWEEN MAXIMUM GROUND STRAIN AND MAXIMUM GROUND CURVATURE

Problem: A longwall panel 500 feet wide and 1500 feet long is to be developed at 600-foot depth in the Northern Appalachian Coal Field.

Sketch the anticipated subsidence profile along a transverse section through the center of the trough, as well as profiles of anticipated ground slope, ground curvature, horizontal ground displacement and ground strata.

Solution: The profiles can be prepared using either the negative exponential function or the hyperbolic tangent function per Section 4.4.4 and Table 4.1. We will use the negative exponential function.

Two site-specific parameters are required to define the profiles: (1) the maximum subsidence along the profile S^*; and (2) the angle of draw β. The angle of draw, in turn, is required to compute the half-width, L of the subsidence profile--the distance between the edge of the subsidence trough and the point of maximum subsidence.

For present purposes, assume that the maximum subsidence has been determined to be 1.9 feet, using the methods of Section 4.4.2 and the angle of draw has been determined to be 20°, using the methods of Section 4.4.3.3.

In recognition that the half-width L of the subsidence profile equals the distance from the edge of the subsidence trough to the edge of the mine panel plus half the width of the mine panel, then $L = H \tan\beta + L_w/2 = 600 \tan 20° + 500/2 = 468$ feet.

Knowledge of S^* and L permits the estimation of subsidence as well as ground slope, curvature, horizontal displacement and strain at 21 points along the half width of the subsidence profile using the normalized parameters (A, A', A", cA', cA") given in Table 4.2

The general mathematical relationships evaluated for the subject site are as follows:

Subsidence $S = S^*A = 1.9A$

Slope $i = (S^*/L)A' = (4.06 \times 10^{-3})A'$

Curvature $k = (S^*/L^2)A'' = (8.67 \times 10^{-6})A''$

Horizontal Displacement $u = (S^*)cA' = (1.9)cA'$

Strain $e = (S^*/L)cA'' = (4.06 \times 10^{-3})cA''$

As an example, consider X/L = 0.25, which represents a point 117 feet (=0.25 x 468 feet) from the center of the trough (the point of maximum subsidence). Here the characteristics of the subsidence profile are computed to be:

$S = 1.9(0.584) = 1.11$ feet

$i = (4.06 \times 10^{-3})(-2.55) = -1.04 \times 10^{-2}$ foot/foot

$k = (8.67 \times 10^{-6})(0.63) = 5.46 \times 10^{-6}$ /foot

$u = (1.9)(-0.300) = -.57$ foot

$e = (4.06 \times 10^{-3})(0.075) = 3.04 \times 10^{-4}$

The other 20 points along the profile are evaluated in the same manner. The results are plotted below, with the origin being the center of trough. The other half of the trough is, of course, a mirror image. (Note that if the panel had been of supercritical width, then the origin would be at the point of maximum subsidence nearest the edge of the mine panel, rather than on the centerline which would lie along the flat bottom of the trough.)

FIGURE 4.19 EXAMPLE 2 - CALCULATION OF SUBSIDENCE, GROUND SLOPE, CURVATURE, HORIZONTAL DISPLACEMENT AND STRAIN

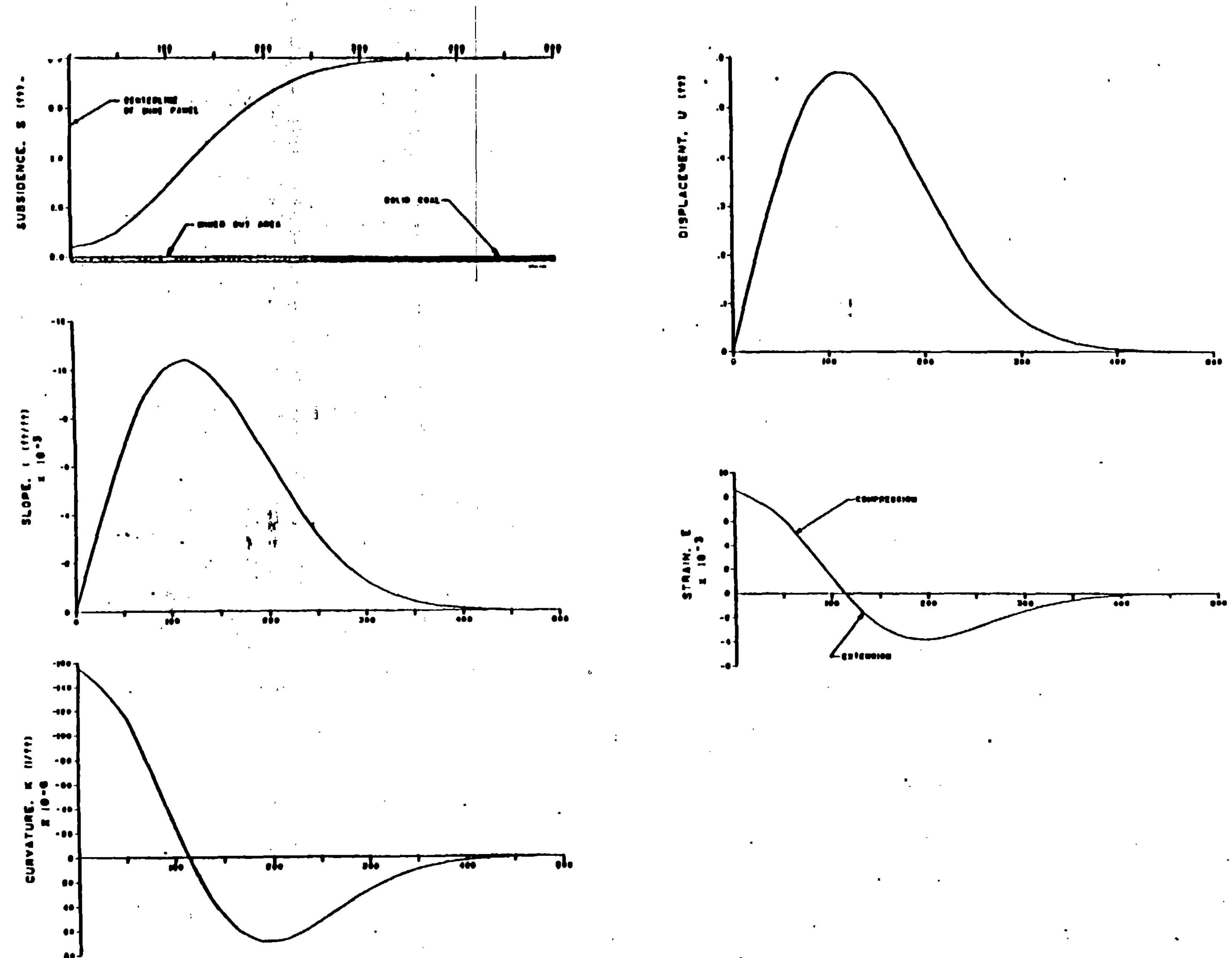


FIGURE 4.19 CONTINUED

subsidence for the particular panel geometry, mine depth and overburden lithology. The profile does not account for the presence of any heave zone around the perimeter of the panel nor does it account for secondary effects due to mining in adjoining panels or to other variations in boundary conditions around the perimeter of the panel. The profile also does not portray irregularities, such as ground cracks or buckled zones, that may develop locally at ground surface, particularly in localities where soil cover is thin and the overburden is composed largely of sandstone and/or limestone.

2) The subsidence profile and associated parameters can be sensitive to the estimated angle of draw. Note that the angle of draw is used in the calculation of the half width of the subsidence profile, which in turn, governs the shape of the subsidence profile. The use of a small angle of draw tends to yield a conservative (that is, high) estimate of maximum slope, curvature, horizontal displacement and strain. However, the areal extent of the subsidence trough may be underestimated. The use of a more liberal estimate of the angle of draw tends to provide a more conservative estimate of the size of the subsidence trough but at the same time may underestimate the maximum values of slope, curvature, horizontal displacement and strain. Given the uncertainties inherent in all computational methods, consideration should be given to presenting a range of values for the subsidence trough and its parameters.

5.0 MINING METHODS TO DEAL WITH SUBSIDENCE

CONTENTS

5.1 Introduction

Damage to surface structures--buildings, towers, pipelines, bridges, roadways, etc.--can be prevented or minimized in three ways:

1. Site Planning--locating new structures where mining is not to be conducted or where mining has already been conducted and all significant ground movements are complete;

2. Implementing Structural Measures--incorporating into the design of new structures appropriate construction joints, foundation elements or other features to allow the structures to better accommodate ground movements; retrofitting existing structures to provide these features, adding structural support, constructing trenches or other external measures that will allow the structure to better accommodate the ground movements or will buffer the structure from the movements; or

3. Conducting mining in such a way that the potential for damage to existing structures is reduced or eliminated.

Discussion in this manual is restricted to the third category and is presented in three parts:

- o Planned Subsidence, which deals with total extraction mining, and in particular with five techniques that have been applied here or abroad to minimize ground surface deformations (Sec. 5.2);
- o Permanent Support, which deals with partial extraction mining, where subsidence is prevented altogether by leaving panel-wide or local pillar support (Sec. 5.3); and
- o The design of coal pillars for both planned subsidence and permanent support situations (Sec. 5.4).

5.2 Planned Subsidence

Total extraction induces nearly all significant subsidence at the time of mining and is accomplished by longwall, room-and-pillar retreat or shortwall operations. Total extraction means that, for practical purposes, all of the coal is removed from the panel. The location and magnitude of the resulting subsidence and the amount of ground surface distortion are predictable within limits and thus are said to be "planned". The predictive aspects of subsidence in Section 4 show that the amount of subsidence and the amount of distortion of the ground surface depend on both the geometry of the panel and the over burden lithology.

A variety of mining options can be considered for controlling subsidence produced by total extraction mining--"controlling" in the sense of exercising some leverage over the amount of subsidence, the amount of ground distortion and the locations above the panel where the maximum distortion takes place. These options are listed in Table 5.1. Some serve a single purpose; others a multiple purpose. Three of the methods reduce the amount of subsidence occurring during mining (narrow panels, backfilling, rapid mining); the other two methods are not useful for this purpose (wide panels, strain cancellation). The same three methods that reduce the amount of subsidence during mining also reduce the amount of ground distortion at both the lead and lateral edges of the subsidence trough. On the other hand, the strain cancellation method reduces ground distortion only at the lead edge, while the wide panel approach does neither--it simply positions the zone of maximum ground distortion a safe distance from surface structures to be protected. It is evident that although a variety of methods are available to achieve subsidence control, not all are of comparable effectiveness for specific purposes, nor could all realistically be used at a particular mine site.

5.2.1 Wide Panels. The vertical and horizontal ground movements accompanying mining produce twisting as well as linear ground strains and curvatures. These three- dimensional ground deformations can contribute significantly to the damage of structures at ground

Table 5.1

RELATIVE ATTRIBUTES OF PARTICULAR SUBSIDENCE CONTROL METHODS IN TOTAL EXTRACTION MINING

	Reduces Maximum Subsidence	Reduced Ground Distortion At Leading Edge	Reduced Ground Distortion At Lateral Edges
Wide Panel[1]	No	No	No
Narrow Panel	Yes	Yes	Yes
Strain Cancellation ("Harmonic Mining")	No	Yes	No
Backfilling Panel	Yes	Yes	Yes
Rapid Mining[2]	No	No	No

1 Intended to minimize damage to surface structures by distancing them from the zone of pronounced ground distortion at the lateral edges of the trough.

2 Strain within influence zone reduces considerably.

surface. For a mine panel of subcritical or critical dimensions, the three- dimensional deformations extend across the full width and length of the subsidence trough (Figure 5.1A). However, for a mine panel of supercritical dimensions — by definition, a panel wide and long enough to have a subsidence trough profile with a flat bottom — the ground surface deformations within the central section of the trough away from the panel's lateral edges are essentially two-dimensional in that they are governed by the longitudinal trough profile.

The mine panel width Lw required to achieve a "two-dimensional" strain field large enough to accommodate a structure of width DP is

$$Lw > Lc + DP + 2Z \qquad (5.1)$$

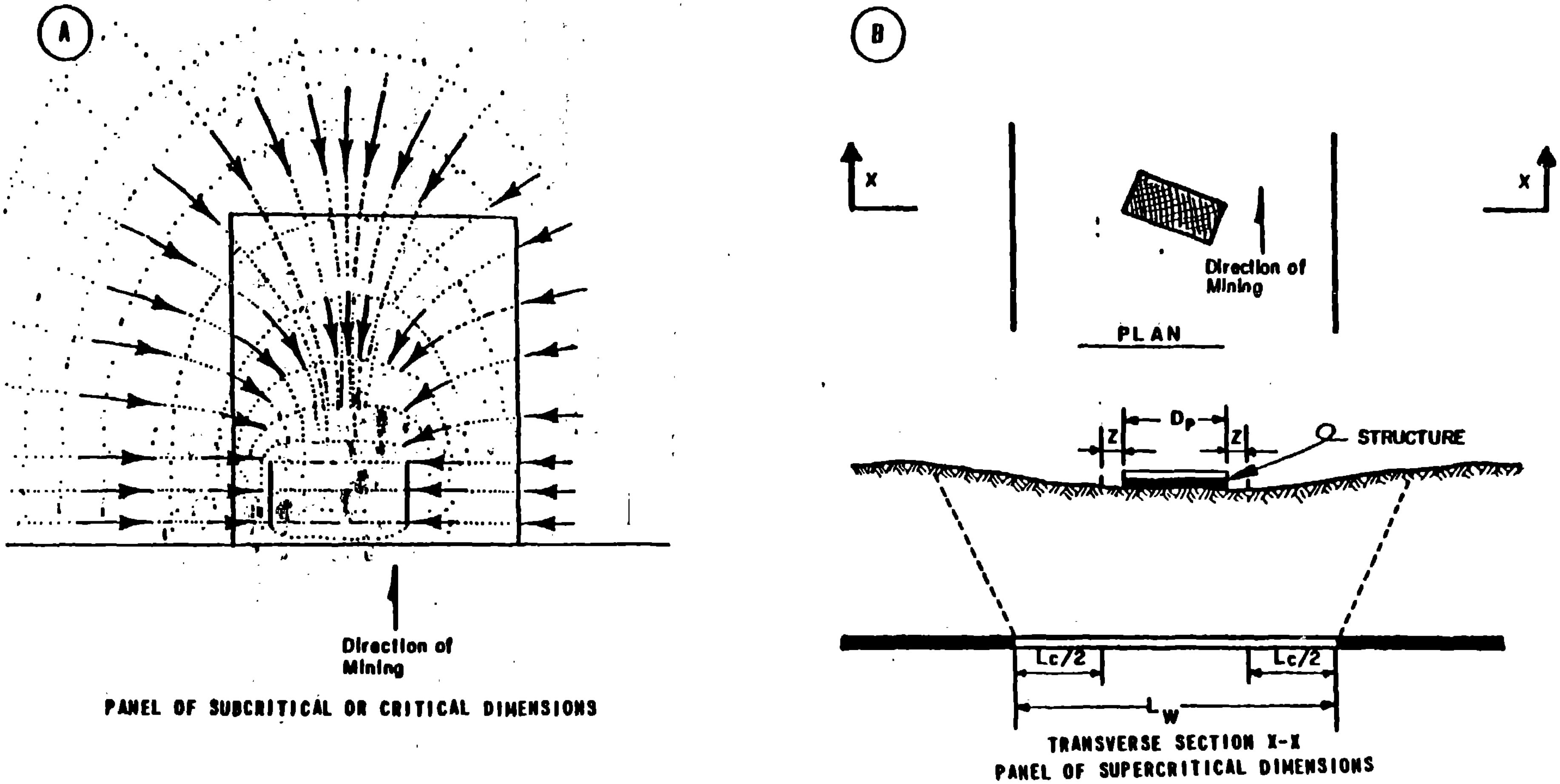
where Lc is the critical panel dimension computed from Figure 4.14.

DP is the plan dimension of the structure as measured across the width of the panel.

Z is the width of the safety zone provided on either side of the structure, taken to be 50 feet unless site conditions indicate a larger value is more appropriate.

Use of a mine panel of width Lw or greater will not necessarily preclude damage to a structure since the structure will still be subjected to the frontal traveling wave that accompanies passage of the mine face. However, lesser damage would be expected since the structure would be spared much of the twisting (racking) that would take place in a narrower panel. No method is currently available to accurately assess how much less the damage might be using a wide panel.

5.2.2 <u>Narrow Panels ("Panel-and-Pillar")</u>. By limiting W/H, the width of the total extraction panel in relation to overburden depth, the amount of subsidence and the maximum ground surface distortion can be reduced below that expected for a panel of critical or supercritical dimensions. In reference to Figure 4.9, for example, a longwall panel of 240-foot width in a 6-foot seam at a depth of 600 feet (W/H=0.4) with 5 percent hard rock in the overburden would produce only about 35 percent of the subsidence produced by a 900-foot wide panel at a comparable depth (W/H=1.5), all other parameters being equal—the subsidence factor for W/H=0.4 being 0.24 and S* being 1.4 feet and the subsidence factor for W/H=1.5 being 0.7 and S* being 4.2 feet. Limiting W/H would at the same time reduce the maximum ground slope from 17×10^{-3} to 9×10^{-3}; the maximum ground curvature from 9×10^{-5}/ft. to 7×10^{-5}/ft. and the maximum ground strain from 2.7×10^{-5} to 2.1×10^{-5}.



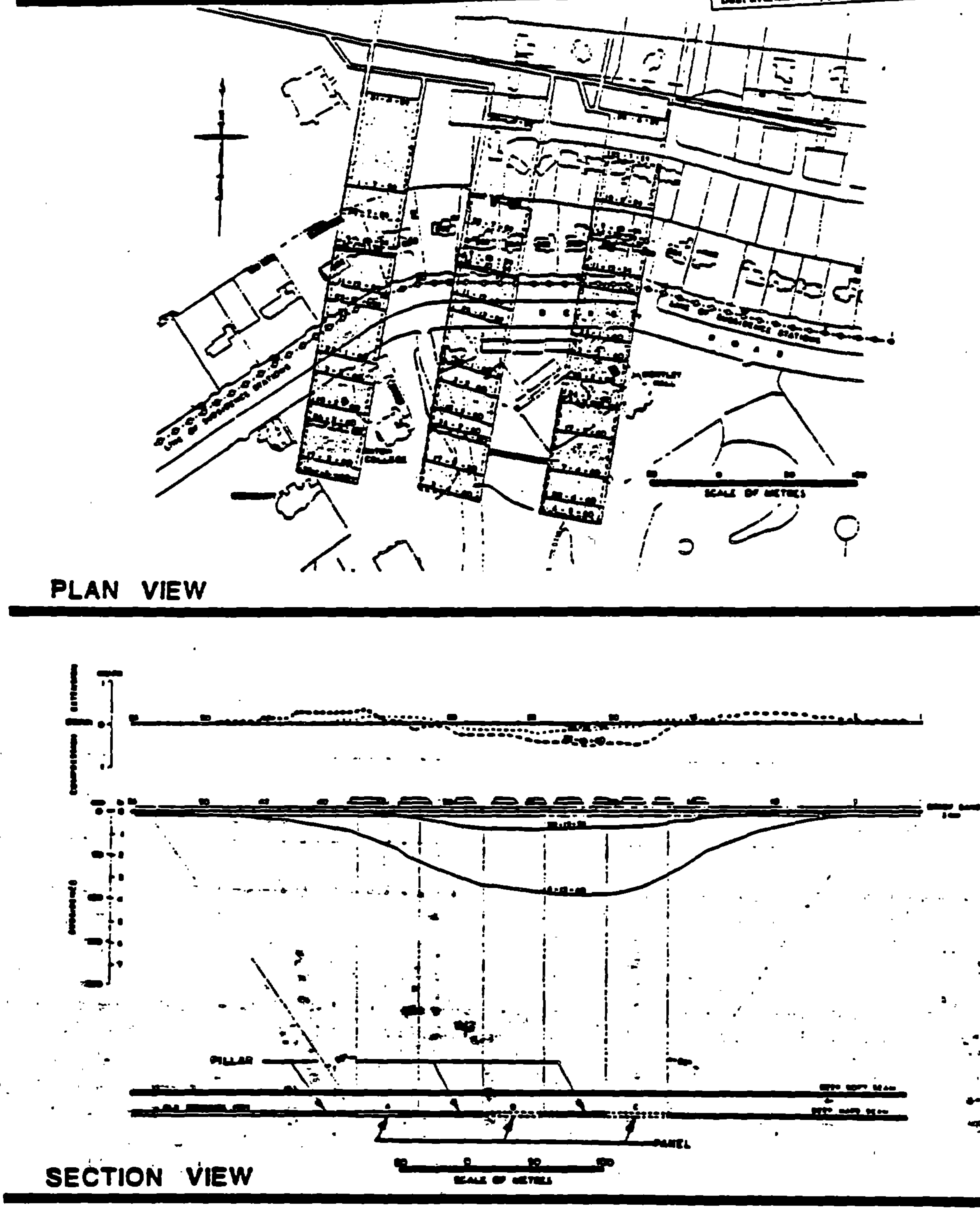
L_c = CRITICAL PANEL DIMENSION COMPUTED FROM FIGURE 4.14

D_p = PLAN DIMENSION OF THE STRUCTURE AS MEASURED ACROSS THE WIDTH OF THE PANEL.

Z = WIDTH OF THE SAFETY MARGIN ON EITHER SIDE OF THE STRUCTURE. TAKEN TO BE 50 FT.

L_w = MINE PANEL WIDTH REQUIRED TO ACHIEVE A "TWO DIMENSIONAL" STRAIN FIELD LARGE ENOUGH TO ACCOMODATE A STRUCTURE OF WIDTH D.

FIGURE 5.1 WIDE PANEL CONCEPT



FROM NATIONAL COAL BOARD, 1975

FIGURE 5.2 NARROW PANEL CONCEPT

The panel-and-pillar approach (Figure 5.2) is generally envisioned as an alternative to isolated groups of support pillars (Section 5.3) more so than as an alternative to the use of a wide panel (Section 5.2.1). Provided that structures at ground surface can tolerate the ground distortion produced by the wide panel—distortion that is somewhat moderated by the panel's "two-dimensional", flat-bottomed character (Section 5.2.1), the wide panel approach is favored since it permits a greater recovery of coal over a given area than the panel-and-pillar system. However, if the ground movements produced by the wide panel are considered excessive, then the choice lies between the panel-and-pillar method and isolated pillar support, with the recogniiion that the panel-and-pillar method reduces, but does not altogether eliminate, ground movements over the panel as do groups of isolated support pillars.

Isolated pillar support has been used successfully for many decades in western Pennsylvania room-and-pillar retreat mining as a method of providing long-term ground support (Section 5.3.2). However, as room-and-pillar retreat mining is conducted at progressively greater depths, the stress anomalies created near mine level by isolated pillar support can more seriously affect caving of the mine roof and can promote squeezes. In addition, isolated pillar support can be disruptive of the mining process itself and is inapplicable in mine panels where longwall methods are practiced. Thus, narrow panels may represent a viable alternative provided that some ground deformation can be tolerated. The design of pillars for permanent support is discussed in Section 5.4.

5.2.3 Strain Cancellation Techniques (Harmonic Mining). The potential for damage to a surface structure can sometimes increase if, as often happens, mining is conducted not in one, but in two panels -- panels alongside or above one another. For example, if two panels were mined at different times, a situation might arise where a structure is first subjected to a sequence of extension and compression strains from mining of the first panel and then to another sequence of extension and compression strains from mining of the second panel. The structure might be damaged twice, the second time in a somewhat weakened condition as a result of the first episode of subsidence. A different situation, potentially as serious if not more so, might arise if the two panels were mined at the same time. If the panels were adversely aligned, the tensile strains produced by one panel could combine with the tensile strains produced by the other to create a more intensified strain, with greater potential for structural damage.

In order to avoid these situations—undermining a structure on two separate occasions or undermining in a way that produces additive (intensified) strains—techniques have been developed in Europe and the United Kingdom for coordinating mining so that the strains from the two panels tend to cancel one another.

There are two common types of strain cancellation techniques--"rolling extraction" used in multiple seam mining and "stepped face extraction" used in single seam mining. The methods are rather difficult to coordinate and implement and have been utilized abroad primarily where mining has been conducted beneath structures of major significance. In the United States, regulations potentially limit such mining.

In the event either strain cancellation method is attempted, the respective panel layouts should be based on subsidence data collected from previous mining on or nearby the subject site in preference to general, regional data. In addition, since the cancellation effect deals with strains along the longitudinal ground surface profile, these techniques are preferably implemented only where panels are wide enough to achieve a "two-dimensional" strain field in the vicinity of the structure being protected (Refer to Section 5.2.1). Use of narrower panels could result in additive strains along transverse sections that are severe enough to negate many of the benefits of these techniques.

5.2.3.1 Rolling Extraction. The extraction of coal in the lower seam lags a distance M behind mining in the upper seam (Figure 5.3). The intention is that the maximum tensile strain produced by the lower seam coincides in position with the maximum compressive strain produced by the upper seam as mining progresses in tandem along the two panels. The two strains cancel one another (partially, if not totally), creating a milder strain condition at ground surface than if the mining had not been coordinated. The success depends on the relative magnitudes and distributions of the two opposing strains, which, in turn, depends upon the thicknesses and depths of the respective coal seams, the dimensions of the mine panels and the character of the overburden between ground surface and each of the two coal seams. Mining of the upper seam can be expected to degrade the overburden so that the strais produced by mining of the lower seam will not necessarily be the same as if the mining had been conducted in "virgin ground". This contributes to the inexactness of strain prediction.

5.2.3.2 Stepped Face Extraction. In this strain cancellation method, the mine face extends across the full width Lw of the panel, except for a center section of width w that precedes the remainder of the face by a distance M (Figure 5.4). The intention is for the maximum compressive strain produced by the center section of the face to coincide in position with the maximum tensile strain produced by the wider trailing section of the face. As with rolling extracton, the tensile and compressive strains ideally cancel one another, creating a zone of no strain that permits mining to pass without incident beneath a structure at ground surface.

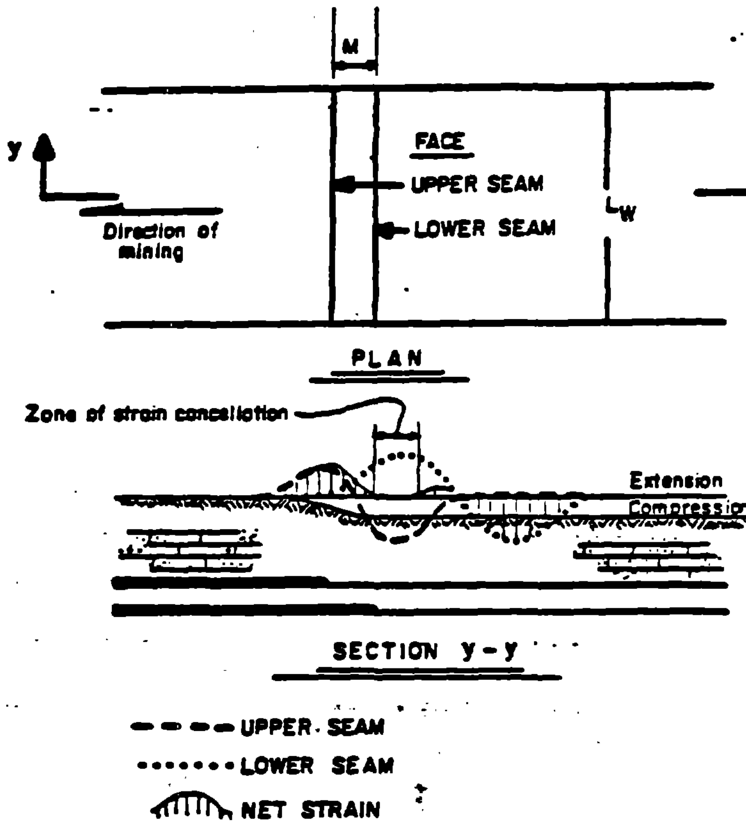


FIGURE 5.3 STRAIN CANCELLATION BY ROLLING EXTRACTION

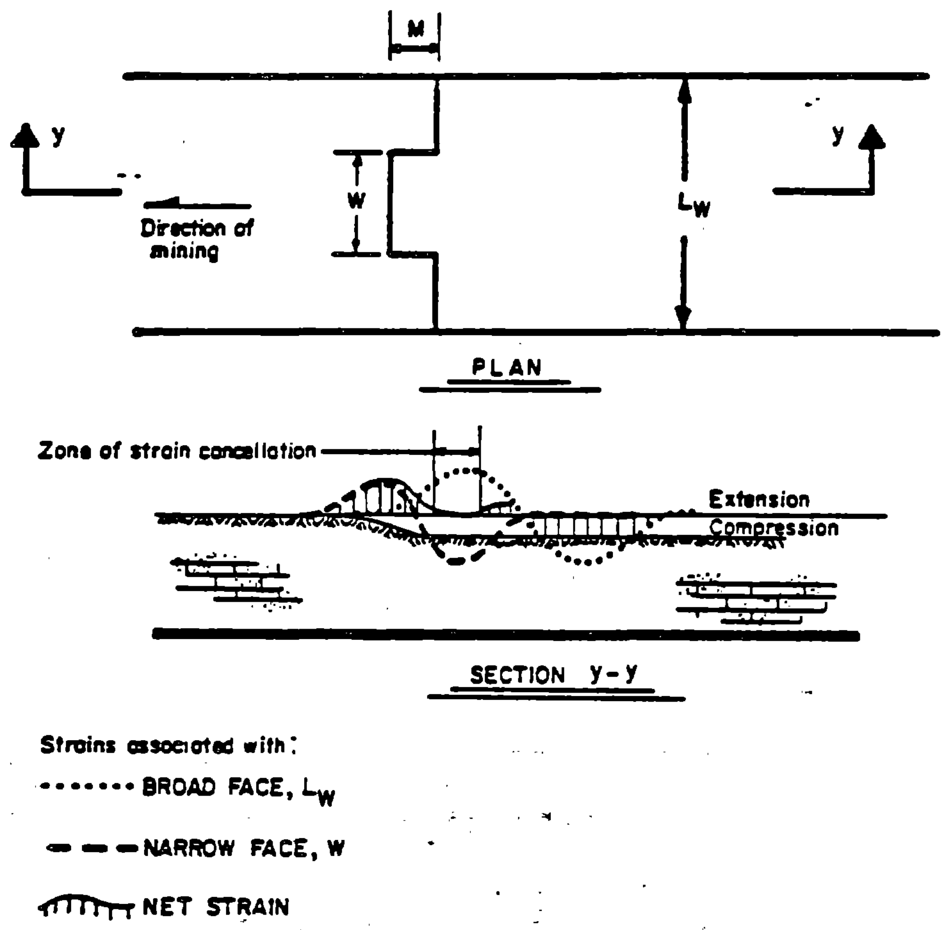


FIGURE 5.4 STRAIN CANCELLATION BY STEPPED-FACE EXTRACTION

Complicating factors similar to those associated with "rolling extraction" apply to the "stepped face" method. And for the same reasons, superposition to achieve strain cancellation is only approximate.

5.2.4 Stowing (also termed Backstowing or Backfilling). The Federal rules and regulations make reference to backstowing or backfilling of voids in the context of subsidence control measures that will prevent or minimize damage in areas not intended for planned subsidence. Whereas the backfilling of mine voids to prevent or minimize subsidence above abandoned mines is rather commonplace, its use in active partial extraction mines is virtually unknown since the benefits derived are usually not commensurate with the cost of application. If any stowing is conducted in active mines it is in areas of planned subsidence—total extraction panels—where the intention is to limit the amount of ground surface movement. In the United Kingdom, backfilling in longwall panels concurrent with mining has been found to reduce subsidence 20 to 30 percent below that for caving, non-backfilled mine panels (National Coal Board, 1975).

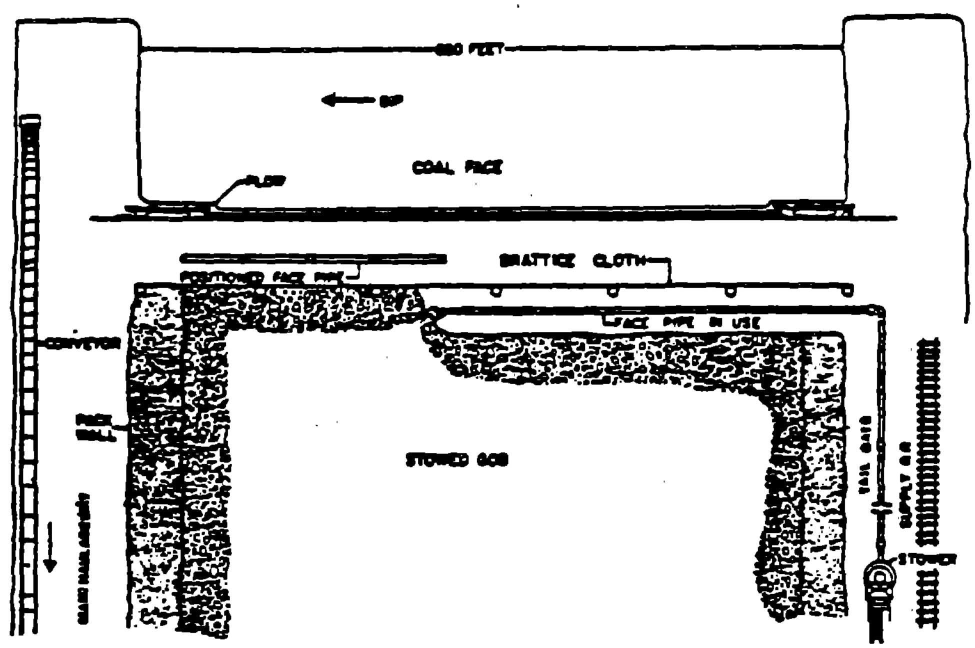
The disposal of coal waste in active mine panels has been shown in Europe and the United Kingdom to be technologically feasible in longwall operations, although the practice has declined substantially with the advent of high production rate mining systems and increasing labor costs.

In the United States, the use of stowing appears to be limited to the construction of pneumatically placed high strength concrete packwalls. These have been employed in an advancing longwall system designed to demonstrate the feasibility of mining thick coal seams using a multilift method (Bourquin and Jaspal, 1984).

Three principal methods of stowing have been employed in underground mining operations--pneumatic, hydraulic and mechanical (NAS, 1975; Wood, 1983). The labor intensive mechanical system of backfilling is now obsolete. The other two have some present application.

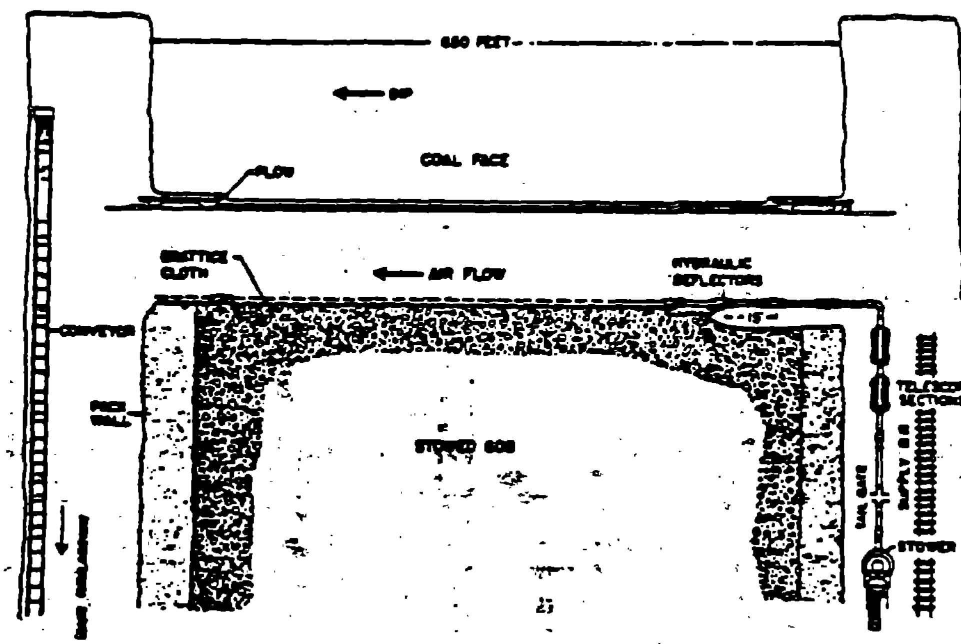
In the pneumatic system (Figure 5.5), the coal waste is transported by conveyor belt or rail through the tail entry to the stowing machine at the longwall face. The coal waste is ejected at high pressure (60 psi) for distances up to 15 feet from a pipe that is directed behind a brattice cloth at the leading edge of the gob. The coal waste is placed the full width of the longwall face. An older type of pneumatic placement was conducted as part of a cyclic mining operation—the first shift for longwall mining, the second shift for haulage and stowing and the third shift for maintenance. The system was not well suited to modern continuous longwall systems and, where pneumatic stowing is still employed, has largely been supplanted by side discharge systems that enable backfilling to better keep pace with mining on a continuous cycle. The pneumatic method has found greater application in Germany and Poland, and the hydraulic method

(A)



CONVEYIONAL PNEUMATIC FROM SINGH AND COURTNEY, 1975

(B)



LATERAL PNEUMATIC FROM SINGH AND COURTNEY, 1975

FIGURE 5.5 STOWING

in Belgium and France. The hydraulic method also found some application decades ago in Pennsylvania's Anthracite Fields.

In the hydraulic method, coal waste is conveyed as a slurry through pipes from mine level bunkers to the face. The pipe is directed behind a brattice cloth barricade at the lead edge of the gob. The water drains off relatively quickly into a sump in the tail entry leaving a backfill comparable in density to that attained by pneumatic placement.

The principal disadvantages of stowing derive from problems associated with losses in productivity, the unavailability and cost of equipment, and unknown affects on the health and safety of miners.

Mine haulage systems are designed primarily to move coal, personnel and supplies. Significant upgrading would be expected if such systems were also required to transport backfill materials to storage locations at the face. Alternatively, stowing-dedicated borehole delivery piping systems could be employed. In either case, piping, backfill storage bunkers (if required) and other materiel could potentially create space problems underground. Extra head room might be required for efficient operations. Scheduling and synchronization of stowage operations with mining could also complicate the overall mining operation. Breakdowns in the stowing operation could impede production. In general, experience in Europe has shown backfilling to be more costly than other means of mitigating subsidence problems. Because stowing has proved to be an impediment to high production mining in the United Kingdom, its use has diminished to the point that it is rarely used. In fact, the economics of stowing are rarely attractive unless the conditions for the environmentally and socially acceptable disposal of coal wastes at ground surface are very unfavorable.

Another disadvantage of stowing is that systems are not currently available for all mining situations. Even though room-and-pillar retreat remains a dominant coal mining method in the United States, no safe method has been developed for stowing concurrent with pillar extraction. Development of such a system could require a significant effort.

A final disadvantage of stowing is the possible adverse effect on the health and safety of underground miners. Besides increasing the number of personnel at the face, the operations could also increase the dust and fire potential (pneumatic system) or the potential for seepage, consequent barricade rupture and softening of the mine floor (hydraulic system). The latter could result in loss of pillar support and reduced traffic ability through entries. MSHA approval is required before stowing operations can be conducted in operating mines.

5.2.5 Rapid Mining. Steady advance of the mine face as rapidly as practicable results in lesser subsidence, and lesser ground surface slopes, curvatures and strains than would otherwise occur in sensitive areas over the mine panel where surface structures are located. This is because a steady rapid advance tends to lessen the time dependent ("creep") component of mining-induced overburden deformations during mining and thereby flattens the profile of the subsidence trough as it enlarges.

After the completion of mining in a panel, the time dependent ground movement then takes the form of residual subsidence, which in some cases represents 10 to 15 percent of the total subsidence and continues in measurable amounts for several months to more than a year after mining. The effect of post-mining residual subsidence—by adding to the subsidence that had occurred during mining—is to steepen the slope of the subsidence trough and increase the ground curvature and the strain along the perimeter of the mine panel, a location where the effects on surface structures ill generally be minimal. The post-mining residual subsidence also produces a general, more or less uniform lowering of the ground surface across the width and length of the mine panel, which by its nature, causes little distress to surface structures.

If prior to completion of mining, a weekend work stoppage, a strike or some other event had allowed a greater proportion of the time dependent ground movements to occur, then the ground slope, curvature and strain above the mine face occurring during that delay would be greater. Any surface structure that might be located between the zones of maximum extension and compression produced by the mine face during such a time span could experience considerably more deformation than otherwise (Figure 5.6).

In general terms, delays in progress should be avoided when a structure lies within the interval 0.5H ahead of the face to 1.5H behind the face. The shape of the subsidence development curve can vary from site to site depending upon the lithology of the overburden and other factors and hence the length of the interval can vary.

Even though its benefits cannot be quantified, a steady, rapid rate of face advance must be considered good practice and should be employed wherever possible.

5.3 Permanent Support

The function of permanent support is to fully prevent movement over a specified area of ground surface so that the damage potential to surface structures is not simply reduced, but is altogether eliminated. The type, size and distribution of structures and other features at ground surface will influence the choice of permanent support area. Three approaches to laying out a protected area at groud surface are (Figure 5.7):

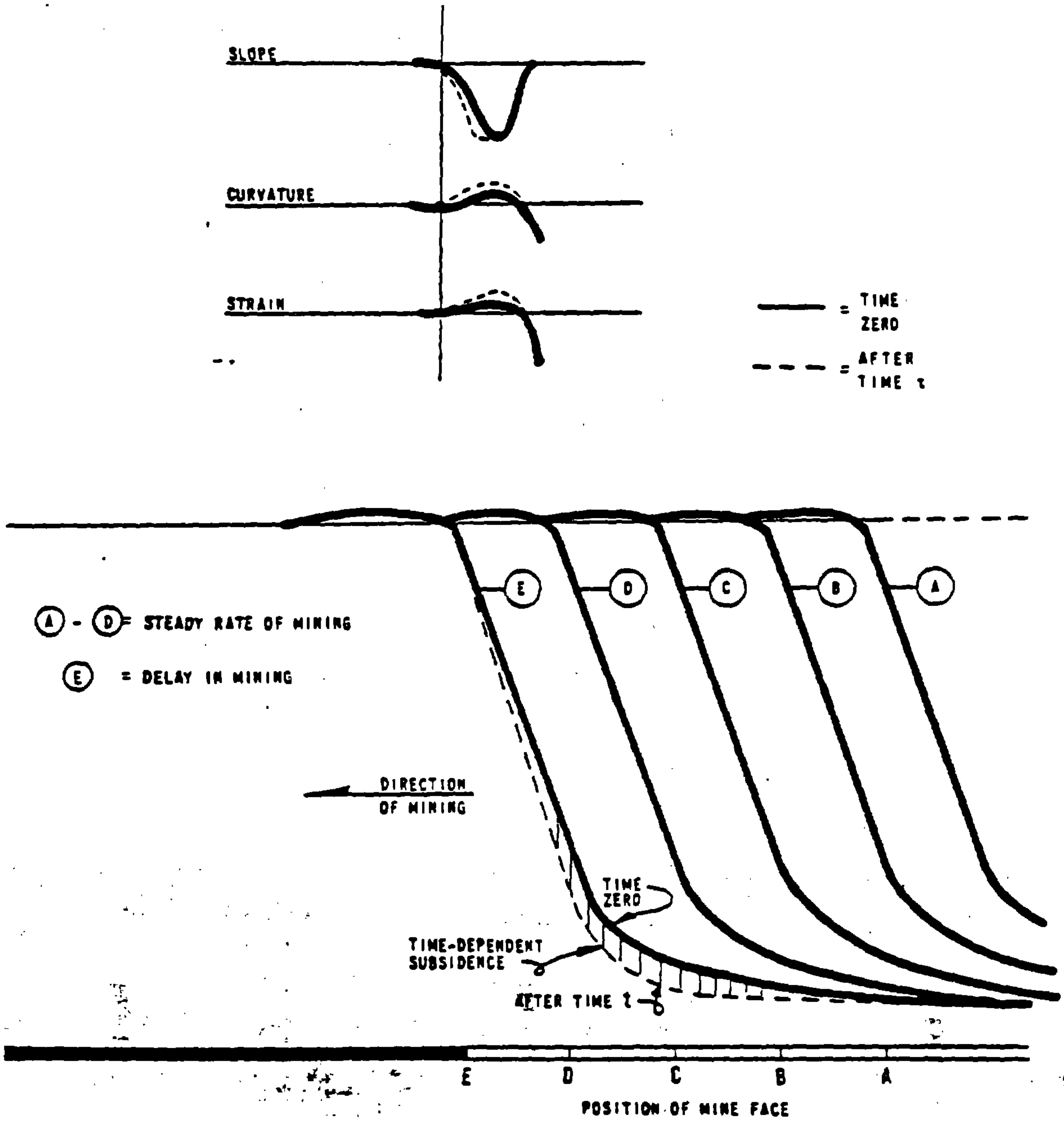


FIGURE 5.6 TIME-DEPENDENT GROUND MOVEMENTS ASSOCIATED WITH A DELAY IN MINING

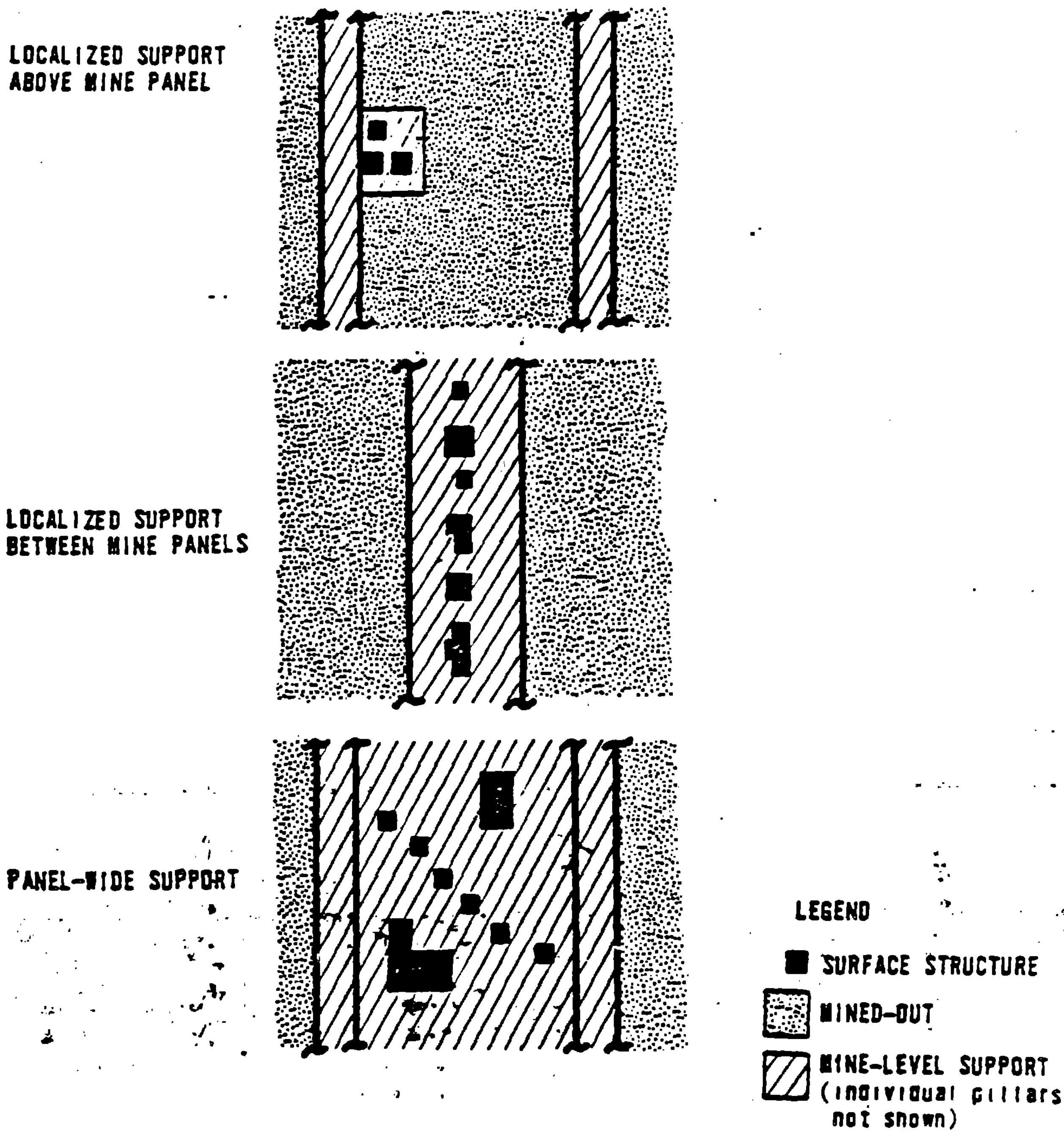


FIGURE 5.7 PROTECTED AREAS AT GROUND SURFACE

(1) Localized support above mine panel — isolating an area around each individual structure or group of structures above the mine panel;

(2) Localized support between mine panels — setting up total extraction panels so that protected areas are positioned over a series of barrier or chain pillars, which in effect represent a strip of partial extraction between areas of total extraction; and

(3) Panel-wide support — designating the entire mine panel as a protected area.

If a single dwelling lies above an area of room-and-pillar mining, the decision may be to provide localized pillar support beneath the sructure and extract the remainder of the pillars in the panel. On the other hand, if the ground surface is flat-lying and is occupied by farm land across which passes a permanent stream, the decision may be to provide panel-wide pillar support. In a location where longwall or shortwall mining is practiced, the opportunity for permanent support presents itself only above the barrier and chain pillars between panels. The total width of the series of chain pillars must be large enough so that ground surface movements from adjacent mining do not affect the structures to be protected.

Four points must be considered in the design of permanent support:

(1) The required size of the protected area at ground surface;

(2) The required size of the area at mine level where support is to be left;

(3) The required size and spacing of the pillars to be left for support; and

(4) The location and alignment of utilities and surface drainage in the immediate vicinity of the protected area.

These points are considered in the next several paragraphs. Section 5.3.1 deals with panel-wide ground support; Section 5.3.2 with ground support along a strip of ground between adjacent mine panels; and Section 5.3.4, with localized pillar support above a room-and-pillar retreat panel. Section 5.4 deals with the design of pillars for these cases.

5.3.1 Panel-Wide Support. Where permanent pillar support is to be provided across the entire mine panel, the principal consideration is the design of the mine level support itself.

5.3.1.1 Size of the Protected Area at Ground Surface. The entire ground surface above the mine panel constitutes a protected area.

5.3.1.2 Size of the Pillar Support Area at Mine Level. Coal pillars are distributed uniformly across the entire width and length of the mine panel.

5.3.1.3 Permanent Mine Level Support. The design of mine level support is discussed in Section 5.4.1 for the case where coal pillars are distributed uniformly across the mine panel.

5.3.1.4 Infrastructure and Ohter Factors. The potential for damaging utilities or adversely affecting drainage will be virtually nil owing to the near absence of measurable ground surface movements.

5.3.2 Support of a Strip of Ground Between Mine Panels.

5.3.2.1 Size of the Protected Area at Ground Surface. The minimum protected area must be large enough to encompass the designated structure(s) as well as a surrounding safety zone, whose purpose is to prevent encroachment on the structure(s) of mining-related ground movements. The appropriate width of the safety zone is a matter of judgment, but in any case should be no less than 15 feet.

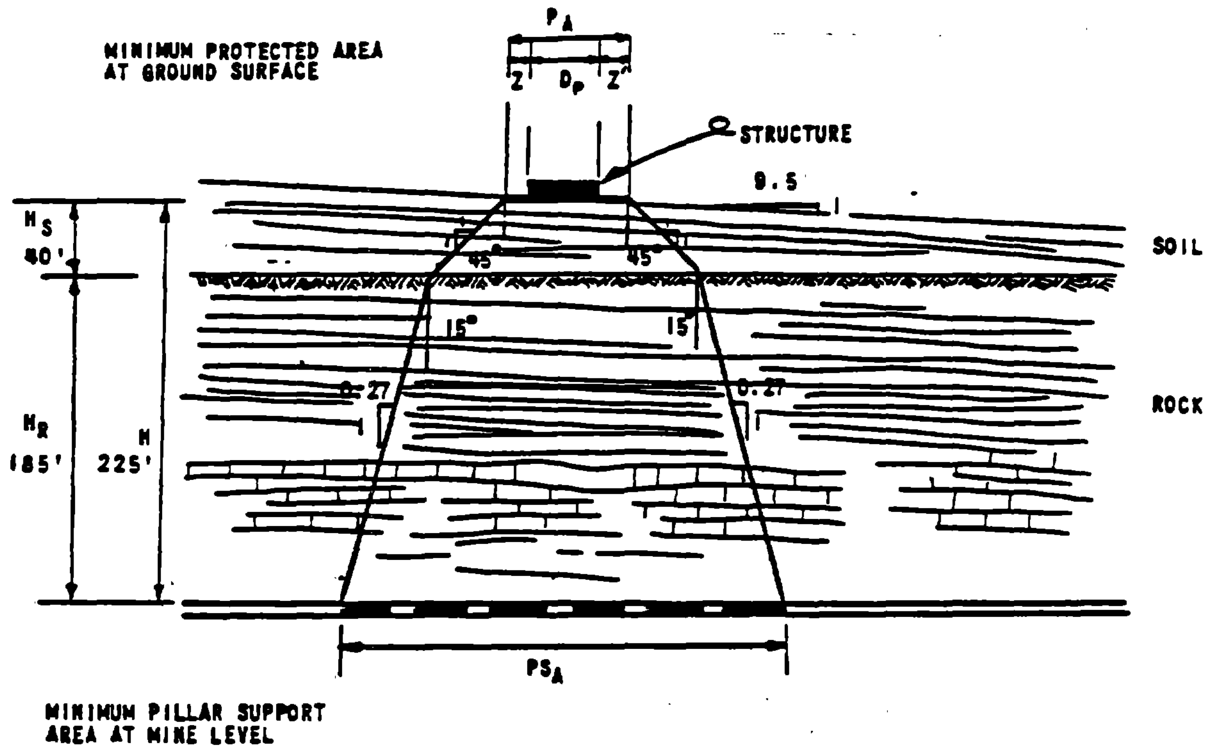
Some guidance can be derived from the Pennsylvania Regulations. Although applying specifically to isolated support areas above total extraction panels (Section 5.3.3), the regulations apply equally well to barrier and chain pillars between panels, which in effect represent long, linear isolated support areas.

According to the Pennsylvania Regulations permanent support must be provided beneath non-commercial buildings used by the public, as well as beneath dwellings used for habitation and in place on April 27, 1966, and burial grounds. The following approach is accepted as a minimum. If the ground surface is level, a safety zone Z no less than fifteen feet in width is left around the structure(s) to be protected. For a structure (or group of structures) of width Dp, the total width of the protected area is:

$$P_A = 2Z + D_p \qquad (5.2)$$

In locations where the ground surface slope exceeds 5 percent (20 horizontal:1 vertical=3 degrees), the width of the safety zone on the downslope side is increased by an amount equal to the product of the mine depth (H) and the ground surface slope (tan θ):

$$Z' = 15 \text{ feet} + H \text{ tangent } \theta \qquad (5.3)$$



EXAMPLE:

GIVEN: A STRUCTURE OF WIDTH D_p = 35 FEET
GROUND SLOPE $\theta = 6°$
OVERBURDEN THICKNESS H = 225 FEET
SOIL THICKNESS H_s = 40 FEET

FIND: WIDTH OF MINIMUM PROTECTED AREA, P_A
WIDTH OF MINIMUM PILLAR SUPPORT AREA AT MINE LEVEL, PS_A

SOLUTION:

$$P_A = Z + Z' + D_p$$
$$= 15 + (15 + H \tan \theta) + D_p$$
$$= 15 + (15 + 225 [0.1]) + 35$$
$$= 88 \text{ FEET}$$

$$PS_A = 2 (H_s + 0.27 H_R) + P_A$$
$$= 2 (40 + 0.27 [225 - 40]) + 88$$
$$= 268 \text{ FEET}$$

NOTE: THE SAME PROCEDURE MUST BE USED TO FIND THE LENGTH OF THESE TWO AREAS.

FIGURE 5.8 EXAMPLE 3 – PARTIAL EXTRACTION – SIZE OF PROTECTED AREA AND PILLAR AREA

The total width of the protected area (Figure 5.8) is then:

$$P_A = Z + Z' + D_p \qquad (5.4)$$

If the ground slopes downhill on both sides of the structure (the slopes being unequal), then the total width of the protected area is:

$$P_A = Z' + Z'' + D_p \qquad (5.5)$$

5.3.2.2 Size of the Permanent Pillar Support Area at Mine Level. The minimum pillar support area is delineated by projecting downward to mine level from the outer edge of the safety zone (Section 5.3.2.1) a series of lines inclined to the vertical at the angle of draw. Methods for estimating the angle of draw (and their shortcomings) are presented in Section 4.4.2.3. In view of the uncertainties in estimating angle of draw from empirical or theoretical relationships, local experience should be a guide. In western Pennsylvania, an angle of 15 degrees is commonly employed.

A separate angle of draw should be used for the soil zone if greater than a few feet thick. Analytically, the width of the support area at mine level PS_A is expressed in terms of the respective angles of draw and thicknesses of the soil and rock intervals as:

$$PS_A = P_A + H_s \tan \beta_s + H_R \tan \beta_R \qquad (5.6)$$

where P_A = total width of the protected area at ground surface
H_s = soil thickness
H_R = rock thickness
β_s = angle of draw in soil (commonly taken to be 45 degrees)
β_R = angle of draw in rock

The use of Equation 5.6 is illustrated in Example 3, Figure 5.8.

5.3.2.3 Permanent Mine Level Support. The design of mine level support is discussed in Section 5.4.2 for the case of chain pillars and barrier pillars at the edge of a total extraction mine panel.

5.3.2.4 Infrastructure and other Factors. Surface drainage as well as utilities (sewer, gas, water) that extend from the protected zone to the adjoining mined-out area will be subjected to changes in curvature, slope and strains. Under certain circumstances, ground deformations may be large enough to break the lines or to reduce or reverse slopes to an unacceptable degree. The maintenance of utilities may require special attention during mining of the area adjoining the support area. This subject is discussed in a related report titled, "Development of Subsidence Damage Criteria", prepared for the OSMRE by Engineers International, Inc., 1985.

5.3.3 Support of an Isolated Area Above a Mine Panel. The support requirements for this situation are established in essentially the same manner as for a strip of ground between mine panels.

5.3.3.1 Size of the Minimum Protected Area at Ground Surface. This value is determined in accordance with Section 5.3.2.1. The only difference is that the area is established on the basis of two mutually perpendicular sections through the structure(s) rather than just one.

5.3.3.2 Size of the Minimum Permanent Pillar Support Area at Mine Level. This value is determined in accordance with Section 5.3.2.2, but using two mutually perpendicular sections. Once again, the uncertainties in reliably estimating angle of draw are to be recognized and accounted for.

5.3.3.3 Permanent Mine Level Support. The design of mine level support is discussed in Section 5.4.2 for the case of isolated groups of pillars in a room-and-pillar retreat mine panel.

5.3.3.4 Infrastructure and Other Factors. These considerations are dealt with as per Section 5.3.2.4.

5.4 Design of Coal Pillar Support

A pillar's function determines its size. A permanent pillar that is to provide support for an indefinite period must be larger than a pillar that is permitted to yield after its temporary support function has been served. In either case, the pillar dimensions are governed by the mechanical properties of the coal, the mine roof and the mine floor and by the load that must be borne by the pillar. The following discussion deals with the design of coal pillars whose function is to furnish permanent support to the ground surface in the manner in Section 5.3. Depending upon the individual case, such pillars may be required to serve in one of three ways:

1. To support a panel-wide area as per Section 5.3.1. Pillar design is discussed in Section 5.4.1.

2. To support a strip of ground between adjacent mine panels as per Section 5.3.2. Pillar design is discussed in Section 5.4.2.

3. To support an isolated area above a room-and-pillar retreat panel as per Section 5.3.3. Pillar design is discussed in Section 5.4.3.

Before dealing with specifics, a fww preliminary comments are made regarding the respective roles in pillar design of the mechanical properties of the rock at mine level, the pattern of mining and expected loads on the support pillars.

The mechanical properties of the coal seam and boundary strata are of two characteristic types:

1. Type I—The mine roof and floor are stronger than the coal seam. Pillar capacity is enhanced by the lateral restraint offered to the coal by the roof and floor. Pillar strength formulas pertaining to Type I conditions are reviewed by Hustrulid (1976), Peng (1978), Babcock et al. (1981), and Bieniawski (1983), among others. Wilson (1981, 1982) also presents formulas for this case and reviews several rules of thumb for pillar sizing that have gained some acceptance by miners, with the emphasis being on pillars used for permanent ground support.

2. Type II—Either of two situations prevail: (a) the coal seam, the mine roof and the mine floor possess similar mechanical properties, or (b) the mine roof and mine floor are weaker than the coal seam. Under Type II conditions, the lateral restraint offered by the mine roof and mine floor is reduced, so that for a particular coal seam, the pillar capacity is less than under Type I conditions. Pillar strength formulas pertaining to certain Type II conditions are presented by Wilson (1981, 1982).

The second factor that governs pillar dimensions-the load delivered to the pillar—is governed largely by the pattern of mining in the panel. Mining patterns and loads conform to three cases:

1. Case A—A partial extraction room-and-pillar panel. The pillars are uniformly distributed throughout the panel. The overburden has not caved. The pillar stress comprises two components — the cover stress q and the stress transferred from the immediately adjacent entries.

2. Case B—A total extraction longwall, shortwall or room-and-pillar retreat panel. Pillars surround a mined-out area that is rectangular in configuration. The overburden has caved. The stress in pillars on the perimeter of the mined-out area comprises two components—the cover stress q and the stress transferred from the adjoining mined-out area.

3. Case C—A room-and-pillar retreat panel with local pillar support. An isolated group of permanent support pillars lies within an otherwise mined-out panel in which the overburden has caved. As with Case B, the stress in pillars within the isolated group comprises components of the cover stress and the stress transferred from the adjoining mined-out area.

Details of the design of pillars for permanent support are presented below.

5.4.1 Design of Panel-wide Support Above a Partial Extraction Room-and-Pillar Panel with Coal Pillars Distributed Uniformly Across Mine Panel (Case A).

5.4.1.1 Mine Roof and Floor Stronger than the Coal Seam (Type I). The design steps are as follows:

1. Establish the desired Extraction Ratio, E. Fifty percent extraction (E=0.5) is generally (although not universally) the upper limit allowed by regulatory agencies for permanent support areas. Where mining is shallow (e.g. 150-250 feet) or mine height is limited (eg., 40 inches), the value of 'E' may exceed fifty percent. At a depth where little previous experience as been gained with long term permanent pillar support, the value of 'E' may be limited to less than fifty percent.

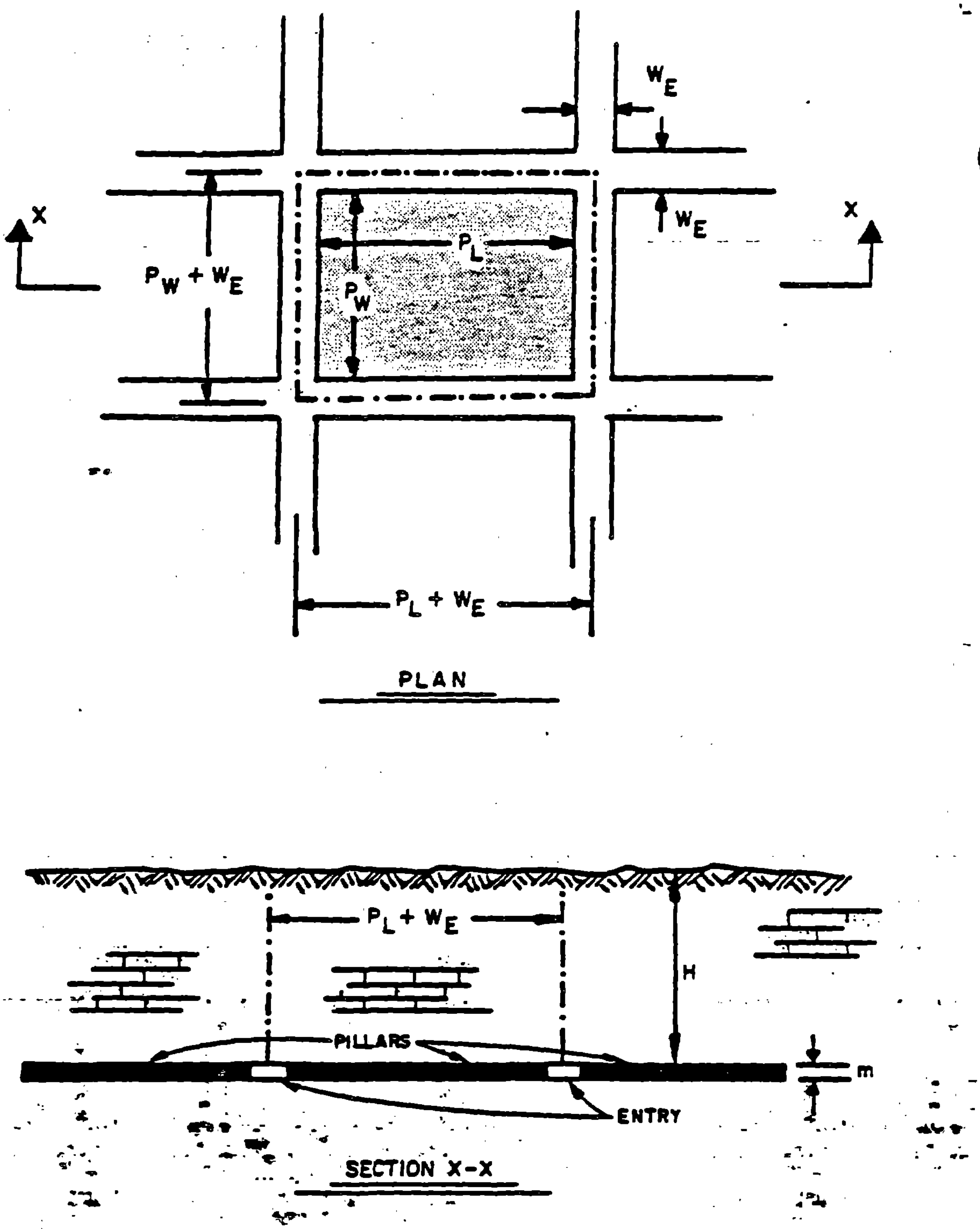
   The following steps may influence the choice of extraction ratio.

2. Compute the nominal Pillar Stress, σ_p.

$$\sigma_p = q/(1-E)$$

where q = H, the overburden (cover) stress.
= unit weight of rock, customarily taken to be 155 pounds per cubic foot = 0.09 pounds per cubic inch. (A rule-of-thumb is that the overburden stress increases by 1.1 pound per square inch (1.1 psi) for every foot of depth below ground surface.)

The pillar stress computation is based on the tributary area theorem, where the load on a pillar is taken to be the weight of a column of overburden extending from ground surface to mine level whose cross sectional dimensions are the length and width of the pillar plus half the width of each adjoining entry (Figure 5.9).



Pillar Area $A_p = P_w \cdot P_l$

Tributary Area $A_T = (P_w + W_E)(P_l + W_E)$

Extraction Ratio $E = 1 - A_p/A_T$

Cover Stress $q = \gamma H$

Vertical Load on Pillar $L_v = q\,A_T$

Vertical Stress on Pillar $\sigma_p = L_v/A_p$ and $\sigma_p = q/(1-E)$

FIGURE 5.9 TRIBUTARY AREA LOADING OF PILLAR

3. Compute the Governing Coal Cube Strength, σ_p. The larger the volume of coal, the lower is its strength. The lower bound strength,—the value appropriate for computing pillar strength—is usually reached when the coal pillar size equals or exceeds 3 feet on a side (Hustrulid, 1976). The lower bound or governing coal cube strength is determined from the empirical expression:

$$\sigma_C = \frac{\sigma_L}{6}\sqrt{D} \qquad (5.8)$$

where σ_L is the unconfined compressive strength in psi of a cube of coal of edge length D in inches (less than or equal to 36 inches).

The cube strength is generally found by testing in uniaxial (unconfined) compression 15 to 30 cubes of coal all having the same edge length (commonly 2-4 inches), and from the test distribution determining a representative value, usually the median. (The median value lies at the center of the distribution so that half the values are greater and half are smaller.)

4. Determine the Pillar Dimensions. Using the values of σ_p and σ_c computed above, along with the mine height 'm', the minimum pillar width 'Pw' that is required to preclude crushing of the coal is:

$$Pw = m\left(\frac{6.82\,\sigma_p}{\sigma_c} - 3.54\right) \qquad (5.9)$$

This expression, presented in graphical form in Figure 5.10, is based on the formula reported by Overt & Duvall (1967) which was verified by Wang et al., 1976 and has been in use for many years.

The values of σ_c and σ_p must be in consistent units (e.g., both in psi, or in psf). The value of 'Pw" will be in the same units as m.

5. Check the Extraction Ratio and Revise the Previous Steps as Necessary. The pillar length Pl must equal or exceed the computed pillar width: $Pl \geq Pw$, and both pillar length and width must be consistent with the extraction ratio assumed at the outset (Step 1). If they are not, the procedure must be repeated beginning with Step 1, as illustrated by Example 4, Figure 5.11.

5.4.1.2 Mine Roof and Floor with Mechanical Properties Similar to or Weaker than the Coal Seam (Type II). Owing to lesser confinement at the top and bottom, a coal pillar having mechanical properties that equal or exceed those of the mine roof and floor

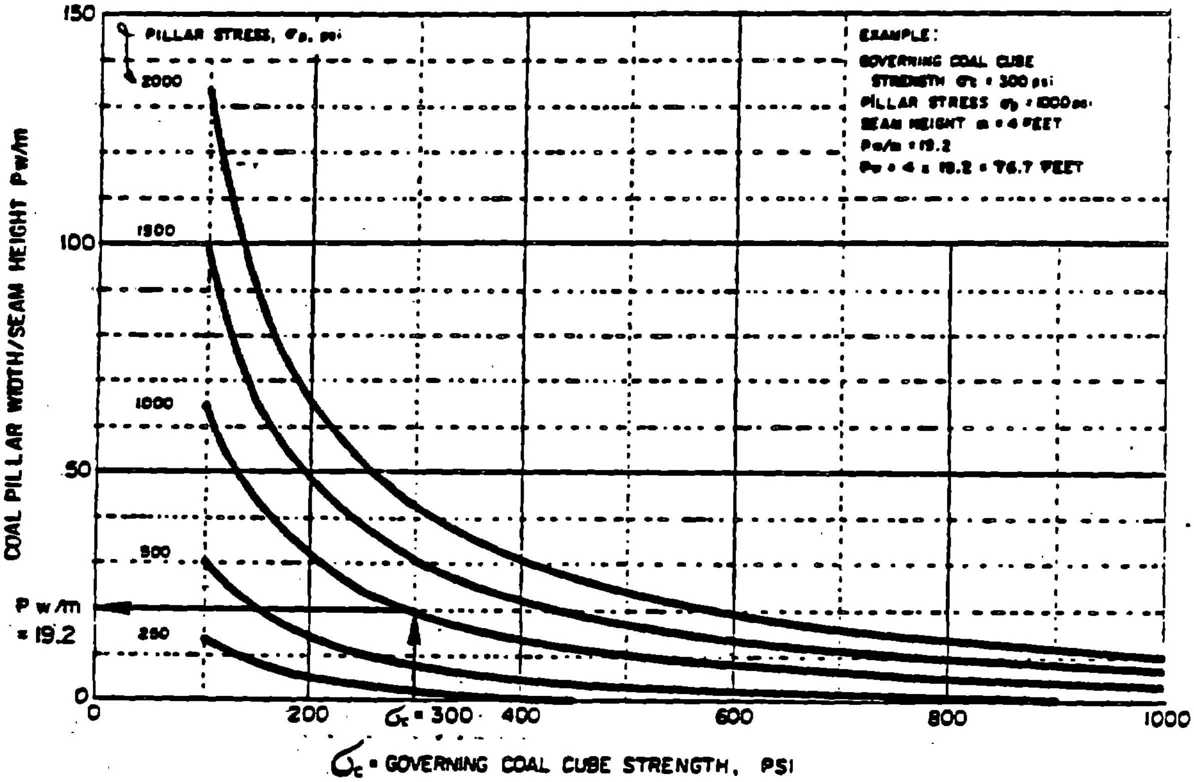


FIGURE 5.10 RELATIONSHIP BETWEEN WIDTH-TO-HEIGHT RATIO OF COAL PILLAR AND GOVERNING COAL CUBE STRENGTH

Problem: Partial extraction mining is to be conducted in a 500-foot-wide by 1500-foot-long mine panel in a 6-foot coal seam at 465-foot depth. Coal pillars are to be uniformly distributed across the mine panel and are to provide permanent support to the overburden. The entries and cross-cuts are fixed at 17-foot width.

The laboratory strength of the coal is 1273 psi, as determined from a series of uniaxial compression tests on 2-inch cubes. The mechanical properties of the roof and floor significantly exceed those of the coal.

n Establish the required width and length of the support pillars.

<u>Solution:</u> Panel-wide support is discussed in Section 5.3.1. The methodology for sizing pillars is outlined in Section 5.4.1., where the problem can be characterized as Case A, Type I--uniformly distributed pillars; mine roof and floor stronger than coal seam.

1. Establish the desired extraction ratio, E.

   It will be assumed for the intended application that fifty percent extraction is desired and is allowed by the regulatory authority. Note that this value of 'E' is, in fact, tentative and subject to revision based on the outcome of the following computations.

2. Compute the nominal pillar stress, σp.

   With E tentatively established at 0.5, the nominal pillar stress σp is expected to be approximately 144,000 psf (equivalent to 1000 psi) using Equation 5.7, $\sigma p = q/(1-E)$, which assumes the validity of the Tributary Area Theorem. The value of σp is based on a cover stress q of 72,000 pounds per square foot (equivalent to 500 psi), where the mine depth is 465 feet and the unit weight of the overburden is taken to be 155 pounds per square foot.

3. Compute the governing Coal Cube Strength, σ_c.

   The governing strength σc of the coal seam--the strength of the coal seam in place--is determined to be 300 psi (equivalent to 43,200 psf) using Equation 5.3 $\sigma_c = \frac{\sigma_L}{6}\sqrt{D}$ where the laboratory strength of the coal σ_L is 1273 psi and the dimension D of the test cubes is 2 inches.

4. Determine the Pillar Dimensions, Pw and Pl.

   The required pillar width Pw is determined either from Figure 5.10 or from Equation 5.9.

   Equation 5.9 yields Pw/m=19.2. Alternatively, Figure 5.10 is entered at σc = 300 psi and exited at Pw/m = 19.2.* The mine height m = 4 feet, so the required pillar wide Pw is 19.2 x 4 = 76.8, say 77 feet.

5. Check the Extraction Ratio and Revise the Previous Computations as necessary.

   Note that if the pillars are to be square, the extraction ratio for 77-foot pillars and 17-foot entries is actually 0.33 rather than 0.5 as assumed at the outset of the solution. E=1-(77x77)/([77+17][77+17])=0.33, Figure 5.9. This inconsistency carries over to the pillar dimensions, pillar stress and extraction ratio.

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*Realistically, one would probably read 19 or 20 from the figure.

FIGURE 5.11 EXAMPLE 4 - SIZING PILLARS FOR PERMANENT SUPPORT STRONG FLOOR

An iterative process, as presented in Table A, must be employed--there is no alternative but to do so. The iterative process entails using an assumed value of extraction ratio (Column 2) to compute corresponding values of pillar stress σp (Column 3) and pillar width Pw (Column 4). If the computed extraction ratio does not equal the assumed extraction ratio, then the computational process is repeated, using the computed extraction ratio from the current trial as input for the next trial. Table A and the associated graph show that the two values of extraction ratio converge to 0.39 after ten trials. The corresponding pillar stress σp is 820 psi and the corresponding pillar width Pw is 60.4 feet, say 61 feet. Since the pillar is square, the pillar length Pl is also 61 feet.

The implication is this: assuming the validity of the pillar capacity formula (Equation 5.9) and the Tributary Area Theorem (Figure 5.9), the site conditions of this problem limit the extraction ratio to no more than 0.39. The originally desired fifty percent extraction is unattainable if a Factor of Safety of 1.5 is to be attained. Obviously, square pillars larger than 61 feet on a side separated by 17-foot-wide entries are acceptable since they produce Factors of Safety in excess of 1.5 (but at a sacrifice of extraction).

Now suppose that rectangular rather than square pillars are desired with length P_l equal to 1.5 times the width Pw. The iterative procedure outlined above shows that the largest extraction ratio attainable is .36 (Table B). The pillar stress σp is then about 780 psi and the pillar width Pw is 57 feet. The pillar length P_L is 86 feet. Larger rectangular pillars separated by 17-foot-wide entries are acceptable since they produce Factors of Safety exceeding 1.5. Corresponding extraction ratios will, of course, be less than 0.36.

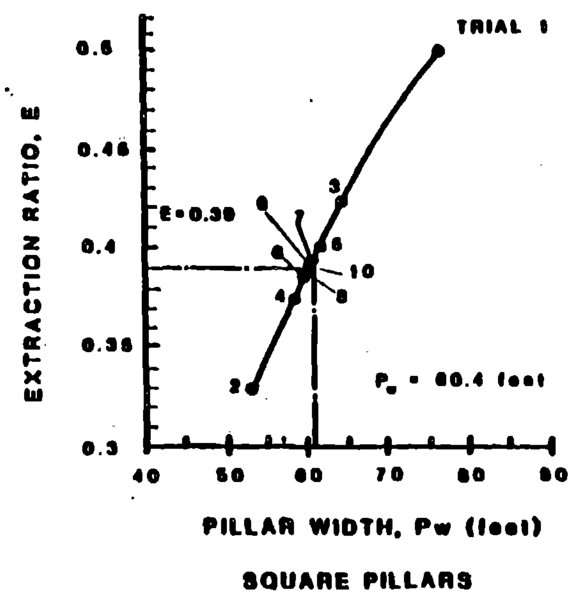

FIGURE 5.11 CONTINUED

Table A

SQUARE PILLARS

Trial (Col. 1)	Assumed Extraction Ratio, E (Col. 2)	Pillar Stress△ σ_p, psi (Col. 3)	Pillar Width‡ P_w, feet (Col. 4)	Computed Extraction Ratio, E* (Col. 5)
1	0.5	1000	76.8	0.33
2	0.33	746	53.7	0.423
3	0.423	867	64.7	0.373
4	0.373	797	58.4	0.40
5	0.40	833	61.6	0.386
6	0.386	814	59.9	0.393
7	0.393	824	60.8	0.389
8	0.389	819	60.3	0.391
9	0.391	822	60.6	0.390
10	0.390	820	60.4	0.390

Table B

RECTANGULAR PILLARS

Trial (Col. 1)	Assumed Extraction Ratio, E (Col. 2)	Pillar Stress△ σ_p, psi (Col. 3)	Pillar Width‡ P_w, feet (Col. 4)	Computed Extraction Ratio, E* (Col. 5)
1	0.5	1000	76.8	0.287
2	0.287	701.3	49.6	0.394
3	0.394	825.1	60.9	0.341
4	0.341	758.7	54.8	0.367
5	0.367	789.9	57.7	0.354
6	0.354	774.1	56.3	0.361
7	0.361	782.5	57.0	0.358
8	0.358	778.8	56.7	0.359
9	0.359	780.0	56.8	0.358

△ Equation 6.7, $\sigma_p = q/(1-E)$.

‡ Equation 6.9, $P_w = m\left(\frac{6.82\,\sigma_p}{\sigma_c} - 3.54\right)$

* Figure 6.9 $E = 1 - A_p/A_t$

Figure 5.11
(continued)

will have less capacity than if the mine roof and floor were stronger. Wilson (1981, 1982) offers a formula for assessing pillar capacity where the floor, roof and coal seam have similar properties. The formula is presented in Table 5.2, Section 5.4.2. Wilson's formula may also be used where the floor and roof are weaker than the coal, assuming that the lowest strength governs.

An alternate approach that should also be investigated for weak floor and roof conditions is based on soil mechanics concepts. Here, the pillar is envisioned as a footing and the floor (or roof) as a foundation. The load capacity of the pillar is governed by the bearing capacity of the foundation material, given by Vesic (1975) as:

$$Qult = N_m C_1/FS \qquad (5.10)$$

where C_1 is the undrained shear strength of the layer immediately beneath the footing,

N_m is a bearing capacity factor that depends upon several factors: the undrained shear strength of the weak foundation layer immediately beneath the footing relative to that of the underlying stronger layer (C1/C2); the thickness of the weaker layer relative to the width of the footing; and the shape of the footing; and

FS is the factor of safety, customarily taken as 3 in bearing capacity analyses.

The bearing capacity is lower where the coal pillars are smaller and where the foundation material is thicker and of lower strength. Because the bearing capacity of the foundation is dependent on the pillar dimensions that are sought, pillar design using this formula is an iterative ("trial-and-error") procedure. To simplify the design process, one can conservatively utilize the lower bound bearing capacity, which is independent of the pillar dimensions. The lower bound bearing capacity is given by:

$$Qult = 5.14\, C_1/FS \qquad (5.11)$$

With the bearing capacity of the floor (or roof) being expressed in these terms, the pillar dimensions are determined using the procedure outlined in Section 5.4.1.1, the only difference being that the extraction ratio 'E' may be limited by the bearing capacity. This is illustrated by Example 5, Figure 5.12.

Foundation bearing capacity can be of particular concern where, for example, the floor contains intervals of underclay ("fireclay"). Underclay is a massive, but relatively soft rock (claystone) that lacks the laminations typical of many other sedimentary strata, but is dissected by smooth, curved slickensides resulting from differential movements that took place while the material was still in a soft state. These slicken sides, spaced at a fraction or an inch to a foot or two, weaken the rock and promote its deterioration when exposed to

Problem: The mine setting is the same as for Example 4, Figure 5.11, with the exception that the strength of the mine floor is sufficiently low to govern the pillar design. The laboratory strength of the mine floor material is nominally 2500 psi, as determined from a series of uniaxial compression tests on NX core.

o Establish the required dimension of permanent support pillars.

Solution: Panel-wide support is discussed in Section 5.3.1. The methodology for sizing pillars is outlined in Section 5.4.1.2, where this problem can be characterized as Case A, Type II--uniformly distributed pillars; mine roof and floor weaker than coal seam.

1. Establish the desired extraction ratio, E.

   It is assumed here, as it was in Example 3, that an extraction ratio of 50 percent is desired.

2. Compute the nominal pillar stress, σp.

   On the basis of E = 0.50, the expected nominal pillar stress is once again 144,000 psf (= 1000 psi), as determined from Equation 5.7. This, of course, is contingent upon the mine floor being able to withstand that level of stress.

3. Compute the governing coal cube strength σc, the governing mine floor strength q_F and the bearing capacity of the mine floor Qult.

   The governing coal cube strength is the same here as it was in Example 4, σc = 300 psi.

In recognition that the in-place strength of the mine floor is less than the laboratory strength due to the presence of slickensides, fissures and other factors, the governing unconfined strength of the mine floor q_F is taken to be one-fifth of the laboratory strength in accordance with the strength reduction factors presented in Table 5.2. q_F = 1500 psi/5 = 300 psi. The strength reduction is comparable to that made for coal in Example 4. The maximum allowable pressure that can be sustained by the mine floor is the ultimate bearing capacity Q_{ult} =5.14C_1 /FS(Equation 6.11), where C_1 is the undrained strength of the mine floor. C_1 in turn, equals half the unconfined compressive strength of the floor material; that is, $C_1 = q_F/2$. The bearing capacity of the floor is therefore Q_{ult} = 2.57 q_F, if FS is taken as 1.*

At this point, we must recognize that the ultimate bearing capacity of the mine floor Q_{ult} of 771 psi is less than the nominal pillar stress σp computed in Step 2. Consequently, the estimate of nominal pillar stress must be revised downward to σp = 771 psi and, accordingly, the extraction ratio must be revised downward to a value not to exceed 0.35=1-(500/771), based upon E=1-(σ/ σp), Equation 5.7 (rearranged). This being done, the pillar dimensions can now be computed.

FIGURE 5.12 EXAMPLE 5 – SIZING PILLARS FOR PERMANENT SUPPORT, WEAK FLOOR

4. Determine the Pillar Dimensions, Pw and Pl.

Note that the extraction ratio E = 0.35 is smaller than the value determined by the iterative procedure of Example 4 (E = 0.39). This confirms that the bearing capacity of the floor governs the pillar design in the present case. If we were now to employ an equation where the bearing capacity was a function both of pillar stress and pillar dimensions, then pillar design would be an iterative process as it was in Example 4, the only difference being that the bearing capacity equation would take the place of the pillar equation (Equation 5.9). As it is, we have elected to use a simpler, more conservative bearing capacity equation that is independent of pillar dimensions. This permits the direct calculation of pillar width Pw from a knowledge of extraction ratio E, which, in turn, is governed by the bearing capacity of the floor, Q_{ult}.

Figure 5.9 shows that extraction ratio 'E' is related to pillar width Pw, pillar length Pl and entry width W_E according to: $E = 1-[Pw \cdot Pl]/[(Pw+W_E)(Pl+W_E)]$.

With E = 0.35 and We = 17 feet,

$0.35 = 1-([Pw \cdot Pl]/[Pw+17)(Pl+17)])$

For a square pillar

$0.35 = 1-([Pw^2]/[Pw^2+34Pw+289])$

For a rectangular pillar with Pl = 1.5Pw

$0.35 = 1-([1.5Pw^2]/[1.5Pw^2+42.5Pw+289])$

These equations can be solved for Pw by rearranging and using the quadratic formula (found in any algebra book) or by trial and error. Either way, one finds that a permanent support pillar would have to be 70.75 feet on a side, if square in plan, and 58.7 feet in width and 88.1 feet in length, if rectangular in plan with Pl = 1.5 Pw. As a check, we find using Equation 5.[illegible] that the factor of safety of these pillars against [illegible] exceeds 1.8, which is acceptable. (Factor of Safety is defined as the ratio of strength to applied stress.)

This example illustrates how the presence of a weak mine floor can necessitate a reduction in extraction ratio in order to reduce the pillar stress to a level that can be tolerated by the mine floor.

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* For discussion purposes, we took the Factor of Safety to be unity. This yields the largest value of the extraction ratio for the conditions specified in the problem. However, as stated in Section 5.4.1.2, the Factor of Safety in bearing capacity analyses is customarily taken as 3. Doing so in the present case would result in an allowable extraction ratio of zero, since the computed value of E = 1 - (q/[illegible]) would be negative. Thus, one could conclude that mining at the site would incur substantial risk of bearing capacity failure and attendant ground control problems regardless of the pillar size. In view of this, the operator might elect to conduct a more refined analysis of mine floor capacity where the thickness of the underclay is accounted for, where the floor strength is more thoroughly assessed and where justification is sought for using a less restrictive Factor of Safety.

FIGURE 5.12 (CONTINUED)

air and moisture for prolonged periods of time. Upon exposure, the rock assumes the character of an overconsolidated clay soil. During mining, efforts are usually made to keep the floor dry. After mining these efforts usually cease. In order for the underclay to support pillar loads indefinitely, the long- term strength of the underclay must be utilized in the design.

The designer should be aware that the long term strength of the floor (or roof)—the strength over many decades of time—may be significantly less than the strength determined after the much shorter time interval to which one is necessarily restricted when conducting laboratory or field strength tests. A proper assessment of the long-term strength requires the combined expertise of a geotechnical specialist and mining personnel experienced in the region.

5.4.2 Design of Support for a Strip of Ground between Adjacent Mine Panels (Case B). The principal function of barrier pillars and chain pillars is to protect the entries passing amidst these pillars from the effects of coal extraction within the panel. For purposes of access, haulage and ventilation, these entries commonly must remain serviceable during the productive life of the panel, if not for the life of the mine.

The pillar nearest to the gob at the panel midsection generally experiences the highest stresses. If it performs satisfactorily, then other pillars against the gob and in rows away from the gob will usually remain functional as well. Two different approaches to design might be taken, depending on whether the ground above the barrier pillars and chain pillars is permitted to subside.

1. If subsidence is permitted above the barrier pillars and chain pillars, the pillars may be designed to yield after passage of the face in the adjoining (second) panel. This optimizes coal recovery in the panel, since the yield pillars are of smaller size than permanent pillars, and also produces a more gentle subsidence profile—a profile exhibiting milder strains, curvatures and slopes. The factor of safety of such pillars is less than unity under the expected maximum loading.

2. Alternatively, if subsidence is not permitted above the barrier pillars and chain pillars, the chain pillars are designed as permanent support. In this situation, the chain pillars do not yield under the maximum imposed load and their factor of safety exceeds unity.

The principal factors that control the size of the pillarsaare the stress distribution around the perimeter of the panel, which is related to mine depth and panel geometry, and the mechanical properties of the coal seam, the mine floor and the roof. With regard to the latter, Hsiung and Peng (1984) find that the stiffer the roof.

and floor relative to the coal, the more stable is the coal pillar, all else being equal. Wilson (1981, 1982) prresents similar arguments with regards to the strength of the coal, roof and floor.

Two approaches to chain pillar design are discussed below. The first (section 5.4.2.1) is a hand calculation method that enables the sizing of chain pillars for conditions of either permanent support or yielding. The second (Section 5.4.2.2) is a nomograph method that enables the rapid sizing of chain pillars that are permitted to yield after passage of the face in the second (adjoining) panel.

5.4.2.1 Chain Pillar Design--Permanent Support or Pillar Yield (Hand Calculations).

Loads Imposed on Ribsides and Chain Pillars. As the coal seam is extracted, the overburden sags into the mined-out area and its weight is redistributed, part being transferred to the rubble in the mined-out area and the remainder to the pillars and solid coal bounding the panel (Figure 5.13).

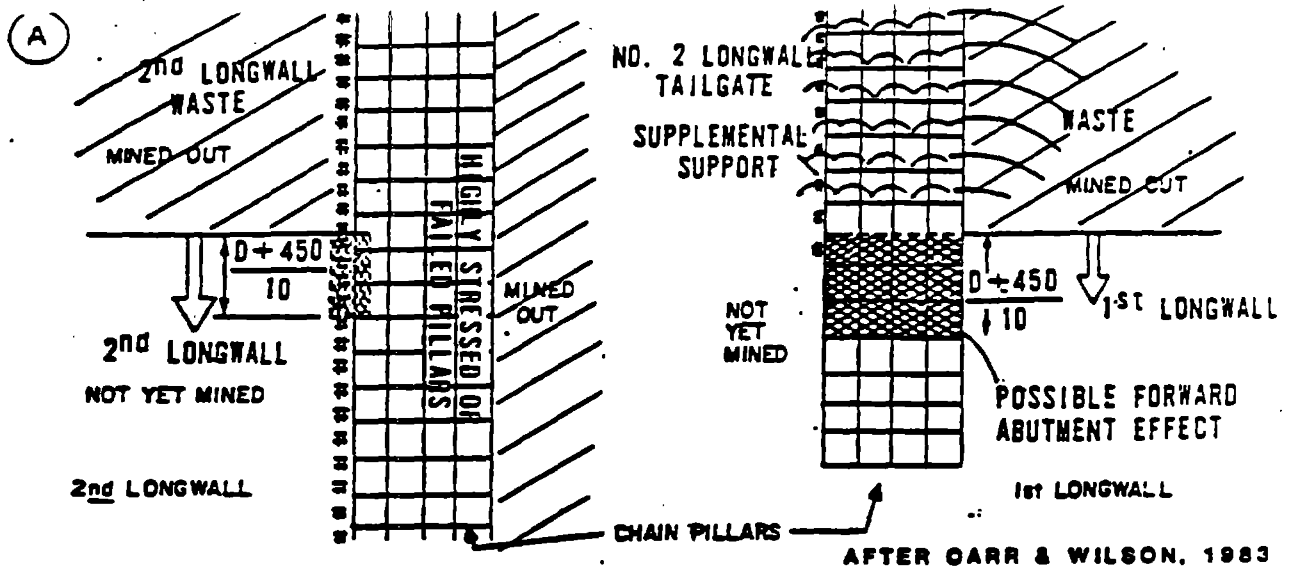
The load carried by the rubble is nil at the ribside, but according to Wilson (1981), increases linearly toward the center of the panel, reaching the cover stress q at a distance 0.3H from the rib.

The distribution of the abutment stress depends on the strength of the coal and the relative strengths of the mine roof and mine floor. Where the mine roof and floor are of similar strength to the coal, the yield zone around the perimeter of the panel tends to be wider and the load distributed farther back from the ribside than where the coal seam is less strong than the mine roof and floor. Equations for estimating the distribution of abutment stresses for these two cases are presented in Table 5.2, based on the work of Wilson (1981, 1982). In both cases, the vertical stress σ_y in the yield zone increases from zero at the ribside to the peak abutment stress σ at the boundary between the yield zone and the elastic core of the pillar. The vertical stress in the elastic core diminishes exponentially with the distance away from the mined-out area.

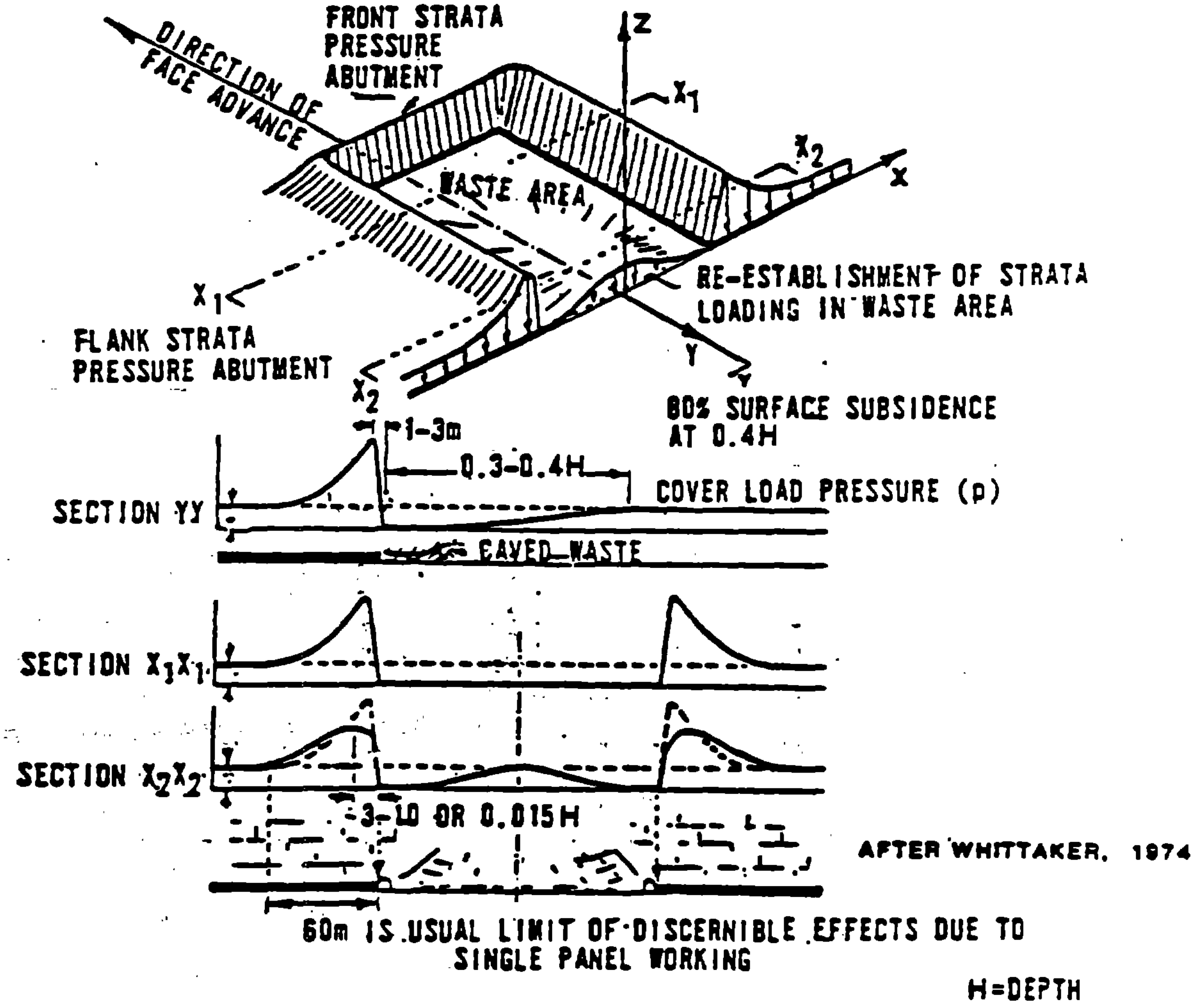
From the foregoing relationships, the average stress imposed--the allowable stress imposed on a pillar bounded by entries at centers a and b from ridside is given by σ_{ab} (Table 5.3).

Pillar Capacity. Two levels of pillar loading are of importance--the allowable stress σ_A and the ultimate stress σ_u. An average pillar stress at or below the ultimate will obviate failure of the pillar as well as promote stability of the entries by limiting the spread of the yield zone on the far side of pillar when mining on the near side.

Wilson expressions for estimating the pillar capacity are presented in Table 5.3 and charts for evaluating certain of the parameters are presented in Figure 5.14. The respective strengths of the mine roof and floor relative to the coal strength influence the pillar capacity, as they do the pillar loading.



A. LOADING ON CHAIN PILLARS FROM MINING TWO ADJACENT PANELS IN SEQUENCE



B. ABUTMENT PRESSURES AROUND A LONGWALL PANEL

FIGURE 5.13 SCHEMATIC OF LOADING ON CHAIN PILLARS

Table 5.2

STRESS IN COAL RIBSIDES AND PILLARS

	Type I Weak Seam Between Strong Roof and Floor	Type II Roof, Seam and Floor of Similar Strength
Width of yield zone	$x_b = \frac{m}{F} \ln (\frac{q}{p^*})$	$x_b = \frac{m}{2} \left[(\frac{q}{p^*})^{\frac{1}{k-1}} - 1 \right]$
Vertical stress in yield zone	$\sigma_y = k\, p^* \exp \frac{xF}{m}$	$\sigma_y = k\, p^* \left[\frac{2x}{m} + 1 \right]^{k-1}$
Peak abutment stress	$\hat{\sigma} = kq + \sigma_o$	$\hat{\sigma} = kq + \sigma_o$
Load carried by yield zone	$A_b = \frac{m}{F} k\, (q - p^*)$	$A_b = \frac{m}{2} p^* \left[(\frac{q}{p^*})^{\frac{k}{k-1}} - 1 \right]$
Vertical stress in elastic zone	$(\hat{\sigma} - q) = (\sigma - q) \exp (\frac{x_b - x}{C^*})$	

where x = distance from ribside.

W = total width of extracted area

k = triaxial stress factor = $\frac{1 + \sin \phi}{1 - \sin \phi}$, where ϕ = angle of internal friction

p^* = support resistance + strength of broken material. The strength of broken material may be taken as 1 Tsf, so that $p^* = p + 1$ Tsf where p is the resistance offered by the support system. p may be taken as zero in the absence of better information.

q = vertical stress field remote from the mine. In the case of a virgin area, $q = \gamma H$, where γ is the average density of strata and H is the depth of cover.

m = height of extraction of coal seam

A_w = $0.15\ \gamma H^2$ for $W > 0.6H$

= $0.5\ \gamma W\ (H - \frac{W}{1.2})$ for $W < 0.6H$

ln() = natural logarithm of the quantity of brackets

exp() = exponential function of the quantity in brackets

Table 5.2
(continued)

$$C^* = \frac{A_w + q.x_b - A_b}{\hat{\sigma} - q}$$

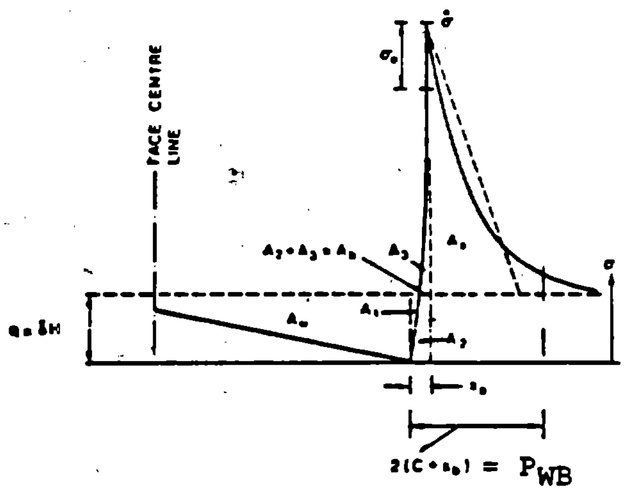
$$F = \frac{k-1}{\sqrt{k}} + \left(\frac{k-1}{\sqrt{k}}\right)^2 \tan^{-1} \sqrt{k} \text{ where } \tan^{-1} \text{ is in radians}$$

σ_o = unconfined compressive strength of strata in situ. This may be obtained approximately by dividing the laboratory determined strength by a factor f where:

f = 1 for strong massive unjointed rock
= 2 for widely spaced joints or bedding planes
= 3 for more jointed but still massive rocks
= 4 for well jointed and weaker rocks
= 5 for coal and unstable underclay
= 6 and 7 for fault zones.

Note: X_b A_b and A_w are graphed in Figure 6.14.

Based on A. H. Wilson (1981, 1982)



IDEALISED STRESS AREA BALANCE ACROSS RIBSIDE

Table 5.3

IMPOSED PILLAR LOADS AND PILLAR CAPACITIES

Imposed average vertical load per unit area on a rectangular pillar bounded by entries at centers a and b from the ribside.

$$\sigma_{ab} = \frac{\sigma - q}{b - a}(\exp[-a/C^*]-\exp[-b/C^*]) + q$$

Allowable load‡ per unit area to maintain the stability of entries

$$R_s = L_R/A$$

where L_R $= \sigma(P_L-2X_b)(Pw-2X_b) + 2A_b(P_L+Pw-2X_b)$

- A = (P_L x Pw)
- P = pillar length
- P_w = pillar width
- W_E = entry width
- X_b = width of yield zone in pillar
- A_b = load carried by yield zone
- q = cover load
- σ = peak abutment stress
- c^* = Refer to Table 5.2

Note: x_b, and A_b are graphed in Figure 5.14

Based on Wilson (1981, 1982)
‡For ultimate load, refer to Wilson, 1982

Measure of Pillar Stability. If the average stress σ imposed on a pillar is less than the allowable stress σ_A, then the entry adjacent to the pillar on the side away from the ribside is expected to be stable. The entry on the near-side may experience some distress since the actual stress on the near side will exceed the average stress.

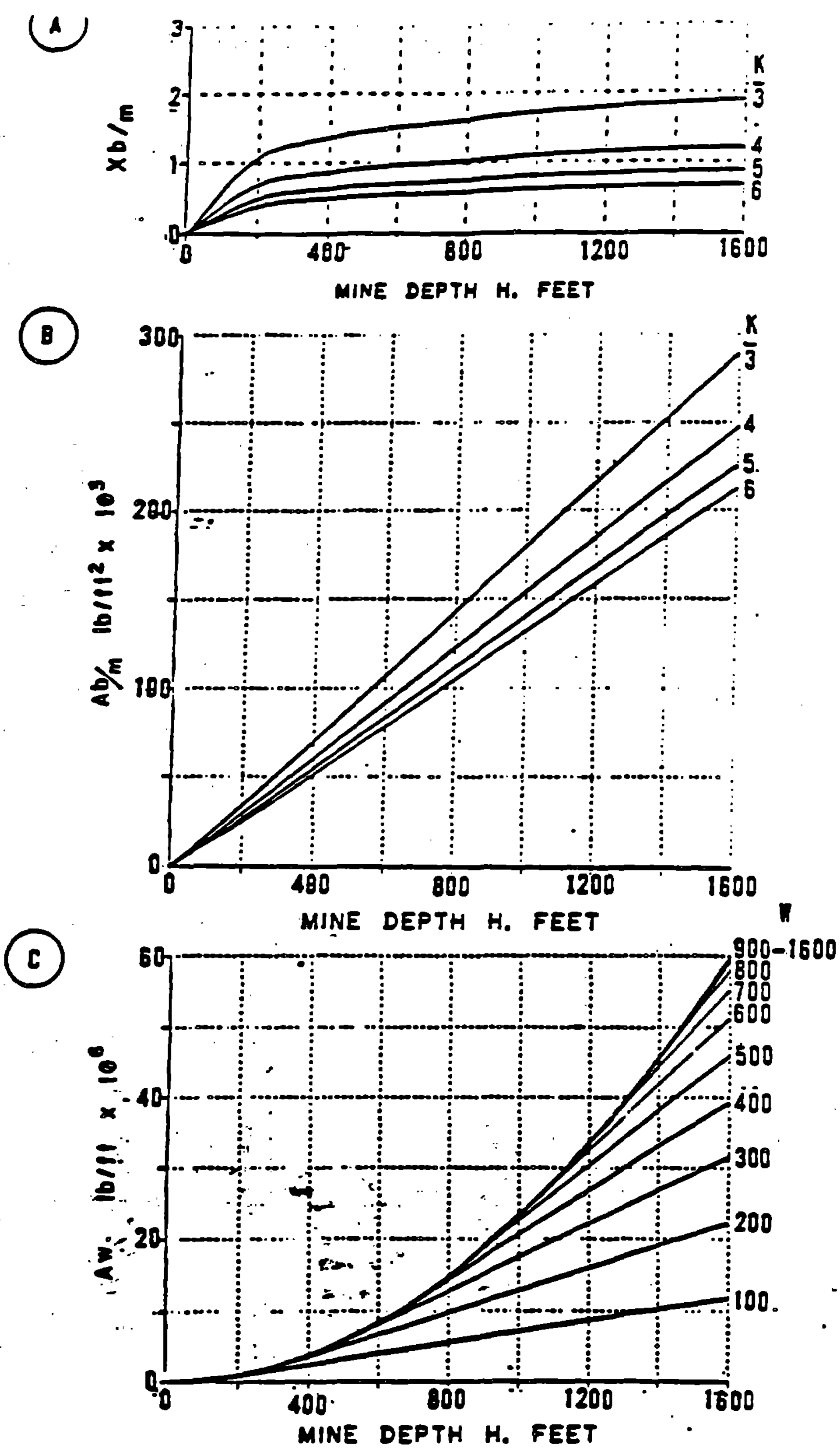
If the value of σ exceeds σ^A but is less than the ultimate pillar capacity σ , then the entries may experience distress but the pillar is expected to retain its integrity and not shed load to pillars in the neighboring row.

If the value of σ exceeds σ , then the excess load will be transferred to the neighboring row of pillars. The stress increase on the next row of pillars is proportional to the relative widths of the two pillars. Depending on the particular site conditions, the stress transfer may ultimately propagate across the entire series of entries.

The pillar stability concept is illustrated by Example 6, Figure 5.15.

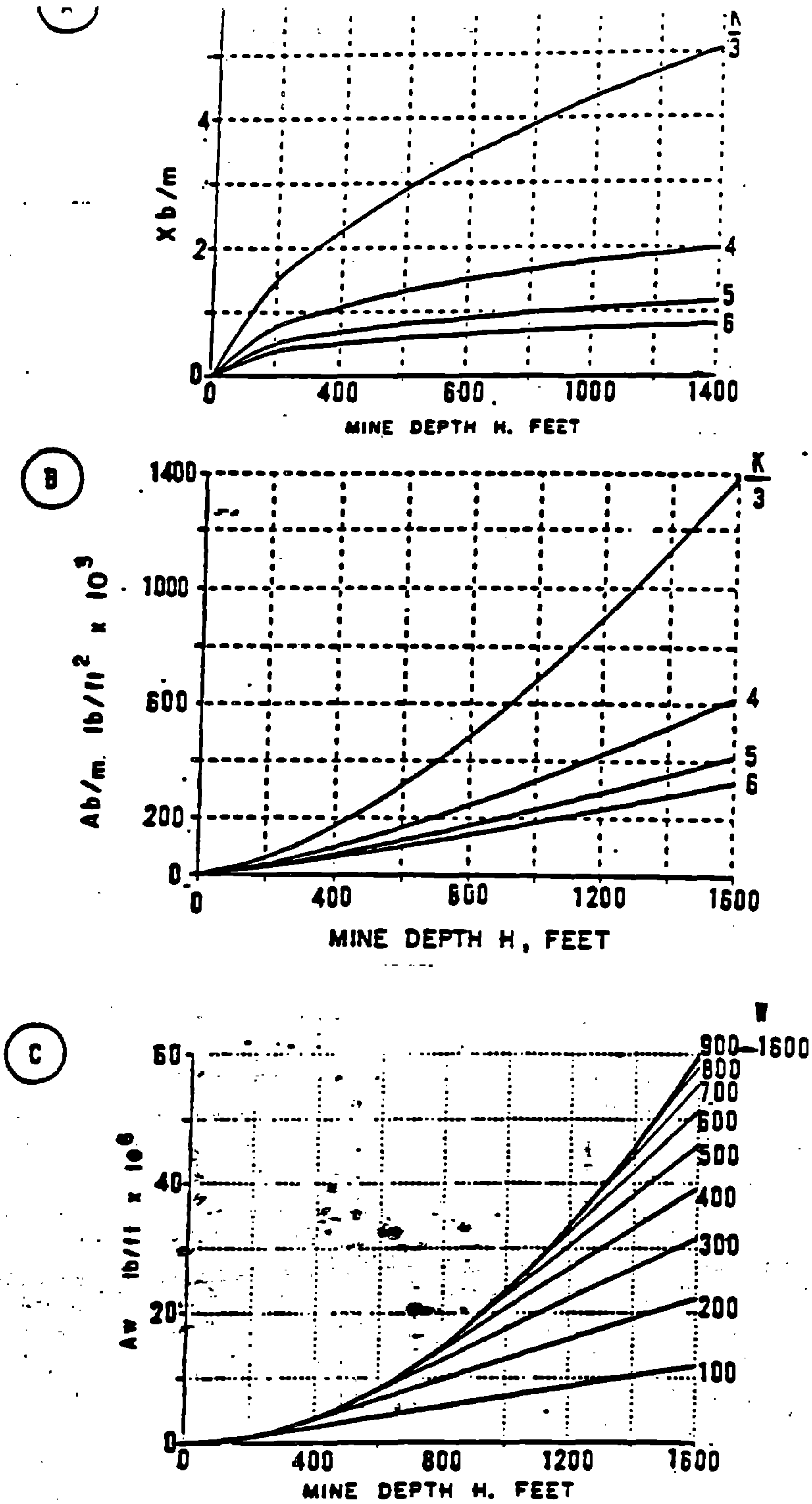
5.4.2.2 Chain Pillar Design - Pillar Yield After Passage of Face (Nomograph). Three-dimensional finite element studies of a series of hypothetical longwall panels provide the basis for the chain pillar design method proposed by Hsiung and Peng (1984). The analyses take into account the interaction of mine roof, mine floor and coal. The longwall is a conventional three-entry system with a panel length of 4000 feet. Panel width ranges from 220 to 700 feet. Entry width ranges from 12 to 20 feet and chain pillar width from 50 to 125 feet. Rock strata are assumed to be shale and sandstone. All stresses are produced by gravitation; regional horizontal stresses are represented implicitly. Caving over the gob, and fracturing and yielding of the coal pillars are accounted for by a modified Coulomb faiure criterion. The factor of safety (stability factor) employed in the analysis represents the ratio of the allowable uniaxial capacity (stress) to the integrated equivalent uniaxial stress over the pillar. The pillar is stable when the stability factor equals or exceeds unity.

