CARDINAL OPERATING COMPANY

Cardinal Power Plant

History of Construction for

Retrofitted Bottom Ash Pond of the Bottom Ash Pond Complex

Issue Purpose: For Use, Rev. 0

Issue Date: March 7, 2022

Project No.: 13770-005/006

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1 PURPOSE

In accordance with 40 CFR 257.74(c)(2) this document provides a history of construction of the newly retrofitted CCR impoundment, the retrofitted "Bottom Ash Pond," and provides updates to portions of the initial history of construction that was prepared for the former Bottom Ash Pond Complex (BAPC) at the Cardinal Power Plant. The BAPC initially consisted of two surface impoundments, the Bottom Ash Pond (North Pond) and the Recirculation Pond (South Pond), which were interconnected and managed as a single CCR unit. The initial history of construction for the BAPC was completed and uploaded to the Plant Operating Record on October 16, 2016.

In August 2021, Cardinal initiated retrofit on the South Pond of the BAPC by removing all CCR and installing a CCR-compliant liner system. Upon completion of the retrofit, the South Pond will continue to receive bottom ash in accordance with 40 CFR 257.102(k), and the name is changed from the former "Recirculation Pond" to the retrofitted "Bottom Ash Pond."

The initial history of construction is included herein as Exhibit A. Additionally, the Ohio EPA Permit to Install (PTI) design drawings, specifications, and as-built drawings from the retrofit activities of the South Pond are included herein as Exhibits B, C, and D, respectively. Finally, the hydrology and hydraulics analysis and an updated sketch showing the instrumentation for the retrofitted "Bottom Ash Pond" are included herein as Exhibit E and F, respectively.

2 APPLICABLE CCR REGULATION

To update the initial history of construction for the BAPC, the following excerpts from 40 CFR Part 257 Subpart D (Federal CCR Rule) are applicable:

- **§257.74(c):**
  "(1) No later than the initial receipt of CCR in the CCR unit, the owner or operator unit must compile the design and construction plans for the CCR unit, which must include, to the extent feasible, the information specified in paragraphs (c)(1)(i) through (xi) of this section.
  (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.
  (ii) The location of the CCR unit identified on the most recent U.S. Geological Survey (USGS) 7½ minute or 15 minute topographic quadrangle map, or a topographic map of equivalent scale if a USGS map is not available.
  (iii) A statement of the purpose for which the CCR unit is being used.
  (iv) The name and size in acres of the watershed within which the CCR unit is located.
  (v) A description of the physical and engineering properties of the foundation and abutment materials on which the CCR unit is constructed.
  (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 dates of construction of each successive stage of construction of the CCR unit.
  (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.

(viii) A description of the type, purpose, and location of existing instrumentation.
(ix) Area-capacity curves for the CCR unit.
(x) A description of each spillway and diversion design features and capacities and calculations used in their determination.
(xi) The construction specifications and provisions for surveillance, maintenance, and repair of the CCR unit.
(xii) Any record or knowledge of structural instability of the CCR unit.

(2) Changes in the design and construction. If there is a significant change to any information compiled 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)(13)."

3 SUMMARY OF OWNERSHIP

Federal CCR Rule Reference: 40 CFR 257.74(c)(1)(i)

The summary of ownership has not changed since the initial history of construction. See Section 3.0 of Exhibit A.

4 LOCATION OF THE CCR UNIT

Federal CCR Rule Reference: 40 CFR 257.74(c)(1)(ii)

The location of the retrofitted Bottom Ash Pond is now in the location of the former BAPC Recirculation Pond (i.e., South Pond).

Figure 1 – Aerial View of the Cardinal Power Plant Bottom Ash Complex

5 STATEMENT OF PURPOSE

Federal CCR Rule Reference: 40 CFR 257.74(c)(1)(iii)

The retrofitted Bottom Ash Pond is utilized for the collection, storage, and removal of bottom ash from process sluice water. The bottom ash is discharged into the south west portion of the pond through six bottom ash transport water (BATW) pipes, two for each unit. Upon entering the pond, the larger bottom ash particles settle to the bottom of the pond closer to the discharge lines while the finer bottom ash particles require more time and distance to settle out. The bottom of the pond is designed with a layer of either concrete (near the discharge location) or riprap (farther away) to protect the pond's CCR Rule-compliant liner from the anticipated dredging activities. Once bottom ash is removed from the retrofitted Bottom Ash Pond, the material is subsequently hauled and disposed of in the Station's onsite permitted landfill. The water in the retrofitted Bottom Ash Pond is recirculated back to the station through the Recirculation Pump House and reused in the bottom ash sluicing system.

6 NAME AND SIZE OF WATERSHED

Federal CCR Rule Reference: 40 CFR 257.74(c)(1)(iv)

The watershed for the retrofitted Bottom Ash Pond has not changed since the initial history of construction. See Section 6.0 in Exhibit A.

The retrofitted Bottom Ash Pond is comprised of diked embankments on three sides which directs stormwater away from the impoundment and limits runoff to that which falls directly on the pond surface. The area of the pond is approximately 7.1 acres. The pond only receives BATW flows from the station. The only stormwater that enters the pond is the direct precipitation falling on the pond and its dikes, no other collection areas drain into the retrofitted Bottom Ash Pond.

7 DESCRIPTION OF THE FOUNDATION AND ABUTMENT MATERIALS

Federal CCR Rule Reference: 40 CFR 257.74(c)(1)(v)

The foundation materials remain unchanged since the initial history of construction. See Section 7.0 of Exhibit A.

8 DESCRIPTION OF EACH CONSTRUCTED ZONE OR STAGE OF THE CCR UNIT

Federal CCR Rule Reference: 40 CFR 257.74(c)(1)(vi)

The description of each constructed zone or stage of the CCR unit as conveyed in the initial history of construction remains valid; however, in 2021 and 2022, after the complete removal of CCR and CCR-mixed material from within the pond, a new CCR Rule-compliant composite liner system was installed in accordance with 40 CFR 257.72(a). A geosynthetic clay liner (GCL) was installed upon a prepared subgrade, followed by a 60 mil HDPE black and textured geomembrane. An 8 oz/sy non-woven geotextile was installed above the geomembrane followed by varying layers of stone and riprap or concrete protective layers depending on the anticipated frequency of dredging within the pond. The deepest part of the retrofitted pond is at an approximate elevation of 655.00’ at the top of the protective layer near the Recirculating Pumphouse.

9 DETAILED DIMENSIONAL DRAWINGS OF THE CCR UNIT

Federal CCR Rule Reference: 40 CFR 257.73(c)(1)(vii)

As part of the Bottom Ash Pond retrofit, the original spillway located at the south end of the South Pond was entirely removed. The pond does not have a spillway to the Ohio River and instead is designed to retain all stormwater and process water during large storm events and recirculate that water to the operating units or for use as blowdown water to the FGD system.

Engineering drawings showing the pond structures and appurtenances prior to the pond retrofit can be found in Attachment C of Exhibit A. Ohio EPA PTI design drawings, technical specifications, and construction as-builts from the Bottom Ash Closure and Lining Project are included herein as Exhibits B, C, and D.

The table below provides the normal operating water level and maximum water level considering a 50% PMP storm based on the Ohio State Requirements. The hydrology and hydraulic analysis for the retrofitted Bottom Ash Pond is included herein as Exhibit E.

	Retrofitted Bottom Ash Pond
Normal operating water level	664
Maximum water level following peak discharge from inflow design flood	666.16
Expected maximum depth of CCR within impoundment	13 ft

At the current maximum operating level, the pond capacity is sufficient to contain the entire design storm with additional freeboard.

10 EXISTING INSTRUMENTATION

Federal CCR Rule Reference: 40 CFR 257.74(c)(1)(viii)

Minor modifications to the instrumentation program have been implemented for the retrofitted pond since the initial history of construction. This includes the installation of three additional monitoring wells and continued monitoring of two open stand pipe piezometers to monitor the buildup of pore pressure to evaluate embankment stability. Additionally, a trench drain was installed during construction to capture seepage from entering the pond.

An updated sketch showing the retrofitted Bottom Ash Pond instrumentation is provided in Exhibit F.

11 AREA-CAPACITY CURVES

Federal CCR Rule Reference: 40 CFR 257.74(c)(1)(ix)

The figure below shows the area capacity curves for the retrofitted Bottom Ash Pond.

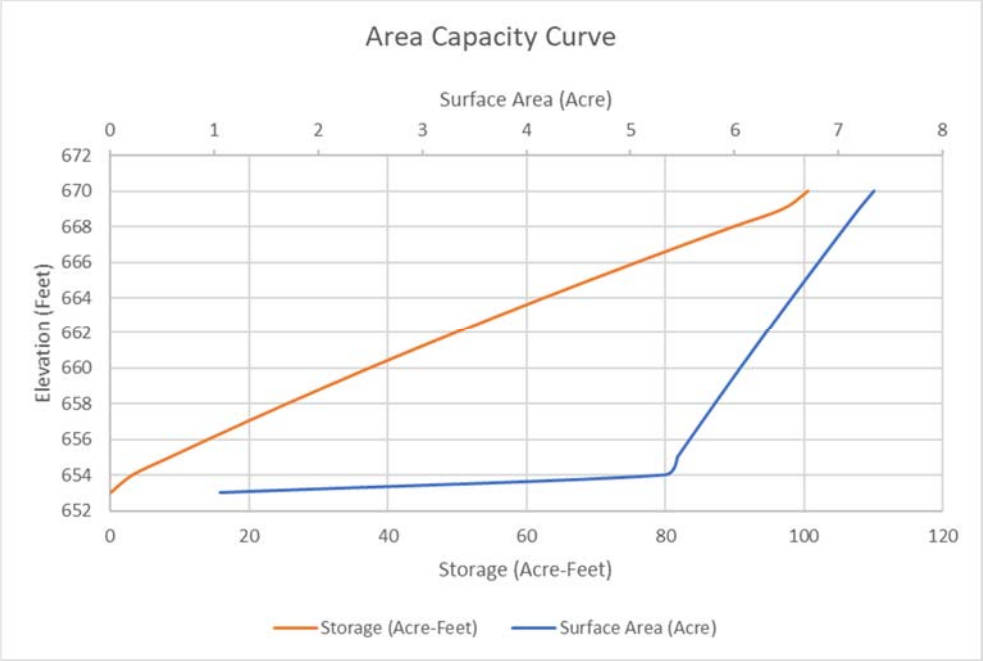

Figure 2 – Area-Capacity Curve for the retrofitted Bottom Ash Pond

12 SPILLWAYS AND DIVERSION DESIGN FEATURES

Federal CCR Rule Reference: 40 CFR 257.74(c)(1)(x)

There are no spillway or diversions present for the retrofitted Bottom Ash Pond. Bottom ash transport water is the only process water inflow, and the Recirculation Pumphouse serves as the only outlet from the pond. The Ohio EPA PTI design drawings are included within Exhibit B.

13 CONSTRUCTION SPECIFICATIONS AND PROVISIONS FOR SURVEILANCE, MAINTENANCE AND REPAIR

Federal CCR Rule Reference: 40 CFR 257.74(c)(1)(xi)

Ohio EPA PTI construction specifications are presented in Exhibit C. As required by the CCR Rule, the Bottom Ash Pond will be inspected at least every 7 days by a qualified person and instrumentation is read on a 30-day basis. Additionally, the impoundment is annually inspected by a professional engineer.

Maintenance and repair to the Bottom Ash Pond will follow Ohio Dam Safety (OAC 1501:21-15-06) rules and the Facility Operation, Maintenance and Inspection Manual presented in Exhibit A.

14 RECORD OR KNOWLEDGE OF STRUCTURAL INSTABILITY

Federal CCR Rule Reference: 40 CFR 257.73(c)(1)(xii)

To date, there has been no record or knowledge of structural instability of the retrofitted Bottom Ash Pond.

EXHIBIT A

History of Construction for the Bottom Ash Pond Complex, Dated September 2016

HISTORY OF CONSTRUCTION

CFR 257.73(c)(1)

Bottom Ash Pond Complex
Cardinal Plant
Brilliant, Ohio

September, 2016

Prepared for: Cardinal Operating Company - Cardinal Plant

Brilliant, Ohio

Prepared by: Geotechnical Engineering Services

American Electric Power Service Corporation

1 Riverside Plaza

Columbus, OH 43215

GERS-16-066

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Attachments

1.0 OBJECTIVE

This report was prepared by AEP- Geotechnical Engineering Services (GES) section to fulfill requirements of CFR 257.73(c)(1) with an evaluation of the facility.

2.0 DESCRIPTION OF CCR THE IMPOUNDMENT

The Cardinal Power Plant in Wells Township, Jefferson County, near the town of Brilliant in eastern Ohio. The Cardinal Power Plant is owned by Buckeye Power and AEP Generation Resources (GENCO) a unit of American Electric Power. is operated by Cardinal Operating Company. The facility operates two surface impoundments for storing CCR; the Bottom Ash Pond (BAP) Complex and Cardinal Fly Ash Reservoir II (FAR II) Dam. The focus of this report is the Bottom Ash Pond Complex.

The BAP complex is comprised of diked embankments on the east and west sides while the north and south sides of the BAP are incised. The complex consists of two separate ponds, the larger bottom ash pond and the smaller recirculation pond. The entire crest length is just over a mile, and the nominal crest width is 20 feet. The north end of the pond has been partially filled in with ash and the exact limits of the pond are poorly defined.

The pond complex was originally developed as part of the construction of Units 1 and 2 in the 1960s. The crest of the dikes forming the original pond was at El. 658.0. However, the pond complex was raised to a crest elevation of 970.0 and extensively modified in 1974 as part of the construction of Unit 3.

3.0 SUMMARY OF OWNERSHIP 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.]

The Cardinal Power Plant is located at 306 County Road 7 East, Brilliant, OH, 43913 County, near the town of Brilliant, Jefferson County, Ohio. It is owned by Buckeye Power and AEP Generation Resources (GENCO) and operated by Cardinal Operating Company. The facility operates the BAP complex dam, ODNR# 0105-004.

4.0 LOCATION OF THE CCR UNIT 257.73 (c)(1)(ii)

[The location of the CCR unit identified on the most recent U.S. Geological Survey (USGS) 7 ½ minute or 15 minute topographic quadrangle map, or a topographic map of equivalent scale if a USGS map is not available.]

A location map is included in Attachment A.

5.0 STATEMENT OF PURPOSE 257.73 (c)(1)(iii)

[A statement of the purpose for which the CCR unit is being used.]

The bottom ash pond complex consists of two components: the bottom ash pond and the recirculation pond (RCP). The bottom ash pond complex is utilized for the storage and collection of bottom ash, Bottom ash-laden water and other storm water is discharged via thirteen (13) pipes into the northwest corner of the bottom ash pond, the coarse bottom ash settles out closer to the discharge lines while the finer bottom ash settles out at farther locations within the pond. The water in the RCP is used to sluice the fly ash from the plant to FAR II via the pump station.

6.0 NAME AND SIZE OF WATERSHED THE CCR UNIT IS LOCATED 257.73 (c)(1)(iv)

[The name and size in acres of the watershed within which the CCR unit is located.]

The Cardinal BAP Complex is located within the Upper Ohio-Wheeling Water Shed (HUC 05030106) which is approximately 1,517.0 square miles (970,876 acres) (USGS).

The Cardinal Bottom Ash Complex is comprised of diked embankments on three sides which directs storm water away from the impoundment and limits runoff to that which falls directly on the pond surface. The area of the pond is approximately 24.3 acres. The pond also receives pumped inflow from plant facilities and stormwater collection areas.

7.0 DESCRIPTION OF THE FOUNDATION AND ABUTMENT MATERIALS 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 located.]

The geotechnical reports in Attachment B provide the specific properties of the foundation materials. The original ground surface at the site is generally located between El. 645 and 655. Near surface soils generally consist of a layer of alluvium silt, clay and fine sand (organic in some locations) over glacial outwash deposits of variable thickness overlying the bedrock surface. The alluvium clays and silts were deposited in the backwater of the Ohio River, while the outwash materials typically consist of sand, gravel and silt deposits deposited during the last ice age. Based on geological literature, the glacial outwash extends to the bedrock surface, estimated to be roughly 50 to 60 feet below the natural ground surface at the pond. The upper most bedrock consists of shale and/or sandstone belonging to the Conemaugh Group of Pennsylvanian Age. The soils were screened for liquefaction potential and found to be non-liquefiable. The geotechnical reports in Attachment B include the screening calculations.

Based on the historical cross-sections extending through both the Bottom Ash Pond and the Recirculation Pond from the vertical expansion, the original ash pond embankments along the Ohio River ranged in height from 4 to 6 feet above the bottom of the ash pond.

A subsurface investigation was conducted in 2009 and the strength parameters of the foundation as well as the embankment were defined based on laboratory tests or correlations to known strengths based on blow counts. Table 1 lists the material properties for the foundation material. The geotechnical reports in Attachment B also provide the specific properties of the foundation materials.

Table 1 Strength Parameters for main Natural/constructed zones.

Layer	γ_m	c'	φ'
	pcf	psf	degrees
Newer Embankment Fill	125	0	31
Original Embankment Fill	125	100	30
Alluvium Silt/Clay	125	0	30
Organic Clayey Silt	125	0	30
Loose Glacial Outwash Sand/Gravel	115	0	29
MDe Glacial Outwash Sand/Gravel	120	0	34

8.0 DESCRIPTION OF EACH CONSTRUCTED ZONE OR STAGE OF THE CCR UNIT 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; and the approximate dates of construction of each successive stage of construction of the CCR unit.]

The BAP complex embankments have maximum height of approximately 25 feet and are constructed of compacted clay on a slope ranging from 2.5:1 (2.5 feet horizontal, 1 foot vertical). The elevation at the top of the embankment around the perimeter of the BAP is approximately 670 feet msl, and the normal operating level is approximately 665 feet msl. The embankment fill materials dike ranged from hard silty Clay to fine and coarse gravel, overlying native material. The interior bottom elevation of the BAP Complex is approximately 645 feet msl.

The pond complex was originally developed as part of the construction of Units 1 and 2 in the 1960s. The crest of the dikes forming the original pond was at El. 658.0. However, the pond complex was raised to a crest elevation of 970.0 and extensively modified in 1974 as part of the construction of Unit 3.

Figure 1 details original embankment and the vertical expansion of the embankment.

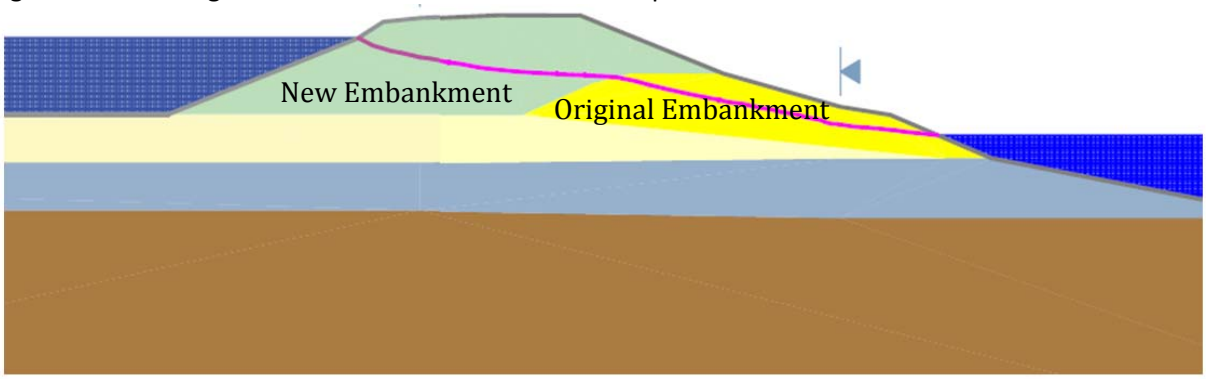


Figure 1. Original grades and subsequent raising.

Table 1 lists the material properties for the material used in the construction of the original and the newer embankment. The geotechnical reports in Attachment B also provide the specific properties of the embankment materials.

9.0 ENGINEERING STRUCTURES AND APPURTENANCES, 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…]

The outlet works for the Bottom Ash Pond is located at southeast side of the bottom ash pond consists of a drop inlet spillway structure with slide gates. The gates are 4 feet in length. A 36-inch outlet pipe conveys the water through the divider dike and into the Recirculation Pond. According to the field survey, the elevation of the top of the current slide gate is 665.20.

Discharge to the Ohio River is through a principal spillway located at the south end of the recirculation pond (a drop outlet and a 36”-pipe). During normal operation, there is no discharge to the river;

rather all flows are re-circulated into the plant via the pump station located on the west side of the re-circulation pond.

The engineering drawings of the engineering structures and appurtenances are included in Attachment C.

10.0 SUMMARY OF POOL SURFACE ELEVATIONS, AND MAXIMUM DEPTH OF CCR, 257.73 (c)(1)(vii)

[…in addition to the normal operating pool surface elevation and the maximum pool elevation following peak discharge from the inflow design flood, the expected maximum depth of CCR within the CCR surface impoundment.]

The Bottom Ash Pond Complex is regulated by ODNR and is identified as a Class II dam, and as such, must safely pass 50% of the Probable Maximum Flood (PMF) in accordance with OAC Rule 1501:21-13-02.

The table below describes the normal pool elevations and maximum pool elevations as well as maximum depth of CCR within the impoundment. The maximum pool elevation have been determined based on the 50% PMP storm analysis based on the Ohio State Requirements. Complete results of the hydrology and hydraulic analysis are included in the Addendum to Bottom Ash Pond Investigation Report by S&ME, December, 2010 in Attachment E.

	Bottom Ash Pond	**Clearwater Pond**
Normal Pool Elevation	665	664.5
Maximum Pool Elevation following peak discharge from inflow design flood	668.1	668.1
Expected Maximum depth of CCR within impoundment	15 ft	0

11.0 FEATURES THAT COULD ADVERSELY AFFECT OPERATION DUE TO MALFUNCTION OR MIS-OPERATION (257.73 (c)(1)(vii))

[…and any identifiable natural or manmade features that could adversely affect operations of the CCR unit due to malfunction or mis-operation]

In the event of malfunction or mis-operation of any of the pond's appurtenances the ponds operations could be adversely affected. These structures include service spillway, weir structures and influent sluicing piping and associated structures. See design drawings in Attachment C for location and details of all appurtenances.

During an extreme flood event, natural debris may collect along the outlet to the service spillway. However, the spillway complete blockage would not be an expected condition. In addition, at the current operating level, the pond capacity is sufficient to contain the entire design storm.

12.0 DESCRIPTION OF THE TYPE, PURPOSE AND LOCATION OF EXISTING INSTRUMENTATION 257.73 (c)(1)(viii)

[A description of the type, purpose, and location of existing instrumentation.]

The instrumentation program for the BAP complex consists of five (5) open stand pipe piezometers. The location of the instruments is shown in plan in Plate 1 drawing (Attachment D). Two out of the five piezometers were originally installed to monitor the phreatic surface in the eastern and the western embankments. Three out of the five piezometers were installed during the 2009 investigation to monitor the phreatic surface in the eastern embankment 2 at the crest and one at the toe of the slope.

The piezometers are read on 30 days basis. This information is used to monitor the buildup of pore pressure during and after construction and to evaluate the embankment stability in terms of effective stresses.

13.0 AREA – CAPACITY CURVES FOR THE CCR UNIT 257.73 (c)(1)(ix)

[Area-capacity curves for the CCR unit.]

Figure 5 shows the area capacity curves for the Cardinal BAP Complex and is included in the Hydrology and Hydraulic Analysis in the Cardinal Generating Plant Addendum to Bottom Ash Pond Investigation Report by SM&E, December, 2010 in Attachment E.

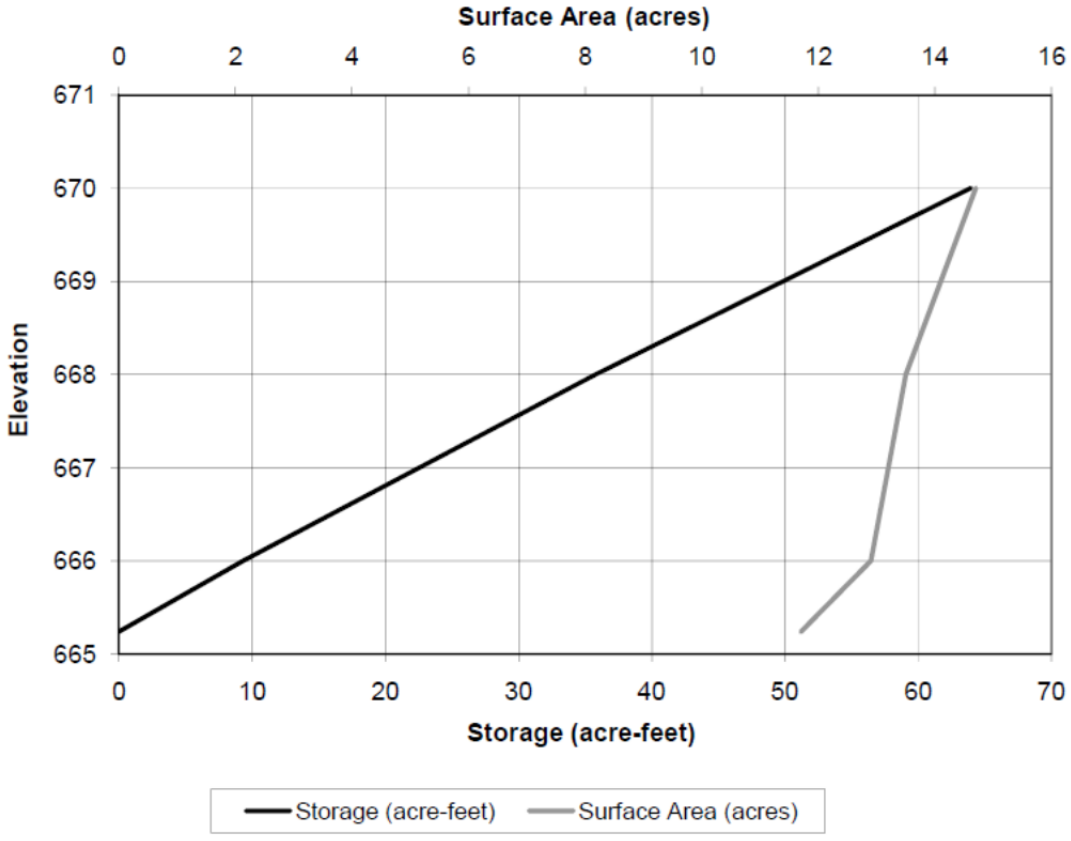


Figure 5. Capacity curves the BAP Complex.

14.0 DESCRIPTION OF EACH SPILLWAY AND DIVERSION 257.73 (c)(1)(x)

[A description of each spillway and diversion design features and capacities and calculations used in their determination.]

The outlet works for the Bottom Ash Pond consists of a drop inlet spillway structure with slide gates. The gates are 4 feet in length. A 36-inch outlet pipe conveys the water to the Recirculation Pond. The elevation of the top of the current slide gate is 665.24 according to the field survey. Complete details of each spillway structure are included with the design drawings in Attachment C. Hydrology and Hydraulic Analysis which include calculations for each spillway structure are included in Attachment E.

There are no diversions present for this facility.

15.0 SUMMARY CONSTRUCTION SPECIFICATIONS AND PROVISIONS FOR SURVEILLANCE, MAINTENANCE AND REPAIR 257.73 (c)(1)(xi)

[The construction specifications and provisions for surveillance, maintenance, and repair of the CCR unit.]

Original and the raising construction specifications are not existent, however the site investigation report included in Attachment B.

As required by the CCR rules the BAP complex is inspected at least every 7 days by a qualified person. Also as a requirement of the CCR rules the impoundment is also inspected annually by a professional engineer.

An impoundment maintenance plan is provided in Attachment F. If repairs are found to be necessary during any inspection they will be completed as needed.