The sizing of chain pillars between longwall panels is accomplished using the nomograph in Figure 5.16—entering the following parameters, in order, beginning at the bottom horizontal axis of the figure and working to the top:



WEAK SEAM BETWEEN STRONG ROOF AND FLOOR

FIGURE 5.14 CHARTS FOR SIZING PILLARS BY WILSON'S METHOD



ROOF, SEAM AND FLOOR OF SIMILAR STRENGTH

FIGURE 5.14 CONTINUED

Problem: A three-entry, 400-foot-wide by 1000-foot-long longwall panel is to be located in a 6-foot-thick coal seam at 500-foot depth. The in-place strength of the coal is 900 psi. The mine roof and floor are of similar strength to the coal seam. The triaxial stress factor is 3.

Establish the appropriate size for pillars that are to furnish permanent support to the overburden between panels.

Solution: The methodology for sizing the chain pillars is presented in Section 5.4.2.1. Wilson's method (1981, 1982) will be used.

The principal consideration in designing chain pillars is accommodating the abutment stresses around the perimeter of the mined-out area. This is done either by 1) placing a barrier pillar between the chain pillars and the area to be mined out, or 2) sizing the chain pillars to carry the abutment stresses without benefit of an intervening barrier pillar.

Barrier Pillar Approach - The barrier pillar is designed to such width that the abutment stresses produced by mining do not affect the entry on the side of the barrier pillar away from the extraction. The required width of pillar is given by Table 5.2* as $P_{WB} = 2(C^{o} + X_b)$.

Because the mine roof and floor are similar in strength to the coal seam, the Type II equations of Table 5.2 apply. From Figure 5.14, the width of the yield zone X_b is estimated to be 15 feet; the load carried by the yield zone Ab, 1.44×10^{6} lb/ft; and the load deficiency Aw, 5.81×10^{6} lb/ft. The peak abutment stress σ is calculated to be 275,700 psf from Kq = σ in Table 5.2. The constant C^{o} is computed to be 27.9 feet from the appropriate equation in Table 5.2. The required width of pillar is therefore 87 feet.

A rule of thumb that has achieved some degree of acceptance claims that the barrier pillar should be no less in width than Pw = 0.1H + 45 feet. On this basis, the pillar width should be 95 feet, which is in reasonable agreement with the former estimate and is conservative.

Chain pillars on the side of the barrier away from the extracted area are, for practical purposes, outside the influence of the abutment stress and consequently can be designed using the Tributary Area Theorem and the procedure in Section 5.4.

* Figure at bottom of table.

FIGURE 5.15 - EXAMPLE 6 - SIZING CHAIN PILLARS BY WILSON'S METHOD

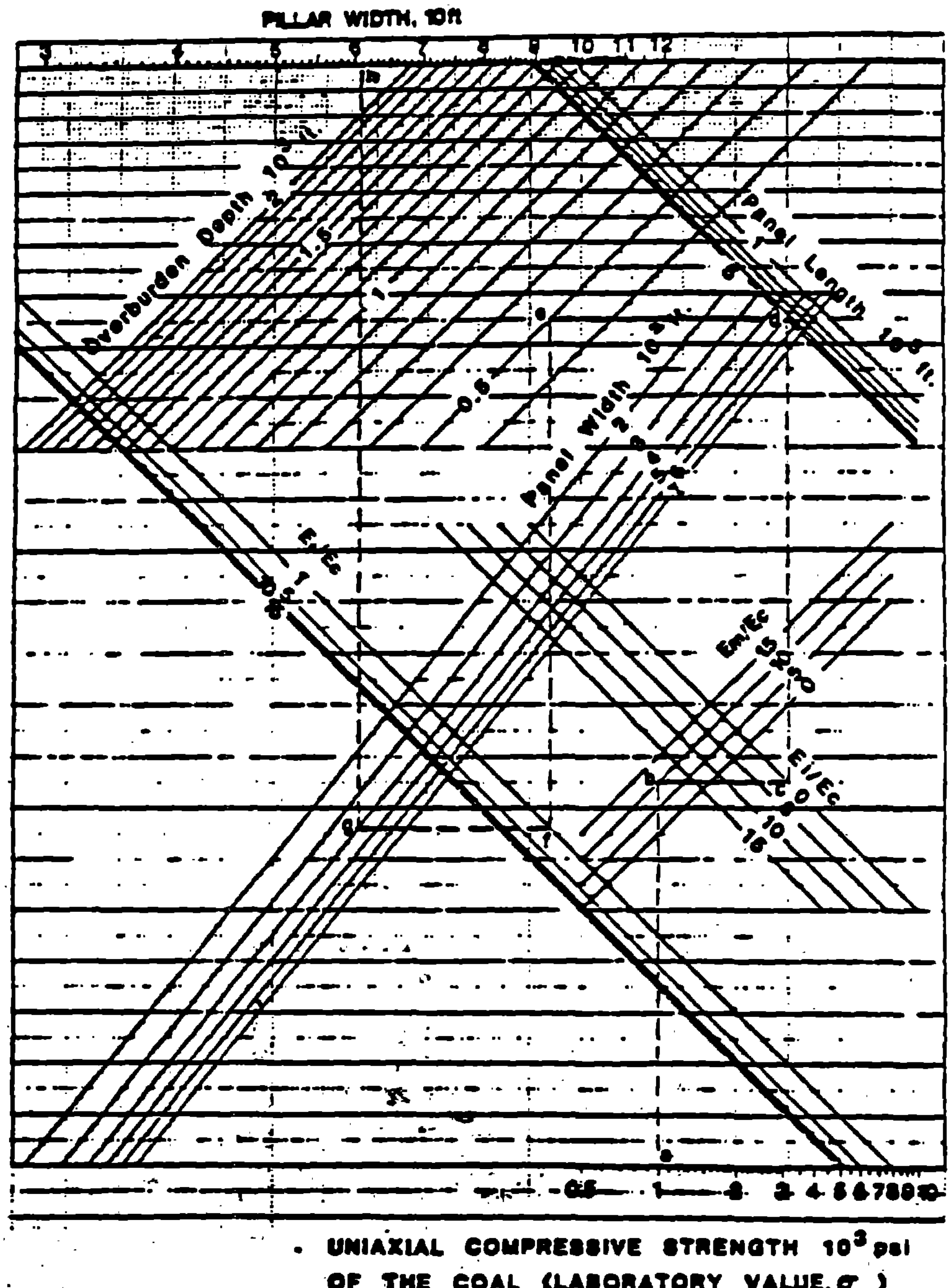


FIGURE 5.16 NOMOGRAPH FOR SIZING CHAIN PILLARS BY HSIUNG - PENG METHOD

a. The uniaxial compressive strength of the coal, in psi. this is the laboratory test strength of small cubes or cylingers.

b. The ratio of the elastic modulus of the main roof to that of the coal, Em/Ec.

This value is taken as zero in the absence of better information.

c. The ratio of the elastic modulus of the immediate roof to that of the coal, Ei/Ec.

This value is taken as zero in the absence of better information.

d. The panel length, in thousands of feet.

e. The overburden depth (mine depth), in thousands of feet.

f. The ratio of the elastic modulus of the floor to that of the coal, Ef/Ec.

This value is taken as unity in the absence of better information.

g. The panel width, in hundreds of feet.

The required width of pillar, in tens of feet, is read from the horizontal axis at the top of the figure. This is the width of a square pillar. The width and length of a rectangular pillar of equivalent capacity is determined from Figure 5.17.

Chain pillar design by this method is subject to the following provisions:

1. Geologic and mining conditions, including mine geometry, must fall within the ranges of parameters on which the nomograph is based.

2. The pillars designed may or may not serve as permanent support. The design method is specifically intended to produce pillars that function for the duration of mining in the first panel, but could yield after passage of the face in the adjoining panel. This being the case, the method provides an estimate of the minimum pillar size required for permanent chain pillar support between longwall panels.

5.4.3 <u>Design of Support for an Isolated Area Above a Room-and-Pillar Retreat Panel (Case C)</u>. The requirements for designing isolated groups of support pillars within a mine panel are the same

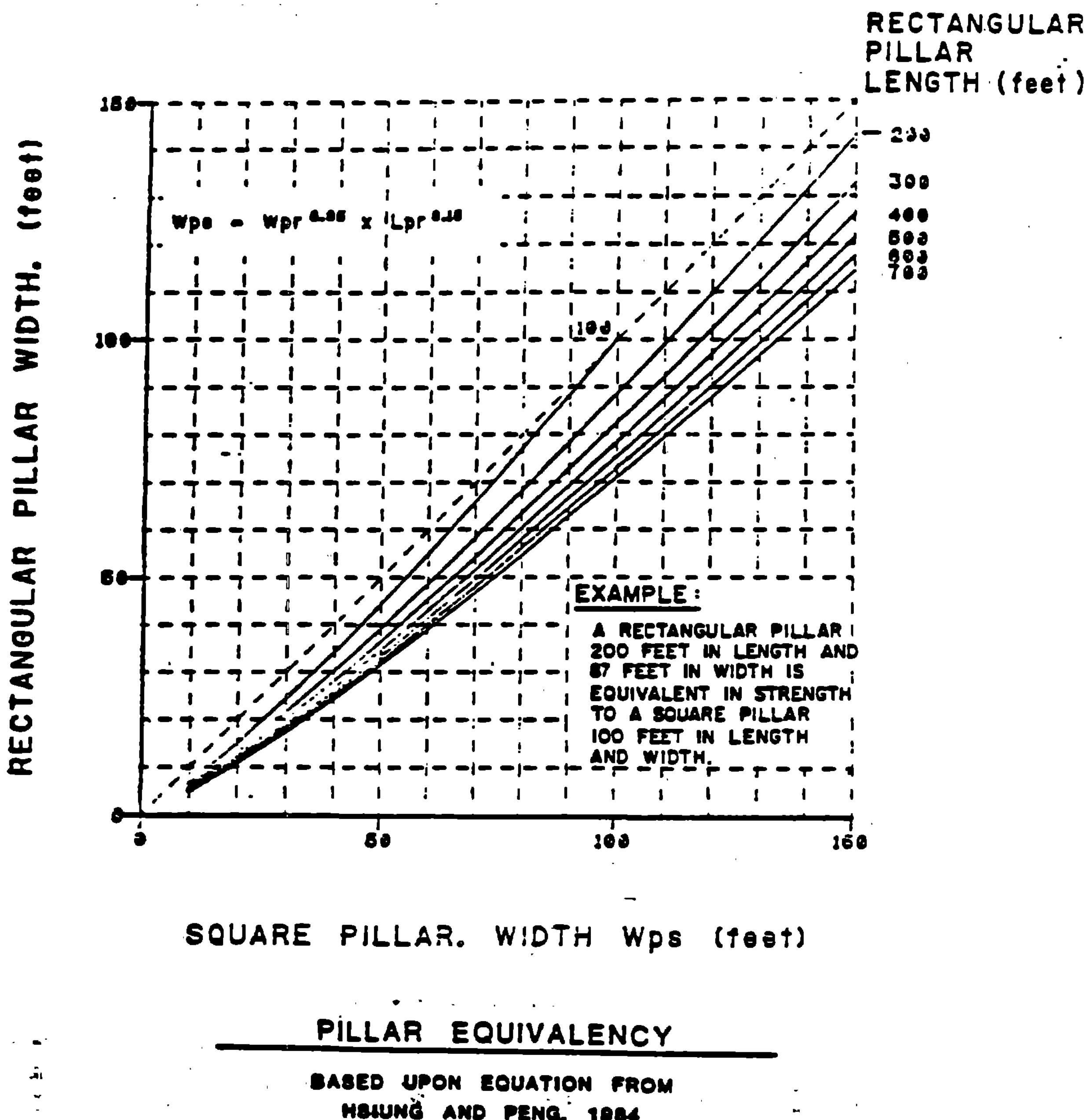


FIGURE 5.17 EQUIVALENCIES BETWEEN RECTANGULAR AND SQUARE PILLARS

as for pillar configurations of Cases A and B. The principal difficulty in isolated-pillar group design lies in estimating the load that must be borne by the pillars.

The pillar stress will exceed the cover stress 'q' since the extraction of adjoining coal and consequent caving will have produced a loading similar to that on chain pillars (Case B). However, extraction on more than one side of the pillar group considerably complicates the load distribution and the methods used to estimate it, as does the position of the pillar group within the panel. Simple charts for formulas for load estimation are unavailable.

Problem: A series of conventional three-entry, 400-foot wide by 5000-foot long longwall panels are to be located in a 6-foot thick coal seam at 500-foot depth. The overburden is composed largely of shale and claystone with lesser amounts of sandstone and siltstone. Little information is available concerning the mechanical properties of the mine floor or immediate roof. The elastic modulus of the main roof is estimated to be about ten times that of the coal. Establish the appropriate size for chain pillars between the mine panels.

Solution: The methodology for sizing the pillars is presented in Section 5.4.2.2 and entails tracking through the nomograph (Figure 5.16) using the following parameters in order:

a. Uniaxial compressive strength of the coal = 1000 psi (given)

b. Ratio of elastic modulus of the main roof to that of the coal, Em/Ec = 10 (given)

c. Ratio of the elastic modulus of the immediate roof to that of the coal, Ei/Ec = 0 (conservative assumption)

d. Panel length in thousands of feet = 0.5 (given)

e. Overburden depth in thousands of feet = 0.5 (given)

f. Ratio of elastic modulus of mine floor to that of the coal, Ef/Ec = 1 (conservative assumption)

g. Panel width in hundreds of feet = 4 (given)

h. Required Pillar Width = 61 feet

To estimate the load, one can resort to computer-based numerical methods, finite elements, or boundary elements. Salamon (1974) and Crouch and Starfield (1983) discussed such approaches. If the load were estimated in this fashion, the desing procedure would be essentially as outlined for Case A.

The alternative to estimating the pillar load is to design the pillars using accepted regional mining practice--practice based on successful past experience with a specific pillar size or range of sizes. Regional practice is rarely committed to written form and cannot often be generalized upon. The Pennsylvania law requires no more than fifty percent extraction for permanent support pillars.

As pointed out above, extraction ratio alone is not sufficient to ensure adequate support, since pillar, floor and roof capacity depend upon, among other things, the cross sectional dimensions of the pillar. In western Pennsylvania, for example, pillar dimensions must be no less than 30 feet on a side under ordinary conditions. Larger dimensions may be appropriate where the mine floor or roof are weak.

6.0 CLOSURE

The information presented in this document represents the current status of subsidence control regulations on the federal and state levels and the current "state of the art" of subsidence control techniques. Continued evolution of subsidence control regulations should be anticipated both in content and in legal interpretation. The selection of subsidence control techniques appropriate for particular situations may change accordingly. Technological innovations, too, may eventually provide other subsidence control techniques, some of which, up to now, have only been attempted abroad. Various computer programs are available for subsidence prediction and pillar size calculations. These may facilitate the computational process. However, the relatively simple computational methods presented in this document are wholly sufficient for subsidence control plan preparation and offer the benefit of greater insight into the computational process.

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APPENDIX - A

FEDERAL RULES AND REGULATIONS

federal register

Tuesday
February 17, 1987

Part V

Department of the Interior

Office of Surface Mining Reclamation and Enforcement

30 CFR Parts 784 and 817

Permanent Program Performance Standards; Underground Activities; Subsidence Control; Final Rule

DEPARTMENT OF THE INTERIOR

Office of Surface Mining Reclamation and Enforcement

30 CFR Parts 784 and 817

Permanent Program Performance Standards; Underground Activities; Subsidence Control

AGENCY: Office of Surface Mining Reclamation and Enforcement, Interior.

ACTION: Final rule.

SUMMARY: The Office of Surface Mining Reclamation and Enforcement (OSMRE) of the U.S. Department of the Interior (DOI) is issuing final subsidence control rules relating to the protection of surface structures and facilities. These final rules are promulgated pursuant to the District Court's order in *In Re: Permanent Surface Mining Regulation Litigation (II)*, No. 79-1144 (D.D.C.) (Memorandum Opinion filed Oct. 1, 1984).

Under the final rule, operator responsibility for material damage to structures or facilities resulting from subsidence will derive from applicable provisions of State law. Also, the final rule addresses whether subsidence control plans should include the results of a pre-subsidence survey of structures and a description of monitoring near structures. The monitoring requirement of § 784.20(d)(5) has been revised to make clear that monitoring may also be appropriate when planned subsidence mining methods are employed.

EFFECTIVE DATE: March 19, 1987.

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SUPPLEMENTARY INFORMATION:

I. Background

On March 13, 1979, OSMRE promulgated permanent program rules (44 FR 14902) as required by section 501(b) of the Surface Mining Control and Reclamation Act of 1977 (the Act), 30 U.S.C. 1201 *et seq.* In the 1979 rules, 30 CFR 817.121, 817.122, 817.124, and 817.126 established performance standards relating to subsidence control and reclamation at underground coal mines. The requirements for a pre-subsidence survey and monitoring and for a subsidence control plan as part of the permit application were established by 30 CFR 784.20.

Section 817.124 of the 1979 rule set forth requirements for the correction of subsidence-caused material damage to both structures and surface lands without reference to State law. The 1979 rule required that underground operators mitigate the subsidence-related material damage by restoring the land to its premining capabilities, and by restoring, rehabilitating, removing and replacing, or purchasing damaged structures or facilities or, alternatively, by compensating surface structure owners through the purchase of non-cancellable, premium-prepaid insurance policy or other means designed to cover the amount of diminution in value caused by subsidence. 44 FR 14902, 15440 (March 13, 1979).

Industry plaintiffs challenged the restoration requirement of former 30 CFR 817.124 in *In Re: Permanent Surface Regulation Litigation*, No. 79-1144 (D.D.C. 1980) *(In Re: Permanent (I))*, and based their attack on the argument that Congress intended the insurance requirement of section 507(f) of the Act as the exclusive means for setting operator responsibility for subsidence damage. The Court rejected that argument and held that the prior rules for remedying the effects of subsidence "find support in the Act. The restoration requirement is consonant with section 515(b)(2) of the Act." *In Re: Permanent (I), supra*, February 26, 1980, Opinion at 63-64. The Court also held that the compensation requirement of the 1979 rules, which extended to surface structures and facilities, was "an insurance mechanism authorized by section 507(f) of the Act." *Id.* at 64.

On April 16, 1982, OSMRE proposed permanent program rules (47 FR 16604) to amend 30 CFR 784.20, 817.121, 817.122, 817.124, and 817.126 pertaining to subsidence control. On June 1, 1983, OSMRE promulgated the final permanent rules on subsidence control. 30 CFR 784.20, 817.121, and 817.122 (48 FR 24638).

The June 1, 1983 rule at 30 CFR 817.121(c)(2) (48 FR 24652) made operators responsible for correcting material damage to any structures and facilities resulting from subsidence only to the extent required by State law. The rule at 30 CFR 817.121(c)(1) (48 FR 24652) required the operator to correct, to the extent technologically and economically feasible, all subsidence-caused material damage to surface lands without regard to State law. In essence, the 1983 rule retained the land restoration requirement of the 1979 rule, but modified the requirement to repair structures by specifying that material damage to structures shall be repaired or corrected in accordance with the requirements of State law. The 1983 rule was intended to remedy inequities created by the 1979 rules which imposed a restoration requirement for structures materially damaged by subsidence regardless of whether the operator purchased the structure overlying the underground workings or purchased or retained the right to cause subsidence under a structure. OSMRE deferred to State property rights regarding structures in part because Congress indicated in section 102(b) and other sections that the Act was not intended to create new property rights but to assure the protection of existing rights.

In the case of *In Re: Permanent Surface Mining Regulation Litigation (II)*, No. 79-1144 (D.D.C.), citizen and environmental groups, industry and States challenged a number of OSMRE rulemaking proceedings, including provisions of the June 1, 1983, subsidence control rules.

On October 1, 1984, the Court issued a memorandum opinion addressing the revised subsidence control rules. *In Re: Permanent Surface Mining Regulation Litigation (II)*, No. 79-1144 (D.D.C. 1984) (*In Re: Permanent (II)*, October Op.).

The Court held that the 1983 final rule, 30 CFR 817.121(c)(2) (48 FR 24652), requiring operators to redress subsidence-caused material damage to structures only to the extent required by State law, represented a "radical change" from both the earlier rule and the 1982 proposed rule, 30 CFR 817.121(c), 47 FR 16604, 16610 (April 16, 1982), which both required such redress irrespective of State law. October Op. at 10. Accordingly, the Court remanded 30 CFR 817.121(c)(2) to the Secretary for proper notice and comment. *Id.* at 10-11. The Court never reached the merits of the Secretary's rule on damage to structures.

The court also determined that the 1979 rule requiring the subsidence control plan to include the results of a pre-subsidence survey of structures, and a detailed description of any monitoring proposed to measure subsidence near structures, 30 CFR 784.20(d), 44 FR 14902, 15389 (March 13, 1979), which was deleted in the 1983 final rule, was "inextricably linked" to the issue of whether the operator must restore structures materially damaged by subsidence. Thus, it ordered the Secretary to request additional public comments on this deletion in conjunction with the comments on 30 CFR 817.121(c)(2). *In Re: Permanent (II)*, October Op. at 14.

On February 21, 1985, in accordance with the Court's ruling, OSMRE suspended the portion of 30 CFR 817.121(c)(2) limiting operator responsibility to State law. 50 FR 7274 (February 21, 1985). Subsequently, on July 8, 1985, OSMRE reproposed 30 CFR 817.121(c)(2) with a provision for deference to State law, with respect to damage to surface structures and facilities and solicited additional public comment on the deletion of former 30 CFR 784.20(d).

II. Response to Comments and Rules Adopted

A. General

Following publication of this rule as a proposed rule in the Federal Register on July 8, 1985, a public hearing was held in Ina, Illinois. That hearing, held on September 12, 1985, was in response to a request from interested citizens. The public comment period provided for in the proposed rule closed on September 16, 1985. However, as announced at the hearing, additional written comments were accepted through September 27, 1985 from persons who attended the public hearing. Through September 27, 1985, a total of forty commenters (including public hearing attendees) provided comments.

Most of the comments received were specifically directed at the rulemaking issues. However, many persons speaking at the public hearing made more broadly directed comments about damages and injuries they claimed to have suffered as a result of subsidence due to longwall mining. Such comments generally involved allegations of not receiving adequate, or any, compensation for damage to homes, barns, businesses, and farmland drainage systems (especially agricultural tiling). Others spoke of emotional trauma stemming from fears for the safety of their families and from being forced to move from subsidence damaged homes.

One commenter representing an interest group objected to not having been consulted earlier in the rulemaking process. In this instance, sufficient public participation occurred following publication of the proposed rule.

B. Subsidence Control Plan—Section 784.20 (Introductory Paragraph)

In addition to the revision to § 784.20(d) discussed at length below, OSMRE is taking this opportunity to correct an error inadvertently introduced into § 784.20 during the June 1, 1983 rulemaking. 48 FR 24638. Although the introductory paragraph to § 784.20 would have been eliminated by the April 16, 1982 proposed rule (47 FR 16604), OSMRE decided to retain that paragraph unchanged in the 1983 final rule. In the preamble at 48 FR 24639, OSMRE concluded:

> * * * OSM has decided to accept the comments suggesting that the previous position be retained and not to eliminate the introductory paragraph of previous § 784.20. * * * The language of the introductory paragraph of previous § 784.20 has been retained and is repeated in the final rule solely for convenience in understanding the other requirements adopted in the final rule.

Despite this preamble statement, the word "and" in the third sentence of the introductory paragraph was unintentionally changed to "or" in the text of the 1983 final rule.

Elimination of the error is accomplished by replacing the second "or" in the third sentence of the paragraph with an "and". This action conforms the paragraph with the preamble discussion of 48 FR 24639 and restores the former parallelism of language between the first and third sentences of the paragraph found in the previous (1979) rule. Thus, a subsidence control plan is to be submitted if the survey shows there are renewable resource lands *and* that subsidence could cause material damage or a diminution of value or the foreseeable use of the land.

C. Subsidence Control Plan—§ 784.20(d)

As explained above, the Court ordered OSMRE to request comments on the deletion of 30 CFR 784.20(d) (44 FR 14902, March 13, 1979), from the 1983 final rule. October Op. at 14. Former 30 CFR 784.20(d) required the subsidence control plan to contain:

> A detailed description of measures to be taken to determine the degree of material damage or diminution of value or foreseeable use of the surface, including such measures as—
>
> (1) The results of a pre-subsidence survey of all structures and surface features which might be materially damaged by subsidence.
>
> (2) Monitoring, if any, proposed to measure deformations near specified structures or features or otherwise as appropriate for the operation.

As explained in the preamble to the April 16, 1982 proposed rule (47 FR 16605) and the June 1, 1983 final rule (48 FR 24638), OSMRE deleted former 30 CFR 784.20(d) from the 1983 final rule to reduce the burden on the operator and to avoid unnecessary duplication. This final rule does not restore the language of § 784.20(d) found in the 1979 rule.

A number of commenters agreed with OSMRE that the 1979 rules should not be reinstated, asserting that the 1983 rules were adequate and that they provided the same degree of protection as the 1979 rules. One of the commenters added that the former 1979 rule was not only redundant but oppressive.

Other commenters disagreed, however, as a number of comments were also received asking for a return to the 1979 rule. OSMRE does not agree with these commenters.

A comment was received stating "the Secretary is correct that monitoring and pre-subsidence surveys must be performed, irrespective of State law and irrespective of the final disposition of the § 817.121(c)(2) rule respecting dependence of State law, in all cases where land or structures might be damaged by subsidence." Other commenters asserted that the previous § 784.20(d) rule was "extremely critical as a means of evaluating and assessing the degree of material damage and as a performance standard indicator," and that there can be no meaningful right under State law "unless there is a way to prove the damage."

Contrary to the commenter's assertion, the Secretary does not take the position that "monitoring and pre-subsidence surveys must be performed, irrespective of State law and irrespective of the final disposition of the § 817.121(c)(2) rule respecting dependence on State law, in all cases where land or structures might be damaged by subsidence." Although OSMRE agrees that surveys must always be performed pursuant to the introductory paragraph of § 784.20, requirements for monitoring are an optional part of the subsidence control plan. Furthermore, OSMRE does not agree that monitoring near structures is required to evaluate and assess the degree of material damage and as a performance standard indicator. Material damage to a structure can be determined by direct comparison not to its post-mining condition, but to its pre-mining condition, regardless of whether the precise extent of subsidence has been monitored. The final rule insures that adequate information will be available to "prove the damage" when, under State law, there is a requirement to repair or compensate.

When deleting the pre-subsidence survey requirements of § 784.20(d)(1) of the 1979 rule on June 1, 1983, OSMRE believed that this requirement was redundant. Several commenters on the 1985 reproposal asserted that the pre-subsidence survey requirement is not redundant since, in their view, the prior rules used that survey to "effect the protections of section 516(b) [of the Act] in a way the 1983 rule fails to do."

OSMRE continues to believe that the requirement is redundant. Former § 784.20(d)(1) is duplicative of the requirement in the introductory paragraph of § 784.20 requiring a premining survey, "which shall show whether structures or renewable resource lands exist * * * and whether subsidence, if it occurred, could cause material damage or diminution of reasonably foreseeable use of such structures or renewable resource lands." Another commenter agreed with OSMRE that the 1979 pre-subsidence survey requirements are redundant stating "there is no distinction between the requirements for a survey showing structures and renewable resource lands and a pre-subsidence survey." Another commenter also favored OSMRE's position and asserted that the former rule was unnecessary because many operators voluntarily conduct pre-subsidence surveys for their own protection. Another commenter asserted that pre-subsidence surveys should be like blasting surveys and include specific descriptions of the conditions of the homes, buildings, etc. However, the language of former § 784.20(d)(1) would not assume such detail. Moreover, § 784.20(h) (formerly § 784.20(g)) provides the opportunity for the regulatory authority to require whatever additional information is deemed necessary including as much detail as required in a blasting survey.

A commenter contended that the preamble of the proposed rule did not clearly explain the pre-subsidence survey requirement issue. OSMRE rejects this comment. The issue is accurately described in the preamble to the proposed rule. If the commenter was unsure of the issue, it could have consulted the 1984 court opinion and the final 1983 rule and preamble, all of which are referenced in the proposed rule. Finally, OSMRE personnel were available for public meetings to discuss any issue relating to the proposal.

Three commenters stated that they opposed "the proposed new wording relating to pre-subsidence surveys and subsidence monitoring" because "the proposed wording of § 784.20 is too general and it could be interpreted to exempt longwall and other planned subsidence mining from doing the surveys." OSMRE disagrees. The introductory paragraph of § 784.20 clearly requires the permit application to include a survey regardless of the mining method employed.

Monitoring

In respone to the Court's linking of the monitoring requirement with the restoration standard for structures, OSMRE stated in the proposal its belief that the monitoring provision contained originally in § 784.20(b)(3)(v), and later in § 784.20(d)(5), was adequate, regardless of whether the obligation to repair structures was controlled by State law. In this regard, commenters were urged to consider whether a more specific requirement for monitoring subsidence near structures is required or whether the monitoring provision of 30 CFR 784.20(d)(5) is sufficient.

Having considered the comments, OSMRE in this final rule revises the language of the 1983 rule (and 1985 proposed rule) to make clear that monitoring may be appropriate regardless of the mining method to be employed by the operator. OSMRE agrees with the commenter that the proposed wording of § 784.20 can be interpreted to exempt operators using planned subsidence mining methods from having to perform subsidence monitoring over the areas where controlled subsidence will occur. Proposed § 784.20(d)(5) required the subsidence control plan to contain "except for those areas where planned subsidence is projected to be used," a detailed description of "monitoring, if any, to determine the commencement and degree of subsidence so that other measures can be taken to prevent or reduce material damage." Consequently, as described above, OSMRE has revised the § 784.20 rule to make it clear that the discretionary monitoring requirement is applicable irrespective of whether the mining method calls for planned or unplanned subsidence. A further, more complete, discussion of the issue of monitoring follows.

This change is effected by deleting § 784.20(d)(5) of the 1983 rule and inserting a new § 784.20(d). Paragraphs 784.20(d) through 784.20(g) of the 1983 rule are redesignated accordingly as 784.20(e) through 784.20(h). New § 784.20(d) requires:

> A description of monitoring, if any, needed to determine the commencement and degree of subsidence so that, when appropriate, other measures can be taken to prevent, reduce, or correct material damage in accordance with § 817.121(c) of this chapter.

OSMRE continues to view the 1979 monitoring requirement as redundant with new § 784.20(d). Furthermore, as under the 1979, 1983, and the proposed 1985 rules, this final rule includes the qualifying phrase "if any" to provide discretion as to the extent of monitoring needed. Therefore, final § 784.20(d) does not mandate monitoring in all cases where material damage to structures or facilities will occur. However, regulatory authorities may refuse to approve permit applications containing subsidence control plans which do not include monitoring provisions when such provisions are essential to fulfilling the performance standards of § 817.121. If the regulatory authority is not satisfied that the operator will mitigate or remedy subsidence related material damage to structures or facilities as required by State law, the regulatory authority may deny the permit or direct that alternative measures be included in the subsidence control plan. Such measures may include a provision for monitoring and may specify where and how such monitoring will take place. Such measures may also include direct measurement of material damage to the structure through a pre-mining and post-mining comparison. One key ingredient is to ensure that the pre-mining condition of the structure was recorded before the subsidence occurred. Essentially this provides the same coverage as provided by the 1979 rule, except that the performance standard which the monitoring provision assists in implementing is tied to State law. Thus, the owners of structures may have the monitoring data made available to them to exercise any rights arising under State law, irrespective of the method of underground mining employed.

A commenter asserted that it is uncertain whether monitoring is required when it has been determined that subsidence is likely.

Under this final rule monitoring will most likely be performed when the pre-subsidence survey indicates that subsidence and related material damage to structures and facilities are anticipated, and State tort, contract, or other law (either codified or enunciated through judicial decisions) requires repair or compensation.

Another commenter stated that the "weak" provisions for monitoring are inconsistent with the District Court's October 1, 1984 decision and congressional intent. OSMRE does not believe it is inconsistent. The court did not rule on the substance of the issue, but only ordered further comment in view of the rule's relation to the restoration standard.

For all the reasons discussed above, OSMRE believes that the pre-subsidence survey and monitoring requirements of this final rule provide the information required to assure the Act can be appropriately enforced.

D. Subsidence Control—Section 817.121(c)(2)

Section 817.121 provides performance standards for subsidence control.

Section 817.121(c) establishes the operator's responsibility for material damage caused by subsidence. The statutory authority for its provisions is sections 507(f), 515(b)(2), 515(b)(3), 516(b)(1), and 516(b)(10) of the Act. Liability for damage to surface and subsurface structures and facilities under section 507(f) of the Act is tied to liability under State law because the Act was not intended to create additional property rights. For this reason, under final § 817.121(c)(2) operator responsibility for material damage caused to structures or facilities is tied to liability under State law. Thus, material damage to structures and facilities must be remedied or monetary damages paid if the operator is liable under State law.

The 1979 subsidence control rules which imposed a restoration requirement for structures materially damaged by subsidence did not provide exceptions for situations where the operator has purchased a structure overlying the underground workings, where the operator has purchased the right to cause subsidence under a structure, or, as in Pennsylvania, where State legislation has established subsidence responsibilities for different classes of structures. The 1979 rules did not defer to State law and allow an operator not to repair damaged structures where the operator had no legal liability under State law. This final rule accommodates situations in which the operator is not liable for subsidence damage to surface structures under State law. Conditioning liability for restoration of materially damaged structures upon State law lessens the concern that the contract in which the operator may have obtained the right to subside the surface under a structure will be impaired. In States which have not enacted special subsidence legislation, State property rights, as established by contracts, deeds, and other agreements, and interpreted in judicial decisions, will determine whether the operator is liable to a surface owner. Liability of the operator where the owner of the surface facility may have conveyed the right to support or may have waived it will also be left to determination under State law.

This final rule is supported by both law and policy. As discussed below, the Surface Mining Act does not require operators to repair subsidence-caused material damage to structures irrespective of State law. As the district court found in 1980, the authority of OSMRE to require an operator to compensate an owner for material damage to structures or facilities resulting from subsidence or to repair such material damage derives from Section 507(f) of the Act. *In re: Permanent (I), supra.*, section 507(f) of the Act requires liability insurance for personal injury and property damage in an amount adequate to compensate any persons damaged as a result of surface coal mining and reclamation operations who are entitled to compensation *under the applicable provisions of State law.* Although the 1979 rule did not limit the compensation requirement to situations where liability exists under State law, a more precise reading of section 507(f) supports the imposition of such a constraint in this final rule.

Sections 515 and 516 do not require subsidence damaged structures to be restored without regard to State law. Section 516(b)(1) of the Act requires underground mine operators to prevent subsidence-caused material damage to the "extent technologically and economically feasible" and to maintain the value and use of "surface lands." This provision does not itself require the restoration of structures damaged by subsidence. Although through section 516(b)(10) of the Act, the surface mining performance standards of section 515 may be made applicable to any surface impacts of underground mining not specified in section 516(b), the standards of section 515 do not apply to structures materially damaged by subsidence. Section 515(b)(2), the provision certain commenters suggest as support for the structure restoration requirement, requires the surface coal mining operator to "restore the land affected" to a condition capable of supporting premining uses. There is no similar explicit mandate from Congress to require restoration of structures materially damaged by subsidence. The word "land," as it is used in section 515(b)(2) is interpreted to refer to land in its unimproved or natural state (see 48 FR 24644). This interpretation of land as a natural resource is consistent with the use of that term in other provisions of the Surface Mining Act. For instance, in order to protect the "stability of the land," section 516(c) of the Act requires the suspension of underground coal mining under "buildings" if imminent danger exists. Also, when setting reclamation priorities for abandoned mine lands, Congress in section 403 distinguished between the "restoration of land and water resources * * * previously degraded by adverse effects of coal mining practices" and the repair of "facilities adversely affected by coal mining practices."

If Congress meant to include structures and facilities in section 515(b)(2), it certainly would have enumerated such. Nothing in the plain wording of that paragraph suggests that its application to structures as well as to land is mandated. To the contrary, as suggested by the Court in upholding the land restoration requirements of 30 CFR 817.121(c)(1), there is a sound basis for distinguishing between the restoration requirement for land and that for structures. See *In Re: Permanent II, supra,* October Op. at 5–6.[2]

In policy, as well as law, there is clear reason to distinguish the protection provided for land and structures. Where an underground mine operator purchases from the surface owner the right to subside the land, or in conveying surface property reserves the right to subside the surface, the individual's property rights are protected, but the long term public interest in the land is not protected. Thus, § 817.121(c)(1) functions to prevent this injury to the land by assuring that in all cases, irrespective of private contract, this valuable natural resource will be restored to its premining capabilities, to the extent technologically and economically feasible. On the other hand, no environmental or public interest exists in protecting a building or structure where its present or past owner has either conveyed or waived a right to subjacent support. For example, in some instances an operator may purchase the right to subside a structure owned by the surface owner. In such an instance, the parties have worked out a mutually agreeable solution to account for private damage. The operator should not have to recompensate the surface owner. This final rule leaves this

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[2] Finding the Secretary's reading of the statute "reasonable," the Court upheld the land restoration requirements of 30 CFR 817.121(c)(1) against an industry challenge that the regulation infringes on State laws which provide for remedies in contract and tort for subsidence damage to land. October Op. at 6–7. This issue has been appealed to the U.S. Court of Appeals for the D.C. Circuit.

The District Court ruled that section 515(b)(2) applied to subsidence damaged *land,* through section 516(b)(10). The Court reasoned that while these State remedies may "redress injuries suffered by private parties" they do not redress injury to the "land itself." *Id.* at 6. As the Court cautioned, private parties should not be able to circumvent Congressional intent by forming contracts. The Court held that the Act was passed not only to protect individual property rights, but also to protect this Nation's land from the surface effects of underground mining for "generations yet unborn." *Id.* at 7. Therefore, the Court found that any State remedy inconsistent with the requirement of section 515(b)(2) to restore land materially damaged by subsidence would be preempted by the Act. *Id.* at 7. However, as explained above, the Court's rationale as to the public interest in protecting land does not extend to structures. Damage to structures are in the nature of injuries suffered by private parties that may be appropriately addressed by State remedies.

determination of the relative rights and liabilities to State law.

While private parties may not be motivated to protect the environment, they have a great incentive to protect structures that they own. State law has traditionally provided remedies in contract and tort for those parties who own subsidence-damaged structures. Accordingly, it is inappropriate for OSMRE to step in and protect owners of these structures thereby creating an additional *private* property right which clearly was not intended by Congress.

In those instances where a public interest does exist in the protection of certain structures, the rules continue to provide such protection without regard to State law. For instance, 30 CFR 817.121(d) prohibits underground mining activities beneath or adjacent to public buildings and facilities, churches, schools and hospitals, and large bodies of water unless an operator can demonstrate before a permit is issued that subsidence will not cause material damage. If damage is caused to such facilities or features regulatory authorities are empowered to suspend mining until the operator ensures that no further material damage will occur (see 30 CFR 817.121(e)). Finally, if imminent danger from underground mining exists to inhabitants of urbanized areas, cities, towns or communities, such mining must be suspended. Taken together with the land restoration requirement of § 817.121(c)(1), OSMRE's rules will amply protect the public interests endangered by subsidence.

At least one State has a statute which specifically addresses subsidence under structures. Pennsylvania's Bituminous Mine Subsidence and Land Conservation Act of 1966, 52 Pa. Stat. Ann. sec. 1406 *et seq.* (Purdon's) establishes certain classes of protected structures. For instance, if a materially damaged occupied dwelling were in existence on the date of enactment of the Pennsylvania statute (April 27, 1966), the operator would have to repair the dwelling or compensate the owner for the diminution in value. This final rule allows a State, such as Pennsylvania, to choose to protect selected classes of structures (see 48 FR 24645). The constitutionality of this scheme is presently before the Supreme Court (*Keystone Bituminous Coal Ass'n* v. *Duncan*, No. 85-1092 (cert. granted March 24, 1986)).

A number of comments were received on the issue of limiting liability for repair of subsidence damaged structures in response to the original proposal of April 16, 1982 (47 FR 16604). The reader is referred to the discussions of those comments found in the preamble to the June 1, 1983 final rule (48 FR 24638) as they will not be repeated here.

During the comment period on the July 8, 1985 proposal, numerous comments were received on the issue of leaving the correction of subsidence-damaged structures up to the requirements of State law. Several commenters favoring the proposed rule agreed with OSMRE's conclusion that the rule is supported by both law and policy. Among the reasons given for this agreement were (1) the Act does not require repair or compensation for damaged structures; it only requires insurance coverage adequate to cover claims arising under State laws; (2) the 1979 rule requiring repair or compensation irrespective of State law is in violation of the Act; (3) the 1979 rule represents an unconstitutional "taking" of property without just compensation; and, (4) there is no support in the legislative history for the 1979 rule. Opposing this viewpoint were commenters who contended that (1) the proposed change is illegal since it violates congressional intent given in section 102(b) of the Act; (2) the old rule was upheld by the District Court; (3) the proposal is contrary to section 101 (d), (e), and (h) and 102(h) of the Act; and the proposed rule is unsupportable in view of the recent Appeals Court decision in *Keystone Bituminous Coal Ass'n* v. *Duncan*, 771 F.2d 707 (3d Cir. 1985) in affirming the constitutionality of the Pennsylvania Bituminous Mine Subsidence and Land Conservation Act and its implementing regulations.

OSMRE's views on the legality of implementing the proposed rule have been addressed above. OSMRE disagrees with the commenters who conclude that the rule change is illegal. Contrary to the commenter's assertion, section 102(b) of the Act supports this final rule. The intent expressed in section 102(b) is to preserve and protect the rights of persons with a legal interest in appurtenances to the land. This rule does just that. Where such a right exists under State law, it is expressly recognized and will continue to exist. The rule is also consistent with the other provisions cited, taken together with section 102(k) of the Act which was not cited by the commenters. Section 102(k) sets forth as one of the Act's purposes the need to "encourage the full utilization of coal resources through the development and application of underground extraction technologies; . . . " 30 U.S.C. 1202. Clearly this rule is intended, in part, to encourage full extraction technologies, such as longwall mining. Also, the contention that the decision of the appeals court in *Keystone* v. *Duncan* renders the proposed rule illegal is incorrect. The holding in that case that the Pennsylvania statute is legal does not affect the validity of OSMRE's final rule. To the contrary, this rule clearly recognizes existing State laws and property rights.

A number of other commenters expressed additional reasons for favoring adoption of the rule. One felt that the preamble discussion for the proposed rule provided accurate and ample justification for the rule. Two others think there is no conflict between section 102(b) of the Act and State common law on subjacent support. Another commenter expressed concern that the former rule entitles persons to compensation for damage to structures built on lands for which a coal company had the prior right to mine. That commenter made the further claim that this has actually occurred in Illinois. Also, a commenter expressed the opinion that the economics of the coal industry and the conservation of the mineral resource have both been adversely affected by the former rule.

OSMRE acknowledges the comments supporting its reasons for the rule change expressed in the preamble to the proposed rule, and agrees in principle with those stating the previous rule created an inequity by granting absolute protection, irrespective of State laws and contractual agreements, to owners of structures built on land for which the owners of the structures do not have the right of subjacent support.

Other comments were received opposing this final rule. Some stated that the changes proposed were arbitrary and unreasonable. Others felt that the rule should be made stronger than the former rule, not weaker, and that standards similar to those imposed for surface mines be imposed on underground mines. Some others expressed the opinion (presumably as a matter of equity) that coal companies should be responsible for making repairs to both structures and land, and that mitigation of damage to structures should be a national policy. Many of these commenters were Illinois property owners who believe the rule would upset an existing balance in that State between coal operators and property owners, creating the potential for inflicting hardship and economic loss on the property owners. The basis for this view rests on a provision in the Illinois surface mining law (several other states have similar provisions) that the State regulations can be "no more stringent than" the Federal regulations. Two commenters claimed that due to this requirement the State of Illinois would have to drop its protection for structures in response to the rule change. Two others disagreed, asserting that Illinois is not absolutely bound to eliminate its current rules requiring repair or compensation for subsidence damage to structures.

One commenter asserted that OSMRE had not indicated why State law is adequate to protect structures from subsidence impacts. Another commenter felt that relying on State law to protect surface structures provides inadequate protection and believes it preferable to have national standards. In its view, national standards would cause consideration of potential subsidence damage at the time of mine planning and design and be coupled with provisions for protection or compensation, thereby avoiding costly litigation which may not result in proper settlement for any of the parties.

OSMRE has no obligation to demonstrate that State law is adequate to protect surface structures from subsidence impacts because the Act does not mandate that structures be protected, particularly in those instances where the right of subjacent support has been transferred or waived by the surface owner or his predecessor in title by valid legal contract.

Notwithstanding the absence of such an obligation, OSMRE has nevertheless analyzed the projected impacts of this rule in those States where most underground mining occurs. The six States chosen (Illinois, Kentucky, Pennsylvania, Utah, Virginia, and West Virginia) accounted for 87 percent of the Nation's underground coal production in 1983. In those States a total of between 107 and 528 dwellings are estimated to be at risk of subsidence annually. Under these final rules this estimated total would not change. However, the compensation received by owners would change. The former rules required operators to correct or compensate for damage to structures irrespective of the requirements of State law. This final rule, depending upon State law and the extent to which property owners have waived their rights, results in responsibility (1) continuing to rest with operators, (2) being shifted to subsidence insurance programs, or (3) being shifted to the property owner. In each of the States analyzed, except Kentucky, some form of compensation would be available under this final rule. Only in Kentucky would neither the law of subjacent support nor a subsidence insurance program offer protection from loss to property owners. Depending upon the extent to which dwellings damaged by subsidence are covered by subsidence insurance, and the extent to which property owners have not waived or conveyed the right to subjacent support in States that recognize the right, it is estimated that the maximum total annual amount of subsidence damage to dwellings (for which responsibility would shift from operators to insurance programs or to property owners under this rule) could range from approximately $2 million to about $10.5 million in the six States that account for 87 percent of the Nation's underground production of coal. A more detailed discussion of these effects is found in the environmental assessment prepared for this final rule.

The impacts are somewhat uncertain because whether a particular surface property owner is entitled to subjacent support depends not just on State law but provisions in deeds and contracts affecting the property. Whereas State law generally requires subjacent support, some States may interpret similar provision differently thus affecting the ultimate amount of the operator's liability. Thus, the State by State analysis somewhat overstates the effect of this rule because it disregards owner waivers that may exist.

Pertinent to the issue of whether the requirement to correct or compensate for damage to structures should be left up to State law is the position of the various States affected by the change, especially the States of West Virginia and Pennsylvania which have the majority of active underground coal mining operations. During the comment period for the 1982 proposed rules (which would have retained the absolute requirement of the 1979 rules), only Montana, Kentucky, Virginia, and Illinois submitted comments on the issue. Montana and Illinois favored leaving the requirement up to State law and Kentucky and Virginia approved the retention of the absolute requirement to correct or compensate. Of the four, only Kentucky, Virginia, and Illinois have significant numbers of active underground coal mining operations. Only the State of Illinois, reversing the position it had taken in 1982, commented during the 1985 comment period for this proposed rule. The failure of West Virginia and Pennsylvania, the States with the largest number of active underground coal mining operations, to submit comments on the 1985 proposed rules does not necessarily indicate their lack of interest. Despite the failure to comment, it appears that West Virginia favors the change since it immediately and voluntarily implemented the change promulgated in the 1983 final rule by amending its State program to eliminate the absolute requirement to restore imposed by the 1979 OSMRE rules. Thus, the State which OSMRE expects (based on the 1986 Environmental Assessment) to experience approximately one-half of all anticipated subsidence damage incidents prefers that the requirement to correct for such damage be left to State law and contractual arrangements. Pennsylvania also favors deference to State law since, following promulgation of the 1983 rule, Pennsylvania voluntarily amended its State program to institute a less stringent regulatory interpretation of its 1966 Statute (as amended in 1980), the Bituminous Mine Subsidence and Land Conservation Act. Thus, under its current law and regulations Pennsylvania provides less than the absolute requirement to correct or compensate for subsidence damage to structures and facilities found in the 1979 OSMRE rules. Consequently, it is apparent that the two States with the greatest number of underground mining operations—ones expected to experience approximately 70 percent of the incidents of subsidence damage to structures support the change leaving the restoration requirements to State law. In any event, because Pennsylvania and West Virginia already have programs which are consistent with this final rule, there will be no change required from the status quo.[8]

Although homeowners may suffer financial and other injury as a result of subsidence due to underground mining in Illinois, the agency does not intend to interfere with State laws on this issue. The Act is not intended to provide rights for the repair of structures to property owners who voluntarily relinquished such rights or whose predecessors in interest did so. Further, whether States, such as Illinois, make their surface mining regulations "no more stringent than" the Federal regulations is a matter for States to determine. States may modify their "no more stringent than" requirements, particularly in specific situations where the State determines that local public policy concerns outweigh the general principle of not regulating in a manner more stringent than OSMRE's national rules.

Moreover, impacts of this rule are lessened because consideration of potential subsidence damage continues to be required at the mine planning state. A subsidence control plan must be submitted as part of the permit

[8] If this final rule were not to recognize state law limits and imposed an absolute obligation to repair or restore materially damaged structures, then the affected State program would have to be amended to reflect such a rule.

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application if structures exist which potentially may be damaged (See 30 CFR 784.20). The plan must demonstrate that the operator will mine in a manner intended to prevent material damage resulting from subsidence.

One commenter claimed § 1817.124 of Illinois law (implementing the 1979 rule's repair or compensation requirement) is illegal and violates the approved Illinois permanent program.

The validity of the subsidence provisions of the Illinois State program is not at issue in this rulemaking. The Illinois State program was approved in 1982. Although a challenge to that program approval is currently in litigation, *Illinois South Project, et al. v. Hodel*, No. 82-2229 (C.D. 111), the validity of Illinois performance standards regarding subsidence is not an issue in this suit.

Another commenter criticized the practicality of the provision that compensation (pursuant to State law) may be accomplished by the purchase prior to mining of a non-cancellable premium-prepaid insurance policy, indicating such policies are not available and will not be available from the insurance industry. Although subsidence liability insurance may not be generally available, this option will be retained in the regulations because there may be some areas where such insurance will be obtainable. The purchase of an insurance policy is only one of several alternatives provided under § 817.121(c)(2). Repair or compensation for subsidence damage may be arranged in other ways.

Several commenters asserted that farmland drainage systems, including agricultural tiling and irrigation ditches, should be subject to the same national repair and restoration standards found under the former rules for structures. OSMRE believes that agricultural tiling and other farmland drainage structures are not part of the land and therefore are directly protected against damage only to the extent required by State law under the provisions of § 817.121(c)(2). However, argicultural tiling and other farmland drainage systems are indirectly protected by the requirements of § 817.121(c)(1) for "restoring the land to a condition capable of maintaining the value and reasonably foreseeable uses which it was capable of supporting before subsidence". If necessary to meet the land restoration requirements of §817.121(c)(1) for farmland, regulatory authorities can require the restoration of agricultural drainage structures as a condition of permit approval.

Another commenter claimed that water supplies should be protected from subsidence damage and that there should be a national requirement to restore or replace water supplies damaged by subsidence. Water supplies are protected from subsidence damage by provisions of § 817.121(d)(3) if they serve as a "significant water source for any public water supply system." That section provides an advance showing that such water supplies will not be damaged. Private water supplies, such as individual wells, are not similarly protected by § 817.121. However, the hydrology requirements of the Act do provide some protection for all water supplies. Although the Act does not mandate replacement of water supplies in every event of damage or loss, it does require protection of water quantity and quality. In the permitting of underground mines, the regulatory authority must find, before the issuance of any permit, that the operation is designed to prevent material damage to the hydrologic balance outside the permit area (see 30 CFR 773.15(c)(5). In addition, each permit application must include a determination of the probable hydrologic consequences (PHC) of the proposed operation upon the quality and quantity of surface water and groundwater (see 30 CFR 784.14(e)(1)). The PHC determination must include findings on, *inter alia*, the impacts the proposed operation will have on "ground-water and surface-water availability" (30 CFR 784.14(e)(3)(iii)(D)). Thus, for every permit application, the regulatory authority will be provided information on the PHC of the proposed operation. Based upon the PHC determination, each permit application must contain a hydrologic reclamation plan that specifically addresses "any potentially adverse hydrologic consequences * * * and shall include preventive and remedial measures" (30 CFR 784.14(g)). If the protection of water quantity or quality cannot otherwise be assured, the regulatory authority may deny the permit or direct that alternative mitigation measures be included in the reclamation plan. Such measures may include, at the operator's discretion, the provision of alternative water supplies. Thus, the requirements of the Act do serve the unified purpose of protecting the environment, including the area's hydrology, from damage caused by subsidence due to underground mining.

Disagreeing, another commenter stated that the rule changes should be dropped rather than made more stringent. OSMRE believes that the rule change is neither arbitrary nor unreasonable and that the dichotomy of opinion expressed by the commenters suggests that this rule has struck a reasonable balance.

One commenter speculated that savings institutions would no longer issue construction loans for homes to be built on lands subject to subsidence if the rule should be adopted. The commenter's concern is unsupported and appears exaggerated. Certainly construction loans existed prior to imposition of the 1979 rule. Business enterprises will adjust to the current rule, just as they did when no absolute protection for structures existed. Moreover, under State law compensation may be required, or the contract itself may prohibit subsidence damage from occurring. Additional protection may be provided through subsidence insurance programs which are either in place or are now being started with the aid of monies from the Abandoned Mines Lands fund established by the Act.

Two commenters objected to the promulgation of the final rule at this time because OSMRE is preparing rulemakings on related issues, particularly the applicability of the prohibitions of Section 522(e) (4) and (5) of the Act to subsidence and underground mining. These commenters suggested that action be delayed on the proposed rule at least until the planned environmental impact statement (EIS) and regulatory impact analysis (RIA) for the Section 522(e) (4) and (5) rule are completed. OSMRE considered delaying the final rule in this rulemaking, but concluded that this rule had an independent basis and there were inadequate reasons for delaying this final rule for more than one year until the rulemaking is completed on the scope of Section 522(e) (4) and (5). However as described below, possible cumulative effects of the two rules were considered prior to finalization of this rule.

Two related comments contended that the analysis in OSMRE's 1983 supplemental EIS regarding subsidence damage to structures is inadequate and that a new EIS should be prepared. Another commenter recommended that such an EIS include an analysis of the effects of protections for structures under the various State laws. Although it previously concluded in the supplemental EIS that there would be no significant impacts due to the promulgation of this rule, OSMRE made the decision to reexamine those earlier conclusions and prepare an environmental assessment (EA) on this rulemaking. In the EA, OSMRE reviewed the protection provided to property owners by the approved State regulatory programs, existing and proposed State subsidence insurance programs, and the extent to which the common law of subjacent support is applicable in selected States. Also, in view of ongoing studies in support of the Section 522(e) (4) and (5) EIS and RIA, the EA analysis assumed as the limiting case, the alternative providing the least protection for structures, i.e., that the Section 522(e) (4) and (5) prohibitions do not apply to subsidence. By assuming the least protection for structures, the conclusion reached in the EA will not be altered in the direction of greater impacts on structures by the ultimate outcome of the Section 522(e) (4) and (5) rulemaking. The EA concluded that there were no significant impacts due to this rulemaking on the quality of the human environment. This supports the conclusions previously reached in the 1983 supplemental EIS. From an environmental standpoint, there is no need therefore, to delay going forward with this rulemaking because the environmental consequences will either remain the same as projected in the EA or be lessened as a consequence of the Section 522(e) (4) and (5) rulemaking.

Finally, three commenters asked for clarification in this final rule preamble that the State law referred to in § 817.121(c)(2) is not limited to State surface mining laws. OSMRE accedes to that request; the State law referred to in the final rule includes all State law whether codified or uncodified, and is not limited to the State surface mining law.

III. Procedural Matters

Federal Paperwork Reduction Act

The information collection requirements in final § 784.20 have been approved by the Office of Management and Budget (OMB) under 44 U.S.C. 3507 and assigned clearance number 1029-0039. OSMRE has codified the OMB approvals in § 784.10.

The information required will be used by the regulatory authority in permitting, monitoring, and inspecting underground mining activities to insure that they are conducted in a manner which preserves and enhances environmental and other values of the Act. The information required by these rules is mandatory.

Executive Order 12291

The DOI has examined this final rule according to the criteria of Executive Order 12291 (Februrary 17, 1981) and has determined that it is not major and does not require a regulatory impact analysis.

Regulatory Flexibility Act

The DOI also has determined, pursuant to the Regulatory Flexibility Act, 5 U.S.C. 601 *et seq.*, that this final rule will have a significant economic impact on a substantial number of small entities.

National Environmental Policy Act

Based on comments received on the proposed rule, OSMRE determined that this final rule required additional environmental analyses to evaluate the validity of the conclusions made by the existing environmental impact statement titled "Final Environmental Impact Statement, OSM-EIS-1: Supplement". Consequently an Environmental Assessment (EA) was done which has resulted in a finding of no significant impacts (FONSI) in agreement with OSM-EIS-1. Therefore, the preparation of any additional environmental documents under section 102(2)(C) is not required. The EA is available in the Administrative Record, Rm. 5315, 1100 L Street NW., Washington, DC.

Agency Approval

Section 516(a) of the Act requires that, with regard to rules directed toward the surface effects of underground mining, OSMRE must obtain written concurrence from the head of the department which administers the Federal Mine Safety and Health Act of 1977, the successor to the Federal Coal Mine Health and Safety Act of 1969. OSMRE has obtained the written concurrence of the Assistant Secretary for Mine Safety and Health, U.S. Department of Labor.

Author

The author of this regulation is Dermot Winters, Regulatory Development and Issues Management Group, Office of the Director, Office of Surface Mining Reclamation and Enforcement, 1951 Constitution Avenue, NW., Washington DC 20240, Telephone (202) 343-1928 (commercial or FTS).

List of Subjects

30 CFR Part 784

Coal mining, Reporting and recordkeeping requirements, Underground mining.

30 CFR Part 817

Coal mining, Environmental protection, Underground mining.

Accordingly, 30 CFR Part 784 and 817 are amended as set forth below.

Dated: January 5, 1987.

J. Steven Griles,

Assistant Secretary for Land and Minerals Management.

PART 784—UNDERGROUND MINING PERMIT APPLICATIONS—MINIMUM REQUIREMENTS FOR RECLAMATION AND OPERATION PLAN

1. The authority citation for Part 784 continues to read as follows:

Authority: Pub. L. 95-87, 91 Stat. 445 (30 U.S.C. 1201 *et seq.*) and sec. 115, Pub. L. 98-146, 97 Stat. 938 (30 U.S.C. 1257), unless otherwise noted.

2. In § 784.20, the third sentence of the introductory paragraph is revised, paragraph (b) is revised, paragraphs (d), (e), (f) and (g) are redesignated as paragraphs (e), (f), (g) and (h) respectively, paragraph (d) is added, paragraphs (e)(3) and (e)(4) are revised, and paragraph (e)(5) is removed, to read as follows:

§ 784.20 Subsidence control plan.

* * * In the event the survey shows that such structures or renewable resource lands exist, and that subsidence could cause material damage or diminution of value or foreseeable use of the land, or if the regulatory authority determines that such damage or diminution could occur, the application shall include a subsidence control plan which shall contain the following information: * * *

* * * * *

(b) A map of underground workings which describes the location and extent of areas in which planned-subsidence mining methods will be used and which includes all areas where the measures described in paragraphs (d) and (e) of this section will be taken to prevent or minimize subsidence and subsidence related damage; and, where appropriate, to correct subsidence-related material damage.

* * * * *

(d) A description of monitoring, if any, needed to determine the commencement and degree of subsidence so that, when appropriate, other measures can be taken to prevent, reduce, or correct material damage in accordance with § 817.121(c) of this chapter.

(e) * * *

(3) Leaving areas in which no coal is removed, including a description of the overlying area to be protected by leaving the coal in place; and

(4) Taking measures on the surface to prevent material damage or lessening of the value or reasonably foreseeable use of the surface.

* * * * *

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PART 817—PERMANENT PROGRAM PERFORMANCE STANDARDS—UNDERGROUND MINING ACTIVITIES

3. The authority citation for Part 817 continues to read as follows:

Authority: Pub. L. 95-87, 91 Stat. 445 (30 U.S.C. 1201 *et seq.*) and sec. 115, Pub. L. 98-146, 97 Stat. 938 (30 U.S.C. 1257), unless otherwise noted.

4. Paragraph (c)(2) of § 817.121 is revised to read as follows:

§ 817.121 Subsidence control.

* * * * *

(c) The operator shall— * * *

(2) To the extent required under applicable provisions of State law, either correct material damage resulting from subsidence caused to any structures or facilities by repairing the damage or compensate the owner of such structures or facilities in the full amount of the diminution in value resulting from the subsidence. Repair of damage includes rehabilitation, restoration, or replacement of damaged structures or facilities. Compensation may be accomplished by the purchase prior to mining of a non-cancellable premium-prepaid insurance policy.

* * * * *

[FR Doc. 87-3194 Filed 2-13-87; 8:45 am]

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APPENDIX - B

STATUS OF STATES' SUBSIDENCE CONTROL REGULATIONS

Table B

STATUS OF SUBSIDENCE CONTROL REGULATIONS IN THE THIRTY FOUR STATES THAT HAVE SOUGHT PRIMACY

State	Primacy (Regulatory) Jurisdiction	State Subsidence Control Regulations Rules & Regulations	Remarks
Alabama	state	Patterned after 1979 Fed.	
Alaska	state	Patterned after 1979 Fed.	
Arkansas	state	Identical to 1979 Fed.	
Colorado	state	Patterned after 1979 Fed.	
Georgia	federal	--	No underground coal mining
Idaho	federal	--	
Illinois	state	Patterned after 1979 Fed.	
Indiana	state	Identical to 1979 Fed.	

Table B
(continued)

State	Primacy (Regulatory) Jurisdiction	State Subsidence Control Regulations Rules & Regulations	Remarks
Iowa	state	Identical to 1979 Fed.	
Kansas	state	Identical to 1979 Fed.	No underground coal mining
Kentucky	state	Patterned after 1979 Fed.	
Louisiana	state	--	No underground coal mining
Maryland	state	Patterned after 1979 Fed.	
Massachusetts	federal	--	No underground coal mining
Michigan	federal	--	No underground coal mining
Mississippi	state	Identical to 1979 Fed.	
Missouri	state	Identical to 1979 Fed.	No underground coal mining
Montana	state	Identical to 1979 Fed.	
New Mexico	state	Patterned after 1979 Fed.	
North Carolina	federal	--	No underground coal mining
North Dakota	state	--	No underground coal mining

Table B
(continued)

State	Primacy (Regulatory) Jurisdiction	State Subsidence Control Regulations Rules & Regulations	Remarks
Ohio	state	Patterned after 1983 Fed.	
Oklahoma	state	Identical to 1979 Fed.	
Oregon	federal	--	No underground coal mining
Pennsylvania	state	Different from Fed.	
Rhode Island	federal	--	No underground coal mining
South Dakota	federal	--	No underground coal mining
Tennessee	federal	--	
Texas	state	Identical to 1979 Fed.	
Utah	state	Identical to 1979 Fed.	
Virginia	state	Identical to 1979 Fed.	
Washington	federal	--	No underground coal mining
West Virginia	state	Patterned after 1983 fed.	
Wyoming	state	Different from Fed.	

APPENDIX - C

LIST OF PARAMETERS AND SYMBOLS

APPENDIX C

LIST OF PARAMETERS AND SYMBOLS

Each parameter and symbol employed in this manual is listed below along with the section of the text where it is introduced. For the most part, parameters and symbols are those of the source material, with changes being made only to avoid duplication and ambiguity. Dimensions are indicated in parentheses.

a	Subsidence Factor (dimensionless)	4.4.2
a'	Subsidence Factor adjusted for panel geometry (dimensionless)	4.4.2.3
a_o	Absolute Maximum Subsidence Factor (dimensionless)	4.4.2.3
a_{pf}	empirical constant used with exponential profile function (dimensionless)	4.4.4.1
A (A', A'')	normalized profile function parameters (dimensionless)	
A_b	load carried by pillar yield zone (force)	5.4.2.1
A_p	pillar area (area)	5.4.1.1
A_T	tributary area (area)	5.4.1.1
A_W	factor used in pillar stress analysis (force/length)	5.4.2.1
b	empirical constant used with exponential profile function (dimensionless)	4.4.4.1
B	measure of distance used with hyperbolic tangent function function (length)	4.3, 4.4.4.1
C	panel geometry adjustment to subsidence factor (dimensionless)	4.4.2.3
$\overline{C}$	empirical constant used with hyperbolic tangent profile function (dimensionless)	4.4.4.1
C1 (C2)	undrained shear strength of mine floor (force/area)	5.4.1.2

C*	factor used in pillar stress distribution analysis (dimensionless)	5.4.2.1
d	horizontal dimension used with hyperbolic tangent profile function (length)	4.4.4.1
D	edge length of cubic coal sample (length)	5.4.1.1
D_p	plan dimension of structure as measured across the width of the panel (length)	5.2.1
e	ground strain (dimensionless	4.4.4.5
E	extraction ratio (dimensionless)	5.4.1.1
E_c	elastic modulus of coal (force/area)	5.4.2.2
E_i	elastic modulus of immediate roof (force/area)	5.4.2.2
E_m	elastic modulus of main roof (force/area)	5.4.2.2
f	strength factor (dimensionless)	5.4.2.1
F	factor used in pillar stress distribution analysis (dimensionless)	5.4.2.1
FS	factor of safety	5.4.1
h	thickness of individual stratum (length)	4.4.2.3
H	mine depth or overburden thickness (length)	
i	ground slope (dimensionless)	4.4.4.2
J	ratio of horizontal movement to ground slope at a point on ground surface (dimensionless)	
k	triaxial stress factor (dimensionless)	5.4.2.1
K	ground curvature (1/length)	4.4.4.3
K_o	maximum ground curvature (1/length)	4.4.4.5
L	measure of distance used with the exponential profile function (length)	4.3, 4.4.4.1
L_c	critical dimension (length or width) of a mine panel (length)	4.4.3.2
L_L	length of mine panel (length)	4.4.2.3
L_{pr}	length of rectangular pillar (length)	5.4.2.2

L_v	vertical load on pillar (force)	5.4.1.1
L_W	width of mine panel; used interchangeably with W (length)	4.4.2.3
m	mined thickness of coal seam, or height of mine working (length)	4.4.2
M	horizontal offset distance between mine faces in strain cancellation mining (length)	5.2.3
n	proportion by thickness of hard rock (sandstone and limestone) in overburden (length)	4.4.2.2
N_m	bearing capacity factor (dimensionless)	5.4.1.2
p*	support resistance and strength of broken material (force/area)	5.4.2.1
P	combined strata coefficient (dimensionless)	4.4.2.3
P_A	total width of protected area at ground surface (length)	5.3.2.1
PL	pillar length (length)	5.4.1.1
P_{sa}	total width of support area at mine level (length)	5.3.2.2
Pw	pillar width (length)	5.4.1.1
q	overburden (cover) stress (force/area)	5.4.1.1
q_F	governing mine floor strength (force/area)	5.4.1.2
Q (Q1,Q2)	stratum property coefficient (dimensionless)	4.4.2.3
Qult	ultimate bearing capacity (force/area)	5.4.1.2
Rs	allowable pillar load per unit area (force/area)	5.4.2.1
Ru	ultimate pillar load per unit area (force/area)	5.4.2.1
S	subsidence at some point along a profile (length)	4.4.4.1
S_o	absolute maximum subsidence that can be achieved given critical or supercritical panel dimensions (length)	4.4.2.3
S*	maximum subsidence along a profile (length)	4.4.2
t	time	5.2.5

u	horizontal ground movement (length)	4.4.4.4
w	width of center section of mine face in stepped face extraction system (length)	5.2.3.1
W	width of mine panel; used interchangeably with Lw (length)	4.4.2.3
W_E	width of mine entry (length)	5.4.1.1
W_{pr}	width of rectangular pillar (length)	5.4.2.2
W_{ps}	width of square pillar (length)	5.4.2.2
x	horizontal distance measured from a specified reference (length)	
X_b	width of pillar yield zone (length)	5.4.2.1
Z (Z',Z'')	width of safety zone within protected area at ground surface (length)	5.2.1, 5.3.2.1
a	angle of advance influence (degrees)	4.3
B (B_R, B_s)	angle of draw (degrees)	4.3, 4.4.3.3
γ	unit weight of rock (weight/volume)	
δ	angle of break (degrees)	4.3
ζ	angle of damage (degrees)	4.3
Ψ	angle of complete mining (degrees)	4.3
σ_A	allowable pillar stress (force/area)	5.4.2.1
σ_{ab}	average pillar stress between points a and b (force/area)	5.4.2.1
σ_C	governing coal cube strength (force/area)	5.4.1.1
σ_L	unconfined compressive strength of laboratory test cubes (force/area)	
σ_o	unconfined compressive strength of rock in situ (force/area)	5.4.2.1
σ_p	nominal pillar stress (force/area)	5.4.1.1
σ_μ	ultimate pillar stress (force/area)	5.4.2.1

σ_y	vertical stress in pillar yield zone (force/area)	5.4.2.1
$\hat{\sigma}$	peak abutment stress in pillar (force/area)	5.4.2.1
$\bar{\sigma}$	average pillar stress (force/area)	5.4.2.1

Attorney Client Privileged

Reference 5

Subsidence from Underground Mining: Environmental Analysis and Planning Considerations

GEOLOGICAL SURVEY CIRCULAR 876

COVER PHOTOGRAPH:

Subsidence pits, troughs, and cracks above an abandoned coal mine in the western Powder River Basin, Wyoming. Photograph by C.R. Dunrud.

Subsidence from Underground Mining: Environmental Analysis and Planning Considerations

By F. T. Lee and J. F. Abel, Jr.

GEOLOGICAL SURVEY CIRCULAR 876

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Subsidence from Underground Mining: Environmental Analysis and Planning Considerations

By F. T. Lee and J. F. Abel, Jr.[1]

ABSTRACT

Subsidence, a universal process that occurs in response to the voids created by extracting solids or liquids from beneath the Earth's surface, is controlled by many factors including mining methods, depth of extraction, thickness of deposit, and topography, as well as the in situ properties of the rock mass above the deposit. The impacts of subsidence are potentially severe in terms of damage to surface utility lines and structures, changes in surface-water and ground-water conditions, and effects on vegetation and animals. Although subsidence cannot be eliminated, it can be reduced or controlled in areas where deformation of the ground surface would produce dangerous or costly effects.

Subsidence prediction is highly developed in Europe where there are comparatively uniform mining conditions and a long history of field measurements. Much of this mining has been carried out beneath crowded urban and industrial areas where accurate predictions have facilitated use of the surface and reduced undesirable impacts. Concerted efforts to understand subsidence processes in the United States are recent. Empirical methods of subsidence analysis and prediction based on local conditions seem better suited to the current state of knowledge of the varied geologic and topographic conditions in domestic coal mining regions than do theoretical/mathematical approaches. In order to develop broadly applicable subsidence prediction methods and models for the United States, more information is needed on magnitude and timing of ground movements and geologic properties.

INTRODUCTION

The worldwide need for energy resources requires increased production of coal and other fuels. A large amount of this production will eventually come from underground mining in areas where surface mining is impractical or uneconomical. Past coal mining practice left much coal in the ground as pillars that are difficult to recover. Present-day emphasis is on improving extraction percentage. Because both the methods of extraction and the number of mines will increase overall subsidence risk, we must be able to accurately predict the surface and underground impacts of subsidence and, if necessary, to suggest means to lessen these impacts. It is clear from poorly controlled mining operations of the past that we no longer have the luxury of mining without regard to present and future land use.

The purpose of this circular is to give an overview of subsidence processes and their potentially harmful consequences, the methods of subsidence prediction, and methods to control and reduce subsidence impacts. The report is primarily intended to serve as an introduction and state-of-the-art review for those individuals or groups concerned with assessing the potential environmental effects of underground mining. The major emphasis is on coal mining.

The time to plan for subsidence impacts is well before mining begins, not after surface effects are noticed. Because subsidence due to underground mining may be inevitable, the relevant questions to be asked are how much, when, and where, and what abatement procedures are possible and might be necessary. The impacts of subsidence are broad, affecting water supplies, transportation and utilities, vegetation, and farming. In addition, in situ extraction techniques for coal gasification and oil shale retorting are supported by extensive, costly surface facilities. The success of these oper-

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ations may depend upon accurately estimating the extent of subsidence, both in area and strain magnitudes, so that surface plants are not damaged or located unnecessarily distant from the mining operations.

Recent Federal regulations implementing the Surface Mining Control and Reclamation Act of 1977 (Federal Register, 1977) will encourage increased consideration of subsidence effects prior to mining. At present, however, very few mining companies in the United States make routine leveling surveys of the ground surface. Increased surface monitoring is needed in order to implement current mining regulations.

To a greater or lesser degree each mining area is different, and no one subsidence prediction method will serve equally well for all cases. For example, the prediction scheme used in the United Kingdom with excellent results for longwall coal mining[2] does not work as well in other areas largely because of different geologic conditions. The great diversity of mining conditions in the United States partly accounts for the circumstance that subsidence prediction is not far advanced in this country. A systematic concentrated effort is needed to develop more broadly applicable and accurate methods of subsidence prediction in the United States. The more general and widely used analytical techniques are discussed here; the reader is cautioned that many circumstances will require specific expert advice.

The term "mining" as used in this report includes all extractive processes for recovering organic and inorganic resources. Thus, we are concerned with deformations caused by several mining methods in a variety of geologic environments. Most emphasis in this report, however, is placed on longwall and room-and-pillar mining of coal. It has been estimated that coal extraction is responsible for over 90 percent of worldwide mining-induced subsidence (Allen, 1978). Longwall mining currently accounts for less than 10 percent of the coal mined in the United States, although it has long been the most popular method in Europe. However, because longwall mining, which removes a complete tabular section of coal, is more efficient than room-and-pillar mining, it is being promoted increasingly in the United States. Also, longwall mining induces a generally uniform and contemporaneous surface subsidence that can be more accurately forecast than subsidence caused by room-and-pillar mining. The current state of knowledge of subsidence permits a more detailed discussion of longwall-induced subsidence than of the other forms.

[2]Technical terms used herein are defined in the glossary, p. 25.

OVERVIEW OF SUBSIDENCE PROCESSES

DEFINITION

Subsidence is a time-dependent process, either natural or man induced, in which there is a lowering of the ground surface in response to the removal of gas, liquid, or solid matter. Deformation of the rock mass may be by either elastic, plastic, or brittle processes or by any combination of these processes. Subsurface deformation leading to surface subsidence includes the local lateral and upward displacements of rock above unmined areas (near mine boundaries or barrier pillars) caused by the downward movement of overburden into mine cavities. Strains induced by mining and transmitted through intervening strata to the surface may be compressive or tensile and may have both horizontal and vertical components.

CONCEPTUAL DESCRIPTION OF SUBSIDENCE

The void created by the underground extraction of coal or other resources causes significant changes in the magnitude and orientation of the in situ stress field and results in deformations both in the remaining coal and in the surrounding rocks. In general, the sides of the excavated area move inward, the floor upward, and the roof downward. The initial deformations may be elastic, that is, they may disappear if the deforming forces are removed. Nonelastic deformations, however, occur with time and, as the region of cavity influence increases with continued extraction, rock strengths are exceeded and irreversible block movements take place. Large bending moments in the mine roof strata will ultimately cause local roof failure and collapse, and the mined-out area will fill with overburden materials. The downward movement of overlying rock will induce lateral movement of rock toward the cavity. These deformations are illustrated in figure 1. Rock outside the vertical limits of the mined area will also subside. The affected ground will lie typically 10°–35° outside the vertical limits of the mined area (angle of draw). Deformations eventually reach the ground surface and may form subsidence depressions, open fractures, pits, and troughs. Com-

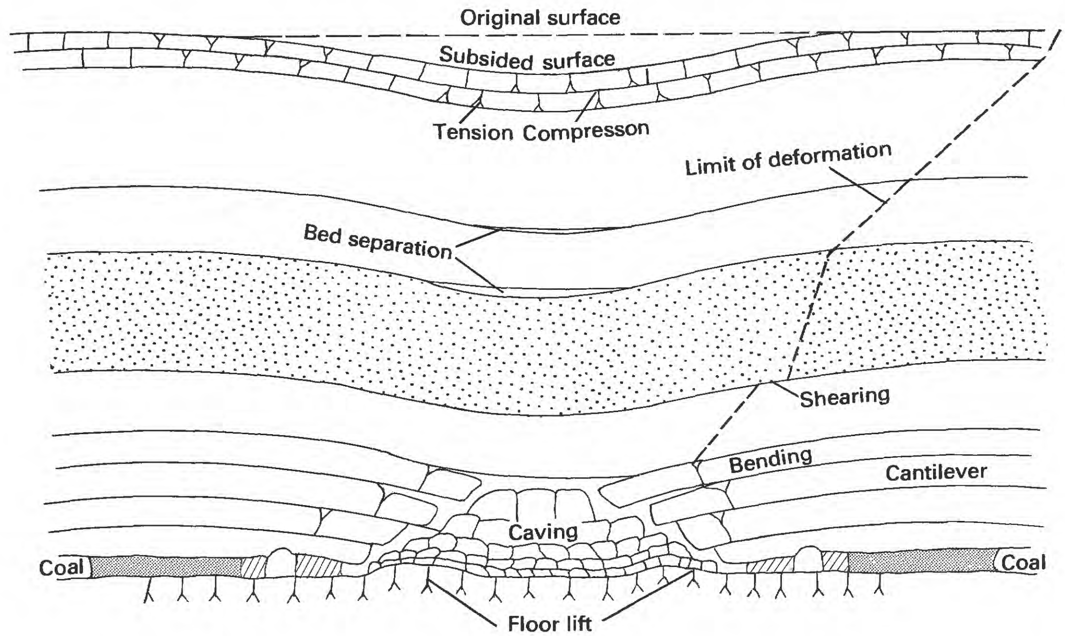


FIGURE 1.—Deformations produced in rocks above and below an extracted coal seam (modified from Shadbolt, 1978).

pression features including doming and thrust faulting have also been reported.

Depending upon several factors including mining methods and rock properties, the changes at the surface may occur almost concurrently with mining or they may be delayed and take place with dramatic suddenness more than 100 years after mining.

SUBSIDENCE PRODUCED BY LONGWALL COAL MINING

The mechanical aspects of the subsidence process in flat-lying coal bearing rocks mined by longwall methods are reasonably well known, compared to room-and-pillar mining, and are documented abundantly in the literature. This knowledge may be summarized as follows. When an underground coalbed of a given thickness is extracted over a wide area, the immediate roof will collapse. Rock displacements are transferred to the ground surface when the ratio of the width of the extracted material to the depth of overburden (*w/h*) exceeds a value which varies from 0.1 to 0.5 (Wardell and Eynon, 1968); the ratio value is controlled largely by the strength and structure of the rock overlying the mined-out area. Field measurements and theory support the concept that there is a stabilizing compression (or pressure) arch in the solid rock above and below the mined-out area. The duration of this arching effect is controlled by the height, width, and length of the mined opening, and subsidence will not begin until a critical void size is exceeded at which the arch will no longer span the excavated area. Consequently, there is often a delay between the onset of a change in state underground and the first appearance of land subsidence at the ground surface. The arching effect may be limited, however, by very weak overburden rocks or by poor mining practice that significantly weakens the overburden. Geologic conditions, mining depth, and seam thickness also affect arching behavior.

After subsidence has begun, it will develop progressively and continue so long as there is a progressive enlargement of the underground opening. Surface effects from longwall mining in mountainous terrain in New Mexico are illustrated in figures 2–4. These conditions occurred essentially contemporaneously with mining.

The concept of a "critical" area (width and length) of extraction is closely related to the ability of the strata above the excavated area to support loads across the mined openings. Assuming an infinite length for an extracted area (in practice

FIGURE 2.—Compression ridges produced contemporaneously with longwall mining near Raton, New Mexico.

a length equal to or greater than the depth of mining), there is a critical width of extraction for which the subsidence (vertical lowering of the surface) reaches a maximum value. Subcritical widths of extraction produce a trough-like subsidence area with vertical subsidence less than the maximum. At supercritical widths of extraction the subsidence area has an essentially flat bottom at approximately the maximum subsidence. These relations are illustrated in figure 5.

The critical width of extraction is normally expressed in terms of the mining depth (fig. 5). In European coal fields it ranges from 1.0 h to 1.4 h, where h is the average depth of mining. This range has been attributed to differences in the types of overlying rock. Quantitative studies are meager; however, the lower values of the depth coefficient appear to be associated with overburden containing thick, strong sandstone and limestone beds whereas the higher values pertain to overburden containing a large percentage of thin-bedded shales, mudstones, siltstones, sandstones, and unconsolidated deposits. Maximum subsidence is also a function of the thickness of the extracted layer or the volume of material extracted, the mining methods, and several other factors discussed in the following sections.

SUBSIDENCE PRODUCED BY ROOM-AND-PILLAR COAL MINING

Room-and-pillar mining is the most frequently used mining method in United States coal mines. The coal is mined in entries (rooms) separated by pillars which may or may not be partially extracted later. Initially, a series of parallel entries

FIGURE 3.—Large open fissure associated with longwall mining in mountainous terrain near Raton, New Mexico. Such features can divert surface runoff, increasing landslide potential.

FIGURE 4.—Rockfalls and tension cracks produced during longwall coal mining near Raton, New Mexico.

are driven through the seam with interconnecting openings (breakthroughs) driven at right angles through the pillars between the rooms. Such a checkerboard pattern of openings is advanced through the coal seam to the limit of the area planned for mining. At this point approximately 50 percent of the coal will have been mined. The coal pillars between adjacent rooms may be fully or partially removed (robbed) during final, or retreat, mining. After full pillar removal, the rock above the mine collapses and the overburden gradually settles, creating surface fissures and subsidence.

The percent extraction by room-and-pillar mining depends upon several factors including the number and size of pillars deemed necessary to temporarily support the mine roof during retreat mining and the need to prevent or limit surface subsidence. In some sections of West Virginia and in other States where surface land is owned by the coal producer, nearly 100 percent of available coal can be mined using the room-and-pillar method. In States such as Illinois, however, where farm and industrial land are extremely valuable, only about 50 percent of the coal may be mined to prevent surface damage from subsidence.

Because of the several stages of coal removal and the slow pillar deformation and deterioration in room-and-pillar mining, surface settlement is not as uniform and immediate as it is in longwall mining; rather, it may be erratic, intermittent, and long delayed. Figure 6 shows a representative example of delayed subsidence features in Wyoming resulting from old shallow underground room-and-pillar mining operations.

SUBSIDENCE FROM MINING OTHER SEDIMENTARY RESOURCES

Other sedimentary resources which are extracted from considerable depth (hundreds of meters) include salt, potash, sulfur, trona, and phosphate. These minerals occur in bedded, usually

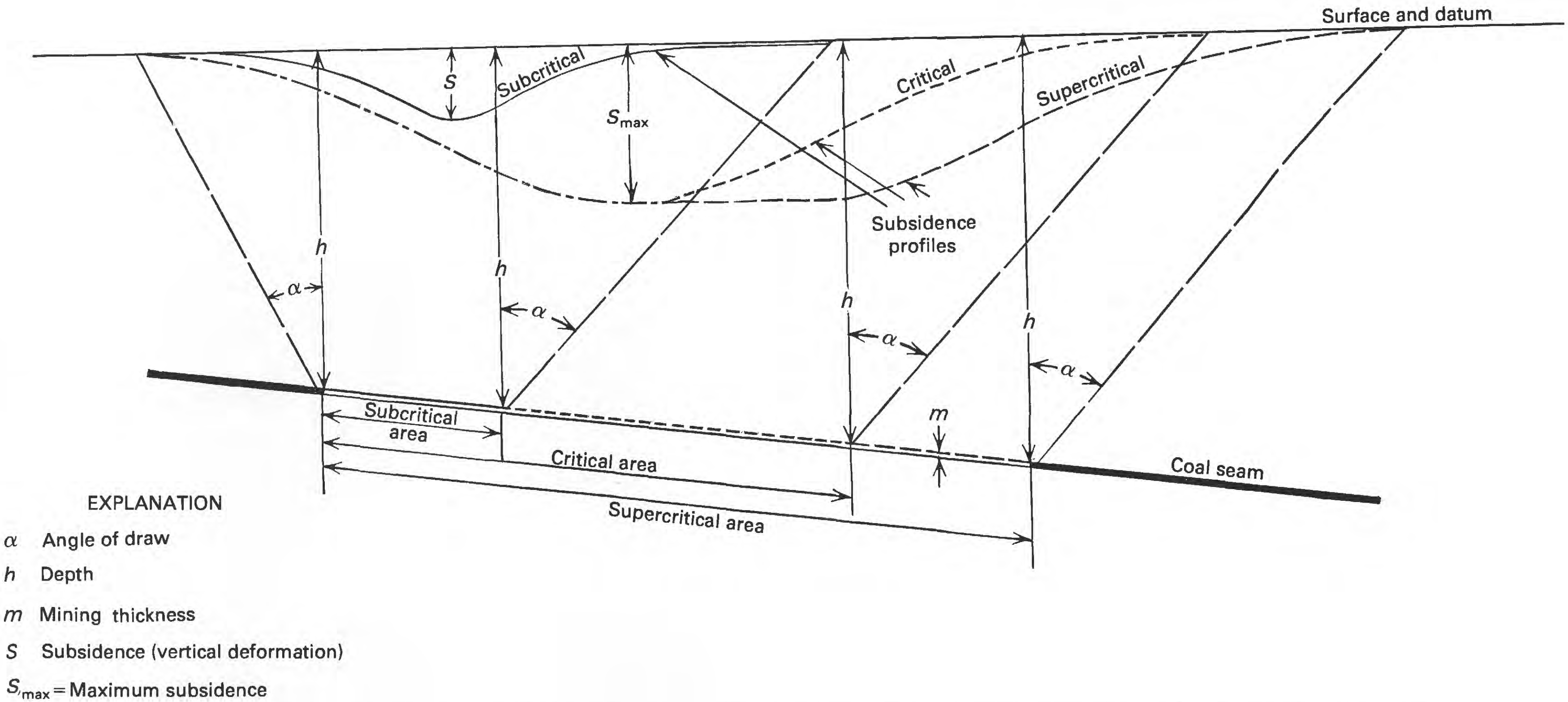


FIGURE 5.—Description of subsidence over longwall mining. Face advance direction is perpendicular to plane of page. (Adapted from National Coal Board, 1975).

flat-lying deposits, and have been mined by several methods: conventional room-and-pillar, longwall, and solution. Pillar and roof collapse and resultant surface deformations are typically delayed and difficult to predict. In solution mining of salt, for example, neither the time nor the location of subsidence can be predicted with confidence because salt deforms slowly in a complex manner and the deformations are different from those of overlying shale and sandstone. Furthermore, solution extraction of salt and other soluble evaporites is a specialized mining technique and the resulting subsidence causes unique problems (Marsden and Lucas, 1973). Drilling through aquifers and salt beds in search of oil, gas, and water has induced salt dissolution and subsequent subsidence (Fader, 1975). As Ege (1979) points out, the construction of highways, dams, and reservoirs over saline or gypsiferous rock has caused subsidence, water loss, and dam failures. A comprehensive discussion of subsidence associated with solution extraction of sulfur is given by Deere (1961).

The subsidence produced by room-and-pillar and longwall mining of potash, phosphate, and most

FIGURE 6.—Southeastward-looking aerial view showing the surface effects of past (room-and-pillar) and present (open pit) coal mining along the Tongue River in Wyoming (July 1977). Pits, troughs, depressions, and cracks have formed because of subsidence over the south part of the Acme mine. The mine was operated from the early 1900's until 1943. Overburden thickness ranges from 15 m in the middle ground to approximately 30 m in the foreground and consists of alluvium and soft interbedded shales, claystones, siltstones, and discontinuous sandstones. The dam in the right foreground across Hidden Water Creek ruptured because of subsidence. The water now is diverted into subsidence depressions, pits, and cracks upstream from the dam. Garbage from the town of Acme was dumped into the large pit at the left side of the photograph. Pits and troughs in the middle of the photograph are in alluvium. Note that the pits near the road and left of the draw do not occur in any noticeable depression; these pits are located above collapsed areas in haulageways of the Acme mine where adjacent coal pillars are strong enough to support the overburden. Alluvium is being removed at the Big Horn surface coal mine to extract the coal (background). Regrading is beginning near the river (right background). (From Dunrud and Osterwald, 1980.)

sedimentary rocks is grossly similar to that of mining coal, being dependent upon the thickness of the bed mined, the depth, the mining methods, and the properties of the overburden. The reader may want to consult Miller and Pierson (1958) for a discussion of subsidence over potash mines.

SUBSIDENCE FROM MINING CRYSTALLINE ROCKS

A very different type of subsidence is produced by the extraction of irregularly shaped metalliferous ore bodies by block caving or by leaching of disseminated deposits where the extracted width is small compared to the depth. A prominent collapse structure, as much as tens to hundreds of meters in depth, may develop rapidly. The subsidence mechanism in jointed crystalline rocks proceeds approximately as follows (Abel and Lee, 1980):

1. Rock collapses progressively upward from the mining horizon (undercut level) as ore is withdrawn from below.
2. The ground surface does not begin to subside measurably until the collapse has so thinned the intact rock above the mined-out area that it cannot support the load of the overlying rock (arching effect). The overlying solid rock will then deflect downward toward the collapsed rock. Lateral movement of adjacent rock into this collapsed rubble column is resisted by the active pressure of the rubble.
3. Further extraction of caved ore from below results in increased subsidence of the ground surface above and outside the area of extraction. This initial trough subsidence is similar in shape to the trough subsidence observed over coal mines.
4. Continued extraction of ore will result in breaching of the surface. The initial breach is typically in the form of a circular depression, or chimney, that is roughly centered over the mining area; it may be offset a minor distance because of preferential collapse along geologic discontinuities.
5. The rock adjacent to the chimney either slides along geologic weaknesses, such as joints or faults, or topples into the collapsing upper part of the chimney.
6. The final, or ultimate, angle of draw is located where either the flattest geologic weakness intersects both the ground surface and mining horizon or where the angle of repose of the broken rock mass is reached, whichever is flatter.

It is common practice to report an initial and final angle of draw for block-caving-induced subsidence. The initial angle of draw marks the extent of subsidence effects at the time the surface is breached. The final angle of draw occurs at the limit of measurable subsidence effects after mining ceases. Negative initial angles of draw, that is, those inside the mining area, have been reported; they were probably derived, however, from insufficient field measurements. Such a negative angle of draw refers to the angle between the vertical and a line connecting the side of the chimney with the nearest side of the mining level. Initial angles of draw in crystalline rocks range from $-5°$ to 40° and final angles of draw between 5° and 65°.

IMPACTS OF SUBSIDENCE

Damage from subsidence over underground mines has been a serious problem in urban areas for many years and will become more widespread as the demand for resources, particularly coal, increases. Continuing subsidence has recently posed hazards in parts of Colorado and Wyoming where urban areas have spread onto land underlain by abandoned coal mines. Delayed subsidence has caused extensive damage in urban areas established over coal mines in the Eastern States.

Economic impacts of subsidence in rural areas can also be significant. Fields must be regraded to eliminate ponding of water, and, as in urban areas, roads must be regraded and homes must be repaired. Water wells may become dry when aquifers are disturbed by rock movements. Gas mains are especially vulnerable to subsidence and, if ruptured, can catch fire and explode.

Damage from surface subsidence can be caused by changes in surface slope, differential vertical displacements, and horizontal strains. Planners must know whether these changes are complete or in progress, permanent or temporary; further mining may restore the original slope or close tensile fractures thereby rendering some remedial measures unnecessary or even harmful. The magnitude of structural damage in buildings and manmade structures will depend to a large extent upon details of design and materials; therefore any damage classification must be a general one.

EFFECTS ON SURFACE STRUCTURES

The effects of subsidence on surface structures are controlled to a large extent by the mining method. The long-term, delayed nature of subsidence over room-and-pillar mines can make the task of repair and maintenance of surface facilities intermittent and not predictable. Longwall mining, however, is associated not only with greater recovery of coal but with increased surface stability after mining and, hence, earlier construction or resumption of previous surface activities.

Many accounts exist of severe surface deformations that occurred, often abruptly, long after mining ceased. With only a few exceptions, the notable delayed residual subsidence has taken place in room-and-pillar mined areas rather than in longwall mined regions. At Farmington, W. Va., intermittent episodes of subsidence occurred because 2-m to 3-m high coal pillars were gradually forced into the weak claystone mine floor (Gray and others, 1977). Surface deformation that damaged dozens of homes and buildings began while the mine, which was 85 m below the surface, was active. Subsidence movements continued intermittently for more than 4 years after mining stopped until the mine was injected with coal waste. At the Geneva coal mine in Colorado, compression features such as fractured bulges and small anticlines formed in massive sandstone 274 m above a mined-out area about 1½ years after mining was completed. Measurements showed that the ground surface was shortened locally by as much as 0.92 m (Dunrud, 1976).

Damage to surface structures over room-and-pillar mines has been particularly noteworthy in those Eastern States underlain by extensive coal deposits. Surface developments overlie room-and-pillar coal mines in Pittsburgh, Pa., and Birmingham, Ala., as well as many smaller cities and towns in 17 States (Allen, 1978). For example, at Scranton, Pa., $29 million worth of property, including 2,000 homes, 50 commercial and office buildings, 2 hospitals, several schools, and various utility lines have either been damaged by or are being threatened by subsidence many years after the mines were abandoned. The total cost of surface stabilization of this area by hydraulic mine backfill is estimated to exceed $8 million (Dunrud, 1976). Subsidence occurred dramatically in 1974 in Lafayette, Colo., above a coal mine abandoned for several decades when a pit 4.5 by 5.5 m wide and 7.3 m deep developed in 24 hours in a then unoccupied part of a trailer court (Ivey, 1978).

Engineers in Poland classified structures into four categories, on the basis of importance and sensitivity to surface movement, and designated acceptable values of tilt and normal strain for each category (Hutchings and others, 1978, table 4). A classification of subsidence damage based on structural length changes and horizontal ground strain caused by longwall coal mining was developed by the British National Coal Board (NCB) and is given in table 1. The NCB has also developed a useful nomogram for estimating deformations of surface structures in the United Kingdom (fig. 7).

Figures 2–4 show surface effects produced by longwall mining in mountainous terrain in New Mexico. Because subsidence is an inevitable consequence of high-extraction mining, planners must be able to forecast its impact not only on surface activities but also on subsurface structures such as aquifers.

HYDROLOGIC IMPACTS

Subsidence depressions and associated fractures may disrupt surface and underground water flow, causing diminished well production, aquifer contamination, and decreased property values. In the dry areas that typically overlie western energy resources, the loss of springs and other surface water is especially critical (fig. 6). Proper planning and development of underground mining will lessen these detrimental effects. Few detailed studies exist to adequately document the effects of mining on the hydrologic regimen. Hydrologic changes may be more subtle than other mining effects; for example, subsurface aquifer disruption may occur because of displacement of rocks above mined-out areas without visible surface manifestation. Some shallow wells in Pennsylvania have experienced reduced production. In one instance, a mine face passed within 30 m of a 20-m-deep well which went dry. The well was deepened by 12 m and a good water supply was encountered (Sossong, 1973).

Of great importance in many areas is the potential hazard that surface waters present to mining. In Pennsylvania a longwall panel having 200–215 m of overburden was successfully mined directly below a reservoir (Sossong, 1973). Normal mining conditions were encountered with $63\text{–}190 \times 10^{-5}$

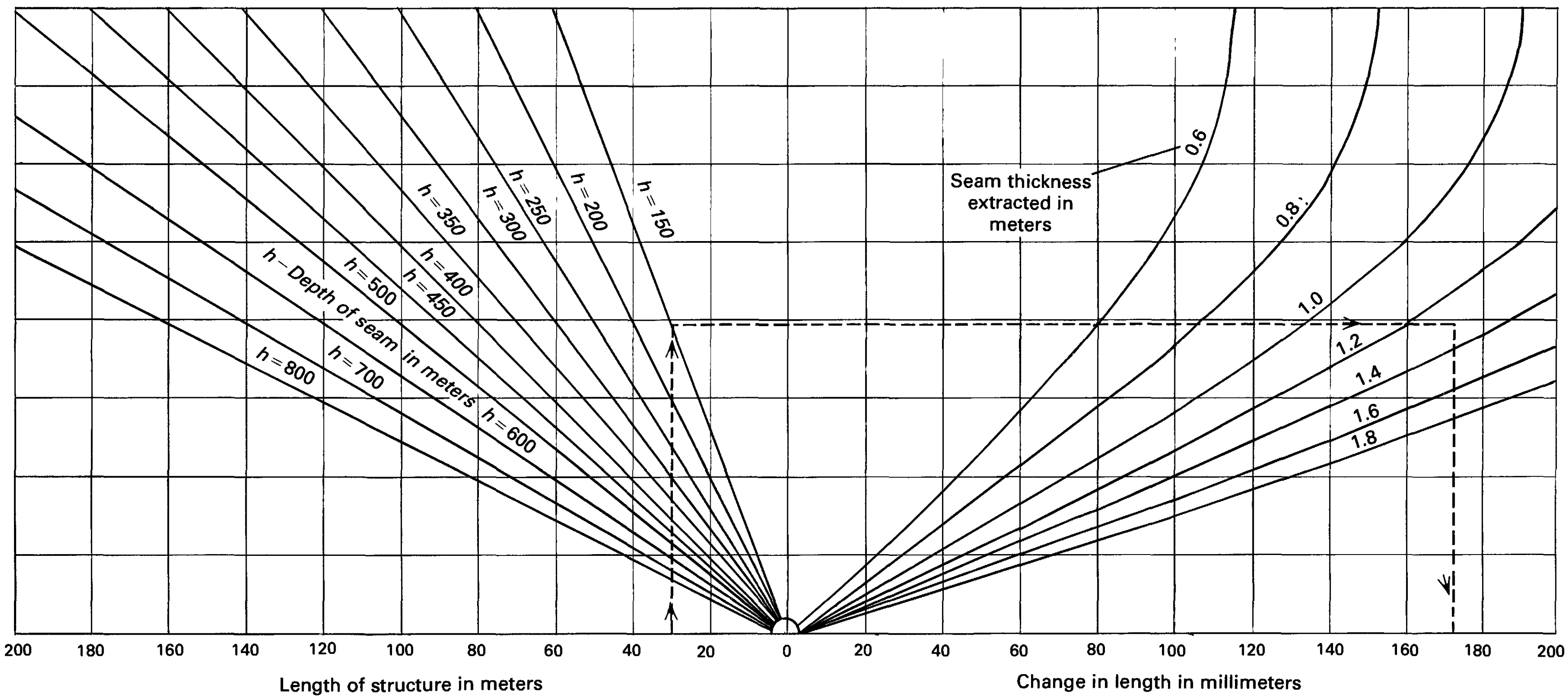


FIGURE 7.—Nomogram for the estimation of change of length of a surface structure for various mining conditions. Example given (dashed line) is for structure with length of 30 m, depth of coal seam of 150 m, and seam thickness of 1.3 m, which results in change of 172 mm in length of structure. (Modified from National Coal Board, 1975.)

TABLE 1.—*Subsidence damage classification for horizontal ground strain and changes in length of manmade structures[1] from longwall mining*

[με = microstrain; 1 ft = 0.305 m]

Class of damage	Change of length of structure	Description of typical damage
Very slight or negligible (example: 15-m long building extended 50 με).	Up to 0.03 m	Hair cracks in plaster. Perhaps isolated slight fracture in the building, not visible on outside.
Slight (example: 33-m long building extended 1,600 με).	0.03–0.06 m	Several slight fractures showing inside the building. Doors and windows stick slightly. Repairs to decoration probably necessary.
Appreciable (example: 27-m long building extended 3,700 με).	0.06–0.12 m	Slight fracture showing on outside of building (or one main fracture). Doors and windows sticking; service pipes may fracture.
Severe (example: 67-m long apartment house compressed 2,300 με).	0.12–0.18 m	Service pipes disrupted. Open fractures requiring rebonding and allowing weather into the structure. Window and door frames distorted; floors sloping noticeably; walls leaning or bulging noticeably. Some loss of bearing in beams. If compressive damage, overlapping of roof joints and lifting of brickwork with open horizontal fractures.
Very severe (example: 55-m long apartment house extended 6,000 με).	More than 0.18 m	As above, but worse, and requiring partial or complete rebuilding. Roof and floor beams lose bearing and need shoring up. Windows broken from distortion. Severe slopes on floors. If compressive damage, severe buckling and bulging of the roof and walls.

[1]Modified from National Coal Board, 1975.

m^3/s (10–30 gal/min) of water developed from the entire 183-m-wide panel. Maximum subsidence induced by an adjacent panel not under the reservoir was 0.65 m or 47 percent of the 1.37-m mining thickness with an average width/depth ratio of 0.85. Numerous shallow workings have taken place under large bodies of water. Many of these workings are essentially dry, although some mined coal seams were less than 30 m below water or saturated alluvium (Orchard, 1973). In the United Kingdom, undersea longwall extraction is permitted with a minimum cover of 105 m and a maximum tensile strain of 0.01.

We have discussed the development of increased rock mass permeability through mining-induced fracturing and the structural and lithologic characteristics that may be important determinants of subsidence. The significance of these factors is increased when mining under bodies of water or under productive aquifers; in such circumstances an adequate monitoring program is essential to warn of a possibly hazardous water inflow.

Guidelines for mining near surface and underground bodies of water have been published by the U.S. Bureau of Mines (Babcock and Hooker, 1977).

In addition to conventional coal mining, the underground coal gasification process and in situ retorting of oil shale can also affect ground-water supplies in complex ways. When ground water reenters a gasified coal bed, the residual reaction products (coal ash, tars, and gases) may undergo leaching, dissolution, and hydrologic transport

(Mead and others, 1978). Subsidence effects such as extensive fracturing or mine roof collapse may cause contaminants to find their way into aquifers that lie above the mined zone. Any meaningful evaluation of this potential hazard must be based on long-term monitoring of typically slow flow rates. As a consequence of the sorptive properties of the rocks associated with coal, the contaminants may move more slowly than the ground water and they may react chemically with each other and with the rocks, potentially lengthy and poorly understood processes.

EFFECTS ON VEGETATION AND ANIMALS

As we have noted previously, collapse over deep mine cavities may induce tension fractures in nearby overlying beds and at the ground surface. Methane gas may leak out of shallow coal seams or mines through these fractures and kill trees and woody plants, leaving only grasses unaffected. Garner (1974) found that certain bacteria in the soil use methane to produce hydrogen sulfide and nitrous oxide. These gases disrupt the root transpiration of woody plants, ultimately killing them. Noxious or toxic gases may also overcome animals grazing on the surface.

Another source of damage to plant life and associated wildlife is the trough-like subsidence areas formed over areas of longwall mining. Unless drainage is maintained, these depressions may fill with water, creating swampy, tree-killing conditions and new types of habitats. Conversely, in some western areas (for example, North Dakota) collapse pits may be the only places wet enough to sustain the growth of cottonwoods and willows. Collapse pits and open fractures may trap animals or interrupt their migration patterns.

Losses of soil water or water in deeper aquifers through fractures created by subsidence could be equally harmful to plant and animal life, especially in semiarid areas.

COAL MINE FIRES

Coal mine fires are an indirect result of coal extraction and contribute to long-term subsidence. According to Dunrud and Osterwald (1980) several fires are burning in long-abandoned underground mines near Sheridan, Wyo. Many of the fires appear to have been started by spontaneous ignition when air and water were introduced through subsidence cracks, pits, and unsealed mine openings. Combustion is supported by the drawing in of oxygen and the exhaustion of smoke, steam, and noxious gases through subsidence cracks and pits. As the coal burns, more cavities are created causing more cracking and collapse which allows greater access for air, thereby accelerating coal burning. This uncontrolled "in situ gasification" process is destroying a valuable resource. In addition, gaseous combustion products locally pollute the air; soil changes are produced, and vegetation is retarded or killed by near-surface fires.

FACTORS GOVERNING SUBSIDENCE

The magnitude, rate of development, and surface expression of the subsidence process are controlled by several factors, most of which are interdependent. These include mining method, depth of extraction, size and configuration of openings, rate of advance or extraction, seam thickness, topography, lithology, structure, hydrology, in situ stresses, and rock strength and deformational properties. We point out the significance of these factors, if only in a cursory fashion, because, taken collectively, they demonstrate the complexity of the subsidence process.

MINING METHOD

Although any underground void will potentially induce subsidence, the manner in which a resource is extracted exerts a large influence on surface deformations. Thus, room-and-pillar, longwall, and in situ extraction techniques will affect the surrounding rock differently; pillar layout, cavity shape, and the volume of material removed govern the timing and configuration of surface expressions. For example, longwall mining generally produces contemporaneous subsidence, whereas room-and-pillar mining may prolong or delay the deformation of walls and roofs for many years. Compulsory recording of mine workings was not introduced in the United Kingdom until 1872, and there are at least 30,000 unrecorded shallow workings, some over 400 years old, where even today gradual deterioration of coal pillars leads to pillar collapse and uneven surface subsidence (Littlejohn, 1979).

MULTIPLE SEAM MINING OF COALBEDS

The sequence in which individual coalbeds of a multiple-seam deposit are mined determines the stress concentrations elsewhere in the mining area, in beds both above and below the bed being mined. According to Dunrud (1976) mining beds from top to bottom generally is safer and more efficient than other procedures, particularly if the final geometry is uniform; uniform geometry prevents stresses from being concentrated in isolated pillars and barriers and transmitted to underlying coalbeds. Several exceptions exist, however, to this generalization. If the stratigraphic interval is 7.5–15.0 m between two coal beds, for example, concurrent, uniform extraction of both beds may be the safest and most efficient mining procedure. Mining from bottom to top might be less hazardous and more productive in those areas where water or methane are present because mined voids in upper beds may store large amounts of these substances, later to become hazardous if tapped by subsidence fractures induced by mining lower beds.

DEPTH OF EXTRACTION

Because rocks are not perfectly elastic and do not deform as homogeneous, intact bodies but as a jointed or layered media, the depth of extraction governs subsidence development, particularly in room-and-pillar mines. The deeper the mining level, the greater the length of time required for rock deformations to reach the surface; thus the earliest surface deformation occurs above the shallowest coal mines. This phenomenon is frequently observed in areas of level topography underlain by dipping coal beds. In the Boulder-Weld County coal field in Colorado, for example, subsidence problems began in the 1860's when room-and-pillar mining of shallow coal started. Subsidence was relatively complete above these shallow mines. Today, many years after mining ceased, the effects of deeper mining continue to create new surface hazards. However, poor information as to the amount of pillar support that remained after mining and the dates of mining make it difficult to accurately estimate the potential for further subsidence.

RATE OF ADVANCE

The British National Coal Board has found that for longwall coal mining the time taken for subsidence to occur depends primarily on the time it takes for a coal face to be worked through the critical area. This time in turn is controlled by the depth and the angle of draw (because these factors determine the critical area) as well as by the rate of advance. Typical longwall advance rates are 0.3–1.2 m per day, and "high-speed" longwall face advance in coal is about 1.5 m per day (Whetton and King, 1961; National Coal Board, 1952, 1963). The maximum longwall face advance reported was approximately 5.5 m per day in a bedded quartzite in South Africa (Cook, 1967). Several studies indicate that subsidence is transmitted rapidly from the workings to the surface. For instance, when mining ceases for holiday periods subsidence stops almost instantaneously; subsidence continues as soon as mining resumes. A smooth, consistent rate of advance promotes consistent, predictable surface settlement.

THICKNESS OF SEAM OR DEPOSIT

In some mining areas the relationship of seam thickness and overburden depth to vertical displacement of the ground surface is well established. A compilation of more than 150 measurements made above longwall mines in the United Kingdom showed that a maximum depth of the subsidence basin of 0.9 times the seam thickness is reached when the span of the void (the area of complete extraction) exceeds 1.4 times the depth of the deposit (National Coal Board, 1975). The depth of the subsidence basin is less for thinner seams or for shorter void spans. For example, the maximum subsidence for a void span of 0.7 times the mining depth is 0.45 times the seam thickness. These relations were derived from empirical observations gathered by the NCB, and although they are voluminous and have been verified repeatedly, their applicability to other geologic environments and different mining methods has not been demonstrated.

LITHOLOGY AND STRUCTURE

The strength and deformational properties of rock masses are largely controlled by rock type and structural features such as joints, faults, and bedding and foliation planes. These geologic conditions are responsible for significant variations in subsidence development and particularly affect the surface extent and timing of subsidence. Knowledge of geologic conditions in advance of mining can aid in subsidence prediction and in the development of a monitoring plan. For example, the angle of draw changes with the dip angle, and this effect can be readily estimated (National Coal Board, 1975, p. 16–18). In addition, monument line layout can be shifted down dip according to the dip magnitude.

A gradual lowering of the surface is associated with weak overburden rocks whereas violent, often delayed, collapse is more typical of strong overburden rocks. The presence of through-going faults or dikes may limit the lateral growth of a surface depression, particularly in crystalline rocks (Lee, 1966; Crane, 1931). Such discontinuities apparently act as barriers because of lateral contrasts of rock properties.

Several examples of the role of lithology and structure may be cited. In the county of Lanark (Lanarkshire) in Scotland, room-and-pillar mining had ceased 118 years before sandstone beds collapsed abruptly over workings that were only 16 m deep. At the surface, structural damage to apartment buildings was so severe that the tenants were evacuated and several blocks of buildings were demolished (Thorburn and Reid, 1978). Orchard and Allen (1965) noted that 9 percent of total potential subsidence occurred during a 6-year period after a 166-m-deep longwall face advance stopped at Peterlee in the United Kingdom. A thick dolomitic limestone bed apparently retarded complete subsidence.

According to Kent (1974) roof falls in the Pittsburgh, Pa., room-and-pillar coal mines show two distinct patterns. In some mine areas where shale directly overlies the coal, nearly all roof falls occur along northeast-trending mine passageways parallel to the butt cleat (joint) direction in the coal. In other mine areas where shale overlies the coal but where thick sandstone lenses overlie nearby coal, severe and frequent roof falls may occur in the shale roof with no consistent orientation relative to the joints or passageways. Regional jointing appears to control the first type of roof fall, and sandstone channel deposits control the second type. The joint spacing is governed by the rock type: joints in the coal are well developed and closely spaced; joints in shale are less well developed and have a spacing of less than 0.3 m; and joints in sandstone are typically more than 0.3 m apart and are well developed. Through careful mine layout it may be possible to control roof falls and to more accurately predict the nature and timing of subsidence.

At a longwall mine in New Mexico, surface subsidence fractures indicated that the overburden was breaking primarily along the major east-west joint system and to a lesser degree along the secondary north-south joint set (Gentry and Abel, 1978). These tension fractures started to close when the mining face was only 20 m past the fracture.

In fractured crystalline rocks, the final angle of draw is typically controlled by faults and joints and is usually located where the flattest geologic weakness intersects the mining level and the ground surface.