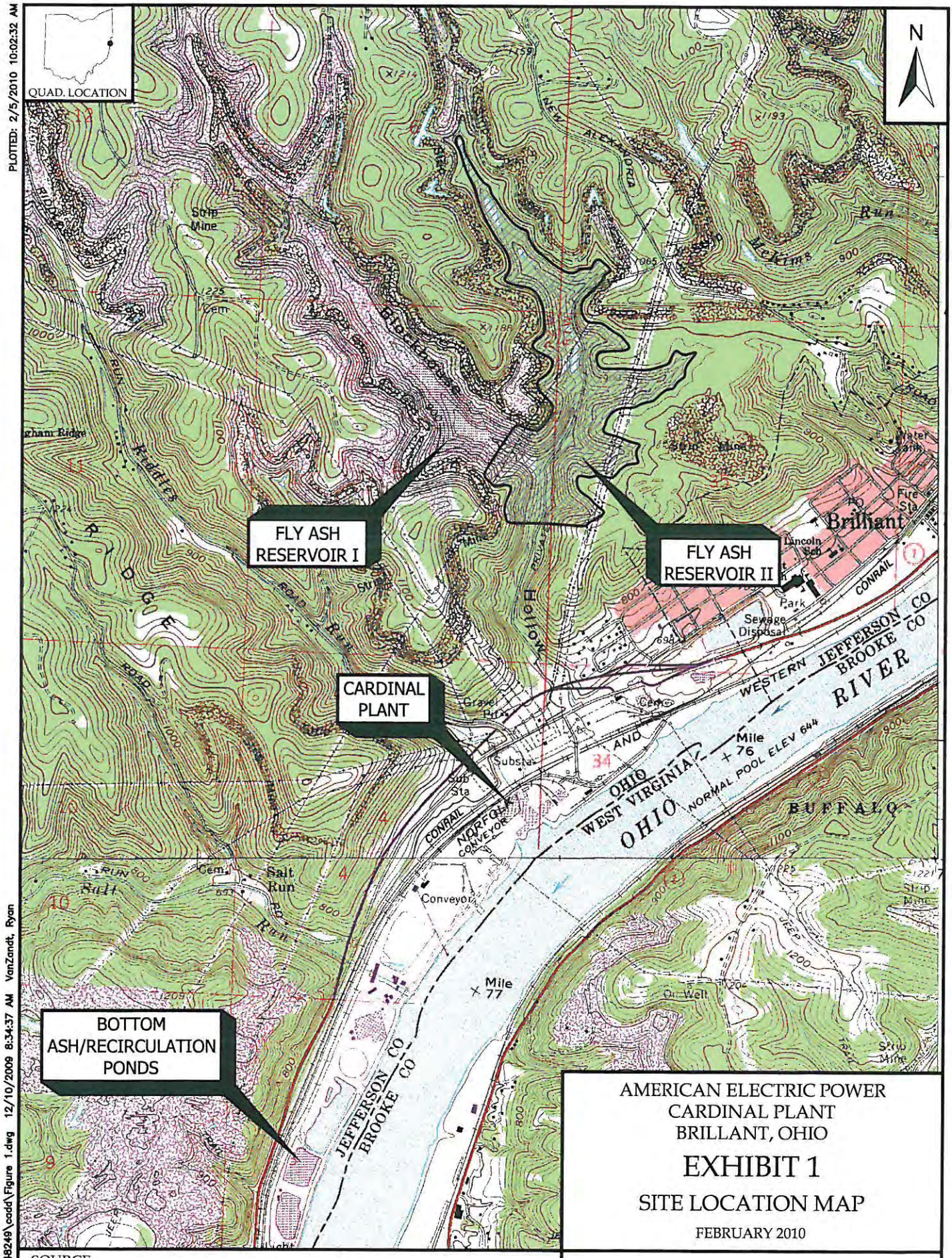
16.0 RECORD OR KNOWLEDGE OF STRUCTURAL INSTABILITY 257.73 (c)(1)(xii)

[Any record or knowledge of the structural instability of the CCR unit.]

To date there has been no record or knowledge of any structural instability of the CCR unit.

ATTACHMENT A

LOCATION MAP



AMERICAN ELECTRIC POWER
CARDINAL PLANT
BRILLANT, OHIO

EXHIBIT 1

SITE LOCATION MAP

FEBRUARY 2010

SOURCE:
7.5 MINUTE TILTONSVILLE, OHIO U.S.G.S. QUADRANGLE MAP

PLOTTED: 2/5/2010 10:02:32 AM
P:\PR48249\cadd\Figure 1.dwg 12/10/2009 8:34:37 AM VanZandt, Ryan

ATTACHMENT B

DESIGN REPORTS

Bottom Ash Pond
Initial Safety Factor Assessment
Cardinal Power Plant
Brilliant, Ohio
S&ME Project No. 7217-15-007A

Prepared for:
American Electric Power
1 Riverside Plaza, 22nd Floor
Columbus, Ohio 43215

Prepared by:
S&ME, Inc.
6190 Enterprise Court
Dublin, OH 43016

December 30, 2015

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Appendices

1.0 Introduction

1.1 Background

In April of 2015, the US EPA formally published national regulations for disposal of coal combustion residuals (CCR) from electric facilities. As part of the rule, the owner or operator of the CCR unit must obtain a certification from a qualified professional engineer stating that aspects of the CCR impoundments are in accordance with the rules. Based on our understanding of the Request for Fee Estimate received from AEP on April 29, 2015, AEP specifically requested P.E. certification to fulfill the requirements of 40 CFR § 257.73(e), *Periodic Safety Factor Assessments*. In the employment of BBC&M Engineering, Inc., the undersigned engineers conducted site investigations at the bottom ash pond in 2009 and 2010. Due to our familiarity with the site, S&ME was selected to perform the Safety Factor Assessment for this facility. S&ME understands that certification and/or documentation for other structural integrity criteria will be performed by AEP or other consultants.

1.2 Location and Geologic Conditions

The Cardinal Generating Plant is located along the Ohio River between Brilliant, Ohio and Tiltonsville, Ohio. The Bottom Ash Pond Complex is located along the west bank of the river just to the south of the Unit 3 area. The Bottom Ash Complex consists of two components: the Bottom Ash Pond and the Recirculation Pond. The Bottom Ash Pond is located north of the Recirculation Pond and they are separated by an earthen embankment. The crest elevation for all of the embankments has a minimum Elevation of 670 feet. The total length of the exterior embankment along the Ohio River is approximately 2,000 feet. Based on the current topography around the bottom ash complex, there is no discernable embankment on the north and south ends, thus the areas of the pond embankments are typically identified by referencing the eastern or western embankments. The bottom ash pond is operated at a constant Elevation of 664.5 feet. For comparison, the normal pool for this stretch of the Ohio River is EL. 644, as controlled by the Pike Island Dam Both ponds are isolated from exterior surface water inflow and during normal operation, all water that enters the pond is pumped back to the plant via the pump station located within the Recirculation Pond. The exception is during high rainfall events where the principal spillway may activate releasing water into the Ohio River through an NPDES outfall. The discharge is controlled by a 4-foot wide weir surveyed at Elevation 666.2. A review of the historical plans available for the bottom ash pond facility is included in Appendix V.

The original ground surface at the site is generally located between El. 645 and 655. Near surface soils generally consist of a layer of alluvium silt, clay and fine sand (organic in some locations) over glacial outwash deposits of variable thickness overlying the bedrock surface. The alluvium clays and silts were deposited in the backwater of the Ohio River, while the outwash materials typically consist of sand, gravel and silt deposits deposited during the last ice age. Based on geological literature, the glacial outwash extends to the bedrock surface, estimated to be roughly 50 to 60 feet below the natural ground surface at the pond. The upper most bedrock most likely consists of shale and/or sandstone belonging to the Conemaugh Group of Pennsylvanian Age.

Figure 1-1 – Cardinal Plant

1.3 Previous Investigations

In 2009, the undersigned engineers, when in the employment of BBC&M Engineering, Inc., completed a subsurface investigation and geotechnical assessment of the bottom ash pond embankments. The assessment, dated August 4, 2009, concluded that the embankment exhibited adequate factors of safety against slope failure under steady-state seepage and seismic loading conditions relative to typical US Army Corps of Engineers requirements. In 2010, BBC&M Engineering, Inc. performed additional geotechnical analyses and an hydrology and hydraulic evaluation of the pond. As part of this work, additional slope stability failure modes were examined, including the maximum surcharge pool and rapid drawdown load cases. A report documenting the additional geotechnical analysis, dated December 17, 2010, was submitted as an addendum to the 2009 report. The text from the 2009 report and an excerpt from the 2010 follow-up report is Appendices V and VI.

2.0 Scope of Work

In accordance with AEP's request, the following work items were performed by S&ME:

1. S&ME completed a cursory review of previously conducted assessment work performed by the undersigned engineers, as well as a limited number of construction documents made available by AEP.

2. S&ME visited the site along with personnel from AEP. The site visit was not a formal inspection, but rather served to document any significant modifications or changed conditions that may have taken place since the time of the previous investigations.

3. Upon completing Tasks 1 and 2, S&ME determined that there was insufficient information to certify the structural integrity of the surface impoundment in accordance with the requirements of 40 CFR § 257.73(e). To this end, S&ME was authorized to perform a supplemental investigation to support the safety factor assessment. Details regarding the investigation are described in the following sections of this report.

3.0 Information Review and Site Visit

S&ME conducted a cursory review of previous documents relating to the bottom ash pond and conducted a site visit at the facility. AEP provided S&ME with the following documents:

- Site Development Plan 1973 (Dwg. 3-3017-5 and 3-3027-3)
- Assessment of Dam Safety Final Report, Clough Harbour, & Assoc., December, 2009
- Bottom Ash Pond Subsurface Investigation & Analysis, BBC&M Engineering, Inc., August, 2009
- Addendum to Bottom Ash Pond Investigation, BBC&M Engineering, Inc., December, 2010

On August 18, 2015, the undersigned S&ME personnel met with Dr. Mohammad Ajlouni (AEP Civil Engineering) and Mr. Randy Sims (Landfill Operations) at the Cardinal Plant and conducted a site visit at the bottom ash pond. The participants discussed and observed the operations of the bottom ash and recirculation ponds, including the hydraulic structures within the ponds. During our visit, two localized possible seepage areas were observed on the outboard slope of the eastern embankment of the recirculation pond. Based on discussions with the group, it was believed that the seepage areas were relatively new.

One apparent seepage area was located immediately north of the existing riprap and the other was approximately 300 feet north of the riprap. The limits of the possible seepage areas were delineated with a handheld GPS unit. The apparent seepage areas range from 35 to 50 feet wide by 6 to 8 feet high. The seepage areas were observed to be wetter than the surrounding area and were muddy in some areas, which may be a result of mowing operations. While the ground surface has been softened as a result of seepage, there was no indication of flowing water emanating at either of the areas at the time of our visit. Additionally there was no indication of piping of soil. S&ME understands the riprap on the outboard slope of the recirculation pond to the south of the new seepage area was constructed as an inverted filter; similar seepage conditions were observed in this area resulting in construction of the filter. Based on the historical drawings, the embankments do not contain any internal drains to intercept/control the phreatic

surface within the embankment. Despite this, S&ME understands the embankments have otherwise performed well, particularly in regard to shallow sloughs along the outboard slope of the 41 years that they have been in service in the current configuration.

While no other visual observations suggested dam safety concerns, S&ME noted the following modifications to the bottom ash pond complex since the 2009 and 2010 assessments:

- The northern section of the western bottom ash pond embankment was widened on the outboard side to create additional space for construction staging.
- Crest improvements were made to raise low areas and establish a consistent top of dam Elevation of 670 feet.
- The 2009 investigation focused only on the river side embankment. Although the river side embankment is significantly taller than the west embankment, investigation of the west embankment was believed to be warranted.

4.0 Field and Laboratory Work

As part of the 2009 investigation, 7 soil borings were performed along the eastern embankment of the bottom ash pond and recirculation pond. For the 2015 supplemental investigation, S&ME performed 4 soil borings along the western embankments, as well as two additional shallow borings through the eastern embankment crest upstream from the identified seepage areas. The borings are designated as CD-BAP-1501 through B-1505 and MW-BAP-4 through MW-BAP-5. Boring CD-BAP-1503, originally planned to be located at the toe of the west embankment could not be accessed and was not performed. Boring numbers with 'MW' indicate a monitoring well was installed at this location, which were performed as part of a separate hydrogeology study. Additionally, S&ME installed three other monitoring wells, designated MW-BAP-1 through MW-BAP-3, and advanced one soil boring designated CD-BAP-1506 as part of the separate hydrogeology study at the bottom ash pond facility. Although not performed as part of this factor of safety assessment, the results from these explorations were considered in developing our understanding of the embankments and foundation soils. Locations of all explorations are shown on the Plan of Borings included as Drawing No. 1 in Appendix I.

Laboratory testing was performed on selected representative soil samples obtained during the field investigations to determine natural moisture content (ASTM D2216), liquid and plastic limits (S&ME adjustment to ASTM D4318), and grain size analyses (ASTM D422). The results of these and other tests permit an evaluation of the strength, compressibility and permeability characteristics of the soils encountered at this site.

The results of the moisture content testing and of the liquid and plastic limits are graphically displayed on the individual boring logs presented in Appendix I. All laboratory test results, including a summary of laboratory test results and grain size analyses are presented in Appendix II.

5.0 Subsurface Conditions

5.1 Stratigraphy

Borings CD-BAP-1501,CD-BAP-1502, and MW-BAP-5 were performed from the crest of the western embankment, while Boring MW-BAP-4 was performed from the toe of the western embankment. Based on the descriptions of the samples recovered in the borings and laboratory testing, the subsurface stratigraphy for each section can generally be described in descending order from the top of the western embankment as follows:

- Borings CD-BAP-1502 and MW-BAP-5 were performed from the crest of the embankment encountered 15 inches of aggregate at the ground surface overlying 10 to 13 feet of embankment fill consisting of medium-dense to dense find to coarse sand and gravel and hard clayey silt. SPT N-values (corrected for 60% energy) ranged from 13 to 60 while hand penetrometer measurements on samples exhibiting cohesion ranged from __ to 4.5+ tons per square foot (tsf).
- Boring CD-BAP-1501 was performed from the widened crest area. The boring encountered 15 inches aggregate underlain by 11.5 feet of embankment fill consisting of a thin stratum of medium-stiff clayey silt over of loose to medium dense fine to coarse sand.
- Underlying the embankments, the borings encountered alluvial soils consisting of

Borings CD-BAP-1504 and CD-BAP-1505 were performed from the crest of the eastern embankment adjacent to the observed seepage areas. The main purpose of these boring was to identify potential anomalies within the embankments that would suggest a unique circumstance which could be contributing to the observed seepage. Both borings were advanced to a depth of 16 feet within the embankment fill. For reference, the seepage areas were observed to begin approximately 6 to 8 feet below the crest. These borings, along with results from the sampling from monitoring wells MW-BAP-1, MW-BAP-2 and MW-BAP-3 did not reveal any appreciable differences from the crest borings performed during the 2009 investigation, such as a layer or zone of clean sand, as the embankment fill was already known to contain soils of a varying degree.

The stratigraphy of the eastern embankments is summarized in the text from the 2009 Investigation included as Appendix V.

5.2 Groundwater Conditions

Groundwater observations were made as each boring was being advanced and measurements were made at the completion of drilling. The groundwater observations are graphically displayed on the boring logs and also noted at the bottom of the log, and are referenced from the ground surface. Groundwater was encountered within the crest borings at a depth of approximately 15 feet. Groundwater in Boring MW-BAP-4 was encountered at a depth of 5.5 feet. The groundwater readings correlate to an approximate Elevation of 655 feet.

Temporary open standpipe piezometers were installed in Borings CD-BAP-1504 and CD-BAP-1505 to obtain groundwater information in relation to the observed seepage area. Unfortunately, owing to the presence of overhead electric along the outboard side of the crest, the borings had to be performed near the inboard side of the crest. Several longer term groundwater readings were taken during the course of

the field work. The readings are summarized on the individual well logs, and generally range between Elevation 661 and Elevation 663. The readings indicate a small decrease in water level from the recirculation pond operating pool. It should be noted that all of the wells positioned within the crest are located on the inboard side to avoid blocking the road as well as the overhead power lines.

5.3 Shear Strength and Permeability

The laboratory testing results for the 2015 investigation were compared to laboratory testing completed as part of the 2009 investigation. The comparison of the index testing was performed to determine if there was any justification for developing different shear strength and permeability values for the subsurface materials encountered in the western side of the complex than had been previously been estimated for cross-sections on the eastern side in 2009. As the results of the 2009 laboratory index testing are very similar to the new index testing results, S&ME is of the opinion that the strength parameters used to characterize the eastern embankment and foundation soils in 2009 are applicable to the supplemental investigation of the western embankment and foundation soils.

The shear strength parameters used in the slope stability analysis are shown in Table 5-1.

Table 5-1 – Shear Strength Parameters

Material Description	γ_{wet} *(pcf)*	*Effective*		*Reference*
		ϕ'	c′ (psf)	
Newer Embankment Fill	125	31°	0	SPT and Index Testing Correlations
Original Embankment Fill	125	30°	100	Index Testing Correlations
Alluvium Silt and Clay	125	30°	0	Index Testing Correlations
Organic Clayey Silt	125	30°	0	Index Testing Correlations and CU Triaxial Test (BBCM 2009)
Very Loose to Loose Glacial Outwash Sand and Gravel	115	29°	0	SPT and Grain Size Correlations
Medium Dense Glacial Outwash Sand and Gravel	120	34°	0	SPT and Grain Size Correlations
Granular Embankment Fill[(1)]	115	30°	0	SPT and Grain Size Correlations

[(1)]Applies only to widened crest area on the northwestern side of bottom ash pond

6.0 Safety Factor Assessment

As part of the safety factor assessment, S&ME completed Parts 1 and 2 of Section 257.73(e) of the Final Rules for the Disposal of Coal Combustion Residuals from Electric Utilities published on April 17, 2015 in the Federal Register. In accordance with the Rule, the analysis was performed for the critical cross-sections(s) that are anticipated to be most susceptible of all cross-sections to structural failure based on appropriate engineering considerations. The Rule specified the following loading conditions for analysis:

i. Static Factor of Safety under the long-term, maximum storage pool loading condition must equal or exceed 1.50.

ii. Calculated static factor of safety under the maximum surcharge pool loading condition must equal or exceed 1.50.

iii. The calculated seismic factor of safety must equal or exceed 1.00.

iv. For dikes constructed of soils susceptible to liquefaction, the calculated liquefaction factor of safety must equal or exceed 1.20.

6.1 Limit Equilibrium Analyses

The 2009 Investigation Report and the 2010 Addendum discuss in detail the subsurface investigation, laboratory testing, parameter justification, seepage analyses and limit equilibrium slope stability analyses that were performed to develop safety factors for the bottom ash pond embankments. As mentioned previously, engineering parameters developed as part of the 2009 and 2010 investigations were utilized for the new analyses associated with the western embankment as the laboratory testing and subsurface investigation did not encounter soil properties that differed greatly from the soils encountered in the previous investigations.

In summary, four sections along the eastern (river-side) embankment and two sections along the western embankment were studied. Both cross-sections through the western embankment are located within the bottom ash pond as the embankment adjacent to the recirculation pond is only 4 to 6 feet high and access to the toe was not readily available. Subsurface information for each section was obtained by performing borings through the crest and toe of the embankment. Based on a review of all six sections explored, three were selected for detailed limit equilibrium stability analysis (two on the eastern embankment and one on the western embankment).

Prior to performing the limit equilibrium stability analyses as part of the 2009 assessment, seepage analyses were performed to develop a better understanding of the likely phreatic surface within the embankment and foundation. The models were calibrated by adding additional total head boundary conditions within the subsurface to best model the groundwater table as observed in the observation wells. Although a classically shaped phreatic surface extending from the ash pond level to the Ohio River was generated by the seepage analyses, much of the seepage emanating from the ponds appears to be moving downward through the newer embankment fill and thin stratum of alluvium soils and into the glacial outwash sand and gravel stratum which essentially serves as a drain.

Results of the slope stability analysis indicate that the critical cross-section occurs through the eastern embankment of the bottom ash pond (referred to as Section D in the 2009 and 2010 assessments). The design cross-section does not vary along the eastern embankment, but Section D yielded the lowest factors of safety due to slight variations in the outboard slope. All load cases performed for the Safety Factor Assessment as well as additional load cases evaluated for typical US Army Corps of Engineer's requirements met the minimum factor of safety for global stability.

One observed seepage area is located just north of Section B and the other is located approximately 200 feet south. Comparison of boring logs for CD-BAP-1504 and CD-BAP-1505 with the log for boring CD-PZ-BAP-0902 located at Section B do not reveal any key differences in the embankment fill. In fact, Boring CD-PZ-BAP-0902 exhibited a larger zone of granular embankment fill located within the observed

elevation of seepage on the outboard slope, but no seepage was observed adjacent to this boring. The fill soils are believed to vary laterally through the embankment as much as it was observed to vary vertically at the boring locations, suggesting that the granular layers observed in the borings are unlikely to extend all the way through the embankment. Considering this, it is the opinion of S&ME that at this time, the seepage areas are representative of localized pockets of more permeable soils within the overall embankment matrix. As such, it is not believed that the phreatic surface intercepts the outboard face, but rather that there are narrow zones of seepage with unsaturated soils beneath. Nonetheless, these areas should be addressed, as further discussed below.

As noted, the seepage observed during our August, 2015 site visit appeared to occur in two isolated areas. With time, the outboard slope at these locations may weaken due to the presence of groundwater within close proximity to the ground surface resulting in reduced shear strength and shallow slope failures. Though such a failure would typically be minor in extent, S&ME recommends these areas be addressed in the near future before they lead to more significant issues over time. Construction of an inverted filter may be suitable given the performance of the existing inverted filter on the south end. S&ME also recommends continued monitoring of these areas to ensure soils particles are not being carried from inside the embankment.

6.2 Liquefaction Potential of Embankment Soils

S&ME evaluated the potential of the embankment soils to liquefy during a seismic event. The embankment material is classified as a fined grained material and the recovered samples with gradation testing were evaluated following guidelines presented in the 2003 NEHRP (National Earthquake Hazards Reduction Program) Recommended Provisions for Seismic Regulations for New Buildings and Other Structures. The provisions in Chapter 7 indicate that liquefaction potential in fine grained soils should be assessed provided the following criteria are met (Seed and Idriss 1982; Seed et al., 1983): the weight of the soil particles finer than 0.005 mm is less than 15 percent of the dry unit weight of a specimen of the soil; the liquid limit of soil is less than 35 percent; and the moisture content of the in-place soil is greater than 0.9 times the liquid limit. If all of these criteria are not met, the soils may be considered non-liquefiable.

Laboratory testing results from 16 fine grained samples that were available from the 2009 and 2015 investigations for evaluation of the screening criteria. Of the 16 samples, 8 samples contained data to check all three screening criteria, and 7 samples contained data to check two screening criterion. Based on the results of the screening, no sample met all 3 criteria; therefore, these fine grained embankment fill can be considered non-liquefiable. A table depicting this evaluation is included in Appendix IV.

The potential for the coarse grained embankment soils to resist liquefaction was evaluated. The fine grained (cohesive) and coarse grained (granular) embankment soils appear to be from the same borrow source as there are no well-defined layers and often only minor variations in the percent by weight of the recovered sample change the main description from fine grained to coarse grained. Although construction records were not available, the density of the coarse grained samples and consistency of the fine grained samples within the embankment fill suggest they were well compacted. Based on the controlled manner in which the fill was placed, the coarse grained embankment soils can be considered non-liquefiable.

6.3 Summary of Results

A summary of the computed safety factors for the critical cross-section is provided in Table 5-2. Also included in the table are the minimum values defined in 40 CFR § 257.73(e)(1) subparts (i) through (iv). Graphical output corresponding to the analysis cases are presented in Appendix IV along with additional slope stability load cases evaluated during the course of the bottom ash pond assessments.

Table 6-1 – Safety Factor Summary

Analysis Case	Minimum Safety Factor	Computed Safety Factor
Long-term, maximum storage pool	1.50	1.52
Maximum surcharge pool	1.40	1.52
Pseudo-static seismic loading	1.00	1.09
Embankment Liquefaction	1.20	Non-liquefiable

7.0 Certification

Based on our previous investigations and current assessment of the Bottom Ash Pond facility, S&ME certifies that this assessment meets the requirements of paragraphs (e)(1) and (e)(2) of Part 257.73 for the critical cross-section of the embankment.

We appreciate having been given the opportunity to be of service on this project. If you have any questions, please do not hesitate to contact this office.

Sincerely,

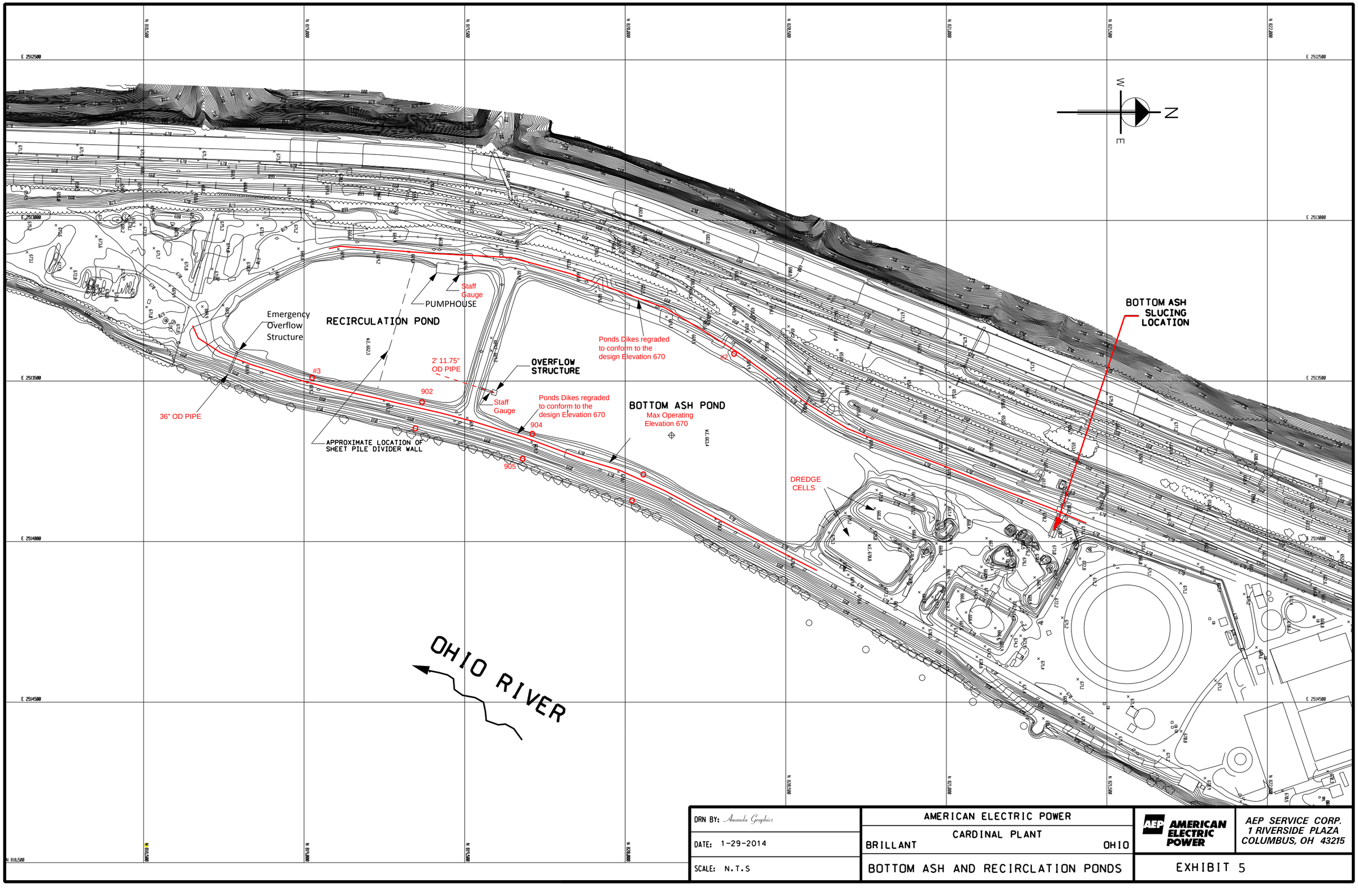
S&ME, Inc.