IN SITU STRESSES AND OTHER GEOTECHNICAL FACTORS

High horizontal stresses, which are common in many shallow crustal rocks, act to inhibit the development of a surface depression by maintaining a strong ground arch in the immediate mine roof. Arch height and stability, however, are very sensitive to the ratio of vertical to horizontal in situ stresses. A highly stressed arch may fail violently as a result of progressive thinning as happened at the Urad mine in Colorado (Kendrick, 1973). At that mine, a molybdenum ore body in country rock of rhyolite and coarse-grained granite was mined by block caving. Horizontal stresses near the mine average 10.2 megapascals (MPa) (1,478 lb/in^2) which is 4.6 times greater than the horizontal stress induced by gravity loading (Hooker and others, 1972). These "anomalous" stresses may have caused the extreme difficulty in breaking down the arch and initiating caving even though very high powder factors were used. An unsupported stable arch 100 by 150 m existed approximately 100 m below the surface. The caving occurred spontaneously and violently; an airblast from rock bursting penetrated 60–75 m of broken muck and was still strong enough to knock people down. The entire back came down breaking through to the surface and forming a "glory hole" 150 m in diameter and 30–100 m deep. Similar violent deformations have been reported in other brittle, highly stressed rocks including sandstone, quartzite, and coal.

In many room-and-pillar mines little or no subsidence is anticipated, and surface use is planned accordingly. Most pillars deteriorate and deform with time, however, and depending upon bulking, deformation may extend to the surface. Lack of knowledge of the physical properties and rock stresses can lead to poor mining practices which in turn create stress problems in other parts of a mine, bringing about further uneven extraction procedures. In some mining regions of the United States, particularly those in the West (Dunrud, 1976), concentrations of earth stresses cause rock bursting and coal bumps which induce roof falls and pillar failures. These rock failures have forced changes in mining plans or abandonment of mine areas before mining is completed in a uniform manner, causing greater subsidence damage because of uneven mine geometry. Knowledge of pillar rock strength and creep properties is most critical in areas of high potential impact. In Allegheny Plateau coal mines, for example, high in situ horizontal stresses and the orientation of the maximum horizontal stress are related to roof instability and floor heave, making mine layout a major concern (Aggson, 1978).

TOPOGRAPHY

Several investigators have noted the complicating effects of topographic variations on subsidence development. In contrast to a level ground surface where the stresses produced by overburden on subsurface rocks are uniform, regions with irregular topographic relief will have irregular stress distributions that vary with the height of the column of rock above a particular underground point. Measurements made above three panels at the York Canyon mine in New Mexico, a longwall operation, show that maximum subsidence occurs under ridgetops and minimum subsidence under draws or topographic lows (Gentry and Abel, 1978). Subsidence decreased from 25 to 30 percent of the maximum under a draw; subsidence was only 1.6 m or 50 percent of the seam thickness mined. Peak subsidence of 2.0 m occurred below a ridgetop. At the same mine, greater horizontal ground movement resulted when the direction of mining was in the downslope direction than when mining was in the upslope direction. This behavior disagrees with the calculations of Kapp (1973), who showed by geometrical considerations that horizontal strain would be greater when the ground surface rose in the direction of mining and less when the ground surface fell in the direction of mining. More field measurements should help resolve this discrepancy.

The natural stability of steep slopes may be affected by subsidence-induced deformations, triggering landslides. The definition of stress distributions related to topography is necessary for accurate slope-stability assessment prior to mining.

TIME

The time factor in mining-induced subsidence has been investigated in the past, mainly as applied to coal mining. It has long been known that the deeper the seam, the longer the duration of surface movement, although the reasons are not well understood.

In longwall mining, the subsidence of a point at the surface theoretically begins when a longwall face enters the "critical area" (fig. 1) and ceases when the face leaves the critical area. The surface point actually continues to subside (residual subsidence) for a variable period, perhaps months, although over 90 percent of the total subsidence occurs while the face is within the critical area. Most investigators point to rate of advance and depth of mining as the factors governing the rate and timing of surface subsidence. As we have stated earlier with respect to the areal limits of subsidence, geological/geomechanical properties influence strain rates and modes of deformation. Orchard and Allen (1974) contend that when the face advances out of the "critical area," further ground movements occur because of complex time-dependent stress redistribution processes in the overlying rocks. The influence of depth of mining and face position on time-dependent subsidence becomes more significant in room-and-pillar mining primarily because of the difficulty of predicting deterioration of pillars.

SUBSIDENCE ANALYSIS

The objectives of subsidence analysis are to predict the occurrence, timing, and magnitude of vertical and horizontal components of surface deformation induced by underground resource extraction. The analysis should consider the likelihood of and the consequence of the impacts discussed in the previous section. Depending on present and future land use plans, how much subsidence is tolerable and, in light of resource conservation, how much of the resource should be extracted? Although it is desirable to recover the total deposit, this can rarely be done; recent United States underground coal mining practice extracted only approximately 57 percent of the coal (Lowrie, 1963).

The person concerned with assessing subsidence potential should determine whether subsidence has occurred previously in the area and its severity. Is future subsidence from old mining a possibility? We have mentioned some of the many factors that control subsidence, and each of them should be evaluated in a comprehensive analysis in order to determine the likelihood of significant harmful environmental impact.

DATA REQUIREMENTS

The following discussion is intended as an overview of the broad data needs for subsidence analysis rather than as an attempt to specify a complete suite of geotechnical properties. Considerable latitude is necessary to allow for site-specific needs. Knowledge of premining conditions is needed for prediction of disturbances that may be caused by mining.

GEOLOGIC DATA

Geologic maps, sections, and core logs are necessary to define topography, depth of mining, rock types and thicknesses, jointing, faults, and variations in the attitudes of beds, including folds. A drilling program should include at least one hole drilled to below the coal seam in the vicinity of the surface monuments and the panel. This drilling should be done for the first panel of a new mine and for one panel in an operating mine. The hole should be logged from the surface. Rotary drilling is satisfactory if cuttings are collected and identified for every 1.5 m of the drill run and if the hole is geophysically logged to produce an electrical resistivity (lithologic) log of the rock overlying the panel. The location of any methane gas in coal beds should be defined as well as the rank of the coal and its composition, including sulfur content. Knowledge of premining seismicity of an area is needed to determine the likelihood of complications such as severe bumps and roof falls.

HYDROLOGIC DATA

Studies should be done to define premining surface-water and ground-water volumes, flow rates, and quality. Aquifers and aquicludes should be identified. It is very important to identify all surface springs, streams, or bodies of water. Well data for the region should be systematically analyzed throughout the mining period. The sorptive properties of the rocks may be closely related to subsidence-induced ground-water changes that were discussed previously.

GEOTECHNICAL DATA

Two categories of rock-behavior data are needed for subsidence analysis. One category deals with the behavior of the underground mine and the surrounding rock and water environment. The other category deals with the behavior of the ground surface above the mine.

The first category includes rock strengths, cohesion, angle of internal friction, and elastic properties including, for example, Young's modulus and Poisson's ratio. Creep behavior data for the overburden materials are needed to forecast delayed subsidence. Knowledge of in situ stresses, especially the magnitude and direction of the horizontal stresses, is needed for planning a safe and efficient mining operation and for applying realistic limits to mine deformation and subsidence calculations. The second category includes horizontal and vertical strains and displacements and their magnitudes, locations, and duration.

MINING PLANS

A proposed mining plan is necessary for early input to the subsidence analysis. The plan should be based not only on geologic, hydrologic, and geotechnical data but also on mining methods, extraction location and sequence, location of panels, barrier pillars, and, in the case of multiple-seam deposits, the seams to be mined and the proposed sequence. The mining plan should anticipate the magnitude, location, and timing of surface disturbance. If the plan is revised, initial subsidence predictions may be altered.

ANALYTICAL TECHNIQUES FOR SUBSIDENCE PREDICTION

BACKGROUND AND STATE-OF-THE-ART

The accuracy of subsidence prediction varies from country to country, and is controlled mainly by knowledge of geologic and topographic conditions and the length of mining experience. In the United Kingdom, for example, data has been collected over a long period of time from more than 150 coal mines in similar geologic environments. The results of these observations have been presented as empirical formulas and procedures for prediction of the nature, areal extent, and severity of subsidence and related events. Subsidence-induced surface deformations can be predicted and described but only under conditions similar to those of the original observation. Particularly in Europe, new methods of extraction such as harmonic mining and stepped-face layout have been developed to minimize surface deformations and reduce damage to structures. It has been possible through integrated systems of prediction, mining techniques, and monitoring procedures to control the development of subsidence basins so that shallow mining may proceed under buildings and even towns.

In the United States, methods of subsidence control and estimation are less well developed. Subsidence theory developed in Europe has not been used extensively in the United States because room-and-pillar mining, rather than the longwall panel system, is the more common mining method in the United States. Although longwall mining is increasing in the United States, empirical methods such as that of the NCB have not found widespread application in U. S. mining because of dissimilar and varied geologic conditions.

We will briefly discuss the current methods of subsidence prediction and some of their limitations. Subsidence prediction techniques fall into two broad groups: empirical methods and mathematical models. Researchers have cited field and laboratory studies to support both approaches.

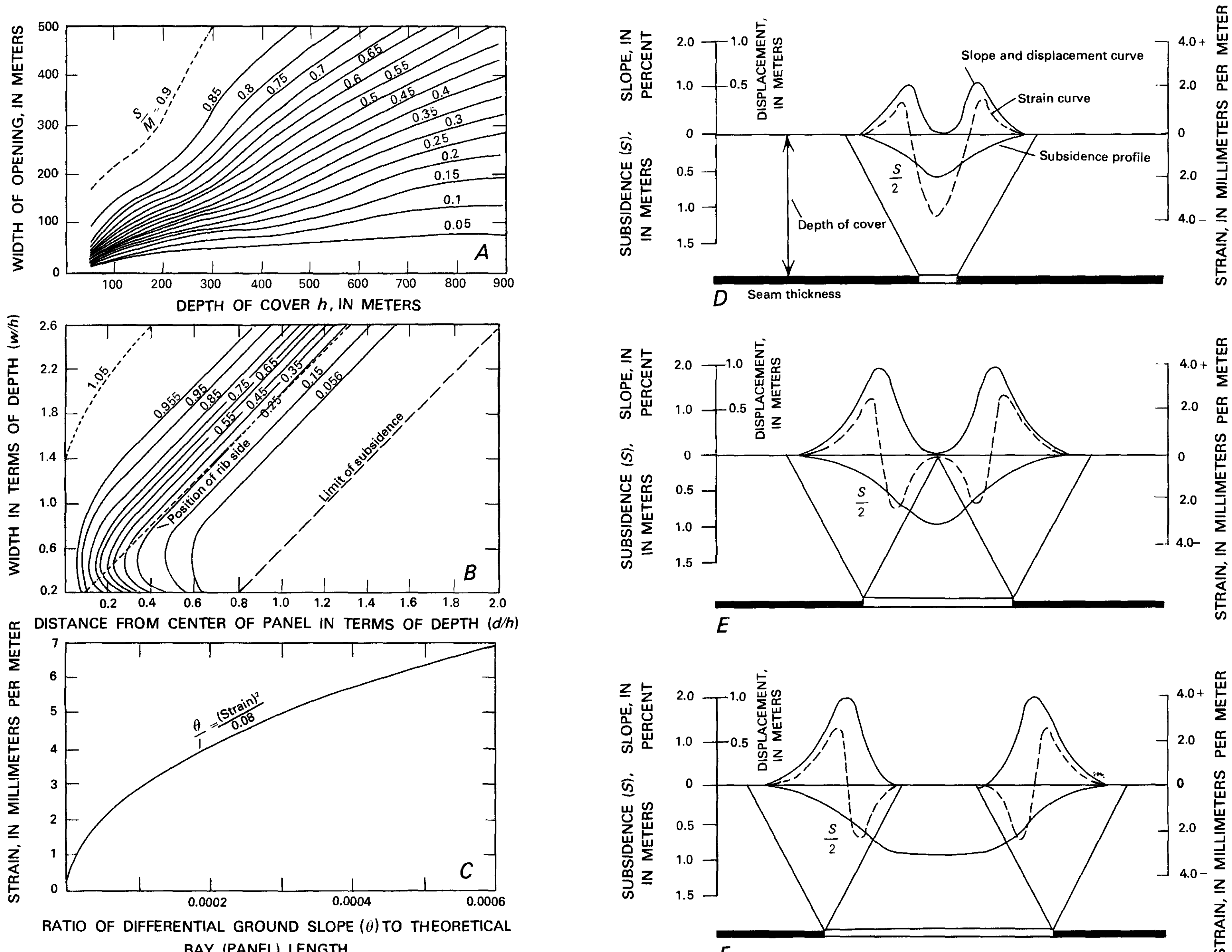
BRITISH NATIONAL COAL BOARD METHOD

This empirical subsidence calculation method was developed in the United Kingdom for the prediction of the vertical component of surface displacement or subsidence (*S*) and the horizontal component of surface strain (ϵ) associated with trough-like subsidence caused by the longwall method of coal extraction (National Coal Board, 1975). This relatively simple method is based on the subsidence data obtained from mining seams that dipped less than 25°, were 0.6–5.5 m thick (*m*), and ranged in depth (*h*) from 30 to 792 m. The face or panel width (*w*) ranged from 30 to 457 m and the panel width to depth ratio (*w*/*h*) ranged from 0.05 to 4.0. These observations were made where the panels contained no zones of special support, and the panel width was averaged if the sides were nonparallel. The NCB system provides for correction of horizontal strain estimates where the ground surface is sloping and where the coal seam is dipping.

Subsidence analysis using the NCB method proceeds as follows. The ratio of *S* to *m* is derived from the planned width and depth of the workings (fig. 8*A*). Subsidence at various points on the predicted subsidence profile is found as a proportion of *S* based on the ratio of *w* to *h* (fig. 8*B*). These points are then related to the position of the rib side for a given value of *w*/*h* and the predicted subsidence profile for the subcritical width of extraction is plotted (fig.8*D*). From the subsidence profile the values of subsidence for points at recommended intervals of *h*/20 are tabulated. Values of ground slope, differential ground slope (ϕ), and the ratio of *S* to the distance between stations are calculated. Figure 8*C* shows the empirical relationship between panel length, ground slope, and horizontal strain in a curve where the strain (ϵ) is read directly. The subsidence profiles and associated slopes and strains for critical and supercritical widths of extraction are plotted (figs. 8*E* and 8*F*). NCB experience shows a range in the angle of draw from 25° to 35°. Probably because of geologic and topographic factors, the angle of draw varies much more when worldwide measurements in a variety of host materials are considered.

On the basis of the NCB curves, the greatest possible subsidence, S_{max}, is approximately 90 percent of the seam thickness and occurs at values of *w*/*h* greater than about 1.2. At values of *w*/*h* less than 0.2, the maximum subsidence is less than 10 percent of the seam thickness extracted. The method may be used to estimate the effect on subsidence of certain barrier pillar spacings and backfilling, both of which reduce subsidence. Further, the NCB method employs other empirical curves relating to surface horizontal strains to enable the computation of maximum tension, maximum compression, the extent of the tensile and compressive areas, and a complete strain profile. The NCB system is the most widely used prediction scheme, particularly to provide a general approximation of subsidence effects; it may be supplemented by other methods suited to local conditions. O'Rourke and Turner (1979) reported on their experience in applying the NCB method to longwall coal mining in Illinois. They found significant differences between longwall subsidence patterns observed in Illinois and those typical in the United Kingdom for similar conditions of panel width, depth, and excavated thickness of coal. Specifically, at the Old Ben No. 24 mine at Benton, Ill., they found the following conditions:

1. The subsidence profile was relatively narrow, as demonstrated by angles of draw that are approximately 10° less than those in the United Kingdom.
2. The maximum curvature of the subsidence profile was four times greater than that predicted by the NCB system.
3. Maximum horizontal surface strains of nearly


WIDTH OF OPENING, IN METERS
DEPTH OF COVER h, IN METERS
S/M = 0.9
A
WIDTH IN TERMS OF DEPTH (w/h)
DISTANCE FROM CENTER OF PANEL IN TERMS OF DEPTH (d/h)
Position of rib side
Limit of subsidence
B
STRAIN, IN MILLIMETERS PER METER
RATIO OF DIFFERENTIAL GROUND SLOPE (θ) TO THEORETICAL BAY (PANEL) LENGTH
θ/l = (Strain)²/0.08
C
SUBSIDENCE (S), IN METERS
SLOPE, IN PERCENT
DISPLACEMENT, IN METERS
Slope and displacement curve
Strain curve
Subsidence profile
Depth of cover
Seam thickness
S/2
D
E
F

2 percent, which are four times larger than those in the United Kingdom, were measured.

Although a few other measurements indicate similar gross trends (Gentry and Abel, 1978), insufficient observations have been made at other U.S. longwall mines to confirm or deny a general trend.

The NCB method is not relevant to mining in crystalline rocks or to in situ extraction techniques.

OTHER EMPIRICAL METHODS

Another empirical prediction method is based on the so-called "stochastic" or random media theory discussed by Voight and Pariseau (1970). The method is seriously restricted because it does not incorporate knowledge of material properties prior to mining but rather transfers field measurements from known areas to areas of new mining via an empirical procedure. This approach may result in the uncertainty of results, and an exceedingly large number of studies would be required to demonstrate the general validity of the method. The same difficulty applies to the NCB system. Statistical methods that treat a broad collection of data concerning geologic controls on subsidence are more broadly applicable. We have found, for example, that as the percentage of shale in the rock mass decreases and the amount of sandstone increases, the angle of draw and the area of potential subsidence decreases (Abel and Lee, 1980).

MATHEMATICAL TECHNIQUES

The mathematical approaches to subsidence prediction attempt to define the conditions that lead to subsidence and, hence, to develop general predictive models. In these approaches the rock mass surrounding the mined opening is assumed to be an ideal material that deforms elastically. Wide applicability and improved understanding are the main advantages claimed for these approaches (Voight and Pariseau, 1970). Included in this group are elastic, viscoelastic, and plastic idealizations. Finite-element analysis is widely used to manipulate elastic or viscoelastic continuum excavation models. As more realistic model properties and boundary conditions are defined, predictions should become more accurate. Voight and Pariseau (1970) were not able to reconcile field observations of surface displacements over British coal mines to subsidence profiles calculated on tne basis of isotropic theory. They did find, however, that transversely isotropic theory was in good agreement with field data.

In general, subsidence-prediction methods are most seriously deficient where subsidence deformations are controlled by structural discontinuities such as faults, joints, and folds, or by rock type.

SELECTION OF AN ANALYTICAL TECHNIQUE

The NCB method is based on the largest systematic analysis of subsidence data available. It is accurate enough to predict trough-like subsidence from longwall mining where the overburden rock is largely shale, siltstone, or marlstone, where it does not contain thick, strong beds of sandstone or limestone, and where the topography is subdued. Thus, the NCB method is applicable to many environmental impact analyses of underground mining.

Where coal is extracted by room-and-pillar methods, subsidence prediction will be very difficult, particularly where there is irregular room development, nonuniform barrier pillars, and poor definition of panels. Under such circumstances, frequently associated with old mining areas, it is usually impossible to predict the time, magnitude, or occurrence of subsidence.

In modern room-and-pillar coal mining, attempts are usually made to control subsidence by leaving a larger percentage of the coal in place, often 40 percent or more. In Illinois (Hunt, 1979), the magnitude, shape, and position of the subsidence profile is delineated on the basis of case-history comparisons in which extraction ratio, depth, panel width, and mining thickness are the principal factors. Where bedrock overburden is less than 50 m thick, smaller sinkhole features pre-

FIGURE 8.—British National Coal Board method of estimating subsidence. *A*, Relation between maximum subsidence, width, and depth. *B*, Lines of equal subsidence for various width/depth ratios. *C*, Strain prediction graph. *D*, Subsidence profiles and associated slopes and horizontal strains for subcritical width of extraction. *E*, Subsidence profiles and associated slopes and strains for critical width of extraction. *F*, Subsidence profiles and associated slopes and strains for supercritical width of extraction. (Modified from National Coal Board, 1975.)

dominate; if it is more than 50 m thick, subsidence is trough-like. Sinkhole development is also related to the hydraulic connection between the surface and the mined-out area. Caving of the roofs of shallow mines allows seepage of surface waters into the mine, decreasing roof and wall stability and promoting caving to the surface. The graphs in figure 9 show the relationship between percent subsidence and panel width for several extraction ratios in Illinois. These examples would be typical trough-like subsidence. Hunt (1979) has shown that where extraction is greater than 80 percent, the NCB method accurately predicts subsidence. Figure 10 indicates that surface tilting is directly proportional to subsidence and increases with the amount of extraction. The findings of Hunt contrast with those of O'Rourke and Turner. Again, more data from longwall coal mines in the United States is needed in order to assess applicability of the NCB method.

Pennsylvania's Bituminous Mine Subsidence and Land Conservation Act of 1966 provides for protection of certain structures including public buildings and residences. Protection is defined in terms of support provided by coal left in the ground. From April 1966 to January 1969 only 1 percent of the 5,500 protected structures were damaged by subsidence, and in 1977 only six cases of damage to the protected structures were reported (Bise, 1980). The formula by which these structures are

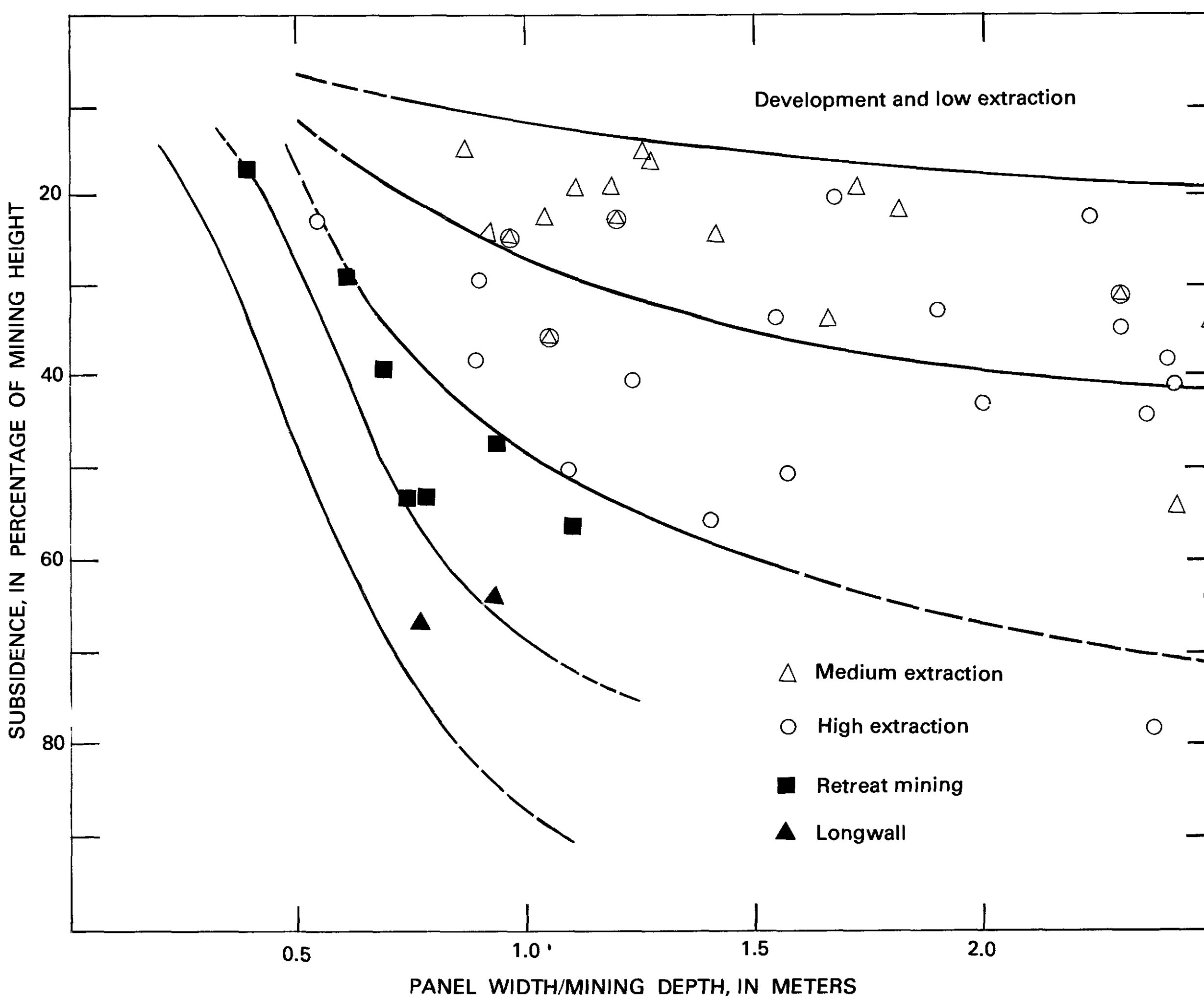


FIGURE 9.—General relation between percent subsidence and panel width to mining depth ratio. Curves indicate approximate range of control of mining method on subsidence. (From Hunt, 1979.)

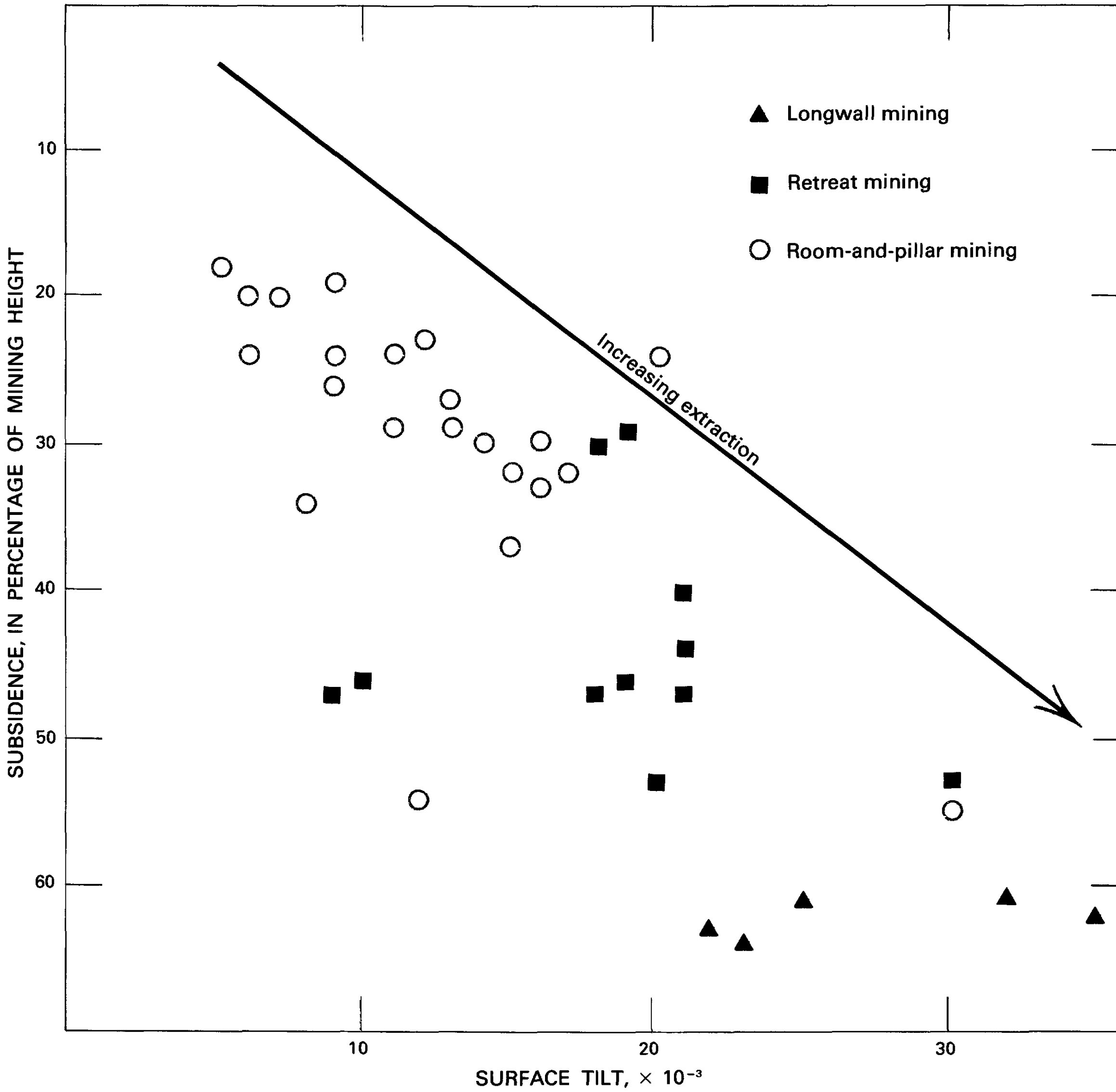


FIGURE 10.—Relation between subsidence and surface tilt (from Hunt, 1979).

protected was derived from many subsidence incidents over the Pittsburgh seam. We quote Bise (1980, p.1):

Where a structure is located on terrain that is level or slopes less than 5%, the lateral distance (LD) of the support area from each side of the structure is equal to the tangent of 15 degrees (0.27), multiplied by the depth of cover (D), plus a safety factor of 4.6 m, or LD=(0.27)×(D)+4.6m. To find the total length or width of the support area, double the result found for LD and add the length or width of the structure.

This guideline deals only with defining the support area. Within this area, 50 percent of the coal must be left in place in uniformly distributed pillars which can be no smaller in plan than 6.1 by 9.1 m. In addition, no mining may be done where the overburden thickness is less than 30.5 m under a protected structure. Barrier pillars cannot be extracted where the pillar width is less than the cover. As Bise (1980) points out, however, this method fails to consider the effect of mining methods on subsidence and does not allow for recovery above 50 percent.

Studies done in Europe have resulted in general schemes for controlling subsidence damage in partial extraction mining. Orchard (1964) found that if both horizontal and pillar dimensions are equal to at least 10 percent of the mining depth, and if the pillars are uniformly spaced, subsidence will be negligible while allowing 50-percent recovery of the coal. Wardell (1969) presented data to show that there is a consistent relationship between the percent of subsidence and depth, extraction ratio, seam thickness, and pillar width. The findings of these researchers are in general agreement.

At the York Canyon mine near Raton, N. Mex., Gentry and Abel (1978) compared vertical and horizontal strains resulting from longwall mining with values calculated from the NCB method. Much of the overburden there is weak shale, grossly similar to the British coal fields. Maximum compressive and tensile horizontal strains determined at the mine were more than twice the predicted values. The NCB method predicted 25 percent less vertical tensile strain than was actually measured. The York Canyon mine subsidence profile was similar in shape, however, to the NCB model. Presence of a strong 12-m-thick sandstone, strong jointing, and mountainous terrain may account for some of the observed differences.

SUBSIDENCE MODELS FOR IN SITU ENERGY EXTRACTION

The subsurface voids remaining after in situ processes such as coal gasification and oil shale retorting will not closely resemble the voids created by coal mining. The change in load-supporting ability of the surrounding rock mass in such "partial extraction" processes may be difficult to determine, and until field measurements are available, the prediction of subsidence effects for in situ extraction will be based mainly on mathematical analyses such as computer solutions of finite element codes. Examples of current practice in this area are given by Langland and Fletcher (1976) and Advani and Lin (1977).

The mathematical solutions have several limitations. Among them are:

1. The solutions are valid only for geometrically simple openings.
2. The material is assumed to be isotropic, homogeneous, and elastic.
3. The effects of water and geologic strucure are not considered.

Mead and others (1978) discussed prediction and measurement of subsidence produced by in situ coal gasification. It is important that early monitoring be conducted to measure ground deformations produced by these types of mining operations so that their subsidence characteristics can be verified.

MONITORING METHODS

Geotechnical measurements are made in order to establish the validity of model predictions and to safeguard surface structures. The monitoring methods and types of instruments used must be carefully selected so that their data output is compatible with the data needed for subsidence calculations.

SURFACE INSTRUMENTATION

Our intent is to briefly describe current monitoring practice, rather than to present a specific set of guidelines. A premining survey should be made to identify geologic conditions or surface facilities that would warrant changes in a conventional monitoring scheme.

The most widely used and important type of subsidence-monitoring measurement is surface leveling. Monuments are installed before mining begins, and readings are taken until stability is reached after mining ceases.

A typical subsidence monitoring layout for a 762-m by 168-m longwall panel below mountainous terrain is shown in figure 11. In this example the seam thickness is approximately 3 m and the average overburden thickness is 107 m. One row of monuments was placed along the centerline of the planned panel and another row perpendicular to the centerline. Two diagonal lines were established radiating from the centerline at 45°. These lines were added to define subsidence effects above the corners of the longwall panel.

For monitoring most coal mine panels in flat terrain, three lines of surface monuments are adequate, two perpendicular to the long axis of the mining panel and one directly above the centerline of the panel. The cross-panel lines should extend 0.9 times the depth of the seam outside the panel on both sides and completely across the panel. The centerline monuments should also extend 0.9 times the depth of the seam outside the starting position of the panel and the same distance past the planned end of the panel. If the panel is terminated because of poor roof conditions or faulting, for example, the centerline monuments can be shortened accordingly. These recommendations

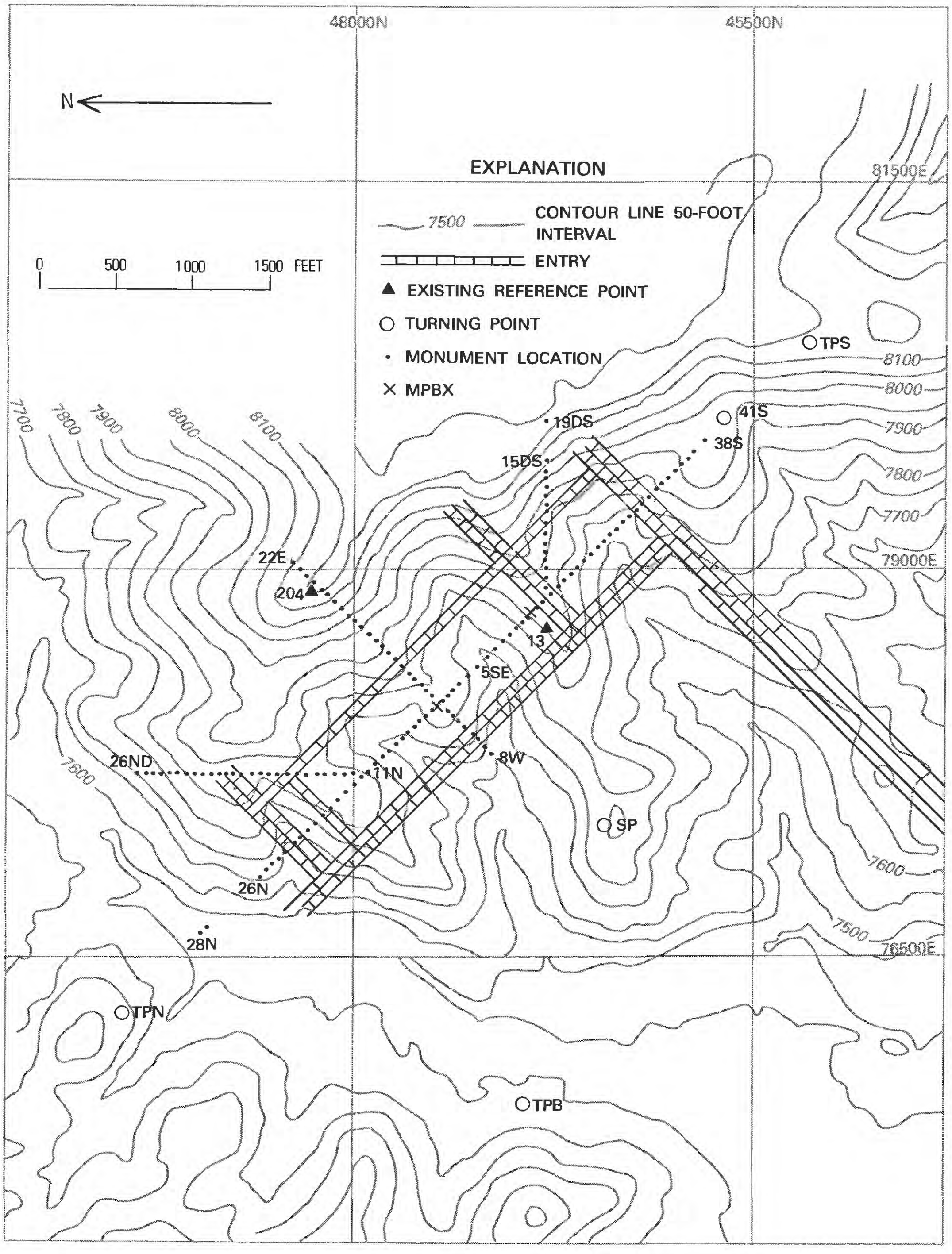


Figure 11.—Location of surface monuments, turning points, and reference points for part of the York Canyon mine, Raton, New Mexico (from Gentry and Abel, 1978).

are in general agreement with current practice in the United States (Wade and Conroy, 1980; Gentry and Abel, 1978).

SPACING OF MONUMENTS

The spacing of monuments directly influences measurement precision. Monuments that are spaced too closely may result in measurement of local anomalous ground movements caused, for example, by the displacement of individual joint blocks in which the monuments are anchored. Widely spaced monuments may reduce costs but could fail to adequately define the subsidence profile, particularly in mountainous terrain. The NCB (1975) suggests a spacing of 0.05 h (where h is equal to the depth of the overburden) or one-twentieth of the depth of mining. Panek (1970) recommended a monument spacing of 0.05–0.1 h.

The presence of critical surface structures may also dictate the location and spacing of monitoring positions. For most situations the monument spacing should probably not exceed 0.1–0.2 h. This relatively wide spacing allows determination of vertical ground movements and permits a rough check of the horizontal strain measurements obtained by extrapolation from the relatively smooth vertical subsidence profile. Spacing monuments more closely in order to better define horizontal deformations is probably not justified. According to Orchard and Allen (1965, p. 622), for example, "It is a fact that although levels taken before and after subsidence will usually produce a smooth subsidence profile, the strain diagram obtained from horizontal measuring between survey stations is often erratic." They attribute this situation to "irregularities" in the subsoil. At the York Canyon mine (Gentry and Abel, 1978), horizontal movement measurements were less reliable than vertical measurements, apparently because of shifting and tilting of the joint blocks on which the concrete monuments were anchored; movement of the joint blocks affected horizontal measurements more than vertical measurements. Additional details of generally accepted monument layout and construction are given by Wade and Conroy (1980) and Gentry and Abel (1978).

Monuments should be surveyed at least twice before starting panel extraction, and any discrepancies should be resolved by an additional survey. The frequency of readings is determined by the rate of movement of the face, seam thickness extracted, and monument spacing. The centerline monuments should be surveyed when mining of the panel has advanced 1.9 times the seam depth. Each row of crossline monuments should be surveyed when mining has progressed 1.0 times the depth past the crossline. All monuments should be resurveyed after panel completion and yearly until no further changes in monument positions are detected. Survey procedures and the need for long-term monitoring are addressed by Collins (1978). Gentry and Abel (1978) give detailed specifications for monument construction and monitoring equipment.

SUBSIDENCE CONTROL AND REDUCTION

An obvious conflict exists between minimizing subsidence and maximizing resource recovery. In some areas more surface settlement can be tolerated than in others. In urban areas, for example, less than 50 percent of the resource may be recovered in order to prevent subsidence. In many European coal fields where overburden thicknesses range from 60 to 900 m, deformation arches are stable within the overlying rocks, and subsidence does not reach the surface if the widths of mined-out areas are held from one-fourth to one-half of the overburden thickness (Zwartendyk, 1971). Much coal must be left in the ground in order to obtain this high degree of surface stability.

In the United Kingdom, a "panel and pillar" method has been used with success when mining beneath towns, factories, railroads, and utility lines. The panels were mined without backfilling, and little subsidence damage occurred. Subsidence ratios were less than 20 percent of the coal thickness above mined panels whose widths were about one-third the average overburden depth.

In sedimentary iron ore deposits of the Lorraine area of France, support pillars were left in a checkerboard pattern; this method was abandoned, however, because of subsidence problems associated with severe pillar bursts. The geometry of the mining plan was changed to create sturdy barrier pillars separating panels whose widths were 0.42 times the overburden depth. These pillars sustained the compression arch within the overburden, minimizing subsidence and allowing safe recovery of 60 percent of the total reserves.

Another mining technique developed in The Netherlands coal mines is known as harmonic mining. This technique involves mining in such a way that the final vertical and horizontal surface strains produced by mining in one area are canceled by strains produced by mining in another area. For example, mine extraction panels might be offset and mined concurrently so as to produce negligible final horizontal strain in the overburden or at the surface perpendicular to the mining panels. Several drawbacks exist, however, to this approach. Damaging transient strains and compression arches can be produced at the surface. The method might also cause high stress concentrations in the rock between coalbeds at the mine boundaries which could cause rock bursts and serious roof falls. Further, mining schedules must be very precise under this system to maintain the required geometry. Other factors that would lessen the effectiveness of this method are uneven topography and steeply dipping coal beds.

Backfilling of mined-out areas in room-and-pillar mines has been effective in preventing subsidence. This method is used primarily in mines below urban areas where surface stability is critical. Backfilling materials may be placed manually, hydraulically, or pneumatically and may consist of sand or larger grained mine waste. Hydraulic backfilling is generally most efficient, and maximum subsidence is frequently less than 10 percent of the seam thickness extracted. The example given previously of backfilling with coal waste at Farmington, W. Va., illustrates the effectiveness of this method.

DESIGN PRECAUTIONS

Buildings and other structures can be designed to resist or tolerate subsidence deformations. Very flexible structures remain intact (and conformable) despite subsidence-caused distortion and, alternately, very rigid foundations have been developed that can be releveled by the use of jacks as subsidence progresses. The design of support mechanisms for facilities built over old mine workings involves a careful appraisal of subsurface conditions. Support by fill, caissons, or piers using boreholes may be feasible.

CONCLUSIONS

Although the damaging surface effects of underground mining have been widely documented, little research has been carried out to determine accurately the effect of subsidence on surface structures under specific geologic conditions in the United States. Further, the potentially broad disruptive effects of mining on water supplies have been studied at only a few domestic locations.

Some of the factors that influence the development of ground movement cannot be quantified precisely. The differences in rock-mass behavior caused by site conditions alone would indicate that subsidence prediction and engineering cannot be treated in purely mathematical terms. Although the NCB has developed quantitative, practical assessments of mining effects in the United Kingdom, there is no generally applicable subsidence model for the United States, nor are there adequately tested, empirical models for any of the major U.S. coal fields: the Appalachian, Interior, or Rocky Mountain. The influence of local geologic environments and mining methods on subsidence in the United States will require the collection of large masses of data in order to construct several accurate prediction models. Virtually no data base exists from which to forecast the surface effects of the various proposed in situ extraction techniques.

The behavior of rock units above longwall operations has been shown to be more accurately predictable than for room-and-pillar mining. An accumulation of quantitative data in the United States similar to that of the NCB for longwall mining would be valuable in establishing sound domestic empirical or mathematical subsidence models. The tools, techniques, and knowledge exist to conduct a coordinated nationwide subsidence research program. If the development of subsidence technology can lessen costly environmental or structural damage, the cost of this development will be repaid.

GLOSSARY

Angle of draw. The angle formed by the vertical and a line drawn from the edge of the underground workings (rib-side) to the point of zero subsidence on the ground surface. *Also called* limit angle.

Arching effect. The mining-induced process by which the roof bows upward spanning the mined-out area and tending to prevent roof falls. The span width is controlled by many factors including depth, seam thickness, mining method, rock strength, structure, and in situ stresses.

Back. Roof of a mine or tunnel.

Backfilling. Placement of material in underground workings in order to retard collapse of roof and pillars and to reduce subsidence.

Barrier pillar. A solid block or rib of coal left unmined between two mine workings for protection against water inflow or squeezing conditions.

Bay. *See* panel.

Block caving. A stoping method of mining in which a thick block of ore is partly isolated from surrounding blocks by a series of drifts. The block is undercut by removing a slice from under the block causing it to cave under its own weight. The broken ore is removed from below, and as the caved mass moves downward, it is further broken by pressure and attrition.

Breakthrough. A passage cut through a pillar to facilitate ventilation from one room to another.

Bulking. The increase in volume, by virtue of increased void volume, of mined rock.

Butt cleat. The minor cleat system or jointing in a coal seam. *Also called* end cleat.

Chimney. Initial surface collapse above a mined-out area in crystalline rocks.

Cleat. A joint system in a seam along which the coal fractures. There are usually two cleat systems developed perpendicular to each other.

Critical subsidence profile. Subsidence profile drawn at the critical width.

Critical width. Width of extraction of coal seam at which the subsidence at the bottom of the trough has the maximum value.

Delayed subsidence. A variable amount of residual subsidence that occurs long after mining, usually controlled by lithologic properties. For example, a strong rock layer between the mine and the surface may retard the collapse process months or years.

Dip angle. The inclination from the horizontal of a seam or bed, measured perpendicular to the strike of the structure.

Extraction ratio. Ratio of mined-out area to the total planned mine area.

Face. A surface on which mining operations are in progress.

Face cleat. The major cleat system or jointing in a coal seam.

In situ. In the natural or original position; in place.

Leaching. The extraction of soluble metals or salts from ore by means of percolating water or other solutions.

Longwall. A method of mining coal or other resources in which the seam is removed in one operation by means of a long working face or wall. The workings (face) are advanced in a continuous line which may be several hundred meters long..

Mining Horizon. The level at which a deposit is mined.

Monument. A stake, rod, or concrete structure that is used to mark ground location points for mining surveys.

Overburden. The rock and (or) soil above a coal seam.

Panel. Areas of extracted coal, separated by long, solid barrier pillars.

Panel length. Dimension of a panel measured in the direction of face advance. *Also called* face length.

Panel width. Distance across a working coal face. *Also called* face width.

Pillar. Solid coal or ore left either temporarily or permanently to support the roof or prevent water inflow.

Powder factor. The amount of explosive used to mine a ton of rock or ore.

Percent recovery. The proportion of coal or other resource mined from a seam or deposit.

Residual subsidence. That amount of the total subsidence that occurs after the face leaves the critical area.

Retreat mining. A mining method by which a pillar of solid coal or ore is left until the final mining while pulling out of a room-and-pillar panel.

Rib. The side of a pillar or the wall of an entry.

Ribside. Edge of mine workings.

Room. An excavation driven from an entry from which coal or ore is produced.

Room and pillar. A method of mining coal or other resources in which the seam is mined in rooms separated by narrow pillars and in which 50 percent or more of the resource is removed during initial mining.

Solution mining. The in-place dissolution of mineral salts of an ore with a leaching solution.

Subcritical subsidence profile. Subsidence profile drawn at a subcritical width.

Subcritical width. Width of extraction of coal seam at which the bottom of the subsidence area is trough-like and has less than the maximum value.

Subsidence. Vertical component of ground movement.

Subsidence area. The entire surface area affected by subsidence over a high-extraction panel.

Subsidence basin. The depression at the surface above high-extraction mining panels.

Subsidence profile. A curve depicting subsidence of the ground surface on a section drawn parallel to the direction of advance of an underground excavation.

Supercritical subsidence profile. Subsidence profile drawn at a supercritical width.

Supercritical width. Width of extraction of coal seam at which the bottom of the subsidence trough is approximately flat at the maximum subsidence value.

Transition point. The point of transition between concave and convex curvature of a subsidence profile.

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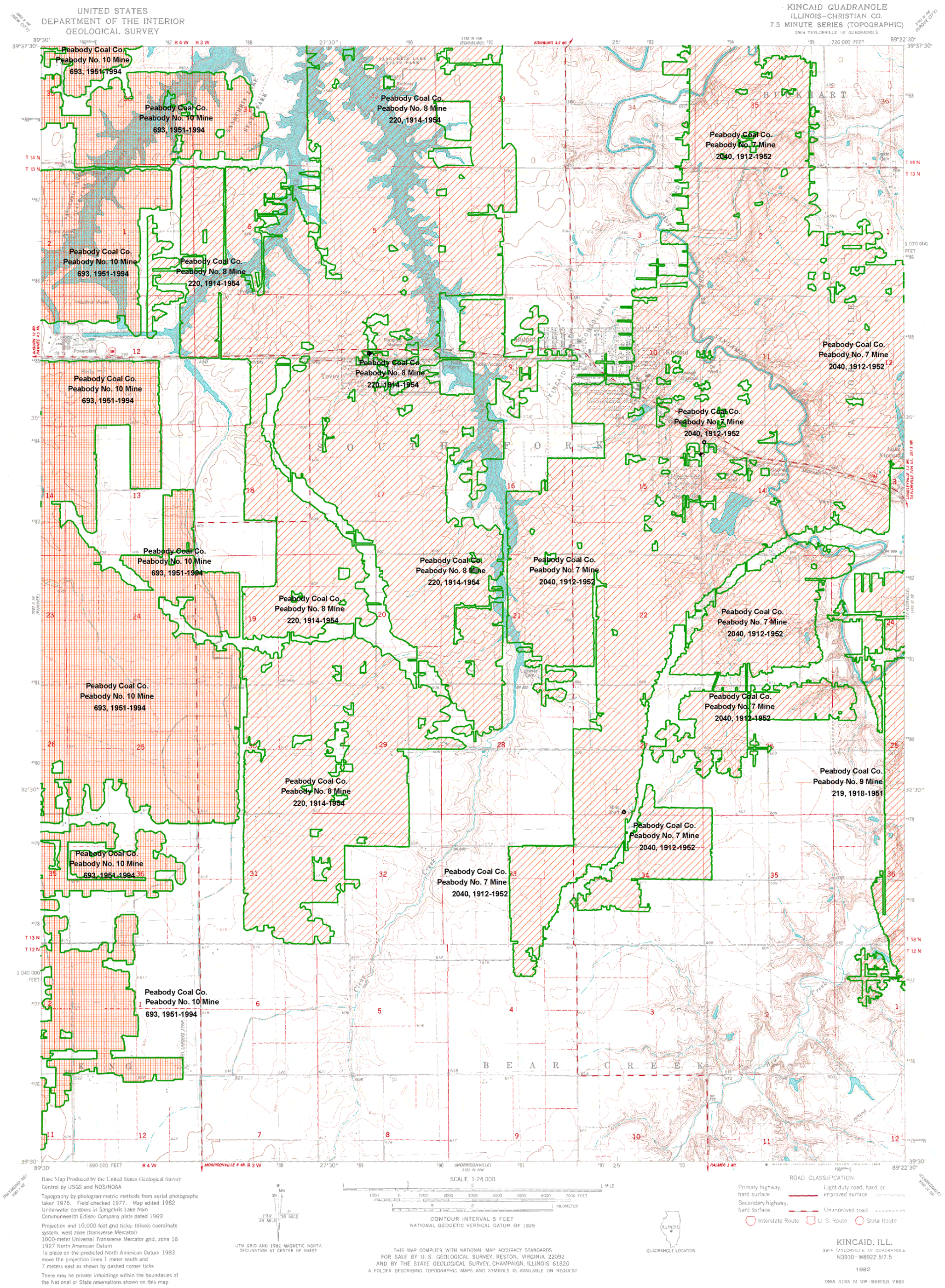
Reference 6

Coal Mines in Illinois
Kincaid Quadrangle

Christian County, Illinois

This map accompanies the Coal Mines Directory for the Kincaid Quadrangle. Consult the directory for a complete explanation of the information shown on this map.



Mining Method

- Room & Pillar (RP)
- Room & Pillar Basic (RPB)
- Modified Room & Pillar (MRP)
- Room & Pillar Panel (RPP)
- Blind Room & Pillar (BRP)
- Checkerboard Room & Pillar (CRP)
- High Extraction Retreat (HER)
- Longwall (LW)
- Underground, Method Unknown
- Strip Mine
- Auger Mine
- General Area of Mining

Source of Mine Outline

- Final Mine Map
- Not Final Mine Map
- Undated Mine Map
- Incomplete Mine Map
- Secondary Source Map

Tipple, Shaft, Slope, Drift Locations

- Strip Mine Tipple - Active
- Strip Mine Tipple - Abandoned
- Mine Shaft - Active
- Mine Shaft - Abandoned
- Mine Slope - Active
- Mine Slope - Abandoned
- Mine Drift - Active
- Mine Drift - Abandoned
- Air Shaft
- Uncertain Location
- Uncertain Type of Opening

Mine Annotation

(space permiting)
Company
Mine Name
ISGS Index No., Years of Operation

Location

DISCLAIMER

These data were compiled and digitized from the best source maps available. Locations of some features may be offset by 500 feet of more due to errors in the original source maps, the compilation process, digitizing or a combination of these factors. Documentation of the source materials used is contained in the directory that accompanies this map. It is the user's responsibility to read this documentation and understand the limitations of the data. Though efforts have been made to compile these data accurately, the Illinois State Geological Survey does not guarantee the validity or the accuracy of these data.

The image of the U.S.G.S. Kincaid Quadrangle used as a basemap was projected from the original UTM to Lambert Conformal Conic.

ILLINOIS DEPARTMENT OF NATURAL RESOURCES

ISGS Illinois State Geological Survey Coal Section

Illinois State Geological Survey
615 E. Peabody Dr.
Champaign, IL 61820

Mine Outlines Compiled by
Alan R. Myers

September 21, 2007

DIRECTORY OF COAL MINES IN ILLINOIS
7.5-MINUTE QUADRANGLE SERIES
KINCAID QUADRANGLE
CHRISTIAN COUNTY

Alan R. Myers

Department of Natural Resources
ILLINOIS STATE GEOLOGICAL SURVEY
2007

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Cover photo Track-mounted duckbill loading machine at a Peabody Coal Company mine, ca. 1915.

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CONTENTS

INTRODUCTION

Coal has been mined in 76 counties of Illinois. More than 7,400 coal mines have operated since commercial mining began in Illinois about 1810; fewer than 30 are currently active. To detail the extent and location of coal mining in Illinois, the Illinois State Geological Survey (ISGS) has compiled maps and directories of known coal mines. The ISGS offers maps at a scale of 1:100,000 and accompanying directories for each county in which coal mining is known to have occurred. Maps at a scale of 1:24,000 and accompanying directories, such as this, are available for selected quadrangles. Contact the ISGS for a list of these quadrangles.

These larger scale maps show the approximate positions of mines in relation to surface features such as roads and water bodies, and indicate the mining method used and the accuracy of the mine boundaries. The maps are useful for locating mine boundaries relative to specific properties and for assessing the potential for subsidence in an area. Mine boundaries compiled from final mine surveys are generally shown within 200 feet of their true position. As a result of poor cartographic quality and inaccuracies in the original mine surveys, boundaries of some older mines may be mislocated on the map by 500 feet or more. Original mine maps should be consulted in situations that require precise delineation of mine boundaries or internal workings of mined areas.

This directory serves as a key to the accompanying mine map and provides basic information on the coal mines in the quadrangle. The directory is composed of two parts. Part I explains the symbols and patterns used on the accompanying map and the summary data presented for each mine. Part II numerically lists the mines in the quadrangle and summarizes the geology and production history of each mine. Total production for the mine, not the portion in the quadrangle, is given.

MINING IN THE KINCAID QUADRANGLE

Mining in this quadrangle took place in the Herrin Coal. Since the seam ranged from 300 to over 400 feet deep, development here began a little later than at nearby towns. The earliest mine was Peabody No. 7 Mine (mine index 2040), which opened in 1912. Mining was continuous until Peabody No. 10 Mine (mine index 693) closed in 1994. The accompanying map shows what may have been the largest obstacle to mining for the planning engineers – the sandstone channels that eroded the coal and made nearby roof conditions troublesome.

PART I EXPLANATION OF MAP AND MINE SUMMARY SHEET

INTERPRETING THE MAP

The map accompanying this directory shows the location of coal mines known to be present in the quadrangle. The map, corresponding to a U.S. Geological Survey (USGS) 7.5-minute quadrangle, covers an area bounded by lines of latitude and longitude 7.5-minutes apart. In Illinois, a quadrangle is approximately 6.5 miles east to west and 8.5 miles north to south, an area of about 56 square miles. The ISGS generally offers one map of mines per quadrangle. In some areas where extensive mining occurred in two or more overlapping seams, separate maps are compiled for mines in each seam to maintain readability of the map.

Mine Type and Mining Method
The mine type is indicated on the map by pattern color: green represents surface mines; red and yellow represent underground mines. The red patterns are used for areas of underground mining that are documented by a primary or secondary source map. A yellow pattern is used for cases where no map of the mine workings is available, but a general area of mining can be inferred from property maps or production figures. The patterns indicate the main mining methods used in underground mines. The methods are (1) room and pillar and (2) high extraction. The method used gives some indication of the amount and pattern of coal extraction within each mined area, and has some influence on the timing and type of subsidence that can occur over a mine.

The following discussion and illustrations of mining methods are based on Guither et al. (1984).

In room-and-pillar mines, coal is removed from haulage-ways (entries) and selected areas called rooms. Pillars of unmined coal are left between the rooms to support the roof. Depending on the size of rooms and pillars, the amount of coal removed from the production areas will range from 40% to 70%.

Room and Pillar - mining is divided into six categories:

- room-and-pillar basic (RPB, fig. 1A), an early method that did not follow a preset mining plan and therefore resulted in very irregular designs;
- modified room and pillar (MRP, fig. 1B);
- room-and-pillar panel (RPP, fig. 1C);
- blind room and pillar (BRP, fig. 1D);
- checkerboard room and pillar (CRP, fig. 1E);
- room and pillar (RP), a classification used when the specific type of room-and-pillar mining is unknown.

Blind and checkerboard are the most common types of room-and-pillar mining used in Illinois today. The knowledge of room-and-pillar mining methods gives a trained engineer information on the nature of subsidence that may occur. A more extensive discussion of subsidence can be found in Bauer et al. (1993).

High-extraction These mining methods are subdivided into high-extraction retreat (HER, Fig 1F) and longwall (LW, Fig 1G, 1H). In these methods, much of the coal is removed within well defined areas of the mine. Subsidence of the surface above these areas occurs within weeks. Once the subsidence activity ceases, the potential for further movement over these areas is low; however, subsidence may continue for several years after mining.

High-extraction retreat mining is a form of room-and-pillar mining that extracts most of the coal. Rooms and pillars are developed in the panels, and the pillars are then systematically removed (fig. 1F).

In early (pre-1960) longwall mines, mining advanced in multiple directions from a central shaft (fig. 1G). Large pillars of coal were left around the shaft, but all coal was removed beyond these pillars. Miners placed rock and wooden props and cribs in the mined-out areas to support the mine roof. The overlying rock gradually settled onto these supports, thus producing subsidence at the surface. In post-1959 longwall mines, room-and-pillar methods have been used to develop the main entries of the mine and panel areas. Modern longwall methods extract 100 percent of the coal in the panel areas (fig. 1H).

SOURCE MAPS

Mine outlines depicted on the map are, whenever possible, based on maps made from original mine surveys. The process of compiling and digitizing the quadrangle map may produce errors of less than 200 feet in the location of mine boundaries. Larger errors of 500 feet or more are possible for mines that have incomplete or inaccurate source maps.

Because of the extreme complexity of some mine maps, detailed features of mined areas have been omitted. The digitized mine boundary includes the exterior boundary of all rooms or entries that were at least 80 feet wide or protruded 500 feet from the main mining area. Unmined areas between mines are shown if they are at least 80 feet wide; unmined blocks of coal within mines are shown if they are at least 400 feet on each side. Original source maps should be consulted when precise information on mine boundaries or interior features is needed.

The mine summary sheet lists the source maps used to determine each mine outline. The completeness of map sources is indicated on the map by a line symbol at the mine boundary. Source maps are organized in five categories.

Final mine map The mine outline was digitized from an original map made from mine surveys conducted within a few months after production ceased. The date of the map and the last reported production are listed on the summary sheet.

Not a final map The mine is currently active or the mine outline was made from a map based on mine surveys conducted more than few months before production ceased. This implies the actual mined-out area is probably larger than the outline on the map. The mine summary sheet indicated the dates of source maps and the last reported production, as well as the approximate tonnage mined between these two dates (if the mine is abandoned). The summary sheet also lists the approximate acreage mined since the date of the map and, in some cases, indicates the area where additional mining may have taken place. This latter information is determined by locating on the map the active faces relative to probable boundaries of the mine property.

Undated map The source map was undated, so it may or may not be based on a final mine survey. When sufficient data are available, the probable acreage of the mined area is estimated from reported production, average seam thickness and a recovery rate comparable to other mines in the area. This information is listed in the summary sheet for the mine.

Incomplete map The source map did not show the entire mine. The summary sheet indicates the missing part of the mine map and the acreage of the unmapped area, which is estimated from the amount of coal known to have been produced from the mine.

Secondary source map The original mine map was not found so the outline shown was determined from secondary sources (e.g., outlines from small-scale regional maps published in other reports). The summary sheet describes the secondary sources.

POINTS AND LABELS

The locations of all known mine openings (shafts, slopes, and drifts) and surface mine tipples are plotted on the map. Tipples are areas where coal was cleaned, stockpiled, and loaded for shipping.

Only openings or tipples are plotted for mines without source maps. If the precise locations of these features are unknown, a special symbol is used to indicate the approximate location of the mine.

Each mine on the map is labeled with the names of the mine and operating company, ISGS mine index number, and years of operation (if known) if space permits. A seam designation is given on maps where more than one seam was mined. For a mine that operated under more than one name, only the most recent name is generally given. When a mine changed names or ownership shortly before closing, an earlier name is listed. All company and mine names are listed on the mine summary sheet in the directory, under the production history segment.

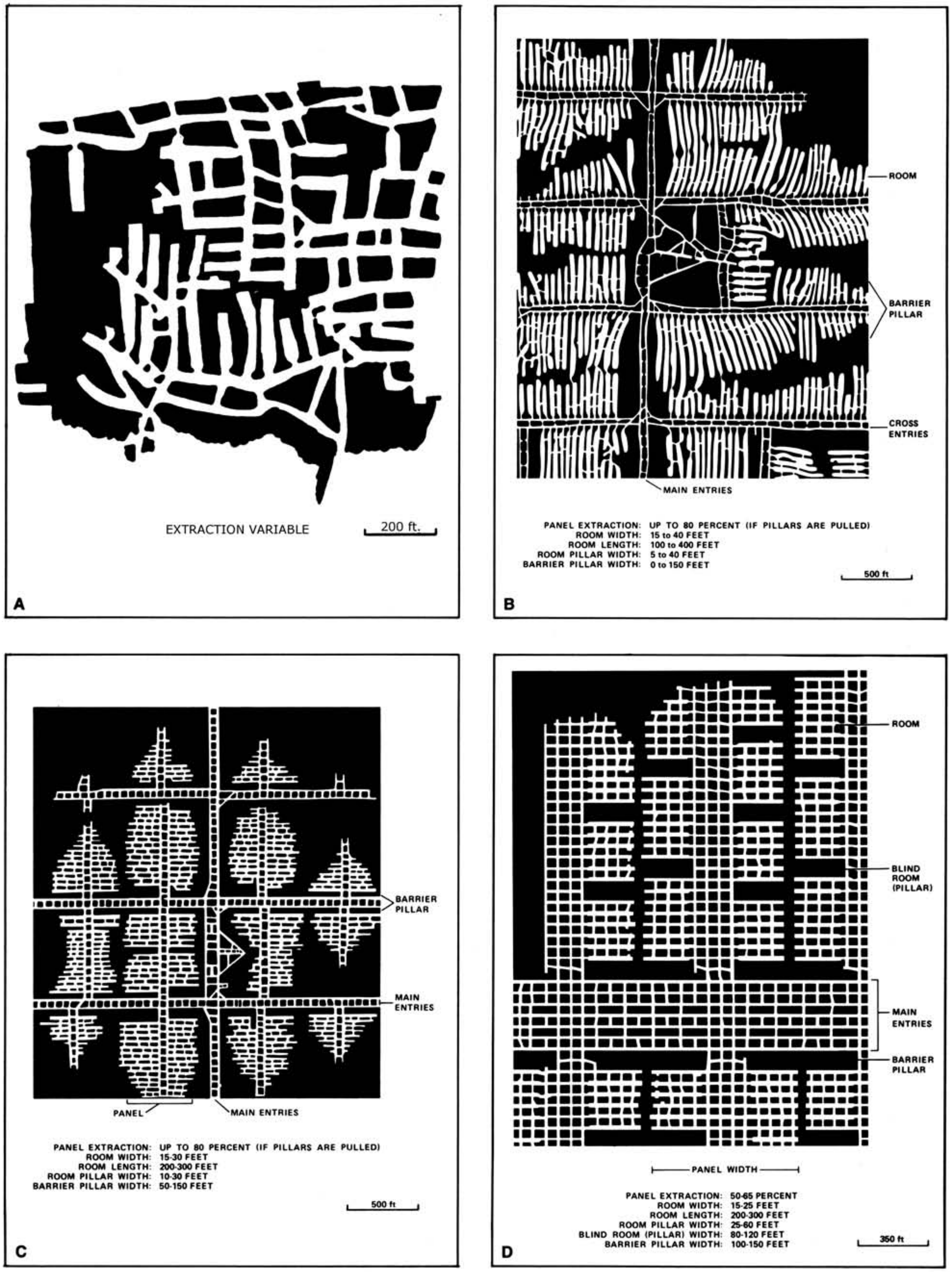


Figure 1 Mining methods: (A) room-and-pillar basic (RPB), (B) modified room and pillar (MRP), (C) room-and-pillar panel (RPP), (D) blind room and pillar (BRP).

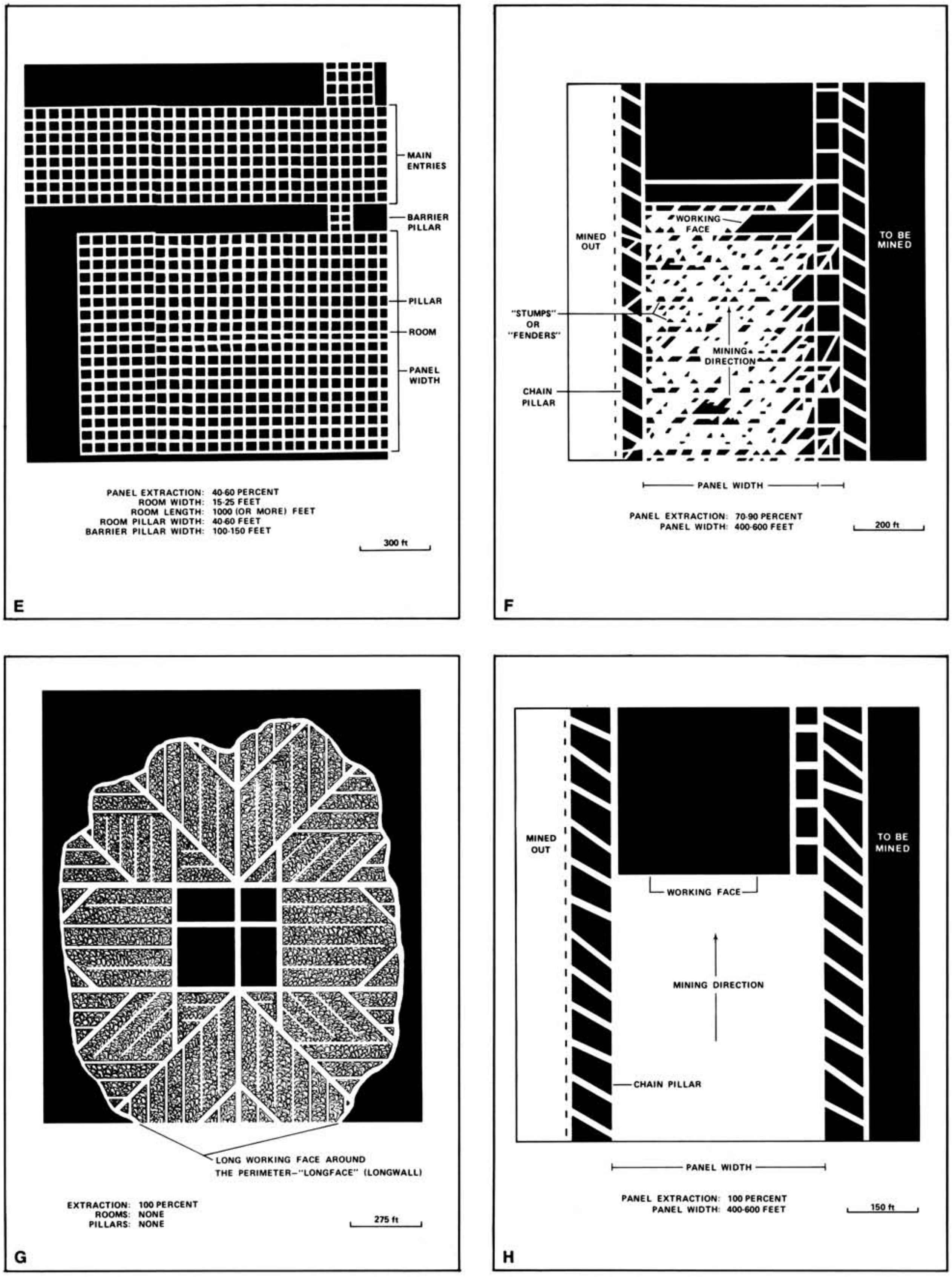


Figure 1 *(cont.)* Mining methods: (E) checkerboard room and pillar (CRP), (F) high extraction retreat (HER), (G) early (pre-1960) longwall, (H) post-1959 longwall

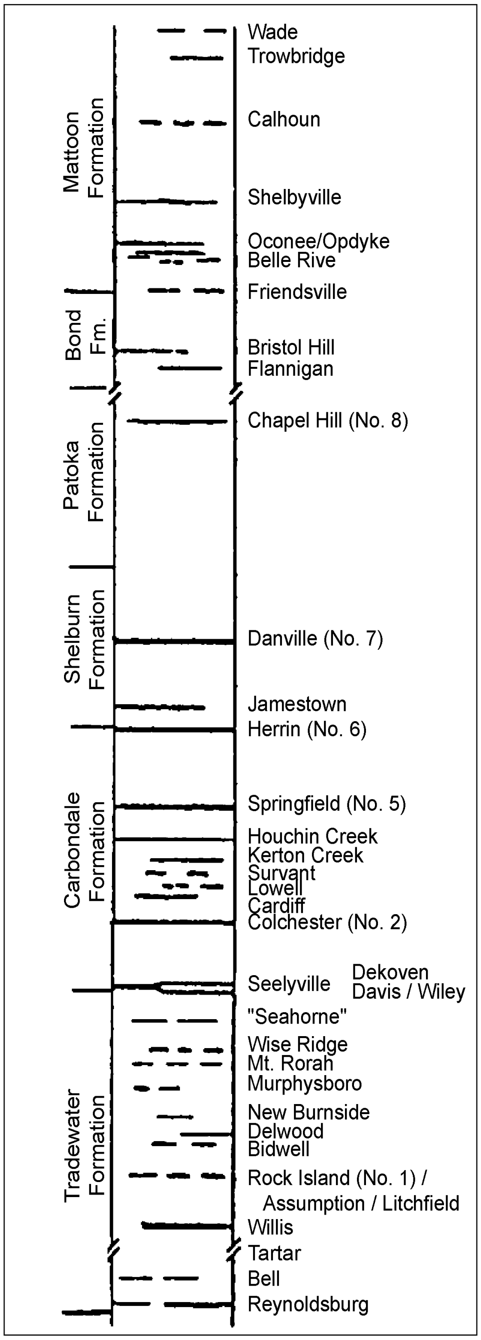


Figure 2 Generalized stratigraphic section, showing approximate vertical relations of coals in Illinois.

INTERPRETING A MINE SUMMARY SHEET

The mine summary sheet is arranged numerically by mine index number. Index numbers are shown on the map and in the mine listing. The mine summary sheet provides the following information (if available).

Company and mine name The last company or owner of the mine is used, unless no production was recorded for the last owner. In that case, the penultimate owner is listed. Mines often have no specific name; in these cases, the company name is also used as the mine name.

Type *Underground* denotes a subsurface mine in which the coal was reached through a shaft, slope, or a drift entry. *Surface* denotes a surface, open pit or strip mine.

Total mined-out acreage shown The total acreage of the mined area mapped, including any acreage mined on adjacent quadrangles, is calculated from the digitized outline of the mine. The acreage of large barrier pillars depicted on the map is excluded from the mined-out acreage. Small pillars not digitized are included in the acreage calculation. If the mine outline is not based on a final mine map, the acreage is followed by an estimate of additional acres that may have been mined. The estimate is determined from reported mine production, approximate thickness of the coal, and recovery rates calculated from nearby mines that used similar mining methods.

SHAFT, SLOPE, DRIFT OR TIPPLE LOCATIONS

Shaft, slope, drift, or tipple locations Locations of all known former entry points to underground mines or the location of coal cleaning, tipple, and shipping equipment used by the mine's facility are listed. The location is described in terms of county, township and range (Twp-Rge), section, and location within the section by quarters. NE SW NW, for instance, would describe the location in the northeast quarter of the southwest quarter of the northwest quarter. When sections are irregular in size, the quarters remain the same size and are oriented (or "registered") from the southeast corner of the section. Approximate footage from the section lines (FEL = from east line, FNL = from north line, for example) is given when that information is known; this indicates a surveyed location and is not derived from maps. Entry points are also plotted on the map and coded for the type of entry or tipple. A mine opening may have had many purposes during the life of the mine. Old hoist shafts are often later used for air and escape shafts; this information is included in the directory when known. The tipple for underground mines was generally located near the main shaft or slope. At surface mines, coal was sometimes hauled to a central tipple several miles from the mine pit.

GEOLOGY

Seam(s) mined The name of the coal seam(s) mined is listed, if known. If multiple seams were mined, they are all listed, although the mined-out area for each seam may be shown on separate maps. Figure 2 shows the stratigraphic section of the coal-bearing interval in Illinois, and the vertical relations among the coals.

Depth The depth to the top of the seam in the vicinity of the shaft is listed, if known. The depth is determined from notes made by geologists who visited the mine during its operation or from drill hole data in ISGS files. Depth generally varies little over the extent of a mine; however, reported depths for an individual mine may vary. Depth for surface-mined coals varies, and is usually represented as a range.

Thickness The approximate thickness of the mined seam is shown, if known. Thickness also comes from notes of geologists who visited the mine during its operation or from borehole data in ISGS files. Minimum, maximum, and average thicknesses are given when this information is available.

Mining method The principal mining method used at the mine (figs. 1A-H) is listed. See the mining methods section at the beginning of this directory for a discussion of this parameter.

Geologic problems reported Any known geologic problems, such as faults, water seepage, floor heaving, and unstable roof, encountered in the mine are reported. This information is from notes made by ISGS geologists who visited the mine, or from reports by mine inspectors published by the Illinois Department of Mines and Minerals, or from the source map(s). Geologic problems are not reported for active mines.

PRODUCTION HISTORY

Production history Tons of coal produced from the mine by each mine owner are totaled. When the source map used for the mine outline is not a final mine map, the tonnage produced since the date of the map is identified. For mines that extend into adjacent quadrangles, the tonnage reported includes areas mined in adjacent quadrangles.

SOURCE OF DATA

Source map This section lists information about the map(s) used to compile the mine outline and the locations of tipples and mine openings. In some cases more than one source map was used. For example, a map drawn before the mine closed may provide better information on original areas of the mine than a later map. When more than one map was used, the bibliography section explains what information was taken from each source.

Date The date of the most recent mine survey listed on the source map is reported.

Original scale The original scale of the source map is listed. Many maps are photo-reductions and are no longer at their original scale. The original scale gives some indication of the level of detail of the mine outline and the accuracy of the mine boundary relative to surface features. Generally, the larger the scale, the greater the accuracy and detail of the mine map. Mine outlines taken from source maps at scales smaller than 1:24,000 may be highly generalized and may well be inaccurately located with respect to surface features.

Digitized scale The scale of the digitized map is reported. The scale may be different from that of the original source map. In many cases the digitized map was made from a photo-reduction of the original source map, or the source map was not in a condition suitable for digitizing and the mine boundaries were transferred to another base map.

Map type Source maps are classified into five categories to indicate the probable completeness of the map. See discussion of source maps in the previous section.

Annotated bibliography Sources that provide information about the mine are listed, with the data taken from each source. Some commonly used sources are described below. Full bibliographic references are given for all other sources. Unless otherwise noted, all sources are available for public inspection at the ISGS.

Coal Reports Published since 1881, these reports contain tabular data on mine ownership, production, employment, and accidents. Some volumes include short descriptions made by mine inspectors of physical features and conditions in selected mines.

Directory of Illinois Coal Mines This source is a compilation of basic data about Illinois coal mines, originally gathered by ISGS staff in the early 1950s. Sources used for this directory are undocumented, but they are primarily Illinois Department of Mines and Minerals annual reports, ISGS mine notes, and coal company officials.

ENR Document 85/01, Guither, H. D., J. K. Hines, and R. A. Bauer, 1985 The Economic Effect of Underground Mining Upon Land Used for Illinois Agriculture: Illinois Department of Energy and Natural Resources Document 85/01, 185 p.

Microfilm map The U.S. Bureau of Mines maintains a microfilm archive of mine maps. A microfilm file for Illinois is available for public viewing at the ISGS.

Mine notes   ISGS geologists have visited mines or contacted mine officials throughout the state since the early 1900s. Notes made during these visits range from brief descriptions of the mine location to long narratives (including sketches) of mining conditions and geology.

Federal Land Bank of St. Louis, Preliminary Reports on Subsidence Investigations Mining engineers working for the Federal Land Bank of St. Louis mapped areas of subsidence due to coal mining in the early 1930s. These reports often include county maps of mine properties with mined-out areas including shaft locations, as well as subsidence areas.

REFERENCES

Bauer, R. A., B. A. Trent, and P. B. Dumontelle, 1993, Mine Subsidence in Illinois: Facts for the Homeowner Considering Insurance, Illinois State Geological Survey, Environmental Geology Note 144, 16p.

Guither, H. D., J. K. Hines, and R. A. Bauer, 1985, The Economic Effects of Underground Mining Upon Land Used for Illinois Agriculture, Illinois Department of Energy and Natural Resources Document 85/01, 185p.

PART II DIRECTORY OF MINES IN THE KINCAID QUADRANGLE

MINE SUMMARY SHEETS

A summary sheet on the geology and production history of each mine in the Kincaid Quadrangle is provided. These summary sheets are arranged numerically by mine index number. Consult Part I for a complete explanation of the data listed in the summary sheet.

Mine Index 219
Peabody Coal Company, Peabody No. 9 Mine

Type: Underground   Total mined-out acreage shown: 5,769

SHAFT, SLOPE, DRIFT or TIPPLE LOCATIONS

Type	County	Township-Range	Section	Quarters-Footage
Main shaft	Christian	13N 2W	19	NE SE NW
Air shaft	Christian	13N 2W	19	SW SW NE

GEOLOGY

		Thickness (ft)			Mining
Seam(s) Mined	Depth (ft)	Min	Max	Avg	Method
Herrin	407-417	4.0	9.0	7.5	RPP

Geologic Problems Reported: The source map shows problem areas designated along the southwestern edge and all along the north and northwestern side of the mine. The symbol is thought to denote sandstone channels. Channels or associated wet areas (from the water seeping from the sandstone) may have also caused some of the problems that resulted in the larger interior un-mined areas. The roof in the eastern and western parts of the mine was black shale, while gray shale predominated in the southeastern part of the mine. The sandy shale in the northeastern part was very dangerous and gave much trouble, because micaceous layers separating the bedding planes parted readily and allowed large parts of the roof to come down. This sandy shale was either directly on the coal or separated from it by 4 to 36 inches of black shale. A persistent pyrite layer in the coal ranged up to 1.5 inches thick. Pyrite lenses up to 1 inch thick were common. The source map shows faulty areas along the northern and southern borders of the mine.

PRODUCTION HISTORY

Company	Mine Name	Years	Production (tons)
Peabody Coal Company	Peabody No. 9	1918-1951 *	36,290,433
			36,290,433

* Idle 1928

Last reported production: March 1951

SOURCES OF DATA

Source Map	Date	Original Scale	Digitized Scale	Map Type
Company	5-29-1952	1:4800	1:4800	Final
Microfilm, document 351393	5-29-1952	1:4800	1:9600	Final

Annotated Bibliography (data source, brief description of information)

Coal Reports - Production, ownership, years of operation.
Directory of Illinois Coal Mines (Christian County) - Mine names, mine index, ownership, years of operation.
ENR Document 85/01 - Mining method.
Mine notes (Christian County) - Mine type, shaft location, seam, depth, thickness, geologic problems.
Company map, ISGS map library, 4103.C4 i5.1-6, copy 1 - Shaft locations, mine outline, mining method, geologic problems.
Microfilm map, document 351393, reel 03135, frames 470-475, map of Peabody #7 (mine index 2040) - Mine outline (far NW part of mine).

Mine Index 220
Peabody Coal Company, Peabody No. 8 Mine

Type: Underground   Total mined-out acreage shown: 8,571

SHAFT, SLOPE, DRIFT or TIPPLE LOCATIONS

Type	County	Township-Range	Section	Quarters-Footage
Main shaft	Christian	13N 3W	8	SW SW NW
Air shaft	Christian	13N 3W	8	SW SW NW

GEOLOGY

		Thickness (ft)			Mining
Seam(s) Mined	Depth (ft)	Min	Max	Avg	Method
Herrin	370	7.0	8.0	7.5	RPP

Geologic Problems Reported: The source map shows a mining pattern indicating a fault that interfered with mining in NW SENE 17-T13N-R3W. This normal fault extended southeast into Peabody No. 10 Mine (mine index 693), where the coal was downthrown 7 to 15 feet to the northeast. The immediate roof over the coal was a black shale that varied from 0 to 5 feet thick. Above the shale was a limestone that also ranged from 0 to 5 feet thick. Timbering was required where the roof was shale over 30 inches thick. When the shale was less than 30 inches, it was taken down when the coal was removed. The limestone made a very good roof. Slips and sandstone rolls were observed in the mine. Rolls were more common in the western part of the mine, and had the effect of lowering the top of the coal 3 to 4 feet. Impurities in the coal were pyrite in lenses and bands, and calcite in fracture fillings. The soft underclay floor heaved, and several bad squeezes had occurred at the mine.

PRODUCTION HISTORY

Company	Mine Name	Years	Production (tons)
Peabody Coal Company	Peabody No. 8	1914-1954	47,406,627
			47,406,627

Last reported production: July 1954

SOURCES OF DATA

Source Map	Date	Original Scale	Digitized Scale	Map Type
Company, 4103.C4 i5.1-10	7-29-1954	1:12000	1:12000	Final

Annotated Bibliography (data source, brief description of information)

Coal Reports - Production, ownership, years of operation, depth.
Directory of Illinois Coal Mines (Christian County) - Mine names, mine index, ownership, years of operation.
Mine notes (Christian County) - Mine type, shaft location, seam, thickness, geologic problems.
Company map, ISGS map library, 4103.C4 i5.1-10 - Shaft locations, mine outline, mining method.

Mine Index 693
Peabody Coal Company, Peabody No. 10 Mine

Type: Underground Total mined-out acreage shown: 24,808 Workings extend into Sangamon and Montgomery Counties.

SHAFT, SLOPE, DRIFT or TIPPLE LOCATIONS

Type	County	Township-Range	Section	Quarters-Footage
Main slope	Christian	13N 4W	10	NE NE SE
Air shaft	Christian	13N 4W	11	SE NW SW
19th North air shaft	Sangamon	13N 4W	30	SW NW SW
South man / air shaft	Sangamon	13N 4W	29	SW SW SW
Air shaft	Christian	13N 4W	26	SW SW SW
Main South air shaft #2	Christian	13N 4W	34	SE SE NE
Zenobia man shaft	Christian	12N 4W	2	NW NW SW
Air shaft	Christian	12N 4W	2	NE NW SW
North air shaft	Christian	14N 4W	27	SE SE SE
North man shaft	Christian	14N 4W	27	SE SE SE
4th East air shaft	Christian	14N 4W	35	NE NW NE
4th West air shaft	Sangamon	14N 4W	32	NE NE NW

GEOLOGY

		Thickness (ft)			Mining
Seam(s) Mined	Depth (ft)	Min	Max	Avg	Method
Herrin	300-380		13.0	6.5-7.5 *	BRP

* The coal was averaged 6.5 feet thick under limestone roof and 7.5 feet thick under Anna Shale. Generally, 2 to 3 feet of top coal was left to support the roof.

Geologic Problems Reported: This mine extended about 11 miles in the north-south direction and 7 miles in the east-west direction, and geologic conditions were diverse. A large normal fault was encountered that halted expansion in the northeastern part of the mine. Displacement was 7 to 15 feet downthrown to the northeast. This fault, or set of parallel faults, extended over 2 miles N-NW and southward into NW SE NW 17-T13N-R3W, in Peabody No. 8 Mine (mine index 220). In 1967, seven entries were driven through a NE-SW trending channel sandstone in NE SW 17-T13N-R4W, Sangamon County. The sandstone was water-bearing, and consequently the mine was wet in that area. The top of the coal was eroded, but 4 to 5 feet of coal remained. These channels of Anvil Rock Sandstone channels are evident in the mining patterns shown on the accompanying map. Most channels were 200 to 400 feet wide with wider flanking zones of wet conditions and/or unstable roof. The black shale roof tended to slab off along prominent jointing breaks. The 3 to 4 feet of black Anna Shale was overlain by 1.5 feet of Brereton Limestone, then 2 to 10 feet of thin-bedded Anvil Rock Sandstone that sometimes had shale interlaminations, another 1.5 feet of limestone, and 2 feet of shale. In some roof falls this entire sequence was exposed. In NW 34-T13N-R4W and SW 27-T13N-R4W, a peat trough resulted in coal up to 13 feet thick, in a north-south trending linear depression. The grades were too steep for the equipment and the feature was difficult to cope with. Roof failures also made this feature difficult to mine, although only the usual 6 to 7 feet of coal was actually removed. A pattern of slips initiated a roof fall of 35 feet of silty shale and gray shale within this area of thick coal. The coal in the northern part of the mine was exceptionally hard but relatively clean of impurities, and the underclay was rather soft. In the southern part of the mine, the coal was softer but had more impurities, and the underclay was much firmer.

PRODUCTION HISTORY

Company	Mine Name	Years	Production (tons)
Peabody Coal Company	Peabody No. 10	1951-1994	147,281,150
			147,281,150

Last reported production: 1994

SOURCES OF DATA

Source Map	Date	Original Scale	Digitized Scale	Map Type
Company	8-1-1994	1:7200	1:7200	Final

Annotated Bibliography (data source, brief description of information)

Coal Reports - Production, ownership, years of operation, depth.
Directory of Illinois Coal Mines (Christian County) - Mine names, mine index, ownership, years of operation.
Mine notes (Christian County) - Mine type, shaft location, seam, thickness, geologic problems.
Company map, state archives - Slope & shaft locations, mine outline, mining method.
Company map, Coal Section files, 2-1-11L - Geologic problems.

Mine Index 2040
Peabody Coal Company, Peabody No. 7 Mine

Type: Underground   Total mined-out acreage shown: 7,127

SHAFT, SLOPE, DRIFT or TIPPLE LOCATIONS

Type	County	Township-Range	Section	Quarters-Footage
Main shaft	Christian	13N 3W	14	SW NW NW
Air shaft	Christian	13N 3W	14	SW NW NW
Air shaft	Christian	13N 3W	27	SE SE SW

GEOLOGY

		Thickness (ft)			Mining
Seam(s) Mined	Depth (ft)	Min	Max	Avg	Method
Herrin	349-365			6.5-7.5	RPP

Geologic Problems Reported: The source map shows a probable sandstone channel that limited mine expansion in the southeastern part of the mine. Only three pairs of entries were driven across the channel to access the coal on the other side, implying that almost no coal was minable there. The coal was either eroded or never deposited. Another channel was between the Peabody No. 7 and Peabody No. 9 Mines (mine index 219). The source map showed unmined areas in 36-T14N-R3W (SE NW, S ½ NE and SE SW), some marked by the same symbol used to denote channels elsewhere on the same map.

PRODUCTION HISTORY

Company	Mine Name	Years	Production (tons)
Illinois Midland Coal Company	Illinois Midland No. 7	1912-1913	74,824
Peabody Coal Company	Peabody No. 7	1913-1952	44,886,555
			44,961,379

Last reported production: May 1952

SOURCES OF DATA

Source Map	Date	Original Scale	Digitized Scale	Map Type
Microfilm, document 351393	5-29-1952	1:4800	1:9600	Final

Annotated Bibliography (data source, brief description of information)

Coal Reports - Production, ownership, years of operation, depth, thickness.
Directory of Illinois Coal Mines (Christian County) - Mine names, mine index, ownership, years of operation.
Mine notes (Christian County) - Mine type, shaft location, seam.
Microfilm map, document 351393, reel 03135, frames 470-475 - Shaft locations, mine outline, mining method.

INDEX OF MINES IN THE KINCAID QUADRANGLE

Funding for this project was supplied by the Illinois Mine Subsidence Insurance Fund.

Attorney Client Privileged

Reference 7

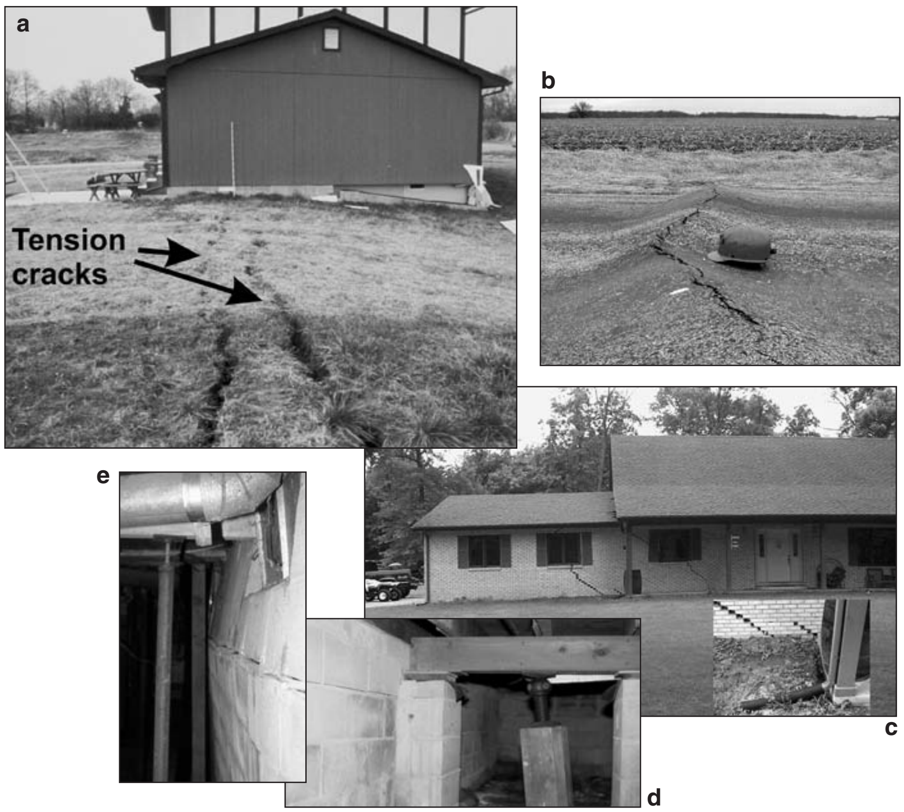
State of Illinois
Rod. R. Blagojevich, Governor
Illinois Department of Natural Resources
Illinois State Geological Survey

Mine Subsidence in Illinois: Facts for Homeowners

Robert A. Bauer

Circular 569 2006

Illinois Department of Natural Resources
1905-2005 ISGS Illinois State Geological Survey



Front Cover: *(a) Tension cracks formed in the ground surface extending through a home; the foundation has settled at the house corner closer to center of sag. (b) Compression ridges formed in a road as the result of ground movement (compression) associated with coal mine subsidence. (c) The brick-sided house in the tension zone shows downward bending (compare roof lines). The left side of the home is closest to the sag center and has dropped down. Insert: ground has pulled away from the porch toward the sag center (left). (d) Settlement of main beam caused by construction problems. (e) This basement damage was unrelated to mine subsidence. It was caused from decades of seasonal wetting and drying of soils, which built up pressure against the basement foundation walls. With each cycle, dryness allows fine grains of soil to fall into the gap between the soil and the foundation wall. When moisture returns, the soil expands, increasing pressure until the wall fails and is pushed inward.*

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Mine Subsidence in Illinois: Facts for Homeowners

Robert A. Bauer

Circular 569 2006

Illinois Department of Natural Resources
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Preface

About 840,000 acres of Illinois land have been undermined for coal and other minerals. About 178,000 acres of residential and other built-up land in Illinois lie close to underground mines and may be susceptible to subsidence. The number of underground coal mines in Illinois has been estimated at 5,500. Maps exist for about 2,600. In 1991, it was estimated that about 320,000 housing units in the state were built over or adjacent to underground mines. Statewide, this number is likely to increase as cities continue to expand outward over mined-out areas.

Subsidence of the surface above abandoned coal mines is uncommon, but homeowners should be aware of nearby mining and the causes and consequences of subsidence. The information provided in this publication should enable homeowners to make a more educated decision as to whether they need to insure their homes against possible mine subsidence damage.

The Illinois State Geological Survey (ISGS) and Illinois Department of Natural Resources, Office of Mines and Minerals (OMM), are on a continual search for missing mine maps. If individuals are aware of any sources of old mine maps, please contact the ISGS or OMM to allow the maps to be copied.

Help for Homeowners

The ISGS has prepared this publication in order to provide information to Illinois homeowners concerned with or experiencing subsidence problems associated with past mining activity. Common damages and problems associated with subsidence are described. Some information is included about problems frequently mistaken as being related to subsidence. Detailed advice is provided as to what to do when subsidence problems are suspected and what help is available for property owners faced with these kinds of problems. Links are provided to other mine information such as maps that will assist the prospective property developer or buyer to avoid known mined-out areas and subsidence problems.

CONTENTS

TABLES

FIGURES

Mine Subsidence in Illinois

Signs of Subsidence

Cracks suddenly appear in the foundation and walls or ceilings, then widen and grow. The ground around the house also starts to crack and lower. Popping and snapping can be heard as the house shifts. Doors and windows stick, jam, or break. Parts of the house tilt, and doors swing open or closed. The chimney, porch, or steps separate from the rest of the house. Water lines break, resulting in dirty tap water, loss of water pressure, and soaked ground. Gas and sewer lines leak.

As subsidence develops, several of these problems are likely to emerge simultaneously within a few days or weeks after onset. Collectively, the damage and ground movements indicate a sense of direction that points to the center of the subsidence event. If only one or two problems occur in a house at random, they may be traced to some cause other than coal mine subsidence.

Underlying Cause

In Illinois, subsidence, or sinking of the land surface, commonly results from underground mining. Soon after the first settlers arrived in Illinois, they developed underground mines to extract coal, lead, zinc, fluorite, shale, claystone, limestone, and dolomite. During the early years, land over mining areas was sparsely populated, and, if the ground settled, homes or other structures were seldom damaged. As towns and cities expanded over mined-out areas, subsidence damage to structures became increasingly common.

In Illinois, the risk of damage to structures has been high enough that a state law, the Mine Subsidence Insurance Act, was passed in 1979 to provide subsidence insurance for homeowners in mining areas. This Act mandates that private insurance carriers include damage coverage as part of the homeowner policy. Amendments to the Act have increased coverage for insured structures from $50,000 (1979) to $350,000 (1990). Mine subsidence insurance in Illinois covers damage caused by underground mining of any solid mineral resource. (More information about the insurance program and the fund is available from the Illinois Mine Subsidence Insurance Fund. See the Contacts for Additional Information section, p. 19.)

Subsidence is possible in any area where any mineral has been mined below the ground surface. One of the state's largest mine subsidence events (700 × 400 feet and 69- to 70-feet deep) took place over a lead-zinc mine near Galena in 1972 (Touseull and Rich 1980). Most mine subsidence in Illinois, however, is related to coal mining, which represents the largest volume extracted and area undermined in the state of any solid commodity. The total acreage where coal mining has occurred (fig. 1) far overshadows the acreage undermined for all other commodities (table 1). A 1991 study showed that about 178,000 acres of residential and other developed areas can be found close to underground mines, and an estimated 320,000 housing units have been built on land over or adjacent to underground mines (Treworgy and Hindman 1991).

Figure 2 shows the extent of underground coal mining in each county. Home insurance policies for residents living in counties with more than 1% of their land undermined have a mine subsidence insurance premium automatically included, as required by the Mine Subsidence Insurance Act of 1979. In these counties, mine subsidence coverage can be declined by signing a waiver.

Geologic Setting

Knowing what geologic (earth) materials lie above and below a coal mine leads to an understanding of how and why subsidence takes place. The ground surface may subside when bedrock or earthen materials fail either above (the roof), within (the coal pillars), or below (the floor) the mine workings.

The term "overburden" refers to all earth materials overlying the mined coal. Overburden includes both the bedrock material and the non-bedrock deposits of sand, silt, clay, and pebbles that are found on top of the bedrock. These upper materials are commonly of glacial origin.

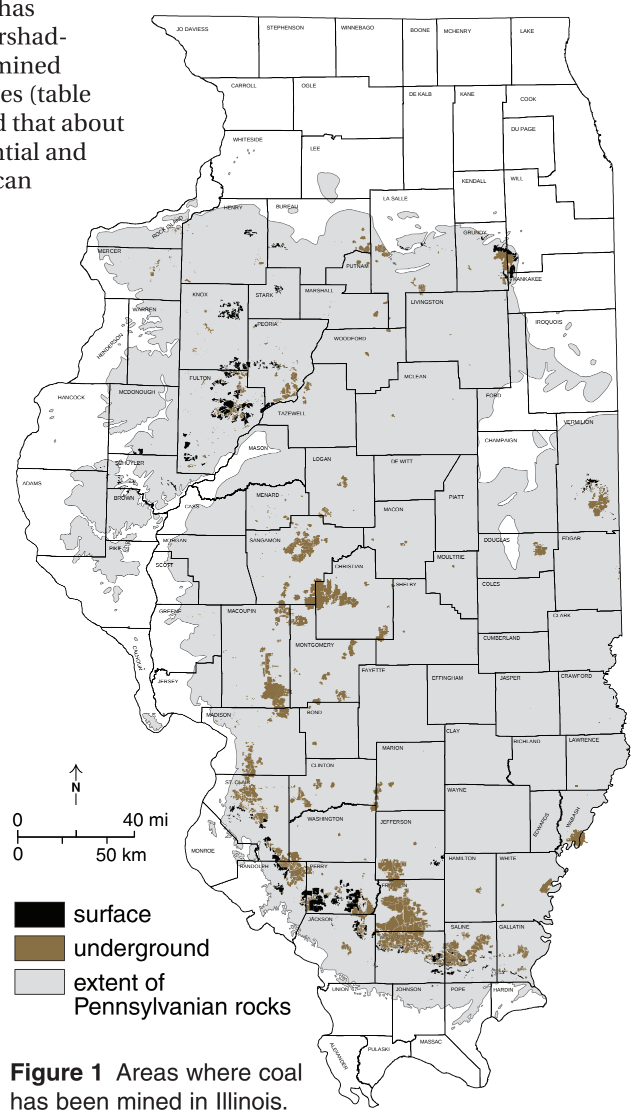


Figure 1 Areas where coal has been mined in Illinois.

From the ground surface downward, first are the windblown silts, called loess, in which Illinois soils have formed. Loess blankets most of the surface of the state. This silt material was blown out of the Mississippi and Illinois River valleys and was deposited across the Illinois land surface. Loess

Table 1 Underground mines producing industrial minerals and metals.

County	Mineral	Mine (no.)	County total
Adams	limestone	4	4
Alexander	ganister	2	6
	tripoli	4	
	clay[1]		
Calhoun	clay	5	5
Carroll	lead	2	2
Cook	dolomite	1	1
Du Page	dolomite		
Greene	limestone	1	1
Hardin	fluorspar[2]	130	131
	lead[2]	1	
	zinc[2]		
Henderson	limestone	1	1
Jackson	clay	1	1
Jo Daviess	lead[3]	93	102
	zinc[3]	9	
Johnson	limestone	1	1
Kane	dolomite	2	2
La Salle	clay	6	8
	limestone	2	
Livingston	clay	1	1
Mc Donough	clay	3	3
Madison	clay	2	4
	limestone	2	
Marshall	clay	1	1
Monroe	limestone	2	2
Pike	limestone	3	3
Pope	fluorspar[4]	51	58
	lead[5]	7	
	zinc[4]		
	barite[4]		
Randolph	limestone	3	3
Rock Island	clay	1	1
Saline	fluorspar[5]	2	2
	lead[5]		
Scott	clay	1	1
Union	clay	12	14
	tripoli	2	
Will	dolomite	2	2

[1] Two of the four tripoli mines also mined clay.
[2] Twenty-nine fluorspar mines also produced lead, ten produced zinc, and four produced lead and zinc.
[3] Fifty-four lead mines also produced zinc.
[4] Twenty-five fluorspar mines also produced lead, three produced zinc, two produced lead and zinc, and one produced barite.
[5] One fluorspar mine also produced lead.

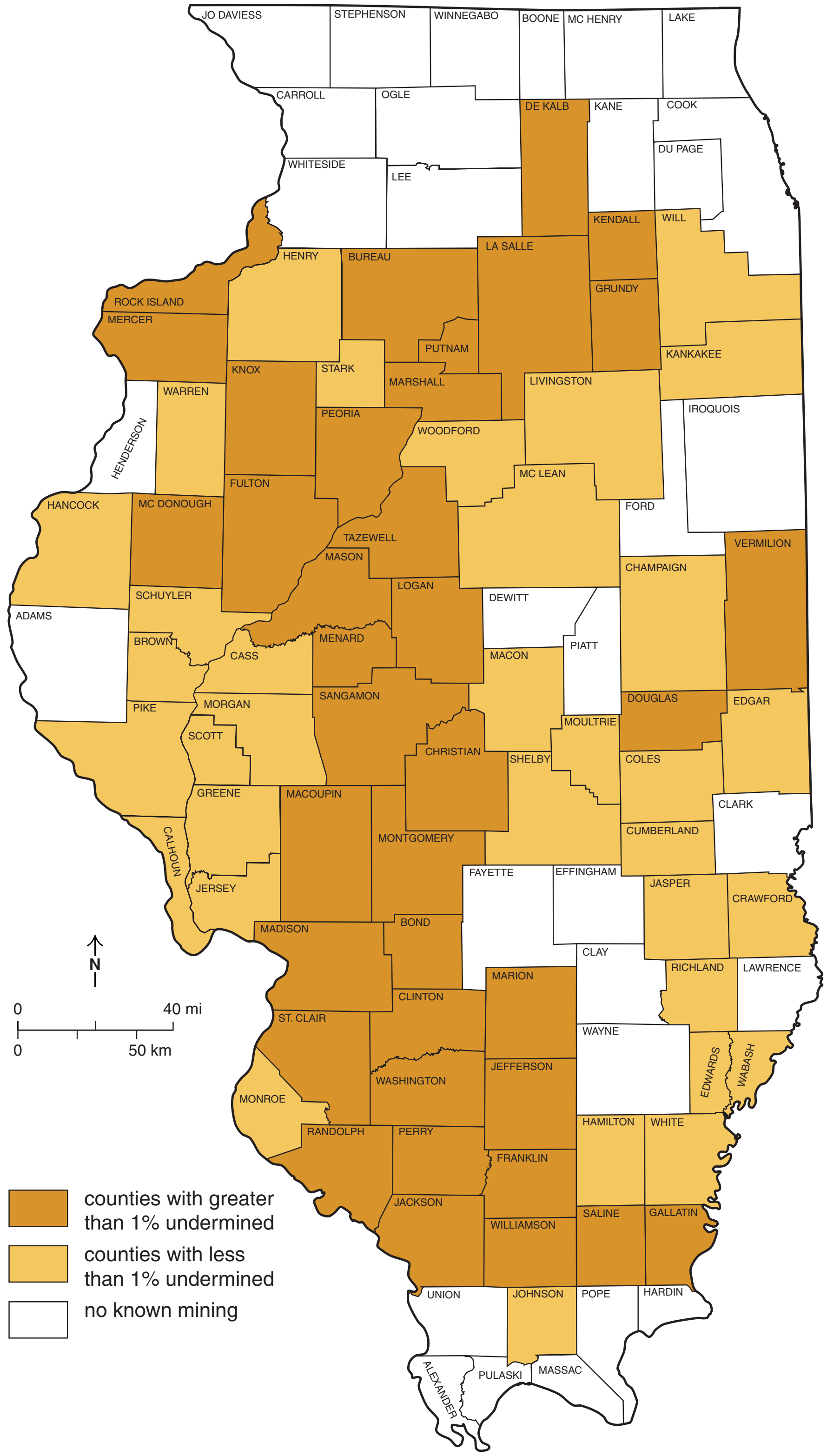


Figure 2 Counties of Illinois undermined for coal. Counties with undermined areas of 1% or more are automatically included in the mine subsidence insurance program.

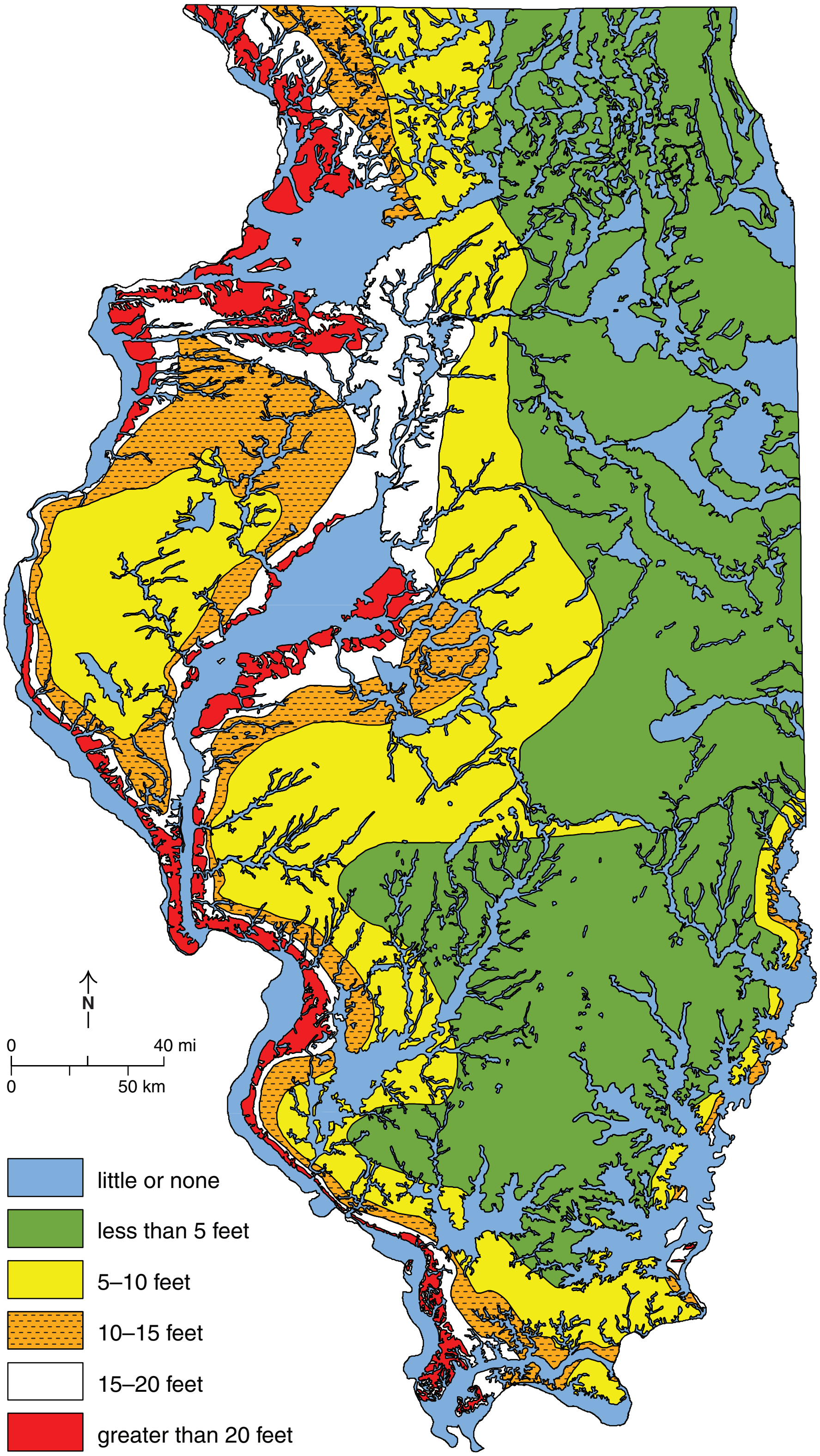


Figure 3 Total loess thickness in Illinois (Fehrenbacher et al. 1986).

ranges from less than 2 feet to about 25 feet thick (fig. 3), except in a part of southwestern Illinois where it may be as much as 100 feet thick near the Mississippi River valley. Below the loess are glacial materials deposited on top of the bedrock. These unconsolidated materials laid down by the moving or melting continental glaciers consist of sand, silt, clay, and gravel. These materials range from less than 10 feet thick to more than 300 feet thick over the areas mined for coal in Illinois. Beneath the glacial deposits is bedrock, the flat-lying or gently dipping layers of shale, coal, claystone, limestone, and sandstone (fig. 4). The layer below most Illinois coals is a soft claystone, also known as underclay.

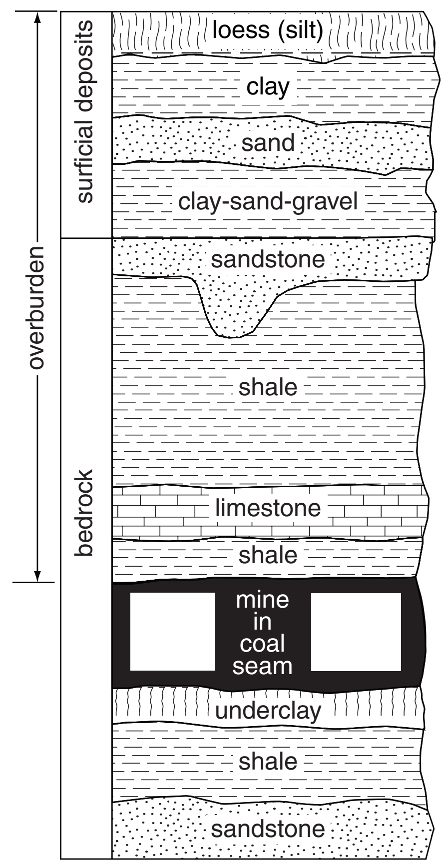


Figure 4 Generalized geologic column showing layers of surficial materials and underlying bedrock layers that are typical of the overburden of many coal mining areas.

Figure 5 Photograph of mining at the face in an early longwall mine. Note the rock support on the right side of photograph. These mines operated from the 1870s to 1951 in fifteen counties. Most were located in the northern counties from Bureau through Will (fig. 2).

Underground Coal Mining Methods

Surface mining, formerly called "strip" mining, accounts for about 15% of the state's current coal production. Although surface-mined land may settle, that settling is not called subsidence.

Much of Illinois coal lies too deep for surface mining and requires an underground mining operation. Two fundamental underground mining methods are used in Illinois: high-extraction (including longwall) and low-extraction room-and-pillar.

High-Extraction—Planned Subsidence

High-extraction mining methods (figs. 5 and 6) remove almost all of the coal in localized areas, and planned surface subsidence is part of the operation. The surface subsides above the mine within several days or weeks after the coal has been removed. The sinking or subsiding of the overburden over the mined-out area will continue for years. The initial large and rapid ground movements associated with this mining method diminish rapidly after a few months. Once subsidence has decreased to levels that no longer cause damage to structures, the land may be suitable for development.