Michael T. Romanello, P.E.
Project Engineer
Registration No. 74384

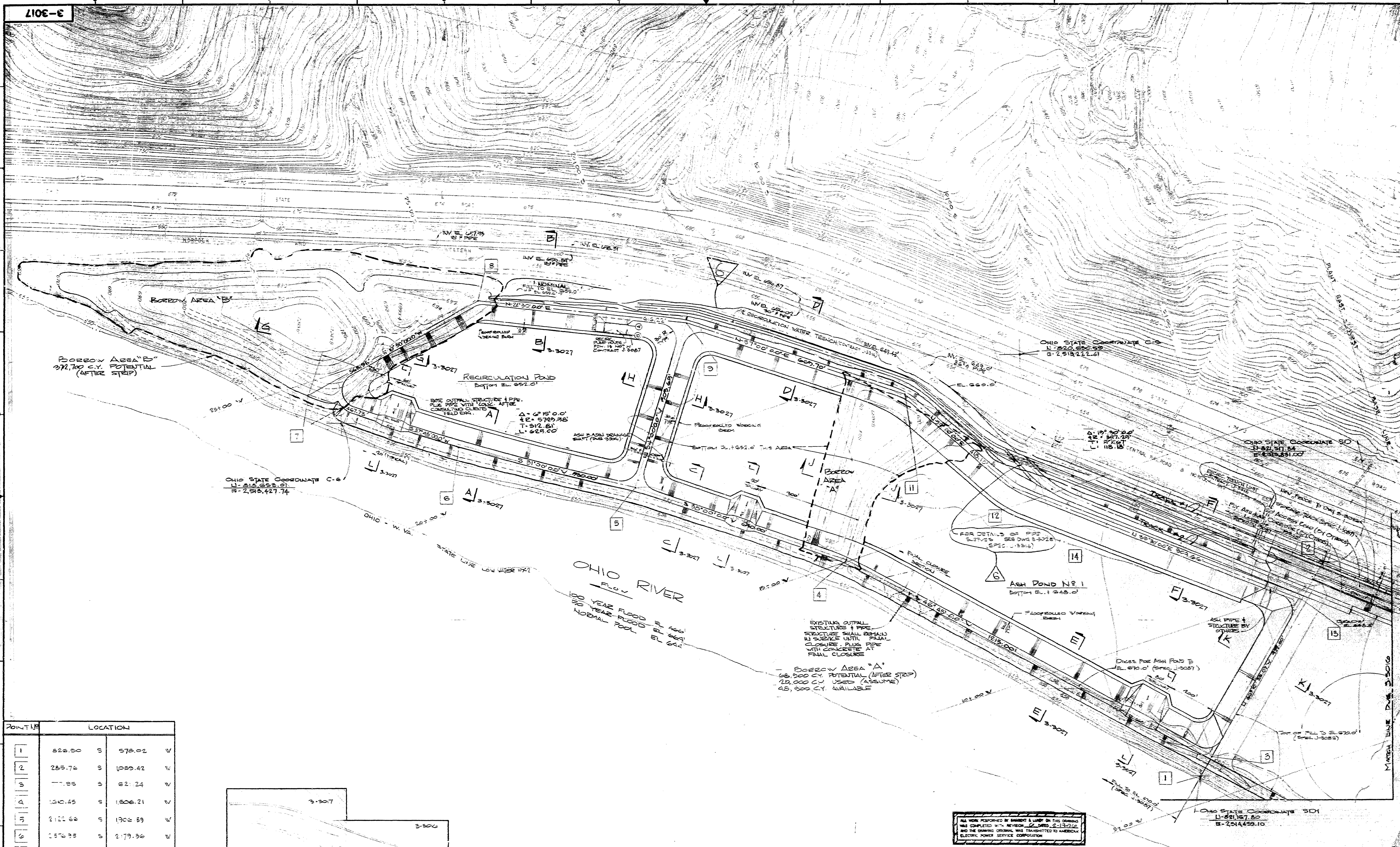
Michael G. Rowland, P.E.
Senior Engineer
Registration No. 65559

ATTACHMENT C

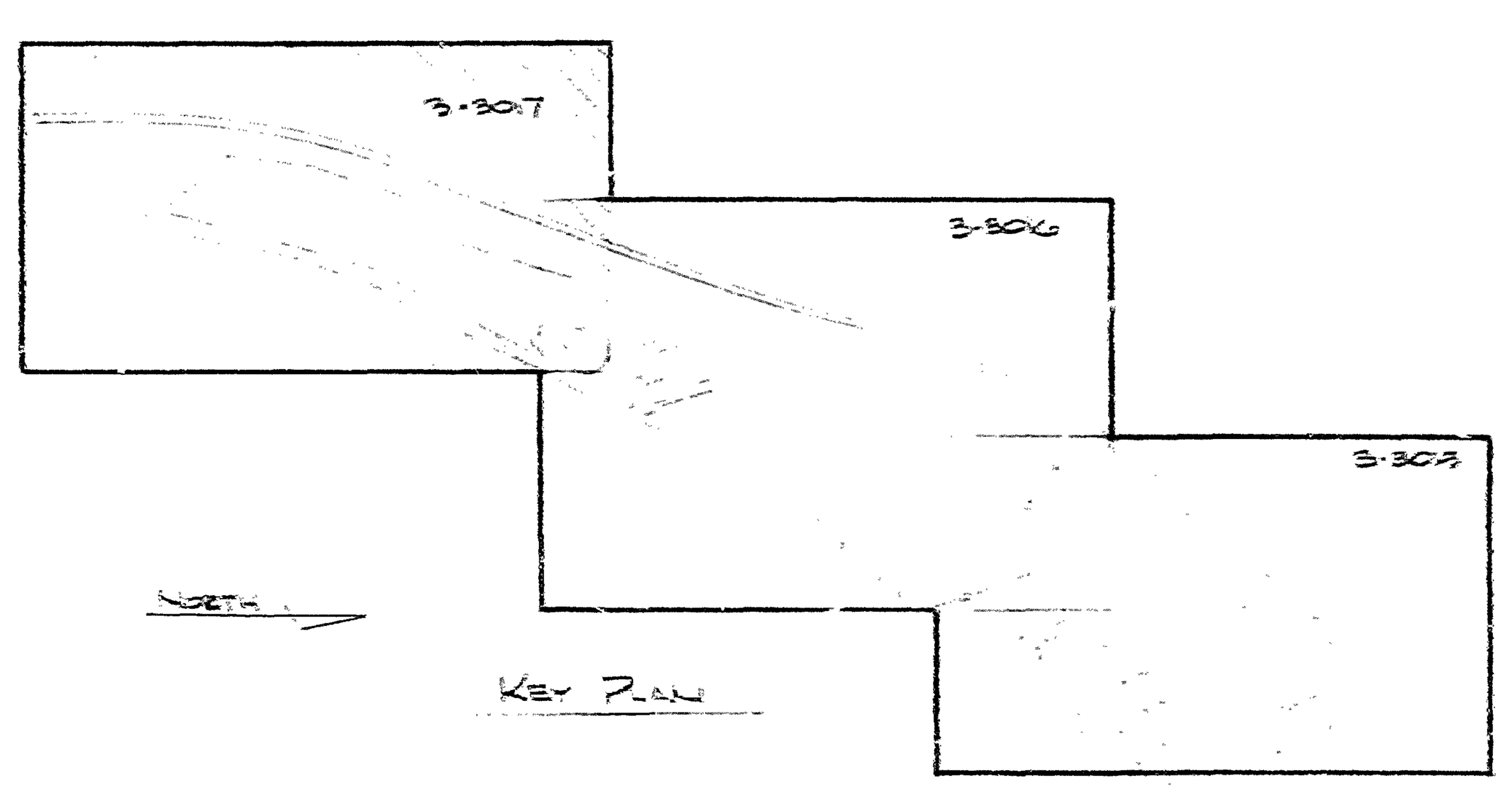
DESIGN DRAWINGS



DRN BY: Amanda Graphics	AMERICAN ELECTRIC POWER	AEP AMERICAN ELECTRIC POWER	AEP SERVICE CORP. 1 RIVERSIDE PLAZA COLUMBUS, OH 43215
DATE: 1-29-2014	CARDINAL PLANT BRILLANT OHIO		
SCALE: N.T.S	BOTTOM ASH AND RECIRCLATION PONDS		EXHIBIT 5



POINT NO.	LOCATION			
1	826.50	S	576.02	W
2	285.76	S	1059.42	W
3	777.85	S	621.24	W
4	1310.45	S	1,506.21	W
5	2121.66	S	1906.59	W
6	2576.95	S	2179.36	W
7	[illegible]	S	2,465.71	W
8	2,387.35	S	2,569.40	W
9	516.61	S	2313.86	W
10				
11	[illegible]91.77	S	1910.32	W
12	[illegible]78.41	S	1,552.41	W
13	578.56	S	976.98	W
14	[illegible]72.47	S	1,514.57	W



ALL WORK PERFORMED BY SARGENT & LUNDY ON THIS DRAWING WAS COMPLETED WITH REVISION 6 DATED 2-13-76 AND THE DRAWING ORIGINAL WAS TRANSMITTED TO AMERICAN ELECTRIC POWER SERVICE CORPORATION

Notes

1. For General Notes See Dwg. 3-3015, Spec. J-3056
2. Stockpiled Topsoil Material Shall Be Deposited In A 4" Layer On The Exterior Slopes Of Sections A-A, B-B, C-C, D-D, E-E, & F-F.
3. Clarify Limit Line Of New Work For Spec. J-3087 South Of Splitter Dike.
4. All Work For Recirculation Water Trench Shall Be Performed Under Contract J-3316 As Directed By Purchaser's Representatives, Unless Otherwise Noted.

Reference Drawings

3-3015	Site Development Plan - Plant Area - Sheet 1
3-3016	Site Development Plan - Plant Area - Sheet 2
3-3027	Site Development - Ash Pond Area - Sections
3-3061	Ash Basin Drainage Shaft - Plan & Sections
3-3028	Site Development - Ash Pond Recirc. Trench - Plan & Sec.
3-3029	Site Development - Ash Pond Recirc. Trench & Road Plan

Plant North / True North

Drawing Release Record

Rev.	Date	Init.	Description
	11-22-72		[illegible]
1	2-14-73	RCO	[illegible]
2	3-15-73		[illegible]
3	4-3-73		[illegible]
4	6-21-73	RCO	[illegible]
5	10-19-73	RCO	[illegible]
6	2-13-76	[illegible]	[illegible]

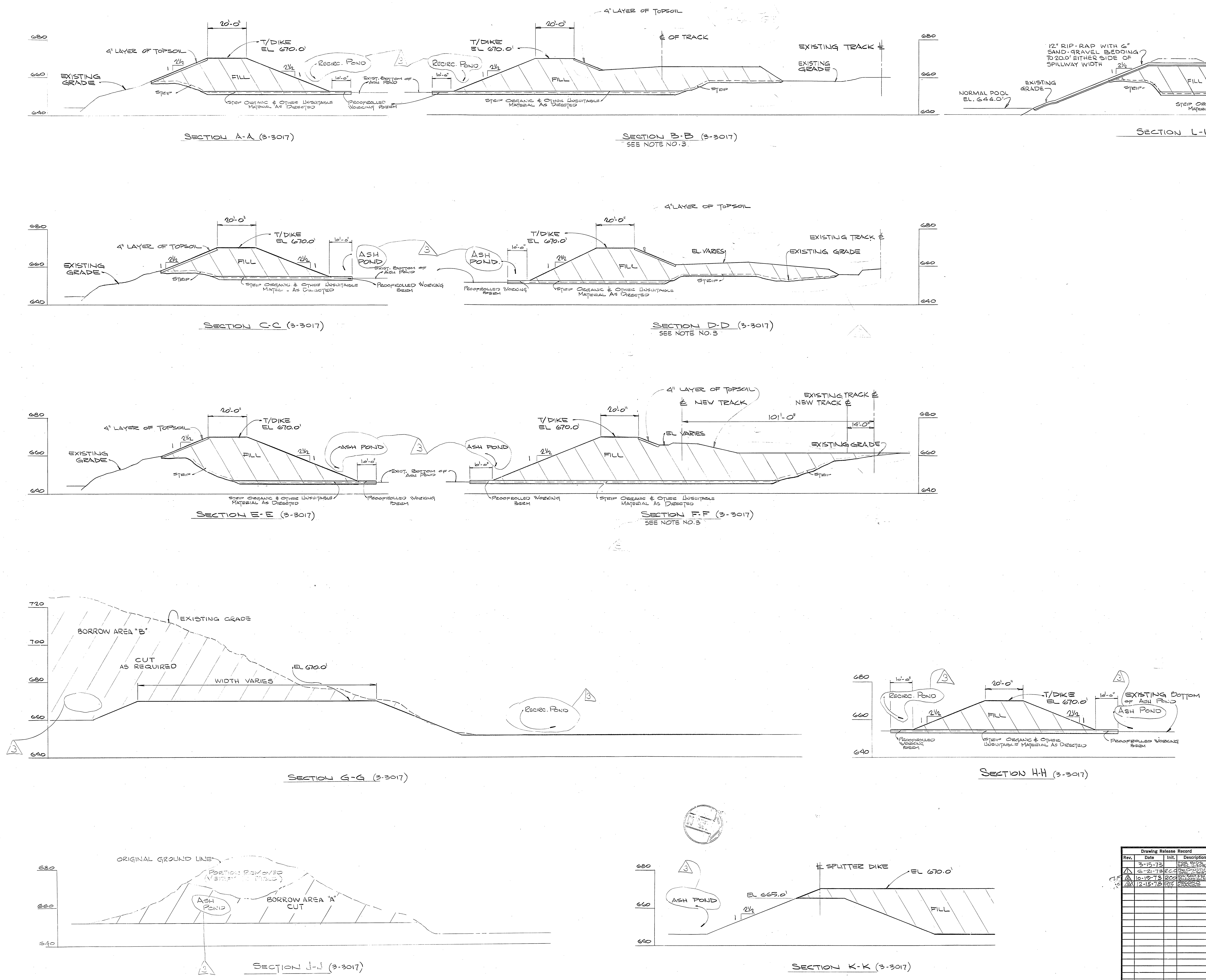
SITE DEVELOPMENT PLAN
ASH STORAGE AREAS SHEET 3
CARDINAL NO. 3
BUCKEYE POWER INC.
BRILLIANT, OHIO

SCALE 1" = 100'-0"
DRAWN A.P. Odishoo Jr. 11-21-72
CHECKED R.C. Odegard 3-13-73
ENGINEER [signature] 3-13-73
APPROVED [signature] 3-13-73
JOB NO. 4422-03

SARGENT & LUNDY ENGINEERS CHICAGO

State of Ohio Registered Professional Engineer (seal)

DRAWING NO. 3-3017-6



NOTES

1. FILL FOR DIKES SHALL CONSIST OF A CONTROLLED COMPACTED FILL CCF2.
2. FOR GENERAL NOTES SEE DWG. 3-3015.
3. EARTHFILL SHOWN ON SECTION B-B, D-D & F-F ARE 'RECORD CHANGE' BASED ON ACTUAL FIELD CONDITIONS AS SURVEYED ON NOV. 9, 1974.

REFERENCE DRAWINGS

3-3017	SITE DEVELOPMENT ASH STORAGE AREA SHEET 3
3-3029	SITE DEVELOPMENT - ASH POND RECIRCULATION TRENCH & ROAD PLAN.
3-3042	SITE DEVELOPMENT - ASH POND RECIRCULATION TRENCH SECTIONS - SHEET 1
3-3043	SITE DEVELOPMENT - ASH POND RECIRCULATION TRENCH SECTIONS - SHEET 2

ALL WORK PERFORMED BY SARGENT & LUNDY ON THIS DRAWING WAS COMPLETED WITH REVISION 3 DATED 12-15-78 AND THE DRAWING ORIGINAL WAS TRANSMITTED TO AMERICAN ELECTRIC POWER SERVICE CORPORATION

STATE OF OHIO — R. N. BERGSTROM E-18613 — REGISTERED PROFESSIONAL ENGINEER

Drawing Release Record

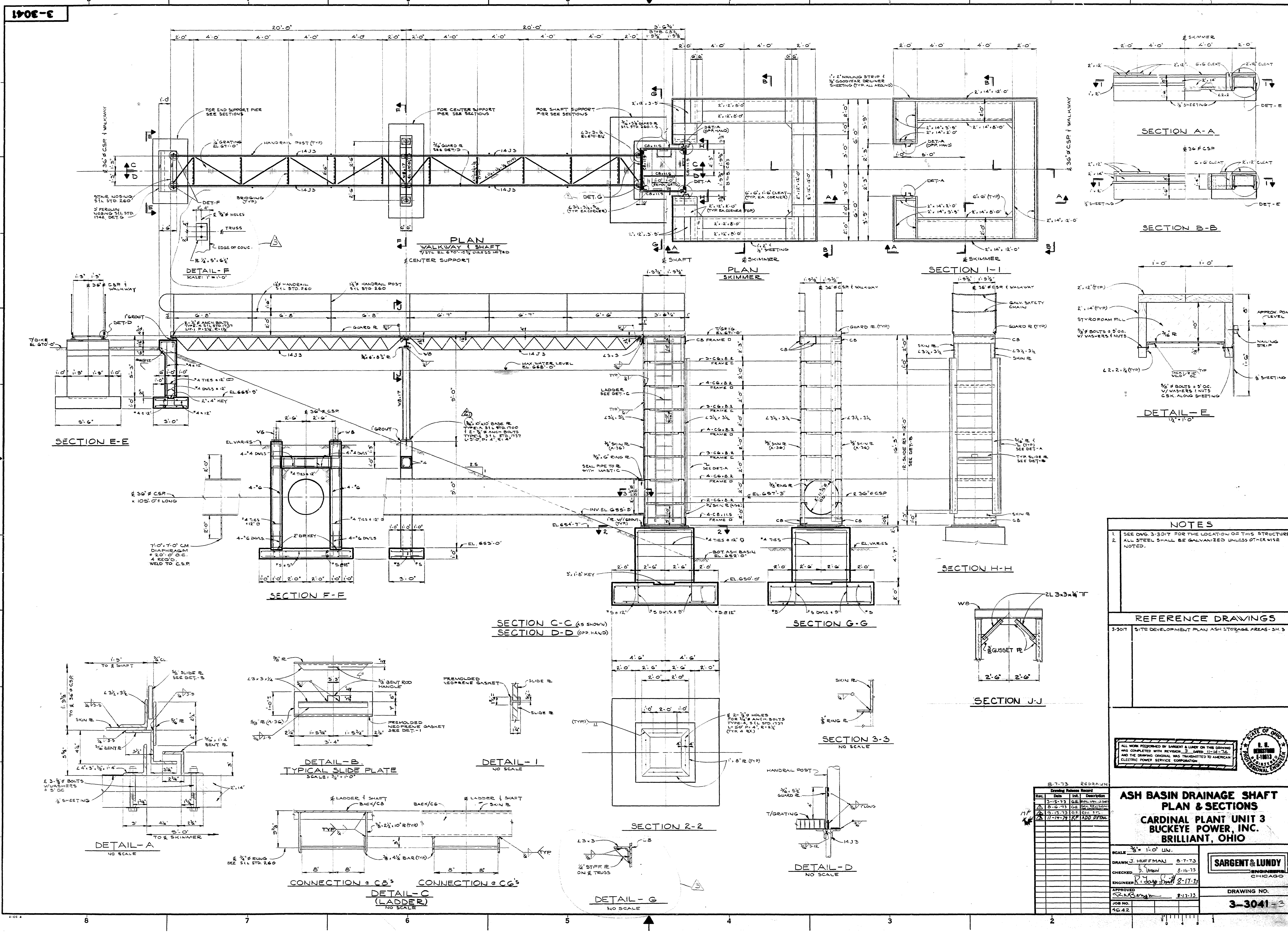
Rev.	Date	Init.	Description
	3-15-73		FOR BIDS SPEC. J-3087
1	6-21-73	R.C.O.	FOR CONST. SPEC. J-3087
2	10-19-73	RCO	REV. SECT. B-B, J-J RELEASED HOLDS
3	12-15-78	RTS	RECORD CHANGE

SITE DEVELOPMENT
ASH STORAGE AREA SECTIONS
CARDINAL PLANT UNIT 3
BUCKEYE POWER, INC.
BRILLIANT, OHIO

SCALE 1" = 20'-0"
DRAWN G. BOLE 11-21-72
CHECKED R.C. ODEGARD 6-19-73
ENGINEER R. Torp-Smith 6-19-73
APPROVED R N Bergstrom
JOB NO. 4642-03

SARGENT & LUNDY ENGINEERS CHICAGO

DRAWING NO. 3-3027-3



NOTES

1. SEE DWG. 3-3017 FOR THE LOCATION OF THIS STRUCTURE.
2. ALL STEEL SHALL BE GALVANIZED UNLESS OTHERWISE NOTED.

REFERENCE DRAWINGS

3-3017	SITE DEVELOPMENT PLAN ASH STORAGE AREAS - SH. 3

ALL WORK PERFORMED BY SARGENT & LUNDY ON THIS DRAWING WAS COMPLETED WITH REVISION 3 DATED 11-14-74 AND THE DRAWING ORIGINAL WAS TRANSMITTED TO AMERICAN ELECTRIC POWER SERVICE CORPORATION

STATE OF OHIO — R. N. BERGSTROM — E-18613 — REGISTERED PROFESSIONAL ENGINEER

8-7-73 REDRAWN

Drawing Release Record

Rev.	Date	Init.	Description
	3-15-73	G.E.	BIDS. SPEC. J-3417
1	8-16-73	GE	GEN. REVISION FOR CONSTRUCTION
2	9-13-73	G.E.	REV. STL.
3	11-14-74	KF	ADD DETAIL

ASH BASIN DRAINAGE SHAFT PLAN & SECTIONS

CARDINAL PLANT UNIT 3
BUCKEYE POWER, INC.
BRILLIANT, OHIO

SCALE 3/8" = 1'-0" UN.

DRAWN J. HUFFMAN 8-7-73

CHECKED [signature] 8-16-73

ENGINEER R. [signature] 8-17-73

APPROVED R N Bergstrom 8-17-73

JOB NO. 4642

SARGENT & LUNDY ENGINEERS CHICAGO

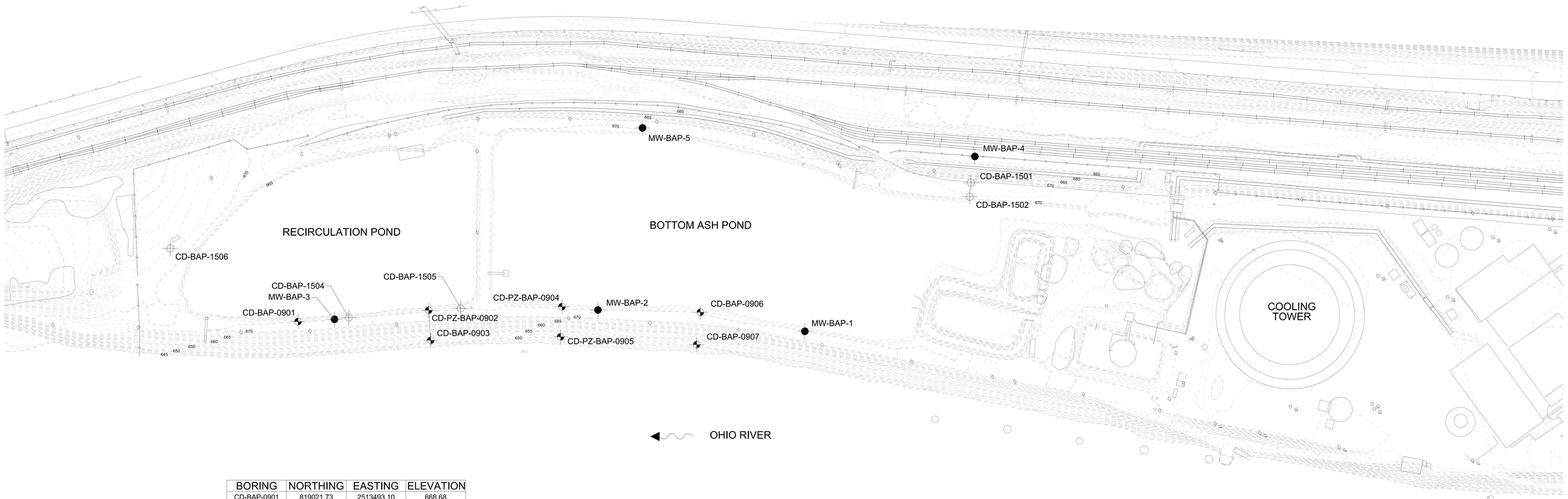
DRAWING NO. 3-3041-3

AEPCDP-000580

ATTACHMENT D

INSTRUMENTATION LOCATION MAP

DWG. NO. PLATE 2



BORING	NORTHING	EASTING	ELEVATION
CD-BAP-0901	819021.73	2513493.10	668.68
CD-PZ-BAP-0902	819364.85	2513568.73	668.04
CD-BAP-0903	819345.90	2513647.44	650.07
CD-PZ-BAP-0904	819708.29	2513666.53	668.05
CD-PZ-BAP-0905	819681.02	2513742.24	650.11
CD-BAP-0906	820058.00	2513791.36	668.64
CD-BAP-0907	820022.70	2513886.71	650.34
CD-BAP-1501	820853.00	2513678.00	671
CD-BAP-1502	820838.80	2513713.00	671
CD-BAP-1504	819154.10	2513525.00	670
CD-BAP-1505	819447.60	2513591.00	670
CD-BAP-1506	818752.90	2513205.00	671
MW-BAP-1	820309.50	2513925.00	670
MW-BAP-2	819797.40	2513705.00	670
MW-BAP-3	819116.30	2513518.00	670
MW-BAP-4	820884.30	2513614.00	660
MW-BAP-5	820057.10	2513275.00	670

DATUM: NAD 27/NGVD 29 OHIO SOUTH

LEGEND

- EXISTING GROUND CONTOUR (1 FT. INTERVAL)
- EXISTING WATER SURFACE (AT TIME OF SURVEY)
- FENCE LINE
- EXISTING VEGETATION
- CV-PZ-BAP-0901 — BORING NUMBER AND LOCATION 2009 INVESTIGATION
- CD-BAP-1501 — BORING NUMBER AND LOCATION 2015 INVESTIGATION
- MW-BAP-1 — MONITORING WELL NUMBER AND LOCATION 2015 INVESTIGATION

SCALE IN FEET
0 100 200

REFERENCE: AEP CARDINAL DRAWING 94151038

DATE	NO.	DESCRIPTION	APPD.
		REVISIONS	

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A.E.P.
CARDINAL PLANT
BRILLIANT OHIO

BOTTOM ASH POND INVESTIGATION
PLAN OF BORINGS

DWG. NO. PLATE 1

SCALE:	CIVIL ENGINEERING
DR:	
CH:	
ENGR:	
PROJ. ENGR:	
DATE:	

PROJECT NUMBER:	7217-15-007B	DRAWN BY:	MRM
DRAWING DATE:	12-30-2015	ENGINEER:	MTR
LAST UPDATED:	12-30-2015	APPROVED BY:	MGR
		SCALE:	1" = 100'

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COLUMBUS, OH 43215

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ATTACHMENT E

HYDROLOGY AND HYDROLOGIC REPORT

Cardinal Generating Plant
Addendum to Bottom Ash Pond Investigation

Brilliant, Ohio

Report to

American Electric Power Service Corp.
Columbus, Ohio

Prepared by

BBC&M Engineering, Inc.
Dublin, Ohio

December, 2010
Addendum to August, 2009 Report

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LIST OF APPENDICES

H&H ANALYSIS

Introduction

The Bottom Ash Pond is located to the north of the Recirculation Pond and they are separated by an earthen embankment. The crest of the embankment surrounding the Bottom Ash Pond is protected with a gravel wearing surface. Water is pumped into the pond from the plant facilities for treatment. Water flows from the Bottom Ash Pond to the Recirculation Pond via a spillway structure. Water is pumped from the Recirculation Pond back into the plant system as necessary. Any overflow would exit the pond to the Ohio River via an NPDES outfall incorporating a weir control structure.