There have been three main high-extraction mining methods used throughout the history of mining in the state: early longwall, high-extraction retreat, and modern longwall.

In the late1800s and early 1900s, longwall mines (figs. 5 and 6a) were excavated by hand, and workers maintained the haulageways (entryways) by placing stacked rock, wooden props, and rock-filled wooden structures to replace the support lost by the removal of coal. The mine roof and the rest of the overburden's weight settled onto the stacks of rock and compressed them. When this occurred, a few feet of subsidence resulted at the ground surface over the entire mined area.

Modern high-extraction systems are designed to achieve a high rate of production and maximize resource removal (fig. 6, b–d). The high-extraction retreat method, used from the 1940s through 2002, had miners remove as much coal as possible in an area within a panel until the roof started to collapse. The miners then retreated and formed the next row of pillars. This process was repeated as the miners worked their way out of the panel toward the haulageway. Roof collapse was controlled in those areas by the use of temporary roof supports. In this manner, relatively small areas were allowed to collapse as the miners retreated safely. Eventually, the entire panel was mined out, and the coalescence of collapsed areas caused the ground surface to lower.

In modern longwall mines, workers remove 100% of the coal along a straight working face within defined panels, up to 1 to 2 miles long and about 1,000 feet wide. The mine roof collapses immediately behind the moving roof supports, causing 4 to 6 feet of maximum subsidence on the ground surface over the centerline of the panel. This amounts to 60% to 70% of the mined height of the coal seam plus any roof or floor materials that have been removed along with the coal.

Low-Extraction Room-and-Pillar—Unplanned Subsidence

Using the room-and-pillar system, miners create openings (rooms) as they work. Enough coal is left in the pillars to support the ground surface. In Illinois, this system results in extraction of 40% to 55% of coal resources in modern mines and up to 75% in some older mines.

The design or layout of the rooms has changed through time. The room-and-pillar method that was generally used before the early 1900s was characterized by rooms that varied considerably in length, width, and sometimes direction (fig. 7a, b). To separate production areas (panels) from the main entries and to improve ventilation, mine operators devised the modified room-and-pillar or panel system (fig. 7c). This system provided a more regular configuration of production areas. The production panels were set back from the main entries. Well-defined boundaries were the result of the broad barrier pillars or unmined areas left between adjacent panels and between the panels and the main entries. Two room-and-pillar methods in current usage are the blind room and the checkerboard (figs. 7, d, e). Using the first method, miners bypass every sixth or seventh room of a production area. The unmined area (blind room) functions as a large pillar to support the roof. This method is still used today. The checkerboard system has evenly spaced square pillars in a checkerboard pattern forming very large panels.

Based on current state regulations, room-and-pillar mines in operation after 1983 that do not have planned subsidence approved as part of their operation have to show that they have a stable design. Although these permitting requirements have improved overall mine stability, no one can guarantee that subsidence will not occur above a room-and-pillar mine in the future. In general, if coal has been removed from an area, subsidence of the overlying geologic materials is always a possibility.

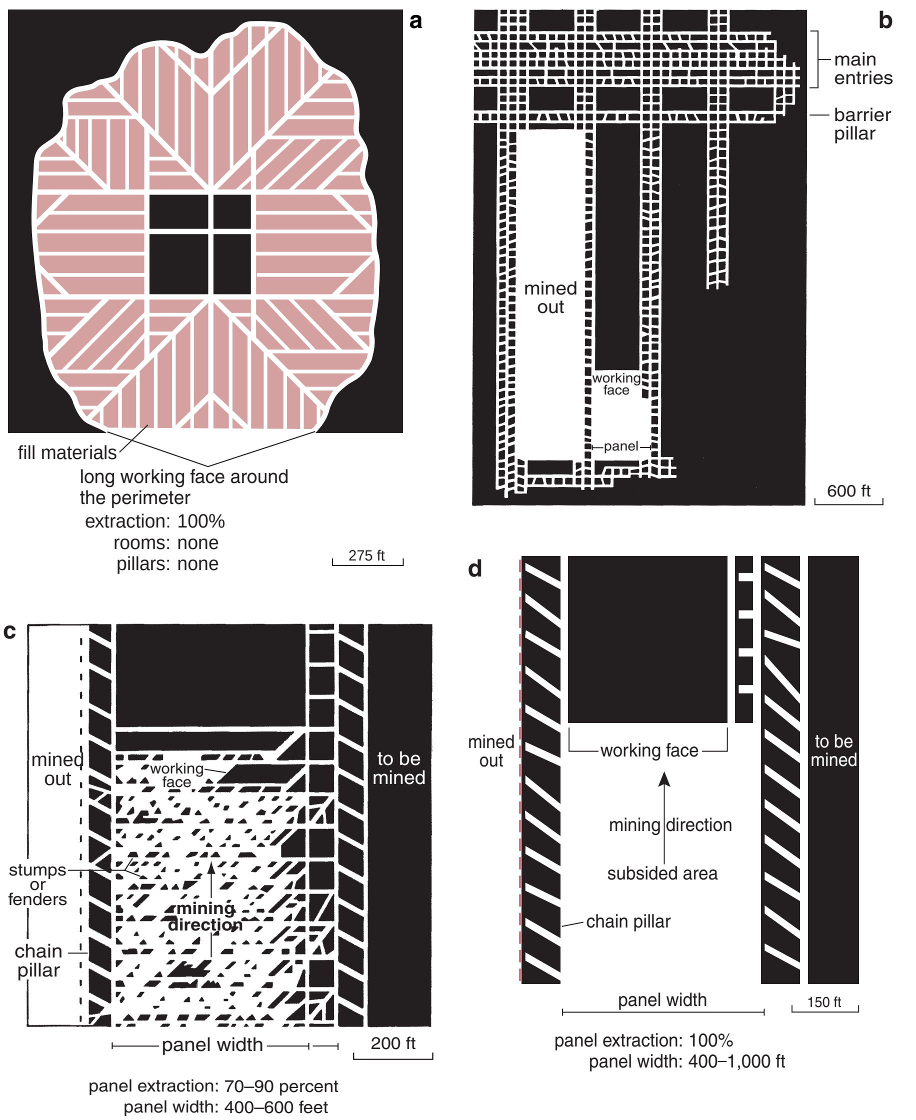


Figure 6 (a) Diagram of an early longwall mine design. Coal was removed starting from the center of the mine (shaft-entrance to mine level) outward along a continuous outside perimeter of the mine. Areas where the coal was removed were backfilled with rock support (see fig. 5) (after Andros 1914a). (b) Diagram of general development plan for modern high-extraction retreat and longwall mine (Hunt 1980). (c) Modern high-extraction retreat method: small stumps of pillars are crushed when roof collapses. Chain pillars may be mined to increase panel width (Hunt 1980). (d) Modern longwall method whereby all coal is removed along a straight mining face, forming a sharply defined panel with no remaining coal support except a row of pillars between panels (after Hunt 1980).

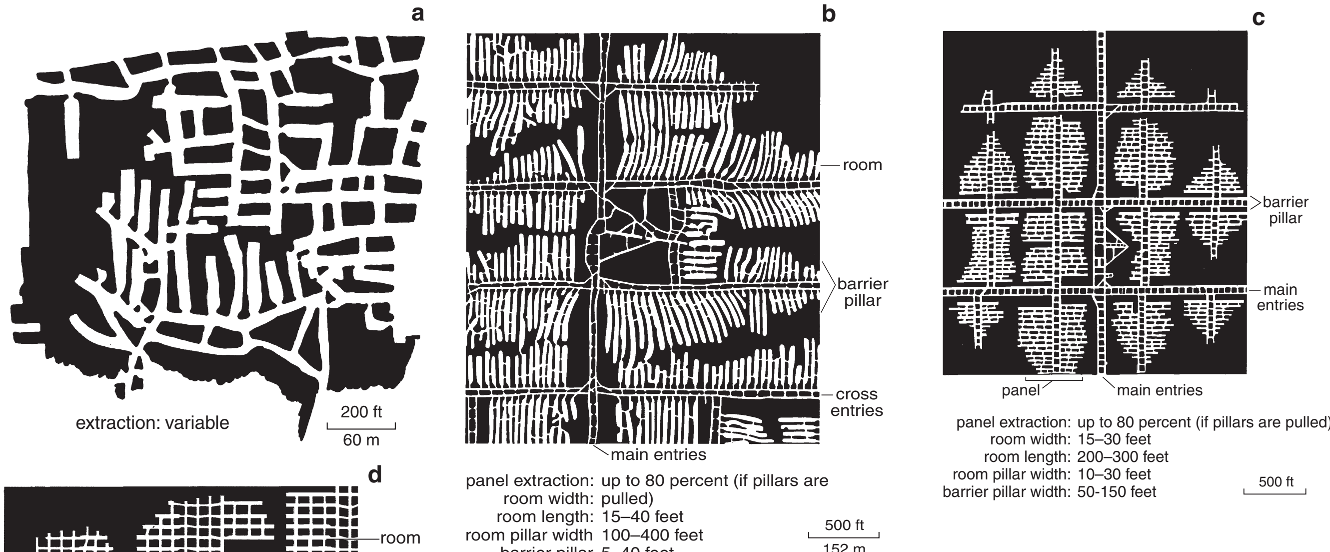
Mine Maps

Copies of original mine maps may contain detailed features such as shaft locations (the entrances to a mine), surface facilities, and location and size of coal pillars left in the mine. Original mine maps are used to accurately determine the type of mining performed in each area and to relate the location of mine features to surface structures. Illinois law requires that mining companies file maps and mining information with the State Mine Inspector, Illinois Department of Natural Resources, Office of Mines and Minerals, in Springfield and with the Office of the County Clerk in the county where the mine is located. These two offices are the official repositories for mine maps.

There are an estimated 5,500 underground coal mines in Illinois. Maps exist for about 2,600 of them. The Illinois State Geological Survey and the Illinois Department of Natural Resources, Office of Mines and Minerals, are continually searching for missing mine maps. If persons are aware of any sources of old mine maps, please contact the Survey or Office of Mines and Minerals to allow them to be copied.

Dangers of Abandoned Mines

Abandoned mines are extremely dangerous for a variety of reasons. Many old mines are partly collapsed or unstable, and thus inaccessible. Some are full of water. Others contain poisonous and/or explosive gases or have



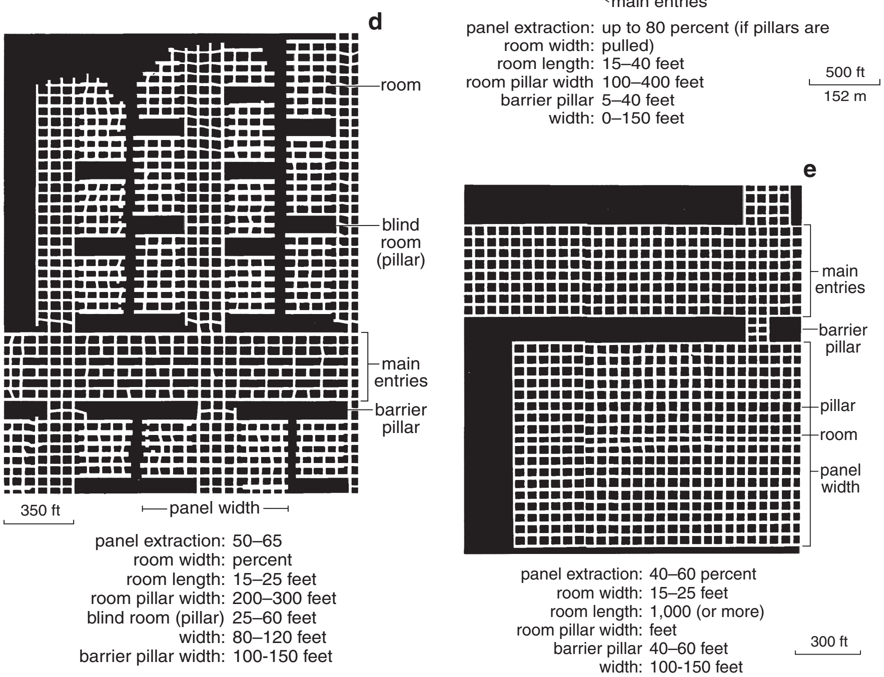


Figure 7 (a, b) Basic early room-and-pillar mining method; this irregular layout was typical of some early mines found mostly before 1910 (Andros 1914b). (c) Modified early room-and-pillar method with a more regular layout; panels were separated from each other and from main entries by solid coal pillars (Andros 1914a). (d) Modern blind room method, where every sixth or seventh room within a panel is left unmined (blind) for additional support of the overburden (after Hunt 1980). (e) Modern checkerboard method places large, evenly spaced square pillars in a checkerboard configuration (Hunt 1980).

too little oxygen to sustain life. Because abandoned mines are so dangerous, mine access requires the approval and supervision of the state mine inspector.

Types of Subsidence

Researchers have learned much about the nature and causes of subsidence by studying ground surface effects, drilling holes down into mines, lowering small television cameras down the holes to view mine conditions, and personally inspecting mines that are still operating and accessible. In Illinois, subsidence of the land surface takes one of two typical forms: pit or sag (trough).

Pit Subsidence

Pits are generally 6 to 8 feet deep and range from 2 to 40 feet in diameter (figs. 8 and 9), although most are less than 16 feet across. Newly formed pits have steep sides with straight or bell-shaped walls.

Pit subsidence mostly occurs over shallow mines that are less than 100 feet deep and where the bedrock over the mine is less than 50 feet thick and composed of weak rock materials such as shale. The pit is produced when the mine roof collapses and the roof fall void works its way up through overlying thin, weak bedrock and surficial layers to the ground surface. Pit subsidence forms very quickly. If the bedrock is only a few feet thick and the surficial deposits are loose, these materials may wash into adjacent mine voids, producing a surface hole deeper than the height of the collapsed mine void.

Sag or Trough Subsidence

Sag subsidence forms a gentle depression over a broad area. Some sags may be as large as a whole mine panel—several hundred feet long and a few hundred feet wide (fig. 10). Several acres of land may be affected. The maximum vertical settlement is gener-

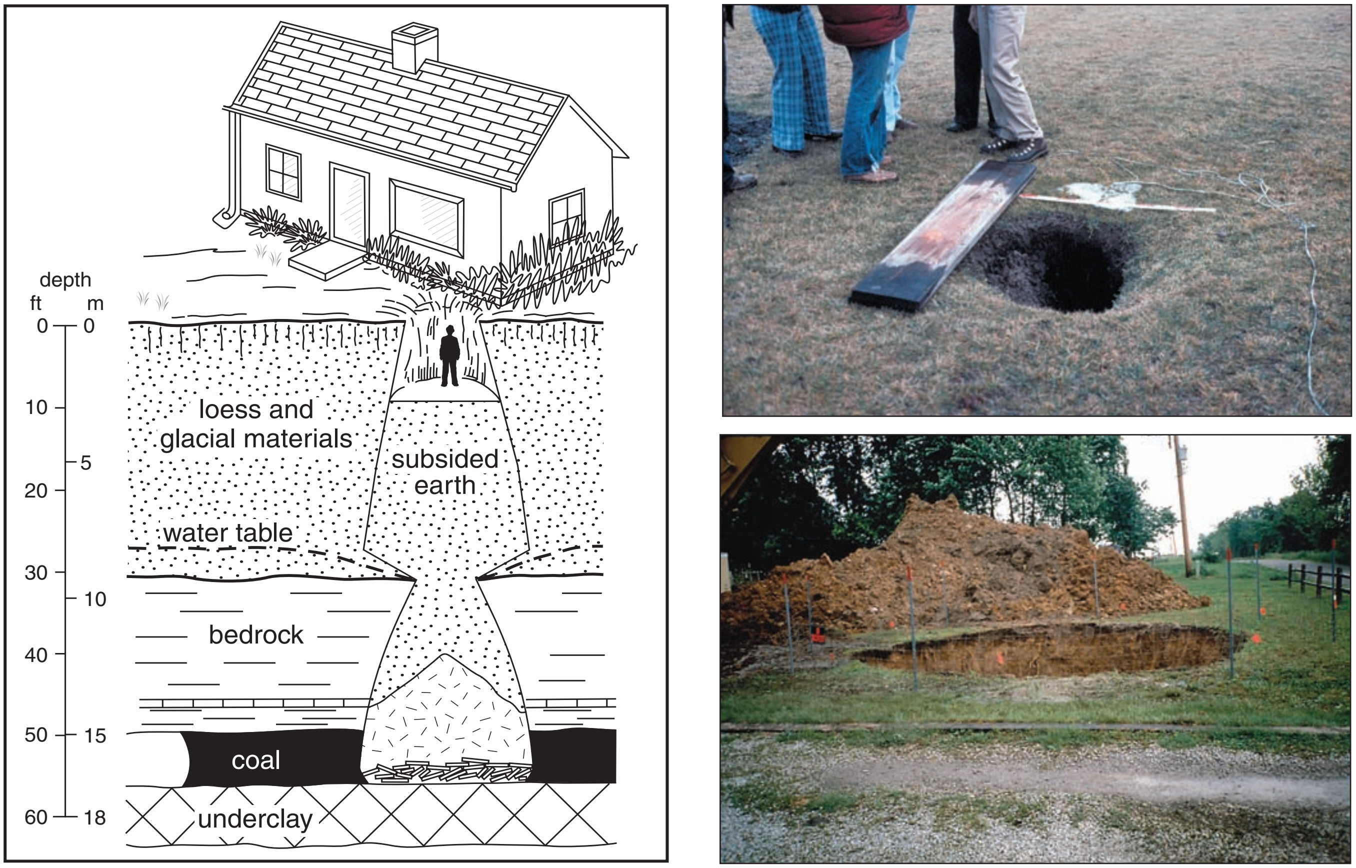


Figure 8 Diagram (Wildanger et al. 1980) and photographs of typical pit subsidence events.

Figure 9 Pit subsidence under the corner of a house from (a) above and (b) below ground.

ally near the center of the depression and is 2 to 4 feet deep (fig. 10).

A major sag may develop suddenly (in a few hours or days) or gradually (over years). The rate of sag development depends on the type of failure in the mine. Sags may originate over places in mines where the coal pillars have disintegrated and collapsed (fig. 11), producing a rapid downward movement at the ground surface or slower downward movements where the coal pillars are being pushed into the relatively soft underclay that forms the floor of most mines (fig. 12). Sags can develop over mines of any depth. The profile in figure 10 shows settlement that took place over 45 weeks.

Tension cracks form as the ground is pulled apart by downward bending of the land near the outside edges of the sag. Generally, the cracks parallel the boundaries of the depression. Near the center of the sag, compression ridges may form as the ground is squeezed by downward bending of the land near the bottom of the sag. Ridges are observed less frequently than tension fractures because the area of compression is much smaller.

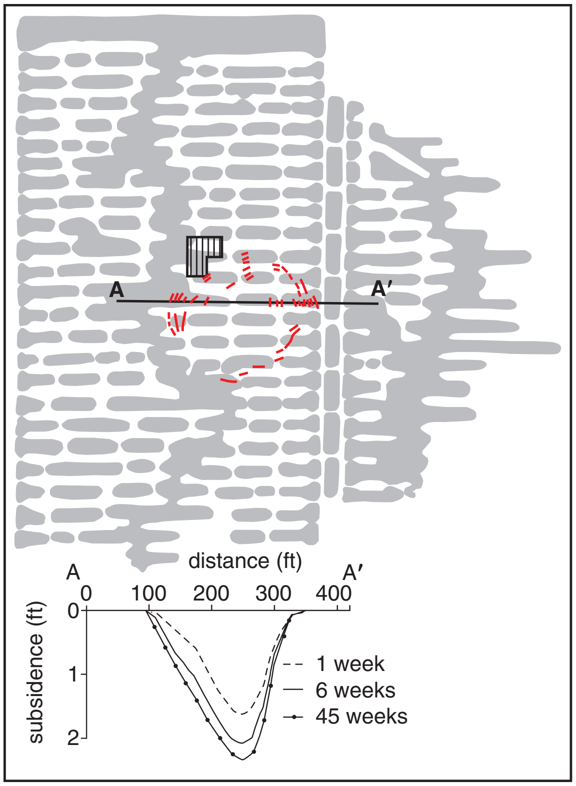


Figure 10 Sag subsidence shown on a map of the underlying mine. Profile A–A′ shows the sag developing. Compression ridges formed near the deepest part of the sag, and tension cracks (red lines) formed around the perimeter. (Data are from Dave Kiesling, Department of Civil Engineering, University of Illinois, personal communication 1981.)

Effects of Subsidence: Problems and Solutions

Pit Subsidence

When pits develop, the ground moves primarily in one direction: it drops vertically. Pits commonly appear after heavy rainfalls or snow melts. Water seldom accumulates in the pit. Instead, it drains down into the mine. A common treatment is to fill the pit with clayey soil and to compact the clay as tightly as possible so that its permeability is very low. The idea is to prevent soil from eroding down into the mine by discouraging water from collecting and draining into the mine through the repaired pit subsidence. Many pits have been permanently filled this way.

Structures can be damaged if pit subsidence develops under the corner of a building, the support posts of a foundation, or another critical spot. Otherwise, the probability of a structure being damaged by pit subsidence is low because most pits are relatively small—only a few feet across. If pit subsidence develops under foundation walls, the house may not be affected immediately because the foundation may temporarily bridge the pit (figs. 8 and 9). Left unfilled, the structure (bridge) may become damaged from lack of support.

Homeowners living where pit subsidence is common should periodically inspect crawl spaces and other hidden areas of their homes. When a pit is discovered below a foundation, the pit should be carefully filled so that proper support is again established.

Subsidence pits that are not filled pose a special danger for both people and animals. They are often deep and steep-sided. Anyone who falls in may find it very difficult to get out.

Sag Subsidence

The ground moves in two directions during sag subsidence (figs. 13 and 14). The ground drops vertically and moves horizontally toward the center of the sag. At the surface, the sag may be much broader than the collapsed part of the mine. For example, a failure in a mine 160 feet deep could cause minor surface subsidence more than 70 feet beyond the edge of the collapsed area underground (edge of panel). The deeper the mine, the larger the area affected out over the unmined area. Collapsed areas in abandoned underground mines may occur in only part of a panel or mined-out area (fig. 15).

Sag subsidence produces an orderly pattern of tensile features (tension cracks) surrounding a central area of possible compression features. Mapping the direction of how the cracks pulled apart shows that the movements point toward the center of the sag. Sub-

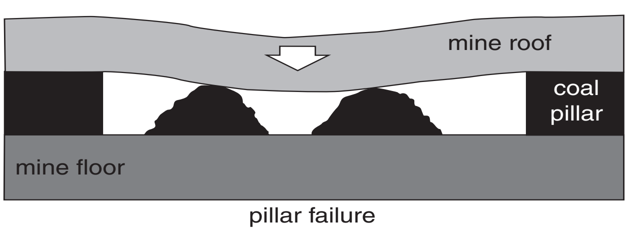


Figure 11 Diagram of a failure of pillars that results in lowering of the ground surface.

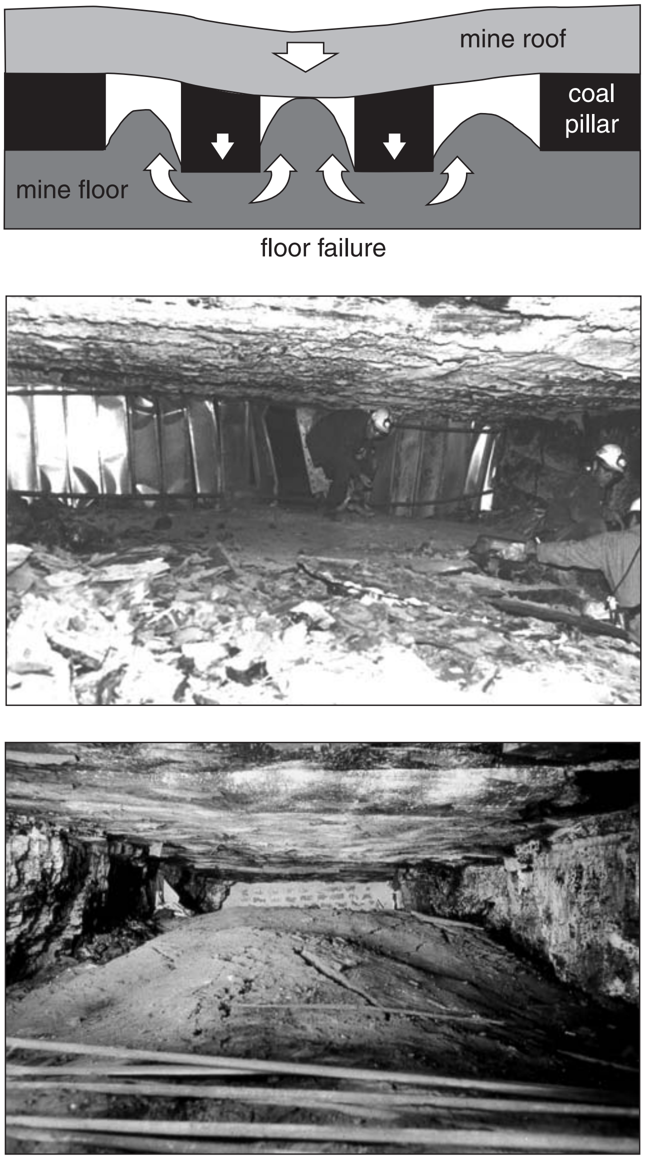


Figure 12 Diagram and photographs of coal pillars being pushed into a soft floor. The claystone material is being squeezed out from under the pillar up into the entryway.

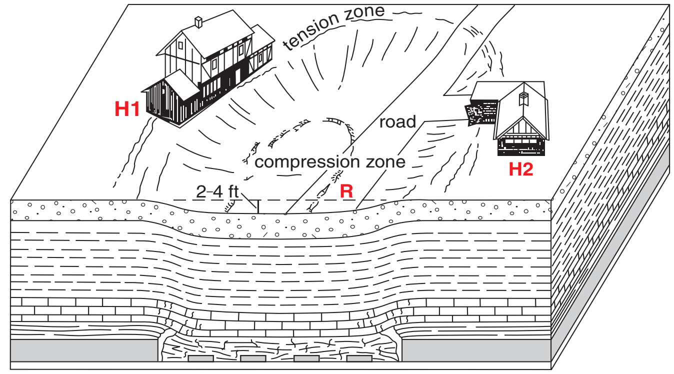


Figure 13 Block diagram of a typical sag subsidence event. The road is in the compression zone (located at R), and asphalt has buckled. The wood frame house (H1) is in the tension zone; the house's foundation has pulled apart and dropped away from the superstructure in one corner. A brick house (H2) in the tension zone shows cracks in walls, ceilings, and floors.

sidence movements are not selective—all structures (buildings, sidewalks, driveways, fences, streets, curbs, etc.) within a sag will be affected and move toward the center of the event.

The type and extent of damage to surface structures relate to their orientation and position within a sag. In the tension zone, the downward-bending movements that develop in the ground may damage buildings and roads as well as driveways, sidewalks, sewer and water pipes, and other utilities. The downward bending of the ground surface causes the soil to crack, forming the tension cracks that pull structures apart. The lowermost portion of the house foundation will be pulled apart where it is in contact with the soil. Houses H1 and H2 (figs. 13 and 14) show cracking and separation caused by tension throughout their structures. Until subsidence has ceased and repairs can be made, house H1 needs to be entirely supported. Damage in house H2 will be restricted mostly to the lowered side, so that only this side may need support.

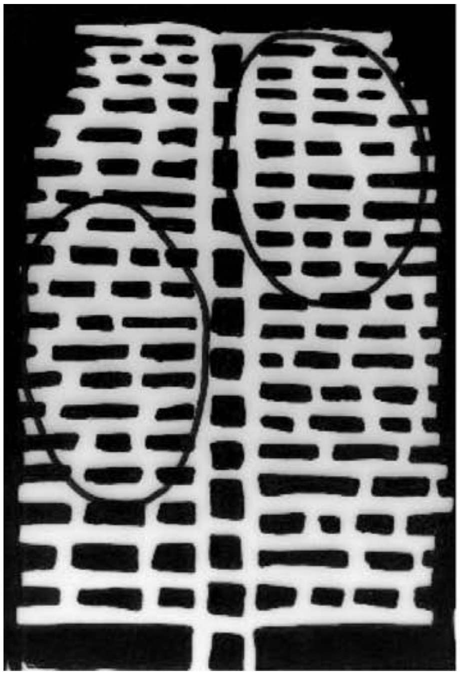
In the comparatively smaller compression zone, roads (fig. 13, R) may buckle, and foundation walls may be pushed inward. The foundation of any house in the center of the sag would be subjected to horizontal compression. Buildings damaged by compression typically need their foundations rebuilt. They may also need to be leveled due to differential settling.

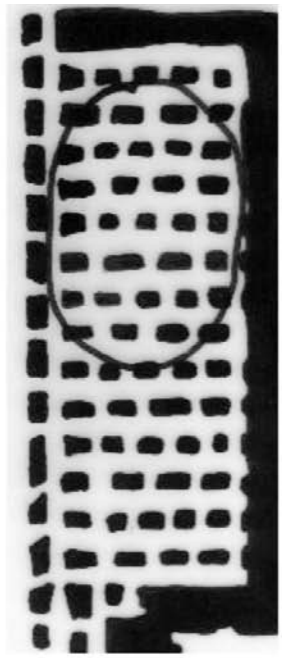
Repair of Subsidence-Damaged Houses

A house may be built on a slab, on footings with a crawl space, or on a basement. Each type of construction requires a different type of treatment for subsidence damage. Permanent or rigid repairs are not advisable until subsidence-related ground movements have been completed. Premature, rigid repairs may exacerbate damages and may break again, resulting in additional financial loss. Temporary repairs, such as weather proofing or making a door functional, should be flexible and be made to accommodate additional movement. It may be necessary to make temporary repairs several times in cases involving large ground movements. The repair of most structures requires detaching the house from the slab or foundation to relieve stress to the frame and to allow re-leveling. The re-leveling technique is unique to each home in order to account for its damage and structural characteristics.

Houses on slabs Some houses are supported by broad, flat concrete pads called slabs or slab-on-grade construction. Areas around the outside edge of the slab and under other supporting

Figure 14 Photographs illustrating the sag subsidence event and features shown in figure 13. (a) Compression ridges formed in the road (feature R) as the result of ground movement (compression) associated with coal mine subsidence. (b) Tension cracks form in the ground surface extending through a home (feature H1); the foundation has settled at the house corner close to the center of the sag. (c) The brick-sided house (feature H2) in the tension zone shows downward bending (compare roof lines). The left side of the home is closest to the sag center and has dropped down. Insert: Ground has pulled away from the porch toward the sag center (left).





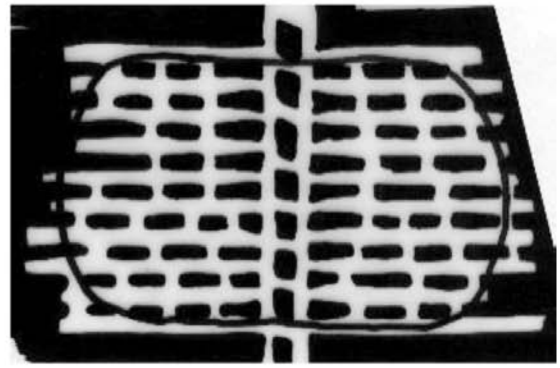


Figure 15 Mine panels containing areas that have collapsed or failed in part. Circled areas represent the extent of the subsidence feature on the ground surface.

interior walls should have foundation walls extending downward from the slab into the soil to below the frost line (where the soil may freeze). The frame of the house is usually attached to the slab with bolts. If subsidence occurs, the slab settles, and the frame is pulled downward.

In many instances, the settlement and resulting damage associated with coal mine subsidence to slab-on-grade homes is sufficient to require leveling the slab and walls as a unit if possible. If not, restoring such a house to a level position may require detaching the house from the slab and raising the frame. Typically, the bolts attaching the frame to the slab can be difficult to find and remove because they are located within the walls. Once the bolt connections are severed, the frame can be raised and leveled, and the walls can be supported until a new foundation can be constructed.

In its raised state, separation between the walls and the floor slab may be sizeable. The home interior may be exposed to the outdoors (fig. 16), which presents security and weatherization problems until a new, level floor is installed. Grading and pouring a new floor cannot be done until subsidence and settling of the ground ends, which may be a year or more. The elevation of the ground around the house can be measured periodically to determine when movement has decreased enough that further damage is no longer expected.

Houses with crawl spaces Some houses are supported by perimeter footings with foundation walls (and interior piers when necessary) so that a crawl space is created between the floor and the ground surface. Bolts attaching the foundation to the wood frame are generally visible and accessible within the crawl space. Once the house is detached from its foundation and support beams are placed under it, the house can be raised to a level position. If foundation walls are constructed of concrete blocks, sections of the wall may be easily removed so that supporting beams can be inserted under the superstructure (frame) of the building (fig. 17). The family can usually continue to occupy the house because the floor is attached to the frame and raised along with it. Typically, temporary steps are constructed to allow access.

Houses with basements In some houses, support is provided by basement walls and, where necessary, interior piers with posts. Subsidence may cause cracks in the basement floors and walls of such houses. If the exterior waterproofing is cracked, water may occasionally enter through the foundation wall.

If basement walls are constructed of concrete blocks or bricks, the blocks or bricks can be easily removed from the walls to allow beams to be inserted under the superstructure (frame) for leveling. Basements with poured concrete walls may present more difficult problems in leveling. For example, basement windows may not be large enough or in the best locations to allow support beams to be brought in and put into position under the frame of the house. Breaking or cutting through poured concrete basement walls can be time consuming and costly. Basements, do, however, allow room for access below the superstructure so that solutions can be devised for each house. Assuming that it is necessary to provide additional support for safety or damage mitigation purposes, the use of the basement as living space can be severely curtailed.

Brick or masonry structures
Houses built with brick exterior siding or other masonry structures will show cosmetic cracks after only small differential movements occur. Large move-

Figure 16 Load-bearing walls of a garage on a slab. The entire superstructure (frame) has been raised to a level position, exposing the interior of the garage. This re-leveling eliminates damaging stresses from differential movements of the foundation and maintains the superstructure level throughout the life of the event.

ments beneath of structures that have full masonry walls may render those structures unstable. A structure with brick or concrete block walls, unlike wood frame walls, generally cannot cantilever or extend over a subsided (lowered) foundation without supplemental support. Expensive remedial measures may be necessary to develop suitable support for heavy masonry structures.

Effects on Utilities and Drainage

Subsidence-related ground movements may also cause damage to water lines, gas lines, sewer lines, telephone lines, electrical wires, and cable TV lines. If utility poles tilt or sink, power and other lines may sag or pull from the poles. In turn, this may drop electrical wires from the poles and create another hazard.

Gas leaks are rare but pose the greatest hazard because an explosion can occur if the gas is allowed to accumulate. If a gas leak is noticed, leave the structure immediately. Do not turn any electrical appliances, including lights, on or off. Phone the local gas utility company or fire department from outside, away from the gas lines and meter, or call from a neighboring property. Flexible piping can be installed between the outside meter and the home to accommodate movements. Water leaks from a

Figure 17 Concrete blocks of a crawl space have been removed to make room to jack the house to a level position. I-beams support the re-leveled house.

broken water main are more common and are usually the first noticeable evidence of major subsidence. Leaking water or sewer pipes cause additional problems by saturating the ground around a foundation or washing soil from under the house, especially in areas with moisture-sensitive soils.

Water can also pond in a sag subsidence event (fig. 18). If any part of a house is in a sag, an attempt should be made to keep water from accumulating around and under it. The ground surrounding the foundation must be kept well drained because excess moisture can cause additional foundation support problems.

Conditions That May Be Mistaken for Mine Subsidence

Soil conditions, tilting floors, support problems, and brick expansion can produce damage that may be mistakenly attributed to mine subsidence (Bauer 1983; Bauer and Van Roosendaal 1992).

Figure 18 Ponding created by sag subsidence. Note the tension cracks around the edge of the depression.

Soils

Shrinking and swelling Moisture-sensitive soils expand when wet and shrink when dry. Many decades of cyclic wetting and drying build up pressure against basement foundation walls as soil and other debris fall into the space between the foundation wall and the dry, shrunken soil. Pressures build until basement walls are pushed inward, forming horizontal cracks that continue across the length of the wall until they propagate downward in a stair-step pattern near the corners. Often these cracks form on all walls but tend to be more severe along the longer, load-bearing walls of rectangular-shaped homes. Typically, these horizontal cracks form a foot or more below the ground surface. If the walls move inward an excessive amount, the floor of the house may drop and tilt (fig. 19).

Reduced load-bearing support of the soil can cause foundations to tilt or sink at the corners (fig. 20). To avoid problems, homeowners should take measures to keep excessive amounts of water away from foundation walls. Downspouts should discharge water several feet from the house. The soil should be built up around the house and graded to slope away from the foundations so that water will then drain away from the house. The cracks produced in foundations by this rotating downward movement of the corner are wide at the top of the foundation and decrease to a nearly hairline crack near the base (footing) of the founda-

Figure 19 Basement damage unrelated to mine subsidence. Damage was caused from decades of seasonal wetting and drying of soils, which built up pressure against the basement foundation walls. With each cycle, dryness allows fine grains of soil to fall into the gap between the soil and the foundation wall. When moisture returns, the soil expands, increasing pressure until the wall fails and is pushed inward.

tion. This pattern is in contrast to that from subsidence, which produces cracking that shows the foundation is being pulled apart at its base where it rests on the soil.

Trees or large shrubs growing near foundations tend to alter soil moisture conditions to a considerable depth. The water contents of the soil can be lowered significantly during a drought when plant roots absorb so much of the available water that the soil shrinks from reduced moisture content. When soil shrinks below the foundation, it may cause plants to sink or tilt outward. When moisture returns, the soils may expand enough that some cracks partially close, only to reopen again during another extremely dry season.

Freezing and thawing As some poorly drained soils freeze and thaw, they expand and contract in a manner similar to that of moisture-sensitive soils (fig. 21). Proper drainage through the use of granular materials (e.g., gravel) can reduce the potential for frost heave. These materials should be used beneath unheated garages, outbuildings, breezeways, driveways, and other structures that are most likely to be affected. Typical signs of heaving are found during extremely cold weather when soil and slabs push upward, causing problems with closing or opening of doors.

Foundation footings that are not installed below the "frost line," where ground freezing may occur during winter, may also see movements in the foundation throughout the year, especially during extreme cold spells. These sections may also heave upward in relation to deeper foundations.

Figure 20 Foundation sinking at the corner of building due to reduced support caused by excessive, repeated moisture changes. Note gutter drainage (arrow) and lack of downspout to channel drainage away from foundation.

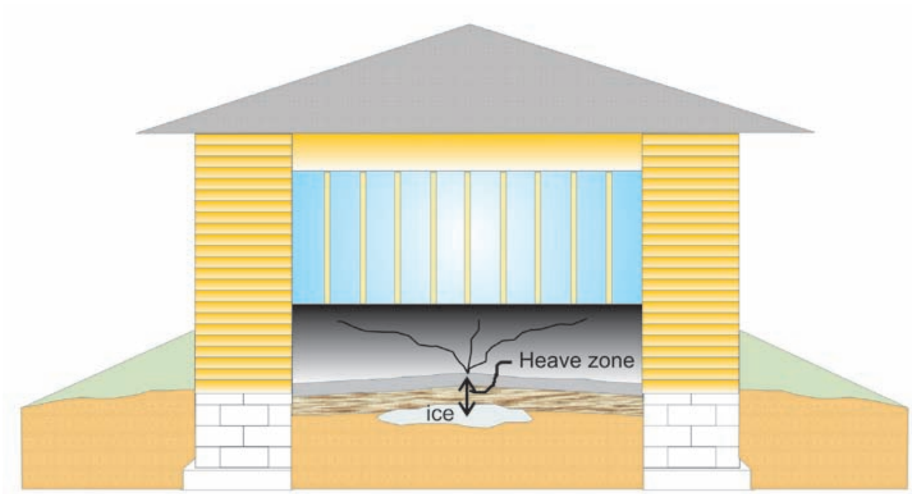


Figure 21 Diagram showing one example of frost heave for a garage floor.

Piping Piping, or subsurface erosion from water washing away fine-grained soil, can occur along broken or separated sewer lines, water lines, old farm tile, and buried downspout extensions (fig. 22). Older drainage systems around the outside base of the foundation—the peripheral drainage system—slowly remove soil particles and lower the ground surface around the house (fig. 23). This removal causes sidewalks, stairs, and patio slabs located along the foundation to drop and tilt toward the house (fig. 24).

When a broken or separated water or sewer line is carrying a high flow, water surges out of the broken pipe and saturates the soil. When the flow is low, water in the saturated soil flows back into the sewer pipe and carries some soil particles with it. This process may excavate a cavity around the line, and the cavity may become large enough to reach the surface, where a hole appears. More often, the piping process slowly lowers the ground surface and causes a depression. A linear depression may occur along the length of the sewer or water line. Piping especially occurs in the highly erodible loess that covers most of the state (fig. 3). Piping depressions are much smaller than subsidence sags and are found near sewer and water lines.

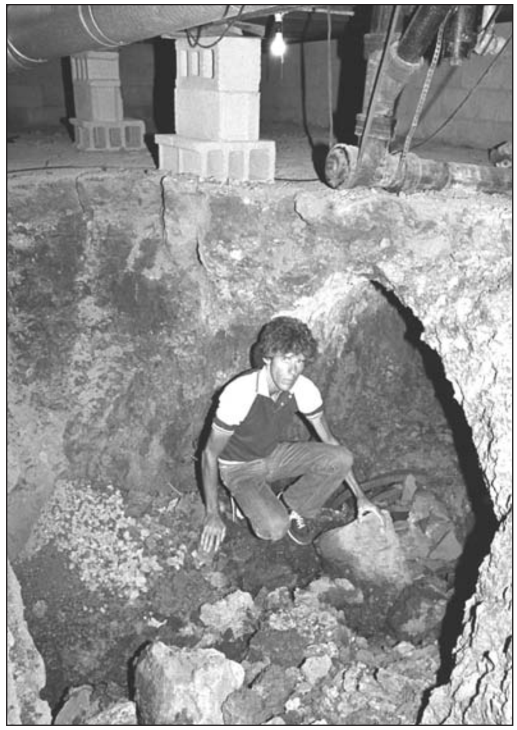


Figure 22 An extreme example of soil piping in a home crawl space. Soil was removed by moving water associated with farm drainage tile. Reproduced by permission of The News-Gazette, Inc. Permission does not imply endorsement by the newspaper. Originally published September 11, 1983.

Tilting Floors and Problems with Supports

Vertical intermediate supports for the main beam of a house may sink if they do not rest on properly sized concrete footings. Many times concrete blocks are used in crawl spaces to support the main beam running down the center of the house. Sometimes these blocks are resting directly on the soil, and, because they do not provide enough bearing area, they will sink into the soil. If there is inadequate contact area between a beam and a vertical support, enough weight can be concentrated onto the beam to crush it, thus lowering the floor. Also, if a thick stack of shims has been used between the beam and the vertical support, the shims may compress, lowering the beam (fig. 25). The ends of the main beam should rest on the foundation walls to reduce the likelihood of the beam moving a different amount than the foundation and causing cracks to develop in the walls above this location. Insufficient spacing and floor joist size can result in sagging floors, a condition sometimes mistaken for subsidence.

Brick Expansion

Clay bricks are smallest when they are new. Bricks continue to expand over time. The amount of brick expansion depends on a large number of variables such as temperature of firing, type of clay content, and various brick additives. Some bricks may expand up to 0.1 to 0.2% within four years (Hosking et al., 1966). This expansion may add up to over 1 to 2 inches or more for a 100-foot-long continuous brick wall with no expansion joints (or joints not functioning properly) and stiff mortar. This amount of cumulative movement is enough to be noticeable and generate enough pressure to cause damage.

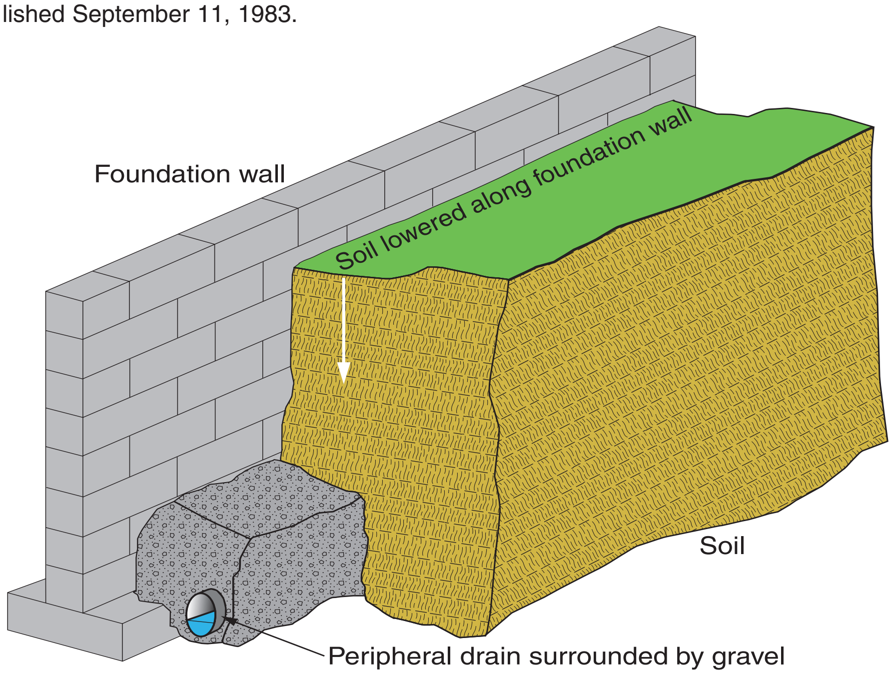


Figure 23 Diagram of a peripheral drainage system around some exterior foundation walls. Over time, the drainage system removes small amounts of soil and lowers the ground surface along the foundation.

Figure 24 A moat-type depression along the foundation wall and lowered sidewalk and patio slabs caused by the kind of peripheral drainage system shown in figure 23.

Figure 25 This main beam is not attached directly to the foundation wall. Because the beam is settling a different amount than the foundation and because some of the thick layers of shims are compressing, cracks have developed in the house above the beam.

This type of damage is commonly associated with long continuous expanses of brick usually found above or below windows or above doors of buildings. Movement increases from none near the center of the brick expanse to the greatest at the edges of the length of the wall (fig. 26). This movement difference occurs because small changes in each brick push adjacent bricks toward the unconfined edge of the wall. Damage is usually at the top of door frames, which move horizontally with the expanding wall in one direction in relation to the bottom of the door frame (fig. 27). This type of movement may result in the brick wall sliding slightly off the foundation at a corner (fig 28); weaker materials in the wall, such as glass blocks, may be crushed (fig. 29), and the sliding wall may become separated from the interior floor slab. To minimize this type of problem, functioning expansion joints should be incorporated into the construction. Expansion joints should be clear of any hard materials that may have fallen in during construction, and pliable caulk should be used to seal the gap.

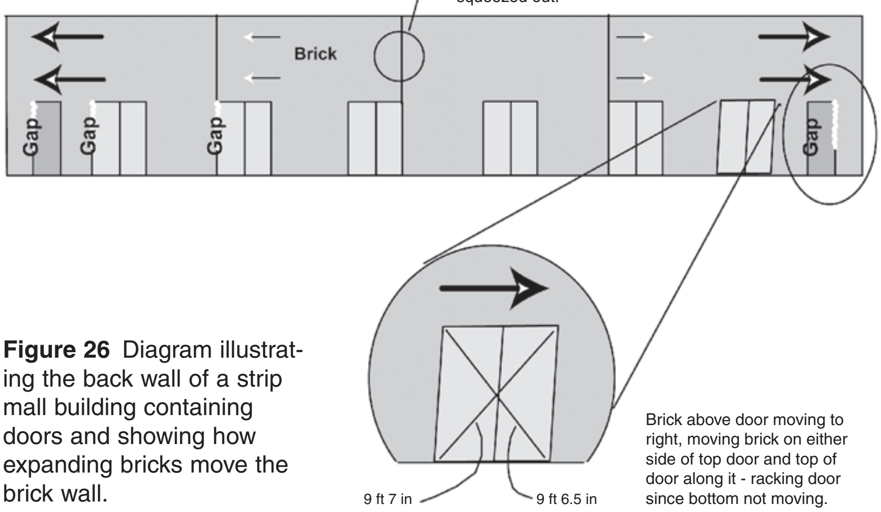


Figure 26 Diagram illustrating the back wall of a strip mall building containing doors and showing how expanding bricks move the brick wall.

Figure 27 The long continuous length of brickwork above the door is expanding, pushing the top of the door frame to the right while the base of the door remains stationary. This movement creates the gap and causes the door to stick while opening and closing.

Disclosure of Previous Mine Subsidence Claims

The Mine Subsidence Disclosure Act of 1989, which became effective on January 1, 1990, allows a buyer to find out if an owner of the property has been paid for mine subsidence damage on the property. The act states that, at the time an agreement to transfer property is made, the owner shall disclose in writing to the buyer and lender all insurance claims paid to the owner for mine subsidence damage on the property.

Property Tax Relief

Some counties offer property tax relief for homes that have been newly damaged by coal mine subsidence. Counties offering tax relief typically require the property owners to protest their taxes and to provide a written report or letter certifying that the damages are subsidence related. Such letters can be obtained from either the Office of Mines and Minerals or the Mine Subsidence Insurance Fund.

Considerations for Mine Subsidence Insurance

The purchase of mine subsidence insurance may be advisable to protect property lying above or near an undermined area or an area soon to be mined.

Homeowners in counties where 1% or more of the land has been undermined (fig. 2) will automatically have subsidence insurance added to their policies when issued. Those individuals refusing coverage will be asked to sign a waiver.

Figure 28 The largest movements are at the edges of the long continuous wall. At this point, the brick wall is being pushed off the foundation.

Insurance agents can describe the mine subsidence insurance program and outline the coverage available. For more information, contact the Illinois Mine Subsidence Insurance Fund headquarters in Chicago. (See Contacts for Additional Information section, p. 19.)

The county clerk's office may be one place to learn about local mining activities. That office may have a map showing general outlines of the underground mines. For general information on coal mines in Illinois, contact the Illinois State Geological Survey in Champaign. The Survey can provide digital copies of original mine maps for some mines. The Survey can also provide county maps (table 2) showing active and abandoned mines and their known extent at a 1:100,000 scale (1 inch on the map represents 1.6 miles on the ground). Township, range, and section lines are included. The county directory of coal mines accompanies each map and lists company names, mine names and numbers, type of mining method used, years operated, coal seam mined, and mine entrance location. Also, some areas have much more detailed outlines of the mines superimposed over topographic maps (1 map inch represents 2,000 feet). The directories that accompany these maps contain more detailed information, such as depth of underground mines, than is available in county directories. Both the county-scale and topographic-scale maps can be viewed on the Illinois State Geological Survey Web site at www.isgs.uiuc.edu/coal sec/coal/index_online pubs_coal.htm.

A report on the state's subsurface operations for minerals other than coal (Cook, unpublished notes, 1979) is on file at the Illinois State Geological Survey library.

Finally, assistance is available from the Illinois Department of Natural Resources, Office of Mines and Minerals, in Springfield. This office is the repository for the original, detailed coal mine maps in the state. The Office of Mines and Minerals also issues mining permits for active and proposed coal mines. All questions concerning active mining and subsidence or mine stability should be directed to the Land Reclamation Division.

What If Mine Subsidence Damage Occurs?

Help is available. Any homeowner with subsidence insurance coverage who suspects property damage due to mine subsidence should immediately call his or her insurance agent, who will have the property examined.

If there are life safety concerns associated with past mining activity, the property owner should contact the Illinois Department of Natural Resources, Office of Mines and Minerals, Abandoned Mined Lands Division. After a brief phone interview, a team can be promptly dispatched to investigate the concerns if warranted and desired by the property owner. If conditions prove to be (1) life threatening and (2) mine related, Abandoned Mined Lands staff will seek federal funds to abate the hazardous conditions. Funds appropriated by the U.S. Congress can be made

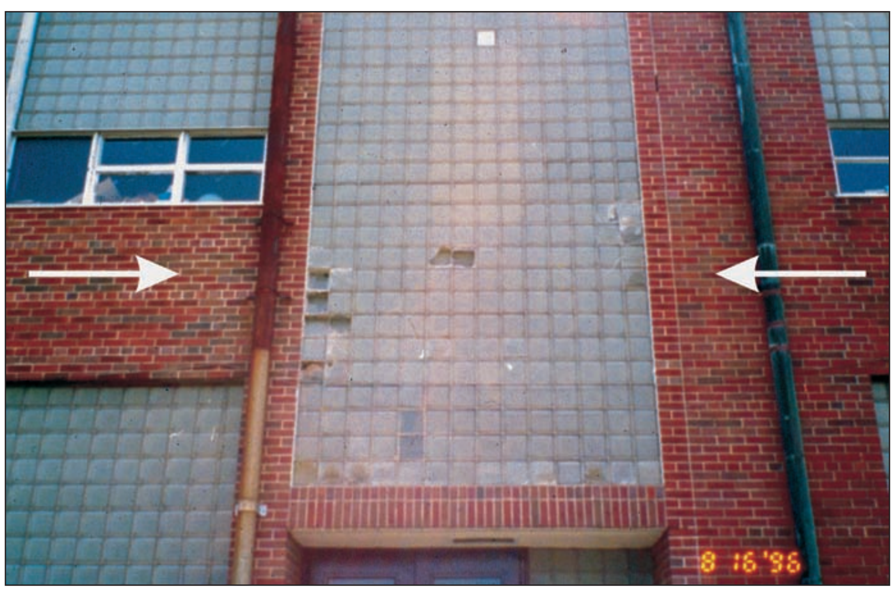


Figure 29 The long, continuous brickwork intersects the vertical glass block wall. Pressures have broken the glass blocks in line with the long continuous expanse of brick work.

Table 2 County maps and directories of Illinois coal mines.

Adams	Jackson	Perry
Bond	Jasper	Pike
Brown	Jefferson	Pope
Bureau	Jersey	Putnam
Calhoun	Johnson	Randolph
Cass	Kankakee	Richland
Champaign	Knox	Rock Island
Christian	La Salle	St. Clair
Clay	Lawrence	Saline (3)[1]
Clinton	Livingston	Sangamon
Coles	Logan	Schuyler
Crawford	McDonough	Scott
Cumberland	McLean	Shelby
Douglas	Macon	Stark
Edgar	Macoupin	Tazewell
Edwards	Madison	Vermilion (2)[2]
Franklin	Marion	Wabash
Fulton	Marshall	Warren
Gallatin (3)[1]	Menard	Washington
Greene	Mercer	White
Grundy	Monroe	Will
Hamilton	Montgomery	Williamson (3)[1]
Hancock	Morgan	Woodford
Hardin	Moultrie	
Henry	Peoria	

[1] Herrin Coal, Springfield Coal, miscellaneous coals.
[2] Danville Coal, Herrin Coal.

available through the Office of Surface Mining Reclamation and Enforcement to be used in abating life-threatening conditions associated with abandoned coal mines. These funds cannot be used for damage repair but are readily available for life protection measures such as providing structural support bracing when necessary, filling of large holes caused by shaft openings or pit type subsidence events, and sealing or venting of dangerous mine gas accumulations. Often the work associated with hazard abatement serves to reduce or control future damages.

If the insurance agent or the Abandoned Mined Lands Reclamation Division finds that a home is not subsiding because of a mine, they may be able to suggest the cause of the problem and, in general, whom to contact. The insurance assessment does not require an investigation into the ultimate cause for the damage; it only determines whether the damage is caused by coal mine subsidence.

Contacts for Additional Information

Illinois Mine Subsidence Insurance Fund
130 E. Randolph Dr., Suite 1130
Chicago, IL 60601-6223
800-433-6743
www.imsif.com

Illinois Department of Natural Resources
Office of Mines and Minerals
Abandoned Mined Lands Reclamation Division
Springfield, IL 62702-1271
217-782-0588

Illinois Department of Natural Resources
Office of Mines and Minerals
Land Reclaimation Division
One Natural Resources Way
Springfield, IL 62702-1271
217-782-6791

Illinois State Geological Survey
615 East Peabody Drive
Champaign, IL 61820-6964
217-333-4747
www.isgs.uiuc.edu

Acknowledgments

This publication is an updated revision of *Mine Subsidence in Illinois: Facts for the Homeowner Considering Insurance,* which was released in 1981 as ISGS Environmental Geology Notes 99 and in 1993 as Environmental Geology 144.

We appreciate the helpful comments provided by peer reviewers: Daniel Barkley, Cheri Chenoweth, Scott Elrick, Robert Gibson, and Dean Spindler.

The Illinois Mine Subsidence Insurance Fund sponsored the reprinting of the original booklet and the printing of the subsequent two updated publications. The distribution of this mine subsidence information for homeowners is largely due to the strong support over several decades of the Fund's recently retired President and CEO, Edmund W. Murphy, and through continued support by the current President and CEO, Randolph J. Beck.

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Attorney Client Privileged

Reference 8

HANSON
Engineering | Architecture | Planning | Allied Services

Hanson Professional Services Inc.
1525 South 6th Street
Springfield, IL 62703
(217) 788-2450
Fax: (217) 788-5241
www.hanson-inc.com

March 20, 2014

Mr. C.J. Saladino
Plant Manager
Kincaid Generation L.L.C.
P.O. Box M
Kincaid, Illinois 62540

Attn: Mr. Don Torricelli

Re: Kincaid Power Station Ash Pond
Dike Inspection

Dear Mr. Saladino:

The Kincaid Power Station Ash Pond dike was inspected on March 11, 2014. The inspection was made by James P. Knutelski, P.E., Hanson Professional Services Inc. He was accompanied by Don Torricelli of Kincaid Generation. The photographs taken during the inspection are attached.

At the time of the inspection, the water level was at the normal operating pool elevation for this facility, approximately 2 ft below the crest of the emergency overflow spillway. The day was mostly sunny and windy and the temperature was about 44°.

Ash Pond Description

The ash pond was built in 1964 to serve as a disposal area for bottom ash produced during coal combustion. The amount of ash stored in the facility has been variable over the operation of the pond. Currently the ash is sold to other industries and the probability of the ash pond being filled to capacity is low in the foreseeable future. Water and ash from the plant enter the pond through 7 pipes located on the south side of the dike. The water level in the ash pond is controlled using a gated drop structure. A large portion of the southern side of the dike that was constructed at about 5 ft lower elevation than the remaining crest of the dike is used as an emergency overflow spillway.

The ash pond is inspected no less than weekly by Kincaid personnel.

Summary of Observations and Recommendations

The drop structure outlet for the ash pond appears to be in good condition (Photograph 1). The outlet conduit appears to be in good condition (Photograph 2).

The emergency spillway appears to be in good condition (Photograph 3).

The earthen dike appears to be in good condition (Photographs 4 through 8). The downstream embankment has been mowed and maintained over the past year.

Within the pond, there are several areas where the elevation of the ash is higher than the normal pool elevation of the pond (Photograph 9). These areas are not considered detrimental to the dike as long as equipment working these areas does not cause rutting within the original dike materials. Also, this material may help prevent unwanted vegetation growth on the upstream side of the dike.

A subsidence event beneath the western portion of the dike was reported to Hanson in July of 2013. The area was observed at that time. No seepage through the dike was observed. Only a noticeable slump and tension cracks were apparent in that area. Tension cracks were observed but less apparent due to weathering and vegetation regrowth. No additional slumping was observed in this area. Surface erosion of the crest due to runoff from a recent intense rainfall event was observed in this area (Photograph 10). Aggregate surfacing was added to crest of the dike in this area to prevent further runoff from topping the dike. The erosion rills in this area should be filled with local cohesive soils and this area should be seeded to promote vegetation cover. The crest should be observed during a rainfall event to assure that the built-up crest surface prevents runoff.

Also, continued observation and maintenance of the ash pond by Kincaid personnel is recommended.

Sincerely,

HANSON PROFESSIONAL SERVICES INC.

James P. Knutelski
Geotechnical Engineer

Attachments: Photographs

INDEX TO PHOTOGRAPHS

1. Outlet drop structure.
2. Outlet Conduit.
3. Emergency spillway.
4. Embankment east side.
5. Embankment north side.
6. Embankment west side.
7. Embankment west side.
8. Embankment south side.
9. Ash widened crest – south side.
10. Erosion at subsided crest.

Photograph 1

Photograph 2

Photograph 3

Photograph 4

Photograph 5

Photograph 6

Photograph 7

Photograph 8

Photograph 9

Photograph 10

Attorney Client Privileged

Reference 9

HANSON
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Hanson Professional Services Inc.
1525 South 6th Street
Springfield, IL 62703
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Fax: (217) 788-5241
www.hanson-inc.com

October 12, 2015

Mr. James Klenke
Plant Manager
Kincaid Generation L.L.C.
P.O. Box M
Kincaid, Illinois 62540

Attn: Mr. Richard Dixon

Re: Kincaid Power Station Ash Pond
Dike Inspection

Dear Mr. Klenke:

The Kincaid Power Station Ash Pond dike was inspected on June 24, 2015. The inspection was made by James P. Knutelski, P.E., Hanson Professional Services Inc. He was accompanied by Richard Dixon of Kincaid Generation. The photographs taken during the inspection are attached.

At the time of the inspection, the water level was at the normal operating pool elevation for this facility, approximately 2 ft below the crest of the emergency overflow spillway. The day was cloudy with scattered showers and the temperature was about 70º.

Ash Pond Description

The ash pond was built in 1964 to serve as a disposal area for bottom ash produced during coal combustion. The amount of ash stored in the facility has been variable over the operation of the pond. Currently the ash is sold to other industries and the probability of the ash pond being filled to capacity is low in the foreseeable future. Water and ash from the plant enter the pond through 7 pipes located on the south side of the dike. The water level in the ash pond is controlled using a gated drop structure. A large portion of the southern side of the dike that was constructed at about 5 ft lower elevation than the remaining crest of the dike is used as an emergency overflow spillway.

The ash pond is inspected no less than weekly by Kincaid personnel.

Summary of Observations and Recommendations

The drop structure outlet for the ash pond appears to be in good condition (Photograph 1). The outlet conduit appears to be in good condition (Photograph 2).

The emergency spillway appears to be in good condition (Photograph 3).

The inlet pipes appear to be in good condition (Photograph 10).

The earthen dike appears to be in good condition (Photographs 4 through 8). The downstream embankment has been mowed and maintained over the past year.

Within the pond, there are several areas where the elevation of the ash is higher than the normal pool elevation of the pond (Photographs 9 and 11). These areas are not considered detrimental to the dike as long as equipment working these areas does not cause rutting within the original dike materials. Also, this material may help prevent unwanted vegetation growth on the upstream side of the dike.

A subsidence event beneath the western portion of the dike was reported in July of 2013. The area was observed at that time. Only a noticeable slump and tension cracks were apparent in that area. In 2014, an intense rainfall event resulted in runoff on the downstream slope in this area and erosion of the slope. The erosion on the slope was repaired, vegetation was established, and the crest elevation was restored. This area appears to be in good condition.

Weekly inspection and maintenance of the ash pond by Kincaid personnel are recommended. No further repairs are necessary.

Sincerely,

HANSON PROFESSIONAL SERVICES INC.

James P. Knutelski
Geotechnical Engineer

Attachments: Photographs

INDEX TO PHOTOGRAPHS

1. Outlet drop structure.
2. Outlet Conduit.
3. Emergency spillway.
4. Embankment east side.
5. Embankment north side.
6. Embankment west side.
7. Embankment west side.
8. Embankment south side.
9. Ash widened crest – south side.
10. Inlet pipes.
11. Pond interior near inlet.

Photograph 1

Photograph 2

Photograph 3

Photograph 4

Photograph 5

Photograph 6

Photograph 7

Photograph 8

Photograph 9

Photograph 10

Photograph 11

Dam Inspection Report

Name of Dam: Kincaid Power Station Ash Pond   Dam ID No.: NA

Permit Number: NA   Class of Dam: II

Location ____ Section: 11 & 12   Township: 13N   Range: 4W

Owner: Dynegy Midwest (Name)   217 237 4311 (Telephone Number (Day))

IL Route 104 (Street)   217 237 4311 (Telephone Number (Night))

Sicily (City)   62540 (Zip Code)   County: Christian

Type of Dam: Earth Embankment with Drop Structure Spilllway

Type of Spillway: Drop structure to outlet condiut

Date(s) Inspected: 6/24/2015

Weather When Inspected: Cloudy, scattered showers.

Temperature When Inspected: 70 F

Pool Elevation When Inspected: 613.0

Tailwater Elevation When Inspected: NA

Inspection Personnel:

Name	Title
James P. Knutelski I	Geotechnical Engineer
Richard Dixon	Kincaid Generation

Professional Engineer's Seal

The Department of Nautural Resources is requesting information that is necessary to accomplish the statutory purpose as outlined under the River, Lakes and Streams Act, 615 ILCS 5. Submittal of this information is REQUIRED. Failure to provide the required information could result in the initiation of non-compliance procedures as outlined in Section 3702.160 of the "Rules for Construction and Maintenance of Dams".

CONDITION CODES

NE - No evidence of a problem

GC - Good condition

MM - Item needing minor maintenance and/or repairs within the year, the safety or integrity of the item is not yet imperiled

IM - Item needing immediate maintenance to restore or ensure its safety or integrity

EC - Emergency condition which if not immediately repaired or other appropriate measures taken could lead to failure of the dam

OB - Condition requires regular observation to ensure that the condition does not become worse

NA - Not applicable to this dam

NI - Not inspected - list the reason for non-inspection under deficiencies

EARTH EMBANKMENT

ITEM	CONDITION CODE	DEFICIENCIES	RECOMMENDED REMEDIAL MEASURES AND IMPLEMENTATION SCHEDULE
Surface Cracks	NE		
Vertical and Horizontal Alignment of Crest	GC		
Unusual Movement or Cracking At or Beyond Toe	NE		
Sloughing or Erosion of Embankment and Abutment Slopes	NE		
Upstream Face Slope Protection	NA		
Seepage	NE		
Filter and Filter Drains	NA		

EARTH EMBANKMENT
(Continued)

ITEM	CONDITION CODE	DEFICIENCIES	RECOMMENDED REMEDIAL MEASURES AND IMPLEMENTATION SCHEDULE
Animal Damage	NE		
Embankment Drainage Ditches	NA		
Vegetative Cover	GC		
Other (Name)			
Other			
Other			
Other			

PRINCIPAL SPILLWAY
APPROACH CHANNEL

ITEM	CONDITION CODE	DEFICIENCIES	RECOMMENDED REMEDIAL MEASURES AND IMPLEMENTATION SCHEDULE
Debris	NA		
Side Slope Stability	NA		
Slope Protection	NA		
Other (Name)			
Other			
Other			
Other			

PRINCIPAL SPILLWAY

☒ Drop Inlet Spillway ☐ Overflow Spillway Structure ☐ Gated

ITEM	CONDITION CODE	DEFICIENCIES	RECOMMENDED REMEDIAL MEASURES AND IMPLEMENTATION SCHEDULE
Erosion, Spalling, Cavitation	NE		
Structure to Embankment Junction	NA		
Drains	NA		
Seepage Around or Into Structure	NE		
Surface Cracks	NE		
Structural Cracks	NE		

IF THE SPILLWAY IS GATED FILL OUT THE GATES SECTION

PRINCIPAL SPILLWAY
(Continued)

[x] Drop Inlet Spillway [ ] Overflow Spillway Structure [ ] Gated

ITEM	CONDITION CODE	DEFICIENCIES	RECOMMENDED REMEDIAL MEASURES AND IMPLEMENTATION SCHEDULE
Alignment of Abutment Walls	NA		
Construction Joints	GC		
Filter and Filter Drains	NA		
Trash Racks	GC		
Bridge and Piers	GC		
Differential Settlement	NE		
Other (Name)			

IF THE SPILLWAY IS GATED FILL OUT THE GATES SECTION

PRINCIPAL SPILLWAY
(Continued)

[x] Conduit   [ ] Gated

ITEM	CONDITION CODE	DEFICIENCIES	RECOMMENDED REMEDIAL MEASURES AND IMPLEMENTATION SCHEDULE
Erosion, Spalling, Cavitation	NE		
Joint Separation	NE		
Seepage Around of Into Conduit	NE		
Surface Cracks	NE		
Structural Cracks	NE		
Trash Racks	NA		
Differential Settlement	NE		
Alignment	GC		
Other (Name)			

IF THE SPILLWAY IS GATED FILL OUT THE GATES SECTION

PRINCIPAL SPILLWAY

(Continued)

☐ Chute

ITEM	CONDITION CODE	DEFICIENCIES	RECOMMENDED REMEDIAL MEASURES AND IMPLEMENTATION SCHEDULE
Erosion, Spalling, Cavitation			
Structure to Embankment Junction			
Construction Joints			
Expansion and Contraction Joints			
Differential Settlement			
Surface Cracks			
Structural Cracks			
Wall Alignment			
Other (Name)			

IF THE SPILLWAY IS GATED FILL OUT THE GATES SECTION

PRINCIPAL SPILLWAY

☐ Principal Spillway ☐ Dewatering ☐ Other: ______________________

ITEM	CONDITION CODE	DEFICIENCIES	RECOMMENDED REMEDIAL MEASURES AND IMPLEMENTATION SCHEDULE
Gate Sill			
Gate Seals			
Gate and Frame			
Operating Machinery			
Emergency Operating Machinery			
Other (Name)			
Other			

EMERGENCY SPILLWAY

[x] Earth Other: Name ____________________

ITEM	CONDITION CODE	DEFICIENCIES	RECOMMENDED REMEDIAL MEASURES AND IMPLEMENTATION SCHEDULE
Erosion	NE		
Weeds, Logs, Other Obstructions	NE		
Side Slope Sloughing	NE		
Vegetation	GC		
Sedimentation	NE		
Riprap	NA		
Settlement of Crest	NE		
Downstream Channel	NA		
Other (Name)			

SUMMARY OF MAINTENANCE DONE AND/OR

REPAIRS MADE SINCE THE LAST INSPECTION

DATE OF PRESENT INSPECTION 6/24/2015

DATE OF LAST INSPECTION 3/11/2014

1. EARTH EMBANKMENT DAMS
   Mowed. Grade and seed areas with previous erosion.

2. CONCRETE MASONRY DAMS
   NA

3. PRINCIPAL SPILLWAY
   None.

4. OUTLET WORKS
   NA

5. EMERGENCY SPILLWAY
   None.

Owner's Maintenance Statement

I, ______________________________, owner of Kincaid Ash Pond dam,

Dam Identification Number NA, in Christian County,

am maintaining the dam in accordance with the accepted maintenance plan which is part of

Permit Number NA.

____
Signature

____
Date

Owner's Operation and Maintenance Plan Statement

I, ______________________________, owner of Kincaid Ash Pond dam,

Dam Identification Number NA, in Christian County,

have reviewed the operation and maintenance plan including the Emergency Action Plan (EAP),

which is part of, Permit Number NA.

I _____ have enclosed the appropriate revisions or

_____ have determined that no revisions to the plan are necessary.

____
Signature

____
Date

The Department of Nautural Resources is requesting information that is necessary to accomplish the statutory purpose as outlined under the River, Lakes and Streams Act, 615 ILCS 5. Submittal of this information is REQUIRED. Failure to provide the required information could result in the initiation of non-compliance procedures as outlined in Section 3702.160 of the "Rules for Construction and Maintenance of Dams".

DOWNSTREAM DEVELOPMENT

APPROXIMATE WIDTH OF AFFECTED FLOODPLAIN NA MILES

MILES DOWNSTREAM FROM DAM	DOWNSTREAM DEVELOPMENT												Loss of Life Potential			Economic Loss Potential		
	OCCUPIED HOMES	UNOCCUPIED HOMES	AGRICULTURAL BUILDINGS	INDUSTRIAL BUILDINGS	COMMERCIAL BUILDINGS	SCHOOLS	HOSPITALS	ROADS & BRIDGES	DAMS	OVERHEAD UTILITIES	OTHER DEVELOPMENT (Name	OTHER DEVELOPMENT (Name	NONE	1 TO 10	OVER 10	MINIMAL EXPECTED	APPRECIABLE EXPECTED	EXCESSIVE EXPECTED
0 to 1/4										1						x		
1/4 to 1/2																x		
1/2 to 3/4																x		
3/4 to 1																x		
1 to 1-1/4																x		
1-1/4 to 1-1/2																x		
1-1/2 to 1-3/4																x		
1-3/4 to 2																x		
OVER 2										1						x		

SKETCH IN DEVELOPMENTS DOWNSTREAM OF THE DAM

NA

The number of homes, buildings, or other items in the floodplain downstream of the dam should be placed in the appropriate row and column to designate their location.

Attorney Client Privileged

Reference 10

CCR Unit: Kincaid Ash Pond
Site Visit Date: 06/9/2015 to 0610/2015
Date Version: 06/23/15, Version B (Draft)
Prepared by: Ed Villano / Brodie Adams
Checked by: Eric Glazier
ITR by: Vic Modeer
Distribution to: AECOM and Dynegy
Initial Classification: Existing Surface Impoundment as of 05/12/2015
Impoundment Size: Approximately 170 acres (to be verified)
Actively Receiving Ash: Yes

Comments on CCR Unit from Initial Site Visit[1]:

1. Surface Conditions:
    a. *Vegetation Cover: None.*
    b. *Tree Cover: None.*
    c. *Exposed CCR Material:* Approximately 64% of the surface area is bottom ash, with active ash deposition / handling in the southwest portion of the impoundment, and filling of recycle reject material in the western portion of the impoundment.
    d. *Water:* Approximately 34% of surface area is water. On eastern third of pond.
    e. *Other:* Approximately 2% of the surface area is ash with random fill, construction debris from plant, or areas on the upstream side of the south embankment which do not appear to be ash covered.
2. Surficial Issues/Concerns:
    a. *Surficial Erosion:* Surface erosion was not observed.
    b. *Wet Vegetation:* None observed.
    c. *Drainage Swales:* Drainage swale conveys water from sluice discharge point in the southwest corner of the pond to the northeast corner.
    d. *Other:* No other items noted.
3. Impounding System Condition:
    a. *General Grading of Pond Surface:* The site generally flows to the southwest to northeast toward the ponded water area.
    b. *Presence of surface water:* Approximately 34% of surface area is water. On eastern third of pond.
    c. *Low areas that could result in ponded water (inactive impoundments):* Not applicable due to active pond status.
    d. *Other features that could result in ponded water (inactive impoundments):* Not applicable due to active pond status.
    e. *Amount of freeboard (vertical distance between water surface and area of lowest crest elevation):* The crest elevation is lowest in the southeast corner, with freeboard estimated to be 1.5 to 2 feet using a hand-held level and tape/rod.
4. Special Features:
    a. *Geometry of Embankment Slopes:*

[1] Please refer to Figure 1 for locations.

i. The east embankment has estimated overall downstream slopes ranging from approximately 2.4H:1V to 3.8H:1V with localized steep sections near the crest that range from approximately 1.9H:1V to 2.2H:1V.
ii. The north embankment has estimated overall downstream slopes of 1.7H:1V with some areas having a flatter slope near the toe.
iii. The NW and SW embankments were estimated to have overall downstream slopes of approximately 1.7H:1V.
iv. The south embankment is made up of 2 east-west trending sections, connected by a dogleg (NW-SE trending).
    1. The western portion and the dogleg have estimated downstream slopes of approximately 1.5H:1V to 1.7H:1V (with some areas possibly steeper). It appears that some construction debris (concrete, inert fill) has been pushed out from the crest of the dogleg in the downstream direction. This slope is estimated to be about 1.4H:1V.
    2. The eastern portion of the south embankment has a lower crest elevation than the rest of the impoundment (based on our freeboard measurements and visual observation) and has estimated downstream slopes of approximately 1.7H:1V.
v. The upstream slopes of the embankments on the interior of the ash pond were generally ash covered. Slopes were 1.8H:1V to 2.3H:1V on the east embankment, 3.7H:1V to 6H:1V on the north embankment, and were mostly relatively flat and/or higher in elevation than the crest upstream of the NW, SW, and south embankments.

b. *Condition of Embankment slopes:*
  i. East Embankment:
    1. Downstream slope sloughing/slides and depressions (Photo 1).
    2. Evidence of prior tree removal and possible inadequate root excavation and backfilling.
    3. Drainage ditch at center portion of downstream toe.
  ii. North Embankment
    1. Ponded water at downstream toe along eastern portion of embankment (Photo 2).
    2. Evidence of prior tree removal and possible inadequate root excavation and backfilling along eastern portion of embankment (Photo 3); at least one remaining large tree stump in slope.
    3. Heavy vegetation obscuring downstream toe/slope condition and possible lake water encroachment into slope, just east of toe buttress (Photo 4).
    4. Large tree at downstream toe and heavy vegetation obscuring downstream toe/slope condition and possible lake water encroachment into slope (Photo 5).
    5. Possible embankment/crest subsidence (Photo 7).
  iii. Northwest Embankment
    1. Scarps, depressions, sloughing, hummocky terrain (small, intermittent earth mounds and ridges) and animal burrows along downstream slope (Photos 6, 9, and 10).
    2. Possible embankment/crest subsidence (Photo 8).
  iv. Southwest Embankment
    1. Ponded water along downstream toe/slope (Photo 11).
    2. Embankment/crest subsidence over old mine workings (Photo 12); wide crest transverse crack shown in historic phot os, now covered with gravel/rock fill.
  v. South Embankment

1. Erosion gullies, sloughing, and animal burrows along downstream slope west of dogleg (Photos 13 and 14).
2. Active penetrating CMP conduit aligned along south embankment east of dogleg; CMP condition suspect due to 2006 failure of nearby CMP conduit (Photo 15).
3. Lowest crest elevation at southeast corner, with less than 2 feet of freeboard (Photo 16).

c. *Structures in/on/through unit:* Emergency spillway at southeast impoundment corner; operability of gate under emergency drawdown conditions unknown (Photos 16 and 17).

5. Final Cover Area:
   a. No existing cover. If covered in the future, cover area would be approximately 170 acres.
6. Additional/Other Waste Streams:
   a. To be determined/evaluated.
7. Lined or Unlined:
   a. Unlined.
8. CCR depth:
   a. Unknown at this time.
9. ARO Cost:
   a. No estimate at present. (MSB to provide)

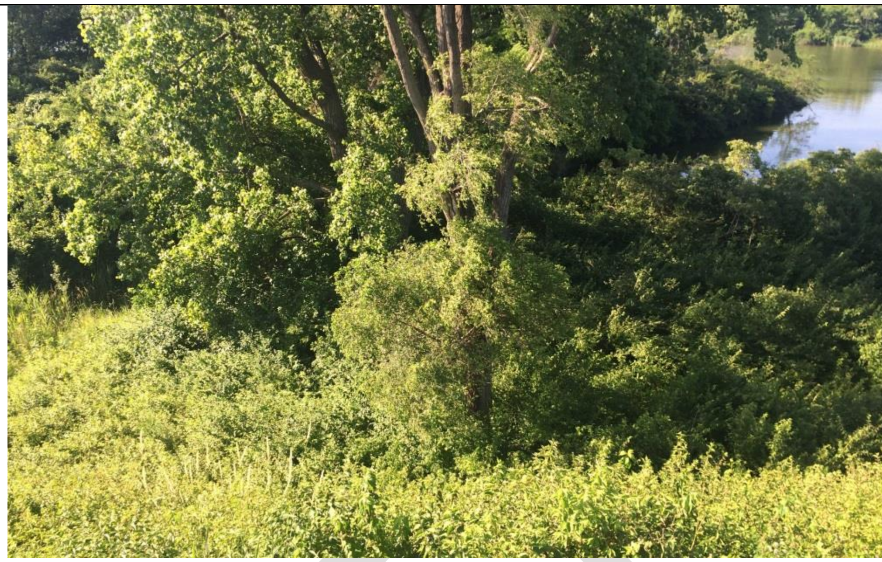
Figure 1 Kincaid Ash Pond

Photo obtained from Google Earth on 06/17/15. Imagery date: 3/16/2014

Photo No. 1	Date: 06/09/15	 Downstream slope sloughing/slide, approximately 80 feet wide (along slope) by 40 feet long (up/down slope); note approximate 2 to 3 foot sloped scarp near embankment crest. Several other areas of sloughing/sliding and depressions were observed along the east embankment slope. Woody debris, roots, and evidence of prior tree removal were observed.
Location: Ash Pond, East Embankment		
Direction: south Coordinates: 39.59997°N 89.48756°W		
Photo No. 2	Date: 06/09/15	 Area of ponded water and heavy vegetation at downstream toe near northeast corner of embankment, which may possibly be partially related to runoff from adjacent agricultural field and possibly partially related to seepage. Ponded water was relatively clear, approximately 8 to 12-inches deep, and approximately 50 feet wide (along toe) by 5 to 8 feet long (up/downstream).
Location: Ash Pond, North Embankment		
Direction: east southeast Coordinates: 39.60144°N 89.48831°W Description:		

<table>
<tr><td>Photo No. 3</td><td>Date: 06/09/15</td><td rowspan="3">
Depressed areas in upper portion of downstream slope, believed to be voids left over from tree removal (possible evidence of inadequate tree root removal, backfilling and compaction), located directly upstream of ponded water noted in previous photo. One 16-inch diameter tree stump left in the slope was observed in this area. Possible remnant tree roots and uncompacted void fill could constitute preferential seepage pathways.</td></tr>
<tr><td colspan="2">Location:
Ash Pond, North Embankment</td></tr>
<tr><td colspan="2">Direction:
south
Coordinates:
39.60143°N
89.48827°W</td></tr>
<tr><td>Photo No. 4</td><td>Date: 06/09/15</td><td rowspan="3">
Toe buttress (foreground) and area of extremely heavy vegetation (background) at downstream toe of north embankment. The heavy vegetation prevented/obscured observation of the condition of the unrepaired portion of the toe, and whether lake water is encroaching on the embankment slope.</td></tr>
<tr><td colspan="2">Location:
Ash Pond, North Embankment</td></tr>
<tr><td colspan="2">Direction:
east
Coordinates:
39.63197°N
89.53563°W</td></tr>
</table>

Photo No. 5	Date: 06/09/15
Location: Ash Pond, North Embankment	
Direction: north Coordinates: 39.60128°N 89.49355°W	



Looking downstream toward lake from embankment crest at area of heavy vegetation and 24-inch diameter tree growing in lower slope/toe area, representing possible seepage/piping risk (along tree roots). Heavy vegetation prevented / obscured condition of lower slope / toe, and whether lake water is encroaching on the embankment slope. Slope at this location is oversteepened (approximately 1.75H:1V), increasing potential for slope instability. Condition of slope obscured by heavy vegetation.

Photo No. 6	Date: 06/09/15
Location: Ash Pond, Northwest Embankment	
Direction: southwest Coordinates: 39.59998°N 89.49651°W	

12-inch high scarp in upper portion of downstream slope, with apparent ash covering exposed scarp. Other areas of scarping, depressions (up to 10-foot wide, 8-foot long, 1-foot deep), sloughing, and hummocky terrain were observed on the downstream slope of the northwest embankment.

<table>
<tr><td>Photo No. 7</td><td>Date: 06/10/15</td><td rowspan="3">
Area of possible embankment/crest subsidence, estimated to be approximately 2 feet of subsidence over a crest length of approximately 500 feet.</td></tr>
<tr><td colspan="2">Location: Ash Pond, North Embankment</td></tr>
<tr><td colspan="2">Direction: east
Coordinates: 39.60126°N 89.49399°W</td></tr>
<tr><td>Photo No. 8</td><td>Date: 06/10/15</td><td rowspan="3">
Area of possible embankment/crest subsidence, measured by hand-held level and tape rod to be approximately 3.5 feet over an approximate 600-foot distance.</td></tr>
<tr><td colspan="2">Location: Ash Pond, Northwest Embankment</td></tr>
<tr><td colspan="2">Direction: northeast
Coordinates: 39.59898°N 89.49794°W</td></tr>
</table>

Photo No. 9	Date: 06/10/15	 Approximate 18-inch high distinct scarp in upper portion of downstream slope. Similar scarping, sloughing, and hummocky terrain were observed over a distance of approximately 300 feet running northeast from the southwest corner of the northwest embankment.
Location: Ash Pond, Northwest Embankment		
Direction: south Coordinates: 39.59875°N 89.49855°W		
Photo No.10	Date: 06/10/15	 Animal burrow observed in mid- to lower-portion of downstream slope near the southwest corner of the northwest embankment, measuring approximately 6- to 12-inches in diameter (wider at mouth) and at least 2 feet deep.
Location: Ash Pond, Northwest Embankment		
Direction: East southeast Coordinates: Not georeferenced		

Photo No. 11	Date: 06/10/15	
Location: Ash Pond, Southwest Embankment		 Ponded water and/or saturated ground at toe and lower portion of downstream slope near MW-7, extending approximately 70 feet along the toe, 25 feet up the slope (five tiers of ponded water up the slope), and 25 feet downstream from the toe. Vehicle ruts were observed in this area, and ponded water may partially be related to precipitation runoff, and partly related to seepage.
Direction: west northwest Coordinates: 39.59755°N 89.49878°W		
Photo No. 12	Date: 06/10/15	
Location: Ash Pond, Southwest Embankment		 Area of embankment/crest subsidence, directly upstream from a second area of standing water and/or wet ground extending approximately 150 feet along toe along toe of downstream slope. A previous study by Hanson Engineering correlated the subsidence in this area to mine workings directly beneath the embankment, possibly suggesting foundation material piping into the tunnels. A historical photo at this area showed a wide transverse crack in the crest. The subsided area has been filled with gravel and rock at recurrent intervals, as evident in the photo.
Direction: northwest Coordinates: 39.59703°N 89.49802°W		

Photo No. 13	Date: 06/10/15	 Two parallel erosion gullies extending from crest to toe of the downstream slope, approximately 8- to 10-foot wide (each), and up to 2 feet deep. A series of similar erosion gullies were observed elsewhere along the south embankment west of the where the embankment doglegs. Kincaid staff said the gullies are related to relatively recent heavy precipitation and runoff. Several areas of slope sloughing/slides (up to 2 feet deep and 15 to 20 feet wide) were also observed in the same area, with accompanying animal burrows (see next photo).
Location: Ash Pond, South Embankment		
Direction: north Coordinates: 39.59445°N 89.49666°W		
Photo No. 14	Date: 06/10/15	 Animal burrow in downstream slope, measuring approximately 8- to 12-inches in diameter (wider at mouth) and at least 5 feet deep, with erosion gully in background. Several other large animal burrows were observed in the same area, and may be contributing to slope instability and erodibility.
Location: Ash Pond, South Embankment		
Direction: Northwest Coordinates: 39.59453°N 89.49541°W		

Photo No. 15	Date: 06/10/15	 Looking west along crest/upstream slope of south embankment from emergency spillway at southeast corner of ash pond, and along alignment of buried CMP conduit that conveys water westward to ash sluice water pumping station. The CMP discharge conduit at this same area failed and was replaced around 2006; this indicates that the CMP conduit still in place may be defective, presenting a potential risk of leakage, internal erosion along/into the conduit, and possible dam breach.
Location: Ash Pond, South Embankment		
Direction: west Coordinates: Not georeferenced		
Photo No. 16	Date: 06/10/15	 View of intake structure of emergency spillway, looking north from southeast corner of impoundment. The intake gate was reported by Dynegy staff to not have been operated since 2006 due to discharge restrictions; operability in the event of emergency reservoir drawdown is therefore in question. The crest elevation is lowest in this area, with freeboard estimated to be 1.5 to 2 feet using a hand-held level and tape/rod.
Location: Ash Pond, South Embankment		
Direction: north Coordinates: Not georeferenced		

Photo No. 17	Date: 06/10/15	 View of CMP emergency spillway conduit, located downstream of intake structure shown in previous photo. The CMP conduit was replaced after the original conduit failed in 2006. Note that there is currently no gate or means of bulkheading at the discharge end to test operability of the intake gate without discharging pond water into the “hot ditch”, violating discharge restrictions.
Location: Ash Pond, South Embankment		
Direction: east Coordinates: Not georeferenced		

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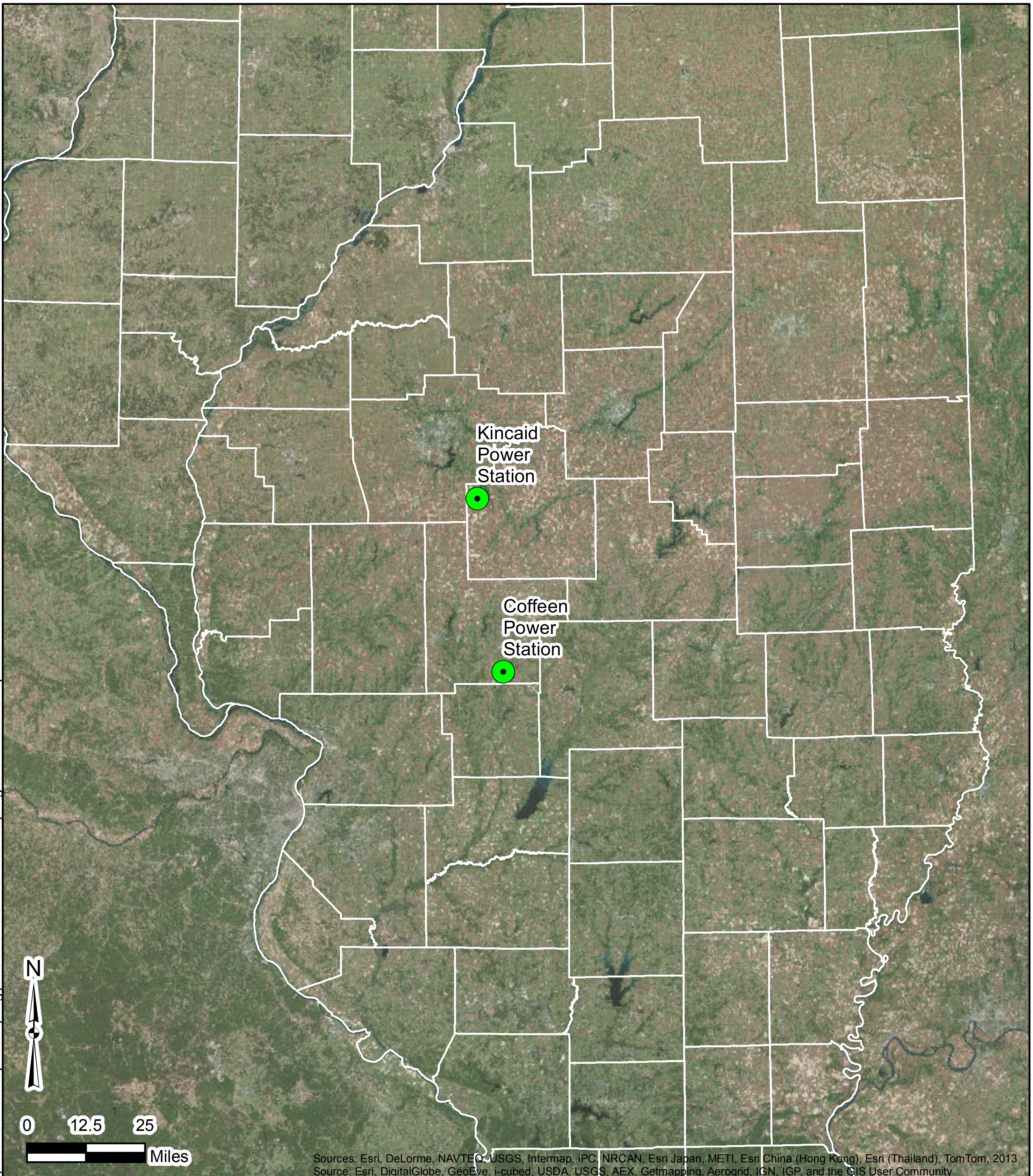
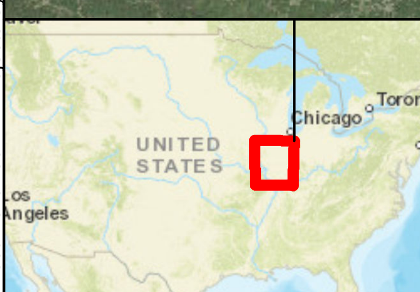
Figure 1





Document Path: P:\Projects\Systems\GIS Projects\Dynegy\CCR\Coal Mines Overlay\Fig 1 - Location Map.mxd

Legend

Plant Location

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Client: DYNEGY	PROJECT NO. 60442970
Plant Location Map	
DRN. BY: SJ CHKD. BY: BP 10/27/2016	AECOM	FIG. NO. 1

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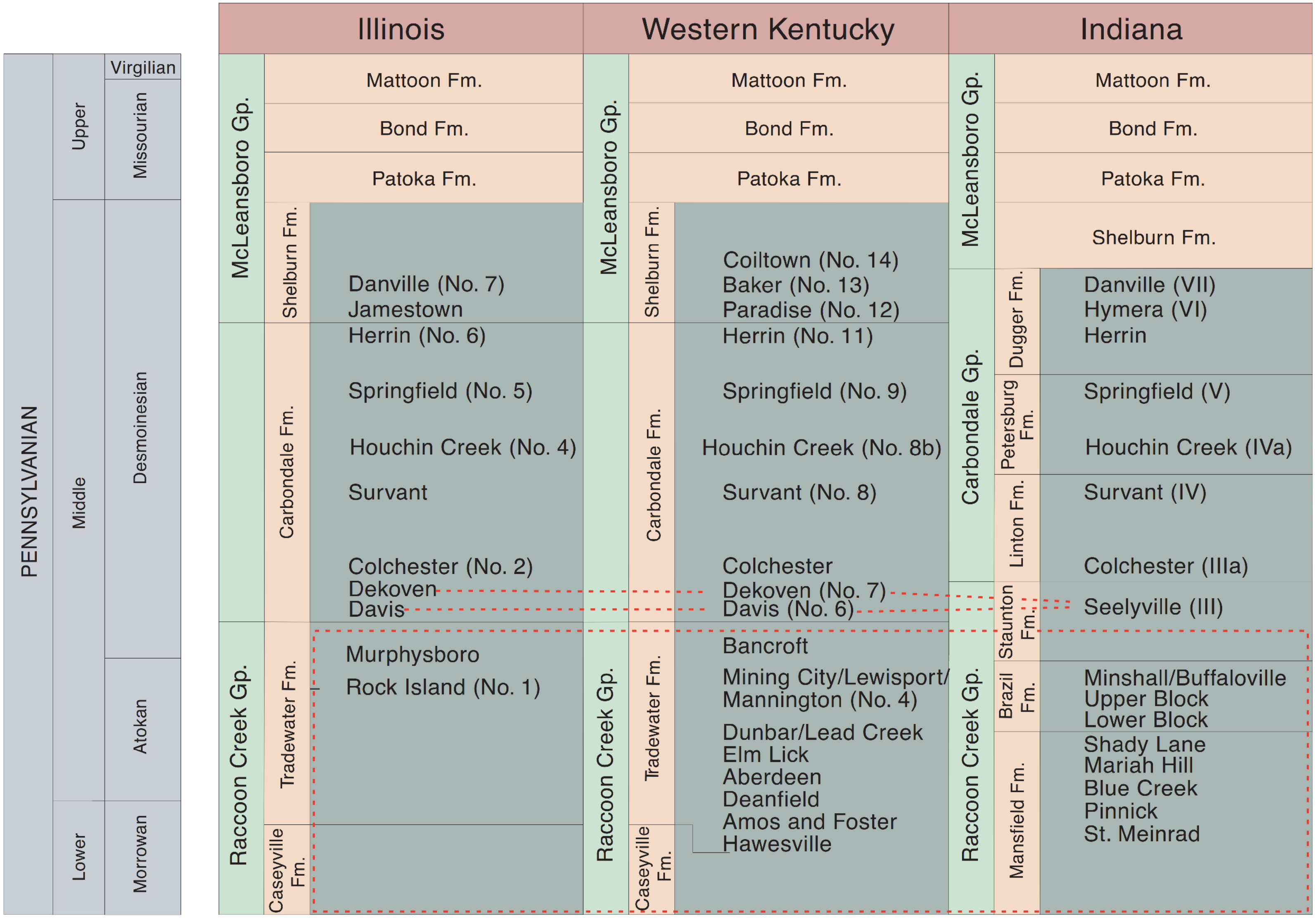
Figure 2

Document Path: P:\Projects\Systems\GIS Projects\Dynegy\CCR\Coal Mines Overlay\Fig 2 Stratigraphic Section.mxd



Stratigraphic chart of the Pennsylvanian System in the Illinois Basin, showing major coal members. Modified from Mastalerz and Harper (1998, fig. 2) and Greb and others (1992, fig. 22). Fm., Formation; Gp., Group; --- , problematic coal correlations.

Source: http://pubs.usgs.gov/pp/p1625d/Chapter_C.pdf
Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2013

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Client: DYNEGY

PROJECT NO. 60442970

Stratigraphic Section

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10/27/2016

AECOM

FIG. NO. 2

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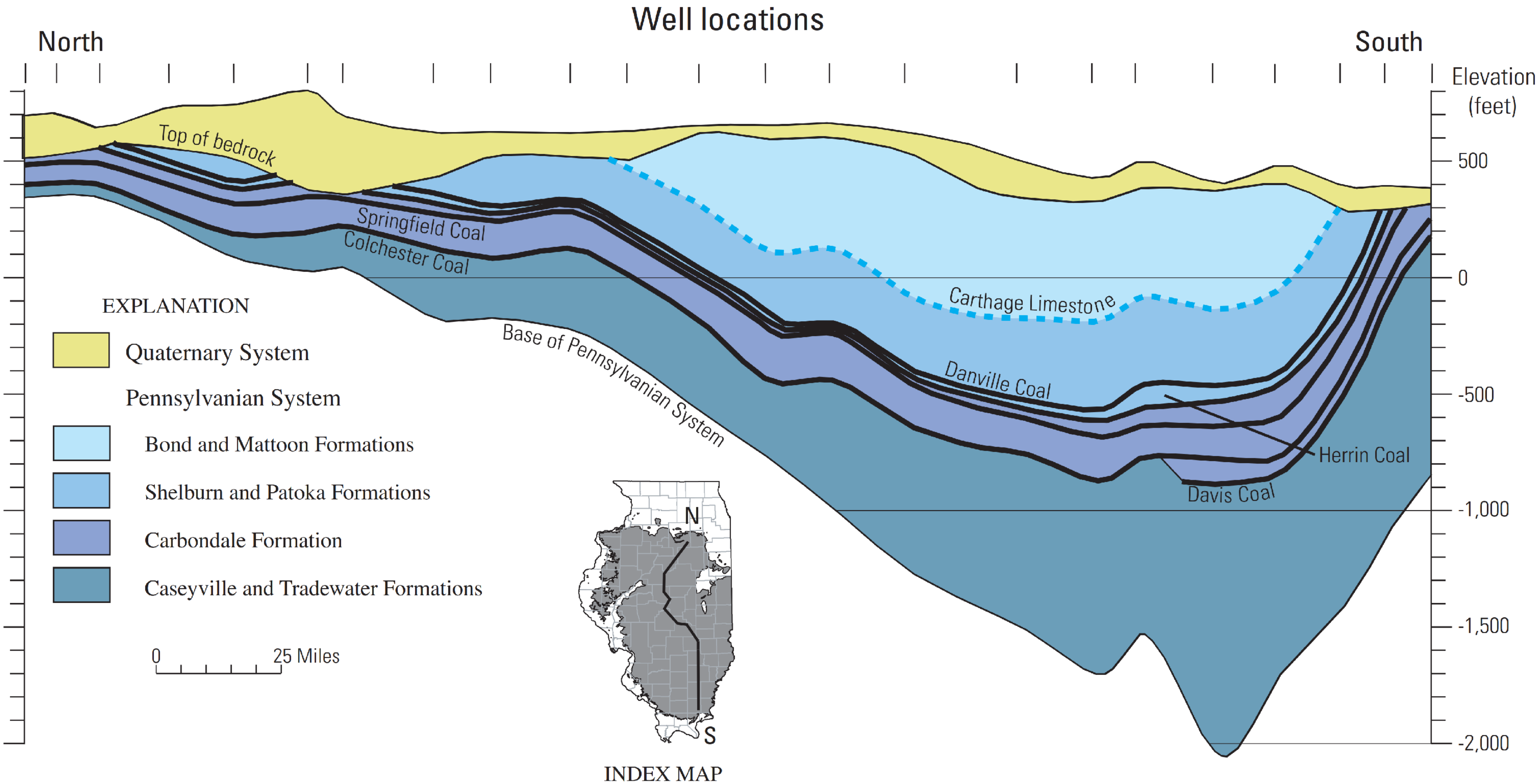
Figure 3



Generalized north-south cross section of the Pennsylvanian System in Illinois. This section illustrates the thickening of the Pennsylvanian strata southward across the basin (provided by C.P. Korose and C.G. Treworgy, Illinois State Geological Survey).