The Bottom Ash Pond is identified as a Class II dam by ODNR, and as such must safely pass 50% of the Probable Maximum Flood (PMF) in accordance with OAC Rule 1501:21-13-02. Regarding minimum required freeboard, OAC Rule 1501:21-13-07(A) states "*...the minimum elevation of the top of the dam shall be at least five feet higher than the elevation of the designed maximum operating pool level unless otherwise approved by the chief*".

Existing Conditions

The crest elevation for the Bottom Ash Pond is listed on the ODNR fact sheet as nominal Elevation 670.0 (msl). A field survey performed by AEP in November 2010, showed that the crest varies in Elevation from 668.3' to 669.4' (see Plate 1 of Appendix C). It is understood that AEP plans to perform maintenance to restore the crest to the original Elevation of 670.0.

The ODNR fact sheet, as well as a stormwater report by FMSM dated December 2005 and provided by AEP, lists the pond drainage area as 24.3 acres, which is slightly larger than the pond footprint. The maximum pumped inflow from plant facilities and stormwater collection areas to the Bottom Ash Pond is 23.32 MGD (36 cfs) according to an AEP water balance diagram dated 7/12/2006. The pond is isolated from substantial exterior surface water runoff.

The outlet works for the Bottom Ash Pond consists of a drop inlet spillway structure with slide gates. The gates are 4 feet in length. A 36-inch oulet pipe conveys the water to the Recirculation Pond. The elevation of the top of the current slide gate is 665.24 according to the field survey. A site visit on October 7, 2010 noted the pool level in the Bottom Ash Pond at Elevation 665.5. The pool level in the Recirculation Pond was at 663.8 during the site visit and is controlled by a 4-foot wide weir surveyed at Elevation 666.20. As the Recirculation Pond level was below the outlet weir, active discharging was not occurring during our site visit.

Analysis

This design storm was analyzed, along with the maximum pumped inflow, to develop maximum pool operating levels. A storage-area-elevation table was developed for the pond's live storage (from normal pool to top of dam) based on 1994 aerial mapping provided by AEP. This table is presented on Plate 6 of Appendix C. Since negligible drainage area runoff is occurring, 50% of the Probable Maximum Precipitation (PMP) was taken as being equivalent to 50% of the PMF. The PMP value used for this site was 33.0 inches for a 24-hour storm event, based on charts contained in HMR-51. A curve number (CN) of 99 was used for the pond area.

Using accepted engineering equations, rating curves for the outlet system were estimated, as shown on Plates 2 through 5 of Appendix C. The total inflow was routed through the pond system using the HEC-HMS computer program, which was developed by the U.S. Army Corps

of Engineers. The analysis was performed assuming tailwater in the Recirculation Pond at Elevation 663.0. Rating curves and other input values are contained in Appendix C. Several cases and iterations were performed with different beginning water elevations to determine the maximum safe operating levels, described as follows:

Case 1: The pond was analyzed with the normal operating level being located at the top of the slide gate weir (Elevation 665.24).

Case 2: Iterations were performed to find the maximum safe operating pool level that would not overtop the dam crest (Elevation 670.0) during the design storm.

Case 3: The pond was analyzed with the normal operating level being located at Elevation 665.0 (5 feet of freeboard).

Case 4: The pond was analyzed with the normal operating level being located at Elevation 666.0 (4 feet of freeboard). It is understood a variance from 5 feet to 4 feet may be requested for the freeboard requirement.

Results

The results of the analysis routing the design storm and pumped inflow through the pond for the various cases are summarized in Table 2.

Table 2: Summary of Pond Routing Results

Case	Normal Operating Water Level El.	Freeboard with nominal Crest El. 670	Max. Resultant Water Level El.
1	665.24	4.76 feet	668.3
2	667.1	2.9 feet	670.0
3	665.0	5.0 feet	668.1
4	666.0	4.0 feet	669.0

Detailed computed results, including flow rates and pond hydrographs, are included on Plates 7 through 15 of Appendix C.

Conclusions

The pond storage is sufficient to contain the design storm. However, the current normal pool level is not sufficient to meet the 5-foot freeboard requirement. It is understood that material will be added to the road surrounding the pond to restore the crest to a consistent elevation of 670.0. If this work is completed, a slide gate will still have to be removed to lower the normal pool level in the Bottom Ash Pond. Based on construction drawings by Sargent & Lundy, dated August 1973, the slide gates each have a height of 1 foot. A reduced weir elevation of 664.24 would allow for a maximum operating pool level of Elevation 665.0 and 5 feet of freeboard. This pool level creates 0.76 feet of head over the spillway weir and allows for a normal pumping inflow rate of 5.5 MGD, given that the pool level (tailwater) for the Recirculation Pond is lower than Elevation 665.0.

One option would be to obtain a variance to change the minimum freeboard requirement to 4 feet. If this is obtained, the maximum operating pool level in the Bottom Ash Pond may be maintained at Elevation 666.0. The maximum operating pool level of the Recirculation Pond should be maintained below the maximum operating pool level of the Bottom Ash Pond.

APPENDIX C

H & H Analysis

BOTTOM ASH POND.

W.E. 663.4

W.E. 670.8

OHIO RIVER

NOTE: TOPOGRAPHY AND FEATURES SHOWN ARE FROM 1994 AERIAL MAPPING PROVIDED BY AEP.

0 150 300

SCALE IN FEET

LEGEND

700.0 SURVEY DATA,PERFORMED BY AEP DURING NOVEMBER 2010

FIELD SURVEY DATA

BOTTOM ASH POND
CARDINAL GENERATING STATION

Project: 011-11497-013	Drawn By: ARW	
Drawing Date: 12-16-2010	Approved By: AJS	
Last Updated: 12-16-2010	Scale: 1"=150'	1:1

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Cleveland (216) 901-1000
Cincinnati (513) 771-8471
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PLATE 1

Images:
Xrefs:
File Last Updated: Dec 16, 2010
Plot Info: 12-16-2010 @ 4:39pm By: AWeinandy
BBC&M Filename: I:\DEPTS\CADD\Drawings\Projects\011-11497-013\Civil3D\Base 11-16-10.dwg Layout: 11x17

Bottom Ash Pond Spillway Capacity - Case 1 - Existing Conditions						
Lake Elevation	Stop Log Weir Flow	Pipe Inlet Flow	Pressure Pipe Flow	**Control Flow**	***Total Outflow***	Control Type
feet	cfs	cfs	cfs	**cfs**	***MGD***	
663.00	0.0	83.3	0.0	**0.0**	***0.0***	Stop Log Weir Flow
664.00	0.0	90.0	31.6	**0.0**	***0.0***	Stop Log Weir Flow
665.00	0.0	96.2	44.7	**0.0**	***0.0***	Stop Log Weir Flow
666.00	8.5	102.1	54.7	**8.5**	***5.5***	Stop Log Weir Flow
667.00	29.8	107.6	63.2	**29.8**	***19.3***	Stop Log Weir Flow
668.00	58.5	112.8	70.7	**58.5**	***37.8***	Stop Log Weir Flow
669.00	93.1	117.8	77.4	**77.4**	***50.0***	Pressure Pipe Flow
670.00	132.6	122.7	83.6	**83.6**	***54.0***	Pressure Pipe Flow

Bottom Ash Pond Spillway Capacity - Case 2 - Max Water at Elev 670						
Lake Elevation	Stop Log Weir Flow	Pipe Inlet Flow	Pressure Pipe Flow	**Control Flow**	***Total Outflow***	Control Type
feet	cfs	cfs	cfs	**cfs**	***MGD***	
665.00	0.0	96.2	44.7	**0.0**	***0.0***	Stop Log Weir Flow
666.00	0.0	102.1	54.7	**0.0**	***0.0***	Stop Log Weir Flow
667.00	0.0	107.6	63.2	**0.0**	***0.0***	Stop Log Weir Flow
668.00	12.8	112.8	70.7	**12.8**	***8.2***	Stop Log Weir Flow
669.00	36.1	117.8	77.4	**36.1**	***23.3***	Stop Log Weir Flow
670.00	66.3	122.7	83.6	**66.3**	***42.9***	Stop Log Weir Flow
671.00	102.1	127.3	89.4	**89.4**	***57.8***	Pressure Pipe Flow

Bottom Ash Pond Spillway Capacity - Case 3 - NP Elev 665						
Lake Elevation	Stop Log Weir Flow	Pipe Inlet Flow	Pressure Pipe Flow	**Control Flow**	***Total Outflow***	Control Type
feet	cfs	cfs	cfs	**cfs**	***MGD***	
664.00	0.0	90.0	31.6	**0.0**	***0.0***	Stop Log Weir Flow
665.00	0.0	96.2	44.7	**0.0**	***0.0***	Stop Log Weir Flow
666.00	12.8	102.1	54.7	**12.8**	***8.2***	Stop Log Weir Flow
667.00	36.1	107.6	63.2	**36.1**	***23.3***	Stop Log Weir Flow
668.00	66.3	112.8	70.7	**66.3**	***42.9***	Stop Log Weir Flow
669.00	102.1	117.8	77.4	**77.4**	***50.0***	Pressure Pipe Flow
670.00	142.7	122.7	83.6	**83.6**	***54.0***	Pressure Pipe Flow

Bottom Ash Pond Spillway Capacity - Case 4 - NP Elev 666						
Lake Elevation	Stop Log Weir Flow	Pipe Inlet Flow	Pressure Pipe Flow	**Control Flow**	***Total Outflow***	Control Type
feet	cfs	cfs	cfs	**cfs**	***MGD***	
665.00	0.0	96.2	44.7	**0.0**	***0.0***	Stop Log Weir Flow
666.00	0.0	102.1	54.7	**0.0**	***0.0***	Stop Log Weir Flow
667.00	12.8	107.6	63.2	**12.8**	***8.2***	Stop Log Weir Flow
668.00	36.1	112.8	70.7	**36.1**	***23.3***	Stop Log Weir Flow
669.00	66.3	117.8	77.4	**66.3**	***42.9***	Stop Log Weir Flow
670.00	102.1	122.7	83.6	**83.6**	***54.0***	Pressure Pipe Flow

Bottom Ash Pond Weir Rating - Case 1
Weir Flow

$$Q = C_{SCW}\, LH^{\frac{3}{2}}$$

$$C_{SCW} = 3.27 + 0.4\left(\frac{H}{H_c}\right)$$

for $H/H_c < 0.3$, C_{SCW} becomes 3.33

***L*= 3.83**
***g*= 32.2**
***Crest Elevation*= 665.24**

Elevation	H	Q
665.24	0.00	0.0
666.00	0.76	8.5
667.00	1.76	29.8
668.00	2.76	58.5
669.00	3.76	93.1
670.00	4.76	132.6

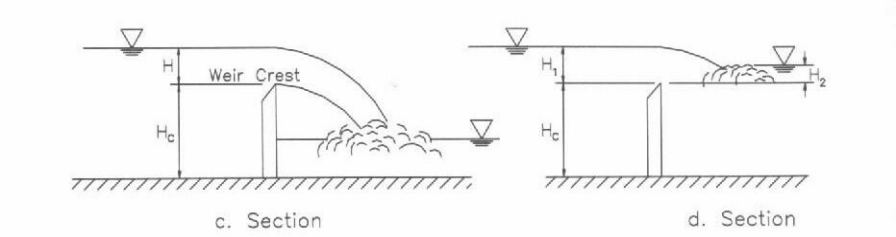


Figure 8-13. Sharp crested weirs.