Source: http://pubs.usgs.gov/pp/p1625d/Chapter_C.pdf
Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2013

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Client: DYNEGY		PROJECT NO. 60442970
Pennsylvanian Geologic Profile		
DRN. BY: SJ CHKD. BY: BP 10/28/2016	AECOM	FIG. NO. 3

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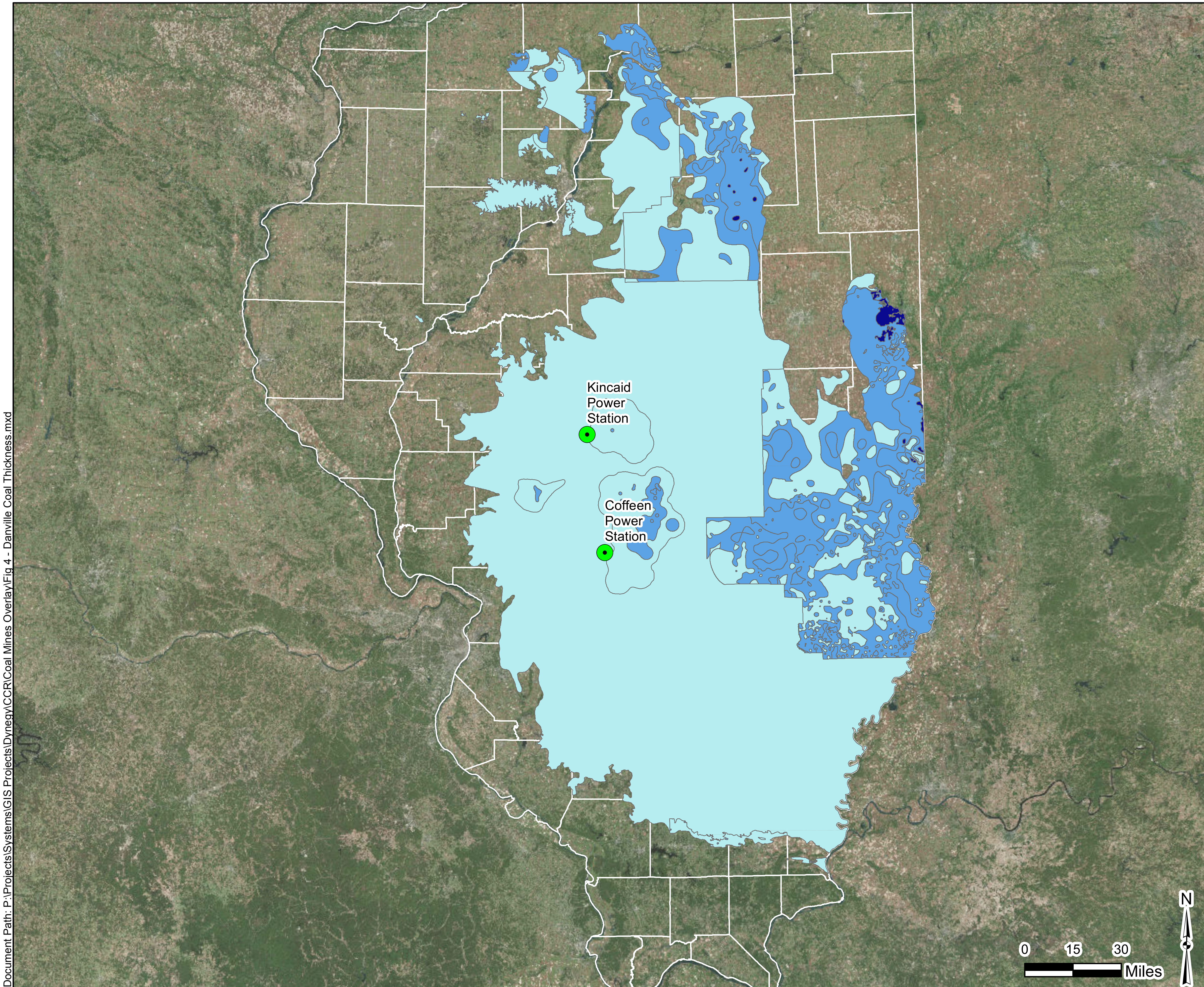
Figure 4



Document Path: P:\Projects\Systems\GIS Projects\Dynegy\CCR\Coal Mines Overlay\Fig 4 - Danville Coal Thickness.mxd

Legend

- Plant Location

Danville Coal Thickness (inches)

- 3 - 27
- 28 - 42
- 43 - 65
- 66 - 100

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Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2013
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA,

Client: DYNEGY	PROJECT NO. 60442970
Danville Coal Thickness	
DRN. BY: SJ CHKD. BY: BP 10/27/2016	AECOM
FIG. NO. 4	

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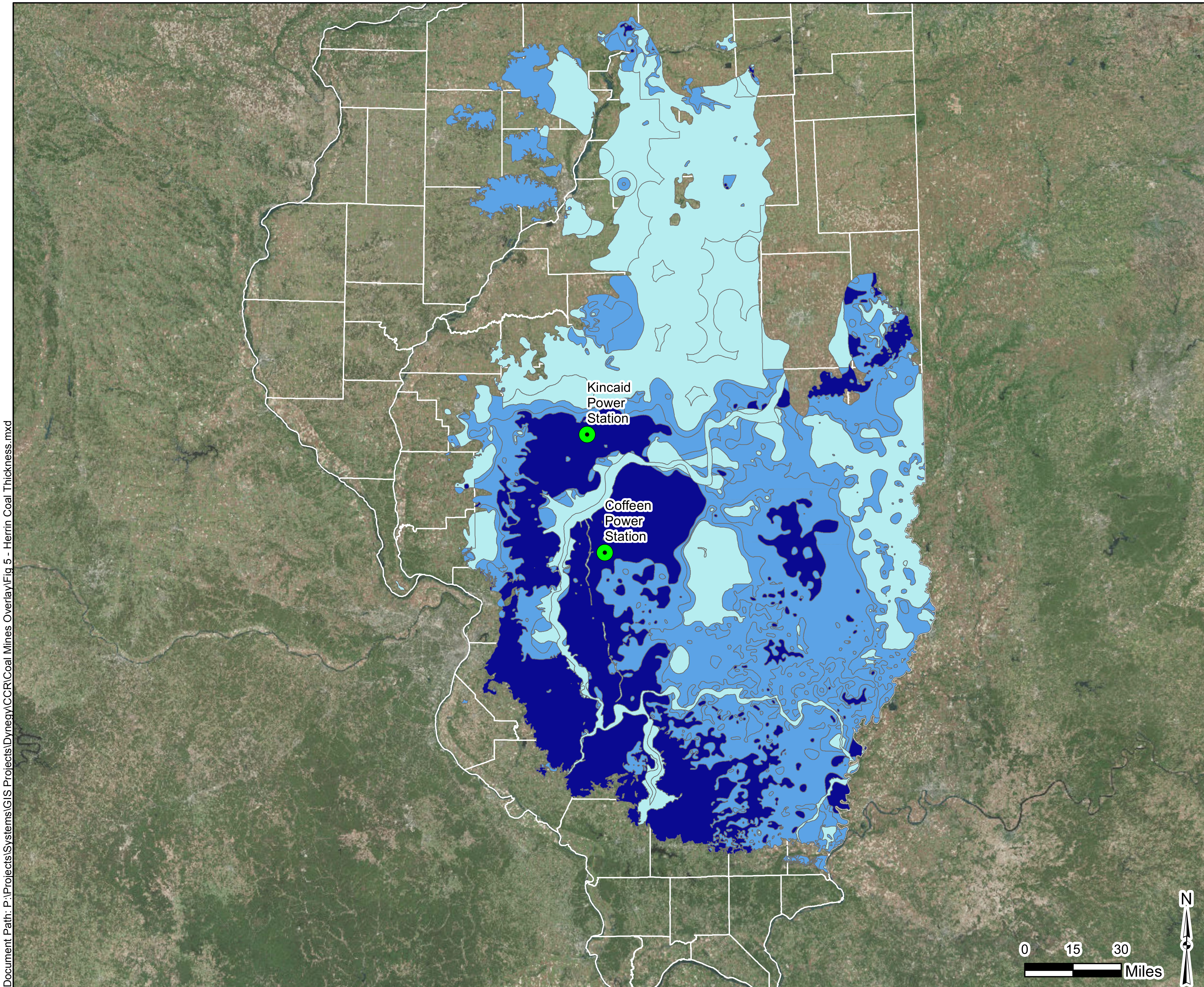
Figure 5



Legend

- Plant Location

Herrin Coal Thickness (inches)

- 2 - 27
- 28 - 42
- 43 - 65
- 66 - 100

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Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2013
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA,

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Herrin Coal Thickness

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FIG. NO. 5

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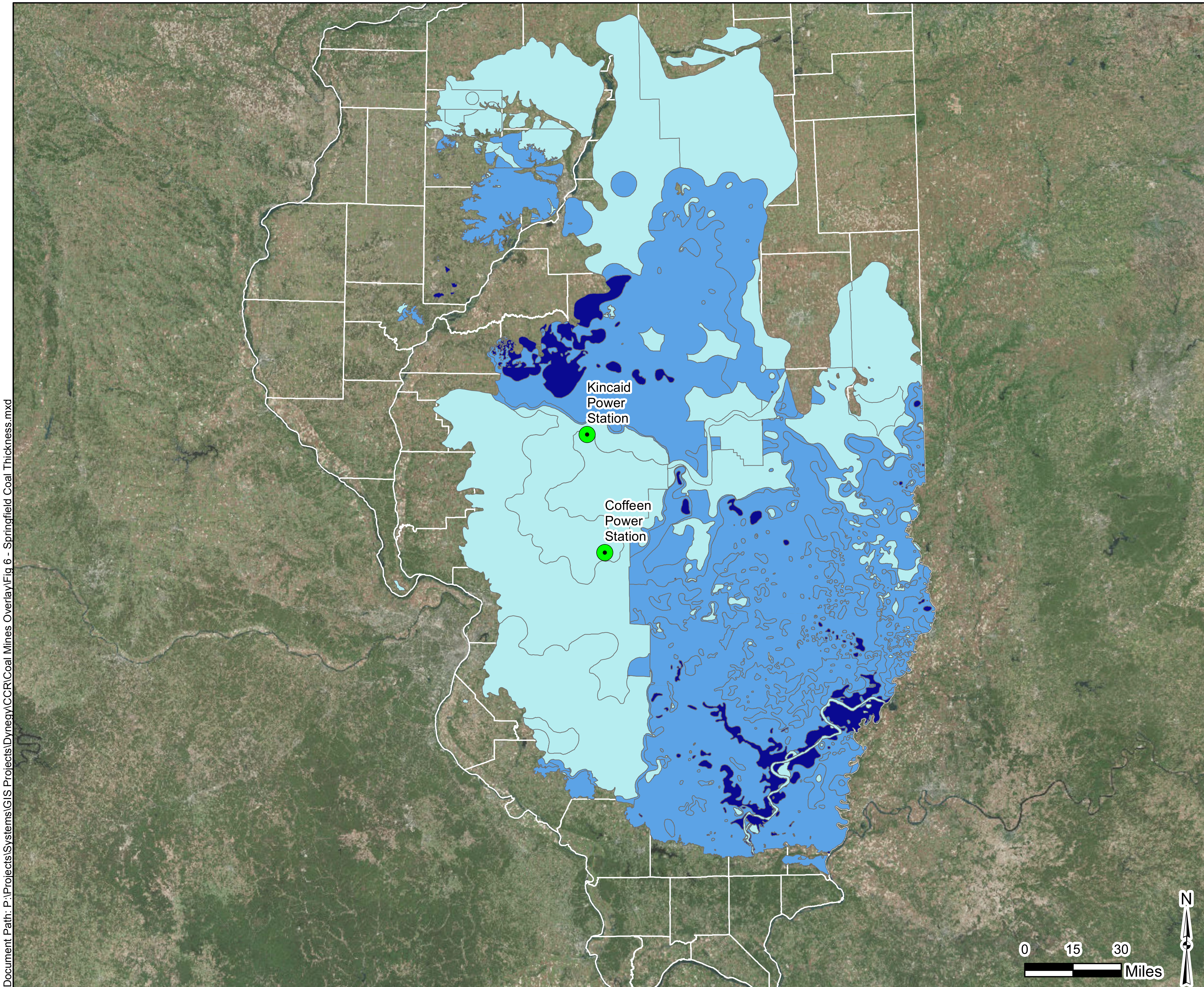
Figure 6



Legend

Plant Location

Springfield Coal Thickness (inches)

- 2 - 27
- 28 - 42
- 43 - 65
- 66 - 100

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Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2013
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA,

Client: DYNEGY	PROJECT NO. 60442970
Springfield Coal Thickness	
DRN. BY: SJ CHKD. BY: BP 10/28/2016 — AECOM	FIG. NO. 6

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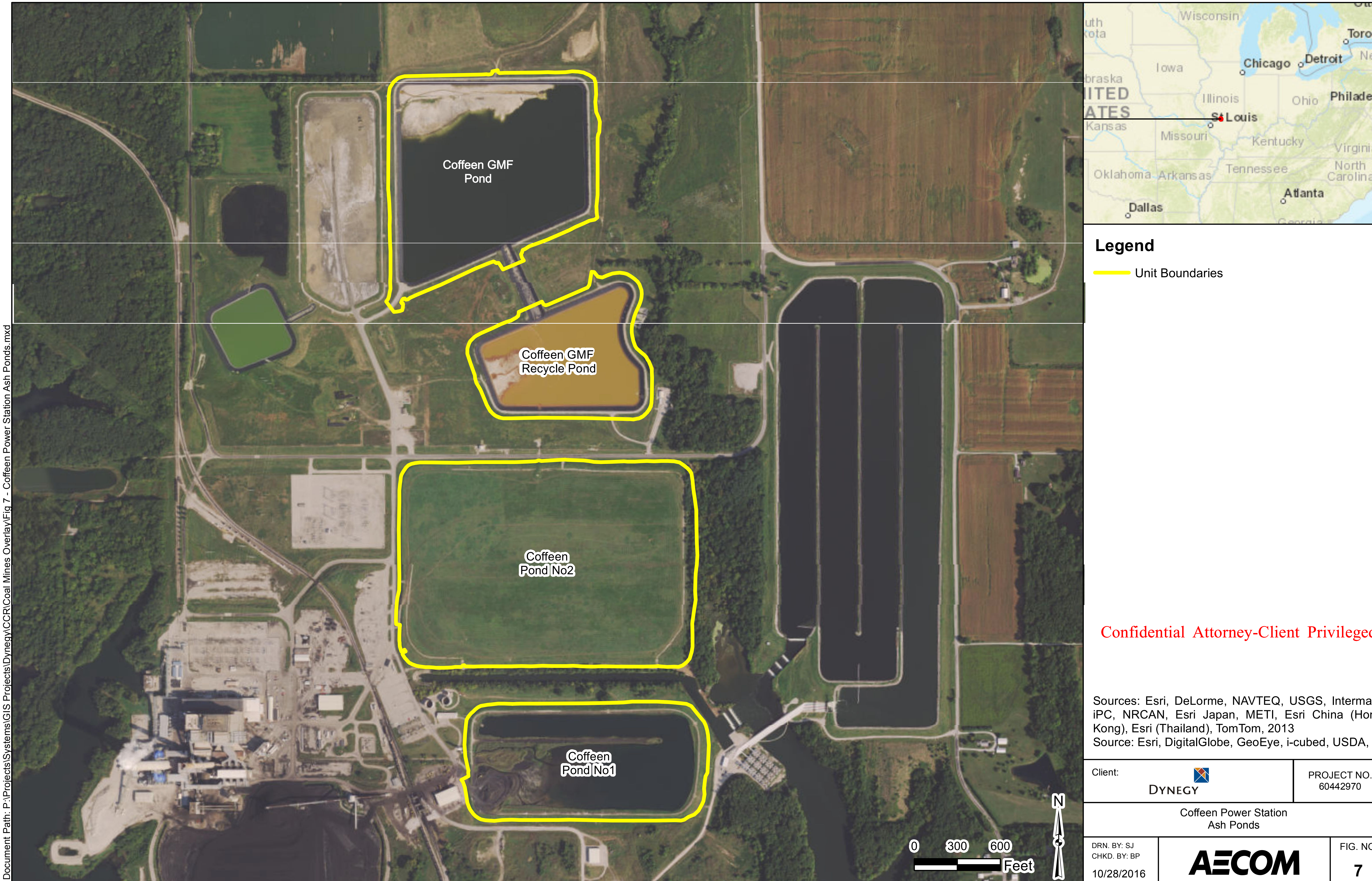
Figure 7



Legend

Unit Boundaries

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Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2013
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA,

Client: DYNEGY | PROJECT NO. 60442970

Coffeen Power Station
Ash Ponds

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10/28/2016

AECOM

FIG. NO. 7

Document Path: P:\Projects\Systems\GIS Projects\Dynegy\CCR\Coal Mines Overlay\Fig 7 - Coffeen Power Station Ash Ponds.mxd

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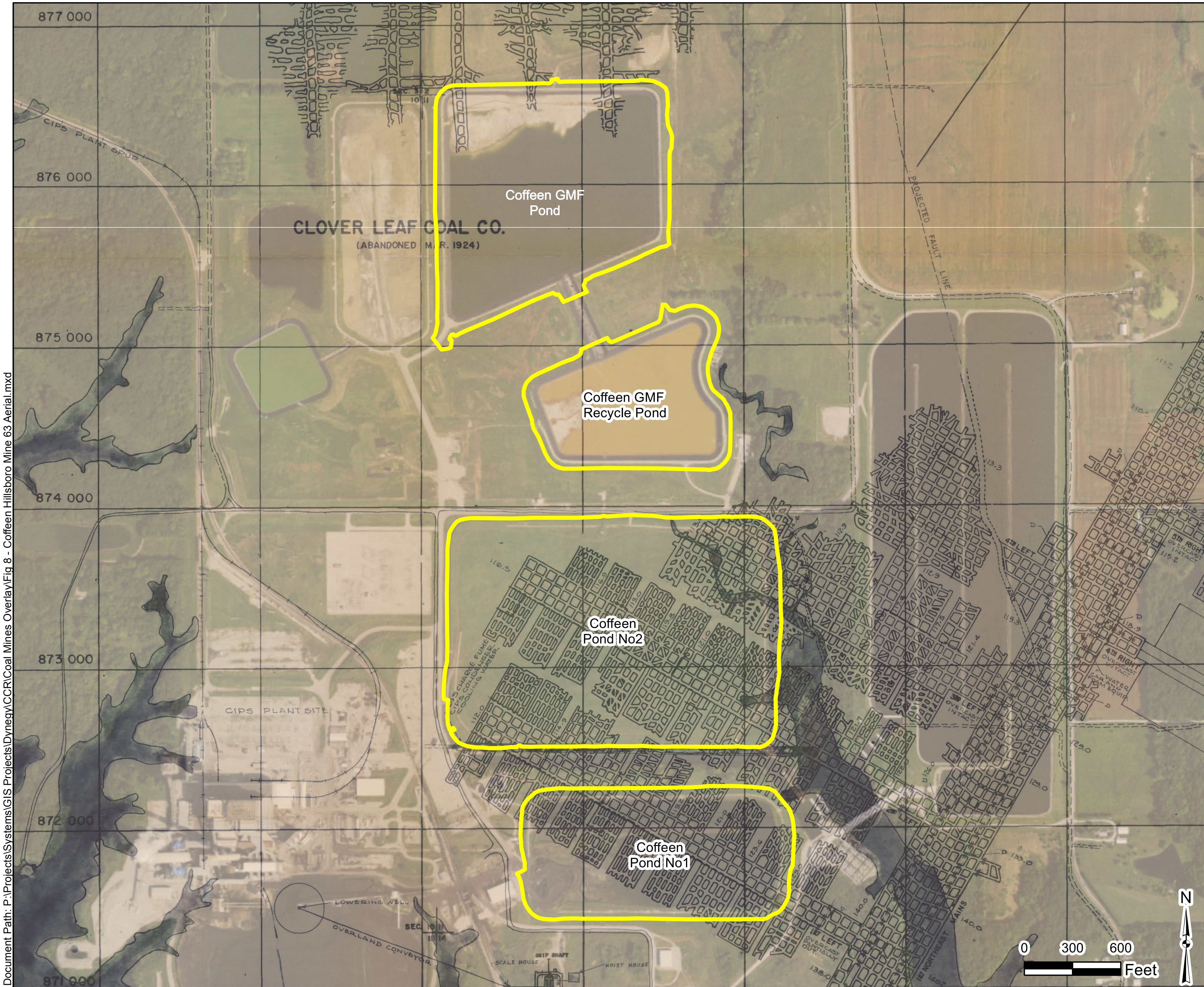
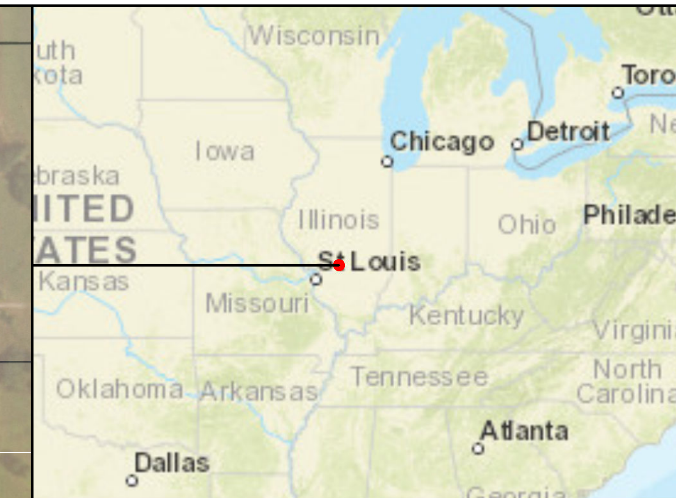
Figure 8





Legend

Unit Boundaries

Confidential Attorney-Client Privileged

Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2013
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA,

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PROJECT NO. 60442970

Coffeen Power Station
Truax-Traer Coal Co. Hillsboro Mine 63, 1969

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10/28/2016

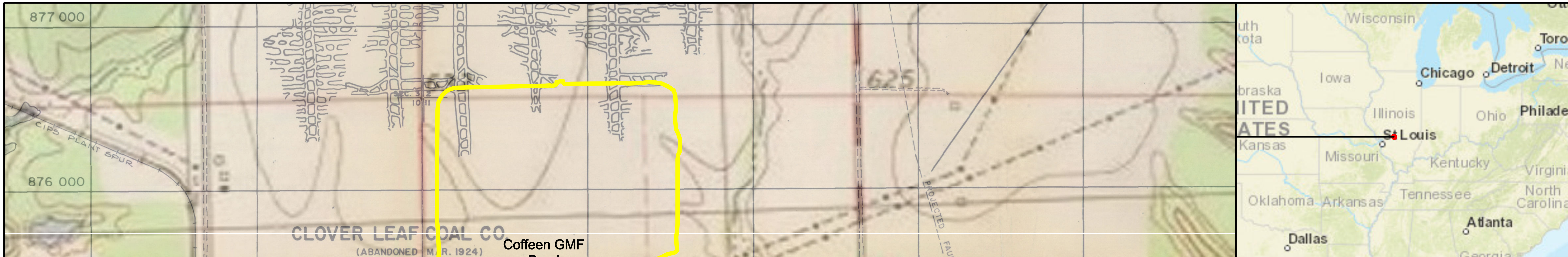
AECOM

FIG. NO. 8

Document Path: P:\Projects\Systems\GIS Projects\Dynegy\CCR\Coal Mines Overlay\Fig 8 - Coffeen Hillsboro Mine 63 Aerial.mxd

Attorney Client Privileged

Figure 9



Document Path: P:\Projects\Systems\GIS Projects\Dynegy\CCR\Coal Mines Overlay\Fig 9 - Coffeen Hillsboro Mine 63 Topo.mxd

Legend

Unit Boundaries

Confidential Attorney-Client Privileged

Source:Truax-Traer Coal Co. Hillsboro Mine 63, Workings Map, 12/31/69
Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2013

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Coffeen Power Station - Topographic Overlay
Truax-Traer Coal Co. Hillsboro Mine 63, 1969

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10/28/2016

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FIG. NO. 9

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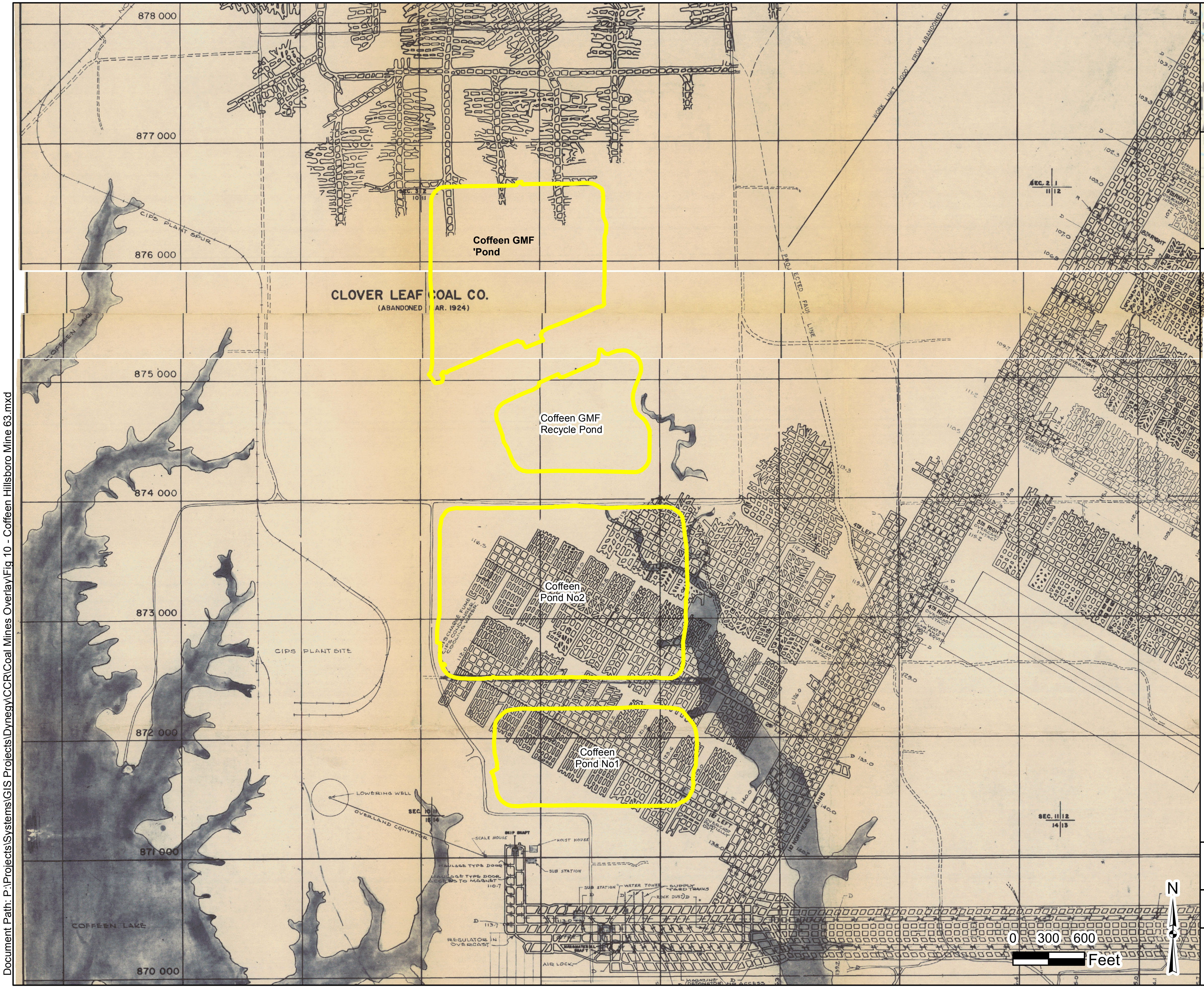
Figure 10



Legend

Unit Boundaries

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Source:Truax-Traer Coal Co. Hillsboro Mine 63, Workings Map, 12/31/69
Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2013

Client: DYNEGY

PROJECT NO. 60442970

Coffeen Power Station
Truax-Traer Coal Co. Hillsboro Mine 63, 1969

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10/28/2016

AECOM

FIG. NO. 10

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Attorney Client Privileged

Figure 11

Legend

Unit Boundary

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Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2013
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA,

Client: DYNEGY	PROJECT NO. 60442970

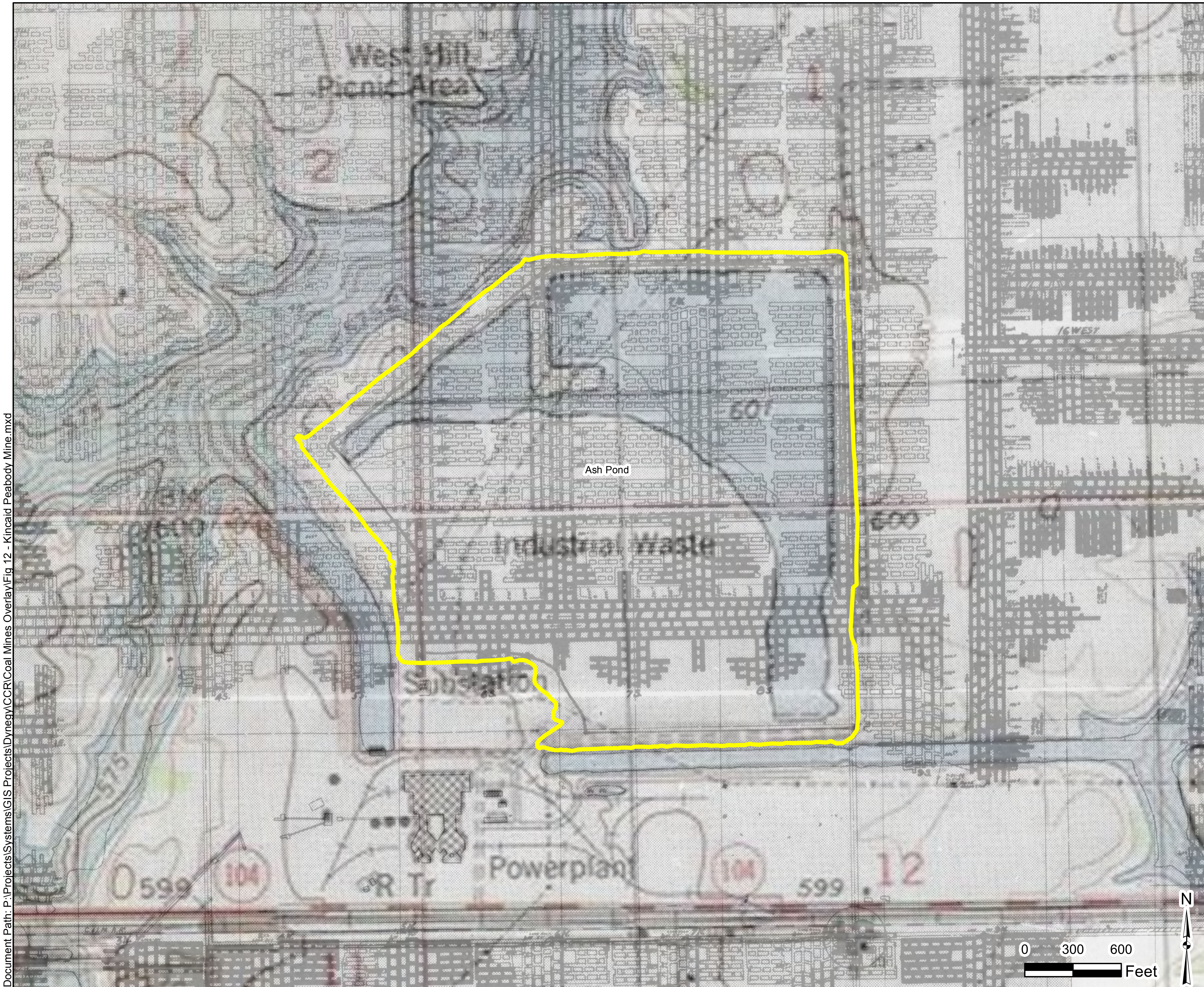
Kincaid Power Station
Ash Pond

DRN. BY: SJ CHKD. BY: BP 10/28/2016	AECOM	FIG. NO. 11

Document Path: P:\Projects\Systems\GIS Projects\Dynegy\CCR\Coal Mines Overlay\Fig 11 - Kincaid Power Station Ash Pond.mxd

Attorney Client Privileged

Figure 12



Legend

Unit Boundary

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Source: Peabody Mine 10, Final Workings Map, 8/1/1994.
Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2013

Client: DYNEGY

PROJECT NO. 60442970

Kincaid Power Station
Peabody Mine 10, 1994

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10/28/2016

AECOM

FIG. NO. 12

Document Path: P:\Projects\Systems\GIS Projects\Dynegy\CCR\Coal Mines Overlay\Fig 12 - Kincaid Peabody Mine.mxd

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Figure 13

Legend

Embankment sloughing

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Source: Peabody Mine 10, Final Workings Map, 8/1/1994.
Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2013

Client: DYNEGY	PROJECT NO. 60442970
Kincaid Power Station Subsidence	
DRN. BY: SJ CHKD. BY: BP 11/1/2016	AECOM
FIG. NO.	13

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APPENDIX G - HYDROLOGIC AND HYDRAULIC DESIGN OF STORMWATER MANAGEMENT SYSTEM

Appendix G – Hydrologic and Hydraulic Design of Stormwater Management System

TABLE OF CONTENTS

Page No.

LIST OF TABLES

LIST OF FIGURES

1.0 PURPOSE

The purpose of this calculation package is to provide documentation of the hydrologic and hydraulic calculations of the cover design for the 84-acre capped portion of the final closure of the Kincaid Power Plant Ash Pond. The closure area is broken in to two basic watersheds that shed to the north and then eventually to Sangchris Lake and one to the south that will drain through five new 18” culverts to the Sangchris Lake Channel. In particular, the analysis evaluates the performance of the cover’s proposed drainage features and outlets for the 25-year and 100-year, 24-hour Soil Conservation Service (SCS) Type II storm event in accordance with the CCR Rule (USEPA, 2015). HydroCAD10.00-24 (HydroCAD) was used for the Hydrologic analysis to estimate the peak runoff rate from each subcatchment for the identified storm events. The calculation was performed for the hydraulic analysis of the Perimeter ditches and letdowns.

2.0 DESIGN BASIS

The proposed perimeter drainage ditches, berms and letdowns were designed to meet the following minimum criteria:

1. The 25-year storm event to satisfy IL Part 845.510; and
2. Safely convey the 100-year storm event to satisfy IL Part 845.510.

For design purposes, the SCS Type-II rainfall distribution was applied to both storm events listed above. The SCS Type-II distribution is a conservative temporal distribution for a 24-hour duration storm event in context of this closure design due to its peak rainfall intensity, which is greater than the other acceptable standardized distributions that were considered, such as Huff 3rd Quartile (for areas less than 10 square miles) as published in the Illinois State Water Survey (ISWS) Circular 173 (ISWS, 1990).

The cap system for the closure of the existing ash pond consists of (from bottom to top) a geomembrane, geotextile, 18" of soil cover and 6" vegetative layer. The top is generally sloped at a 3% slope that sheet flows down to tag along berms running horizontally across the slopes about midway up the slope. These tag-on berms carry the surface water across the slope and empty into letdowns that run vertically down the slope. These letdown channels convey stormwater down to the perimeter ditch that runs along the toe of the ash pond. The perimeter ditch drains to the north into the natural drainage path that leads to Sangchris Lake. A portion of the existing berm along the north that forms the current ash pond will be removed to allow the surface water to flow through a rip rap channel and into Sangchris Lake. The southern half of the perimeter ditch drains to the southeast corner and empties into the Sangchris Lake Channel through (5) 18-inch CHDPE pipes under the perimeter road. The Letdown channels consist of an eight-foot flat bottom ditch and will have a riprap surface underlain by geotextile to protect the cap system. The perimeter ditches will consist of the same section as the capping system and will also be an eight-foot flat bottom ditch.

3.0 ASSUMPTIONS AND DATA INPUT

The following section presents a summary of the assumptions and inputs associated with the hydrologic and hydraulic analysis and design.

3.1 Summary of Survey Data and Site Improvement Data

Site topographic surveys of existing conditions (e.g., pre-closure conditions) were performed by IngenAE, LLC in December 2020, which were prepared and provided to Vistra as a drawing set (IngenAE, March 2021).

Site improvements are based on the preliminary closure design for the Kincaid Ash Pond (KAP) prepared by Burns & McDonnell as part of the construction permit application.

3.2 Hydrological Inputs

The following design assumptions and hydrologic parameters were used to perform the hydrologic analysis.

3.2.1 Rainfall Depth and Distribution

Rainfall depths were based on NOAA Atlas 14 (NOAA, 2006) Point Precipitation Frequency Estimates, as shown in Appendix 1. The Type II SCS storm distribution was used to evaluate the imbedded high rainfall intensity portion of the storm as a critical flood risk analysis. The SCS was preferred over the huff distribution as it is more conservative and will reduce the long-term structural maintenance of channels/letdown structures. This storm temporal distribution is considered conservative for a 24-hour duration event and therefore adequate for design purposes (see Section 2 for detailed explanation). The following storm events were used to size the proposed stormwater features:

- Type II SCS 25-year, 24-hour event is 5.15 inches (Design)
- Type II SCS 100-year, 24-hour event is 6.43 inches (Safely Convey)

3.2.2 Curve Number (CN)

Curve numbers (CN) were estimated using the capping system described above with an assumed CN of 89.

3.2.3 Time of Concentration (Tc)

The time of concentration (Tc) for each drainage area was computed using the HydroCAD software with a minimum Tc of 6-minutes.

3.2.4 Subcatchments

The proposed site was subdivided into two drainage areas as shown on drainage area sketch in Appendix 2. Drainage area south is approximately 36 acres and includes subcatchments DA-1 to DA-8 that discharge through five new 18" culverts under the perimeter road and into the Sangchris Lake Channel; Drainage area north is approximately 38 acres and includes subcatchments DA-9 to DA-13 that discharge through a riprap channel at north end of the area where the CCR materials have been removed and consolidated and then into Sangchris Lake.

3.2.5 Perimeter Ditches

The location and longitudinal slope of the cover ditches were based on the 30% conceptual design. The ditches were designed as eight-foot flat bottom ditches with side slopes of 4 foot horizontal and 1 foot vertical and longitudinal slope of one percent. The channels were oversized to accommodate mowing equipment and allow for any additional maintenance needs. According to Manning's n for Channels (Chow, 1959), a manning's roughness coefficient of 0.03 was used for excavated earthen channels with short grass and few weeds.

Table 3-1: Perimeter Ditches

Perimeter Ditches:	Peak Inflow (cfs)		Max. Velocity (fps)		Average Flow depth (ft)		Capacity (cfs)
	25YR	100YR	25YR	100YR	25YR	100YR	
D-1	2.81	3.63	2.32	2.54	0.14	0.16	1532
D-2	15.27	19.77	4.27	4.66	0.37	0.43	1549
D-3	21.21	27.70	2.15	2.33	0.86	0.99	485
D-4	116.70	152.81	3.05	3.29	2.02	2.31	430
D-5	22.69	29.38	4.19	4.55	0.51	0.59	10918
D-6	43.97	57.01	5.12	5.54	0.77	0.89	10578
D-7	3.77	4.87	2.11	2.32	0.19	0.23	1128
D-8	16.85	21.77	3.62	3.93	0.47	0.54	1150
D-9	19.87	25.73	1.95	2.12	0.81	0.94	241
D-10	18.32	23.74	2.34	2.54	0.67	0.78	605
D-11	23.77	30.79	2.00	2.17	0.88	1.02	447
D-12	26.08	33.78	2.13	2.31	0.90	1.04	469
D-13	13.76	22.48	2.20	2.40	0.66	0.77	576

Perimeter ditches were designed to convey the 25-year, 24-hour event. Peak discharge outputs were taken from the HydroCAD model to determine the critical drainage area. Table 3-1 displays critical ditch results for the drainage areas while all of the HydroCAD peak flow outputs are shown in Appendix 3. The peak flows are 116.7 cfs and 152.81 cfs for the 25-year, and 100-year events respectively. Additionally, ditch velocities and depths were calculated from HydroCAD calculation based on the peak discharges and the typical ditch cross-section. Ditches were designed to have side slopes of 4-foot horizontal to 1-foot vertical-, and a graded longitudinal slope of 0.3-3 percent. This resulted in maximum velocities of 5.12 ft/s and 5.54 ft/s and depths of 2.02 feet and 2.31 feet for the 25-year and 100-year events, respectively (shown in Table 3-1).

Using guidance from Chapter 8 of the Natural Resources Conservation Services (NRCS) Engineering Handbook (NRCS, 2007), temporary erosion control blanket and grass cover provide enough protection to prevent erosion. Using the max velocities of 3.29 ft/s for the 100-year storm event and Table 8-11 from Chapter 8, table shown below in Figure 1, the ditches can use “coconut fiber with net” or “Fiberglass roving” as a temporary erosion control product. Grass vegetation is expected to establish through the temporary erosion control product within the ditches and has a recommended allowable velocity of 5 to 7 ft/s dependent on grass type – e.g., bermudagrass versus Kentucky bluegrass per Table 8-11 for Chapter 8.

Figure 1: Excerpt Table 8-11 from Chapter 8 of the NRCS Engineering Handbook

Table 8–11 Allowable velocity and shear stress for selected lining materials[1/]

Boundary category	Boundary type	Allowable velocity (ft/s)	Allowable shear stress (lb/ft^2)	Citation(s)
Temporary degradable reinforced erosion control products (RECP)	Jute net	1–2.5	0.45	B, E, F
	Straw with net	1–3	1.5–1.65	B, E, F
	Coconut fiber with net	3–4	2.25	B, F
	Fiberglass roving	2.5–7	2	B, E, F
Nondegradable RECP	Unvegetated	5–7	3	B, D, F
	Partially established	7.5–15	4–6	B, D, F
	Fully vegetated	8–21	8	C, F
Hard surface	Gabions	1–19	10	A
	Concrete	>18	12.5	E

1/ Ranges of values generally reflect multiple sources of data or different testing conditions

(Goff 1999)
(Gray and Sotir 1996)
(Julien 1995)
(Kouwen, Li, and Simons 1980)
(Norman 1975)
(TXDOT 1999)

3.2.6 Letdown Design

The letdowns were designed using D50 rock size of 12" and calculated by HydroCAD. The peak flows and maximum velocity arre presented in Table 3-2. The letdown channels are riprap lined eight-foot flat bottom channels with 4-foot horizontal and 1-foot vertical side slopes.

Table 3-1: Letdown Channel

Letdown channel	Peak Inflow (cfs)		Max. Velocity (fps)		Average Flow depth (ft)		Capacity (cfs)
	25YR	100YR	25YR	100YR	25YR	100YR	
LD-1	6.05	7.84	2.99	3.28	0.23	0.26	332
LD-2-1	32.67	42.42	2.74	2.95	0.99	1.13	129
LD-2-2	31.95	41.52	3.48	3.76	0.81	0.94	182
LD-3-1	25.79	33.49	2.34	2.52	0.93	1.07	114
LD-3-2	25.15	32.68	4.54	4.93	0.54	0.63	298
LD-4	13.69	17.76	3.40	3.70	0.42	0.48	261
LD-5	33.22	43.41	5.17	5.61	0.61	0.71	1411
LD-6	37.22	48.35	3.07	3.31	1.00	1.15	143
LD-7	72.33	94.54	6.10	6.60	0.99	1.14	288
LD-8	26.11	33.92	2.23	2.41	0.97	1.11	106
LD-9	25.41	33.09	1.96	2.11	1.05	1.20	89
LD-10	59.75	78.08	5.80	6.27	0.89	1.03	1282

4.0 CONCLUSION

The three design features are summarized as follows:

1. An eight-foot flat bottom ditch with a longitudinal slope of 1% and side slopes of 4-foot horizontal to 1-foot vertical is expected to safely convey the 25-year, and 100-year events at flow depths of 2.65 feet and 3.05 feet for respectively.
2. According to Table 8-11 in Chapter 8 of the Natural Resources Conservation Services Engineering Handbook, the max velocities of 5.54 ft/s for the 100-year storm event in the perimeter ditches are low enough to be supported by temporary erosion control blanket and grass cover.
3. 18" base of Riprap with D50 of 12" riprap will be utilized on letdown channels to safely convey the stormwater down to natural drainage paths.

5.0 REFERENCES

IngenAE,2021 . IngenAE, 2021. “Kincaid Power Station, February 2, 2021.

National Oceanic and Atmospheric Administration (NOAA), 2006. NOAA Atlas 14, Precipitation-Frequency Atlas of the United States, Volume 2, Version 4. Available online at http://www.nws.noaa.gov/oh/hdsc/PF_documents/Atlas14_Volume2.pdf.

National Resource Conservation Service (NRCS), 1997. Part 630 Hydrology, National Engineering Handbook.

United States Environmental Protection Agency (USEPA, 2015). Final Rule: Disposal of Coal Combustion Residuals from Electric Utilities.

APPENDIX A - NOAA ATLAS 14, VOLUME 2, VERSION 3

NOAA Atlas 14, Volume 2, Version 3
Location name: Pawnee, Illinois, USA*
Latitude: 39.5978°, Longitude: -89.4937°
Elevation: 605.39 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M.Yekta, and D. Riley

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]										
Duration	**Average recurrence interval (years)**									
	1	**2**	**5**	**10**	**25**	**50**	**100**	**200**	**500**	**1000**
5-min	**0.401** (0.365-0.442)	**0.477** (0.435-0.526)	**0.566** (0.517-0.624)	**0.638** (0.580-0.702)	**0.728** (0.660-0.799)	**0.800** (0.721-0.878)	**0.870** (0.780-0.954)	**0.943** (0.842-1.03)	**1.04** (0.924-1.15)	**1.12** (0.986-1.23)
10-min	**0.623** (0.568-0.686)	**0.745** (0.679-0.821)	**0.880** (0.803-0.970)	**0.984** (0.896-1.08)	**1.11** (1.01-1.22)	**1.21** (1.09-1.33)	**1.31** (1.17-1.44)	**1.41** (1.26-1.55)	**1.53** (1.36-1.68)	**1.63** (1.44-1.79)
15-min	**0.763** (0.696-0.841)	**0.910** (0.830-1.00)	**1.08** (0.986-1.19)	**1.21** (1.10-1.33)	**1.38** (1.25-1.51)	**1.50** (1.35-1.65)	**1.63** (1.46-1.78)	**1.75** (1.56-1.92)	**1.92** (1.70-2.10)	**2.04** (1.80-2.24)
30-min	**1.01** (0.921-1.11)	**1.22** (1.11-1.34)	**1.48** (1.35-1.63)	**1.68** (1.53-1.85)	**1.94** (1.76-2.13)	**2.15** (1.94-2.36)	**2.35** (2.11-2.58)	**2.56** (2.28-2.80)	**2.84** (2.51-3.11)	**3.06** (2.69-3.36)
60-min	**1.23** (1.12-1.36)	**1.50** (1.36-1.65)	**1.86** (1.70-2.05)	**2.14** (1.95-2.36)	**2.52** (2.28-2.77)	**2.83** (2.55-3.10)	**3.14** (2.82-3.44)	**3.47** (3.10-3.81)	**3.92** (3.48-4.30)	**4.29** (3.78-4.71)
2-hr	**1.47** (1.33-1.62)	**1.77** (1.61-1.96)	**2.22** (2.02-2.44)	**2.57** (2.33-2.82)	**3.05** (2.76-3.35)	**3.44** (3.10-3.78)	**3.85** (3.45-4.22)	**4.29** (3.81-4.69)	**4.90** (4.33-5.37)	**5.41** (4.74-5.93)
3-hr	**1.56** (1.42-1.72)	**1.88** (1.71-2.08)	**2.36** (2.14-2.61)	**2.74** (2.48-3.02)	**3.28** (2.95-3.61)	**3.72** (3.33-4.08)	**4.18** (3.73-4.59)	**4.69** (4.15-5.15)	**5.41** (4.74-5.94)	**6.01** (5.22-6.61)
6-hr	**1.83** (1.67-2.01)	**2.21** (2.02-2.43)	**2.76** (2.52-3.03)	**3.21** (2.92-3.52)	**3.84** (3.47-4.20)	**4.35** (3.92-4.76)	**4.91** (4.39-5.37)	**5.50** (4.89-6.01)	**6.35** (5.58-6.94)	**7.07** (6.16-7.72)
12-hr	**2.15** (1.98-2.34)	**2.59** (2.39-2.83)	**3.22** (2.96-3.51)	**3.72** (3.42-4.05)	**4.43** (4.05-4.82)	**5.01** (4.55-5.44)	**5.62** (5.08-6.10)	**6.27** (5.64-6.81)	**7.21** (6.42-7.83)	**7.99** (7.05-8.68)
24-hr	**2.49** (2.31-2.69)	**3.01** (2.80-3.25)	**3.76** (3.50-4.06)	**4.35** (4.03-4.69)	**5.15** (4.76-5.55)	**5.78** (5.34-6.22)	**6.43** (5.92-6.92)	**7.11** (6.53-7.65)	**8.05** (7.36-8.66)	**8.80** (8.02-9.46)
2-day	**2.88** (2.67-3.10)	**3.47** (3.23-3.75)	**4.32** (4.02-4.67)	**4.98** (4.63-5.37)	**5.87** (5.44-6.32)	**6.57** (6.07-7.08)	**7.29** (6.72-7.85)	**8.03** (7.39-8.64)	**9.06** (8.30-9.74)	**9.87** (9.02-10.6)
3-day	**3.08** (2.86-3.30)	**3.71** (3.46-3.99)	**4.61** (4.30-4.96)	**5.31** (4.94-5.70)	**6.24** (5.79-6.70)	**6.97** (6.46-7.48)	**7.72** (7.14-8.28)	**8.48** (7.82-9.10)	**9.52** (8.76-10.2)	**10.3** (9.49-11.1)
4-day	**3.28** (3.06-3.51)	**3.95** (3.69-4.24)	**4.90** (4.58-5.26)	**5.63** (5.25-6.04)	**6.61** (6.15-7.08)	**7.37** (6.85-7.89)	**8.14** (7.55-8.72)	**8.93** (8.26-9.56)	**9.99** (9.22-10.7)	**10.8** (9.96-11.6)
7-day	**3.87** (3.62-4.12)	**4.64** (4.36-4.96)	**5.69** (5.33-6.08)	**6.47** (6.06-6.91)	**7.49** (7.00-7.99)	**8.28** (7.72-8.82)	**9.06** (8.44-9.66)	**9.85** (9.15-10.5)	**10.9** (10.1-11.6)	**11.7** (10.8-12.5)
10-day	**4.38** (4.12-4.66)	**5.26** (4.95-5.60)	**6.40** (6.02-6.82)	**7.25** (6.81-7.72)	**8.37** (7.84-8.90)	**9.22** (8.63-9.80)	**10.1** (9.40-10.7)	**10.9** (10.2-11.6)	**12.0** (11.2-12.8)	**12.9** (12.0-13.7)
20-day	**5.97** (5.65-6.31)	**7.14** (6.75-7.57)	**8.61** (8.13-9.11)	**9.67** (9.13-10.2)	**11.0** (10.4-11.7)	**12.1** (11.4-12.8)	**13.1** (12.3-13.8)	**14.1** (13.2-14.9)	**15.4** (14.5-16.3)	**16.4** (15.4-17.4)
30-day	**7.36** (6.99-7.76)	**8.79** (8.35-9.28)	**10.5** (9.96-11.1)	**11.7** (11.1-12.3)	**13.3** (12.5-14.0)	**14.4** (13.6-15.2)	**15.5** (14.6-16.4)	**16.6** (15.6-17.6)	**18.1** (17.0-19.1)	**19.2** (17.9-20.2)
45-day	**9.23** (8.78-9.70)	**11.0** (10.5-11.6)	**13.0** (12.4-13.7)	**14.4** (13.7-15.1)	**16.2** (15.4-17.0)	**17.5** (16.6-18.4)	**18.8** (17.8-19.7)	**20.0** (18.9-21.0)	**21.6** (20.4-22.7)	**22.8** (21.5-24.0)
60-day	**10.9** (10.3-11.4)	**12.9** (12.3-13.6)	**15.2** (14.5-16.0)	**16.8** (16.0-17.7)	**18.8** (17.9-19.8)	**20.3** (19.3-21.3)	**21.7** (20.6-22.8)	**23.1** (21.9-24.3)	**24.9** (23.5-26.2)	**26.2** (24.8-27.6)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

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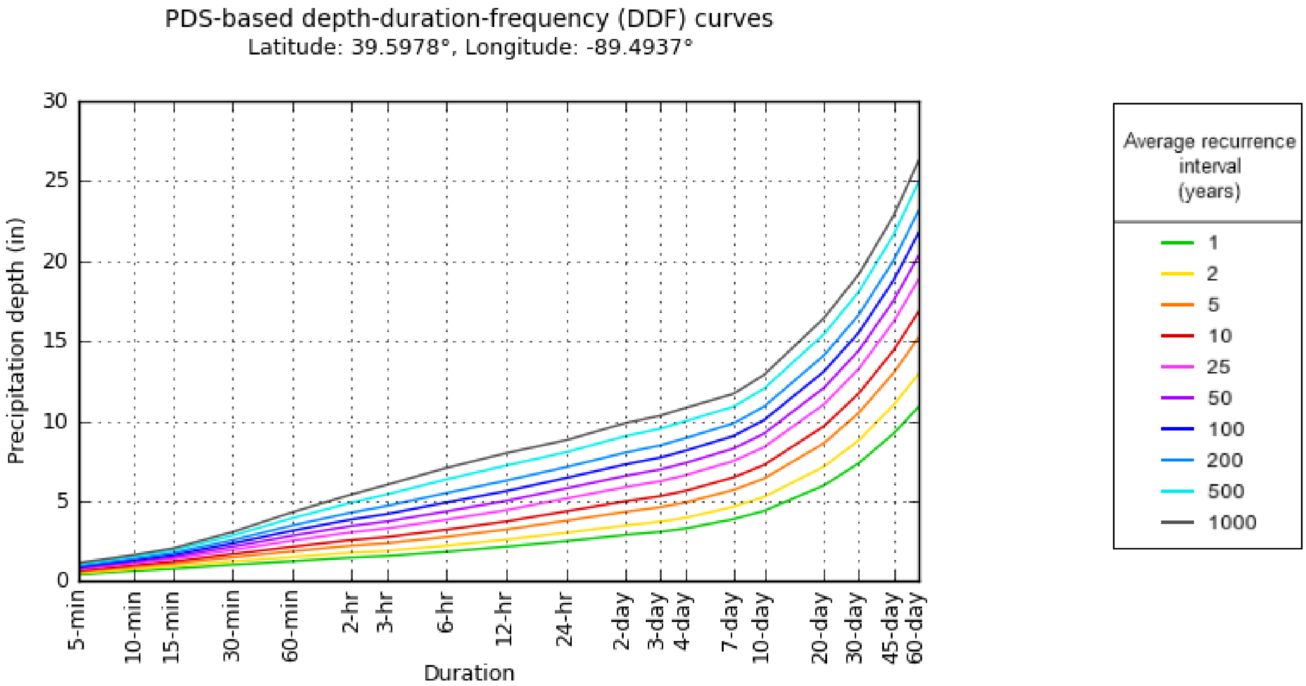
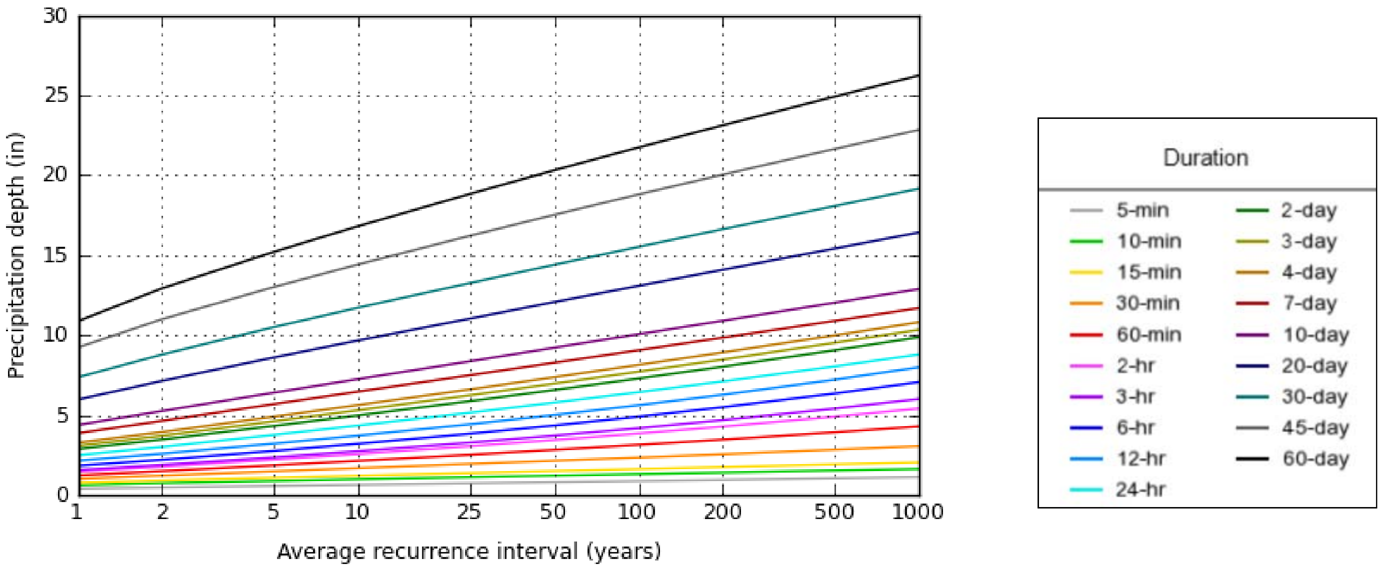
PF graphical





NOAA Atlas 14, Volume 2, Version 3

Created (GMT): Thu Jul 14 20:22:25 2022

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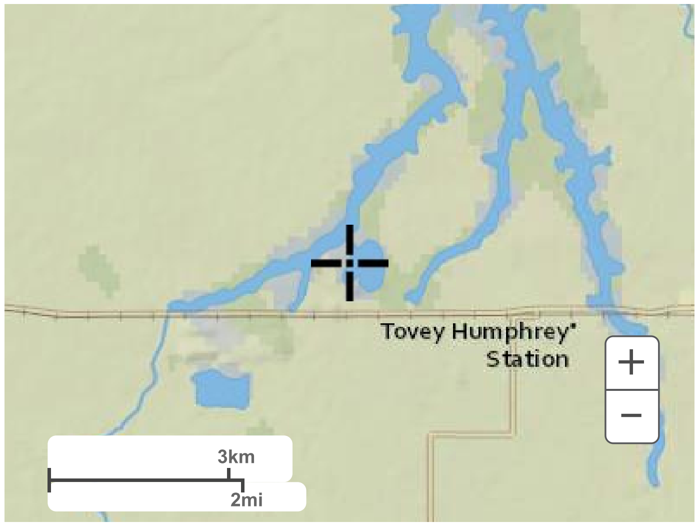
Maps & aerials

Small scale terrain



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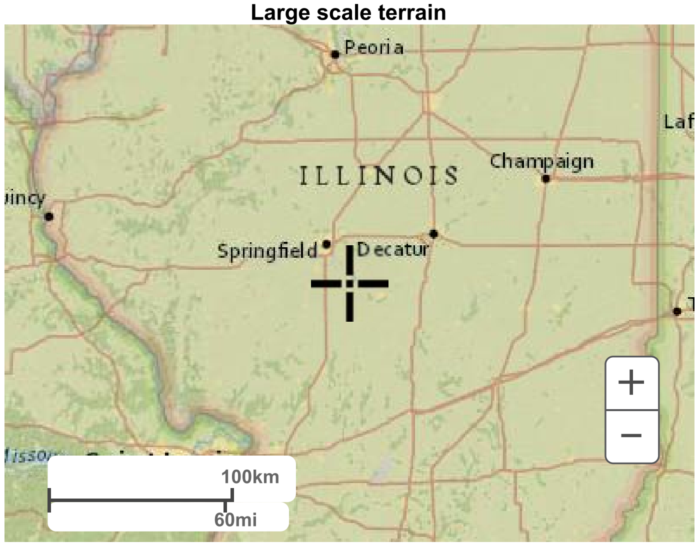
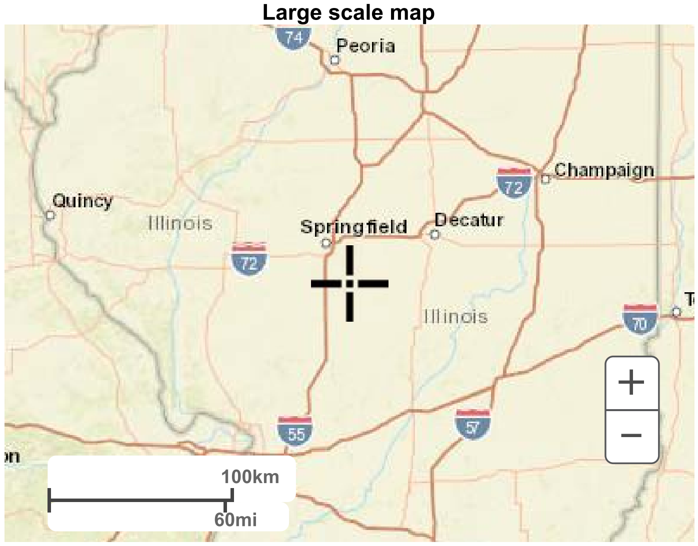
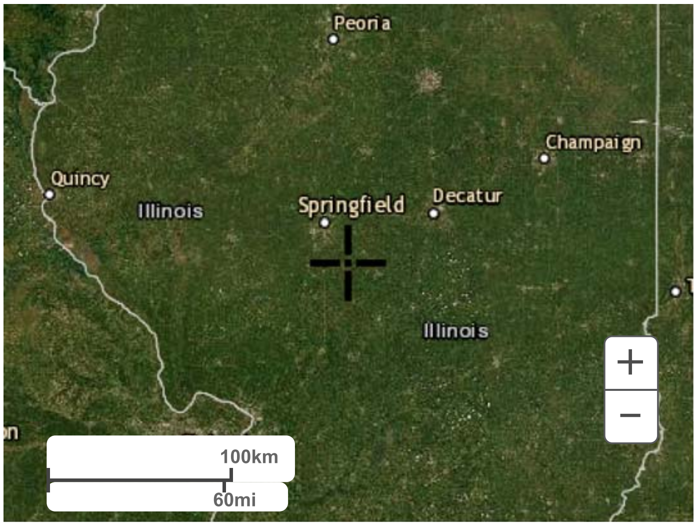


Large scale map



Large scale aerial



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US Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service
National Water Center
1325 East West Highway
Silver Spring, MD 20910
Questions?: HDSC.Questions@noaa.gov

APPENDIX B – COVER GRADING PLAN AND DRAINAGE MAP

NOTES:

1. ASSUMED BOTTOM OF CCR SURFACE BASED ON TOPOGRAPHIC SURFACE FILE BOA_v5A.DWG PROVIDED BY RAMBOLL ON MARCH 14, 2022.
2. UTILITY EASEMENT DELINEATION DESCRIPTION CAN BE FOUND ON DOCUMENT NO. 1998R1245.
3. EXISTING CONTOURS SHOWN ARE FROM TOPOGRAPHY AND BATHYMETRY SURVEY PROVIDED BY INGENAE DATED 2/26/2021.
4. EXISTING PIPES THROUGH DIKES TO BE ABANDONED IN PLACE AND FILLED WITH NON-SHRINK GROUT.
5. SHEET PILING INSTALLED IN INITIAL PHASE TO REMAIN IN PLACE.
6. EXISTING TRANSMISSION LINES WILL BE RELOCATED, RAISED, OR MODIFIED TO ALLOW FOR CONSTRUCTION ACCESS.
7. AREA OF POTENTIALLY SATURATED CCR. SATURATED CCR UNDER SEPARATION BERM WILL BE REMOVED AND REPLACED WITH LOW PERMEABLE SOIL.

7. AREA OF POTENTIALLY SATURATED CCR. SATURATED CCR UNDER SEPARATION BERM WILL BE REMOVED AND REPLACED WITH LOW PERMEABLE SOIL.

NORTH

0 200' 400' SCALE IN FEET

FOR PERMITTING PURPOSES ONLY

no.	date	by	ckd	description
E	07/26/22	RNO	MDB	ISSUED FOR PERMIT REVIEW
D	07/20/22	RNO	MDB	ISSUED FOR OWNER REVIEW
C	07/11/22	RNO	MDB	ISSUED FOR OWNER REVIEW
B	07/06/22	RNO	MDB	ISSUED FOR OWNER REVIEW
A	05/03/22	RNO	MDB	ISSUED FOR OWNER REVIEW

BURNS McDONNELL
9400 WARD PARKWAY
KANSAS CITY, MO 64114
816-333-9400
Burns & McDonnell Engineering Co, Inc.
Firm Reg. No. 184.001310-0006

designed R. OWENS
detailed S. NICHOLS

Luminant

SOUTH FORK TOWNSHIP, ILLINOIS

KINCAID ASH POND
CONSOLIDATED GRADING PLAN
PHASE 2

project 132803 contract 8110

drawing CG002 — rev. E

sheet 1 of 1 sheets

file 135946CG002.DGN

APPENDIX C – HYDROLOGIC SUMMARY

BURNS McDONNELL

WORKSHEET TITLE	Kincaid ash pond	**CALCULATION NO.:**	C002
CREATED:	7/25/2022	**REVISION:**	A
PERFORMED BY:	B. LIU	**REVIEWED BY:**	R. Owens
OBJECTIVE:	letdown channel peak flow and velocity calculation with post-construction phase 25yr 24hr storm and checking with 100yr 24 hr storm		

REFERENCES:

National Oceanic and Atmospheric Administration. (2018). NOAA Atlas 14, Volume 9, Version 2.

SOFTWARE:

HydroCAD 10.00-24 (40 node s/n 08510)

HYDROCAD INPUTS:

SCS Storm	Depth (in)
2yr, 24hr	3.01
25yr, 24hr	5.15
100yr, 24hr	6.43

Surface	CN
CCR	89
Riprap	96

North Drainage Area (to riprap area)		Tc (min)
DA-9 (sf)	25,797	6
DA-10 (sf)	128,351	16.5
DA-11 (sf)	156,707	10.7
DA-12 (sf)	400,062	21.5
DA-13 (sf)	144,536	10.7
DA-14 (sf)	187,472	10.7
DA-15 (sf)	175,790	21.5
DA-16 (sf)	96,365	17.1
DA-17 (sf)	205,685	10.7
DA-18 (sf)	135,964	10.5
Total (sf)	1,656,729	
Total (ac)	38.03	

HYDROCAD OUTPUTS:

Drainage :

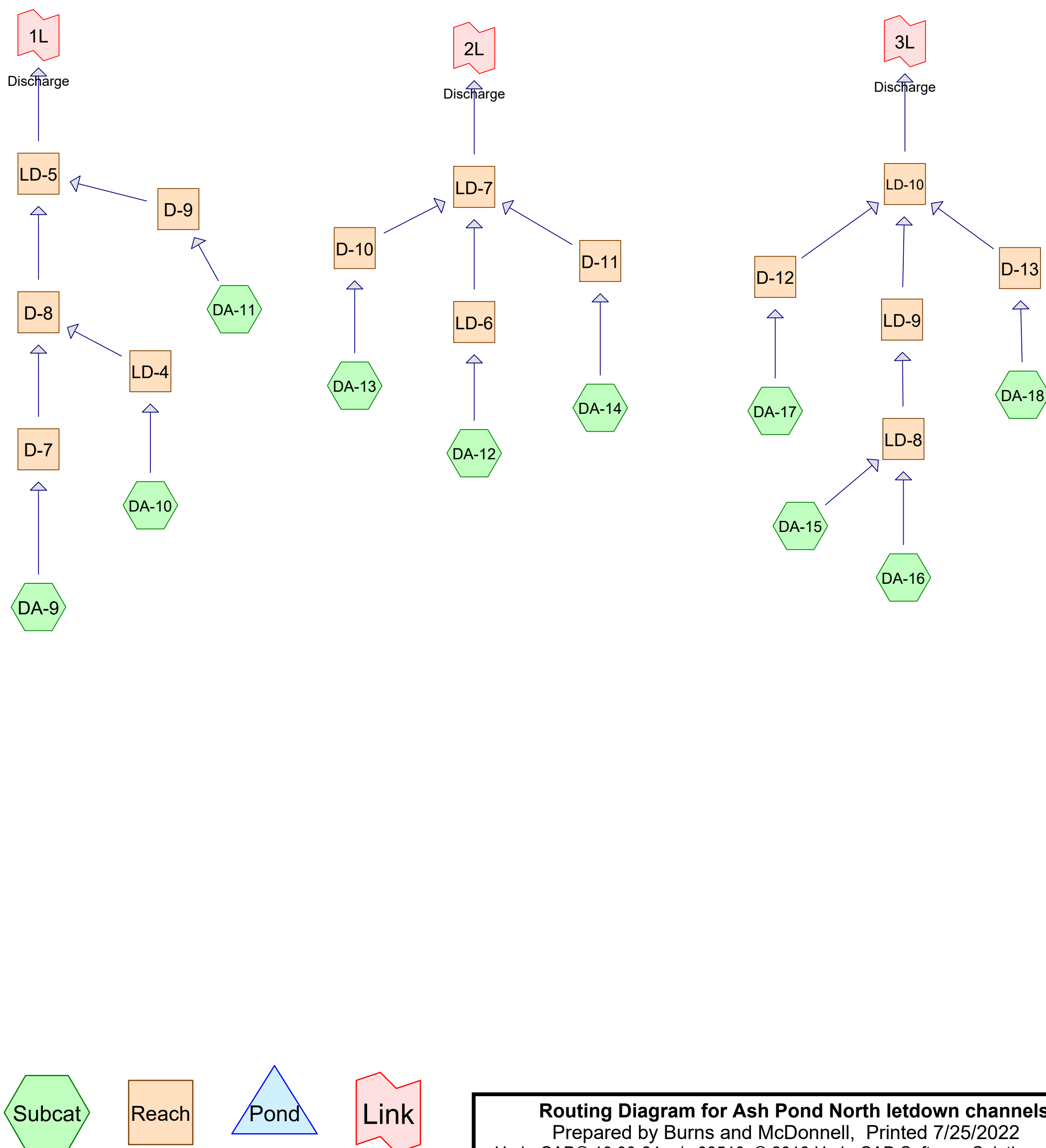
South area	Peakflow (cfs)	
	25YR	100 YR
DA-9	3.77	4.87
DA-10	13.69	17.76
DA-11	19.87	25.73
DA-12	37.22	48.35
DA-13	18.32	23.74
DA-14	23.77	30.79
DA-15	16.36	21.25
DA-16	10.10	13.10
DA-17	26.08	33.78
DA-18	17.36	22.48

Ditches:

Ditches:	Peak Inflow (cfs)		Max. Velocity (fps)		Average Flow depth (ft)		Capacity (cfs)
	25YR	100YR	25YR	100YR	25YR	100YR	
D-7	3.77	4.87	2.11	2.32	0.19	0.23	1128
D-8	16.85	21.77	3.62	3.93	0.47	0.54	1150
D-9	19.87	25.73	1.95	2.12	0.81	0.94	241
D-10	18.32	23.74	2.34	2.54	0.67	0.78	605
D-11	23.77	30.79	2.00	2.17	0.88	1.02	447
D-12	26.08	33.78	2.13	2.31	0.90	1.04	469
D-13	13.76	22.48	2.20	2.40	0.66	0.77	576

Letdown channel:

Letdown channel	Peak Inflow (cfs)		Max. Velocity (fps)		Average Flow depth (ft)		Capacity (cfs)
	25YR	100YR	25YR	100YR	25YR	100YR	
LD-4	13.69	17.76	3.40	3.70	0.42	0.48	261
LD-5	33.22	43.41	5.17	5.61	0.61	0.71	1411
LD-6	37.22	48.35	3.07	3.31	1.00	1.15	143
LD-7	72.33	94.54	6.10	6.60	0.99	1.14	288
LD-8	26.11	33.92	2.23	2.41	0.97	1.11	106
LD-9	25.41	33.09	1.96	2.11	1.05	1.20	89
LD-10	59.75	78.08	5.80	6.27	0.89	1.03	1282



Routing Diagram for Ash Pond North letdown channels
Prepared by Burns and McDonnell, Printed 7/25/2022
HydroCAD® 10.00-24 s/n 08510 © 2018 HydroCAD Software Solutions LLC

Area Listing (all nodes)

Area (acres)	CN	Description (subcatchment-numbers)
38.033	89	CCR (DA-10, DA-11, DA-12, DA-13, DA-14, DA-15, DA-16, DA-17, DA-18, DA-9)
38.033	**89**	**TOTAL AREA**

Ground Covers (all nodes)

HSG-A (acres)	HSG-B (acres)	HSG-C (acres)	HSG-D (acres)	Other (acres)	Total (acres)	Ground Cover	Subcatchment Numbers
0.000	0.000	0.000	0.000	38.033	38.033	CCR	DA-10, DA-11, DA-12, DA-13, DA-14, DA-15, DA-16, DA-17, DA-18, DA-9
0.000	**0.000**	**0.000**	**0.000**	**38.033**	**38.033**	**TOTAL AREA**	

Summary for Subcatchment DA-10:

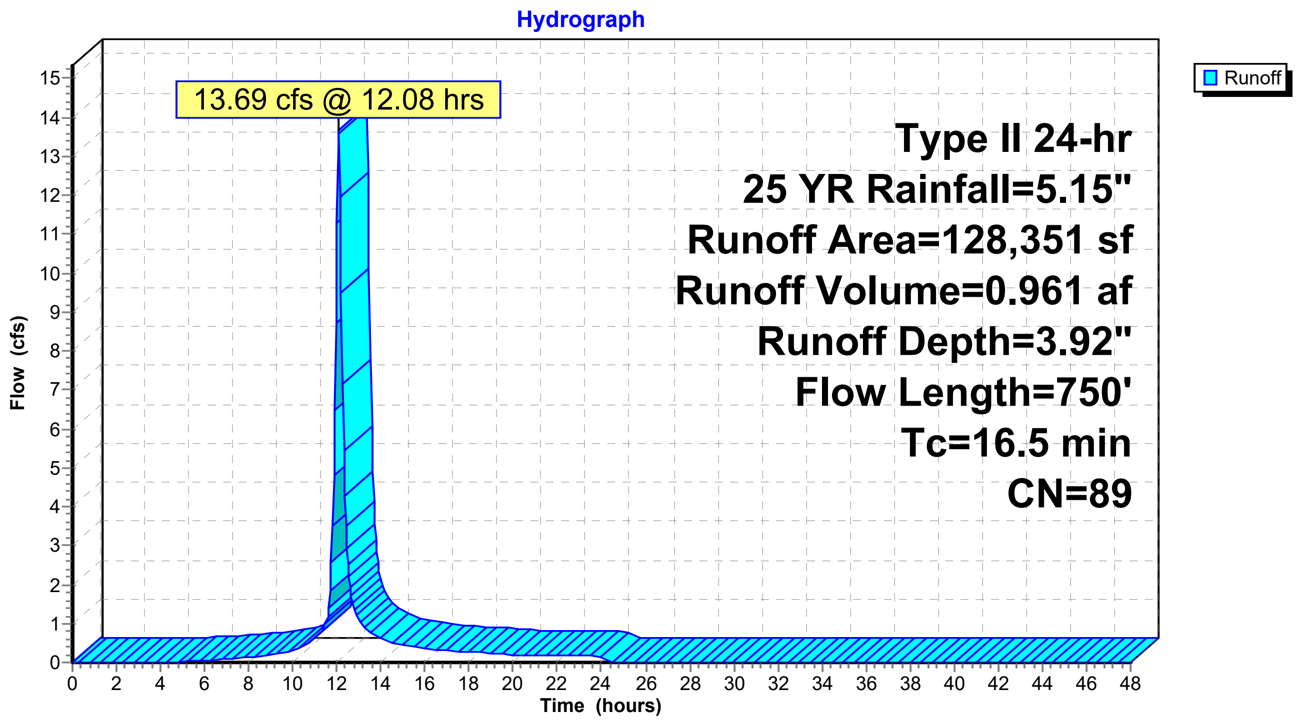
Runoff = 13.69 cfs @ 12.08 hrs, Volume= 0.961 af, Depth= 3.92"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 25 YR Rainfall=5.15"

	Area (sf)	CN	Description
*	128,351	89	CCR
	128,351		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.8	93	0.0100	0.11		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.49"
1.3	218	0.0300	2.79		**Shallow Concentrated Flow,** Unpaved Kv= 16.1 fps
1.4	439	0.0080	5.30	349.62	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=2.00' Z= 30.0 & 3.0 '/' Top.W=66.00' n= 0.025 Earth, clean & winding
16.5	750	Total			

Subcatchment DA-10:



Summary for Subcatchment DA-11:

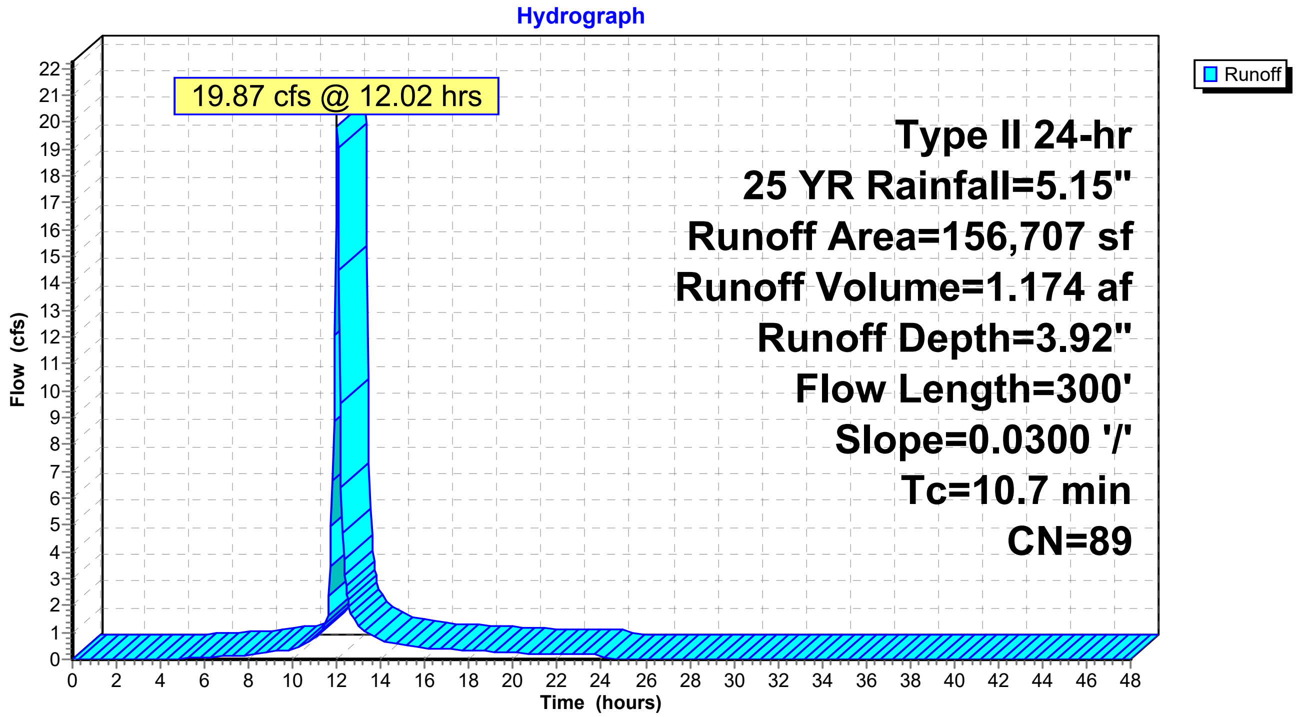
Runoff = 19.87 cfs @ 12.02 hrs, Volume= 1.174 af, Depth= 3.92"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 25 YR Rainfall=5.15"

	Area (sf)	CN	Description
*	156,707	89	CCR
	156,707		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
9.4	100	0.0300	0.18		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.49"
1.3	200	0.0300	2.60		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
10.7	300	Total			

Subcatchment DA-11:



Summary for Subcatchment DA-12:

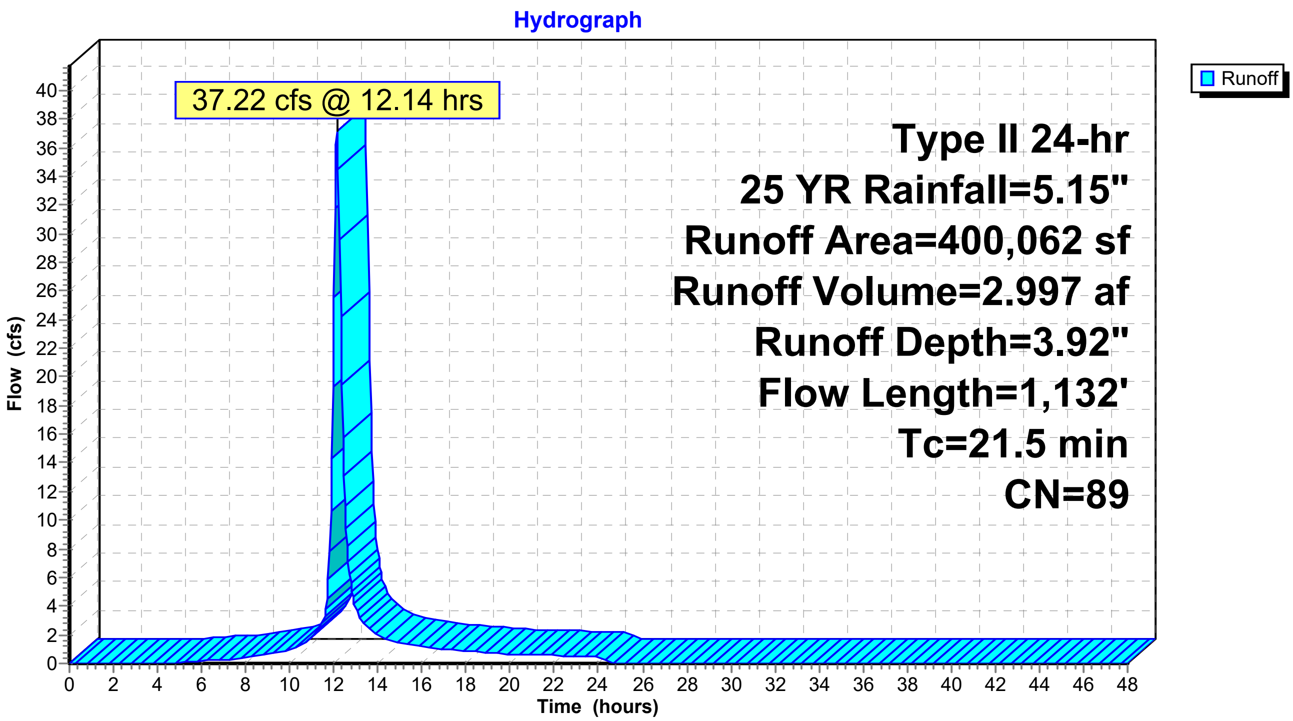
Runoff = 37.22 cfs @ 12.14 hrs, Volume= 2.997 af, Depth= 3.92"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 25 YR Rainfall=5.15"

	Area (sf)	CN	Description
*	400,062	89	CCR
	400,062		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
14.7	100	0.0100	0.11		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.49"
2.3	204	0.0100	1.50		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
1.3	206	0.0300	2.60		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
3.2	622	0.0030	3.24	214.10	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=2.00' Z= 30.0 & 3.0 '/' Top.W=66.00' n= 0.025 Earth, clean & winding
21.5	1,132	Total			

Subcatchment DA-12:



Summary for Subcatchment DA-13:

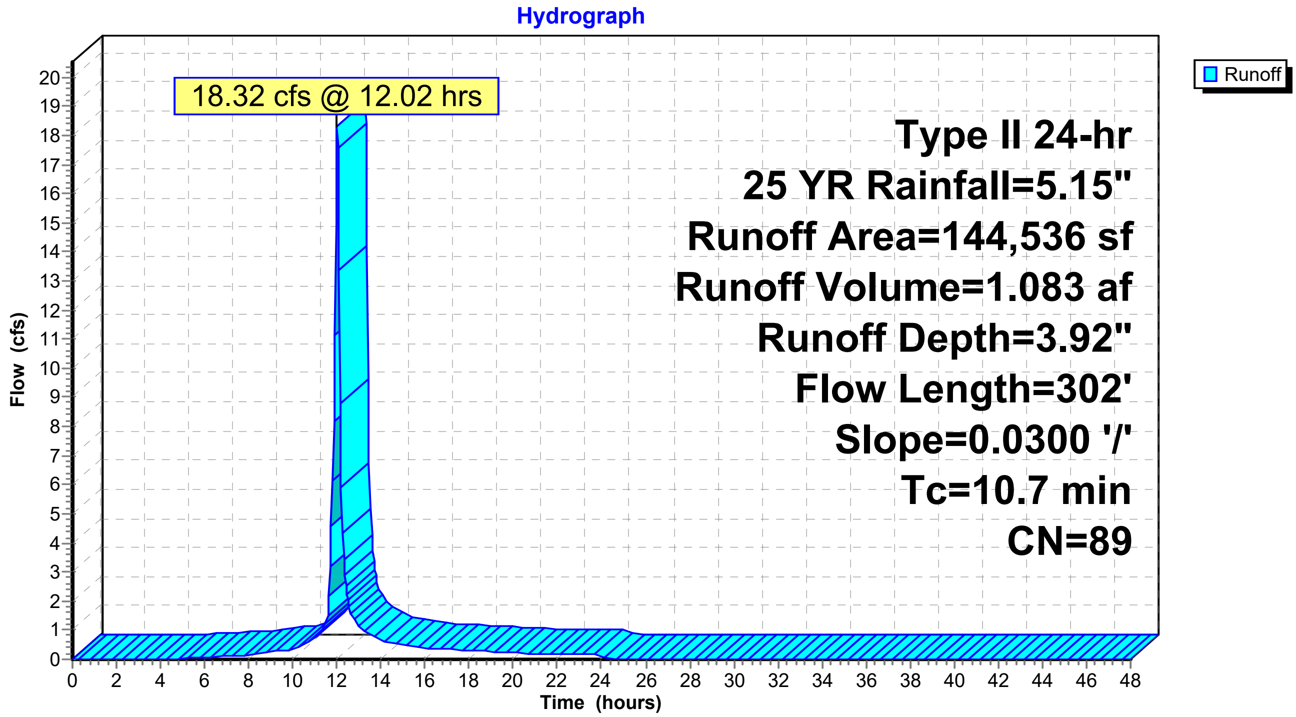
Runoff = 18.32 cfs @ 12.02 hrs, Volume= 1.083 af, Depth= 3.92"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 25 YR Rainfall=5.15"

	Area (sf)	CN	Description
*	144,536	89	CCR
	144,536		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
9.4	100	0.0300	0.18		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.49"
1.3	202	0.0300	2.60		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
10.7	302	Total			

Subcatchment DA-13:



Summary for Subcatchment DA-14:

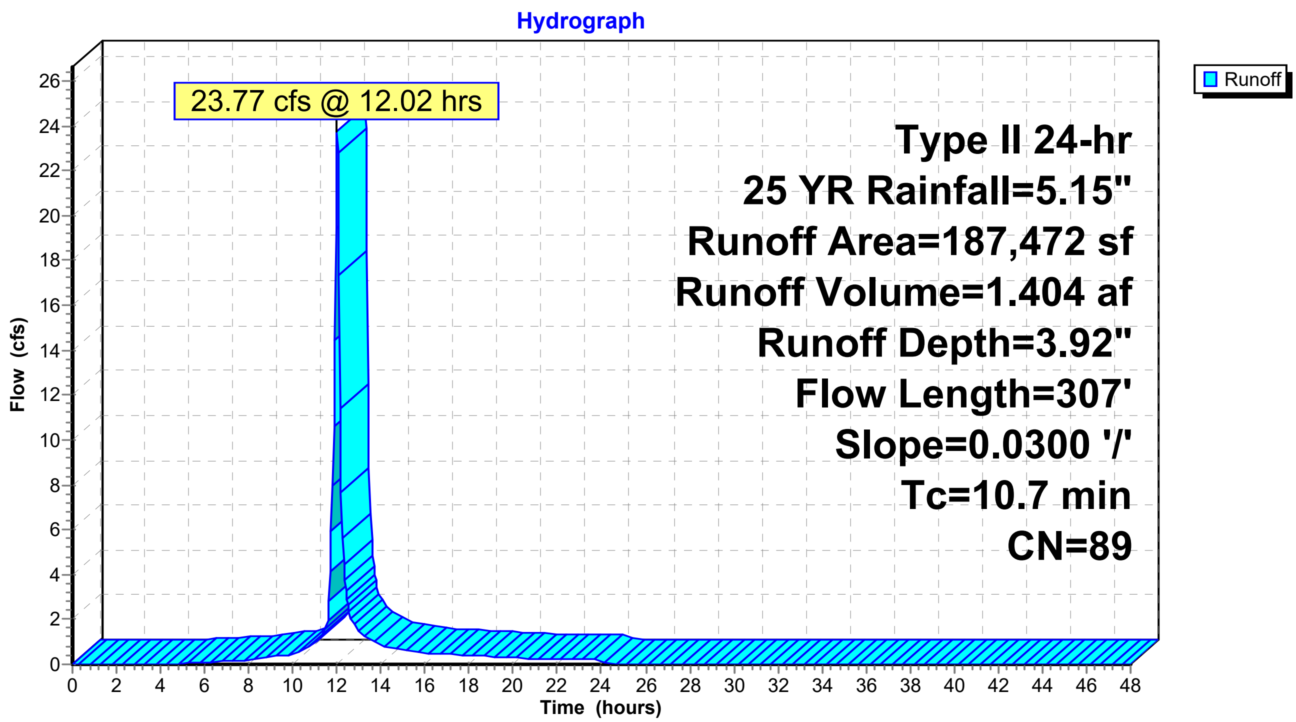
Runoff = 23.77 cfs @ 12.02 hrs, Volume= 1.404 af, Depth= 3.92"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 25 YR Rainfall=5.15"

	Area (sf)	CN	Description
*	187,472	89	CCR
	187,472		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
9.4	100	0.0300	0.18		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.49"
1.3	207	0.0300	2.60		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
10.7	307	Total			

Subcatchment DA-14:



Summary for Subcatchment DA-15:

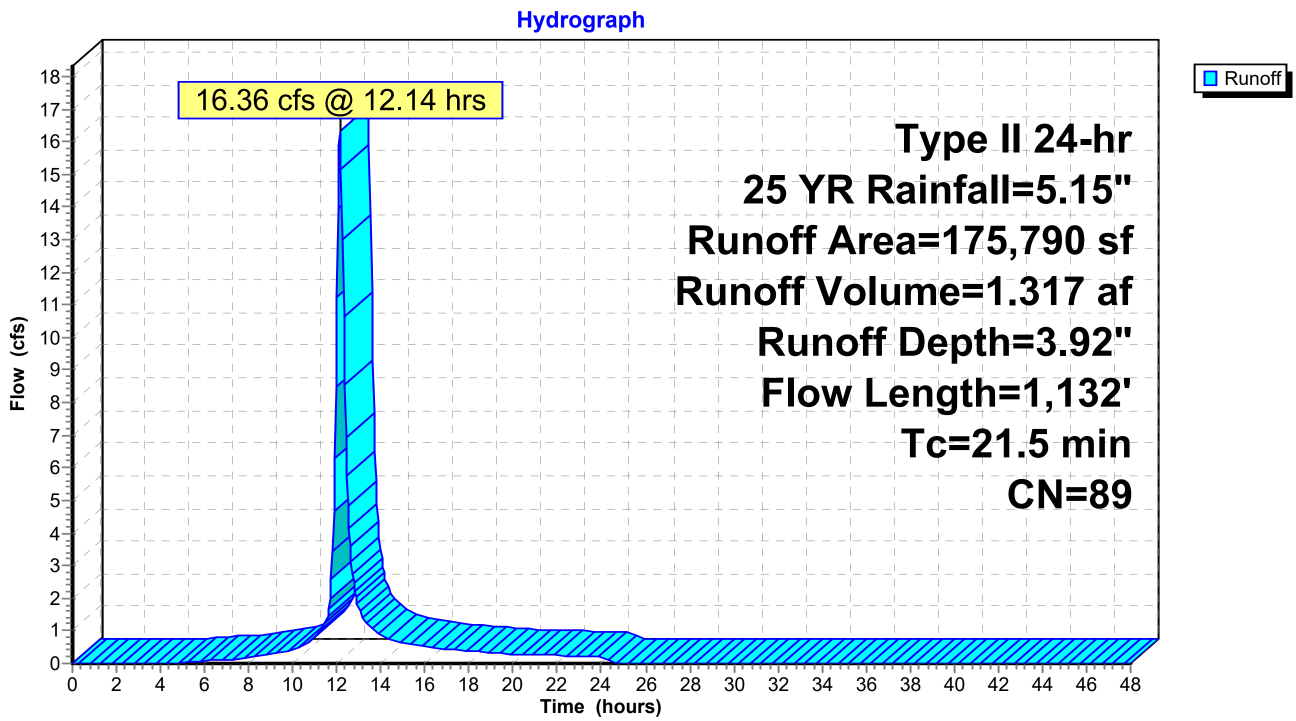
Runoff = 16.36 cfs @ 12.14 hrs, Volume= 1.317 af, Depth= 3.92"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 25 YR Rainfall=5.15"

	Area (sf)	CN	Description
*	175,790	89	CCR
	175,790		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
14.7	100	0.0100	0.11		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.49"
2.3	204	0.0100	1.50		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
1.3	206	0.0300	2.60		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
3.2	622	0.0030	3.24	214.10	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=2.00' Z= 30.0 & 3.0 '/' Top.W=66.00' n= 0.025 Earth, clean & winding
21.5	1,132	Total			

Subcatchment DA-15:



Summary for Subcatchment DA-16:

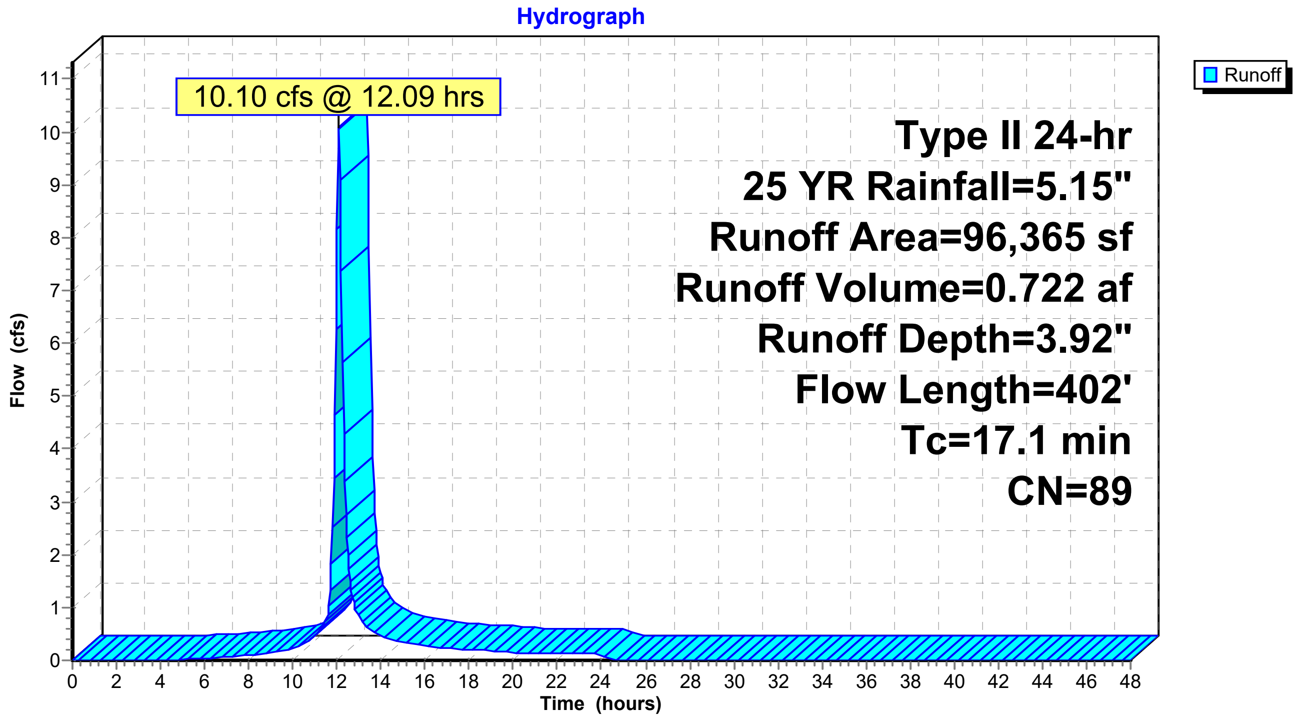
Runoff = 10.10 cfs @ 12.09 hrs, Volume= 0.722 af, Depth= 3.92"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 25 YR Rainfall=5.15"

	Area (sf)	CN	Description
*	96,365	89	CCR
	96,365		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
14.7	100	0.0100	0.11		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.49"
1.1	100	0.0100	1.50		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
1.3	202	0.0300	2.60		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
17.1	402	Total			

Subcatchment DA-16:



Summary for Subcatchment DA-17:

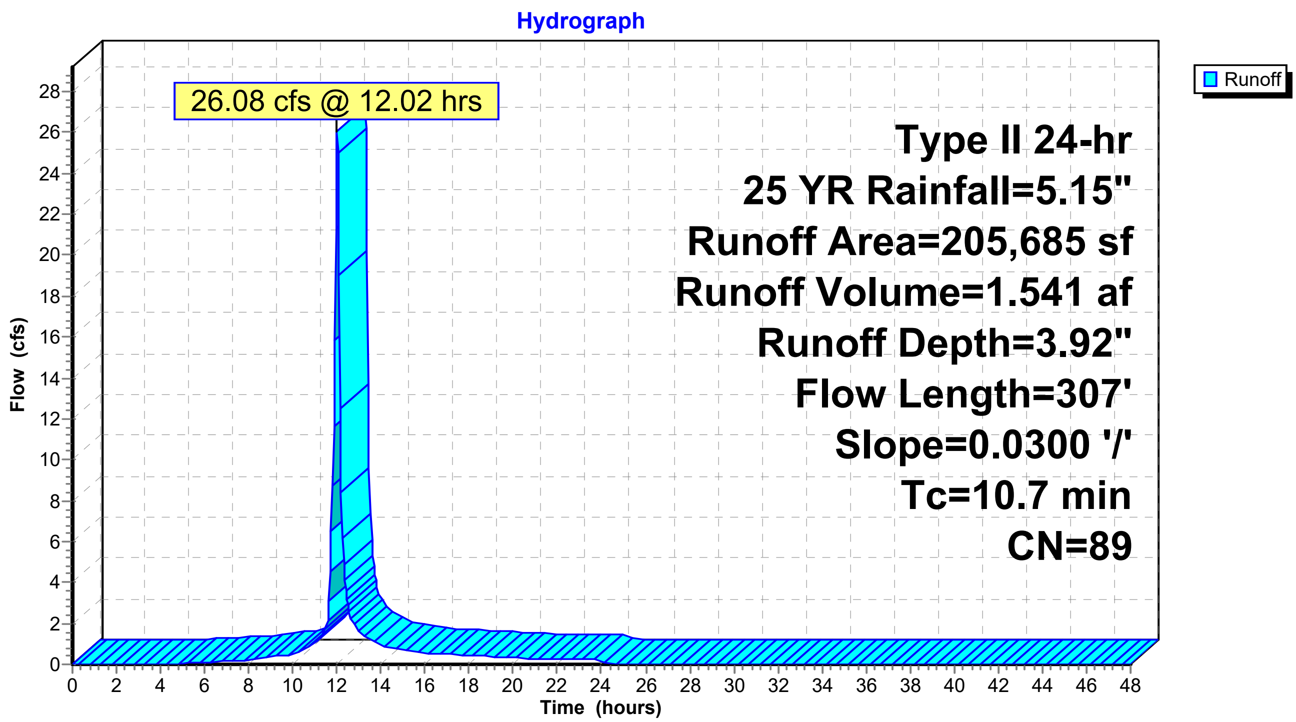
Runoff = 26.08 cfs @ 12.02 hrs, Volume= 1.541 af, Depth= 3.92"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 25 YR Rainfall=5.15"

	Area (sf)	CN	Description
*	205,685	89	CCR
	205,685		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
9.4	100	0.0300	0.18		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.49"
1.3	207	0.0300	2.60		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
10.7	307	Total			

Subcatchment DA-17:



Summary for Subcatchment DA-18:

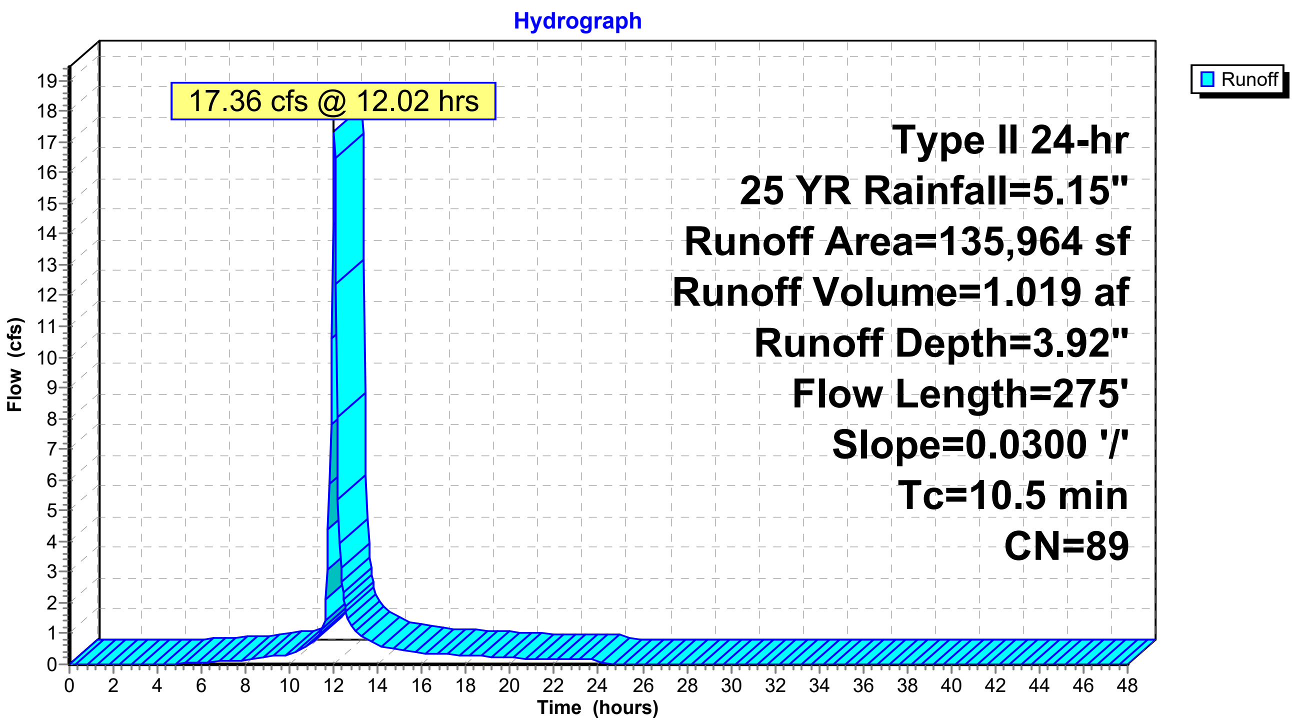
Runoff = 17.36 cfs @ 12.02 hrs, Volume= 1.019 af, Depth= 3.92"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 25 YR Rainfall=5.15"

	Area (sf)	CN	Description
*	135,964	89	CCR
	135,964		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
9.4	100	0.0300	0.18		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.49"
1.1	175	0.0300	2.60		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
10.5	275	Total			

Subcatchment DA-18:



Summary for Subcatchment DA-9:

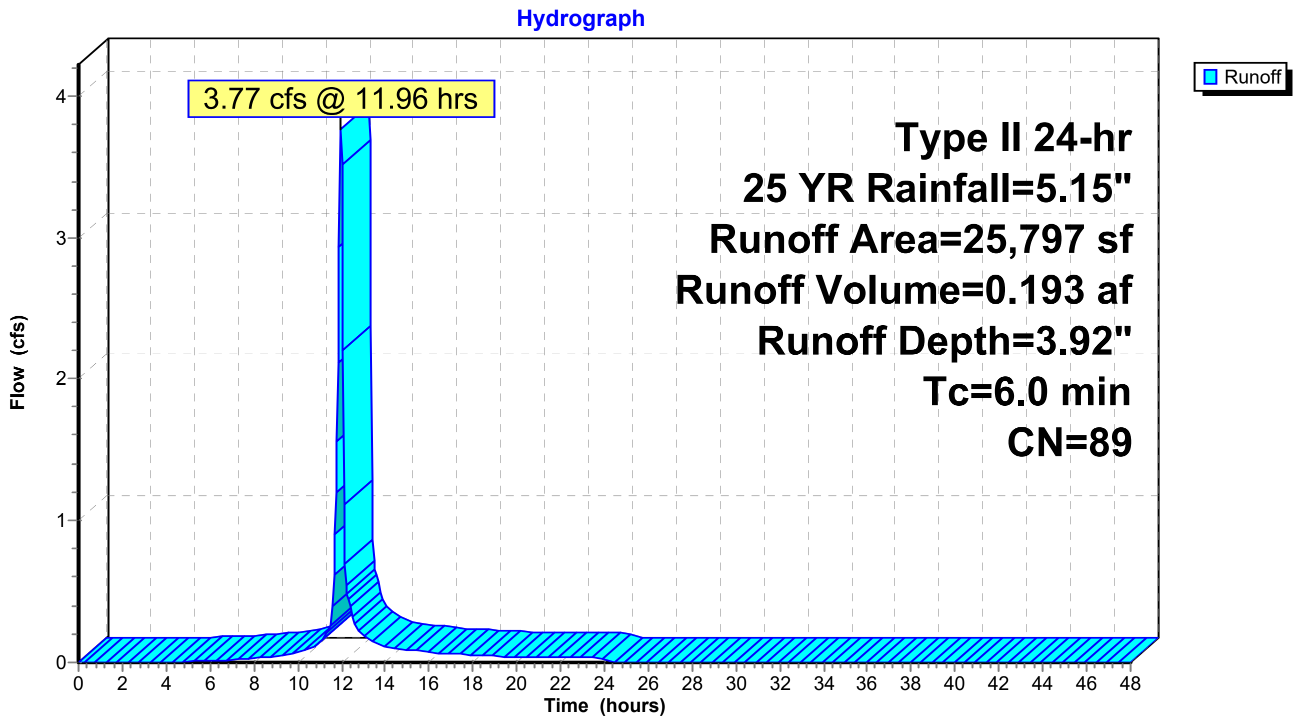
Runoff = 3.77 cfs @ 11.96 hrs, Volume= 0.193 af, Depth= 3.92"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 25 YR Rainfall=5.15"

	Area (sf)	CN	Description
*	25,797	89	CCR
	25,797		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA-9:



Summary for Reach D-10:

Inflow Area = 3.318 ac, 0.00% Impervious, Inflow Depth = 3.92" for 25 YR event
Inflow = 18.32 cfs @ 12.02 hrs, Volume= 1.083 af
Outflow = 16.38 cfs @ 12.13 hrs, Volume= 1.083 af, Atten= 11%, Lag= 6.9 min

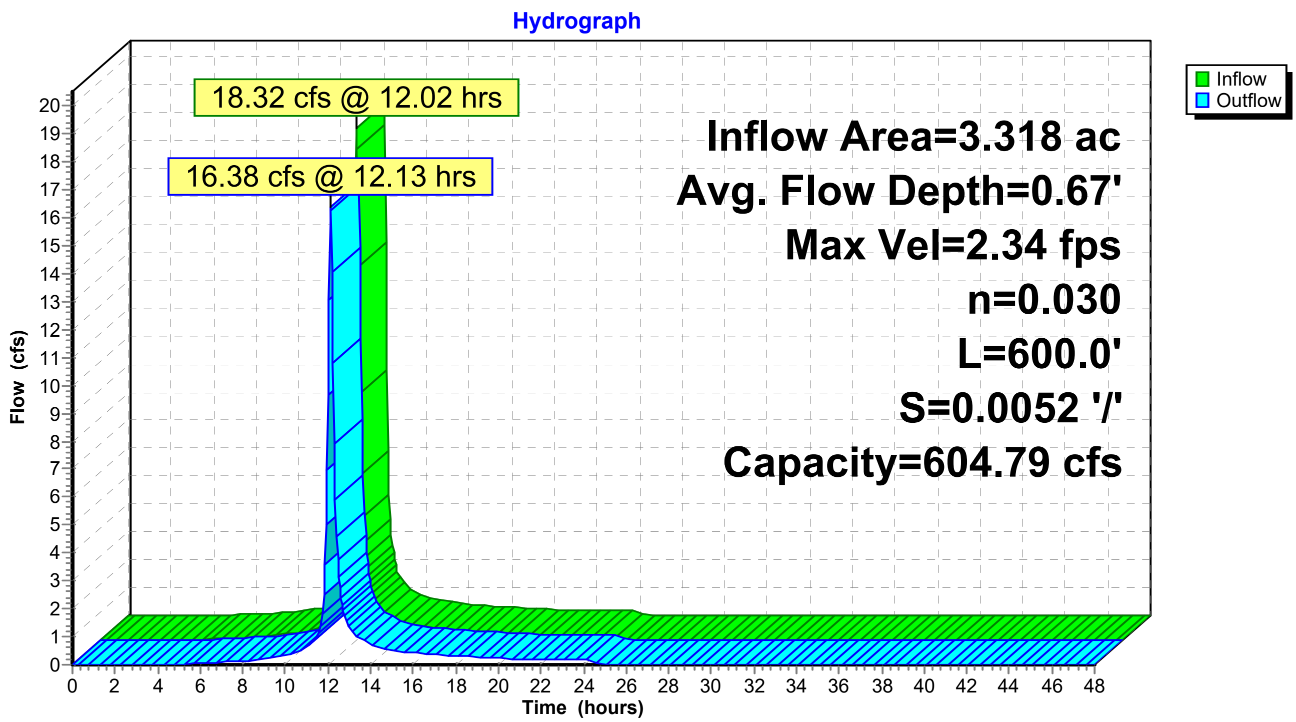
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.34 fps, Min. Travel Time= 4.3 min
Avg. Velocity = 0.60 fps, Avg. Travel Time= 16.8 min

Peak Storage= 4,307 cf @ 12.06 hrs
Average Depth at Peak Storage= 0.67'
Bank-Full Depth= 4.00' Flow Area= 96.0 sf, Capacity= 604.79 cfs

8.00' x 4.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 4.0 '/' Top Width= 40.00'
Length= 600.0' Slope= 0.0052 '/'
Inlet Invert= 614.00', Outlet Invert= 610.88'

‡

Reach D-10:



Summary for Reach D-11:

Inflow Area = 4.304 ac, 0.00% Impervious, Inflow Depth = 3.92" for 25 YR event
Inflow = 23.77 cfs @ 12.02 hrs, Volume= 1.404 af
Outflow = 20.19 cfs @ 12.18 hrs, Volume= 1.404 af, Atten= 15%, Lag= 9.8 min

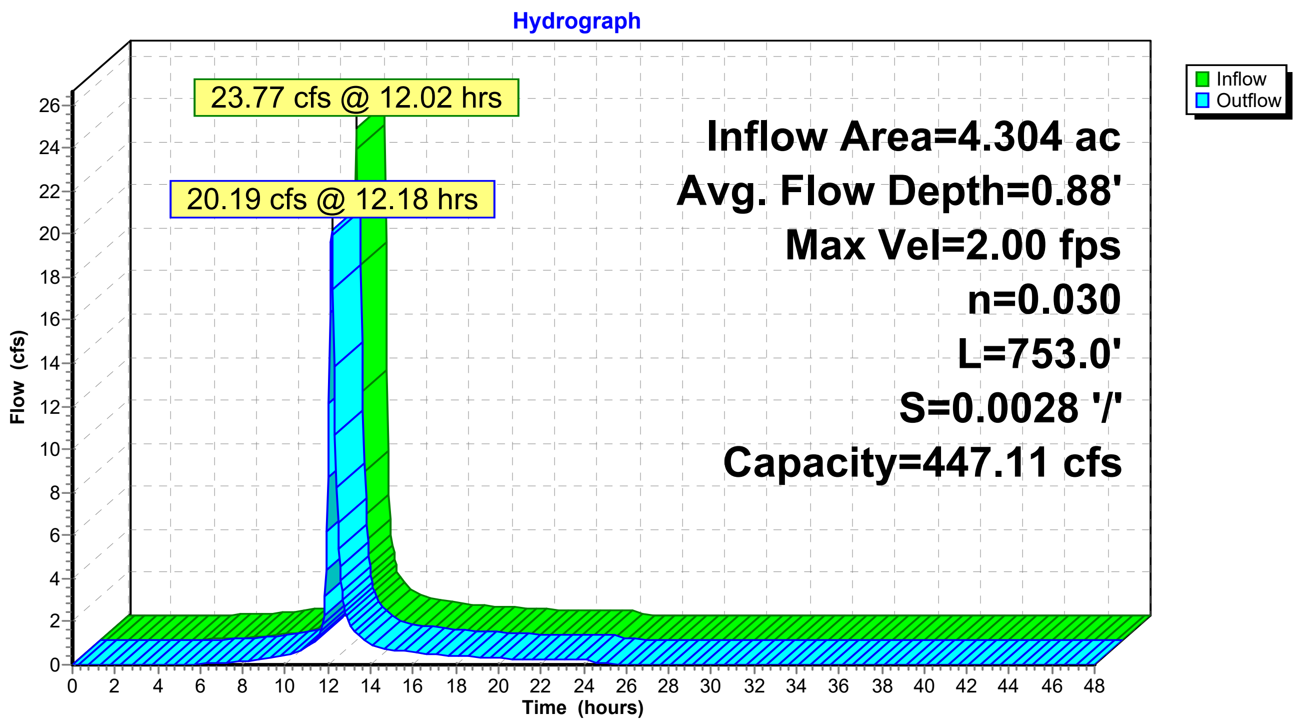
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.00 fps, Min. Travel Time= 6.3 min
Avg. Velocity = 0.50 fps, Avg. Travel Time= 25.1 min

Peak Storage= 7,617 cf @ 12.08 hrs
Average Depth at Peak Storage= 0.88'
Bank-Full Depth= 4.00' Flow Area= 96.0 sf, Capacity= 447.11 cfs

8.00' x 4.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 4.0 '/' Top Width= 40.00'
Length= 753.0' Slope= 0.0028 '/'
Inlet Invert= 613.02', Outlet Invert= 610.88'

‡

Reach D-11:



Summary for Reach D-12:

Inflow Area = 4.722 ac, 0.00% Impervious, Inflow Depth = 3.92" for 25 YR event
Inflow = 26.08 cfs @ 12.02 hrs, Volume= 1.541 af
Outflow = 22.13 cfs @ 12.18 hrs, Volume= 1.541 af, Atten= 15%, Lag= 9.8 min

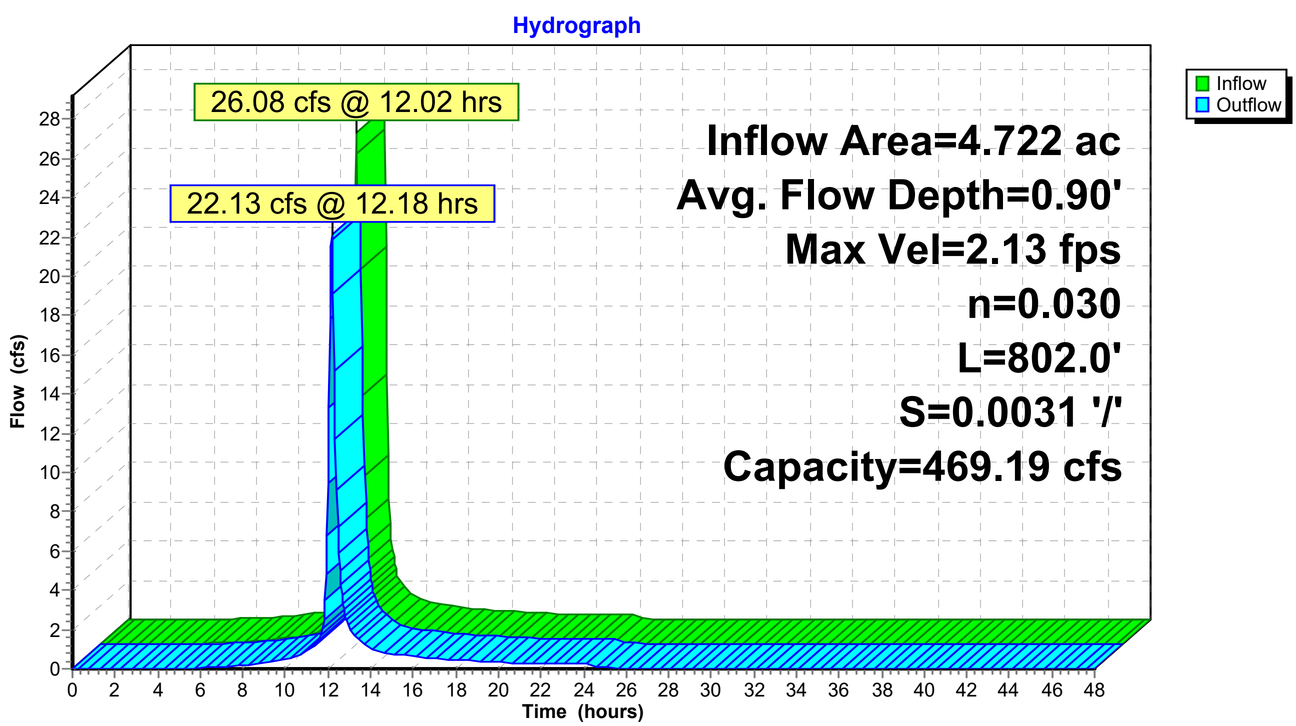
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.13 fps, Min. Travel Time= 6.3 min
Avg. Velocity = 0.53 fps, Avg. Travel Time= 25.2 min

Peak Storage= 8,367 cf @ 12.08 hrs
Average Depth at Peak Storage= 0.90'
Bank-Full Depth= 4.00' Flow Area= 96.0 sf, Capacity= 469.19 cfs

8.00' x 4.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 4.0 '/' Top Width= 40.00'
Length= 802.0' Slope= 0.0031 '/'
Inlet Invert= 613.02', Outlet Invert= 610.51'

‡

Reach D-12:



Summary for Reach D-13:

Inflow Area = 3.121 ac, 0.00% Impervious, Inflow Depth = 3.92" for 25 YR event
Inflow = 17.36 cfs @ 12.02 hrs, Volume= 1.019 af
Outflow = 15.19 cfs @ 12.15 hrs, Volume= 1.019 af, Atten= 12%, Lag= 8.2 min

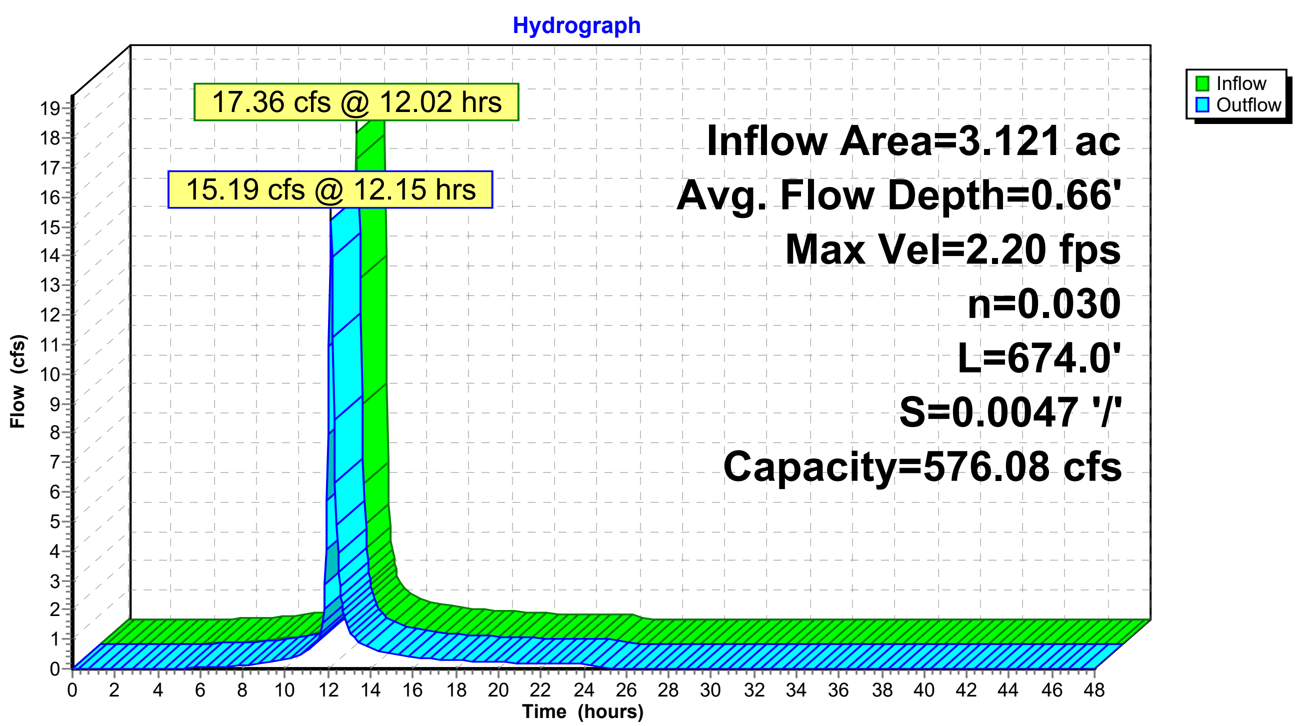
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.20 fps, Min. Travel Time= 5.1 min
Avg. Velocity = 0.56 fps, Avg. Travel Time= 20.0 min

Peak Storage= 4,727 cf @ 12.06 hrs
Average Depth at Peak Storage= 0.66'
Bank-Full Depth= 4.00' Flow Area= 96.0 sf, Capacity= 576.08 cfs

8.00' x 4.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 4.0 '/' Top Width= 40.00'
Length= 674.0' Slope= 0.0047 '/'
Inlet Invert= 614.00', Outlet Invert= 610.82'

‡

Reach D-13:



Summary for Reach D-7:

Inflow Area = 0.592 ac, 0.00% Impervious, Inflow Depth = 3.92" for 25 YR event
Inflow = 3.77 cfs @ 11.96 hrs, Volume= 0.193 af
Outflow = 3.54 cfs @ 12.04 hrs, Volume= 0.193 af, Atten= 6%, Lag= 4.3 min

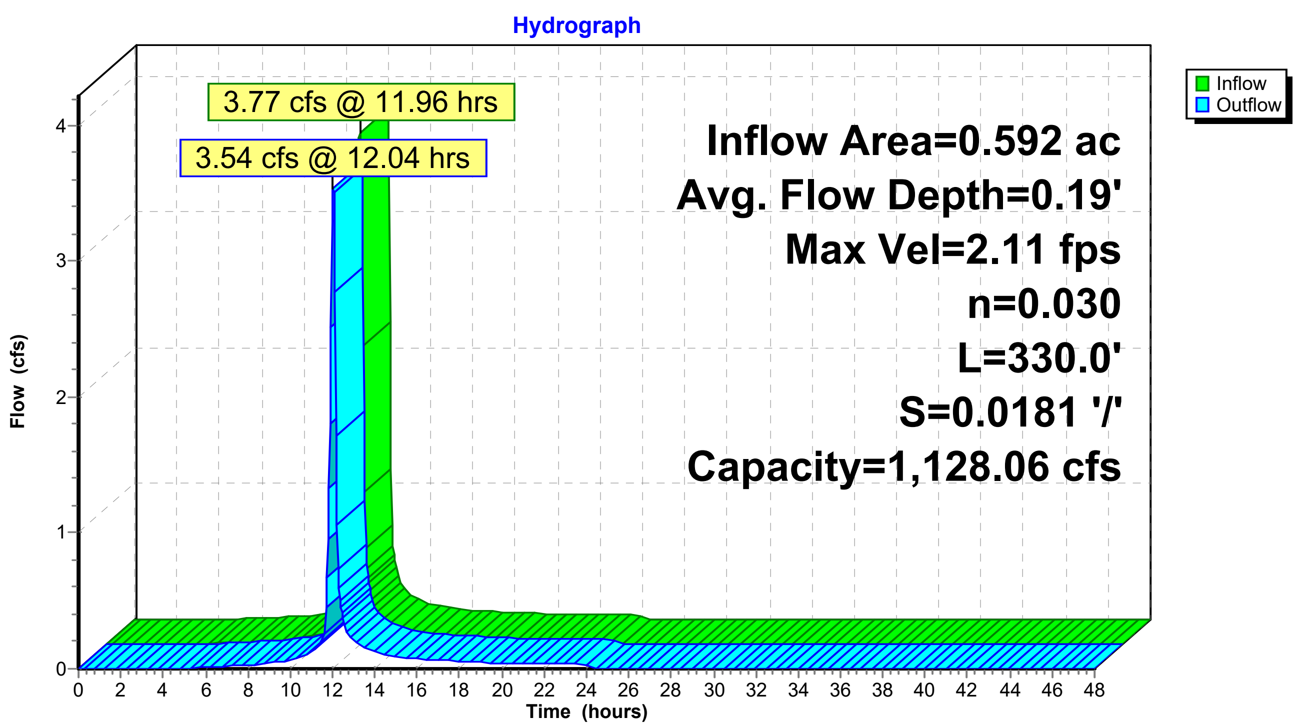
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.11 fps, Min. Travel Time= 2.6 min
Avg. Velocity = 0.80 fps, Avg. Travel Time= 6.9 min

Peak Storage= 563 cf @ 11.99 hrs
Average Depth at Peak Storage= 0.19'
Bank-Full Depth= 4.00' Flow Area= 96.0 sf, Capacity= 1,128.06 cfs

8.00' x 4.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 4.0 '/' Top Width= 40.00'
Length= 330.0' Slope= 0.0181 '/'
Inlet Invert= 623.11', Outlet Invert= 617.14'

‡

Reach D-7:



Summary for Reach D-8:

Inflow Area = 3.539 ac, 0.00% Impervious, Inflow Depth = 3.92" for 25 YR event
Inflow = 16.85 cfs @ 12.07 hrs, Volume= 1.155 af
Outflow = 16.43 cfs @ 12.10 hrs, Volume= 1.155 af, Atten= 2%, Lag= 2.1 min

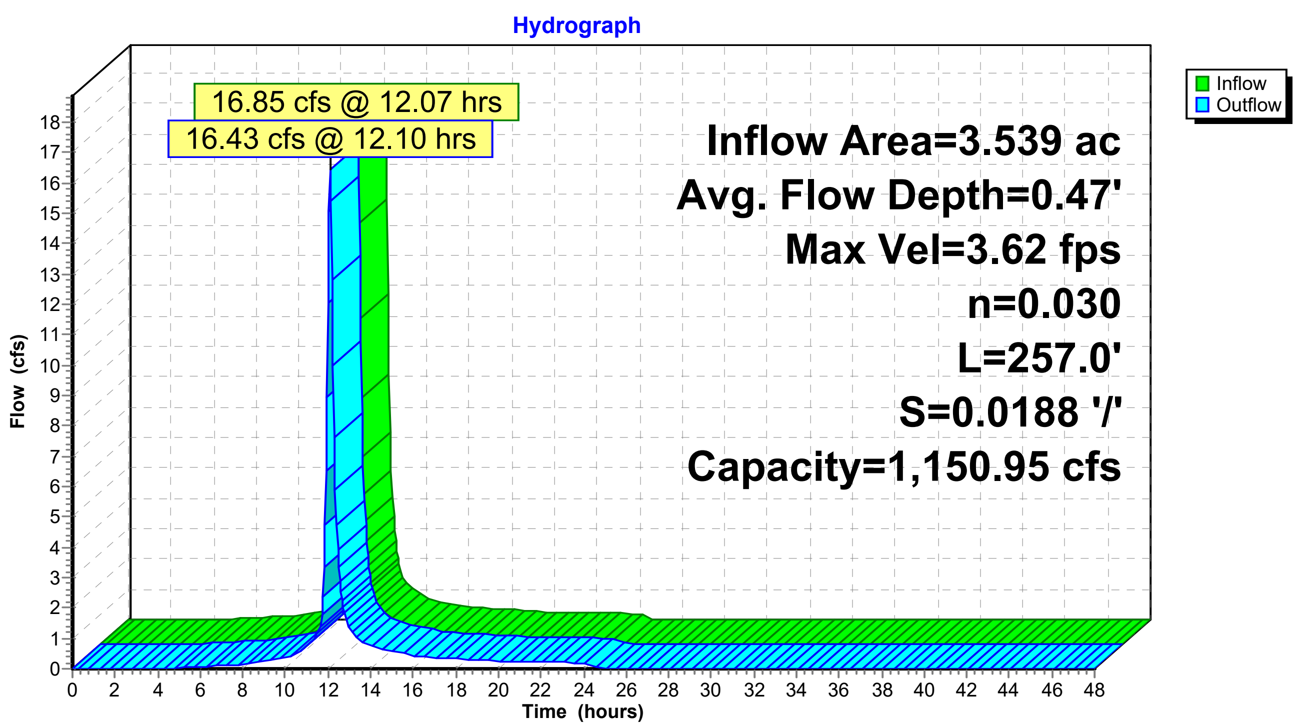
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.62 fps, Min. Travel Time= 1.2 min
Avg. Velocity = 0.99 fps, Avg. Travel Time= 4.3 min

Peak Storage= 1,186 cf @ 12.08 hrs
Average Depth at Peak Storage= 0.47'
Bank-Full Depth= 4.00' Flow Area= 96.0 sf, Capacity= 1,150.95 cfs

8.00' x 4.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 4.0 '/' Top Width= 40.00'
Length= 257.0' Slope= 0.0188 '/'
Inlet Invert= 617.14', Outlet Invert= 612.30'

‡

Reach D-8:



Summary for Reach D-9:

Inflow Area = 3.597 ac, 0.00% Impervious, Inflow Depth = 3.92" for 25 YR event
Inflow = 19.87 cfs @ 12.02 hrs, Volume= 1.174 af
Outflow = 17.45 cfs @ 12.15 hrs, Volume= 1.174 af, Atten= 12%, Lag= 8.0 min

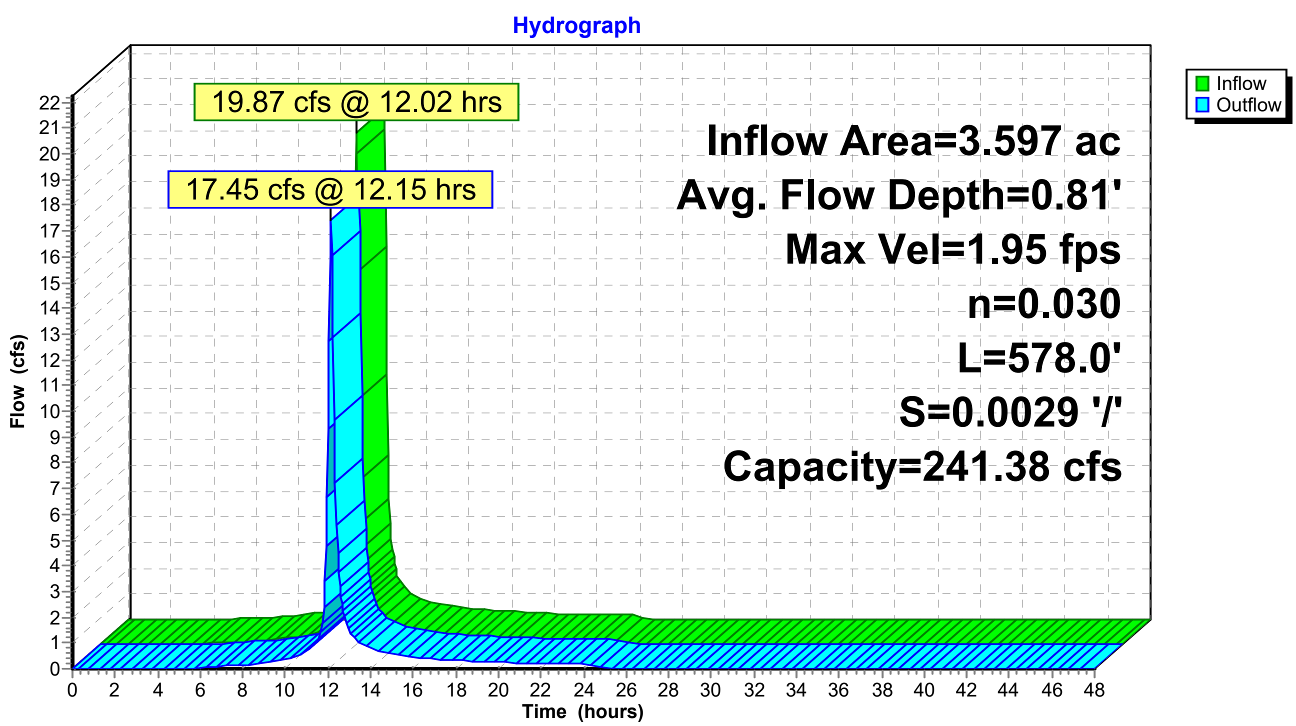
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.95 fps, Min. Travel Time= 4.9 min
Avg. Velocity = 0.47 fps, Avg. Travel Time= 20.6 min

Peak Storage= 5,265 cf @ 12.07 hrs
Average Depth at Peak Storage= 0.81'
Bank-Full Depth= 3.00' Flow Area= 60.0 sf, Capacity= 241.38 cfs

8.00' x 3.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 4.0 '/' Top Width= 32.00'
Length= 578.0' Slope= 0.0029 '/'
Inlet Invert= 614.00', Outlet Invert= 612.30'

‡

Reach D-9:



Summary for Reach LD-10:

Inflow Area = 14.091 ac, 0.00% Impervious, Inflow Depth = 3.92" for 25 YR event
Inflow = 59.75 cfs @ 12.19 hrs, Volume= 4.598 af
Outflow = 59.53 cfs @ 12.20 hrs, Volume= 4.598 af, Atten= 0%, Lag= 0.4 min

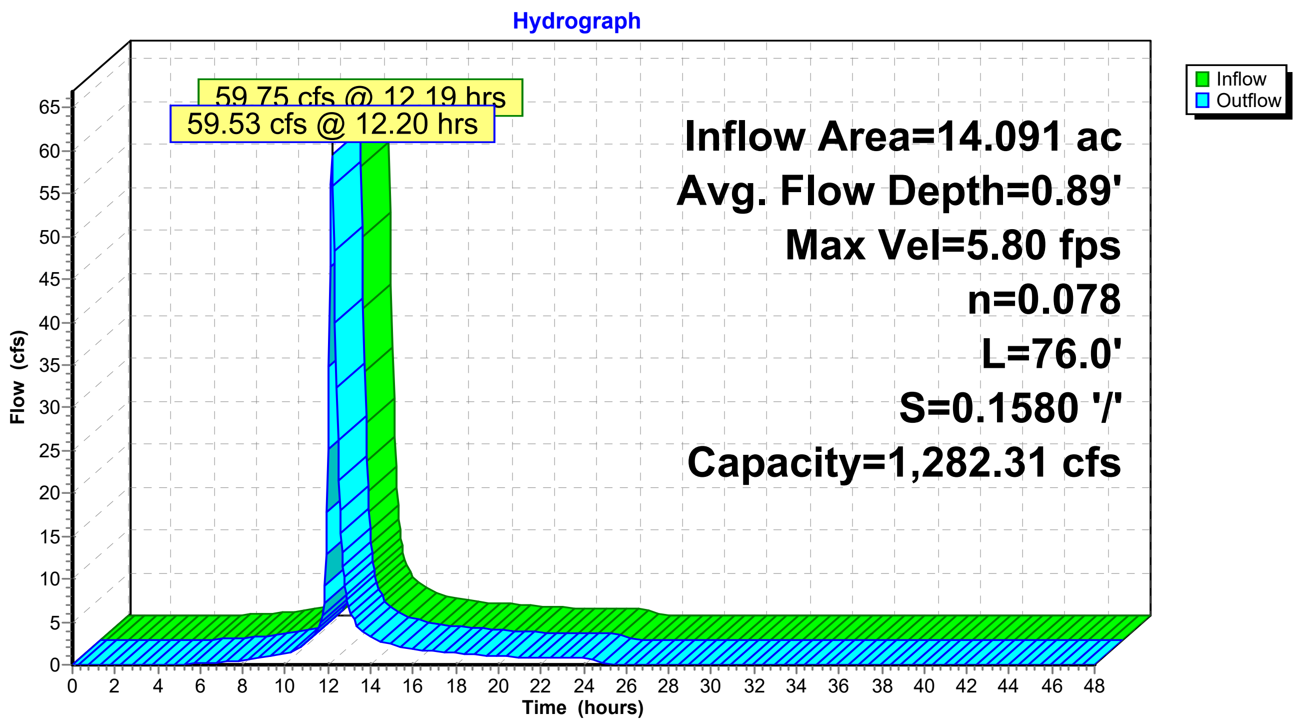
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 5.80 fps, Min. Travel Time= 0.2 min
Avg. Velocity = 1.50 fps, Avg. Travel Time= 0.8 min

Peak Storage= 782 cf @ 12.20 hrs
Average Depth at Peak Storage= 0.89'
Bank-Full Depth= 4.00' Flow Area= 96.0 sf, Capacity= 1,282.31 cfs

8.00' x 4.00' deep channel, n= 0.078 Riprap, 12-inch
Side Slope Z-value= 4.0 '/' Top Width= 40.00'
Length= 76.0' Slope= 0.1580 '/'
Inlet Invert= 610.51', Outlet Invert= 598.50'

‡

Reach LD-10:



Summary for Reach LD-4:

Inflow Area = 2.947 ac, 0.00% Impervious, Inflow Depth = 3.92" for 25 YR event
Inflow = 13.69 cfs @ 12.08 hrs, Volume= 0.961 af
Outflow = 13.65 cfs @ 12.09 hrs, Volume= 0.961 af, Atten= 0%, Lag= 0.2 min

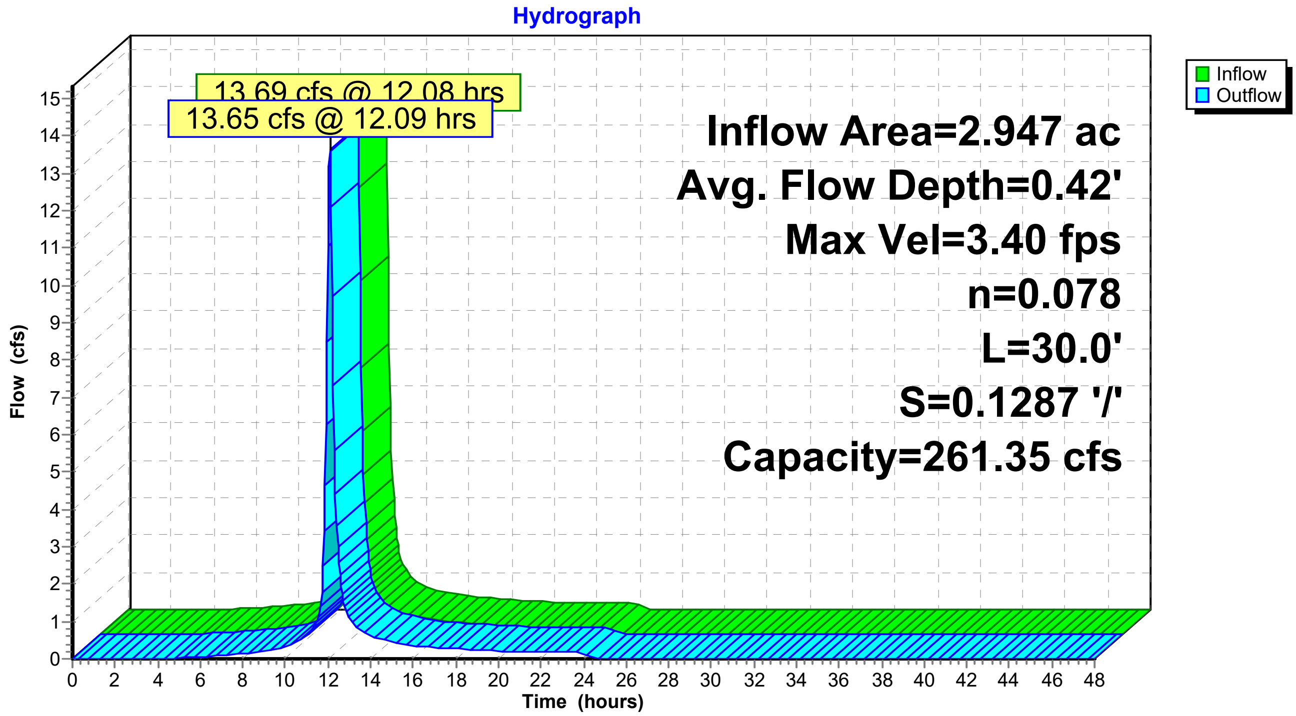
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.40 fps, Min. Travel Time= 0.1 min
Avg. Velocity = 0.87 fps, Avg. Travel Time= 0.6 min

Peak Storage= 121 cf @ 12.08 hrs
Average Depth at Peak Storage= 0.42'
Bank-Full Depth= 2.00' Flow Area= 32.0 sf, Capacity= 261.35 cfs

8.00' x 2.00' deep channel, n= 0.078 Riprap, 12-inch
Side Slope Z-value= 4.0 '/' Top Width= 24.00'
Length= 30.0' Slope= 0.1287 '/'
Inlet Invert= 621.00', Outlet Invert= 617.14'

‡

Reach LD-4:



Summary for Reach LD-5:

Inflow Area = 7.136 ac, 0.00% Impervious, Inflow Depth = 3.92" for 25 YR event
Inflow = 33.22 cfs @ 12.13 hrs, Volume= 2.329 af
Outflow = 33.06 cfs @ 12.14 hrs, Volume= 2.329 af, Atten= 0%, Lag= 0.4 min

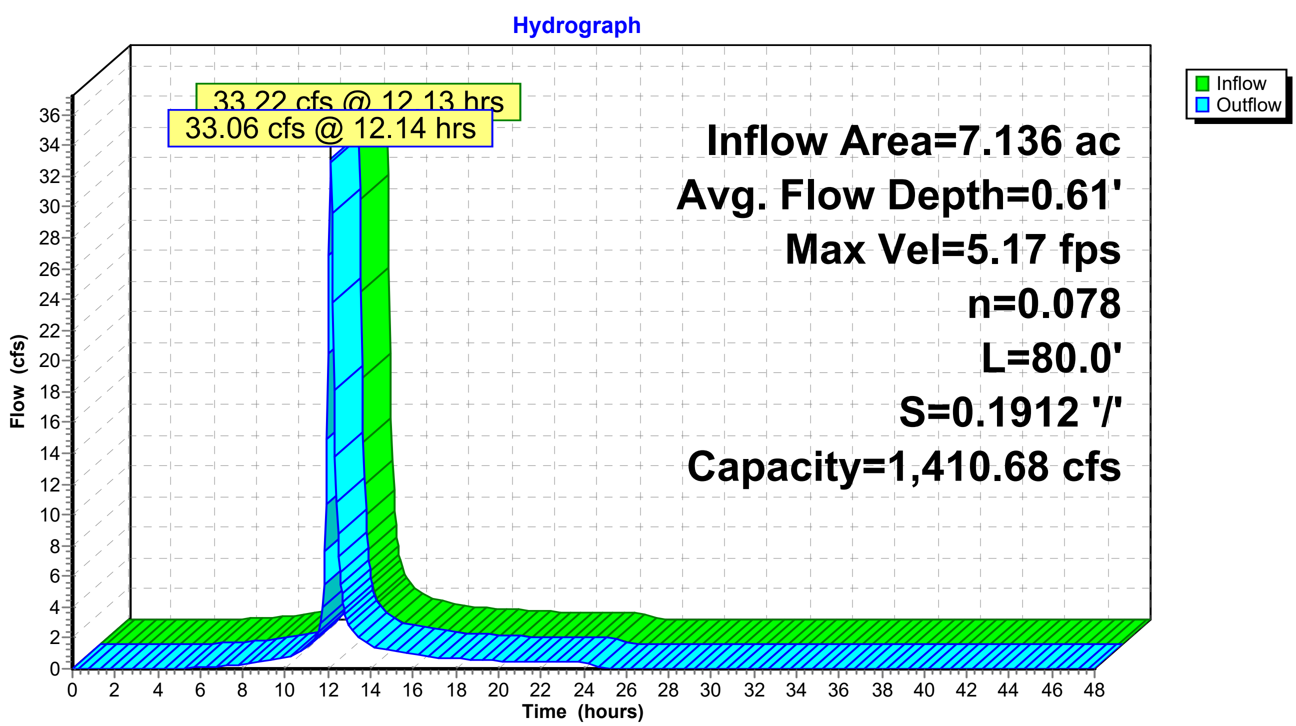
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 5.17 fps, Min. Travel Time= 0.3 min
Avg. Velocity = 1.34 fps, Avg. Travel Time= 1.0 min

Peak Storage= 513 cf @ 12.13 hrs
Average Depth at Peak Storage= 0.61'
Bank-Full Depth= 4.00' Flow Area= 96.0 sf, Capacity= 1,410.68 cfs

8.00' x 4.00' deep channel, n= 0.078 Riprap, 12-inch
Side Slope Z-value= 4.0 '/' Top Width= 40.00'
Length= 80.0' Slope= 0.1912 '/'
Inlet Invert= 612.30', Outlet Invert= 597.00'

‡

Reach LD-5:



Summary for Reach LD-6:

Inflow Area = 9.184 ac, 0.00% Impervious, Inflow Depth = 3.92" for 25 YR event
Inflow = 37.22 cfs @ 12.14 hrs, Volume= 2.997 af
Outflow = 36.52 cfs @ 12.18 hrs, Volume= 2.997 af, Atten= 2%, Lag= 2.5 min

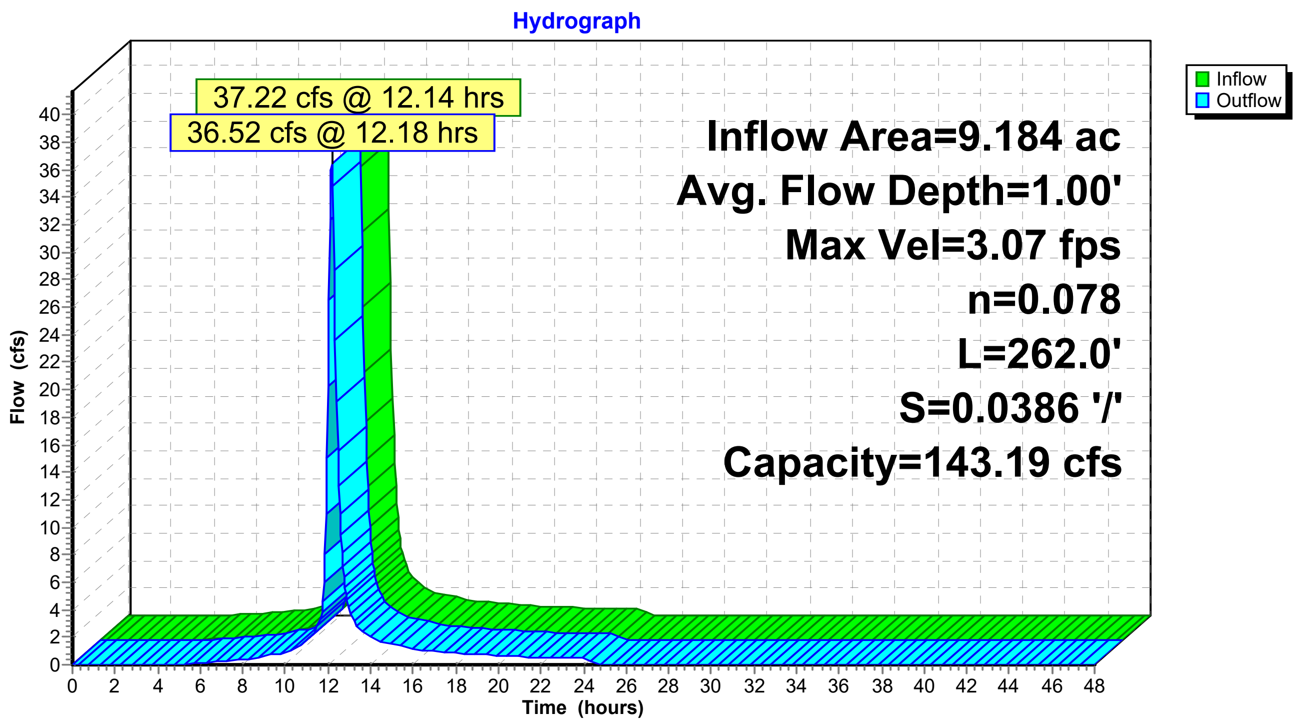
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.07 fps, Min. Travel Time= 1.4 min
Avg. Velocity = 0.83 fps, Avg. Travel Time= 5.3 min

Peak Storage= 3,164 cf @ 12.15 hrs
Average Depth at Peak Storage= 1.00'
Bank-Full Depth= 2.00' Flow Area= 32.0 sf, Capacity= 143.19 cfs

8.00' x 2.00' deep channel, n= 0.078 Riprap, 12-inch
Side Slope Z-value= 4.0 '/' Top Width= 24.00'
Length= 262.0' Slope= 0.0386 '/'
Inlet Invert= 621.00', Outlet Invert= 610.88'

‡

Reach LD-6:



Summary for Reach LD-7:

Inflow Area = 16.806 ac, 0.00% Impervious, Inflow Depth = 3.92" for 25 YR event
Inflow = 72.33 cfs @ 12.17 hrs, Volume= 5.484 af
Outflow = 71.89 cfs @ 12.17 hrs, Volume= 5.484 af, Atten= 1%, Lag= 0.5 min

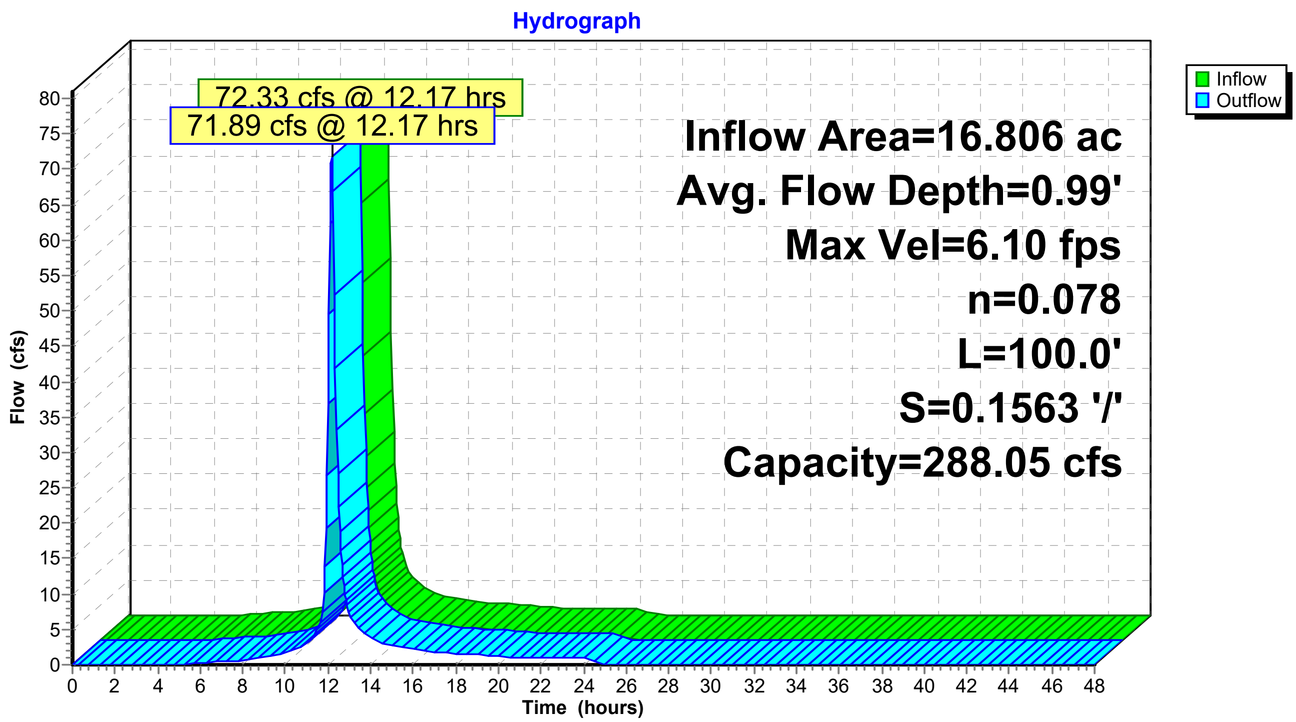
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 6.10 fps, Min. Travel Time= 0.3 min
Avg. Velocity = 1.49 fps, Avg. Travel Time= 1.1 min

Peak Storage= 1,182 cf @ 12.17 hrs
Average Depth at Peak Storage= 0.99'
Bank-Full Depth= 2.00' Flow Area= 32.0 sf, Capacity= 288.05 cfs

8.00' x 2.00' deep channel, n= 0.078 Riprap, 12-inch
Side Slope Z-value= 4.0 '/' Top Width= 24.00'
Length= 100.0' Slope= 0.1563 '/'
Inlet Invert= 610.88', Outlet Invert= 595.25'

‡

Reach LD-7:



Summary for Reach LD-8:

Inflow Area = 6.248 ac, 0.00% Impervious, Inflow Depth = 3.92" for 25 YR event
Inflow = 26.11 cfs @ 12.11 hrs, Volume= 2.039 af
Outflow = 25.41 cfs @ 12.18 hrs, Volume= 2.039 af, Atten= 3%, Lag= 3.7 min

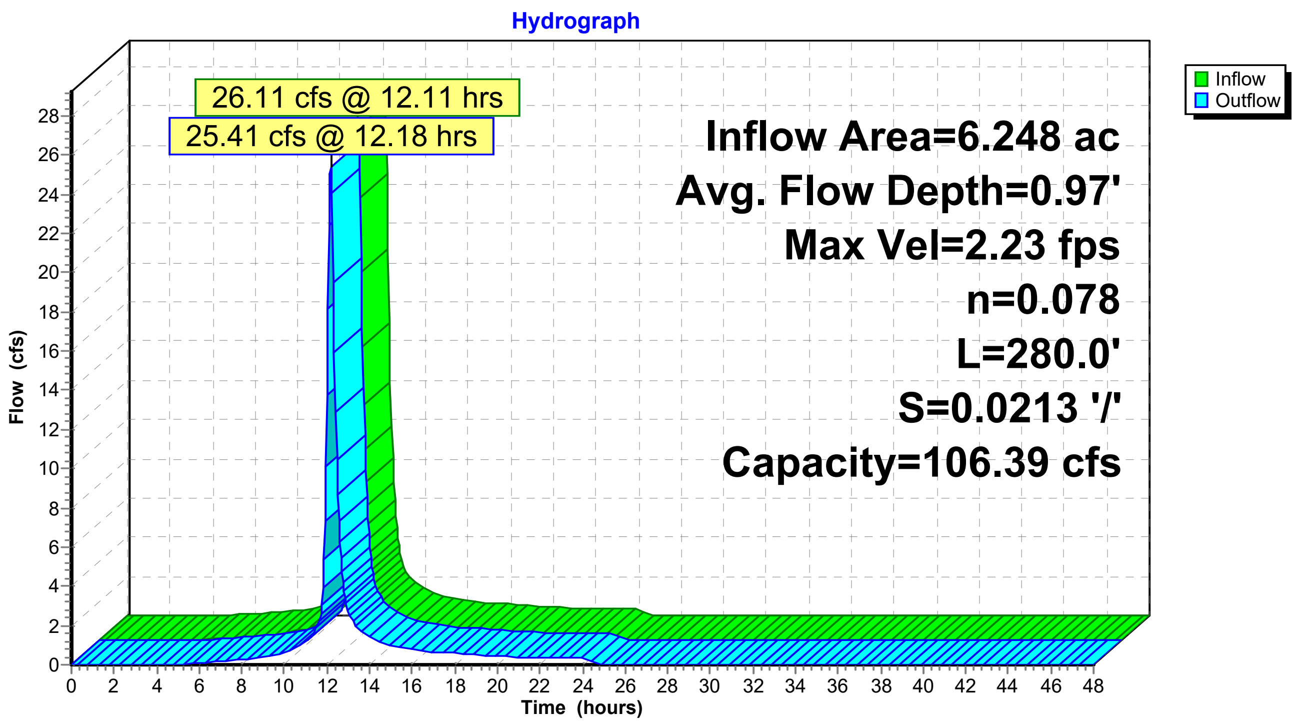
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.23 fps, Min. Travel Time= 2.1 min
Avg. Velocity = 0.58 fps, Avg. Travel Time= 8.0 min

Peak Storage= 3,224 cf @ 12.14 hrs
Average Depth at Peak Storage= 0.97'
Bank-Full Depth= 2.00' Flow Area= 32.0 sf, Capacity= 106.39 cfs

8.00' x 2.00' deep channel, n= 0.078 Riprap, 12-inch
Side Slope Z-value= 4.0 '/' Top Width= 24.00'
Length= 280.0' Slope= 0.0213 '/'
Inlet Invert= 621.00', Outlet Invert= 615.03'

‡

Reach LD-8:



Summary for Reach LD-9:

Inflow Area = 6.248 ac, 0.00% Impervious, Inflow Depth = 3.92" for 25 YR event
Inflow = 25.41 cfs @ 12.18 hrs, Volume= 2.039 af
Outflow = 24.83 cfs @ 12.25 hrs, Volume= 2.039 af, Atten= 2%, Lag= 4.3 min

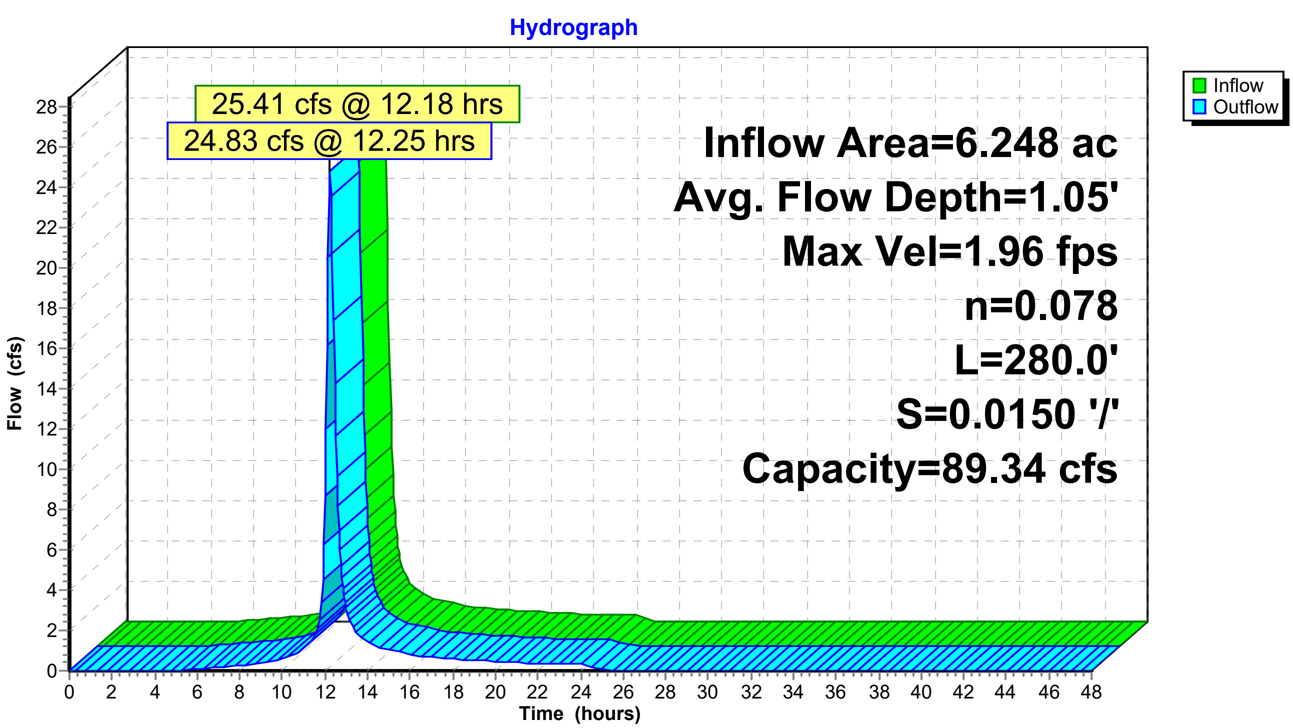
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.96 fps, Min. Travel Time= 2.4 min
Avg. Velocity = 0.50 fps, Avg. Travel Time= 9.3 min

Peak Storage= 3,579 cf @ 12.21 hrs
Average Depth at Peak Storage= 1.05'
Bank-Full Depth= 2.00' Flow Area= 32.0 sf, Capacity= 89.34 cfs

8.00' x 2.00' deep channel, n= 0.078 Riprap, 12-inch
Side Slope Z-value= 4.0 '/' Top Width= 24.00'
Length= 280.0' Slope= 0.0150 '/'
Inlet Invert= 615.03', Outlet Invert= 610.82'

‡

Reach LD-9:

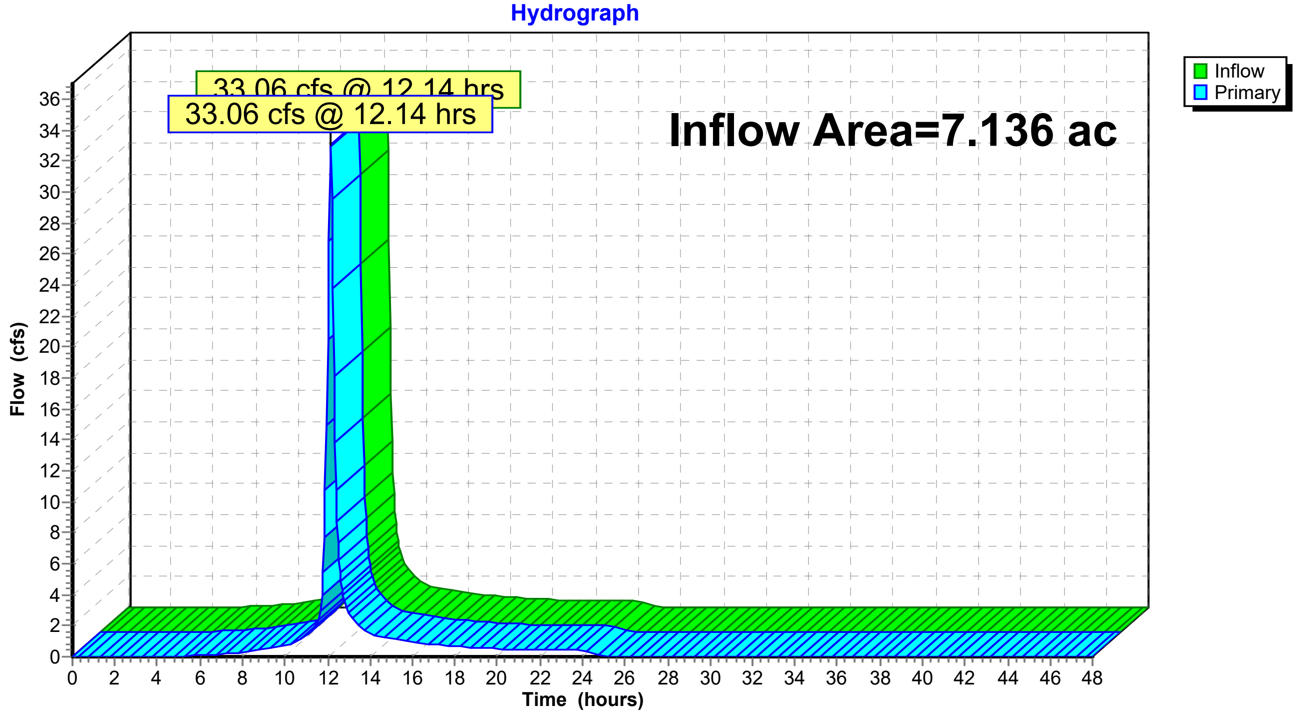


Summary for Link 1L: Discharge

Inflow Area = 7.136 ac, 0.00% Impervious, Inflow Depth = 3.92" for 25 YR event
Inflow = 33.06 cfs @ 12.14 hrs, Volume= 2.329 af
Primary = 33.06 cfs @ 12.14 hrs, Volume= 2.329 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

Link 1L: Discharge

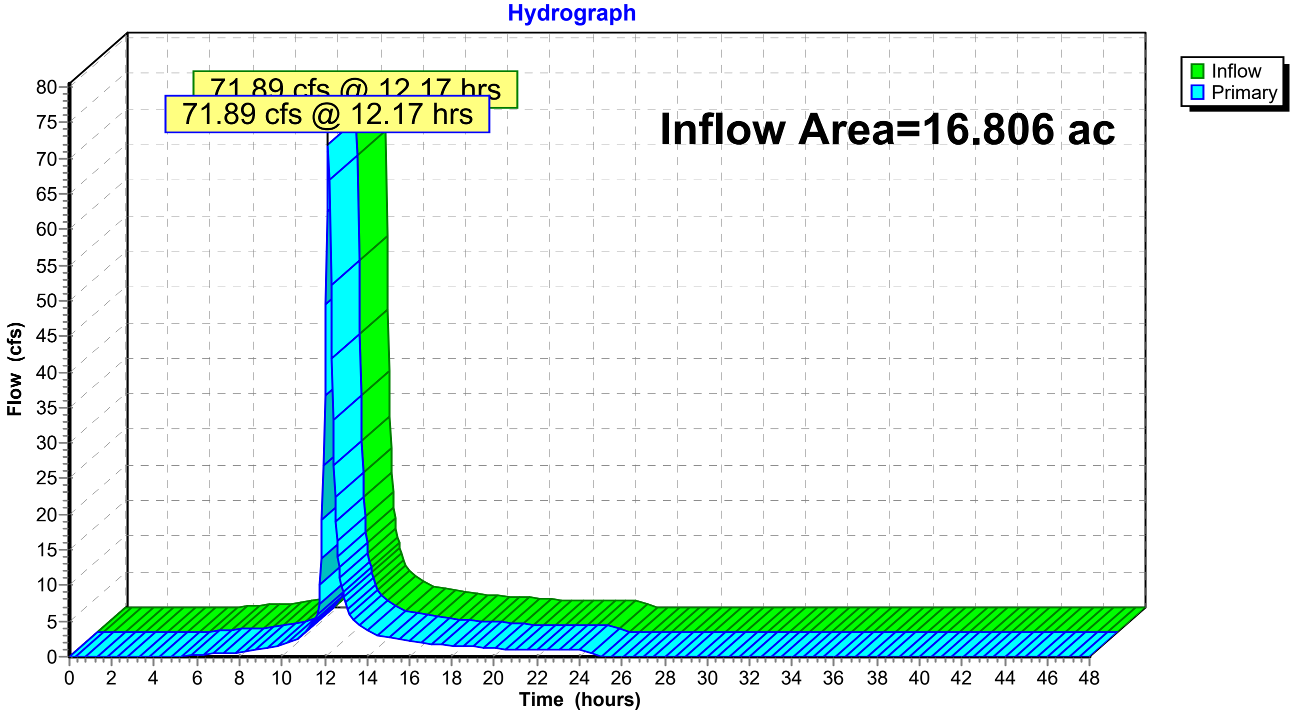


Summary for Link 2L: Discharge

Inflow Area = 16.806 ac, 0.00% Impervious, Inflow Depth = 3.92" for 25 YR event
Inflow = 71.89 cfs @ 12.17 hrs, Volume= 5.484 af
Primary = 71.89 cfs @ 12.17 hrs, Volume= 5.484 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

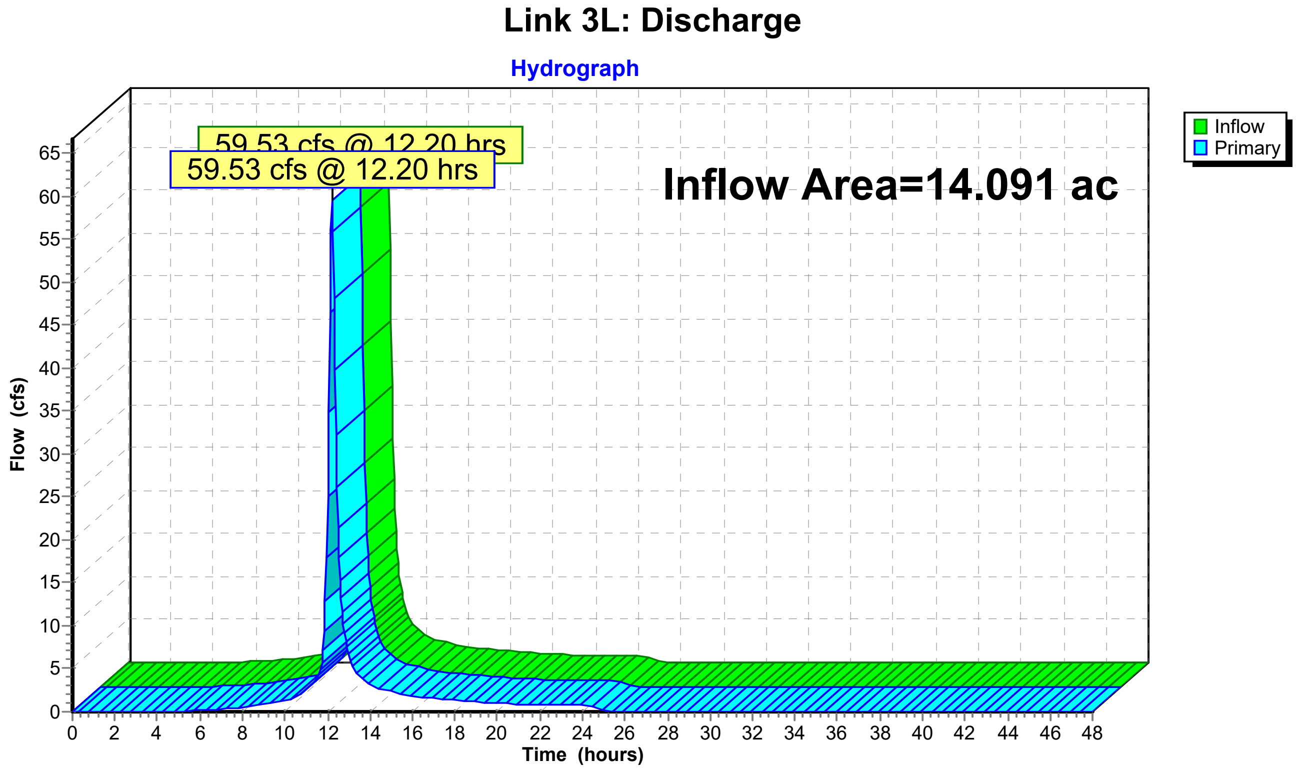
Link 2L: Discharge



Summary for Link 3L: Discharge

Inflow Area = 14.091 ac, 0.00% Impervious, Inflow Depth = 3.92" for 25 YR event
Inflow = 59.53 cfs @ 12.20 hrs, Volume= 4.598 af
Primary = 59.53 cfs @ 12.20 hrs, Volume= 4.598 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs



Summary for Subcatchment DA-10:

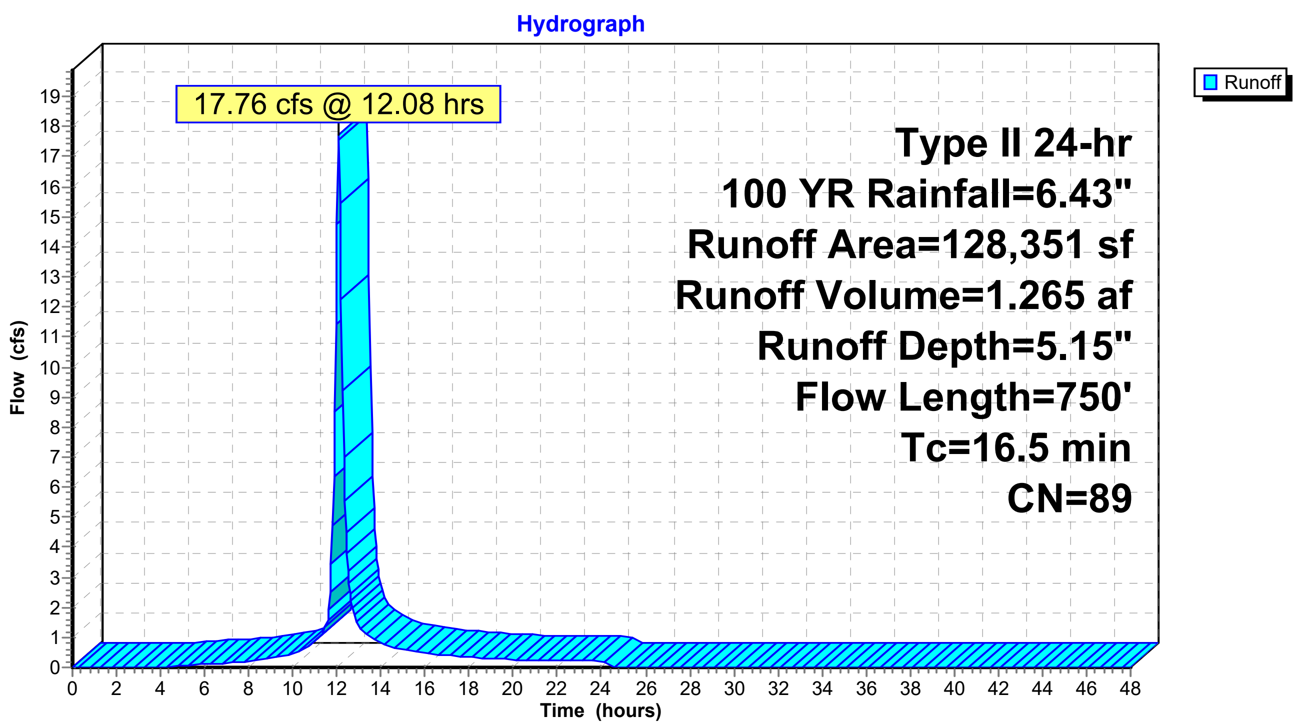
Runoff = 17.76 cfs @ 12.08 hrs, Volume= 1.265 af, Depth= 5.15"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 100 YR Rainfall=6.43"

	Area (sf)	CN	Description
*	128,351	89	CCR
	128,351		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.8	93	0.0100	0.11		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.49"
1.3	218	0.0300	2.79		**Shallow Concentrated Flow,** Unpaved Kv= 16.1 fps
1.4	439	0.0080	5.30	349.62	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=2.00' Z= 30.0 & 3.0 '/' Top.W=66.00' n= 0.025 Earth, clean & winding
16.5	750	Total			

Subcatchment DA-10:



Summary for Subcatchment DA-11:

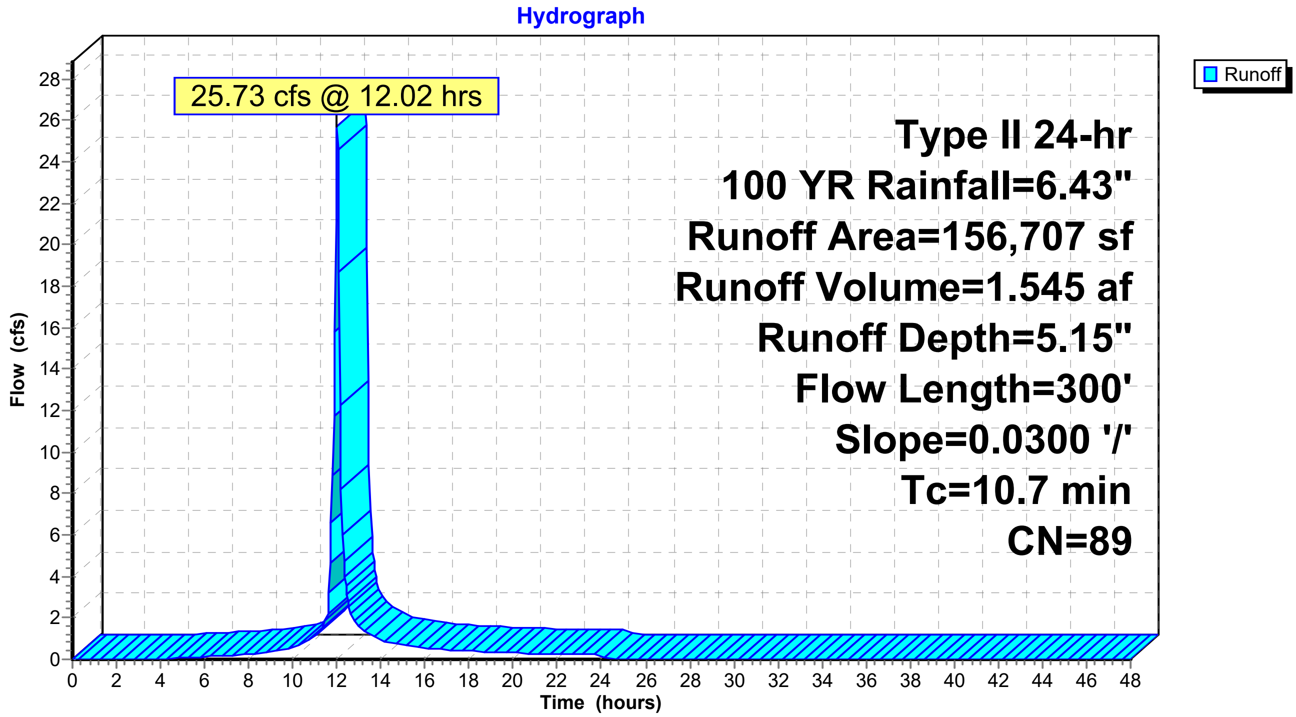
Runoff = 25.73 cfs @ 12.02 hrs, Volume= 1.545 af, Depth= 5.15"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 100 YR Rainfall=6.43"

	Area (sf)	CN	Description
*	156,707	89	CCR
	156,707		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
9.4	100	0.0300	0.18		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.49"
1.3	200	0.0300	2.60		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
10.7	300	Total			

Subcatchment DA-11:



Summary for Subcatchment DA-12:

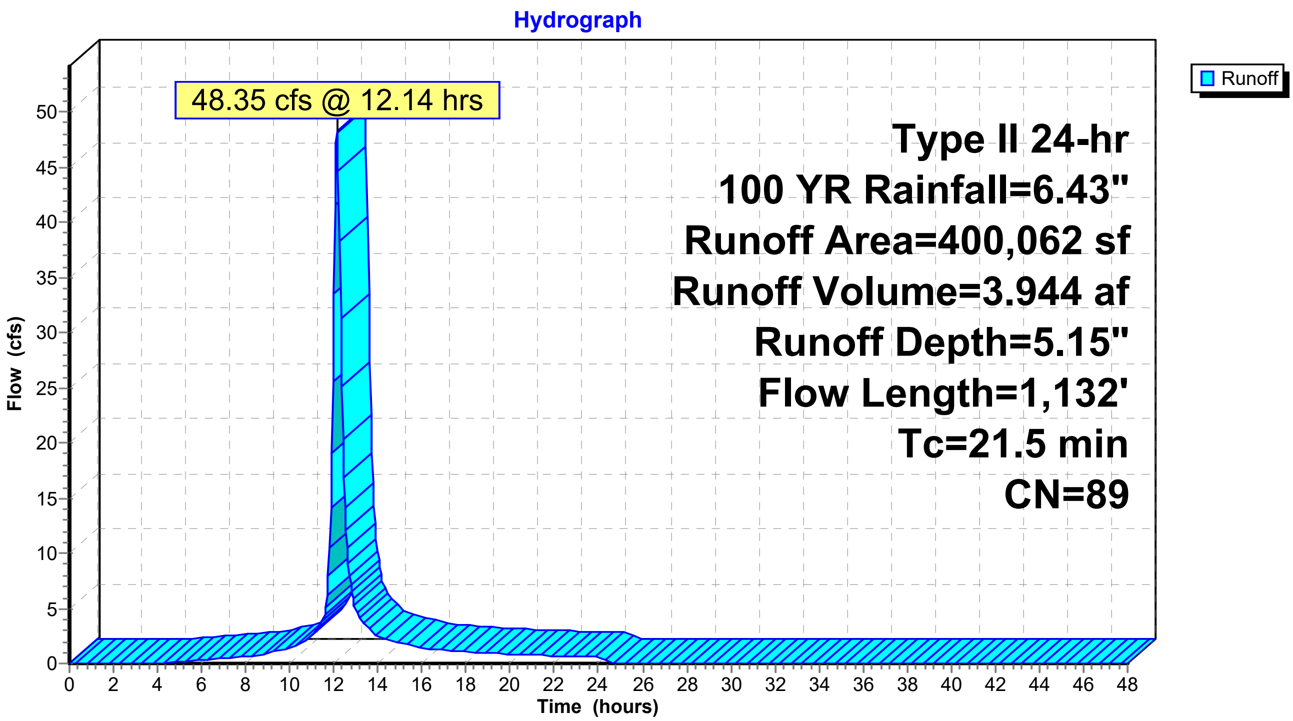
Runoff = 48.35 cfs @ 12.14 hrs, Volume= 3.944 af, Depth= 5.15"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 100 YR Rainfall=6.43"

	Area (sf)	CN	Description
*	400,062	89	CCR
	400,062		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
14.7	100	0.0100	0.11		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.49"
2.3	204	0.0100	1.50		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
1.3	206	0.0300	2.60		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
3.2	622	0.0030	3.24	214.10	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=2.00' Z= 30.0 & 3.0 '/' Top.W=66.00' n= 0.025 Earth, clean & winding
21.5	1,132	Total			

Subcatchment DA-12:



Summary for Subcatchment DA-13:

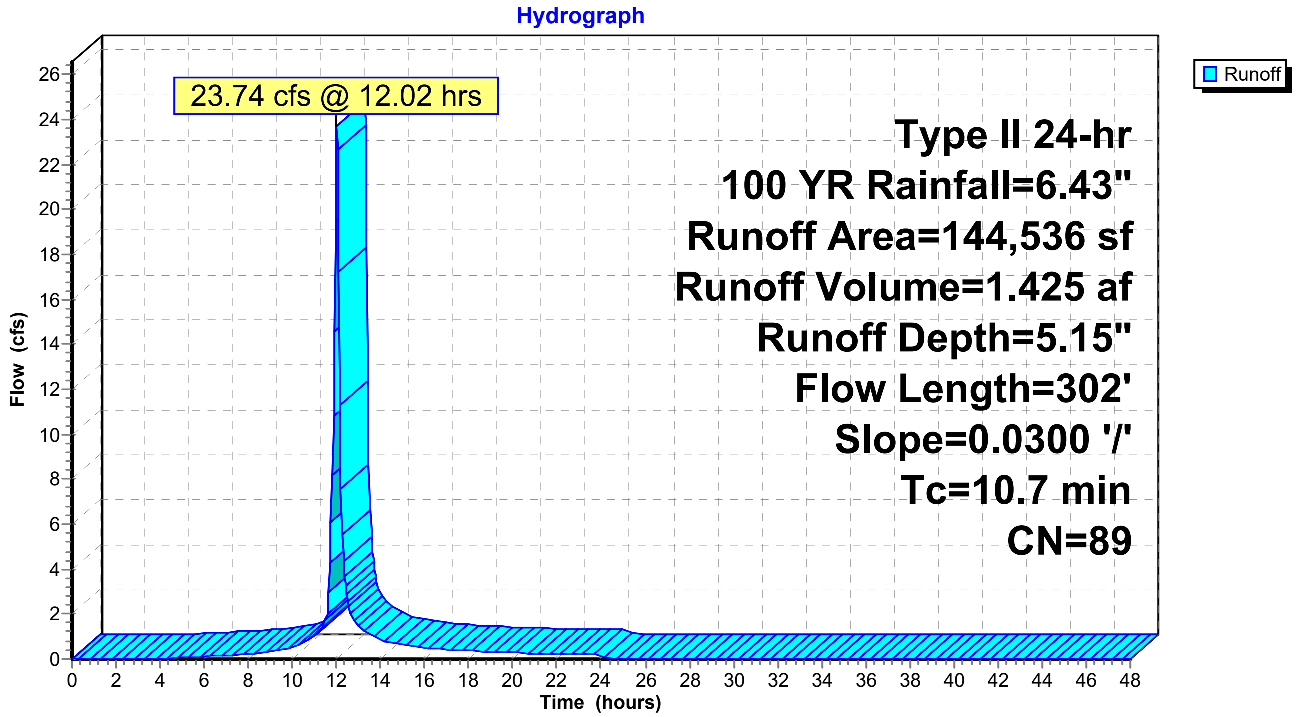
Runoff = 23.74 cfs @ 12.02 hrs, Volume= 1.425 af, Depth= 5.15"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 100 YR Rainfall=6.43"

	Area (sf)	CN	Description
*	144,536	89	CCR
	144,536		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
9.4	100	0.0300	0.18		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.49"
1.3	202	0.0300	2.60		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
10.7	302	Total			

Subcatchment DA-13:



Summary for Subcatchment DA-14:

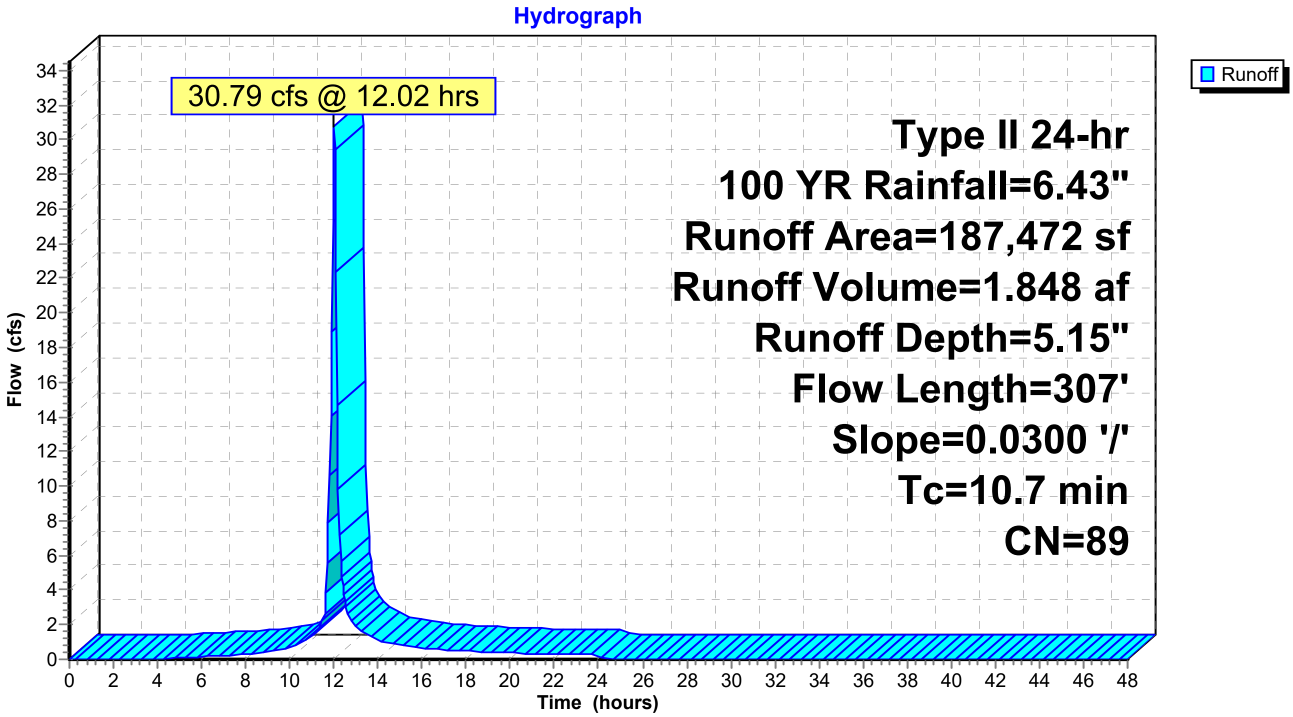
Runoff = 30.79 cfs @ 12.02 hrs, Volume= 1.848 af, Depth= 5.15"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 100 YR Rainfall=6.43"

	Area (sf)	CN	Description
*	187,472	89	CCR
	187,472		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
9.4	100	0.0300	0.18		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.49"
1.3	207	0.0300	2.60		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
10.7	307	Total			

Subcatchment DA-14:



Summary for Subcatchment DA-15:

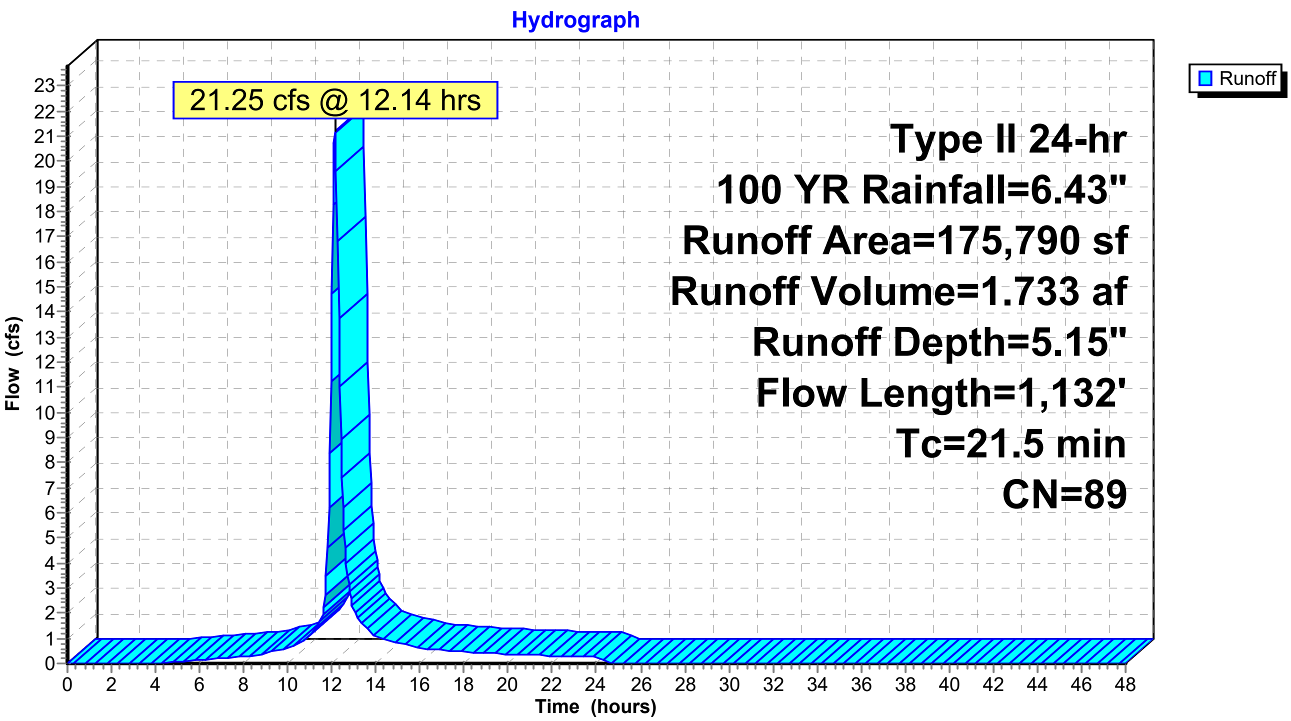
Runoff = 21.25 cfs @ 12.14 hrs, Volume= 1.733 af, Depth= 5.15"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 100 YR Rainfall=6.43"

	Area (sf)	CN	Description
*	175,790	89	CCR
	175,790		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
14.7	100	0.0100	0.11		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.49"
2.3	204	0.0100	1.50		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
1.3	206	0.0300	2.60		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
3.2	622	0.0030	3.24	214.10	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=2.00' Z= 30.0 & 3.0 '/' Top.W=66.00' n= 0.025 Earth, clean & winding
21.5	1,132	Total			

Subcatchment DA-15:



Summary for Subcatchment DA-16:

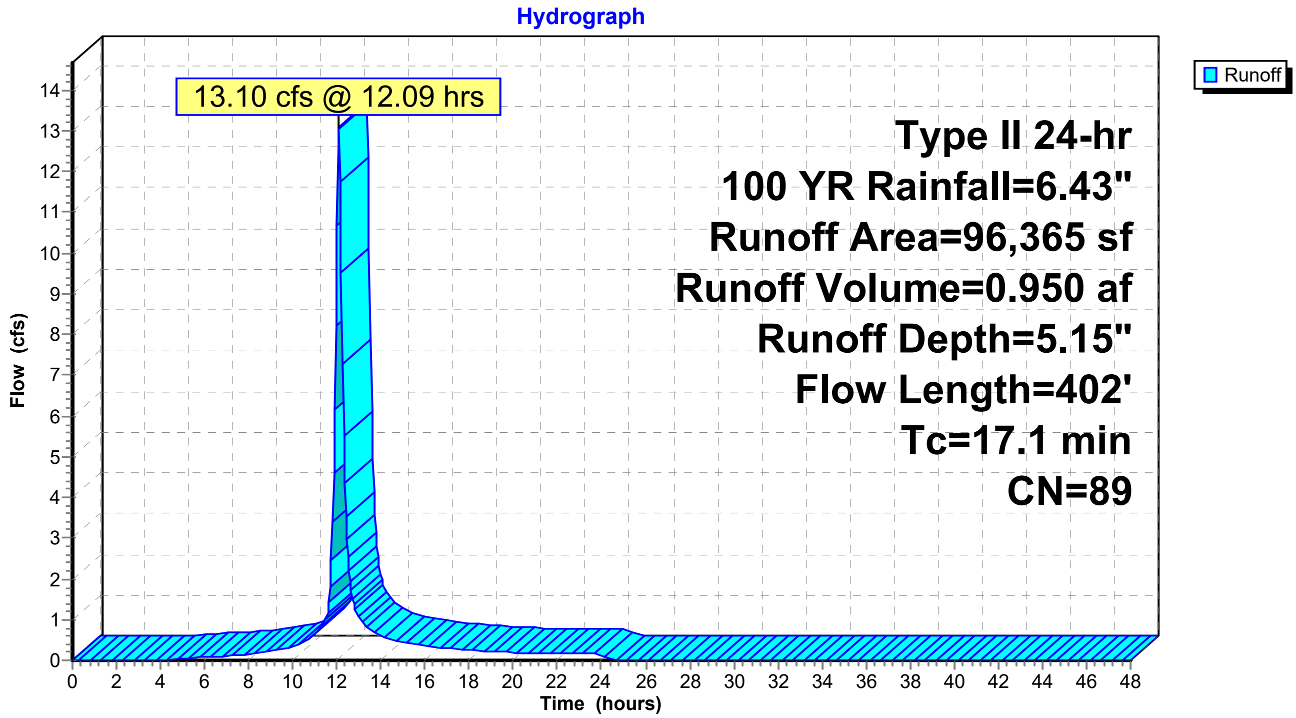
Runoff = 13.10 cfs @ 12.09 hrs, Volume= 0.950 af, Depth= 5.15"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 100 YR Rainfall=6.43"

	Area (sf)	CN	Description
*	96,365	89	CCR
	96,365		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
14.7	100	0.0100	0.11		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.49"
1.1	100	0.0100	1.50		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
1.3	202	0.0300	2.60		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
17.1	402	Total			

Subcatchment DA-16:



Summary for Subcatchment DA-17:

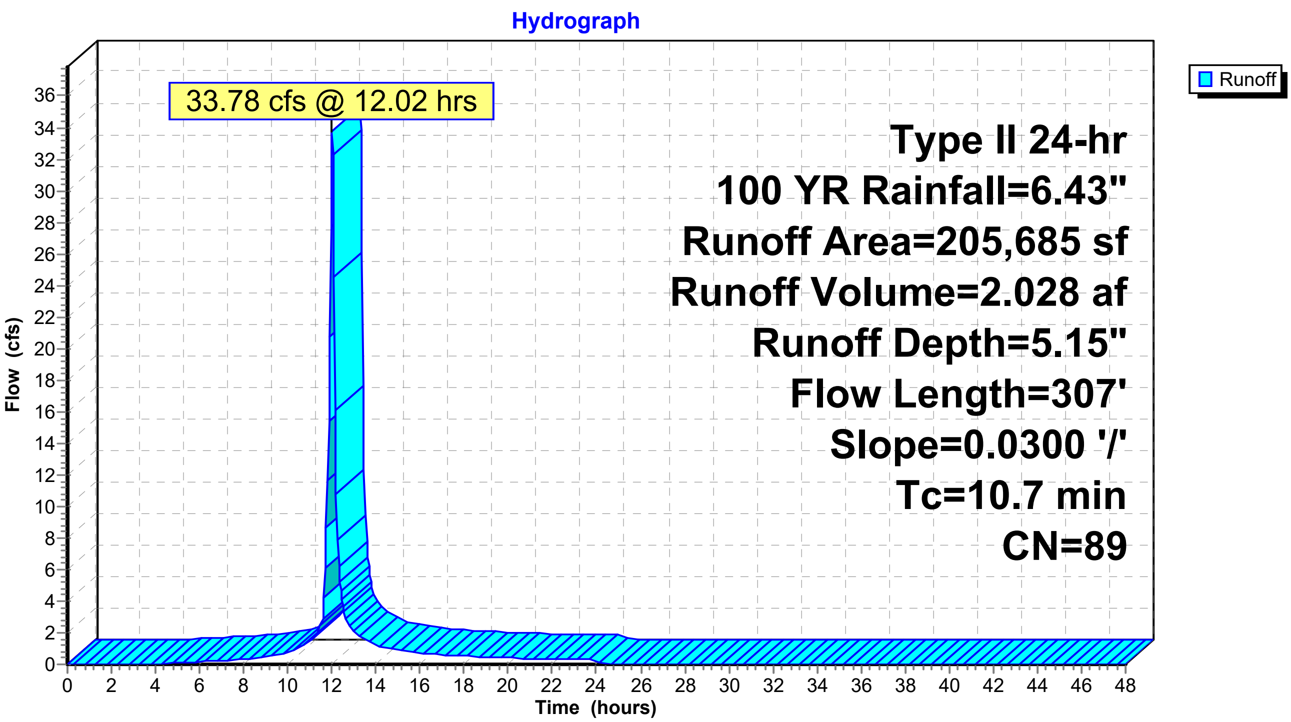
Runoff = 33.78 cfs @ 12.02 hrs, Volume= 2.028 af, Depth= 5.15"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 100 YR Rainfall=6.43"

	Area (sf)	CN	Description
*	205,685	89	CCR
	205,685		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
9.4	100	0.0300	0.18		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.49"
1.3	207	0.0300	2.60		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
10.7	307	Total			

Subcatchment DA-17:



Summary for Subcatchment DA-18:

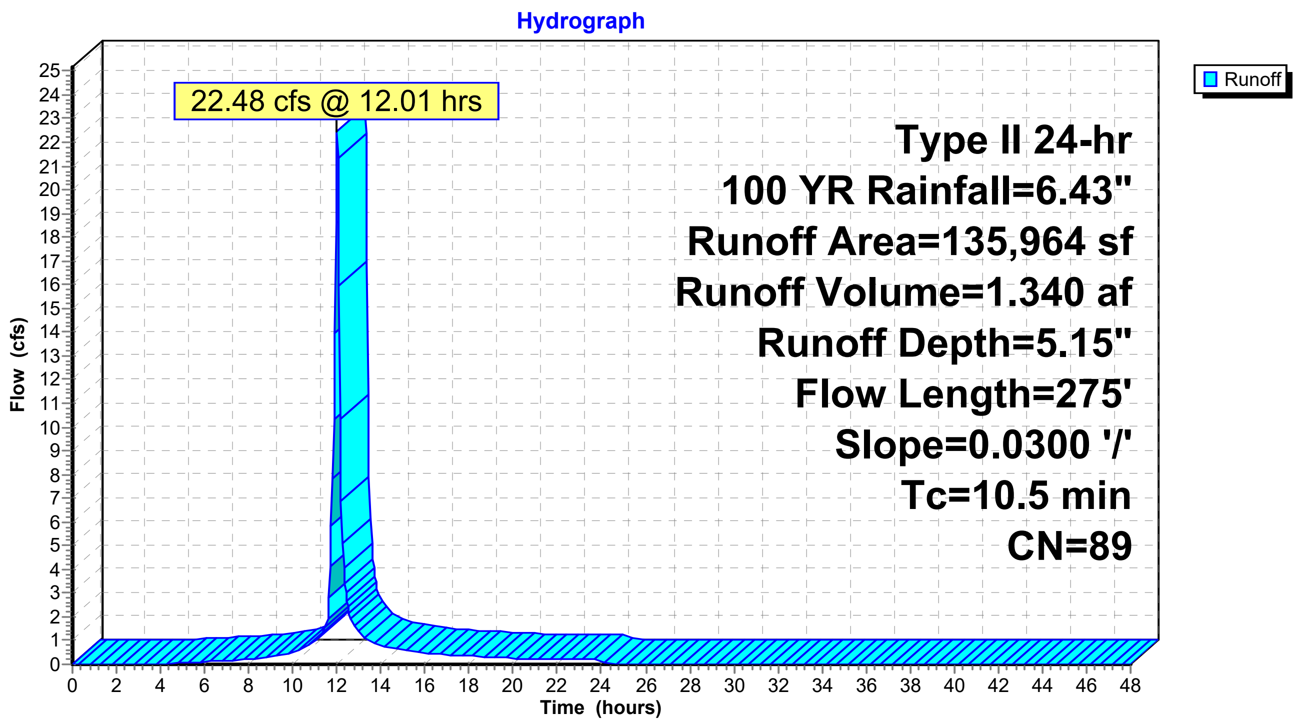
Runoff = 22.48 cfs @ 12.01 hrs, Volume= 1.340 af, Depth= 5.15"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 100 YR Rainfall=6.43"

	Area (sf)	CN	Description
*	135,964	89	CCR
	135,964		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
9.4	100	0.0300	0.18		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.49"
1.1	175	0.0300	2.60		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
10.5	275	Total			

Subcatchment DA-18:



Summary for Subcatchment DA-9:

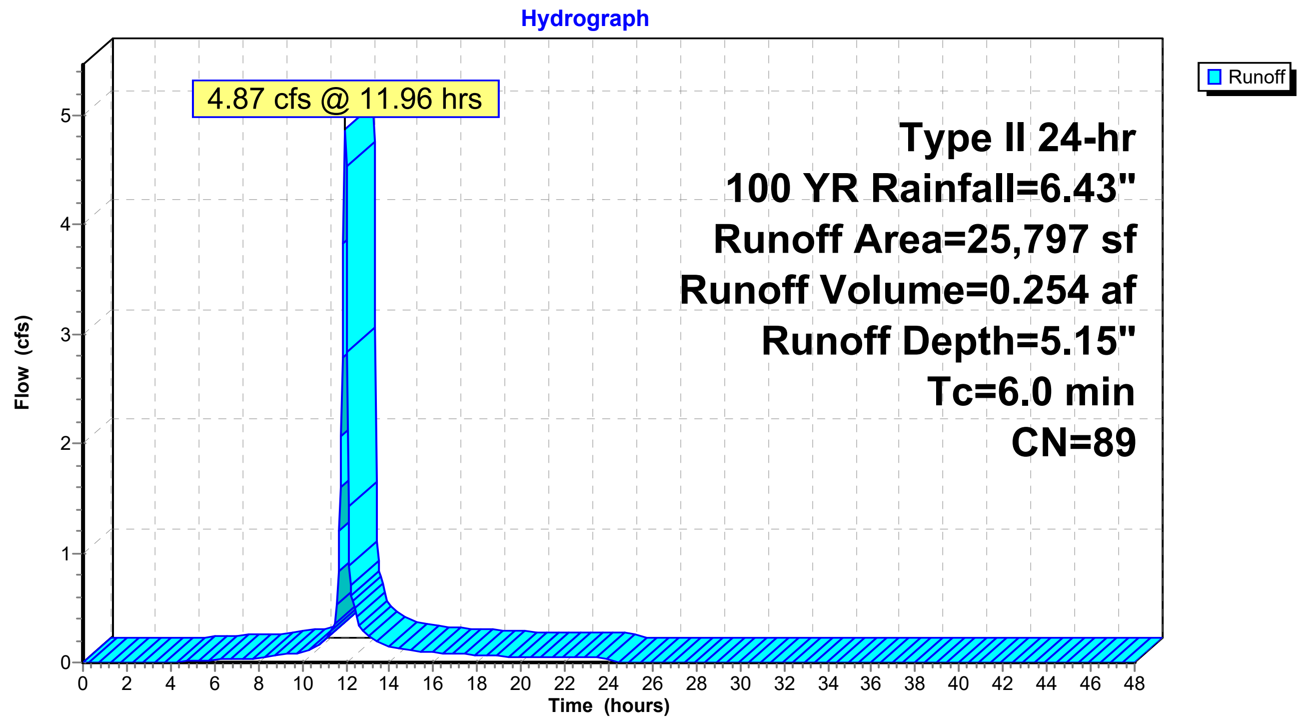
Runoff = 4.87 cfs @ 11.96 hrs, Volume= 0.254 af, Depth= 5.15"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 100 YR Rainfall=6.43"

	Area (sf)	CN	Description
*	25,797	89	CCR
	25,797		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA-9:



Summary for Reach D-10:

Inflow Area = 3.318 ac, 0.00% Impervious, Inflow Depth = 5.15" for 100 YR event
Inflow = 23.74 cfs @ 12.02 hrs, Volume= 1.425 af
Outflow = 21.48 cfs @ 12.12 hrs, Volume= 1.425 af, Atten= 10%, Lag= 6.4 min

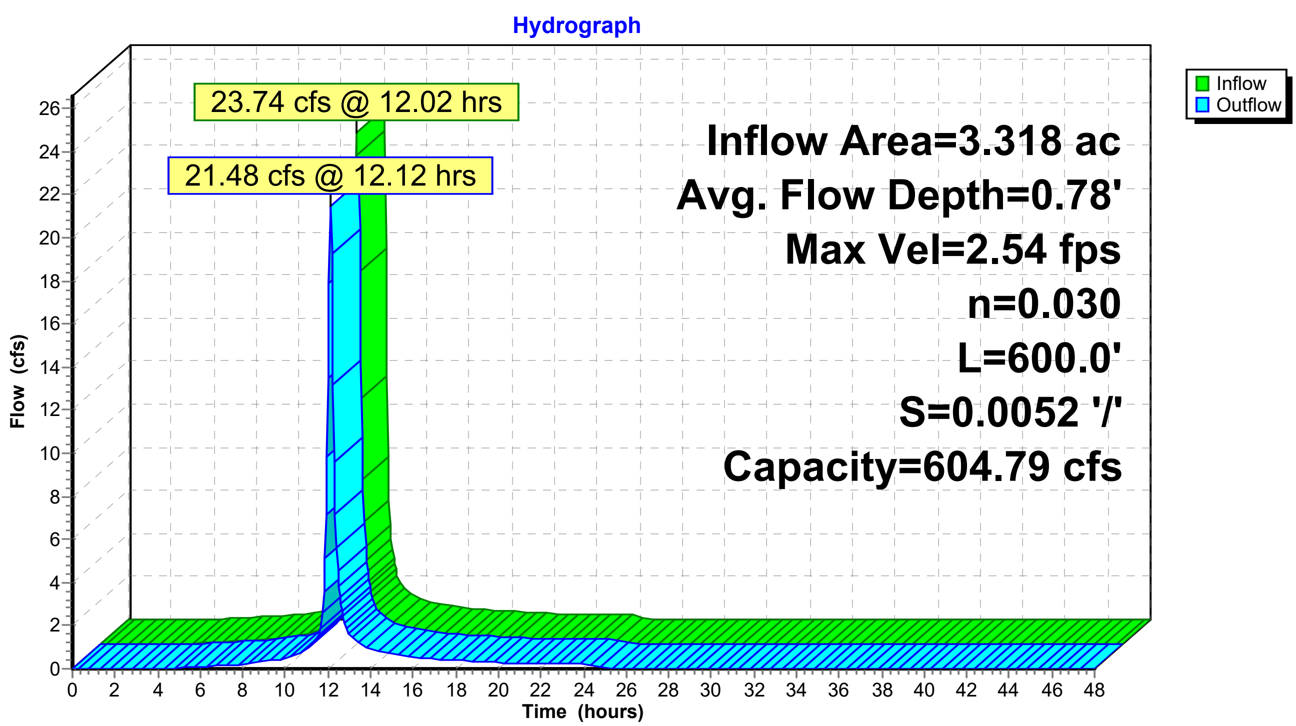
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.54 fps, Min. Travel Time= 3.9 min
Avg. Velocity = 0.64 fps, Avg. Travel Time= 15.6 min

Peak Storage= 5,192 cf @ 12.06 hrs
Average Depth at Peak Storage= 0.78'
Bank-Full Depth= 4.00' Flow Area= 96.0 sf, Capacity= 604.79 cfs

8.00' x 4.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 4.0 '/' Top Width= 40.00'
Length= 600.0' Slope= 0.0052 '/'
Inlet Invert= 614.00', Outlet Invert= 610.88'

‡

Reach D-10:



Summary for Reach D-11:

Inflow Area = 4.304 ac, 0.00% Impervious, Inflow Depth = 5.15" for 100 YR event
Inflow = 30.79 cfs @ 12.02 hrs, Volume= 1.848 af
Outflow = 26.67 cfs @ 12.17 hrs, Volume= 1.848 af, Atten= 13%, Lag= 9.1 min

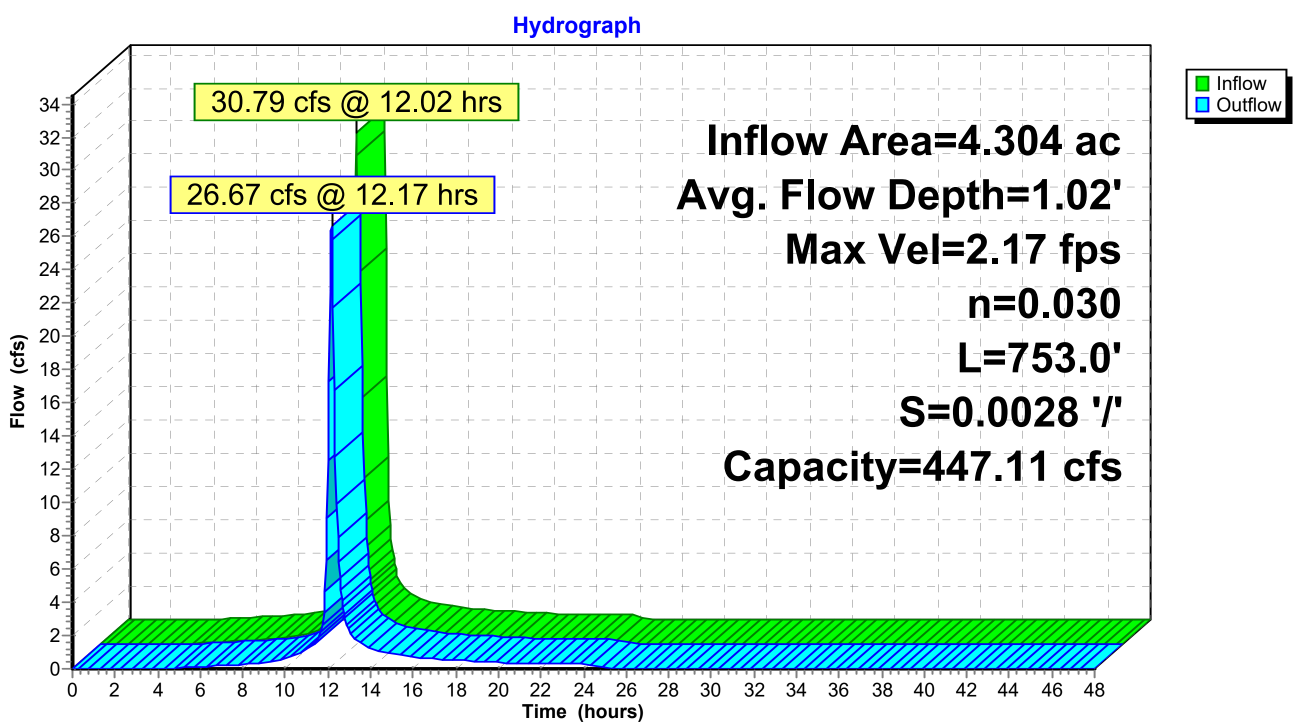
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.17 fps, Min. Travel Time= 5.8 min
Avg. Velocity = 0.54 fps, Avg. Travel Time= 23.4 min

Peak Storage= 9,262 cf @ 12.07 hrs
Average Depth at Peak Storage= 1.02'
Bank-Full Depth= 4.00' Flow Area= 96.0 sf, Capacity= 447.11 cfs

8.00' x 4.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 4.0 '/' Top Width= 40.00'
Length= 753.0' Slope= 0.0028 '/'
Inlet Invert= 613.02', Outlet Invert= 610.88'

‡

Reach D-11:



Summary for Reach D-12:

Inflow Area = 4.722 ac, 0.00% Impervious, Inflow Depth = 5.15" for 100 YR event
Inflow = 33.78 cfs @ 12.02 hrs, Volume= 2.028 af
Outflow = 29.25 cfs @ 12.17 hrs, Volume= 2.028 af, Atten= 13%, Lag= 9.1 min

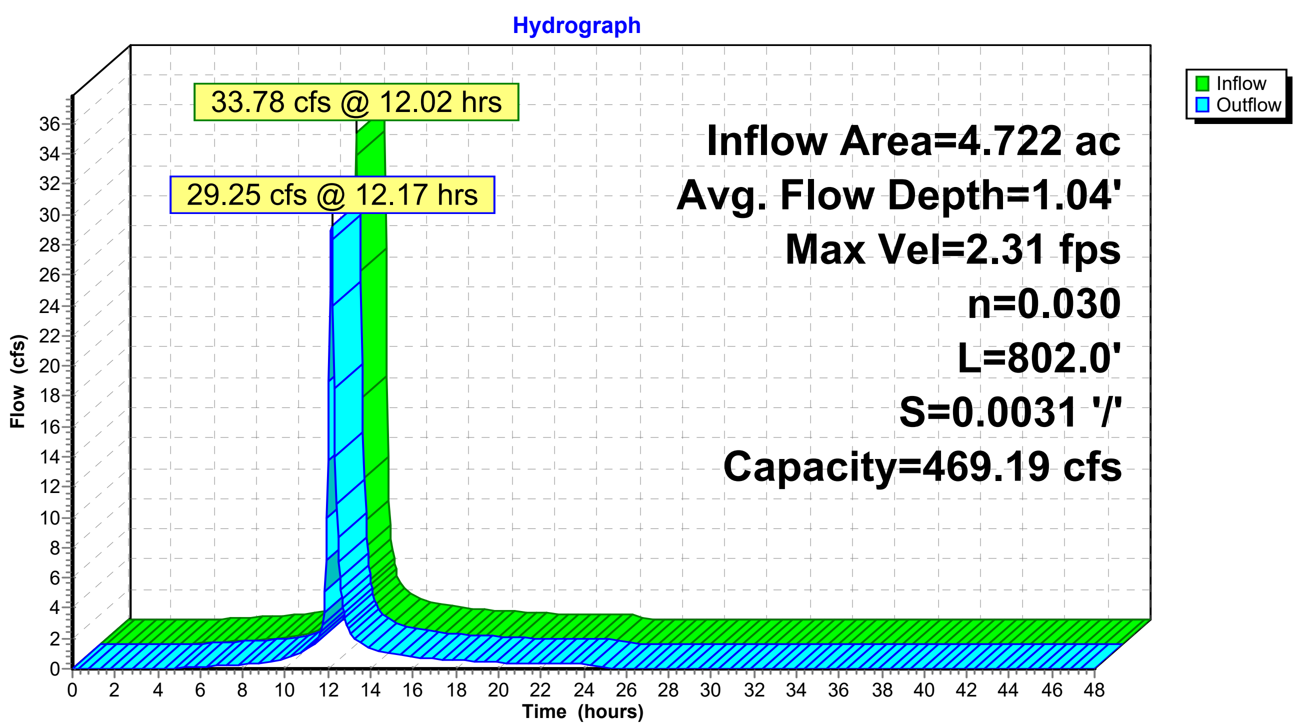
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.31 fps, Min. Travel Time= 5.8 min
Avg. Velocity = 0.57 fps, Avg. Travel Time= 23.4 min

Peak Storage= 10,177 cf @ 12.07 hrs
Average Depth at Peak Storage= 1.04'
Bank-Full Depth= 4.00' Flow Area= 96.0 sf, Capacity= 469.19 cfs

8.00' x 4.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 4.0 '/' Top Width= 40.00'
Length= 802.0' Slope= 0.0031 '/'
Inlet Invert= 613.02', Outlet Invert= 610.51'

‡

Reach D-12:



Summary for Reach D-13:

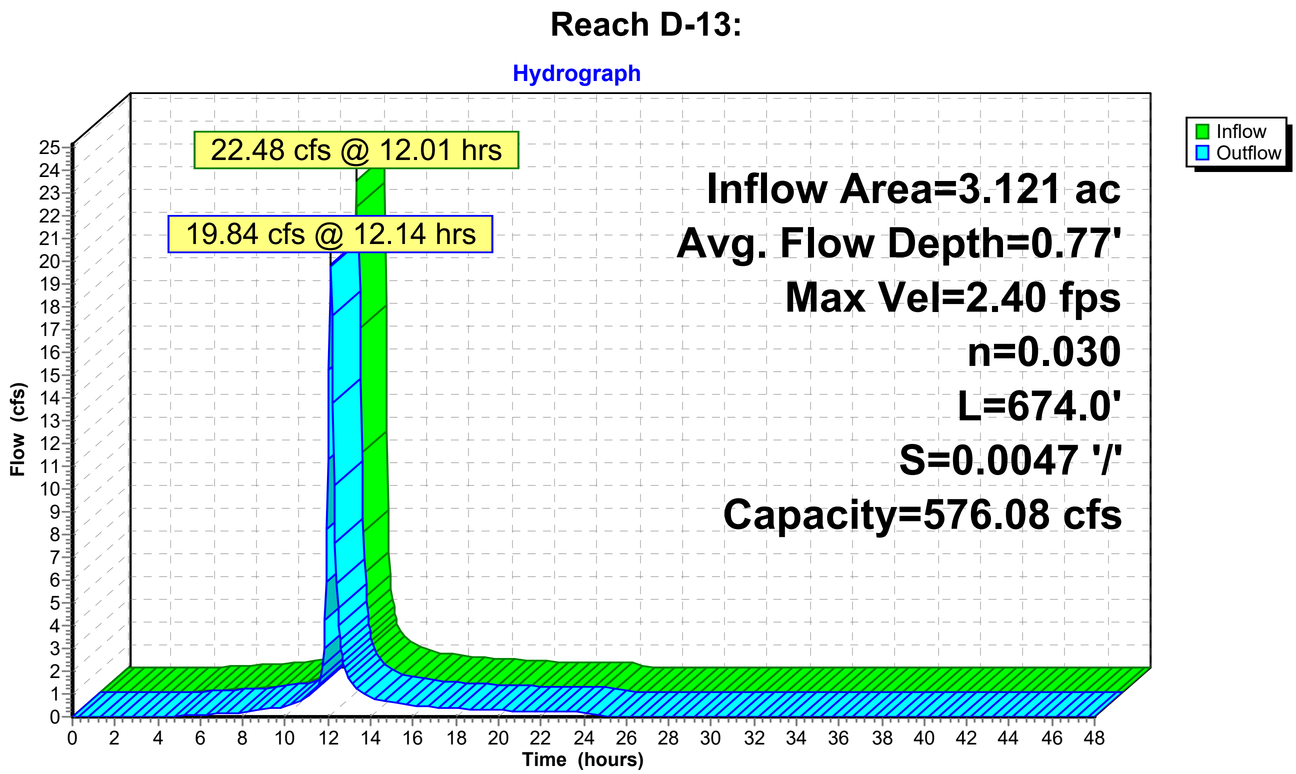
Inflow Area = 3.121 ac, 0.00% Impervious, Inflow Depth = 5.15" for 100 YR event
Inflow = 22.48 cfs @ 12.01 hrs, Volume= 1.340 af
Outflow = 19.84 cfs @ 12.14 hrs, Volume= 1.340 af, Atten= 12%, Lag= 7.6 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.40 fps, Min. Travel Time= 4.7 min
Avg. Velocity = 0.60 fps, Avg. Travel Time= 18.7 min

Peak Storage= 5,708 cf @ 12.06 hrs
Average Depth at Peak Storage= 0.77'
Bank-Full Depth= 4.00' Flow Area= 96.0 sf, Capacity= 576.08 cfs

8.00' x 4.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 4.0 '/' Top Width= 40.00'
Length= 674.0' Slope= 0.0047 '/'
Inlet Invert= 614.00', Outlet Invert= 610.82'

‡



Summary for Reach D-7:

Inflow Area = 0.592 ac, 0.00% Impervious, Inflow Depth = 5.15" for 100 YR event
Inflow = 4.87 cfs @ 11.96 hrs, Volume= 0.254 af
Outflow = 4.56 cfs @ 12.03 hrs, Volume= 0.254 af, Atten= 6%, Lag= 4.0 min

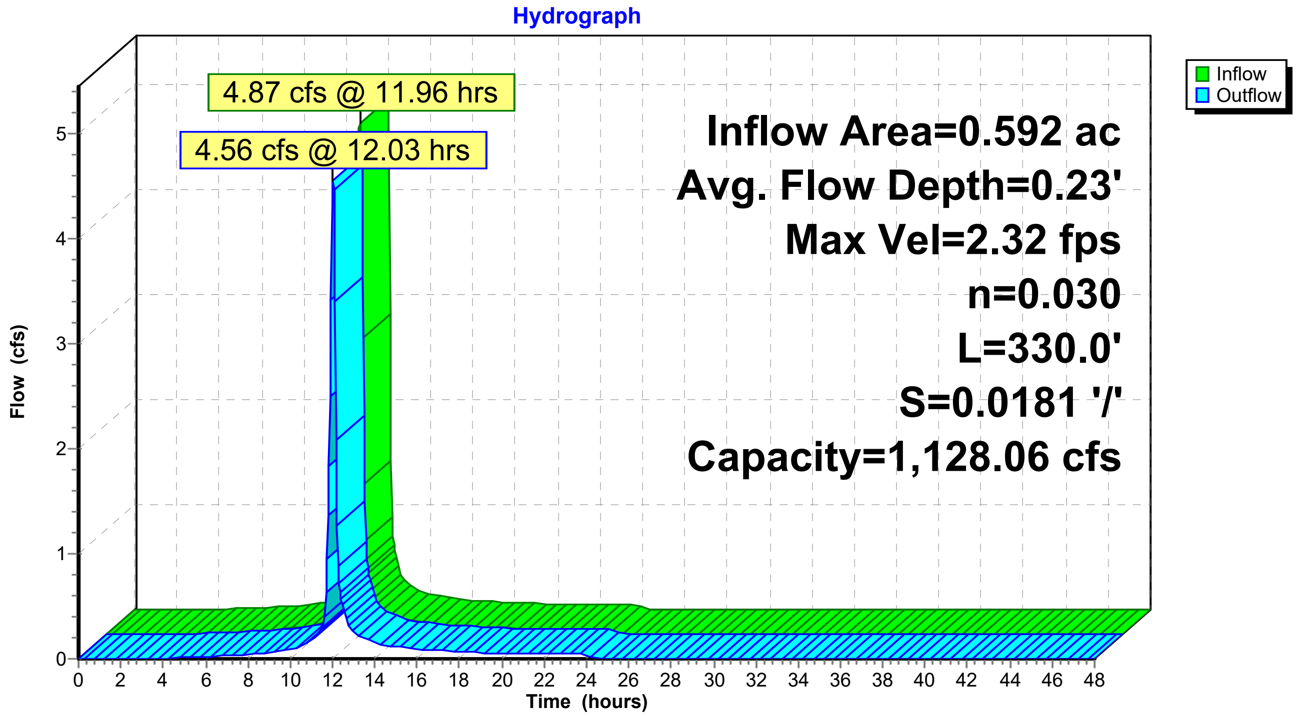
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.32 fps, Min. Travel Time= 2.4 min
Avg. Velocity = 0.80 fps, Avg. Travel Time= 6.9 min

Peak Storage= 668 cf @ 11.99 hrs
Average Depth at Peak Storage= 0.23'
Bank-Full Depth= 4.00' Flow Area= 96.0 sf, Capacity= 1,128.06 cfs

8.00' x 4.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 4.0 '/' Top Width= 40.00'
Length= 330.0' Slope= 0.0181 '/'
Inlet Invert= 623.11', Outlet Invert= 617.14'

‡

Reach D-7:



Summary for Reach D-8:

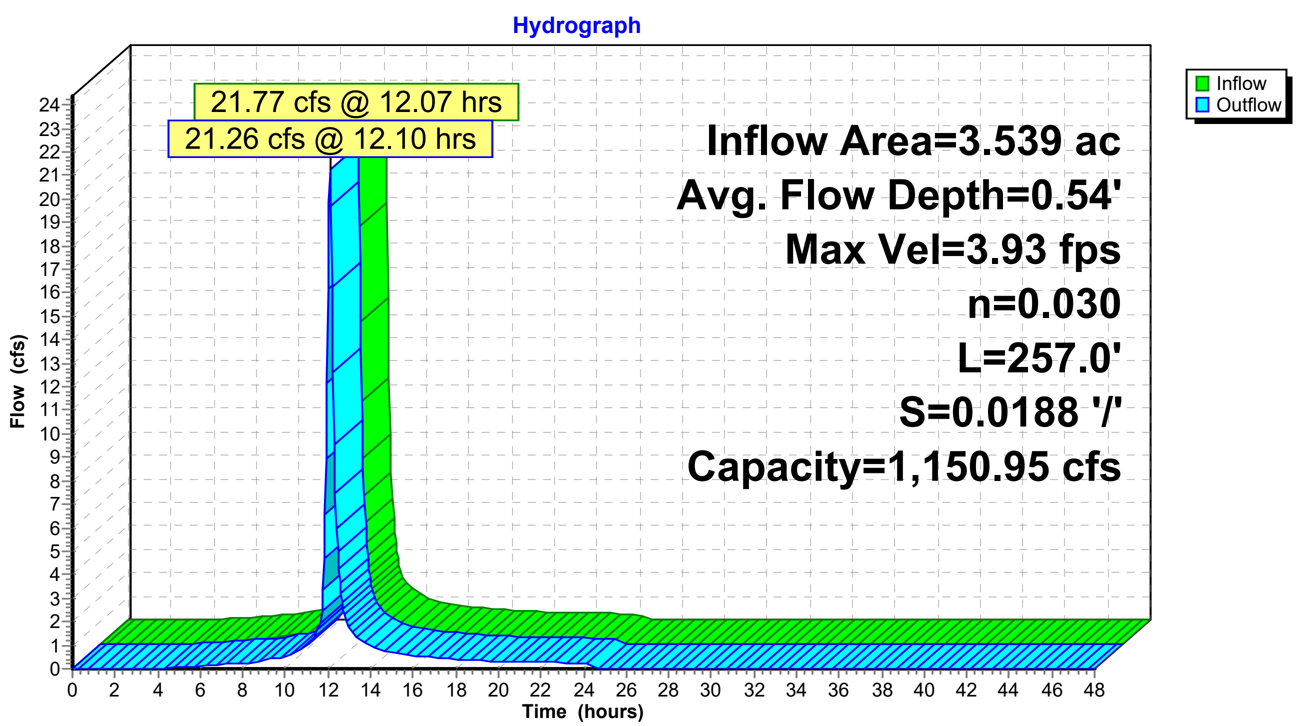
Inflow Area = 3.539 ac, 0.00% Impervious, Inflow Depth = 5.15" for 100 YR event
Inflow = 21.77 cfs @ 12.07 hrs, Volume= 1.520 af
Outflow = 21.26 cfs @ 12.10 hrs, Volume= 1.520 af, Atten= 2%, Lag= 2.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.93 fps, Min. Travel Time= 1.1 min
Avg. Velocity = 1.05 fps, Avg. Travel Time= 4.1 min

Peak Storage= 1,411 cf @ 12.08 hrs
Average Depth at Peak Storage= 0.54'
Bank-Full Depth= 4.00' Flow Area= 96.0 sf, Capacity= 1,150.95 cfs

8.00' x 4.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 4.0 '/' Top Width= 40.00'
Length= 257.0' Slope= 0.0188 '/'
Inlet Invert= 617.14', Outlet Invert= 612.30'

Reach D-8:



Summary for Reach D-9:

Inflow Area = 3.597 ac, 0.00% Impervious, Inflow Depth = 5.15" for 100 YR event
Inflow = 25.73 cfs @ 12.02 hrs, Volume= 1.545 af
Outflow = 22.81 cfs @ 12.14 hrs, Volume= 1.545 af, Atten= 11%, Lag= 7.4 min

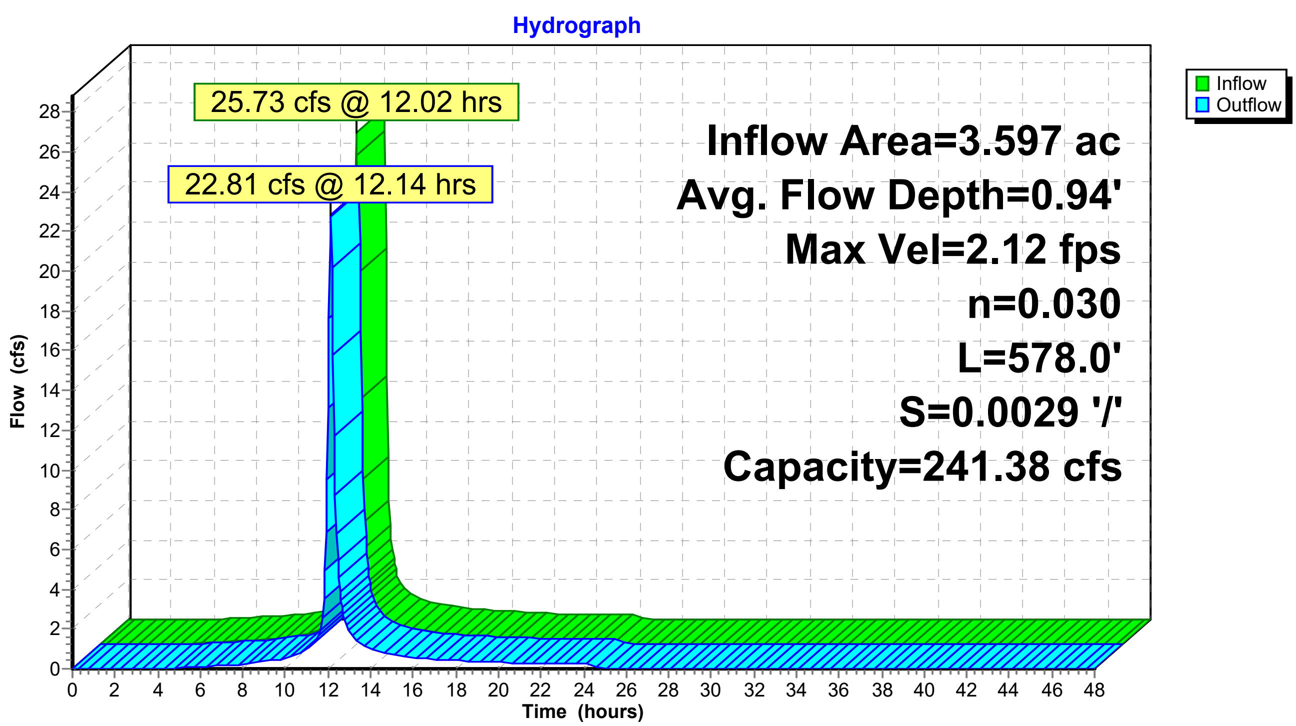
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.12 fps, Min. Travel Time= 4.6 min
Avg. Velocity = 0.51 fps, Avg. Travel Time= 19.1 min

Peak Storage= 6,370 cf @ 12.06 hrs
Average Depth at Peak Storage= 0.94'
Bank-Full Depth= 3.00' Flow Area= 60.0 sf, Capacity= 241.38 cfs

8.00' x 3.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 4.0 '/' Top Width= 32.00'
Length= 578.0' Slope= 0.0029 '/'
Inlet Invert= 614.00', Outlet Invert= 612.30'

‡

Reach D-9:



Summary for Reach LD-10:

Inflow Area = 14.091 ac, 0.00% Impervious, Inflow Depth = 5.15" for 100 YR event
Inflow = 78.08 cfs @ 12.18 hrs, Volume= 6.051 af
Outflow = 77.82 cfs @ 12.19 hrs, Volume= 6.051 af, Atten= 0%, Lag= 0.4 min

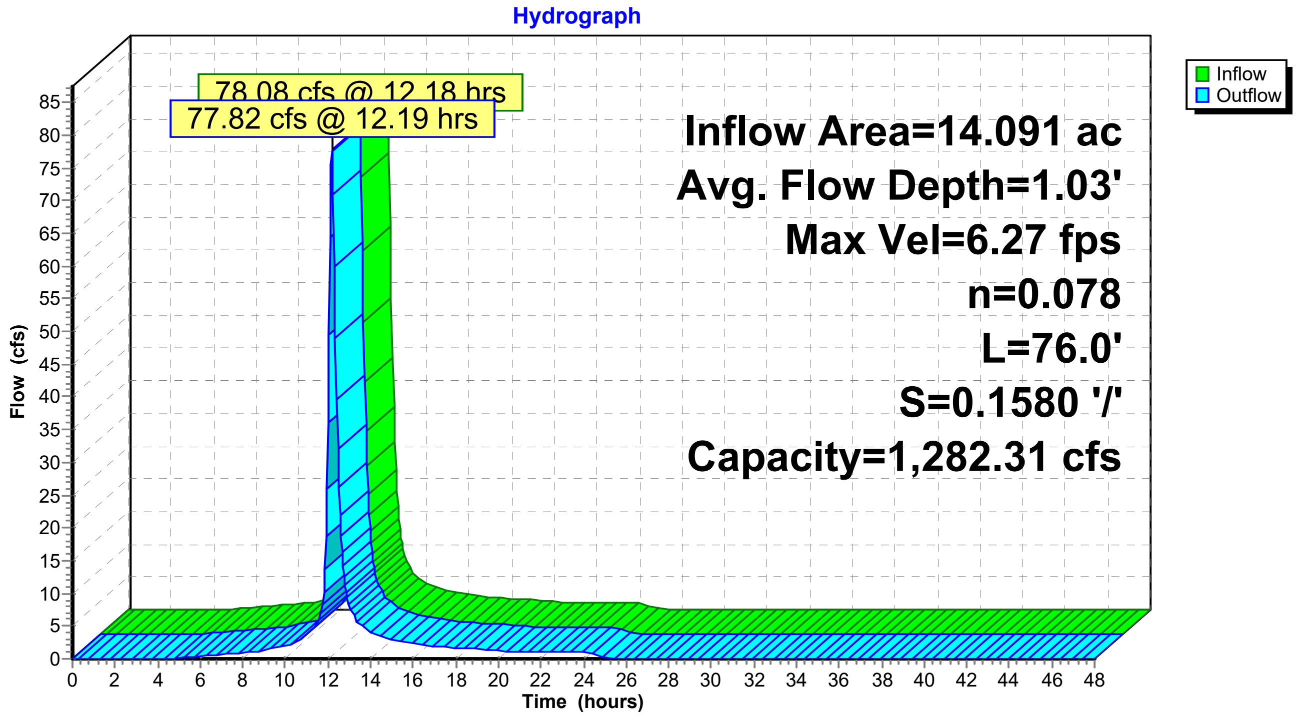
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 6.27 fps, Min. Travel Time= 0.2 min
Avg. Velocity = 1.62 fps, Avg. Travel Time= 0.8 min

Peak Storage= 945 cf @ 12.18 hrs
Average Depth at Peak Storage= 1.03'
Bank-Full Depth= 4.00' Flow Area= 96.0 sf, Capacity= 1,282.31 cfs

8.00' x 4.00' deep channel, n= 0.078 Riprap, 12-inch
Side Slope Z-value= 4.0 '/' Top Width= 40.00'
Length= 76.0' Slope= 0.1580 '/'
Inlet Invert= 610.51', Outlet Invert= 598.50'

‡

Reach LD-10:



Summary for Reach LD-4:

Inflow Area = 2.947 ac, 0.00% Impervious, Inflow Depth = 5.15" for 100 YR event
Inflow = 17.76 cfs @ 12.08 hrs, Volume= 1.265 af
Outflow = 17.71 cfs @ 12.08 hrs, Volume= 1.265 af, Atten= 0%, Lag= 0.2 min

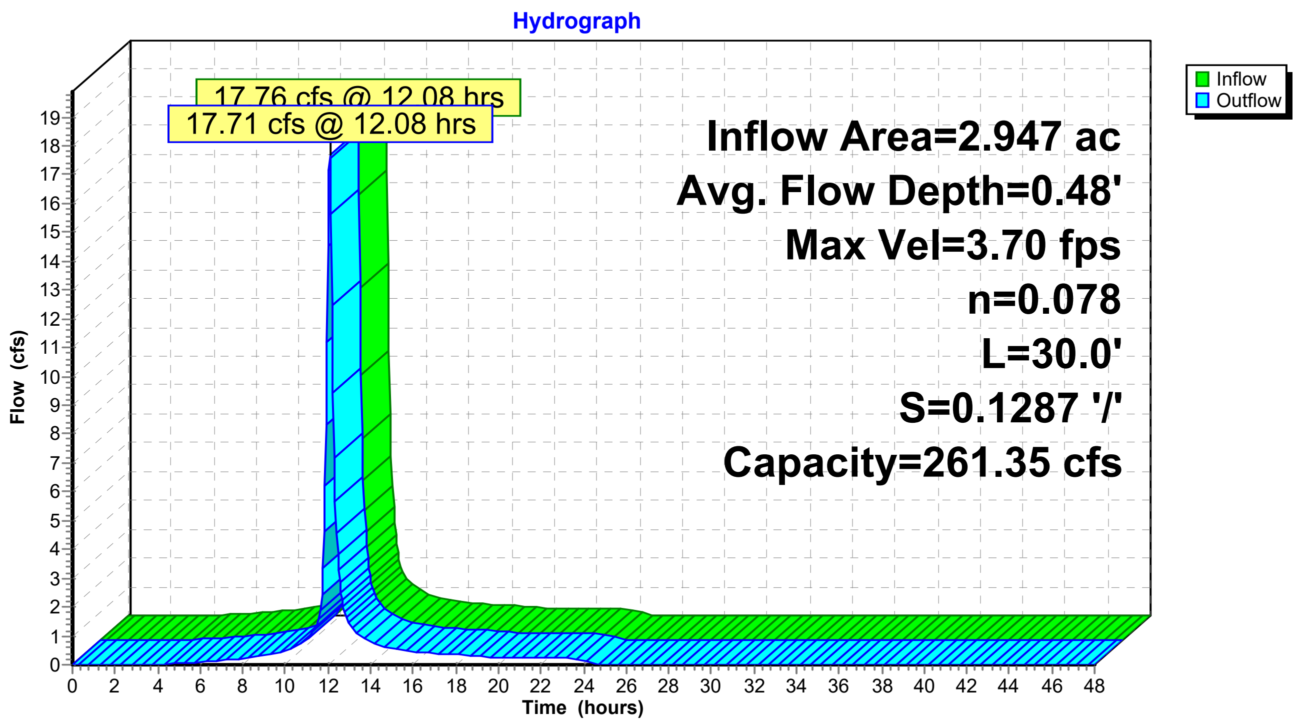
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.70 fps, Min. Travel Time= 0.1 min
Avg. Velocity = 0.94 fps, Avg. Travel Time= 0.5 min

Peak Storage= 144 cf @ 12.08 hrs
Average Depth at Peak Storage= 0.48'
Bank-Full Depth= 2.00' Flow Area= 32.0 sf, Capacity= 261.35 cfs

8.00' x 2.00' deep channel, n= 0.078 Riprap, 12-inch
Side Slope Z-value= 4.0 '/' Top Width= 24.00'
Length= 30.0' Slope= 0.1287 '/'
Inlet Invert= 621.00', Outlet Invert= 617.14'

‡

Reach LD-4:



Summary for Reach LD-5:

Inflow Area = 7.136 ac, 0.00% Impervious, Inflow Depth = 5.15" for 100 YR event
Inflow = 43.41 cfs @ 12.12 hrs, Volume= 3.064 af
Outflow = 43.15 cfs @ 12.13 hrs, Volume= 3.064 af, Atten= 1%, Lag= 0.4 min

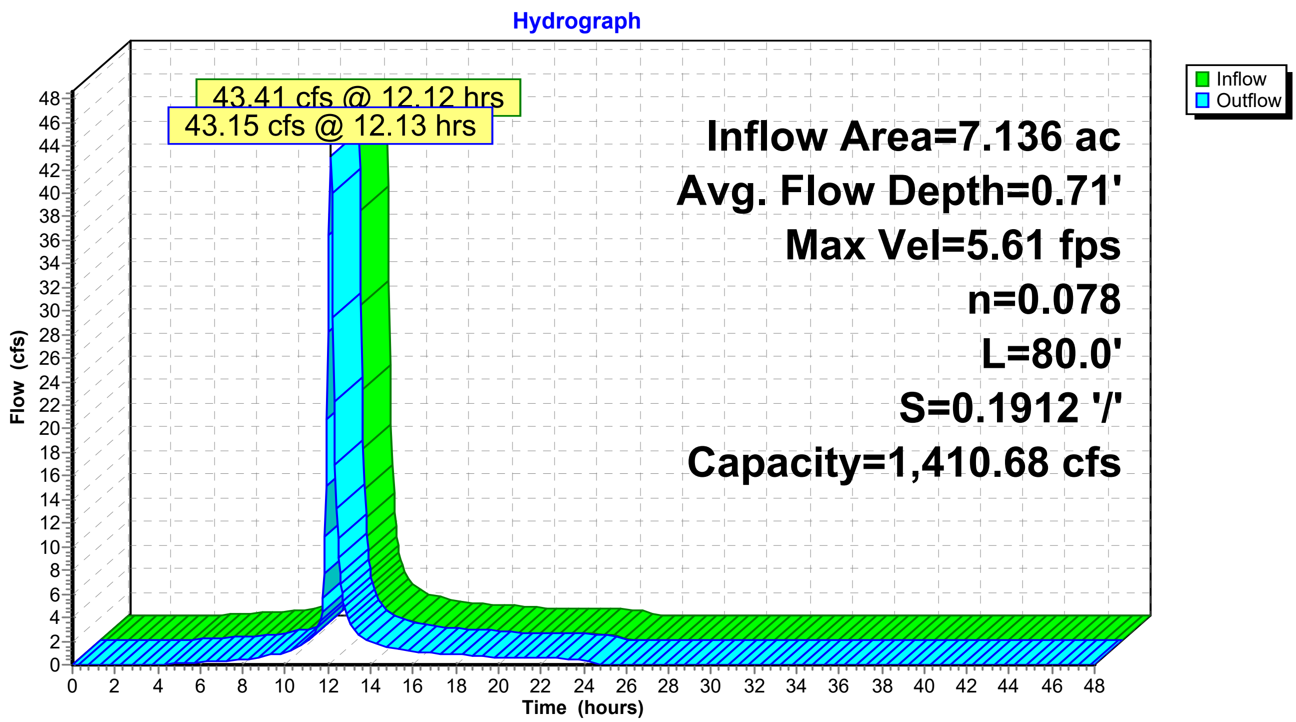
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 5.61 fps, Min. Travel Time= 0.2 min
Avg. Velocity = 1.44 fps, Avg. Travel Time= 0.9 min

Peak Storage= 616 cf @ 12.12 hrs
Average Depth at Peak Storage= 0.71'
Bank-Full Depth= 4.00' Flow Area= 96.0 sf, Capacity= 1,410.68 cfs

8.00' x 4.00' deep channel, n= 0.078 Riprap, 12-inch
Side Slope Z-value= 4.0 '/' Top Width= 40.00'
Length= 80.0' Slope= 0.1912 '/'
Inlet Invert= 612.30', Outlet Invert= 597.00'

‡

Reach LD-5:



Summary for Reach LD-6:

Inflow Area = 9.184 ac, 0.00% Impervious, Inflow Depth = 5.15" for 100 YR event
Inflow = 48.35 cfs @ 12.14 hrs, Volume= 3.944 af
Outflow = 47.54 cfs @ 12.17 hrs, Volume= 3.944 af, Atten= 2%, Lag= 2.3 min

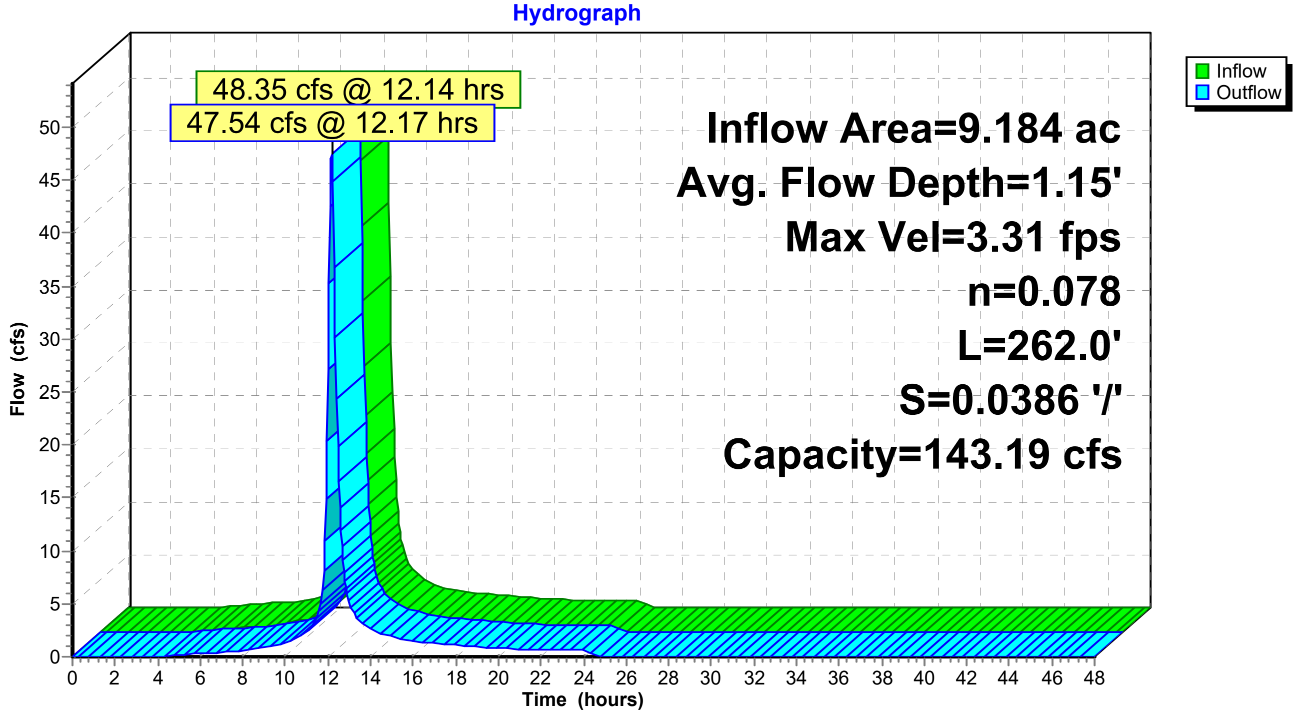
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.31 fps, Min. Travel Time= 1.3 min
Avg. Velocity = 0.90 fps, Avg. Travel Time= 4.8 min

Peak Storage= 3,813 cf @ 12.15 hrs
Average Depth at Peak Storage= 1.15'
Bank-Full Depth= 2.00' Flow Area= 32.0 sf, Capacity= 143.19 cfs

8.00' x 2.00' deep channel, n= 0.078 Riprap, 12-inch
Side Slope Z-value= 4.0 '/' Top Width= 24.00'
Length= 262.0' Slope= 0.0386 '/'
Inlet Invert= 621.00', Outlet Invert= 610.88'

‡

Reach LD-6:



Summary for Reach LD-7:

Inflow Area = 16.806 ac, 0.00% Impervious, Inflow Depth = 5.15" for 100 YR event
Inflow = 94.54 cfs @ 12.16 hrs, Volume= 7.216 af
Outflow = 94.02 cfs @ 12.17 hrs, Volume= 7.216 af, Atten= 1%, Lag= 0.4 min

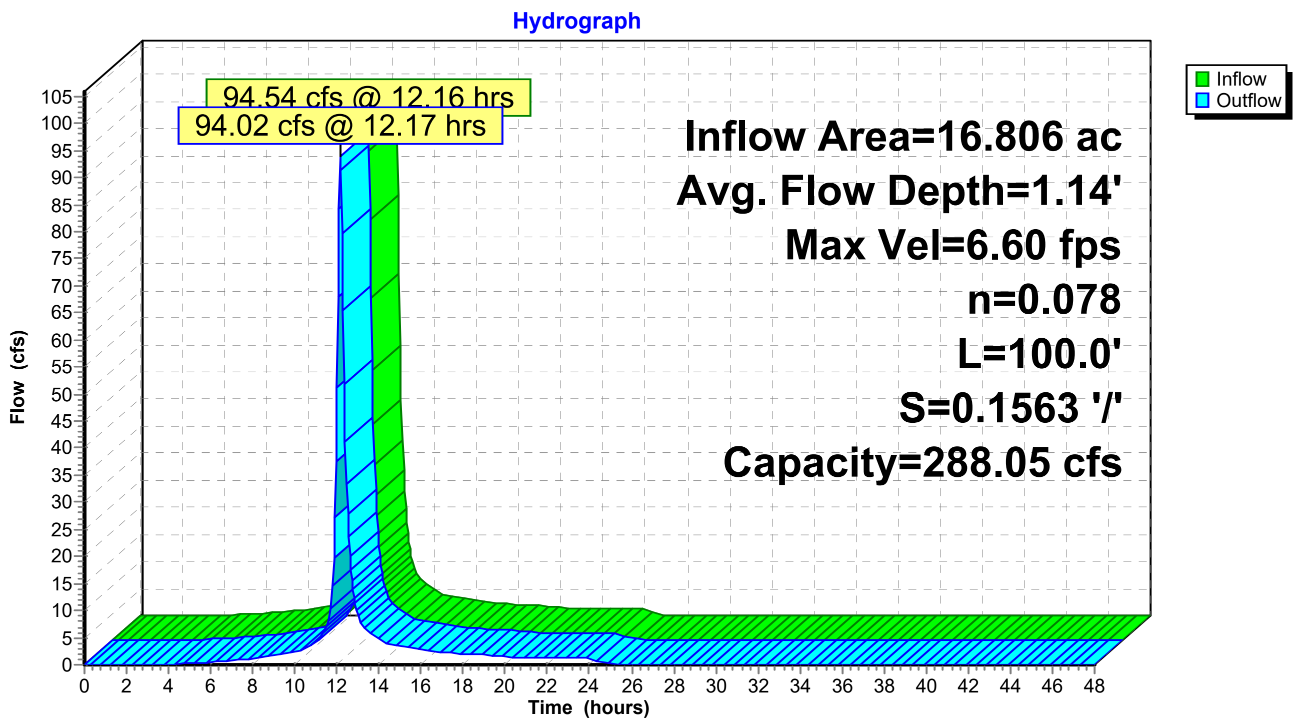
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 6.60 fps, Min. Travel Time= 0.3 min
Avg. Velocity = 1.62 fps, Avg. Travel Time= 1.0 min

Peak Storage= 1,430 cf @ 12.16 hrs
Average Depth at Peak Storage= 1.14'
Bank-Full Depth= 2.00' Flow Area= 32.0 sf, Capacity= 288.05 cfs

8.00' x 2.00' deep channel, n= 0.078 Riprap, 12-inch
Side Slope Z-value= 4.0 '/' Top Width= 24.00'
Length= 100.0' Slope= 0.1563 '/'
Inlet Invert= 610.88', Outlet Invert= 595.25'

‡

Reach LD-7:



Summary for Reach LD-8:

Inflow Area = 6.248 ac, 0.00% Impervious, Inflow Depth = 5.15" for 100 YR event
Inflow = 33.92 cfs @ 12.11 hrs, Volume= 2.683 af
Outflow = 33.09 cfs @ 12.17 hrs, Volume= 2.683 af, Atten= 2%, Lag= 3.4 min

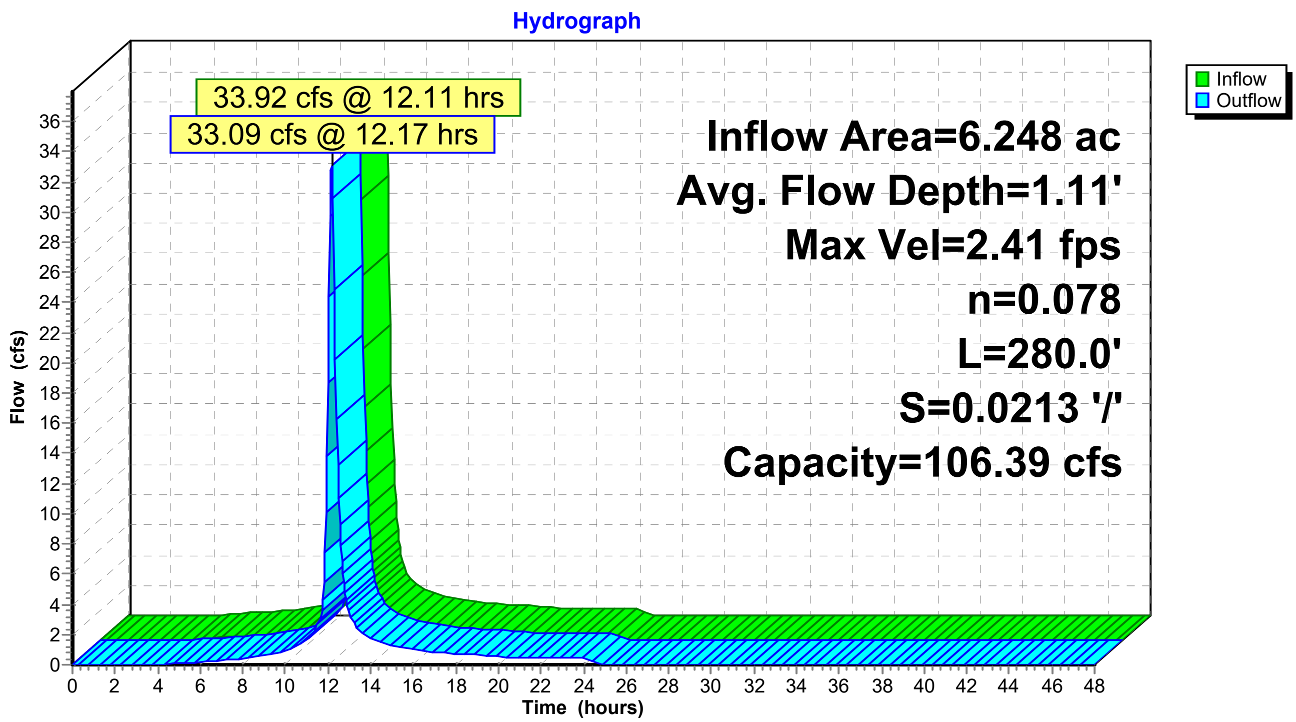
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.41 fps, Min. Travel Time= 1.9 min
Avg. Velocity = 0.63 fps, Avg. Travel Time= 7.4 min

Peak Storage= 3,886 cf @ 12.14 hrs
Average Depth at Peak Storage= 1.11'
Bank-Full Depth= 2.00' Flow Area= 32.0 sf, Capacity= 106.39 cfs

8.00' x 2.00' deep channel, n= 0.078 Riprap, 12-inch
Side Slope Z-value= 4.0 '/' Top Width= 24.00'
Length= 280.0' Slope= 0.0213 '/'
Inlet Invert= 621.00', Outlet Invert= 615.03'

‡

Reach LD-8:



Summary for Reach LD-9:

Inflow Area = 6.248 ac, 0.00% Impervious, Inflow Depth = 5.15" for 100 YR event
Inflow = 33.09 cfs @ 12.17 hrs, Volume= 2.683 af
Outflow = 32.27 cfs @ 12.24 hrs, Volume= 2.683 af, Atten= 2%, Lag= 4.0 min

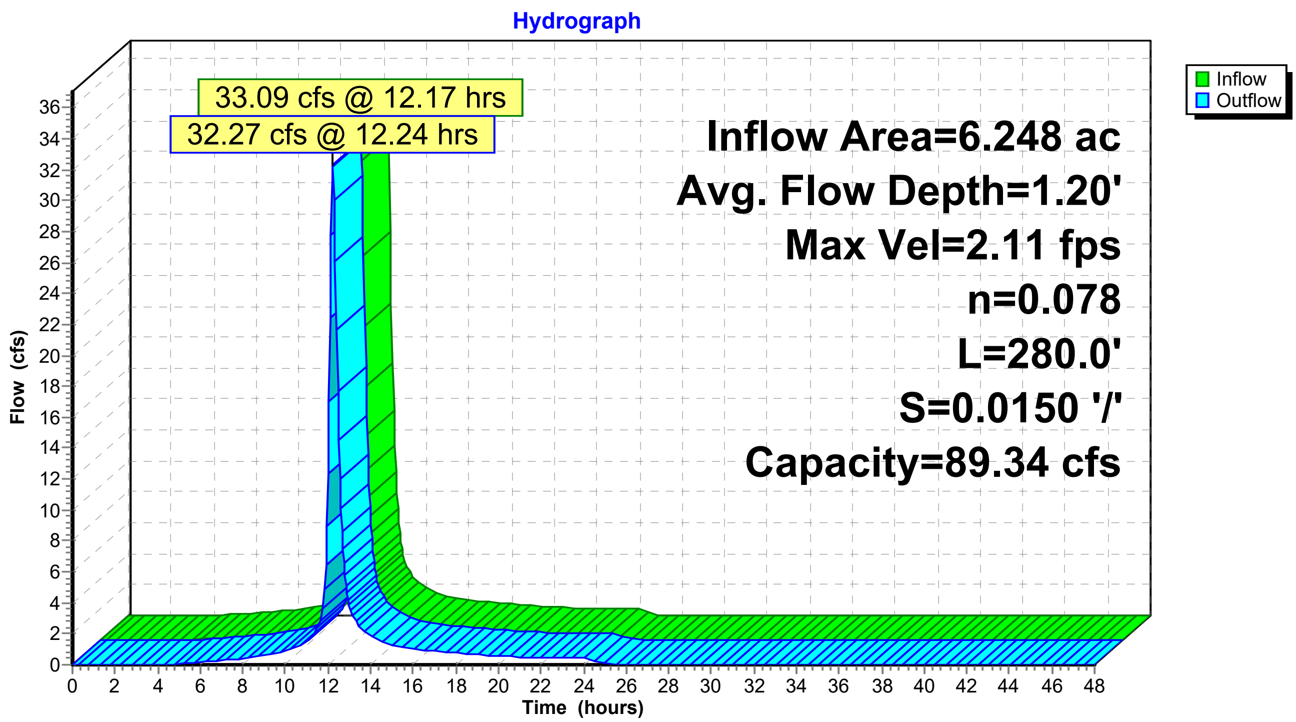
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.11 fps, Min. Travel Time= 2.2 min
Avg. Velocity = 0.55 fps, Avg. Travel Time= 8.5 min

Peak Storage= 4,320 cf @ 12.20 hrs
Average Depth at Peak Storage= 1.20'
Bank-Full Depth= 2.00' Flow Area= 32.0 sf, Capacity= 89.34 cfs

8.00' x 2.00' deep channel, n= 0.078 Riprap, 12-inch
Side Slope Z-value= 4.0 '/' Top Width= 24.00'
Length= 280.0' Slope= 0.0150 '/'
Inlet Invert= 615.03', Outlet Invert= 610.82'

‡

Reach LD-9:

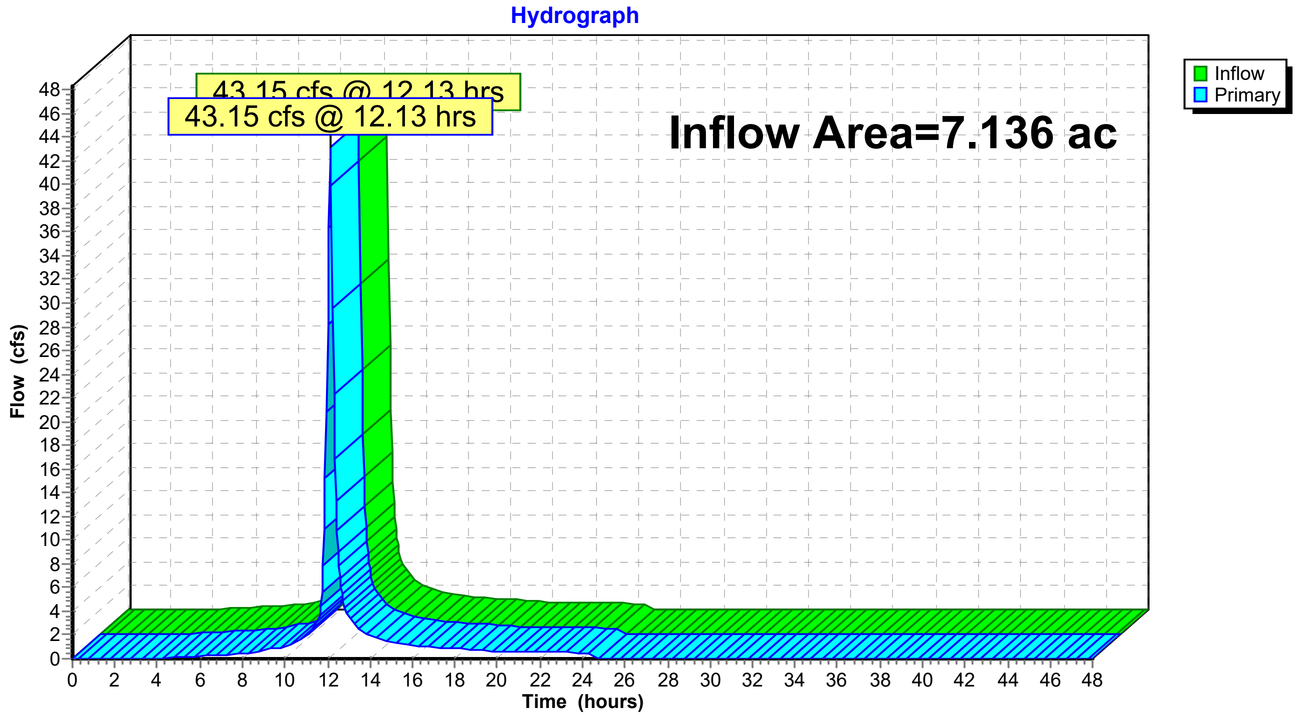


Summary for Link 1L: Discharge

Inflow Area = 7.136 ac, 0.00% Impervious, Inflow Depth = 5.15" for 100 YR event
Inflow = 43.15 cfs @ 12.13 hrs, Volume= 3.064 af
Primary = 43.15 cfs @ 12.13 hrs, Volume= 3.064 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

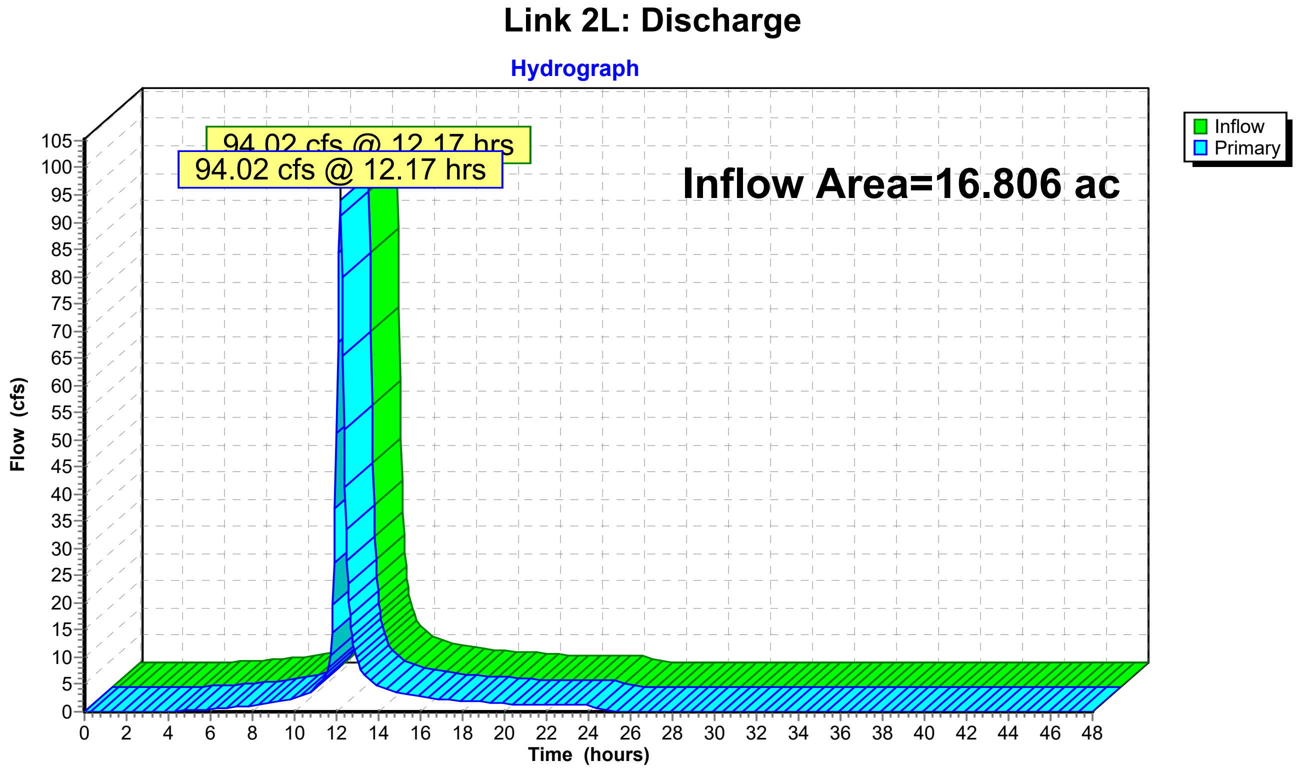
Link 1L: Discharge



Summary for Link 2L: Discharge

Inflow Area = 16.806 ac, 0.00% Impervious, Inflow Depth = 5.15" for 100 YR event
Inflow = 94.02 cfs @ 12.17 hrs, Volume= 7.216 af
Primary = 94.02 cfs @ 12.17 hrs, Volume= 7.216 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

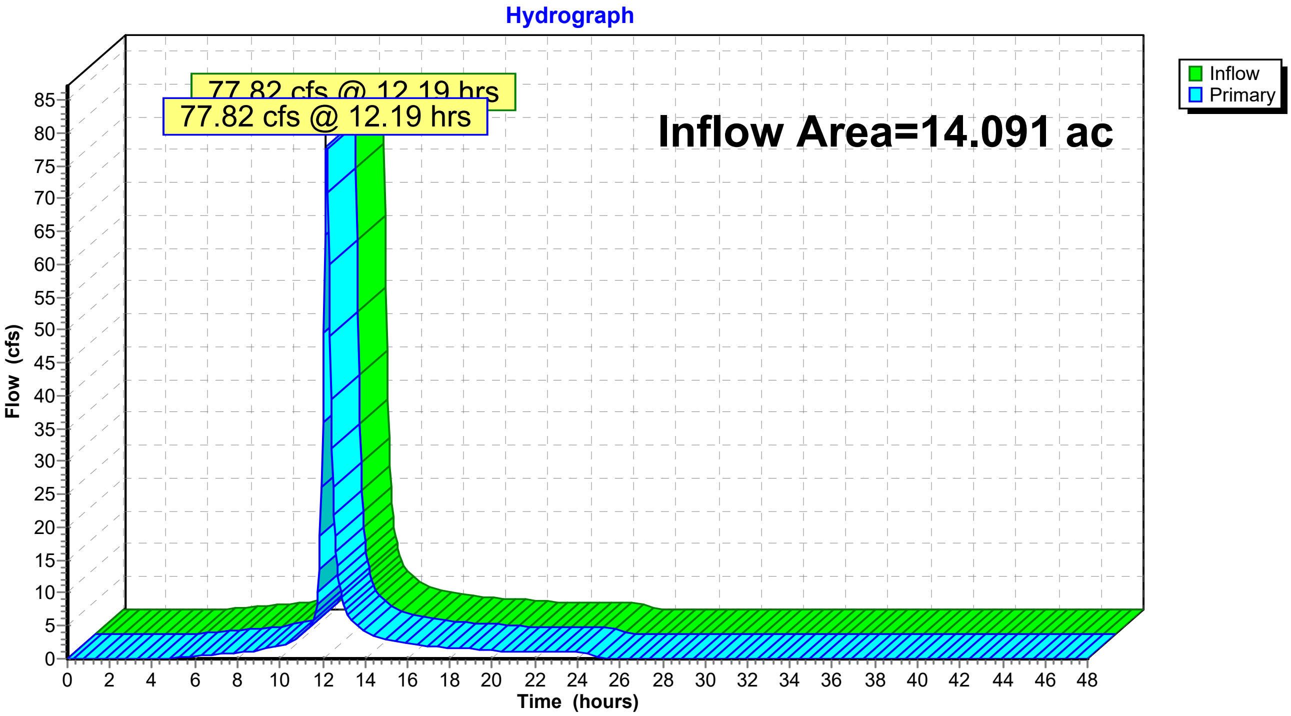


Summary for Link 3L: Discharge

Inflow Area = 14.091 ac, 0.00% Impervious, Inflow Depth = 5.15" for 100 YR event
Inflow = 77.82 cfs @ 12.19 hrs, Volume= 6.051 af
Primary = 77.82 cfs @ 12.19 hrs, Volume= 6.051 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

Link 3L: Discharge



BURNS McDONNELL

WORKSHEET TITLE Kincaid ash pond
CREATED: 7/14/2022
PERFORMED BY: B. LIU
OBJECTIVE: New discharge culverts sizing with post-construction phase flow 25yr 24hr storm and checking with 100yr 24 hr storm

CALCULATION NO.: C001
REVISION: A
REVIEWED BY: R. Owens

REFERENCES:

National Oceanic and Atmospheric Administration. (2018). NOAA Atlas 14, Volume 9, Version 2.

SOFTWARE:

HydroCAD 10.00-24 (40 node s/n 08510)

HYDROCAD INPUTS:

SCS Storm	Depth (in)
2yr, 24hr	3.01
25yr, 24hr	5.15
100yr, 24hr	6.43

Surface	CN
CCR	89

South Drainage Area (to new culverts)		Tc (min)
DA-1 (sf)	19,245	6
DA-2 (sf)	55,256	15.6
DA-3 (sf)	55,390	10.3
DA-4 (sf)	57,254	10.3
DA-5 (sf)	327,400	18.9
DA-6 (sf)	615,322	10.3
DA-7 (sf)	258,458	18.9
DA-8 (sf)	172,145	9.6
Total (sf)	1,560,470	
Total (ac)	35.82	

HYDROCAD OUTPUTS:

Drainage area:

South area	Peakflow (cfs)	
	25YR	100 YR
DA-1	2.81	3.63
DA-2	6.05	7.84
DA-3	7.12	9.22
DA-4	7.36	9.53
DA-5	32.67	42.42
DA-6	79.11	102.42
DA-7	25.79	33.49
DA-8	22.69	29.38

Ditches:

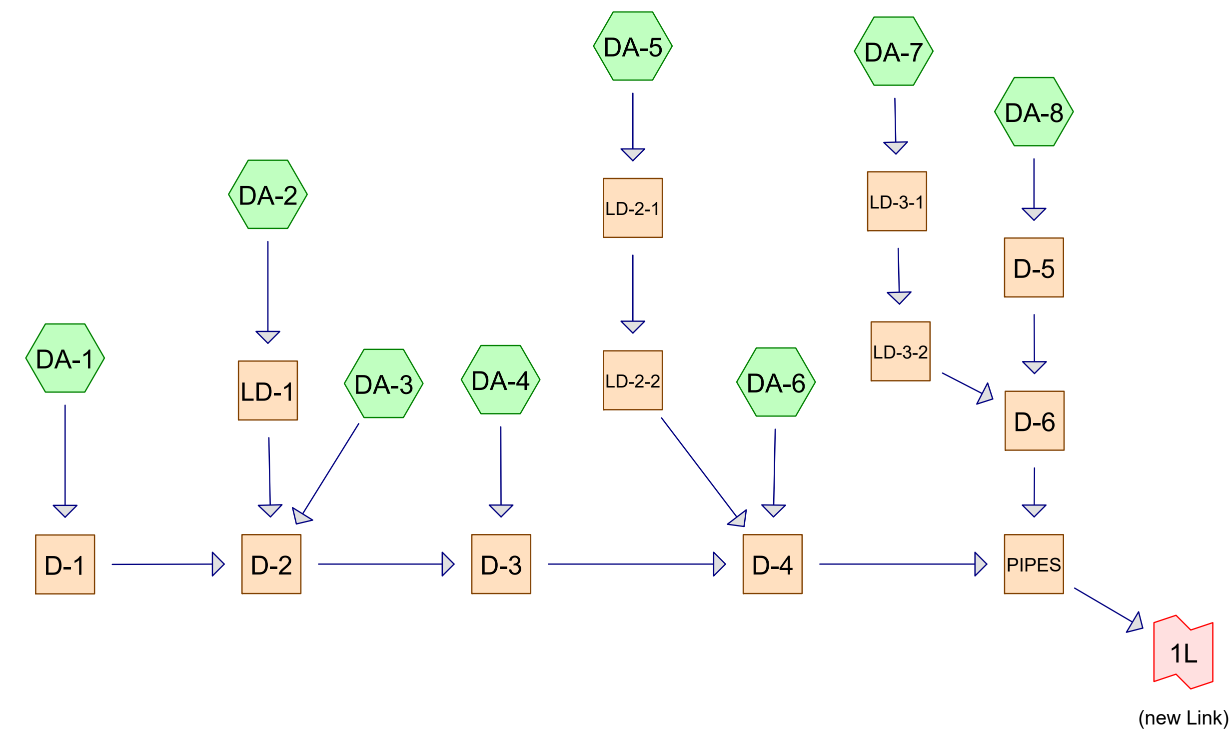
Ditches:	Peak Inflow (cfs)		Max. Velocity (fps)		Average Flow depth (ft)		Capacity (cfs)
	25YR	100YR	25YR	100YR	25YR	100YR	
D-1	2.81	3.63	2.32	2.54	0.14	0.16	1532
D-2	15.27	19.77	4.27	4.66	0.37	0.43	1549
D-3	21.21	27.70	2.15	2.33	0.86	0.99	485
D-4	116.70	152.81	3.05	3.29	2.02	2.31	430
D-5	22.69	29.38	4.19	4.55	0.51	0.59	10918
D-6	43.97	57.01	5.12	5.54	0.77	0.89	10578

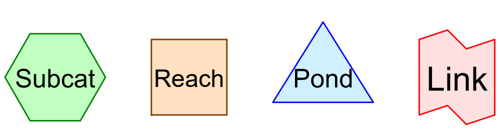
Letdown channel:

Letdown channel	Peak Inflow (cfs)		Max. Velocity (fps)		Average Flow depth (ft)		Capacity (cfs)
	25YR	100YR	25YR	100YR	25YR	100YR	
LD-1	6.05	7.84	2.99	3.28	0.23	0.26	332
LD-2-1	32.67	42.42	2.74	2.95	0.99	1.13	129
LD-2-2	31.95	41.52	3.48	3.76	0.81	0.94	182
LD-3-1	25.79	33.49	2.34	2.52	0.93	1.07	114
LD-3-2	25.15	32.68	4.54	4.93	0.54	0.63	298

New culvert:

CHDPE pipe	Peak Inflow (cfs)		Max. Velocity (fps)		Average Flow depth (ft)		Capacity (cfs)
	25YR	100YR	25YR	100YR	25YR	100YR	
5x18" CHDPE	132.95	177.29	8.88	8.92	1.50	1.50	69.62





Routing Diagram for Ash Pond South
Prepared by Burns and McDonnell, Printed 7/15/2022
HydroCAD® 10.00-24 s/n 08510 © 2018 HydroCAD Software Solutions LLC

Area Listing (all nodes)

Area (acres)	CN	Description (subcatchment-numbers)
35.823	89	CCR (DA-1, DA-2, DA-3, DA-4, DA-5, DA-6, DA-7, DA-8)
35.823	**89**	**TOTAL AREA**

Ground Covers (all nodes)

HSG-A (acres)	HSG-B (acres)	HSG-C (acres)	HSG-D (acres)	Other (acres)	Total (acres)	Ground Cover	Subcatchment Numbers
0.000	0.000	0.000	0.000	35.823	35.823	CCR	DA-1, DA-2, DA-3, DA-4, DA-5, DA-6, DA-7, DA-8
0.000	**0.000**	**0.000**	**0.000**	**35.823**	**35.823**	**TOTAL AREA**	

Summary for Subcatchment DA-1:

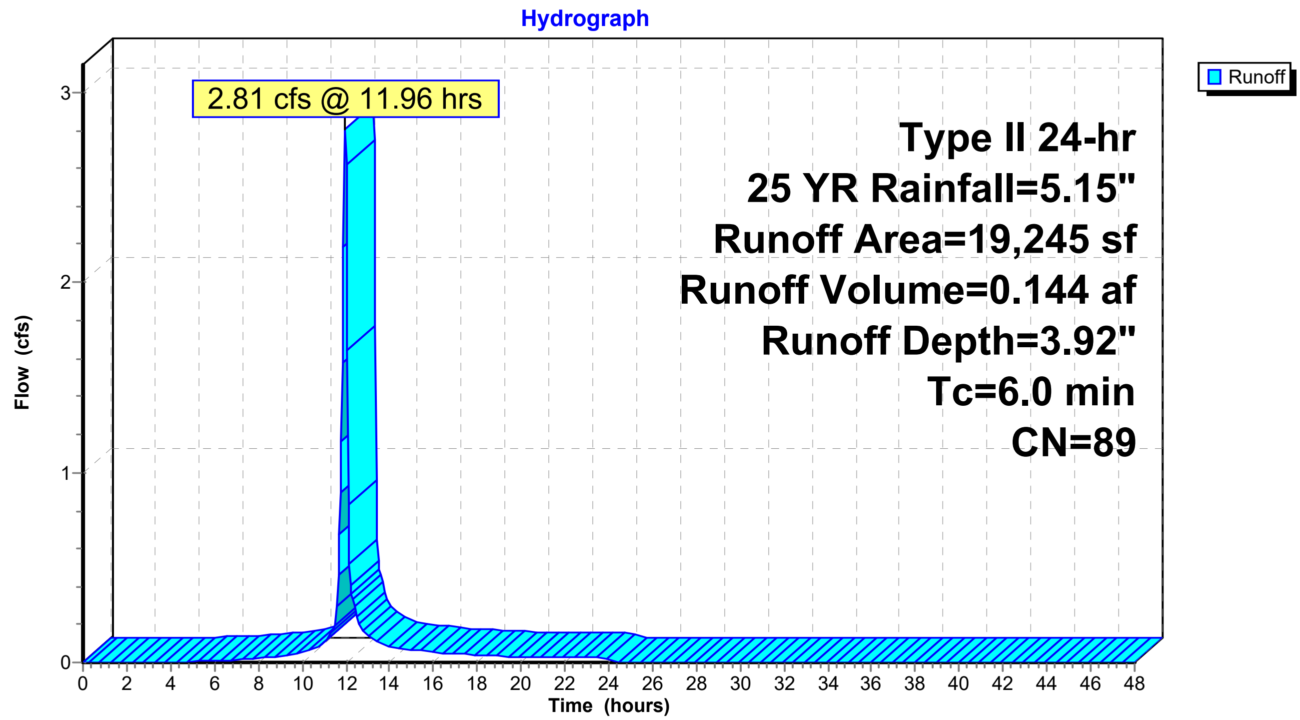
Runoff = 2.81 cfs @ 11.96 hrs, Volume= 0.144 af, Depth= 3.92"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 25 YR Rainfall=5.15"

	Area (sf)	CN	Description
*	19,245	89	CCR
	19,245		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA-1:



Summary for Subcatchment DA-2:

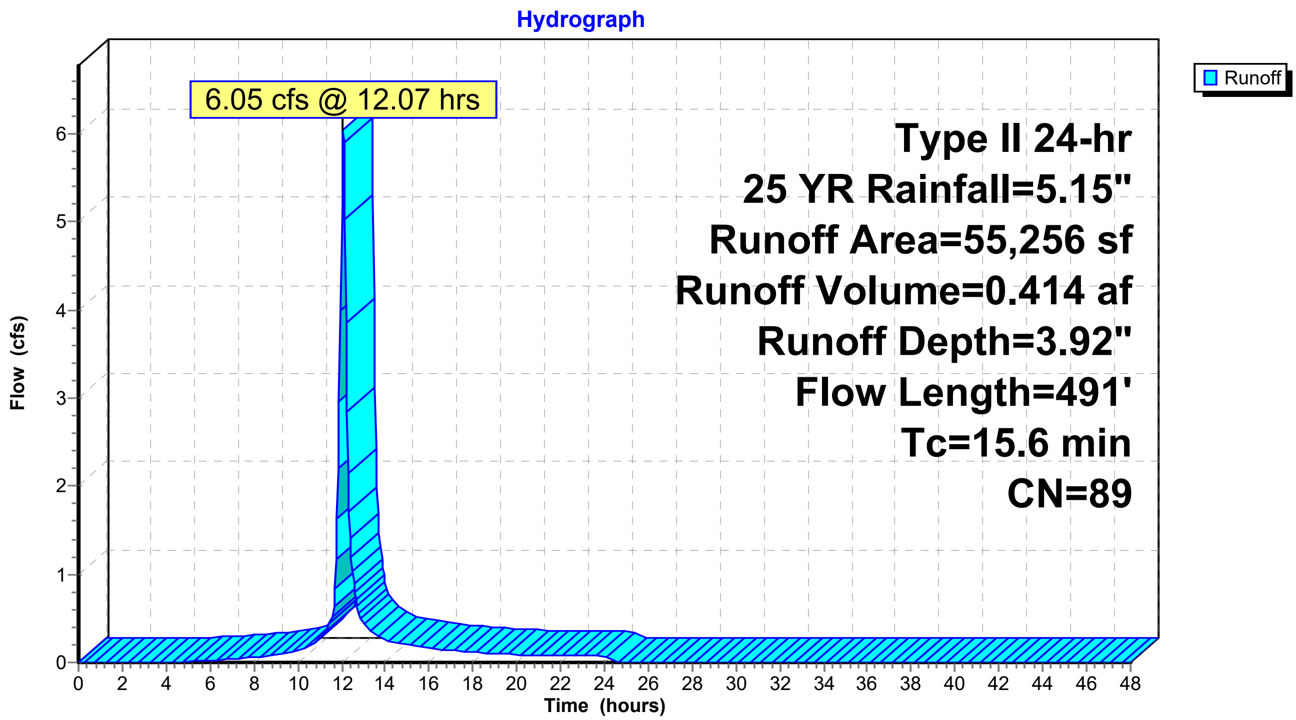
Runoff = 6.05 cfs @ 12.07 hrs, Volume= 0.414 af, Depth= 3.92"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 25 YR Rainfall=5.15"

	Area (sf)	CN	Description
*	55,256	89	CCR
	55,256		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.3	100	0.0100	0.13		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.01"
1.6	251	0.0300	2.60		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
0.7	140	0.0030	3.24	214.10	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=2.00' Z= 30.0 & 3.0 '/' Top.W=66.00' n= 0.025 Earth, clean & winding
15.6	491	Total			

Subcatchment DA-2:



Summary for Subcatchment DA-3:

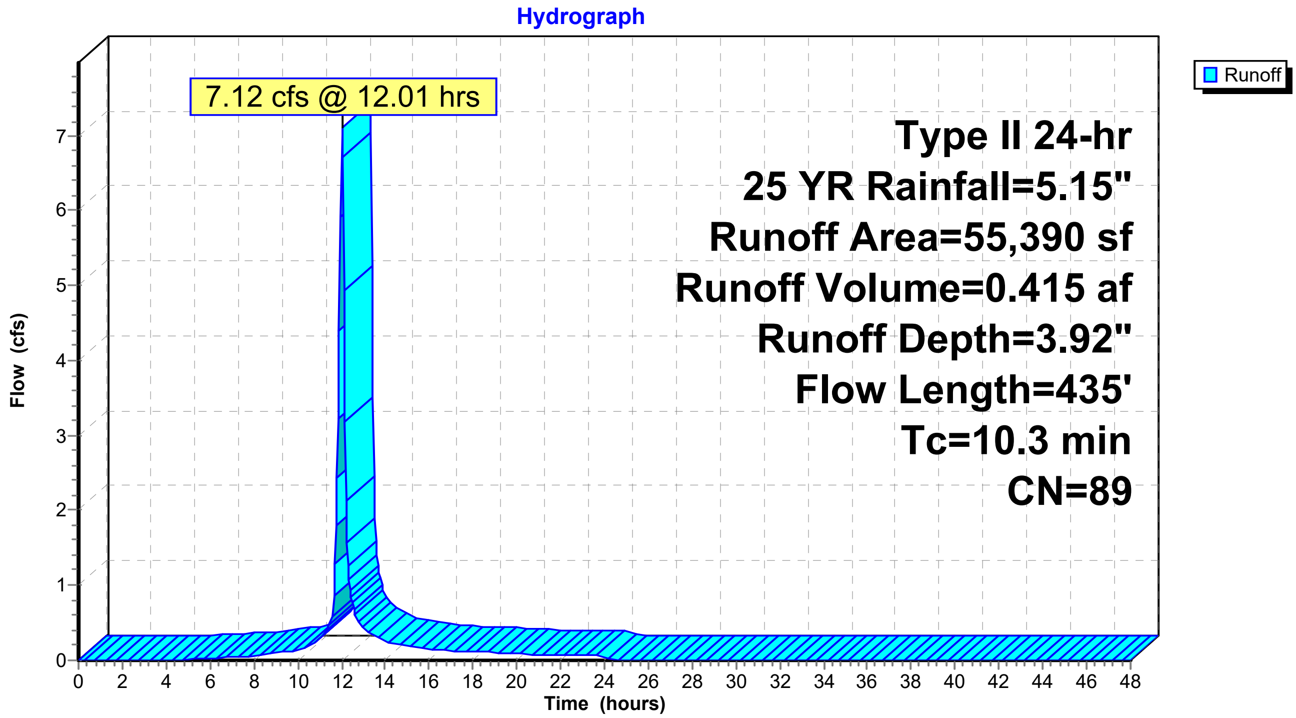
Runoff = 7.12 cfs @ 12.01 hrs, Volume= 0.415 af, Depth= 3.92"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 25 YR Rainfall=5.15"

	Area (sf)	CN	Description
*	55,390	89	CCR
	55,390		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.6	100	0.0300	0.19		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.01"
0.8	126	0.0300	2.60		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
0.9	209	0.0700	3.97		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
10.3	435	Total			

Subcatchment DA-3:



Summary for Subcatchment DA-4:

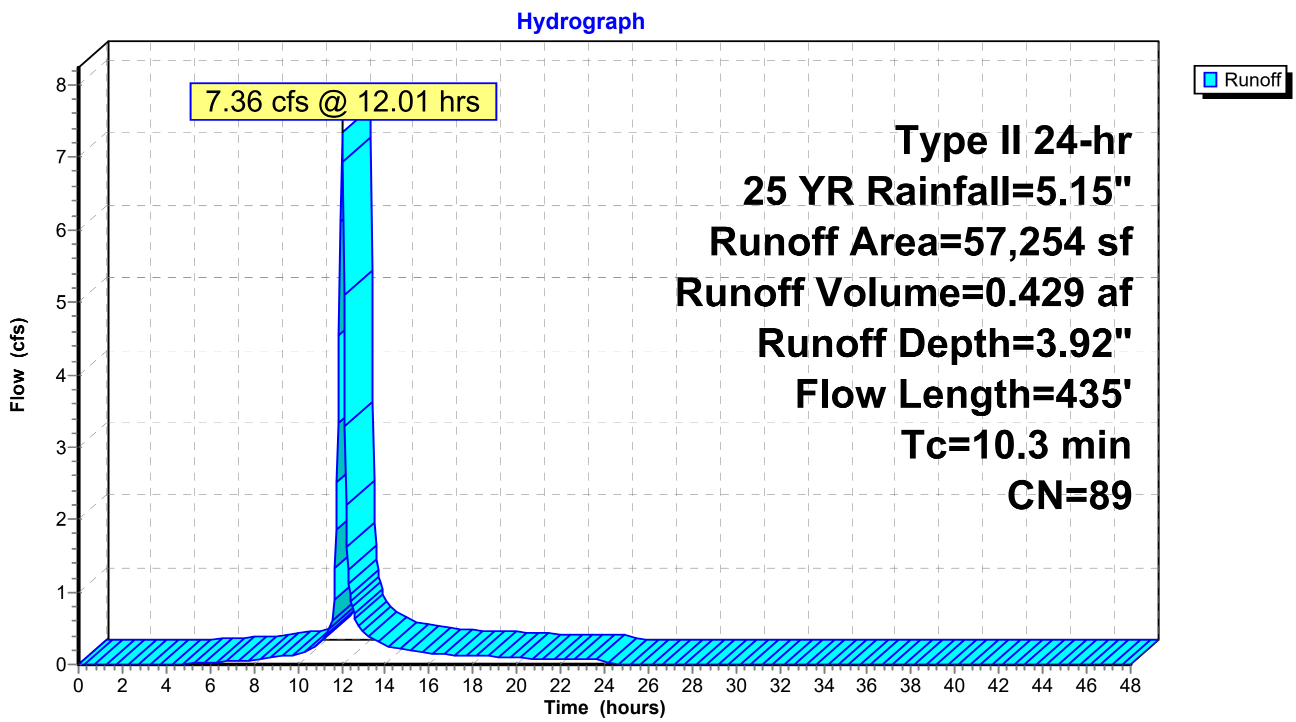
Runoff = 7.36 cfs @ 12.01 hrs, Volume= 0.429 af, Depth= 3.92"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 25 YR Rainfall=5.15"

	Area (sf)	CN	Description
*	57,254	89	CCR
	57,254		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.6	100	0.0300	0.19		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.01"
0.8	126	0.0300	2.60		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
0.9	209	0.0700	3.97		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
10.3	435	Total			

Subcatchment DA-4:



Summary for Subcatchment DA-5:

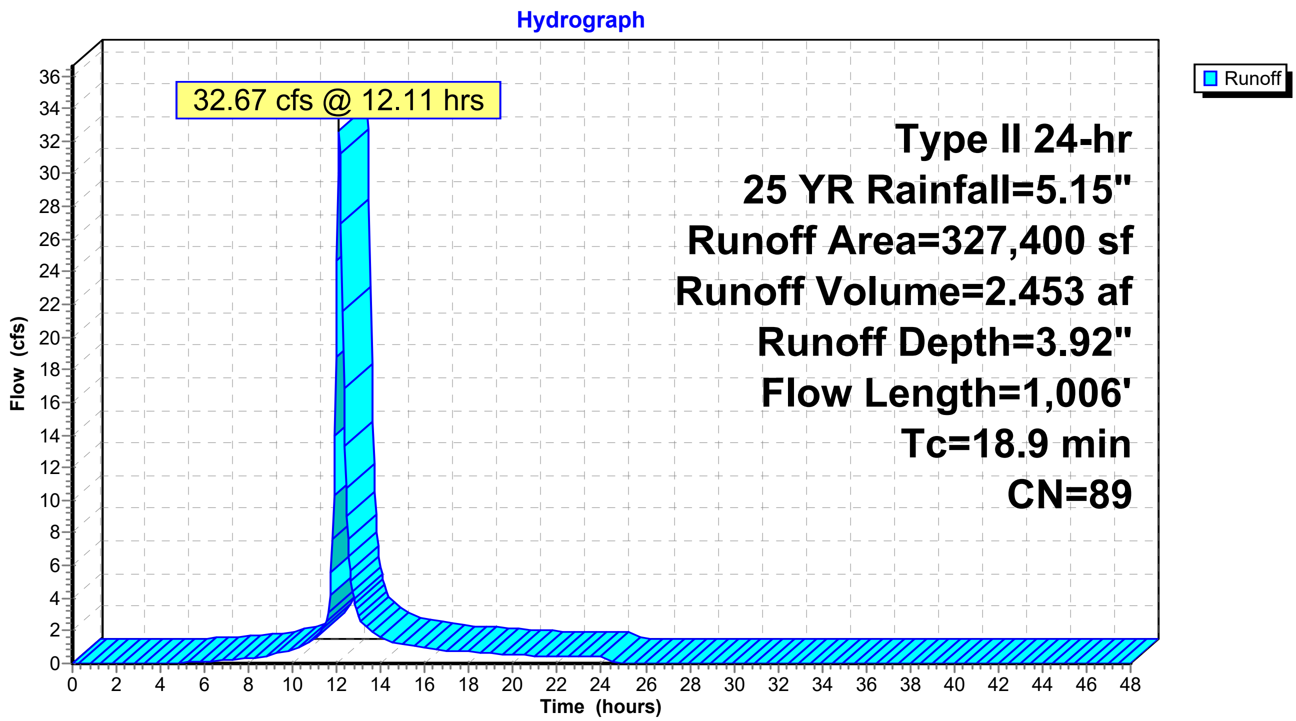
Runoff = 32.67 cfs @ 12.11 hrs, Volume= 2.453 af, Depth= 3.92"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 25 YR Rainfall=5.15"

	Area (sf)	CN	Description
*	327,400	89	CCR
	327,400		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.3	100	0.0100	0.13		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.01"
1.3	119	0.0100	1.50		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
1.3	200	0.0300	2.60		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
3.0	587	0.0030	3.24	214.10	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=2.00' Z= 30.0 & 3.0 '/' Top.W=66.00' n= 0.025 Earth, clean & winding
18.9	1,006	Total			

Subcatchment DA-5:



Summary for Subcatchment DA-6:

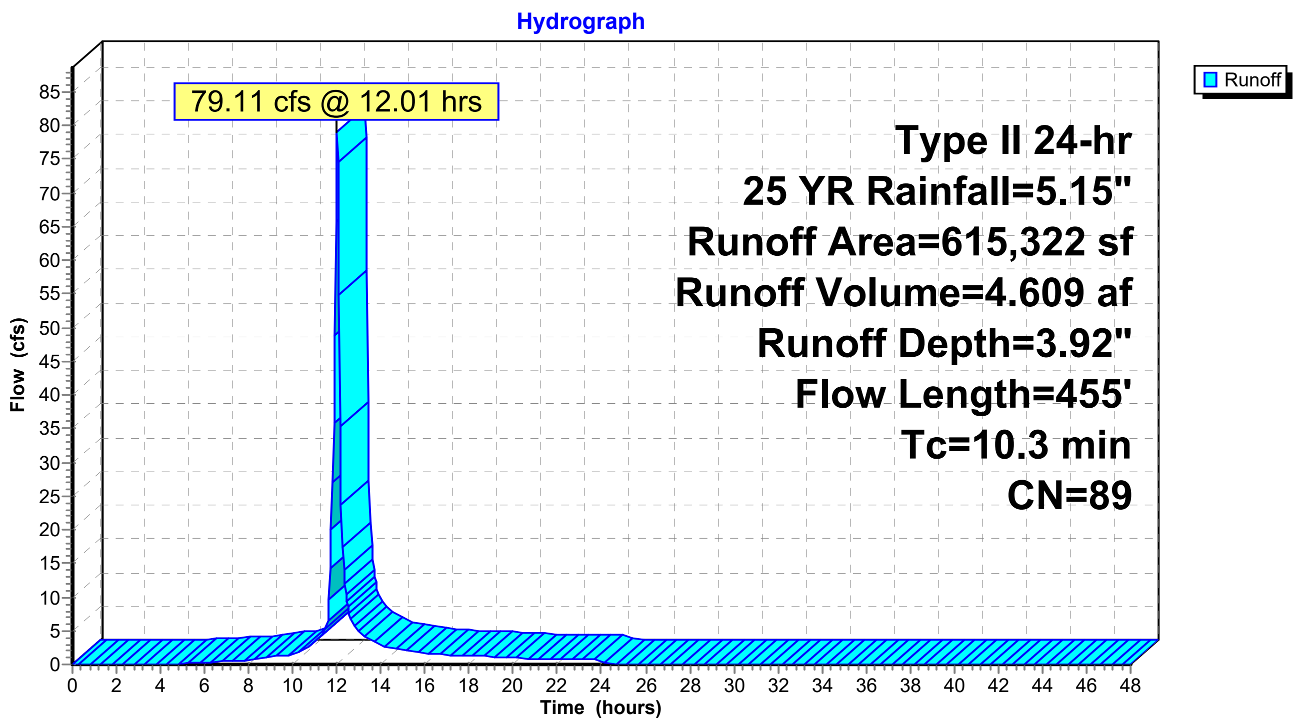
Runoff = 79.11 cfs @ 12.01 hrs, Volume= 4.609 af, Depth= 3.92"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 25 YR Rainfall=5.15"

	Area (sf)	CN	Description
*	615,322	89	CCR
	615,322		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.6	100	0.0300	0.19		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.01"
0.8	131	0.0300	2.60		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
0.9	224	0.0700	3.97		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
10.3	455	Total			

Subcatchment DA-6:



Summary for Subcatchment DA-7:

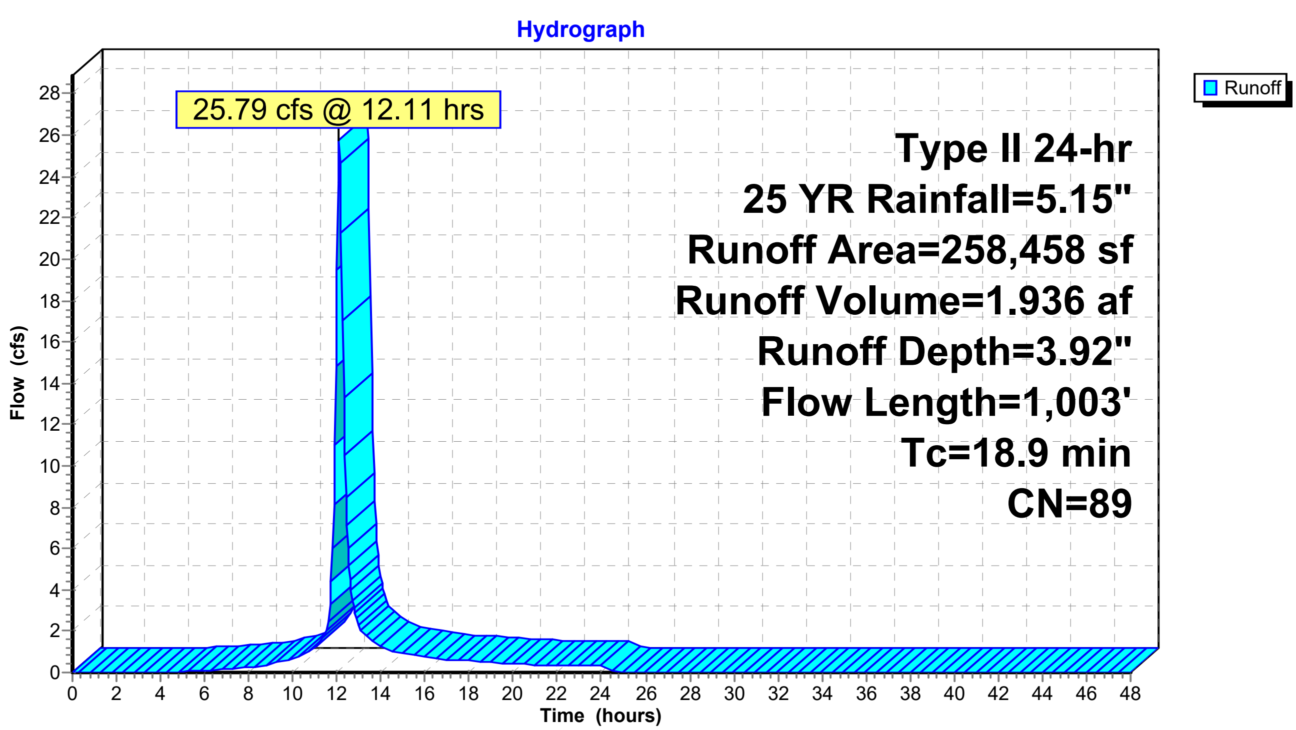
Runoff = 25.79 cfs @ 12.11 hrs, Volume= 1.936 af, Depth= 3.92"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 25 YR Rainfall=5.15"

	Area (sf)	CN	Description
*	258,458	89	CCR
	258,458		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.3	100	0.0100	0.13		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.01"
1.3	119	0.0100	1.50		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
1.3	200	0.0300	2.60		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
3.0	584	0.0030	3.24	214.10	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=2.00' Z= 30.0 & 3.0 '/' Top.W=66.00' n= 0.025 Earth, clean & winding
18.9	1,003	Total			

Subcatchment DA-7:



Summary for Subcatchment DA-8:

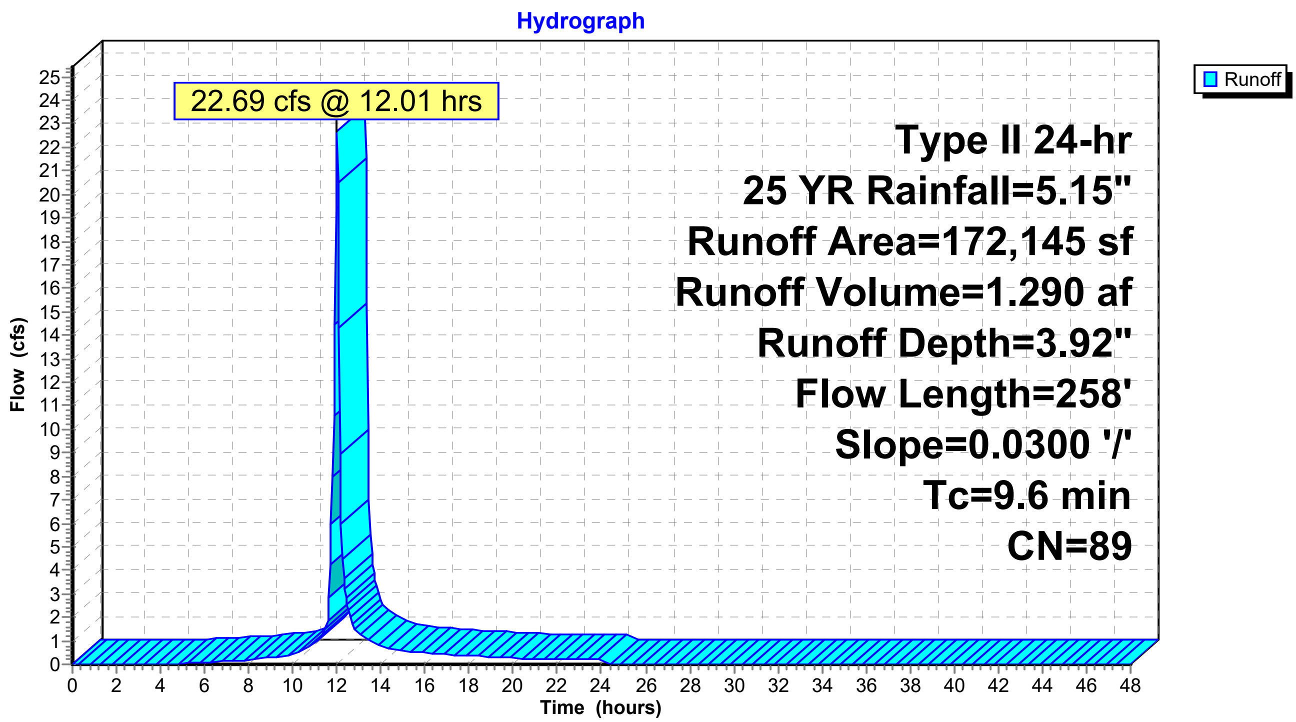
Runoff = 22.69 cfs @ 12.01 hrs, Volume= 1.290 af, Depth= 3.92"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 25 YR Rainfall=5.15"

	Area (sf)	CN	Description
*	172,145	89	CCR
	172,145		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.6	100	0.0300	0.19		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.01"
1.0	158	0.0300	2.60		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
9.6	258	Total			

Subcatchment DA-8:



Summary for Reach D-1:

Inflow Area = 0.442 ac, 0.00% Impervious, Inflow Depth = 3.92" for 25 YR event
Inflow = 2.81 cfs @ 11.96 hrs, Volume= 0.144 af
Outflow = 2.63 cfs @ 12.01 hrs, Volume= 0.144 af, Atten= 6%, Lag= 2.9 min

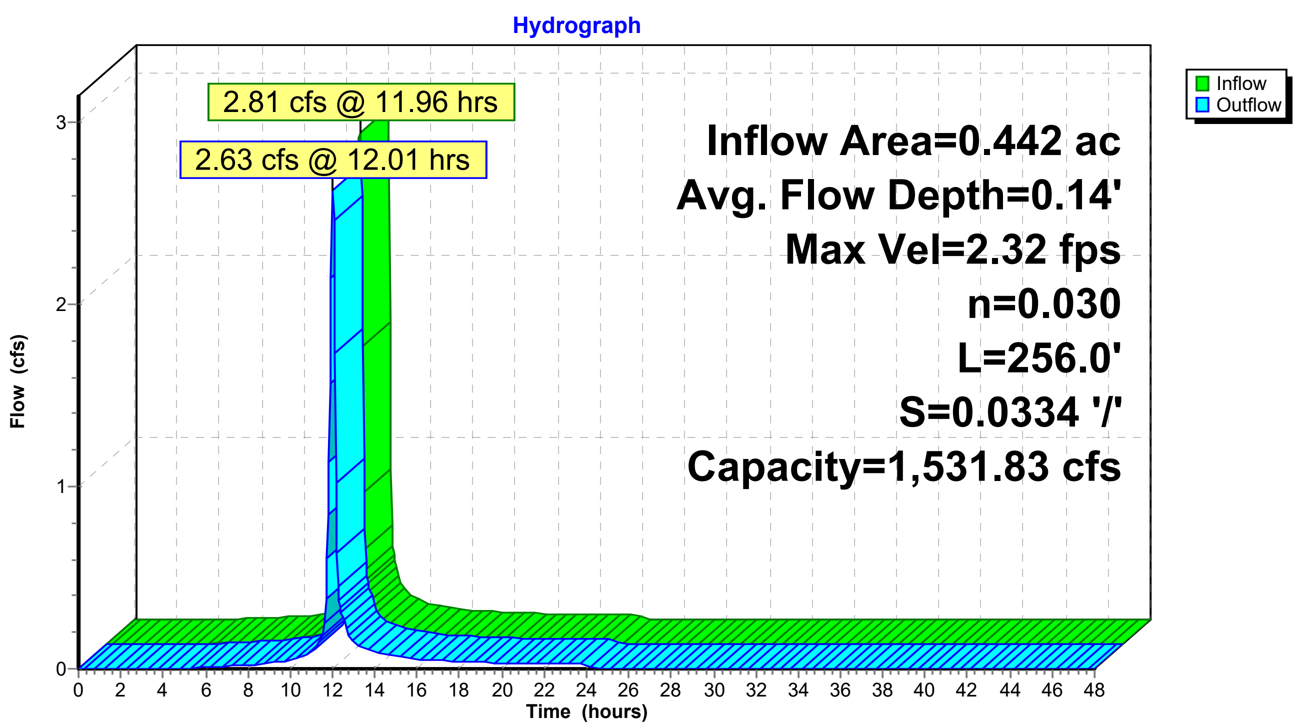
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.32 fps, Min. Travel Time= 1.8 min
Avg. Velocity = 1.06 fps, Avg. Travel Time= 4.0 min

Peak Storage= 302 cf @ 11.99 hrs
Average Depth at Peak Storage= 0.14'
Bank-Full Depth= 4.00' Flow Area= 96.0 sf, Capacity= 1,531.83 cfs

8.00' x 4.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 4.0 '/' Top Width= 40.00'
Length= 256.0' Slope= 0.0334 '/'
Inlet Invert= 623.11', Outlet Invert= 614.57'

‡

Reach D-1:



Summary for Reach D-2:

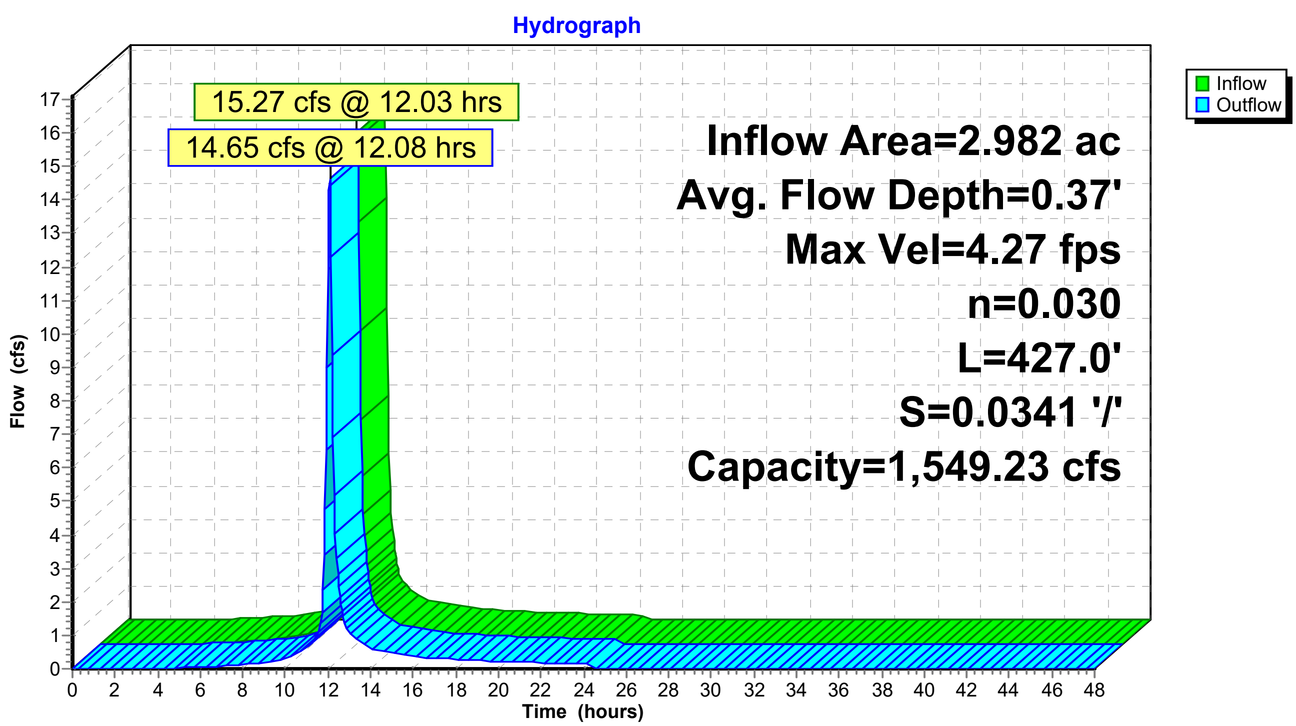
Inflow Area = 2.982 ac, 0.00% Impervious, Inflow Depth = 3.92" for 25 YR event
Inflow = 15.27 cfs @ 12.03 hrs, Volume= 0.973 af
Outflow = 14.65 cfs @ 12.08 hrs, Volume= 0.973 af, Atten= 4%, Lag= 2.8 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 4.27 fps, Min. Travel Time= 1.7 min
Avg. Velocity = 1.22 fps, Avg. Travel Time= 5.9 min

Peak Storage= 1,506 cf @ 12.05 hrs
Average Depth at Peak Storage= 0.37'
Bank-Full Depth= 4.00' Flow Area= 96.0 sf, Capacity= 1,549.23 cfs

8.00' x 4.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 4.0 '/' Top Width= 40.00'
Length= 427.0' Slope= 0.0341 '/'
Inlet Invert= 614.57', Outlet Invert= 600.00'

Reach D-2:



Summary for Reach D-3:

Inflow Area = 4.296 ac, 0.00% Impervious, Inflow Depth = 3.92" for 25 YR event
Inflow = 21.21 cfs @ 12.05 hrs, Volume= 1.402 af
Outflow = 20.59 cfs @ 12.09 hrs, Volume= 1.402 af, Atten= 3%, Lag= 2.1 min

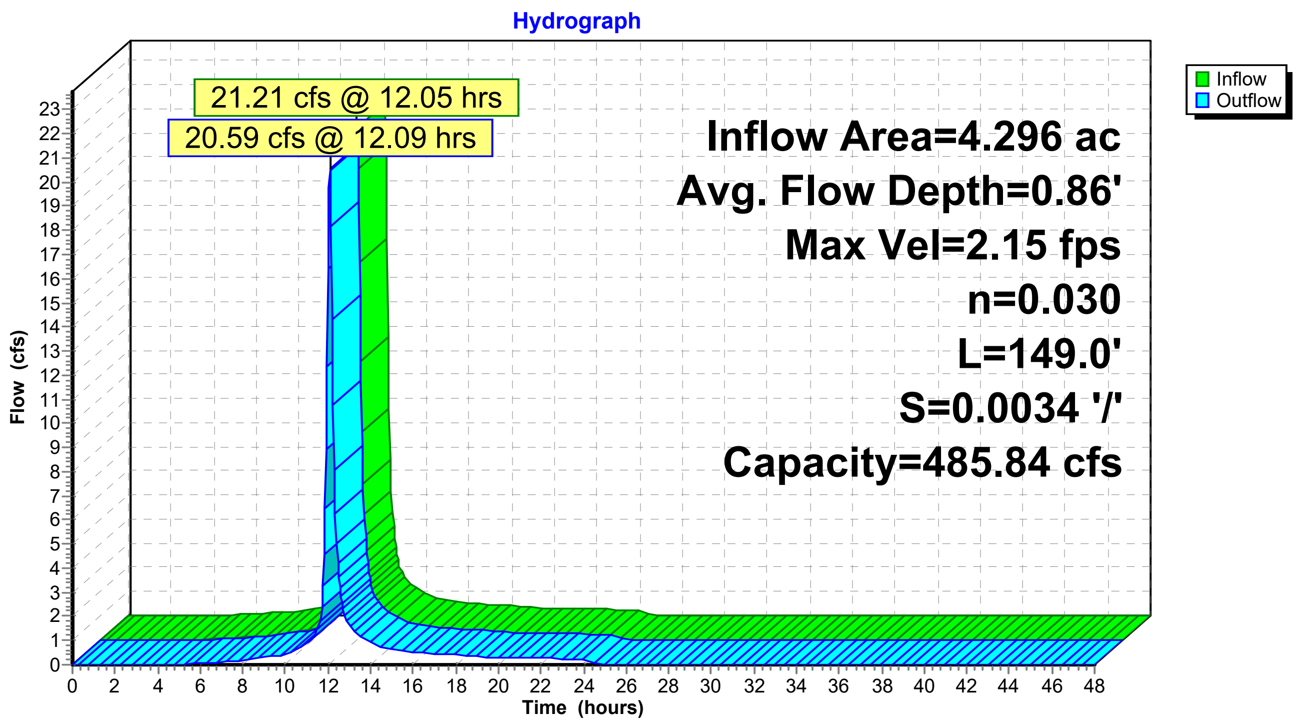
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.15 fps, Min. Travel Time= 1.2 min
Avg. Velocity = 0.57 fps, Avg. Travel Time= 4.4 min

Peak Storage= 1,457 cf @ 12.07 hrs
Average Depth at Peak Storage= 0.86'
Bank-Full Depth= 4.00' Flow Area= 96.0 sf, Capacity= 485.84 cfs

8.00' x 4.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 4.0 '/' Top Width= 40.00'
Length= 149.0' Slope= 0.0034 '/'
Inlet Invert= 600.00', Outlet Invert= 599.50'

‡

Reach D-3:



Summary for Reach D-4:

Inflow Area = 25.938 ac, 0.00% Impervious, Inflow Depth = 3.92" for 25 YR event
Inflow = 116.70 cfs @ 12.04 hrs, Volume= 8.464 af
Outflow = 97.33 cfs @ 12.24 hrs, Volume= 8.464 af, Atten= 17%, Lag= 12.1 min

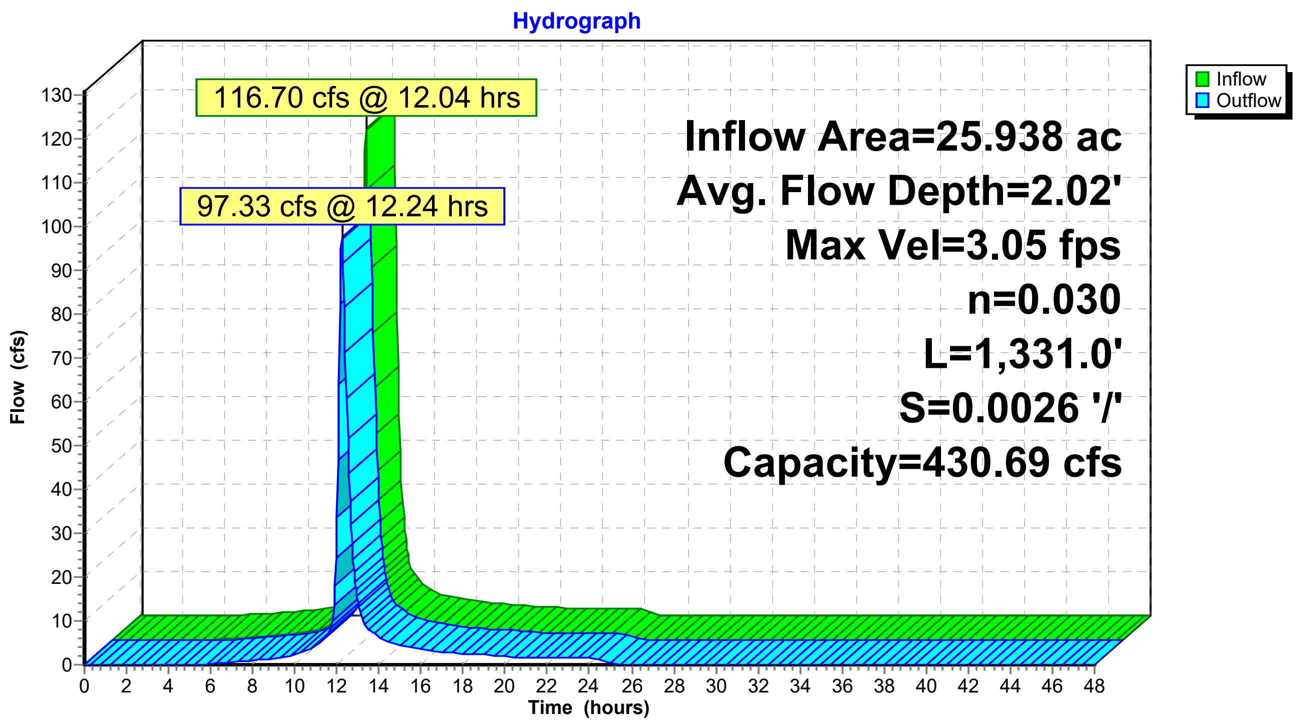
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.05 fps, Min. Travel Time= 7.3 min
Avg. Velocity = 0.75 fps, Avg. Travel Time= 29.8 min

Peak Storage= 43,101 cf @ 12.12 hrs
Average Depth at Peak Storage= 2.02'
Bank-Full Depth= 4.00' Flow Area= 96.0 sf, Capacity= 430.69 cfs

8.00' x 4.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 4.0 '/' Top Width= 40.00'
Length= 1,331.0' Slope= 0.0026 '/'
Inlet Invert= 599.00', Outlet Invert= 595.49'

‡

Reach D-4:



Summary for Reach D-5:

Inflow Area = 3.952 ac, 0.00% Impervious, Inflow Depth = 3.92" for 25 YR event
Inflow = 22.69 cfs @ 12.01 hrs, Volume= 1.290 af
Outflow = 21.41 cfs @ 12.09 hrs, Volume= 1.290 af, Atten= 6%, Lag= 4.8 min

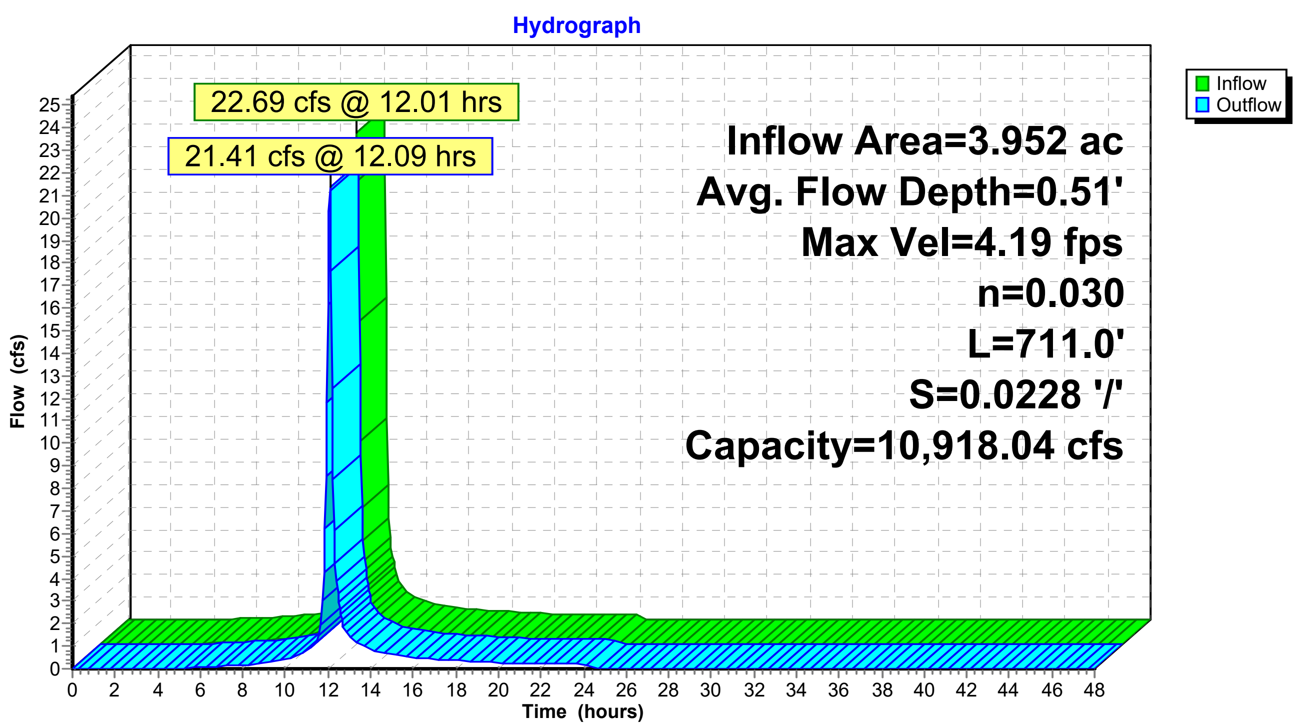
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 4.19 fps, Min. Travel Time= 2.8 min
Avg. Velocity = 1.62 fps, Avg. Travel Time= 7.3 min

Peak Storage= 3,650 cf @ 12.04 hrs
Average Depth at Peak Storage= 0.51'
Bank-Full Depth= 10.00' Flow Area= 480.0 sf, Capacity= 10,918.04 cfs

8.00' x 10.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 4.0 '/' Top Width= 88.00'
Length= 711.0' Slope= 0.0228 '/'
Inlet Invert= 614.00', Outlet Invert= 597.80'

‡

Reach D-5:



Summary for Reach D-6:

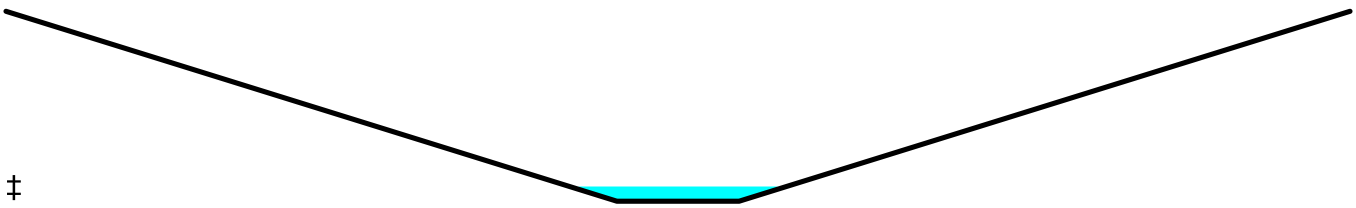
Inflow Area = 9.885 ac, 0.00% Impervious, Inflow Depth = 3.92" for 25 YR event
Inflow = 43.97 cfs @ 12.12 hrs, Volume= 3.226 af
Outflow = 43.44 cfs @ 12.13 hrs, Volume= 3.226 af, Atten= 1%, Lag= 0.6 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 5.12 fps, Min. Travel Time= 0.4 min
Avg. Velocity = 1.69 fps, Avg. Travel Time= 1.1 min

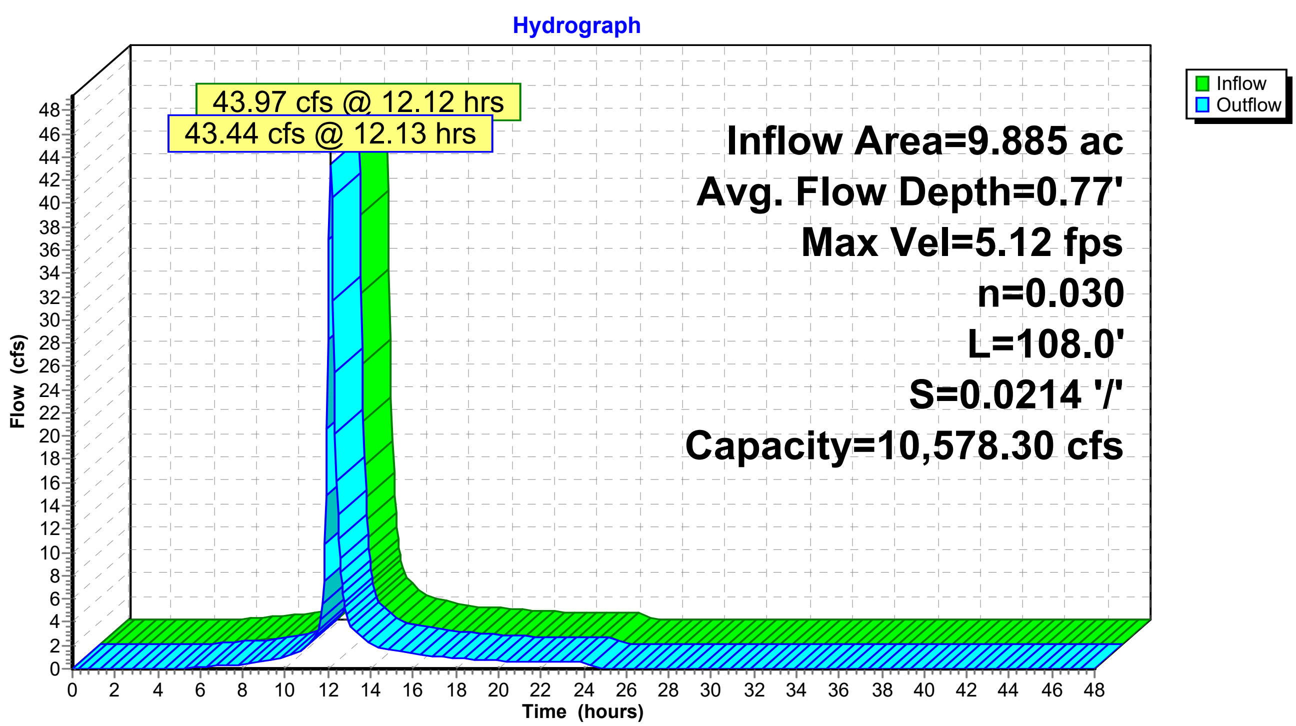
Peak Storage= 924 cf @ 12.12 hrs
Average Depth at Peak Storage= 0.77'
Bank-Full Depth= 10.00' Flow Area= 480.0 sf, Capacity= 10,578.30 cfs

8.00' x 10.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 4.0 '/' Top Width= 88.00'
Length= 108.0' Slope= 0.0214 '/'
Inlet Invert= 597.80', Outlet Invert= 595.49'

‡



Reach D-6:



Summary for Reach LD-1:

Inflow Area = 1.269 ac, 0.00% Impervious, Inflow Depth = 3.92" for 25 YR event
Inflow = 6.05 cfs @ 12.07 hrs, Volume= 0.414 af
Outflow = 6.02 cfs @ 12.08 hrs, Volume= 0.414 af, Atten= 0%, Lag= 0.3 min

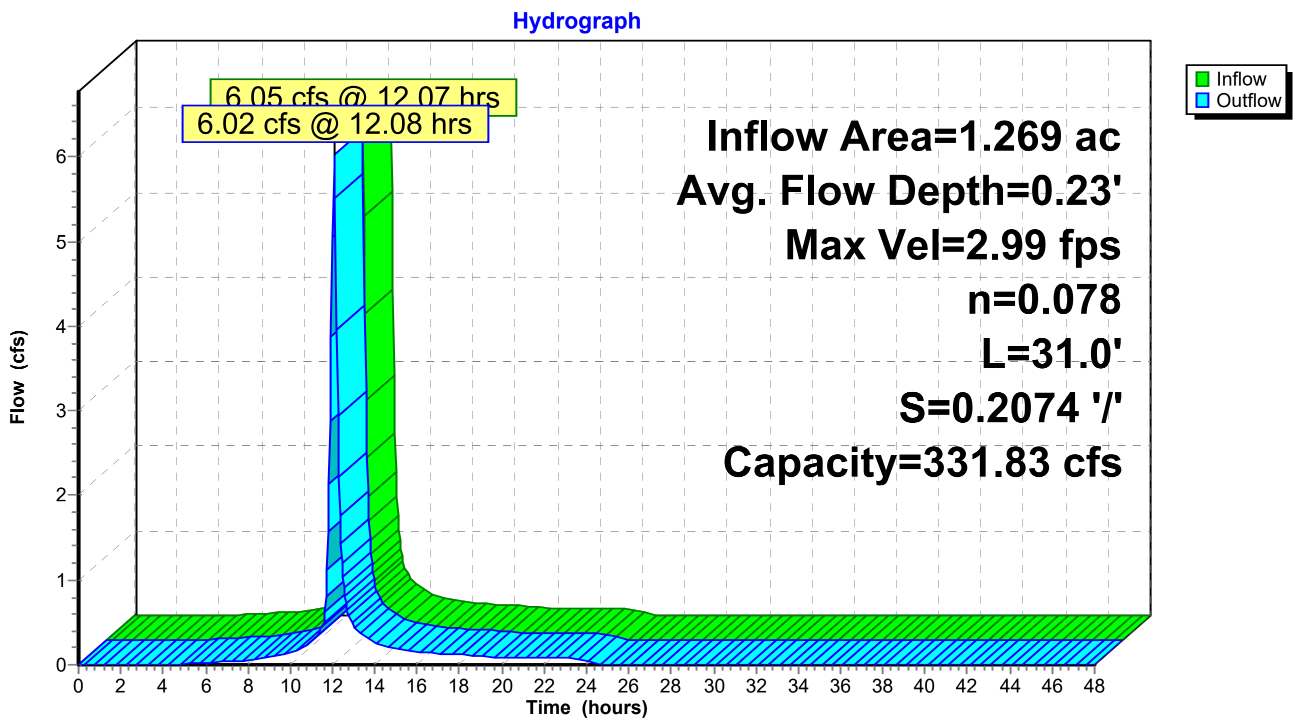
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.99 fps, Min. Travel Time= 0.2 min
Avg. Velocity = 0.79 fps, Avg. Travel Time= 0.7 min

Peak Storage= 62 cf @ 12.07 hrs
Average Depth at Peak Storage= 0.23'
Bank-Full Depth= 2.00' Flow Area= 32.0 sf, Capacity= 331.83 cfs

8.00' x 2.00' deep channel, n= 0.078 Riprap, 12-inch
Side Slope Z-value= 4.0 '/' Top Width= 24.00'
Length= 31.0' Slope= 0.2074 '/'
Inlet Invert= 621.00', Outlet Invert= 614.57'

‡

Reach LD-1:



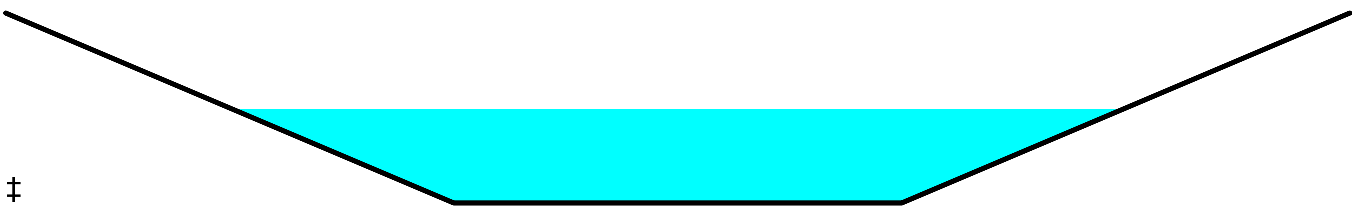
Summary for Reach LD-2-1:

Inflow Area = 7.516 ac, 0.00% Impervious, Inflow Depth = 3.92" for 25 YR event
Inflow = 32.67 cfs @ 12.11 hrs, Volume= 2.453 af
Outflow = 31.95 cfs @ 12.15 hrs, Volume= 2.453 af, Atten= 2%, Lag= 2.4 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.74 fps, Min. Travel Time= 1.4 min
Avg. Velocity = 0.73 fps, Avg. Travel Time= 5.1 min

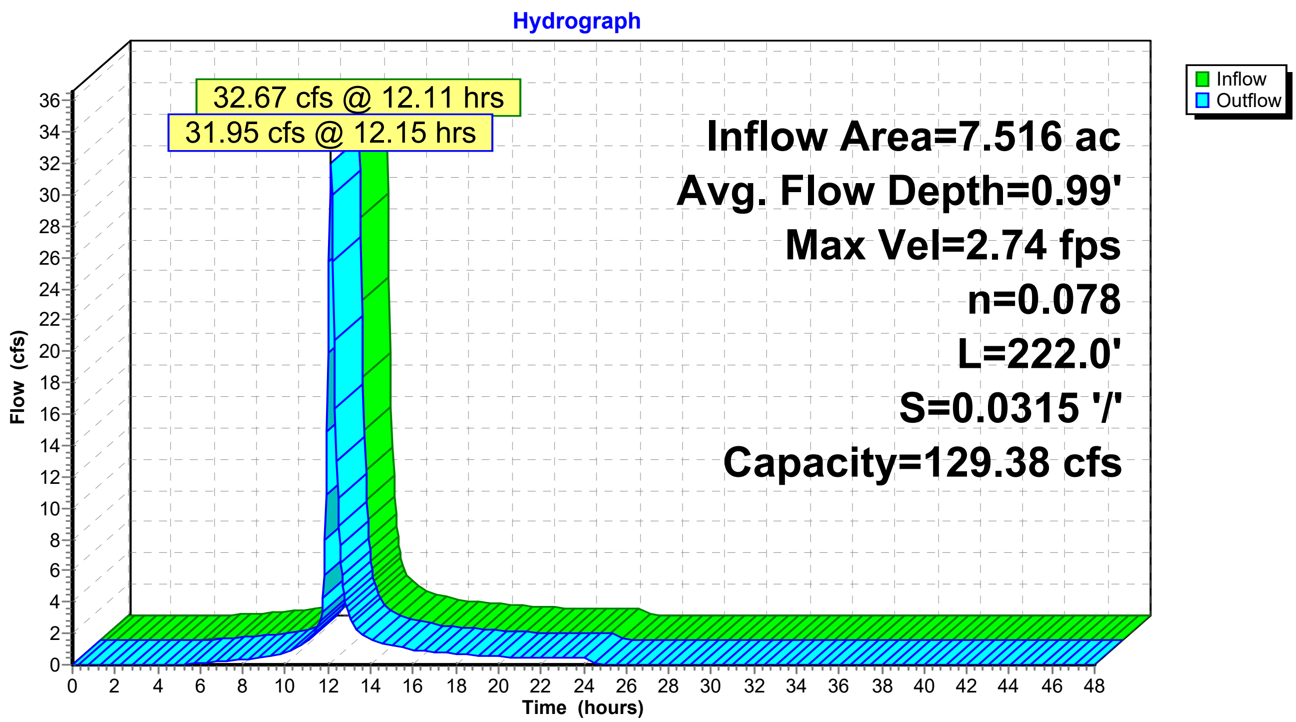
Peak Storage= 2,622 cf @ 12.12 hrs
Average Depth at Peak Storage= 0.99'
Bank-Full Depth= 2.00' Flow Area= 32.0 sf, Capacity= 129.38 cfs

8.00' x 2.00' deep channel, n= 0.078 Riprap, 12-inch
Side Slope Z-value= 4.0 '/' Top Width= 24.00'
Length= 222.0' Slope= 0.0315 '/'
Inlet Invert= 621.00', Outlet Invert= 614.00'



‡

Reach LD-2-1:



Summary for Reach LD-2-2:

Inflow Area = 7.516 ac, 0.00% Impervious, Inflow Depth = 3.92" for 25 YR event
Inflow = 31.95 cfs @ 12.15 hrs, Volume= 2.453 af
Outflow = 31.36 cfs @ 12.18 hrs, Volume= 2.453 af, Atten= 2%, Lag= 1.9 min

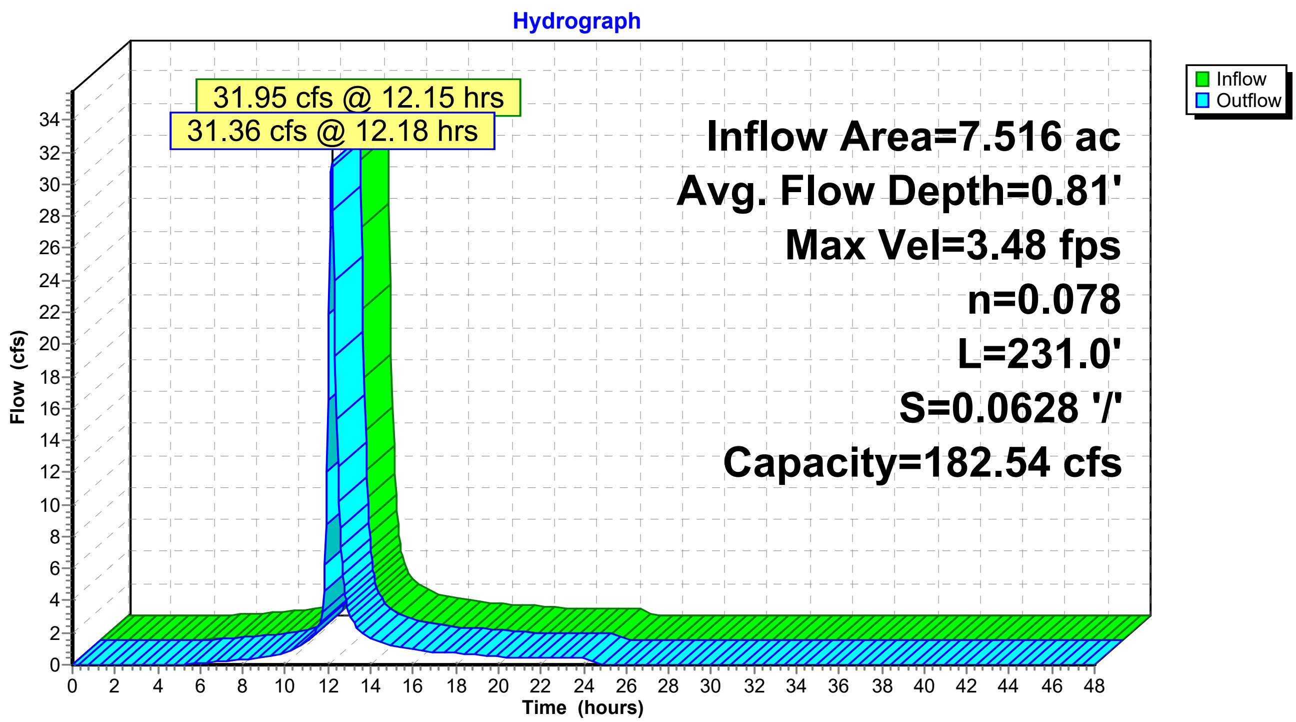
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.48 fps, Min. Travel Time= 1.1 min
Avg. Velocity = 0.91 fps, Avg. Travel Time= 4.2 min

Peak Storage= 2,114 cf @ 12.16 hrs
Average Depth at Peak Storage= 0.81'
Bank-Full Depth= 2.00' Flow Area= 32.0 sf, Capacity= 182.54 cfs

8.00' x 2.00' deep channel, n= 0.078 Riprap, 12-inch
Side Slope Z-value= 4.0 '/' Top Width= 24.00'
Length= 231.0' Slope= 0.0628 '/'
Inlet Invert= 614.00', Outlet Invert= 599.50'

‡

Reach LD-2-2:



Summary for Reach LD-3-1:

Inflow Area = 5.933 ac, 0.00% Impervious, Inflow Depth = 3.92" for 25 YR event
Inflow = 25.79 cfs @ 12.11 hrs, Volume= 1.936 af
Outflow = 25.15 cfs @ 12.16 hrs, Volume= 1.936 af, Atten= 2%, Lag= 3.0 min

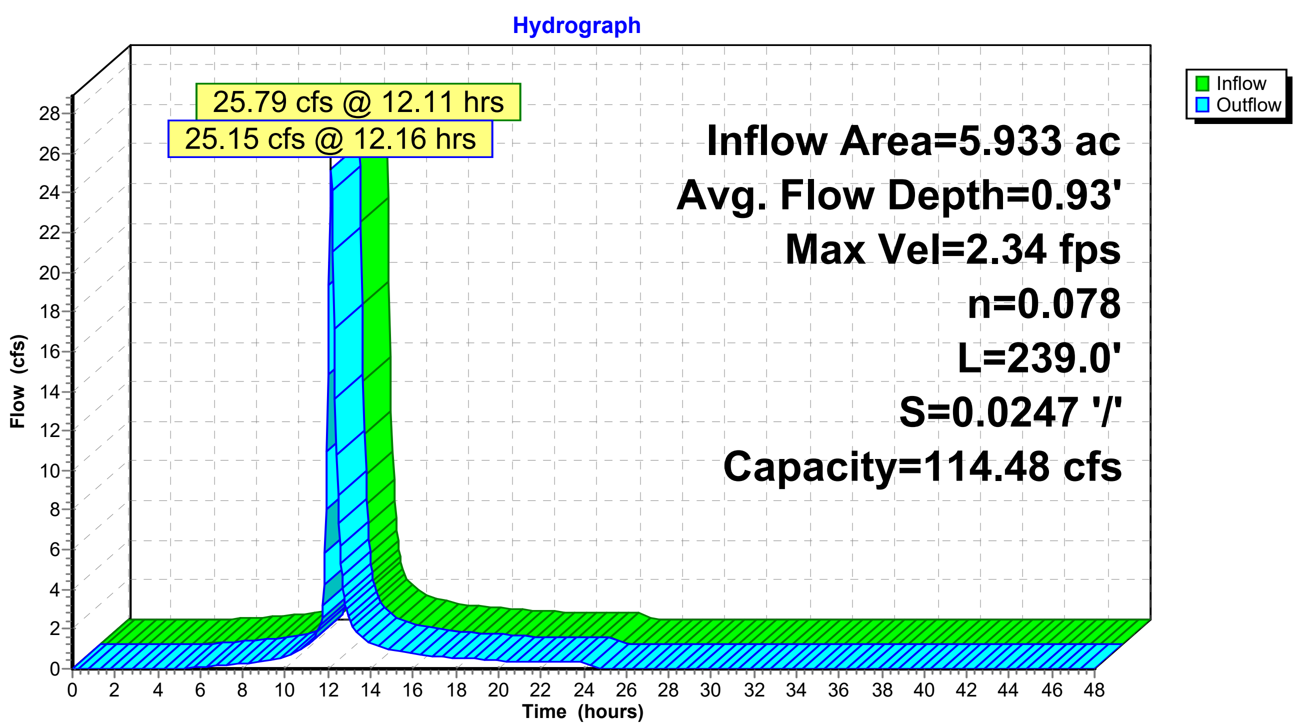
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.34 fps, Min. Travel Time= 1.7 min
Avg. Velocity = 0.61 fps, Avg. Travel Time= 6.5 min

Peak Storage= 2,595 cf @ 12.13 hrs
Average Depth at Peak Storage= 0.93'
Bank-Full Depth= 2.00' Flow Area= 32.0 sf, Capacity= 114.48 cfs

8.00' x 2.00' deep channel, n= 0.078 Riprap, 12-inch
Side Slope Z-value= 4.0 '/' Top Width= 24.00'
Length= 239.0' Slope= 0.0247 '/'
Inlet Invert= 621.00', Outlet Invert= 615.10'

‡

Reach LD-3-1:



Summary for Reach LD-3-2:

Inflow Area = 5.933 ac, 0.00% Impervious, Inflow Depth = 3.92" for 25 YR event
Inflow = 25.15 cfs @ 12.16 hrs, Volume= 1.936 af
Outflow = 24.97 cfs @ 12.17 hrs, Volume= 1.936 af, Atten= 1%, Lag= 0.6 min

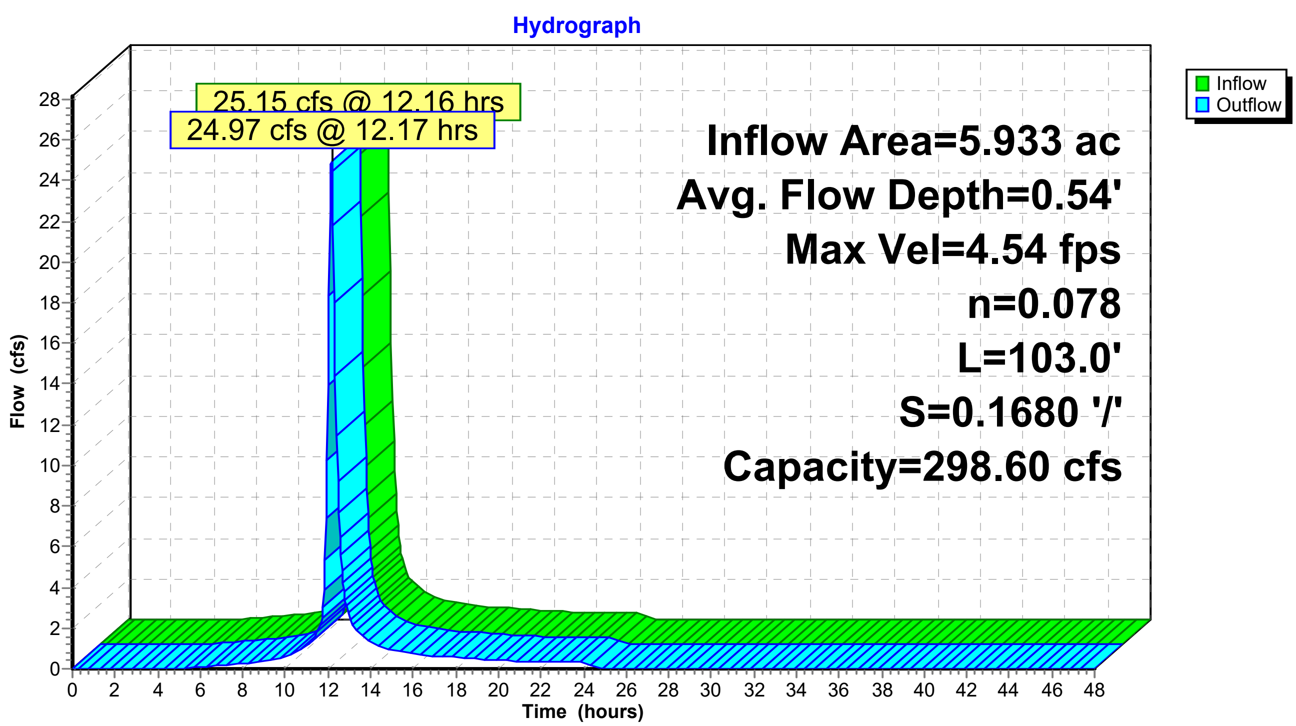
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 4.54 fps, Min. Travel Time= 0.4 min
Avg. Velocity = 1.16 fps, Avg. Travel Time= 1.5 min

Peak Storage= 570 cf @ 12.16 hrs
Average Depth at Peak Storage= 0.54'
Bank-Full Depth= 2.00' Flow Area= 32.0 sf, Capacity= 298.60 cfs

8.00' x 2.00' deep channel, n= 0.078 Riprap, 12-inch
Side Slope Z-value= 4.0 '/' Top Width= 24.00'
Length= 103.0' Slope= 0.1680 '/'
Inlet Invert= 615.10', Outlet Invert= 597.80'

‡

Reach LD-3-2:



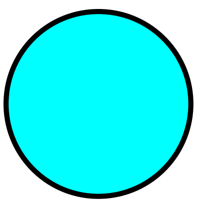
Summary for Reach PIPES:

Inflow Area = 35.823 ac, 0.00% Impervious, Inflow Depth = 3.92" for 25 YR event
Inflow = 132.95 cfs @ 12.21 hrs, Volume= 11.689 af
Outflow = 69.62 cfs @ 12.10 hrs, Volume= 11.689 af, Atten= 48%, Lag= 0.0 min

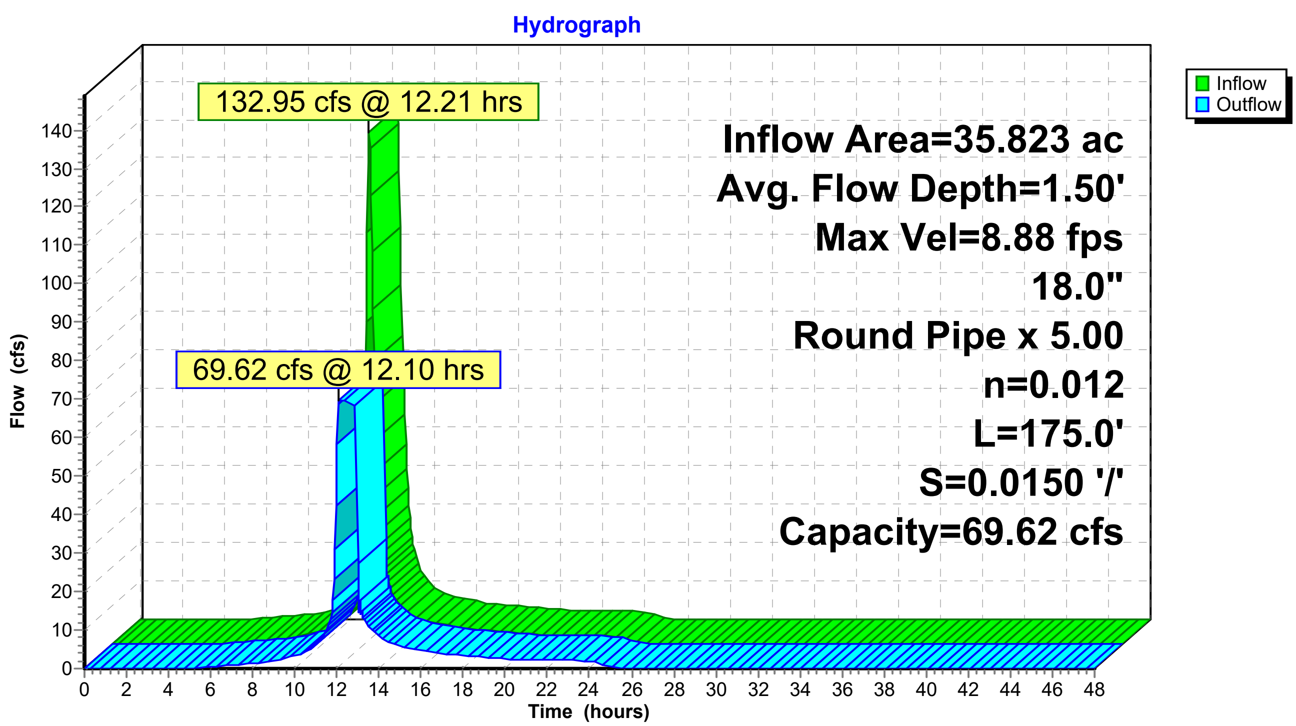
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 8.88 fps, Min. Travel Time= 0.3 min
Avg. Velocity = 2.96 fps, Avg. Travel Time= 1.0 min

Peak Storage= 1,546 cf @ 12.05 hrs
Average Depth at Peak Storage= 1.50'
Bank-Full Depth= 1.50' Flow Area= 8.8 sf, Capacity= 69.62 cfs

A factor of 5.00 has been applied to the storage and discharge capacity
18.0" Round Pipe
n= 0.012 Corrugated PP, smooth interior
Length= 175.0' Slope= 0.0150 '/'
Inlet Invert= 595.49', Outlet Invert= 592.87'



Reach PIPES:

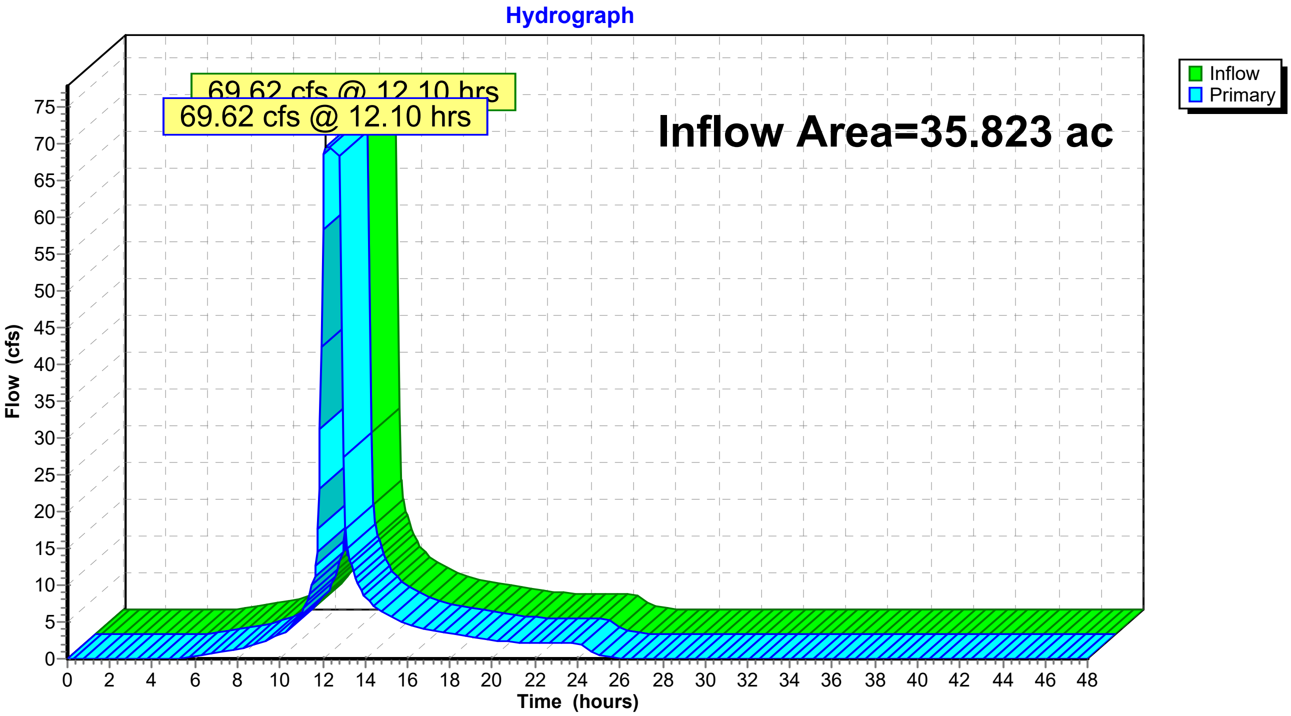


Summary for Link 1L: (new Link)

Inflow Area = 35.823 ac, 0.00% Impervious, Inflow Depth = 3.92" for 25 YR event
Inflow = 69.62 cfs @ 12.10 hrs, Volume= 11.689 af
Primary = 69.62 cfs @ 12.10 hrs, Volume= 11.689 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

Link 1L: (new Link)



Summary for Subcatchment DA-1:

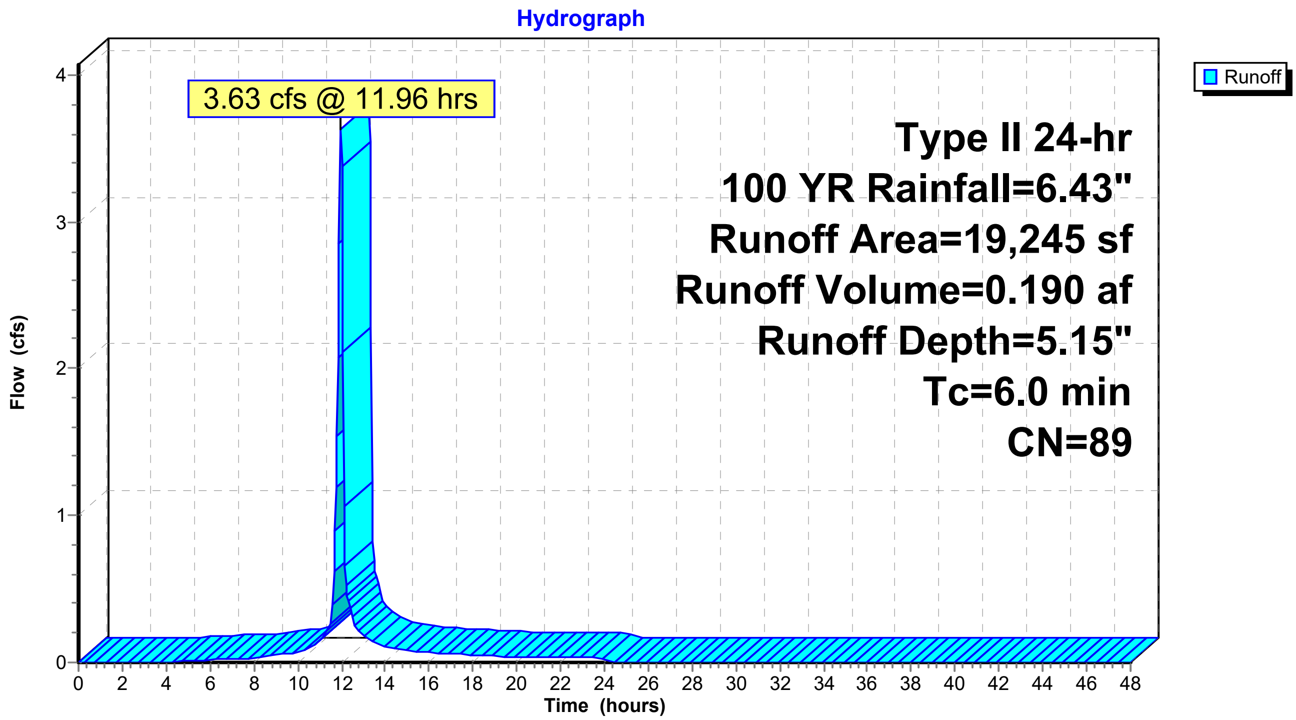
Runoff = 3.63 cfs @ 11.96 hrs, Volume= 0.190 af, Depth= 5.15"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 100 YR Rainfall=6.43"

	Area (sf)	CN	Description
*	19,245	89	CCR
	19,245		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA-1:



Summary for Subcatchment DA-2:

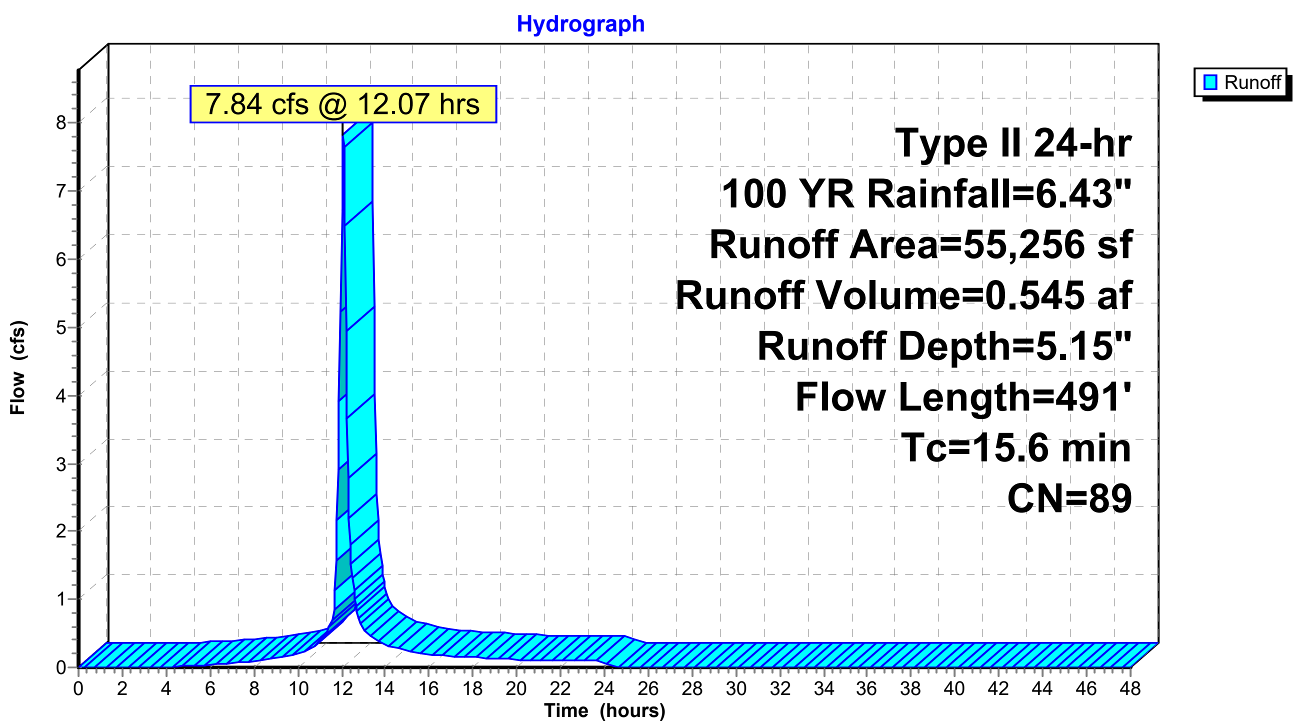
Runoff = 7.84 cfs @ 12.07 hrs, Volume= 0.545 af, Depth= 5.15"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 100 YR Rainfall=6.43"

	Area (sf)	CN	Description
*	55,256	89	CCR
	55,256		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.3	100	0.0100	0.13		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.01"
1.6	251	0.0300	2.60		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
0.7	140	0.0030	3.24	214.10	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=2.00' Z= 30.0 & 3.0 '/' Top.W=66.00' n= 0.025 Earth, clean & winding
15.6	491	Total			

Subcatchment DA-2:



Summary for Subcatchment DA-3:

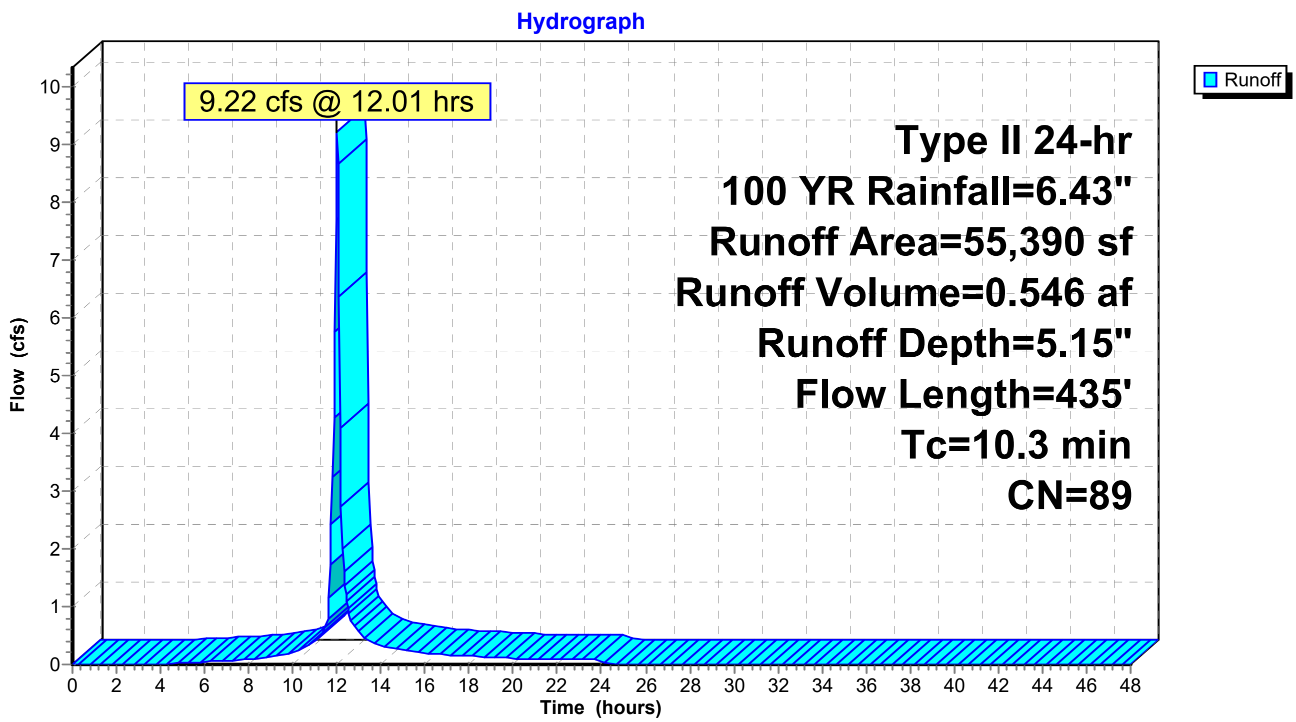
Runoff = 9.22 cfs @ 12.01 hrs, Volume= 0.546 af, Depth= 5.15"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 100 YR Rainfall=6.43"

	Area (sf)	CN	Description
*	55,390	89	CCR
	55,390		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.6	100	0.0300	0.19		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.01"
0.8	126	0.0300	2.60		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
0.9	209	0.0700	3.97		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
10.3	435	Total			

Subcatchment DA-3:



Summary for Subcatchment DA-4:

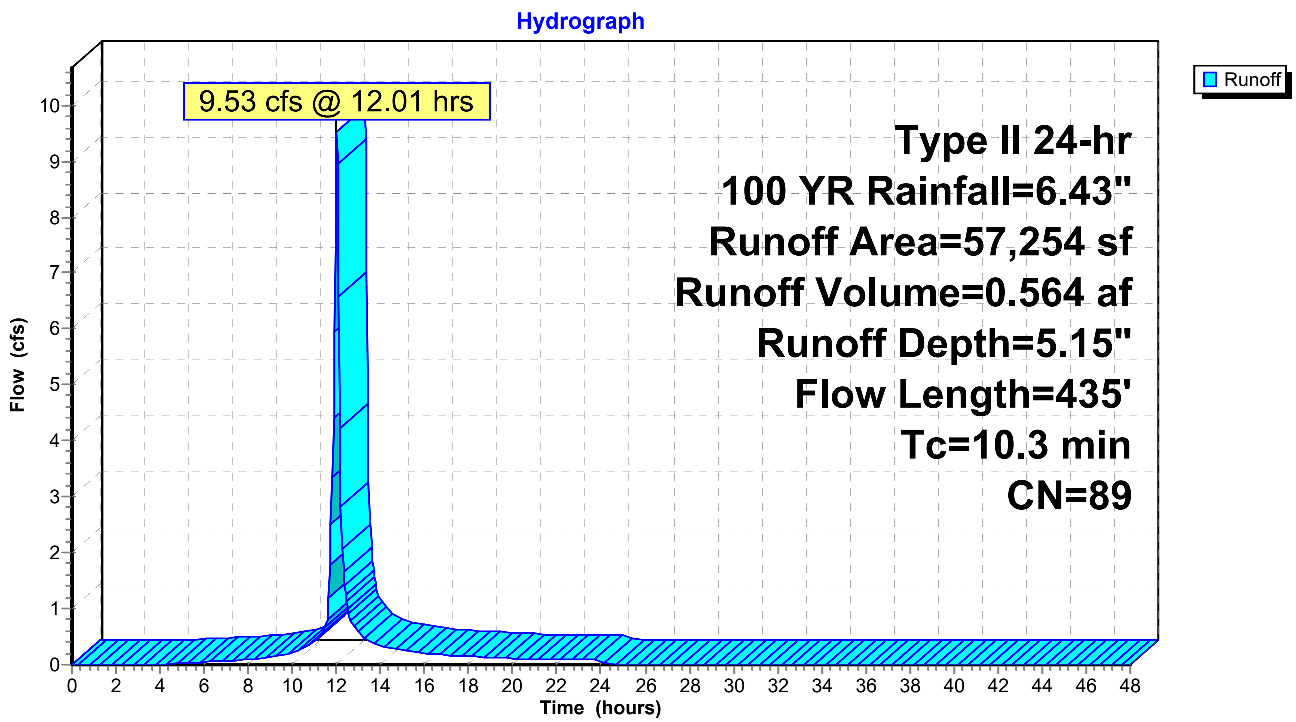
Runoff = 9.53 cfs @ 12.01 hrs, Volume= 0.564 af, Depth= 5.15"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 100 YR Rainfall=6.43"

	Area (sf)	CN	Description
*	57,254	89	CCR
	57,254		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.6	100	0.0300	0.19		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.01"
0.8	126	0.0300	2.60		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
0.9	209	0.0700	3.97		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
10.3	435	Total			

Subcatchment DA-4:



Summary for Subcatchment DA-5:

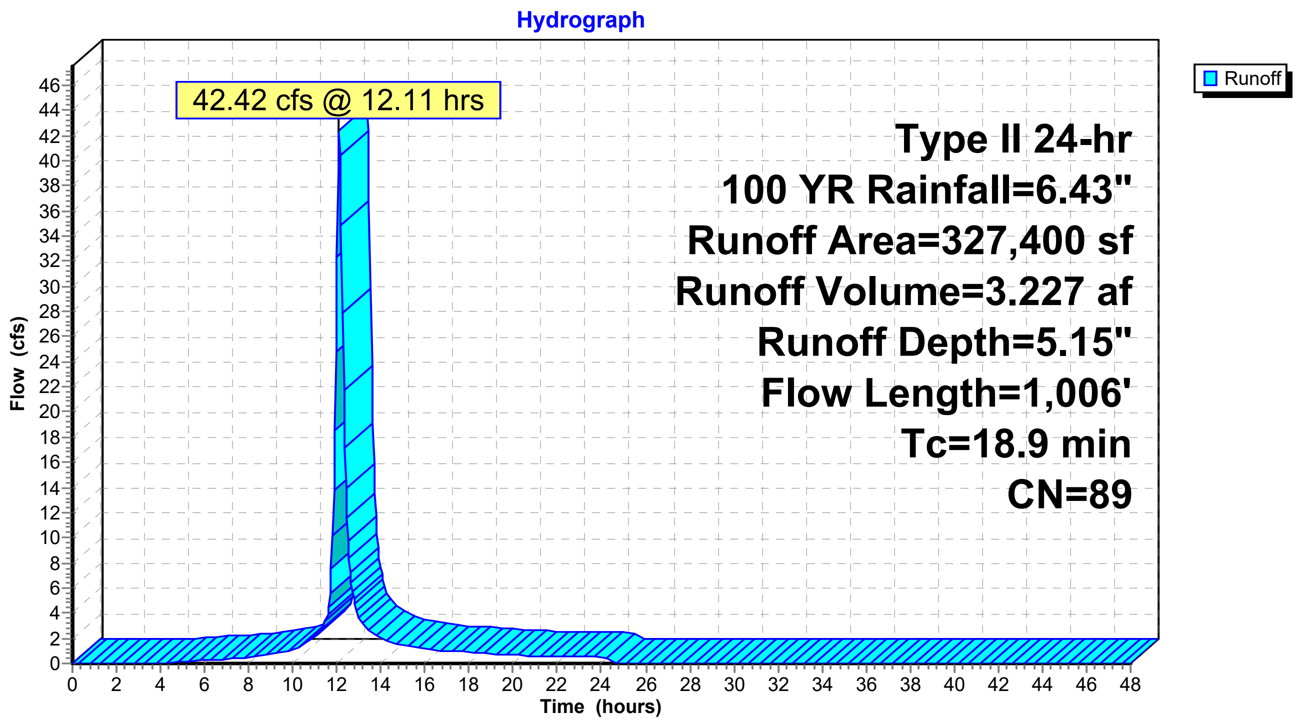
Runoff = 42.42 cfs @ 12.11 hrs, Volume= 3.227 af, Depth= 5.15"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 100 YR Rainfall=6.43"

	Area (sf)	CN	Description
*	327,400	89	CCR
	327,400		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.3	100	0.0100	0.13		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.01"
1.3	119	0.0100	1.50		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
1.3	200	0.0300	2.60		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
3.0	587	0.0030	3.24	214.10	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=2.00' Z= 30.0 & 3.0 '/' Top.W=66.00' n= 0.025 Earth, clean & winding
18.9	1,006	Total			

Subcatchment DA-5:



Summary for Subcatchment DA-6:

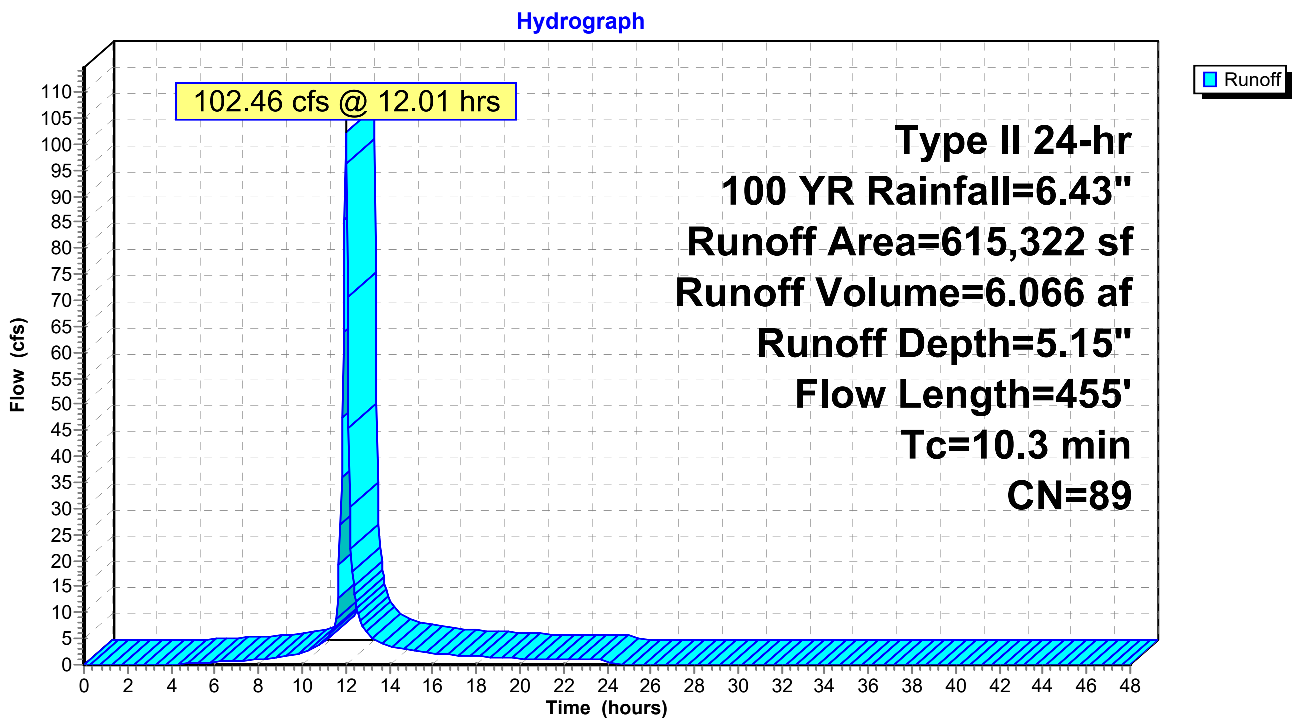
Runoff = 102.46 cfs @ 12.01 hrs, Volume= 6.066 af, Depth= 5.15"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 100 YR Rainfall=6.43"

	Area (sf)	CN	Description
*	615,322	89	CCR
	615,322		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.6	100	0.0300	0.19		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.01"
0.8	131	0.0300	2.60		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
0.9	224	0.0700	3.97		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
10.3	455	Total			

Subcatchment DA-6:



Summary for Subcatchment DA-7:

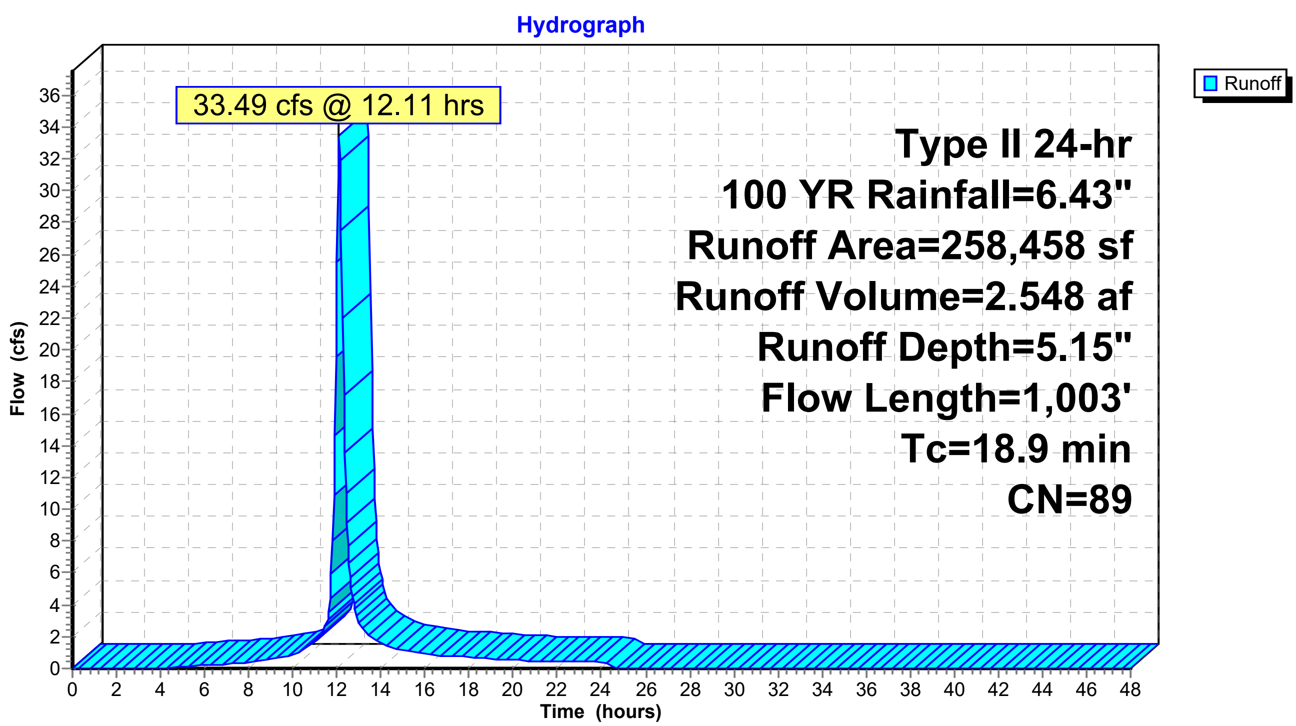
Runoff = 33.49 cfs @ 12.11 hrs, Volume= 2.548 af, Depth= 5.15"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 100 YR Rainfall=6.43"

	Area (sf)	CN	Description
*	258,458	89	CCR
	258,458		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.3	100	0.0100	0.13		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.01"
1.3	119	0.0100	1.50		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
1.3	200	0.0300	2.60		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
3.0	584	0.0030	3.24	214.10	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=2.00' Z= 30.0 & 3.0 '/' Top.W=66.00' n= 0.025 Earth, clean & winding
18.9	1,003	Total			

Subcatchment DA-7:



Summary for Subcatchment DA-8:

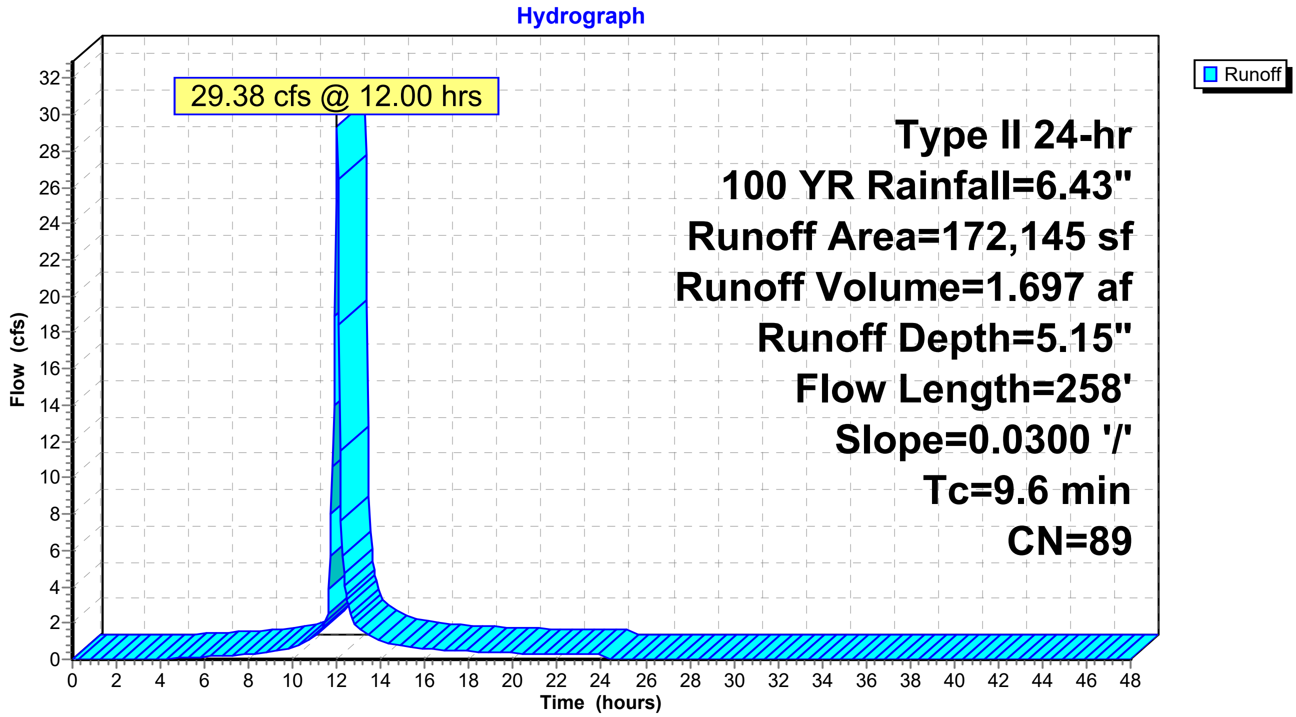
Runoff = 29.38 cfs @ 12.00 hrs, Volume= 1.697 af, Depth= 5.15"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 100 YR Rainfall=6.43"

	Area (sf)	CN	Description
*	172,145	89	CCR
	172,145		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.6	100	0.0300	0.19		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.01"
1.0	158	0.0300	2.60		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
9.6	258	Total			

Subcatchment DA-8:



Summary for Reach D-1:

Inflow Area = 0.442 ac, 0.00% Impervious, Inflow Depth = 5.15" for 100 YR event
Inflow = 3.63 cfs @ 11.96 hrs, Volume= 0.190 af
Outflow = 3.41 cfs @ 12.01 hrs, Volume= 0.190 af, Atten= 6%, Lag= 2.7 min

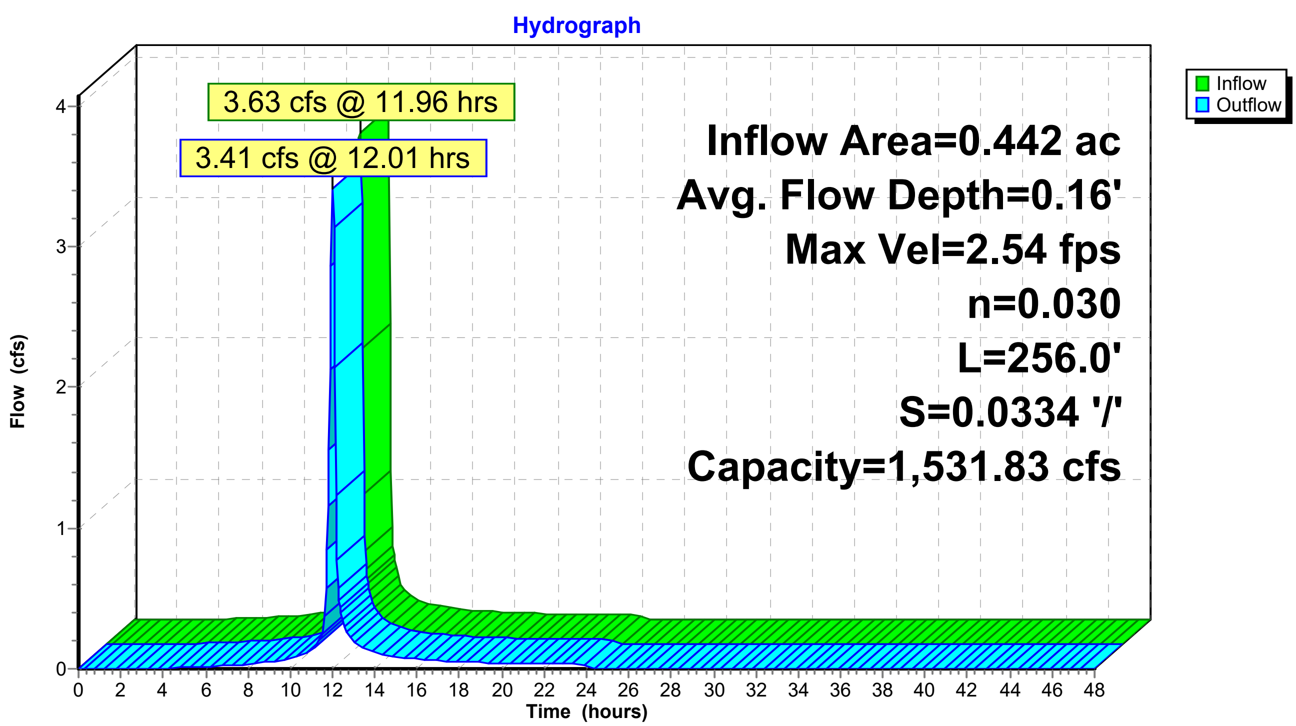
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.54 fps, Min. Travel Time= 1.7 min
Avg. Velocity = 1.07 fps, Avg. Travel Time= 4.0 min

Peak Storage= 358 cf @ 11.98 hrs
Average Depth at Peak Storage= 0.16'
Bank-Full Depth= 4.00' Flow Area= 96.0 sf, Capacity= 1,531.83 cfs

8.00' x 4.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 4.0 '/' Top Width= 40.00'
Length= 256.0' Slope= 0.0334 '/'
Inlet Invert= 623.11', Outlet Invert= 614.57'

‡

Reach D-1:



Summary for Reach D-2:

Inflow Area = 2.982 ac, 0.00% Impervious, Inflow Depth = 5.15" for 100 YR event
Inflow = 19.77 cfs @ 12.03 hrs, Volume= 1.280 af
Outflow = 19.03 cfs @ 12.07 hrs, Volume= 1.280 af, Atten= 4%, Lag= 2.6 min

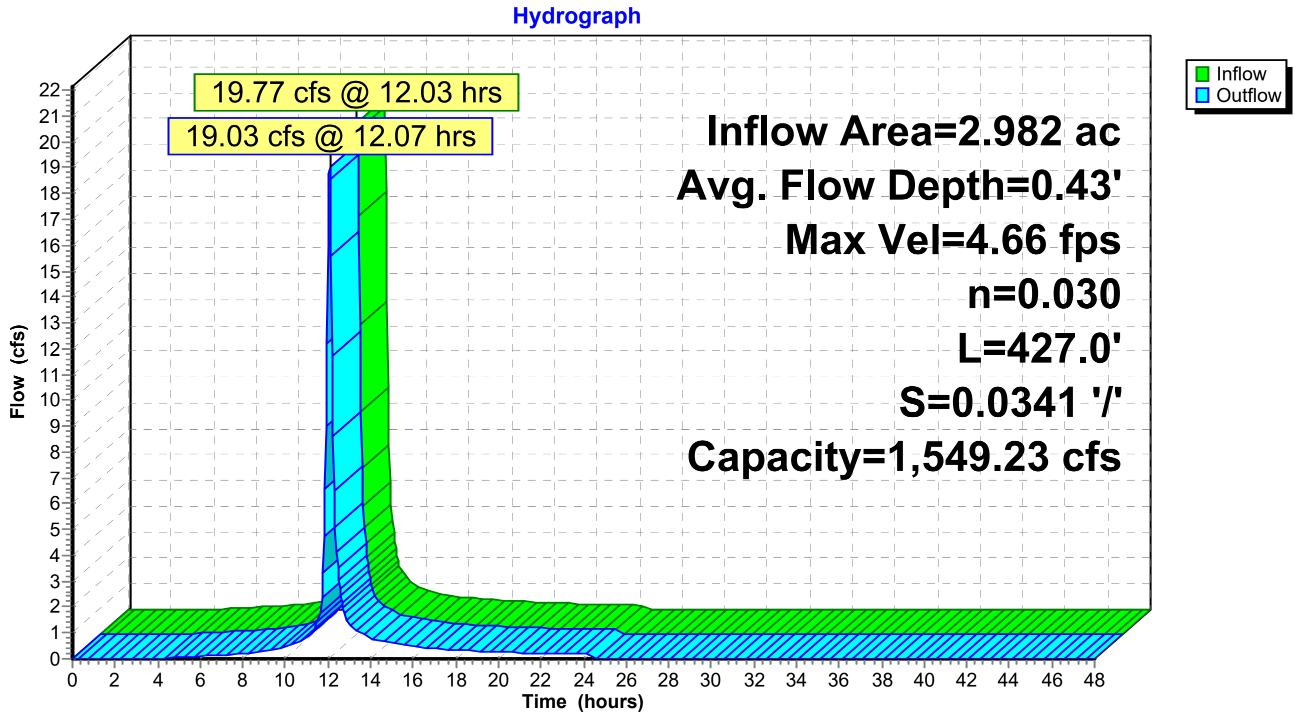
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 4.66 fps, Min. Travel Time= 1.5 min
Avg. Velocity = 1.27 fps, Avg. Travel Time= 5.6 min

Peak Storage= 1,793 cf @ 12.05 hrs
Average Depth at Peak Storage= 0.43'
Bank-Full Depth= 4.00' Flow Area= 96.0 sf, Capacity= 1,549.23 cfs

8.00' x 4.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 4.0 '/' Top Width= 40.00'
Length= 427.0' Slope= 0.0341 '/'
Inlet Invert= 614.57', Outlet Invert= 600.00'

‡

Reach D-2:



Summary for Reach D-3:

Inflow Area = 4.296 ac, 0.00% Impervious, Inflow Depth = 5.15" for 100 YR event
Inflow = 27.70 cfs @ 12.05 hrs, Volume= 1.845 af
Outflow = 26.88 cfs @ 12.08 hrs, Volume= 1.845 af, Atten= 3%, Lag= 1.9 min

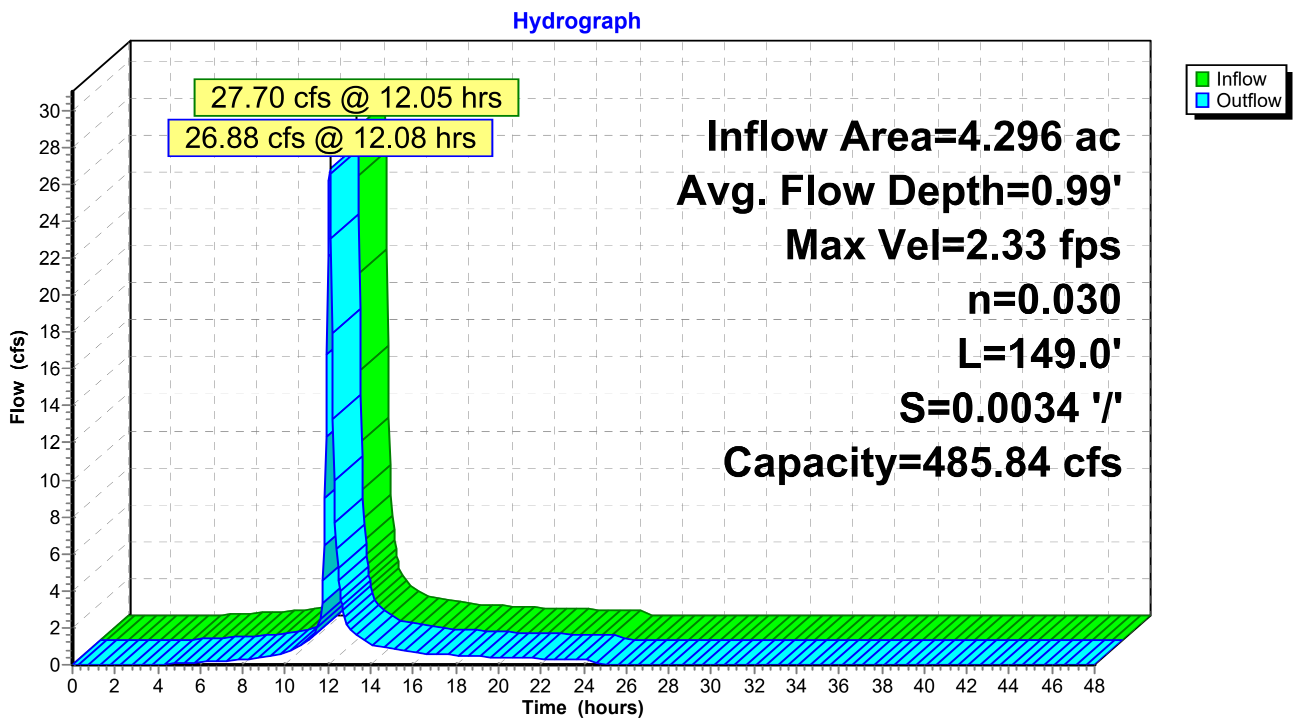
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.33 fps, Min. Travel Time= 1.1 min
Avg. Velocity = 0.62 fps, Avg. Travel Time= 4.0 min

Peak Storage= 1,759 cf @ 12.06 hrs
Average Depth at Peak Storage= 0.99'
Bank-Full Depth= 4.00' Flow Area= 96.0 sf, Capacity= 485.84 cfs

8.00' x 4.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 4.0 '/' Top Width= 40.00'
Length= 149.0' Slope= 0.0034 '/'
Inlet Invert= 600.00', Outlet Invert= 599.50'

‡

Reach D-3:



Summary for Reach D-4:

Inflow Area = 25.938 ac, 0.00% Impervious, Inflow Depth = 5.15" for 100 YR event
Inflow = 152.81 cfs @ 12.04 hrs, Volume= 11.138 af
Outflow = 130.14 cfs @ 12.22 hrs, Volume= 11.138 af, Atten= 15%, Lag= 11.1 min

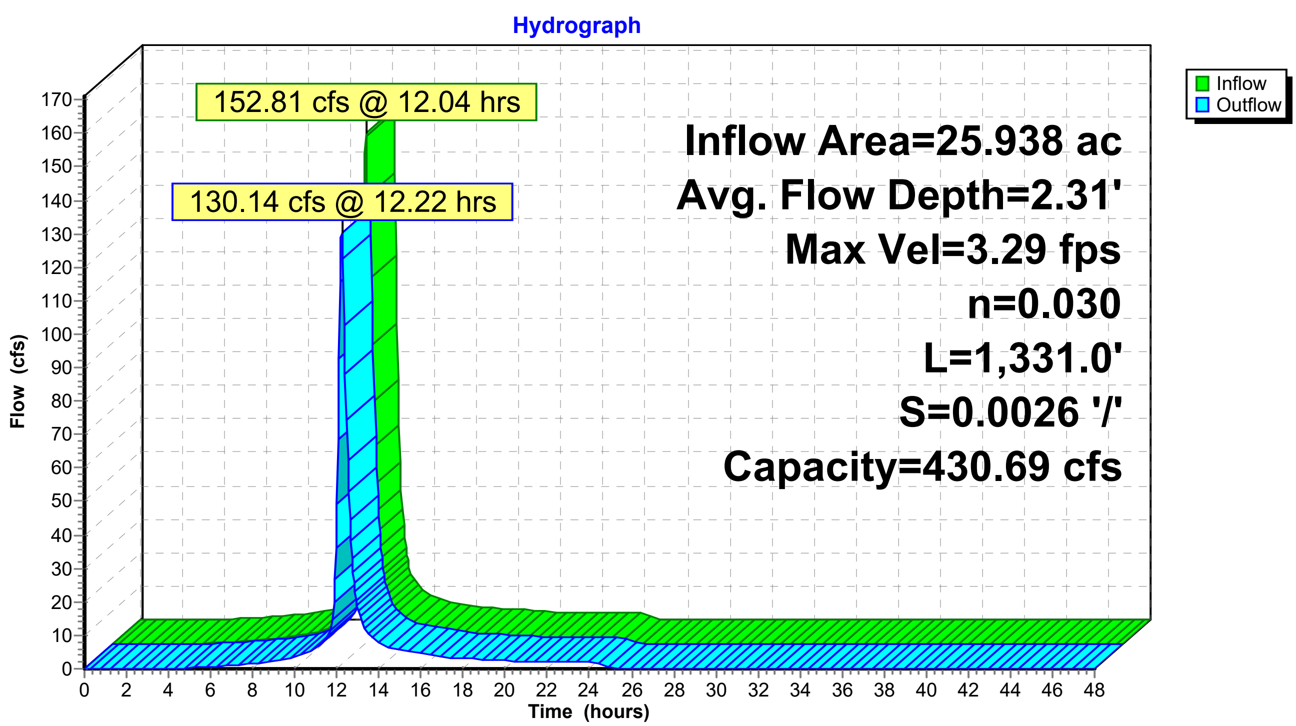
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.29 fps, Min. Travel Time= 6.7 min
Avg. Velocity = 0.81 fps, Avg. Travel Time= 27.5 min

Peak Storage= 53,135 cf @ 12.11 hrs
Average Depth at Peak Storage= 2.31'
Bank-Full Depth= 4.00' Flow Area= 96.0 sf, Capacity= 430.69 cfs

8.00' x 4.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 4.0 '/' Top Width= 40.00'
Length= 1,331.0' Slope= 0.0026 '/'
Inlet Invert= 599.00', Outlet Invert= 595.49'

‡

Reach D-4:



Summary for Reach D-5:

Inflow Area = 3.952 ac, 0.00% Impervious, Inflow Depth = 5.15" for 100 YR event
Inflow = 29.38 cfs @ 12.00 hrs, Volume= 1.697 af
Outflow = 27.66 cfs @ 12.08 hrs, Volume= 1.697 af, Atten= 6%, Lag= 4.4 min

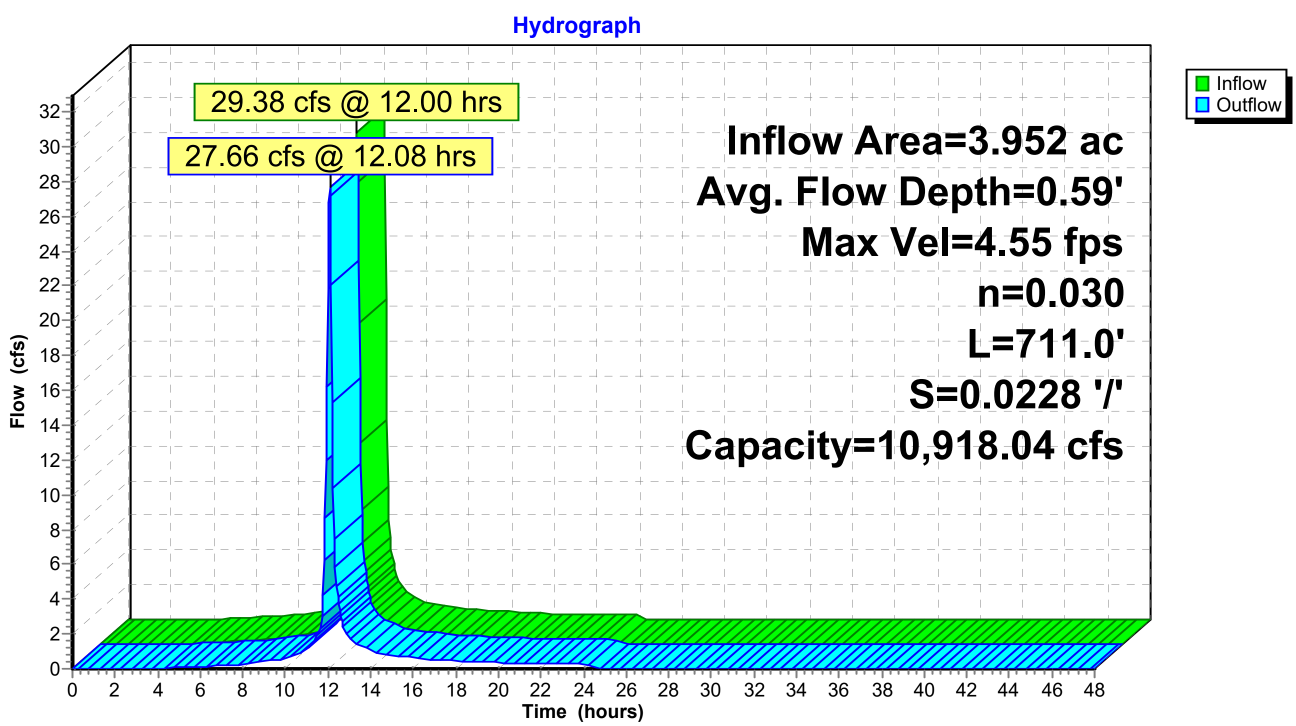
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 4.55 fps, Min. Travel Time= 2.6 min
Avg. Velocity = 1.64 fps, Avg. Travel Time= 7.2 min

Peak Storage= 4,368 cf @ 12.03 hrs
Average Depth at Peak Storage= 0.59'
Bank-Full Depth= 10.00' Flow Area= 480.0 sf, Capacity= 10,918.04 cfs

8.00' x 10.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 4.0 '/' Top Width= 88.00'
Length= 711.0' Slope= 0.0228 '/'
Inlet Invert= 614.00', Outlet Invert= 597.80'

‡

Reach D-5:



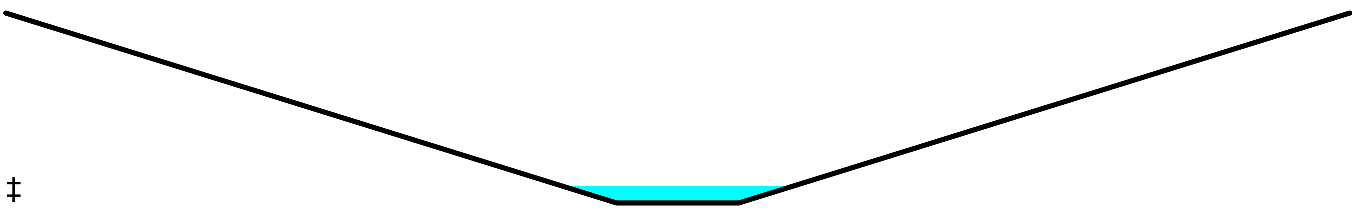
Summary for Reach D-6:

Inflow Area = 9.885 ac, 0.00% Impervious, Inflow Depth = 5.15" for 100 YR event
Inflow = 57.01 cfs @ 12.11 hrs, Volume= 4.245 af
Outflow = 56.56 cfs @ 12.12 hrs, Volume= 4.245 af, Atten= 1%, Lag= 0.5 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 5.54 fps, Min. Travel Time= 0.3 min
Avg. Velocity = 1.75 fps, Avg. Travel Time= 1.0 min

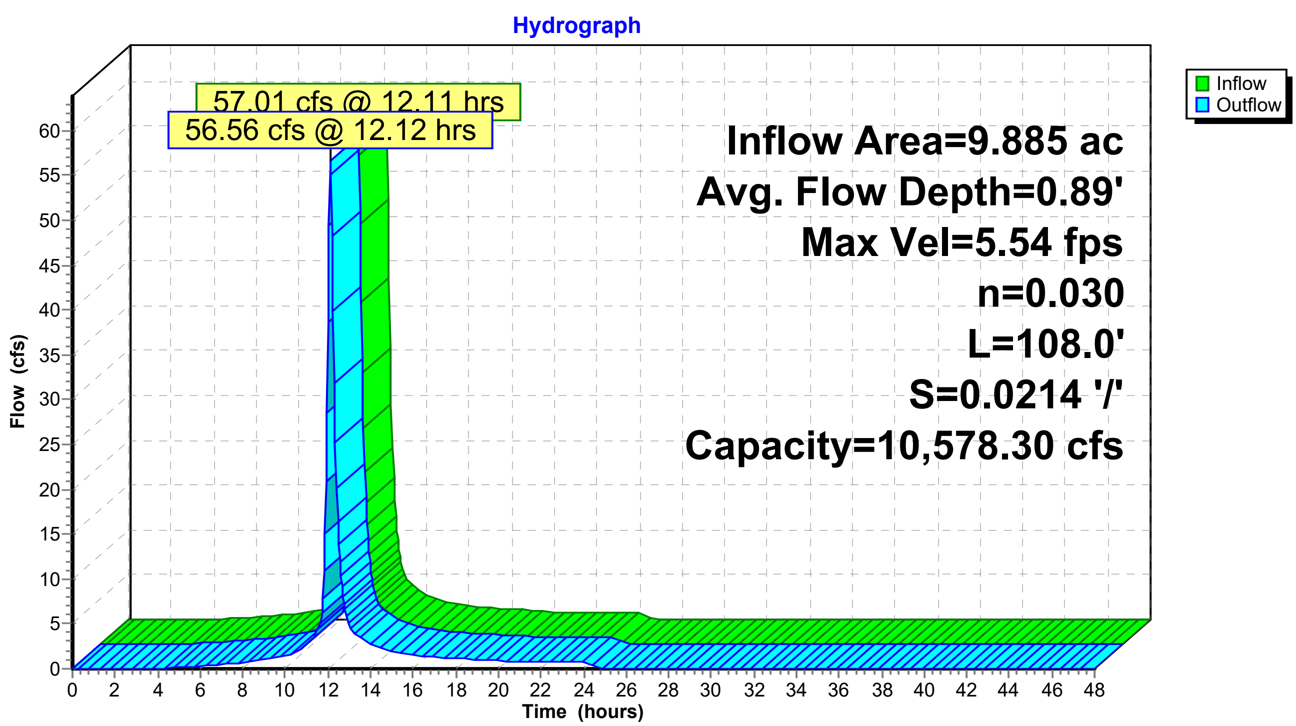
Peak Storage= 1,109 cf @ 12.11 hrs
Average Depth at Peak Storage= 0.89'
Bank-Full Depth= 10.00' Flow Area= 480.0 sf, Capacity= 10,578.30 cfs

8.00' x 10.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 4.0 '/' Top Width= 88.00'
Length= 108.0' Slope= 0.0214 '/'
Inlet Invert= 597.80', Outlet Invert= 595.49'



‡

Reach D-6:



Summary for Reach LD-1:

Inflow Area = 1.269 ac, 0.00% Impervious, Inflow Depth = 5.15" for 100 YR event
Inflow = 7.84 cfs @ 12.07 hrs, Volume= 0.545 af
Outflow = 7.81 cfs @ 12.07 hrs, Volume= 0.545 af, Atten= 0%, Lag= 0.3 min

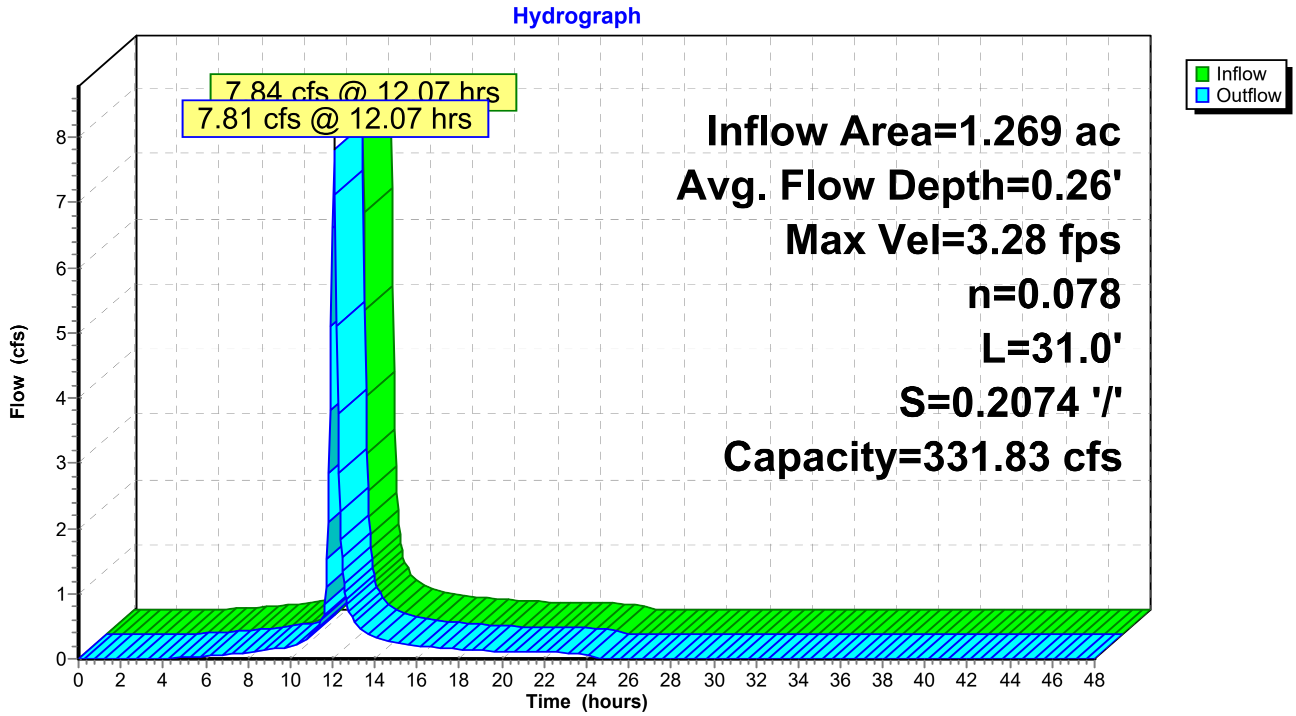
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.28 fps, Min. Travel Time= 0.2 min
Avg. Velocity = 0.84 fps, Avg. Travel Time= 0.6 min

Peak Storage= 74 cf @ 12.07 hrs
Average Depth at Peak Storage= 0.26'
Bank-Full Depth= 2.00' Flow Area= 32.0 sf, Capacity= 331.83 cfs

8.00' x 2.00' deep channel, n= 0.078 Riprap, 12-inch
Side Slope Z-value= 4.0 '/' Top Width= 24.00'
Length= 31.0' Slope= 0.2074 '/'
Inlet Invert= 621.00', Outlet Invert= 614.57'

‡

Reach LD-1:



Summary for Reach LD-2-1:

Inflow Area = 7.516 ac, 0.00% Impervious, Inflow Depth = 5.15" for 100 YR event
Inflow = 42.42 cfs @ 12.11 hrs, Volume= 3.227 af
Outflow = 41.52 cfs @ 12.14 hrs, Volume= 3.227 af, Atten= 2%, Lag= 2.3 min

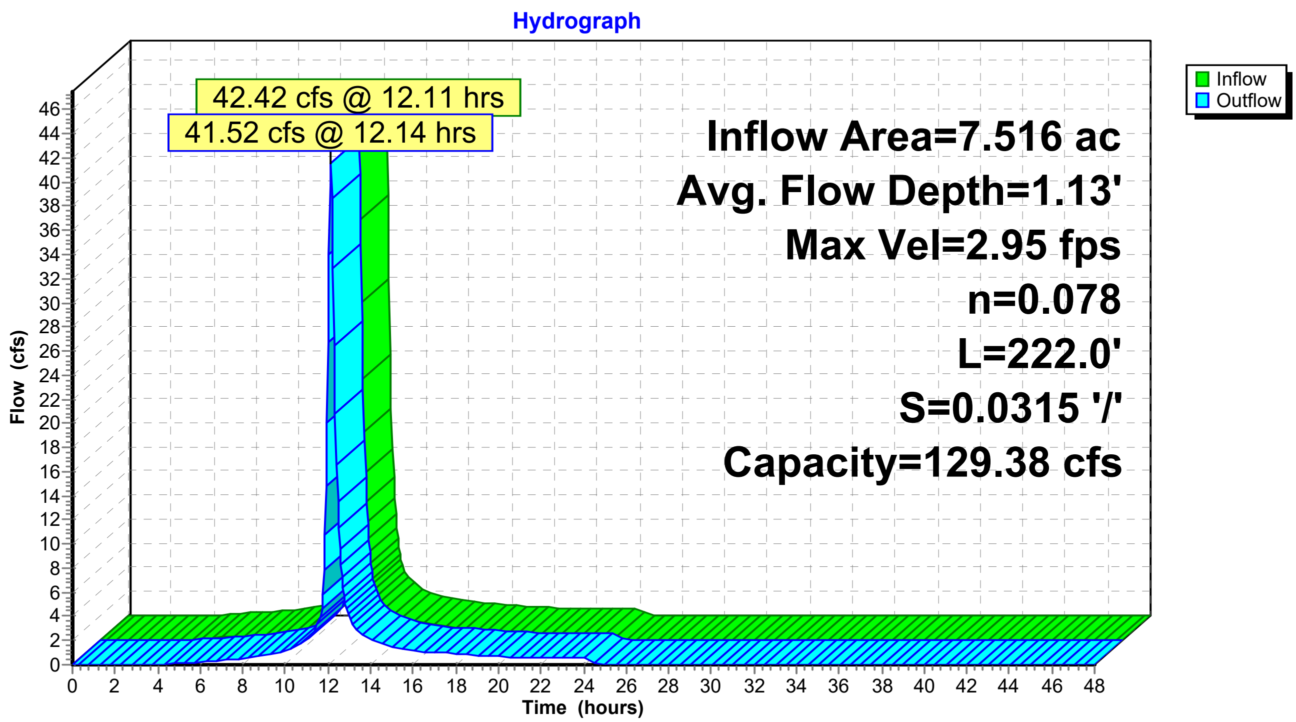
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.95 fps, Min. Travel Time= 1.3 min
Avg. Velocity = 0.79 fps, Avg. Travel Time= 4.7 min

Peak Storage= 3,158 cf @ 12.12 hrs
Average Depth at Peak Storage= 1.13'
Bank-Full Depth= 2.00' Flow Area= 32.0 sf, Capacity= 129.38 cfs

8.00' x 2.00' deep channel, n= 0.078 Riprap, 12-inch
Side Slope Z-value= 4.0 '/' Top Width= 24.00'
Length= 222.0' Slope= 0.0315 '/'
Inlet Invert= 621.00', Outlet Invert= 614.00'

‡

Reach LD-2-1:



Summary for Reach LD-2-2:

Inflow Area = 7.516 ac, 0.00% Impervious, Inflow Depth = 5.15" for 100 YR event
Inflow = 41.52 cfs @ 12.14 hrs, Volume= 3.227 af
Outflow = 40.84 cfs @ 12.17 hrs, Volume= 3.227 af, Atten= 2%, Lag= 1.7 min

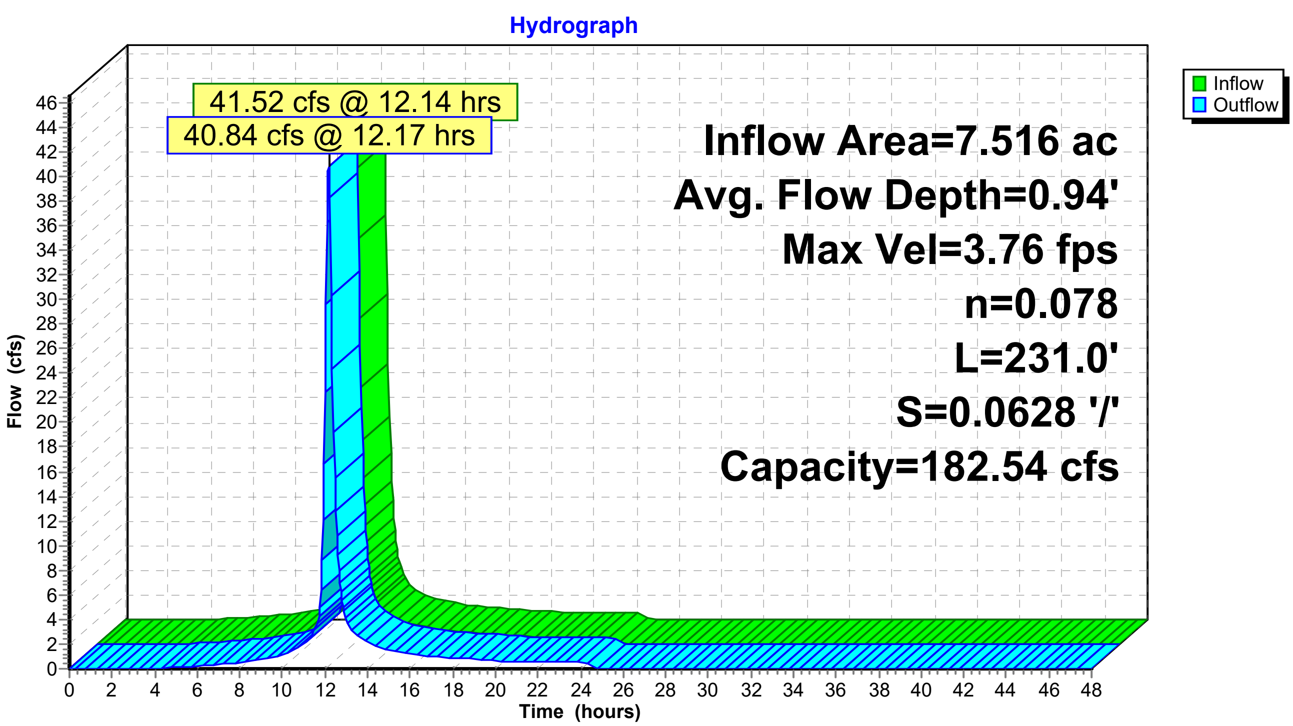
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.76 fps, Min. Travel Time= 1.0 min
Avg. Velocity = 0.99 fps, Avg. Travel Time= 3.9 min

Peak Storage= 2,542 cf @ 12.16 hrs
Average Depth at Peak Storage= 0.94'
Bank-Full Depth= 2.00' Flow Area= 32.0 sf, Capacity= 182.54 cfs

8.00' x 2.00' deep channel, n= 0.078 Riprap, 12-inch
Side Slope Z-value= 4.0 '/' Top Width= 24.00'
Length= 231.0' Slope= 0.0628 '/'
Inlet Invert= 614.00', Outlet Invert= 599.50'

‡

Reach LD-2-2:



Summary for Reach LD-3-1:

Inflow Area = 5.933 ac, 0.00% Impervious, Inflow Depth = 5.15" for 100 YR event
Inflow = 33.49 cfs @ 12.11 hrs, Volume= 2.548 af
Outflow = 32.68 cfs @ 12.15 hrs, Volume= 2.548 af, Atten= 2%, Lag= 2.8 min

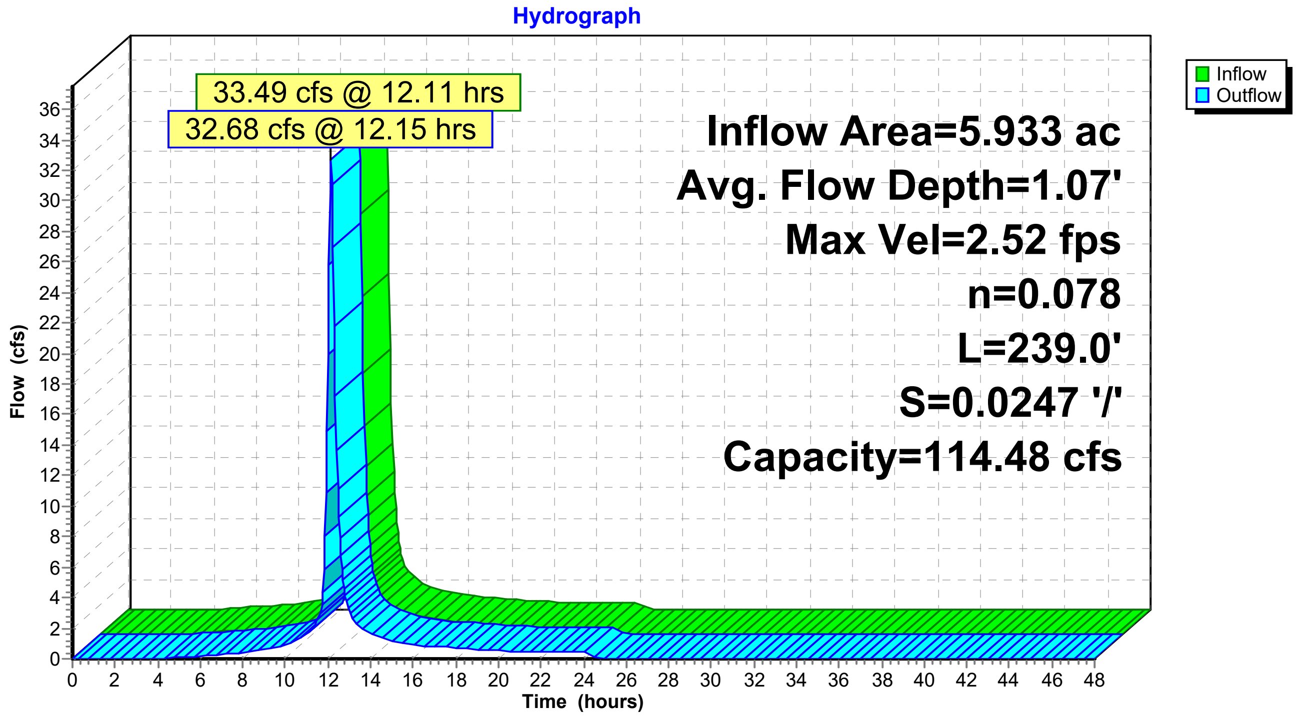
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.52 fps, Min. Travel Time= 1.6 min
Avg. Velocity = 0.67 fps, Avg. Travel Time= 6.0 min

Peak Storage= 3,124 cf @ 12.13 hrs
Average Depth at Peak Storage= 1.07'
Bank-Full Depth= 2.00' Flow Area= 32.0 sf, Capacity= 114.48 cfs

8.00' x 2.00' deep channel, n= 0.078 Riprap, 12-inch
Side Slope Z-value= 4.0 '/' Top Width= 24.00'
Length= 239.0' Slope= 0.0247 '/'
Inlet Invert= 621.00', Outlet Invert= 615.10'

‡

Reach LD-3-1:



Summary for Reach LD-3-2:

Inflow Area = 5.933 ac, 0.00% Impervious, Inflow Depth = 5.15" for 100 YR event
Inflow = 32.68 cfs @ 12.15 hrs, Volume= 2.548 af
Outflow = 32.48 cfs @ 12.16 hrs, Volume= 2.548 af, Atten= 1%, Lag= 0.6 min

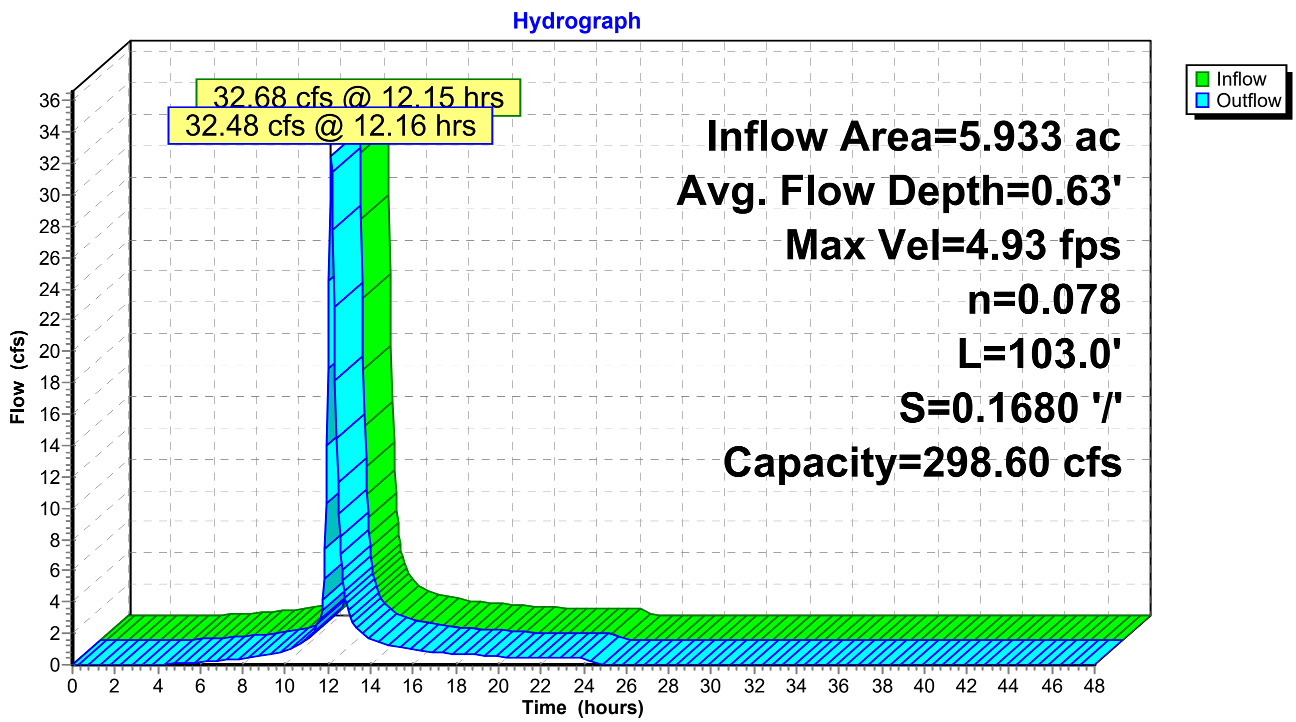
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 4.93 fps, Min. Travel Time= 0.3 min
Avg. Velocity = 1.26 fps, Avg. Travel Time= 1.4 min

Peak Storage= 682 cf @ 12.16 hrs
Average Depth at Peak Storage= 0.63'
Bank-Full Depth= 2.00' Flow Area= 32.0 sf, Capacity= 298.60 cfs

8.00' x 2.00' deep channel, n= 0.078 Riprap, 12-inch
Side Slope Z-value= 4.0 '/' Top Width= 24.00'
Length= 103.0' Slope= 0.1680 '/'
Inlet Invert= 615.10', Outlet Invert= 597.80'

‡

Reach LD-3-2:



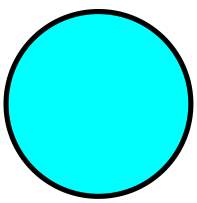
Summary for Reach PIPES:

Inflow Area = 35.823 ac, 0.00% Impervious, Inflow Depth = 5.15" for 100 YR event
Inflow = 177.29 cfs @ 12.19 hrs, Volume= 15.382 af
Outflow = 69.62 cfs @ 12.05 hrs, Volume= 15.382 af, Atten= 61%, Lag= 0.0 min

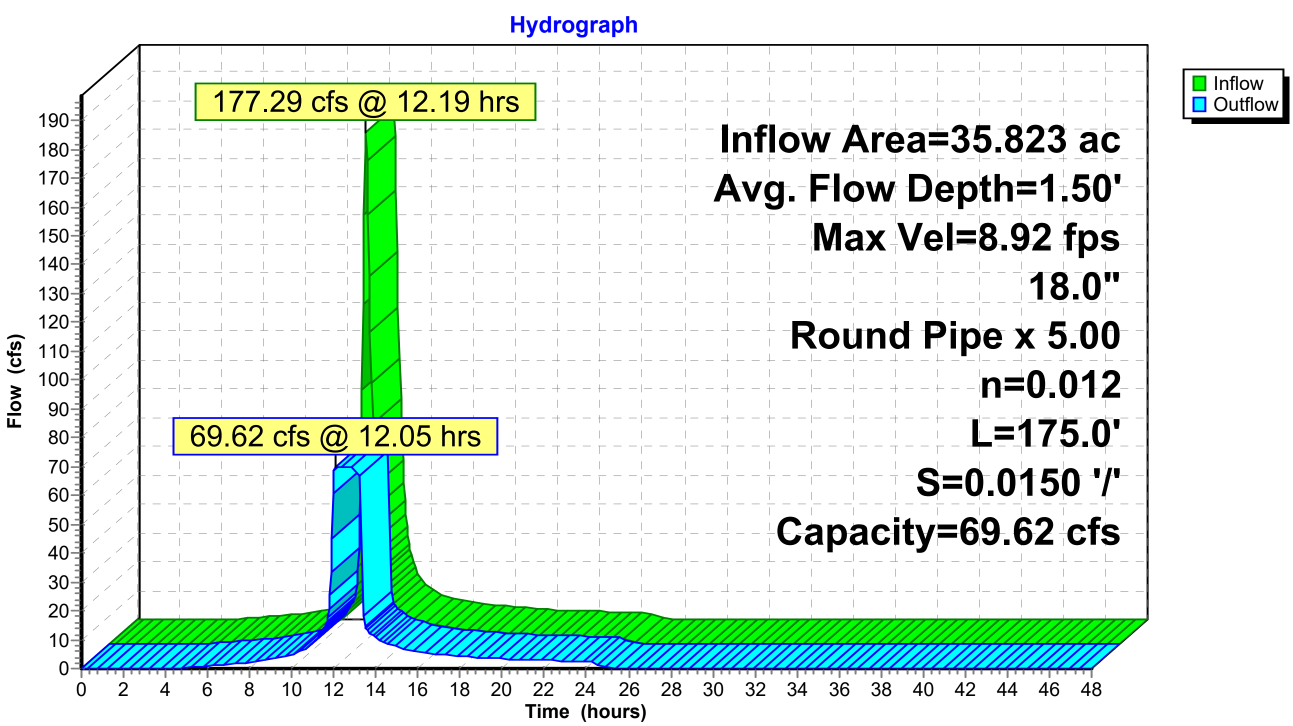
Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 8.92 fps, Min. Travel Time= 0.3 min
Avg. Velocity = 3.17 fps, Avg. Travel Time= 0.9 min

Peak Storage= 1,546 cf @ 12.00 hrs
Average Depth at Peak Storage= 1.50'
Bank-Full Depth= 1.50' Flow Area= 8.8 sf, Capacity= 69.62 cfs

A factor of 5.00 has been applied to the storage and discharge capacity
18.0" Round Pipe
n= 0.012 Corrugated PP, smooth interior
Length= 175.0' Slope= 0.0150 '/'
Inlet Invert= 595.49', Outlet Invert= 592.87'



Reach PIPES:

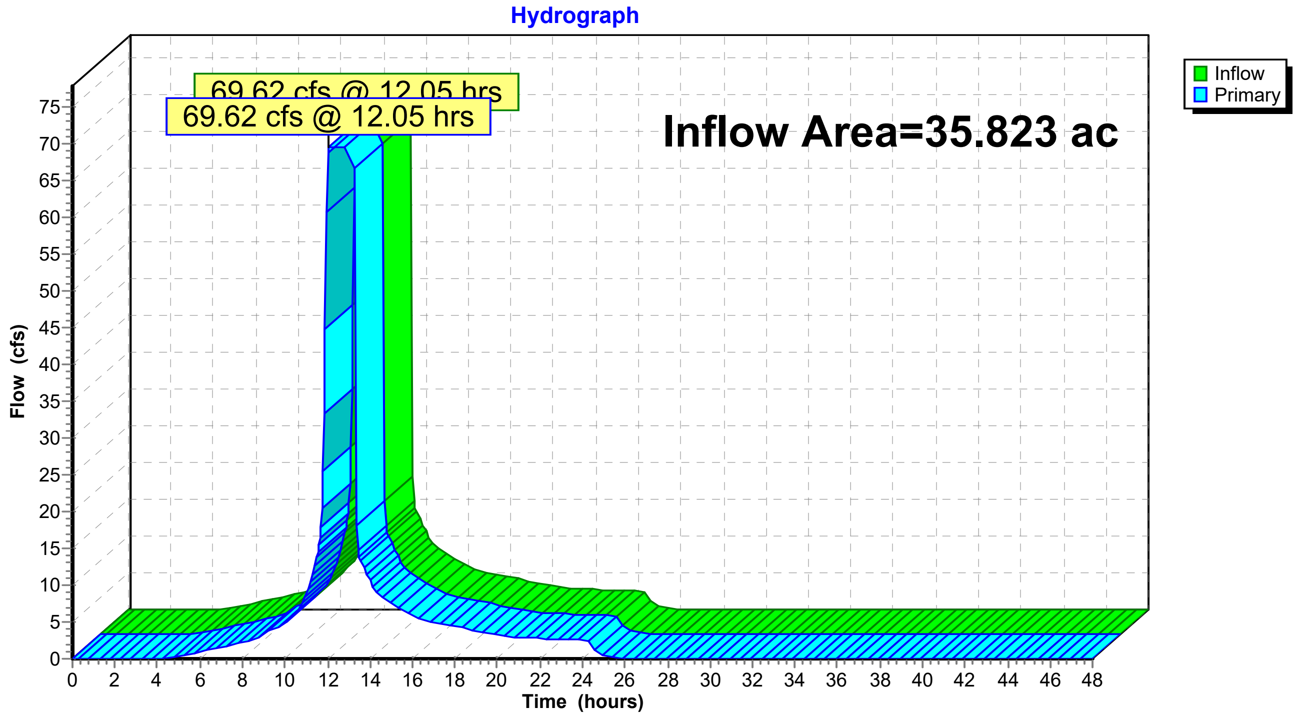


Summary for Link 1L: (new Link)

Inflow Area =	35.823 ac,	0.00% Impervious,	Inflow Depth = 5.15"	for 100 YR event	
Inflow =	69.62 cfs @	12.05 hrs,	Volume=	15.382 af	
Primary =	69.62 cfs @	12.05 hrs,	Volume=	15.382 af,	Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

Link 1L: (new Link)



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ATTACHMENT H: PUBLIC NOTIFICATION AND PUBLIC MEETING CERTIFICATION
845.220(a)(9)

Luminant

Stephen Wait
Kincaid Generation, L.L.C.
199 Illinois Route 104
Kincaid, IL 62540

July 27, 2022

Illinois Environmental Protection Agency
DWPC – Permits MC # 15
ATTN: Part 845 Coal Combustion Residual Rule Submittal
1021 North Grand Avenue East
P.O. Box 19276
Springfield, IL 62794-9276

Re: 35 IAC 845.220(a)(9) Certification Statement
Kincaid Power Plant; Ash Pond (IEPA ID # W0218140002-01)

Dear Mr. Darin LeCrone:

For the above-refenced CCR surface impoundments and in accordance with 35 IAC 845.220(a)(9), Kincaid Generation, LLC. certifies that the public notification and public meetings required under 35 IAC 845.240 were completed. Please find enclosed both the public meeting summary and listserv.

Sincerely,
Kincaid Generation, LLC

Stephen Wait
Plant Manager

Kincaid Public Meeting Summary, June 15, 2022

On May 16, 2022, Kincaid Generation, LLC made available to the public its plans to close the Ash Pond (AP) located at the Kincaid Power Plant. On Wednesday, June 15, 2022, Kincaid held in-person public meetings at 3:00 pm and 5:30 pm at the Pillars Event Center in Taylorville, Illinois to present its decision-making process. A comparison of projected groundwater impacts for the alternatives presented, and an objective comparison of the pros and cons of each alternative were presented. Section 845.240(g) requires a general summary of the issues or comments raised by the public relating to the closure, a summary of the company's responses to those issues or comments, and a summary of any revisions or changes made to the proposed closure action as a result of issues and comments raised by the public. The public did not ask any questions or provide comments during either meeting.

In accordance with 845.240(f)(4), a list people who requested to be added to the IEPA Listserv for Kincaid is as follows:

Kincaid construction permit public meetings	
People requesting to be added to IEPA Listserv	
Name	Email address
no one requested to be added to IEPA listserv	

# ATTACHMENT I: CLOSURE PRIORITIZATION CATEGORY LETTER
845.220(d)(1)

Phil Morris
Kincaid Generation, L.L.C.
Luminant
1500 Eastport Plaza Drive
Collinsville, IL 62234

May 19, 2021

Mr. Darin LeCrone, P.E.
Manager, Industrial Unit
Bureau of Water, Division of Water Pollution Control, Permits Section
Illinois Environmental Protection Agency
1021 North Grand Avenue, East
Springfield, IL 62794-9276

Re: CCR Surface Impoundment Category Designation and Justification for Kincaid Generation, L.L.C.

Dear Mr. LeCrone:

Pursuant to 35 I.A.C. 845.700(c), Kincaid Generation, L.L.C. submits the information necessary to categorize the CCR surface impoundment located at the Kincaid Power Plant. The following parameters were used in assessing and justifying each assigned category.

- Category 1 – *Impacts to existing potable water supply well or impacts to groundwater quality within the setback of an existing potable water supply well.*
    - This review includes an assessment of potable water wells within 2,500 feet of CCR surface impoundments to determine whether any potential impacts are occurring within the setback zone of any community water supply well established under the Illinois Groundwater Protection Act.
    - This information was developed during the Part 845 rulemaking and is summarized in Attachment 1, Table 2: Impacts to Potable Water Supply.
- Category 2 – *Imminent threat to human health or the environment or have been designated by IEPA under (g)(5)*
    - The surface impoundment at the Kincaid Power Plant does not pose an imminent threat to human health or the environment. There are no known conditions at or around the facility where someone or something may be exposed to contaminant concentrations reasonably expected to cause harm
- Category 3 – *Located in areas of environmental justice ("EJ") concern*
    - EJ areas were evaluated using the EJ mapping link from IEPA's webpage located at https://www2.illinois.gov/epa/topics/environmental-justice. Per the IEPA mapping tool, the EJ Status thresholds were determined as twice the state averages for Minority and Low Income consistent with 35 IAC 845.700(g)(6).
    - An EJ map denoting the facilities with impoundments is located in Attachment 2.

- Category 4-7
  - Category 4 - Inactive CCR surface impoundments that have an exceedance of the groundwater protection standards in Section 845.600
  - Category 5 - Existing CCR surface impoundments that have exceedances of the groundwater protection standards in Section 845.600
  - Category 6 - Inactive CCR surface impoundments that are in compliance with the groundwater protection standards in Section 845.600.
  - Category 7 – Existing CCR surface impoundments that are in compliance with the groundwater protection standards in Section 845.600

Based on the information above, category designations have been assigned. The category designations for each CCR impoundment are shown in Attachment 1, Table 1: Category Designations.

If you have any questions regarding this submittal, please contact Phil Morris at 618-343-7794 or phil.morris@vistracorp.com.

Sincerely,

Phil Morris
Senior Environmental Director

Attachments

Attachment 1

Table 1: Category Designation

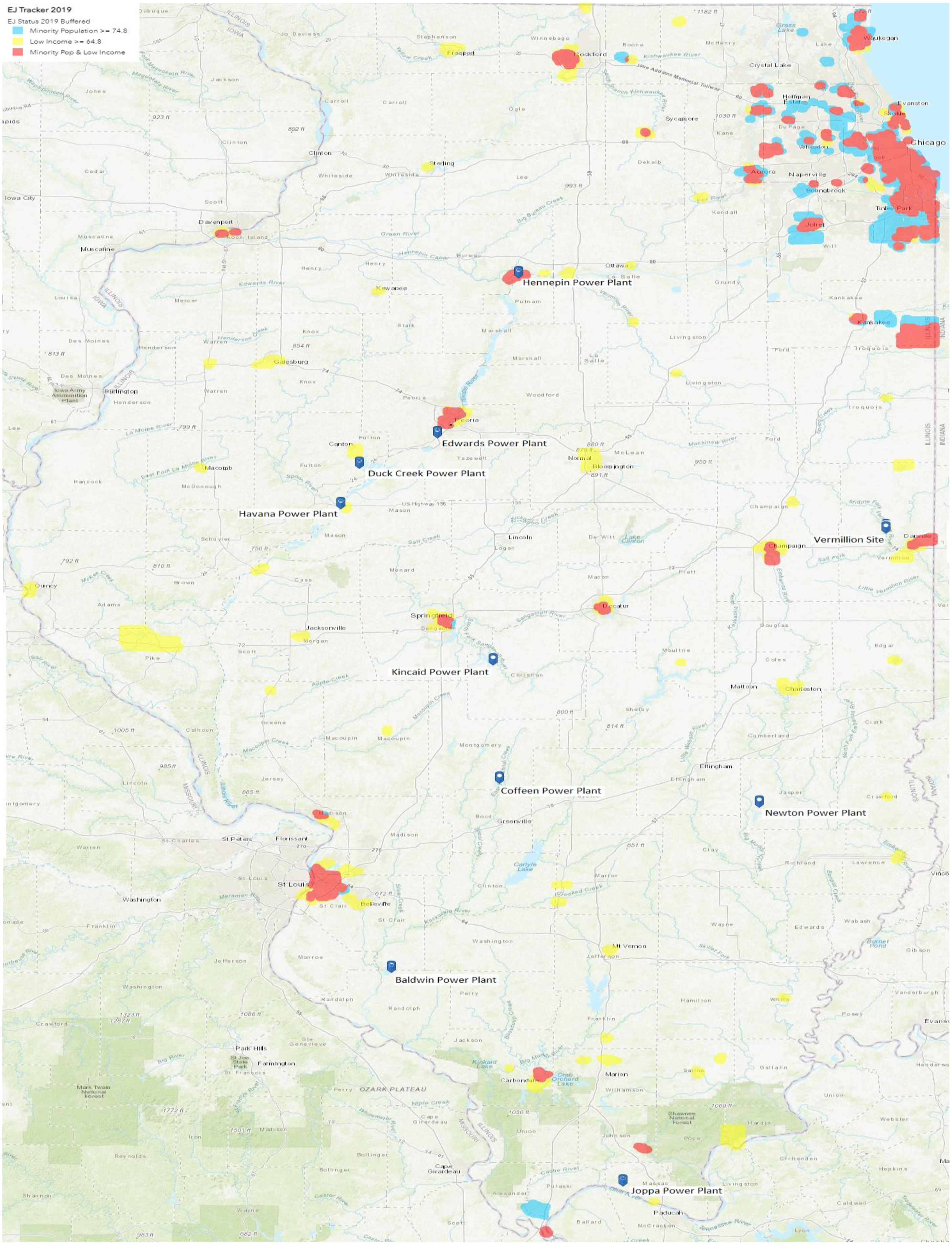
Facility	Pond Description	Classifications	Potable Water Supply Impacts (Category 1)	Human Health or Environment Threat (Category 2)	Located within Environmental Justice Areas[1] (Category 3)	Standards Exceedances[2] (Categories 4,5,6,7)	Impoundment Category 845.700(g)
Kincaid	Ash Pond	Existing	No	No	No	Yes	5

[1] See Attachment 2 Environmental Justice Area Map
[2] Ground water analyses for purposes of categories 4-7, assumptions have been made based on current groundwater data. However, since sampling and analysis is ongoing and subject to IEPA review and approval, IPGC reserves the right to update its category designations for Categories 4-7.

Table 2: Impacts to Potable Water Supply

Site Name	Private and Semi-Private Wells	Non-Community Water Supply (CWS) Wells	Non-CWS Surface Water Intakes	Community Water Supply Wells	CWS Surface Water Intakes
Kincaid	**Present, but not at risk** Twelve (12) water wells were identified; however, they are unlikely to be at risk because of their hydrogeologic location relative to the power plant and/or abandoned status. No off-site wells are located in the downgradient direction.	Absent	**Present, but inactive** One non-CWS surface water intake was identified; however, it is unlikely to be at risk because it is listed as inactive.	Absent	Absent

Attachment 2: EJ Mapping Denoting Facilities with Impoundments



ATTACHMENT J: POST-CLOSURE CARE PLAN
845.220(d)(5)

POST-CLOSURE PLAN FOR EXISTING CCR SURFACE IMPOUNDMENT
40 C.F.R. § 257.104 and 35 I.A.C. 845.780
REV 0 –10/30/2021

SITE INFORMATION			
Site Name / Address	Kincaid Power Plant / 199 Illinois Route 104, Kincaid, IL 62234		
Owner Name / Address	Kincaid Generation, LLC / 6555 Sierra Drive Irving, Texas 75039		
CCR Unit	Ash Pond	Closure Method and Final Cover Type	Close In-Place Clayey Soil Cover with Vegetation

POST-CLOSURE PLAN DESCRIPTION	
40 C.F.R. § 257.104(c)(1) and 35 I.A.C. 845.780(c)(1) – Length of post-closure care period.	Post-closure care will be conducted for a period of 30 years as required by 40 C.F.R. § 257.104(c)(1) and 35 I.A.C. 845.780(c)(1), except as provided by 40 C.F.R. § 257.104(c)(2) and 35 I.A.C. 845.780(c)(2).
40 C.F.R. § 257.104(c)(2) and 35 I.A.C. 845.780(c)(2) - Circumstances extending the post closure care period.	If at the end of the post-closure care period the CCR unit is operating under assessment monitoring in accordance with §257.95, the post-closure care as described in this plan will continue until returning to detection monitoring in accordance with §257.95. Under 35 I.A.C. 845.780(c)(2), the post-closure care period will be extended until groundwater monitoring data demonstrate that concentrations are below the groundwater protection standards in Section 845.600 and are not increasing for those constituents over background, using the statistical procedures and performance standards in Section 845.640(f) and (g), provided that concentrations have been reduced to the maximum extent feasible and concentrations are protective of human health and the environment.
40 C.F.R. § 257.104(d)(1)(i) and 35 I.A.C. 845.780(d)(1)(A) – A description of the monitoring and maintenance activities required in 40 C.F.R. § 257.104(b) and 35 I.A.C. 845.780(b), and the frequency at which these activities will be performed, to maintain the integrity and effectiveness of the final cover system, maintain the groundwater monitoring system and monitor the groundwater.	Pursuant to § 257.104(b)(1) and 35 I.A.C. 845.780(b)(1), throughout the post-closure care period, periodic visual observations of the final cover system and stormwater management system will be performed at least annually for evidence of settlement, subsidence, erosion, or other damage that may adversely affect the integrity and effectiveness of the final cover system. When practical, visual observations of the final cover will be made concurrent with groundwater monitoring activities. Noted evidence of damage, such as rills, surface cracks and settlement, will be repaired to maintain the integrity and effectiveness of the final cover system. Vegetation will be established and maintained on the final cover system, including storm drainage areas, where appropriate, to provide long-term erosion control. Established vegetation and the slope design of the final cover system will prevent potential erosion and damage that may be caused by run-on and run-off. Repair activities may include, but are not limited to, replacing and

	compacting soil cover, repairing drainage channels that have been eroded, filling in depressions with soil, regrading, and reseeding areas of failed vegetation, as necessary. Pursuant to § 257.104(b)(3) and 35 I.A.C. 845.780(b)(3), the groundwater monitoring system will be maintained, and groundwater will be monitored as required by 40 C.F.R. § 257.90 through 40 C.F.R. § 257.98 and 35 I.A.C. 845.600 through 35 I.A.C. 845.680. Monitoring wells will be inspected during each groundwater sampling event. Monitoring wells and associated instrumentation will be maintained so that they perform to the design specifications throughout the life of the monitoring program. Groundwater monitoring frequency will be at least quarterly, except as provided in 40 C.F.R. § 257.94(d) and 35 I.A.C. 845.650(b)(4).
40 C.F.R. § 257.104(d)(1)(ii) and 35 I.A.C. 845.780(d)(1)(B) – The name, address, telephone number and email address of the person or office to contact about the facility during the post-closure care period.	Kincaid Generation, LLC 6555 Sierra Drive Irving, Texas 75039 800.633.4704 ccr@dynegy.com
40 C.F.R. § 257.104(d)(1)(iii) and 35 I.A.C. 845.780(d)(1)(C) – A description of the planned uses of the property during the post-closure period.	The CCR unit is located at an operating electric generation facility. Planned uses of the property during the post-closure period are currentlyunknown, except for post-closure care of the CCR unit. Post-closure use of the property will not disturb the integrity of the final cover system or other components of the containment system, or the function of the monitoring systems unless necessary to comply with the requirements of 40 C.F.R. Part § 257, Subpart D and 35 I.A.C. Part 845. Any other disturbance will be conducted following a demonstration that it will not increase the potential threat to human health or the environment, as required by 40 C.F.R. § 257.104(d)(1)(iii) and 35 I.A.C. 845.780 (d)(1)(C). The demonstration will be certified by a qualified professional engineer and submitted to the Illinois Environmental Protection Agency (IEPA). Per 40 C.F.R. § 257.104(d)(1)(iii) notification shall be provided to the State Director that the demonstration has been placed in the operating record and on the owners or operator's publicly accessible internet site. Following closure of the CCR unit, a notation on the deed to the property, or some other instrument that is normally examined during title search, will be recorded in accordance with 40 C.F.R. § 257.102(i) and 35 I.A.C. 845.760(h). The notation will notify potential purchasers of the property that the land has been used as a CCR unit and its use is restricted under the post-closure care requirements in 40 C.F.R. § 257.104(d)(1)(iii) and 35 I.A.C. 845.780(d)(1)(C) or groundwater monitoring requirements per 35 I.A.C. 845.740(b). Within 30 days of recording the deed notation, a notification stating that the notation has been recorded will be submitted to the IEPA and placed in the facility's operating record per 35 I.A.C. 845.760(h)(3). The notification will be placed on the owner or operator's publicly accessible CCR Web site in accordance with 40 C.F.R. 40 C.F.R. § 257.107(i)(9) and 35 I.A.C. 845.810(e) and placed in the facility's operating record as required by 35 I.A.C. 845.800(d)(26) and §257.105(i)(9).

40 C.F.R. § 257.104(d)(3) and 35 I.A.C. 845.780(d)(3) - Amendments to the initial or subsequent written post-closure plan.	Pursuant to 40 C.F.R. § 257.104(d), the initial post closure care plan for the Kincaid Ash Pond was prepared on October 17, 2016. That plan is being amended pursuant to 40 C.F.R. § 257.104(d)(3)(i). This plan also serves as the initial post-closure care plan, prepared in accordance with 35 I.A.C. 845.780(d). Pursuant to § 257.104(d)(3) and 35 I.A.C. 845.780(d)(3), an operating permit modification application to amend the initial or any subsequent written post-closure care plan developed under 35 I.A.C. 845.780 (d)(1) and § 257.104(d)(1) will be submitted to IEPA. The written post-closure care plan will be amended whenever there is a change in the operation of the CCR surface impoundment that would substantially affect the written post-closure care plan in effect; or unanticipated events necessitate a revision of the written post-closure care plan, after post-closure activities have started. The written post-closure care plan will be amended at least 60 days before a planned change in the operation of the facility or CCR surface impoundment, or within 60 days after an unanticipated event requires the need to revise the existing plan. If the plan is revised after post-closure activities have started, a request to modify the operating permit, including an amended written post-closure care plan, will be submitted to the IEPA within 30 days following the triggering event.
40 C.F.R. § 257.104(d)(4) and 35 I.A.C. 845.780(d)(4) – Qualified professional engineering certification.	Certification by a qualified professional engineer will be appended to this plan and any amendment of this plan.
35 I.A.C. 845.780(e) – Termination of post-closure care	Upon completion of the post-closure period, a request to terminate post-closure care will be submitted to the IEPA. The request will include a certification by a qualified professional engineer verifying that post-closure care has been completed in accordance with the post-closure care plan specified in 35 I.A.C. 845.780(d) and the requirements of 35 I.A.C. 845.780.
40 C.F.R. § 257.104(e) and 35 I.A.C. 845.780(f) – Notification of completion of the post-closure care period.	A notification of completion of post-closure care will be prepared and placed in the facility's operating record within 30 days after IEPA approval of the request to terminate post-closure care. The notification will be placed in the facility's operating record in accordance with 35 I.A.C. 845.800(d)(31) and § 257.105(i)(13). The notification will be placed on the owner or operator's publicly accessible CCR Internet site in accordance with the requirements of § 257.107(i)(13) and 35 I.A.C. 845.810(e). The IEPA will be notified when the notification has been placed in the operating record and on the owner or operator's publicly accessible Internet site in accordance with the requirements of § 257.106(i)(13).

Certification Statement 40 C.F.R. § 257.104 (d)(4) and 35 I.A.C. 845.780(d)(4) – Amended/Initial Written Post Closure Plan for a CCR Surface Impoundment

CCR Unit: Kincaid Generation, LLC; Kincaid Power Plant; Ash Pond

I, John R. Hesemann, being a Registered Professional Engineer in good standing in the State of Illinois, do hereby certify, to the best of my knowledge, information, and belief, that the information contained in this certification has been prepared in accordance with the accepted practice of engineering. I certify, for the above referenced CCR Unit, that the information contained in the amended/initial written post closure plan, dated October 30, 2021, meets the requirements of 40 C.F.R. § 257.104 and 35 I.A.C. 845.780.

John R. Hesemann

Printed Name

9/29/2021

Date

JOHN ROBERT HESEMANN
062-058523
LICENSED PROFESSIONAL ENGINEER OF
ILLINOIS

Exp: 11/30/2021

ATTACHMENT K: CONTRACTOR TRAINING CERTIFICATION
45 ILCS 5/22.59(b)(4)

Luminant

Phil Morris
Kincaid Generation, LLC
1500 Eastport Plaza Drive
Collinsville, IL 62234

July 28, 2022

Illinois Environmental Protection Agency
DWPC – Permits MC # 15
ATTN: Part 845 Coal Combustion Residual Rule Submittal
1021 North Grand Avenue East
P.O. Box 19276
Springfield, Illinois 62794-9276

Re: 415 ILCS 5/22.59(b)(4) Certification Statement
Kincaid Power Plant Ash Pond (IEPA ID# W0218140002-01)

Dear Mr. Darin LeCrone:

For the above-referenced CCR surface impoundment and in accordance with 415 ILCS 5/22.59(b)(4), Kincaid Generation, LLC certify that all contractors, subcontractors, and installers utilized to construct, install, modify, or close a CCR surface impoundment will be participants in a training program that is approved by and registered with the US Department of Labor's Employment and Training Administration and that includes instruction in the following: erosion control, environmental remediation, operation of heavy equipment and excavation.

Sincerely,
Kincaid Generation, LLC

Phil Morris, P.E.
Senior Director, Environmental

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Kansas City, MO 64114
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