Reference:
FHWA-SA-96-078
Urban Drainage Design Manual
Hydraulic Engineering Circular 22
November, 1996

Bottom Ash Pond 36" Pipe Rating
Pipe Inlet Control

$$Q = CA\sqrt{2gh_1}$$

for C=0.6 orifice equation becomes:

$$Q = 3.78D^2\sqrt{h_1}$$

d= **36.0** **INCHES**

Orifice Elevation = **657.00**

Headwater Elevation (ft.)	Orifice	
	Discharge (cfs)	Velocity (ft/s)
657.00	*0.0*	0.0
658.00	*34.0*	4.8
659.00	*48.1*	6.8
660.00	*58.9*	8.3
661.00	*68.0*	9.6
662.00	*76.1*	10.8
663.00	*83.3*	11.8
664.00	*90.0*	12.7
665.00	*96.2*	13.6
666.00	*102.1*	14.4
667.00	*107.6*	15.2
668.00	*112.8*	16.0
669.00	*117.8*	16.7
670.00	*122.7*	17.4
671.00	*127.3*	18.0

Reference:
FHWA-SA-96-078
Urban Drainage Design Manual
Hydraulic Engineering Circular 22
November, 1996

Pressure Pipe Flow Computed with the Energy Equation

(from inlet to Recirc. Pond)

Manning's n= 0.013
Inlet Invert: 657
Outlet Invert (z_2): 656
Entrance Coefficent K_e= 0.5
Outlet Coefficent K_o= 1
Bend Coefficent K_b= 0
Pipe Diameter in inches= 36
Pipe Diameter in feet (D)= *3.00*
Pipe Length in feet (L)= 100
Darcy-Weisbach *f* = *0.022*

(Assuming tailwater at El. 663.0):

Headwater Elevation (z_1) (ft)	Outlet Velocity (ft/s)	Outlet Flow Rate (ft^3/s)
657.00	0.00	0.00
658.00	0.00	0.00
659.00	0.00	0.00
660.00	0.00	0.00
661.00	0.00	0.00
662.00	0.00	0.00
663.00	0.00	0.00
664.00	4.47	31.60
665.00	6.32	44.69
666.00	7.74	54.73
667.00	8.94	63.20
668.00	10.00	70.66
669.00	10.95	77.40
670.00	11.83	83.60
671.00	12.64	89.38

The Darcy-Weisbach friction factor is related to Manning's n through the following equation:

$$f = \frac{185 \quad n^{2}}{D^{\frac{1}{3}}}$$

The Energy Equation is:

$$\frac{p_1}{\gamma}+\frac{v_1^2}{2g}+z_1=\frac{p_2}{\gamma}+\frac{v_2^2}{2g}+z_2+\sum h_L$$

Where:

$$\sum h_L=\frac{v^2}{2g}\left(f\frac{L}{D}+K_e+K_o+K_b\right)$$

Because p_1, v_1 and p_2 all are equal to 0 the energy equation becomes:

$$z_1-z_2=\frac{v^2}{2g}+\frac{v^2}{2g}\left(f\frac{L}{D}+K_e+K_o+K_b\right)$$

Solving for v gives:

$$v=\sqrt{\frac{2g(z_1-z_2)}{\left(1+\left(f\frac{L}{D}+K_e+K_o+K_b\right)\right)}}$$

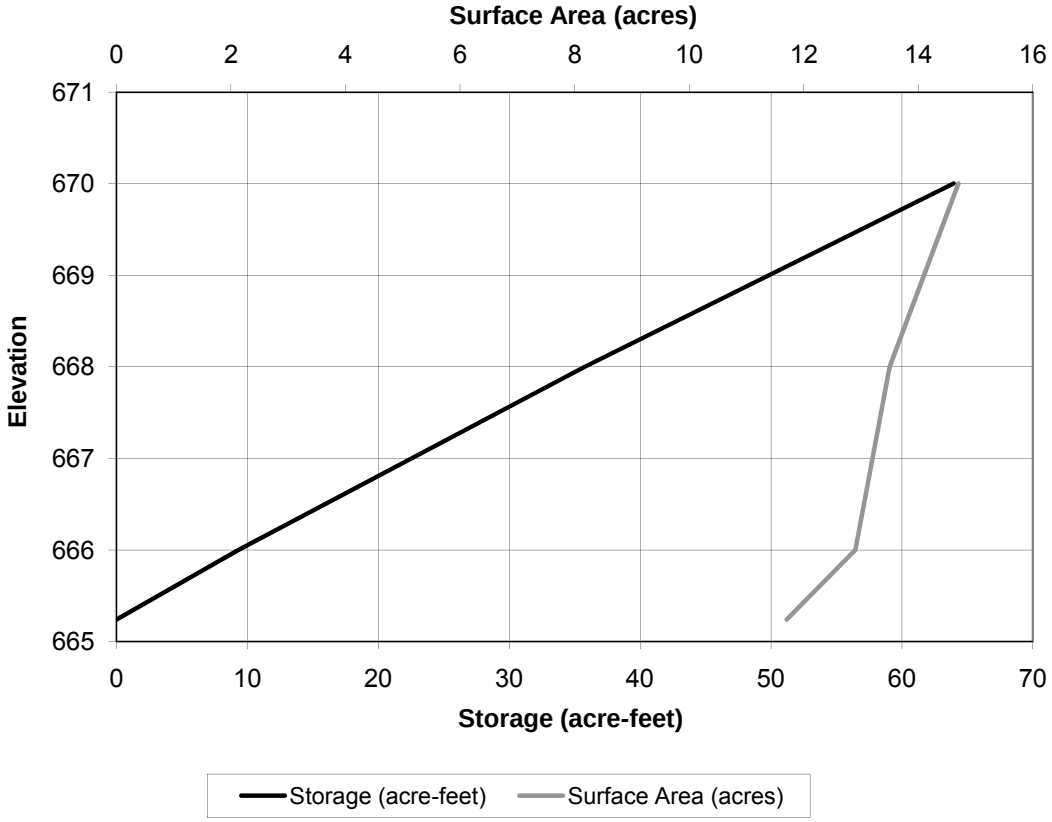
Determine flow rate Q by:

$$Q = VA$$

Bottom Ash Pond - Live Storage Volume Computations					
Elevation	Area	Avg Area	Distance	Volume	Cum Vol
	acres	acres	feet	ac-ft	ac-ft
Normal Pool 665.24	11.70				0
		12.30	0.76	9.35	
666	12.90				9.3
		13.20	2	26.40	
668	13.50				35.7
		14.10	2	28.20	
670	14.70				63.9

Bottom Ash Pond- Surface Area/Storage/Elevation

Note: From topography provided by AEP



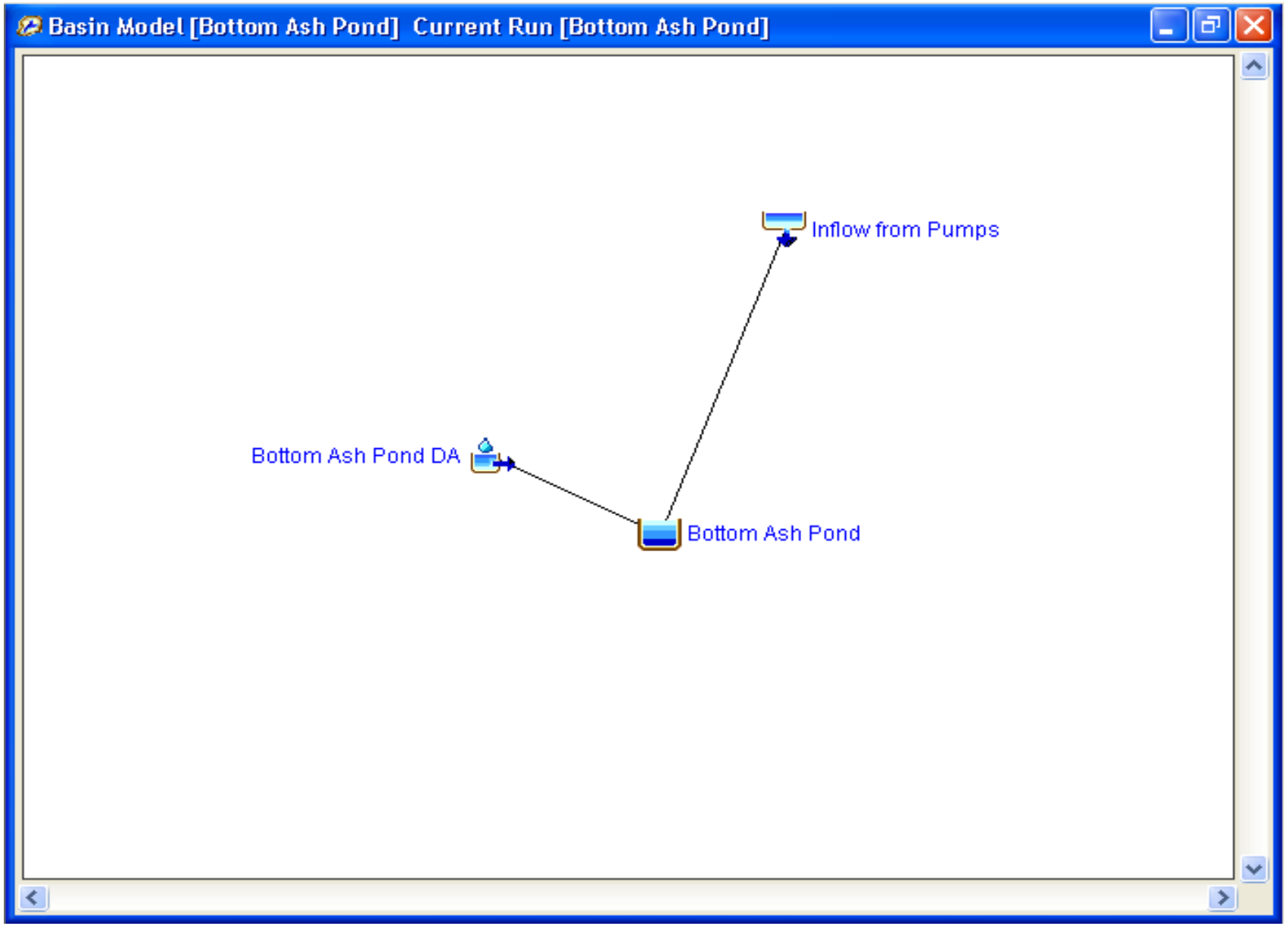

Basin Model [Bottom Ash Pond] Current Run [Bottom Ash Pond]
Inflow from Pumps
Bottom Ash Pond DA
Bottom Ash Pond

PLATE 7

Project: Bottom Ash Pond

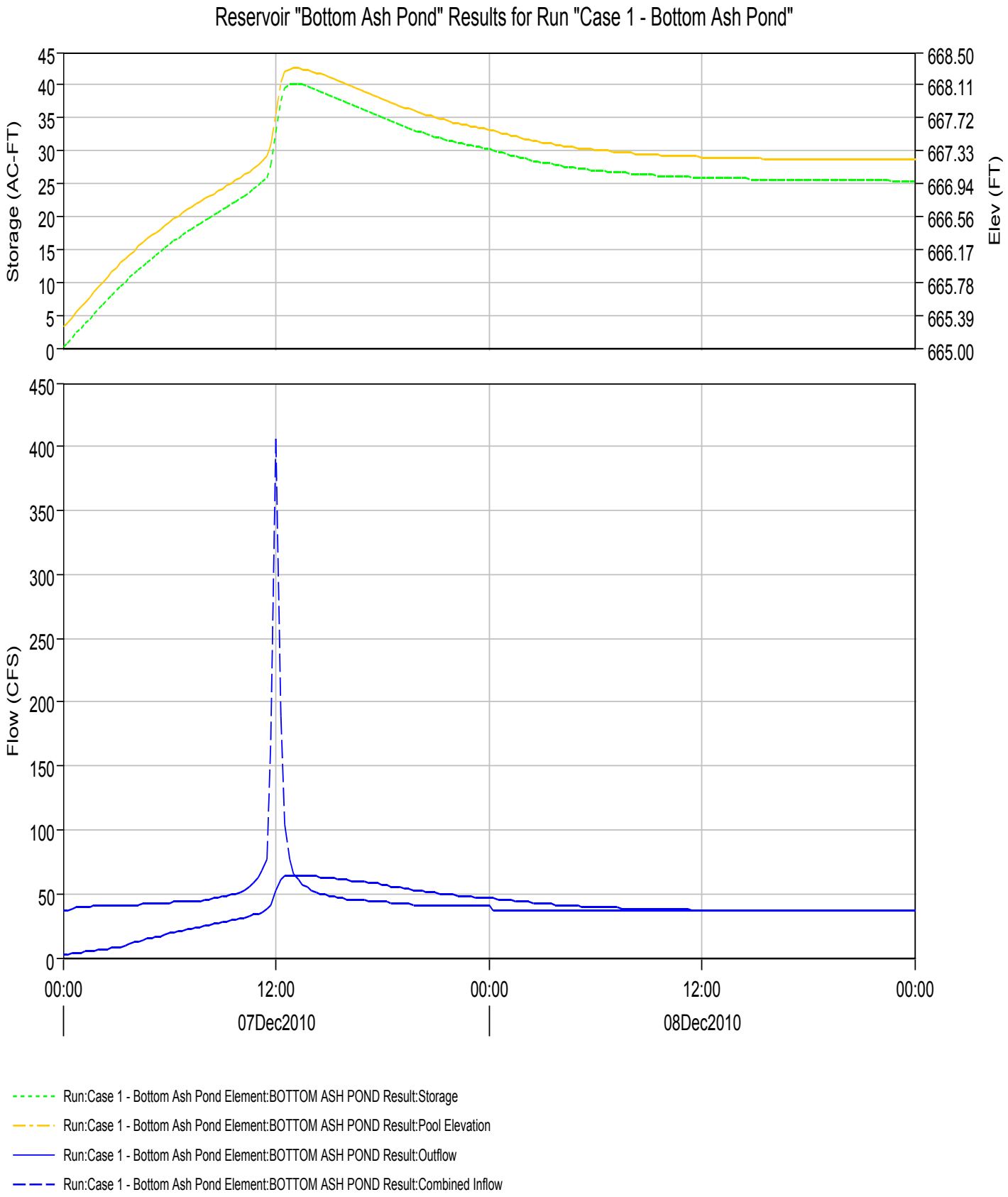
Simulation Run: Case 1 - Bottom Ash Pond Reservoir: Bottom Ash Pond

Start of Run:	07Dec2010, 00:00	Basin Model:	Case 1 - Bottom Ash Pond
End of Run:	09Dec2010, 00:00	Meteorologic Model:	50 Percent PMP - 24 Hour
Compute Time:	08Dec2010, 12:23:27	Control Specifications:	Bottom Ash Pond

Volume Units: AC-FT

Computed Results

Peak Inflow :	406.2 (CFS)	Date/Time of Peak Inflow :	07Dec2010, 12:00
Peak Outflow :	64.4 (CFS)	Date/Time of Peak Outflow :	07Dec2010, 13:00
Total Inflow :	176.0 (AC-FT)	Peak Storage :	40.1 (AC-FT)
Total Outflow :	150.7 (AC-FT)	Peak Elevation :	668.3 (FT)


Reservoir "Bottom Ash Pond" Results for Run "Case 1 - Bottom Ash Pond"
Storage (AC-FT)
Elev (FT)
45
40
35
30
25
20
15
10
5
0
668.50
668.11
667.72
667.33
666.94
666.56
666.17
665.78
665.39
665.00
Flow (CFS)
450
400
350
300
250
200
150
100
50
0
00:00
12:00
00:00
12:00
00:00
07Dec2010
08Dec2010
Run:Case 1 - Bottom Ash Pond Element:BOTTOM ASH POND Result:Storage
Run:Case 1 - Bottom Ash Pond Element:BOTTOM ASH POND Result:Pool Elevation
Run:Case 1 - Bottom Ash Pond Element:BOTTOM ASH POND Result:Outflow
Run:Case 1 - Bottom Ash Pond Element:BOTTOM ASH POND Result:Combined Inflow

Project: Bottom Ash Pond

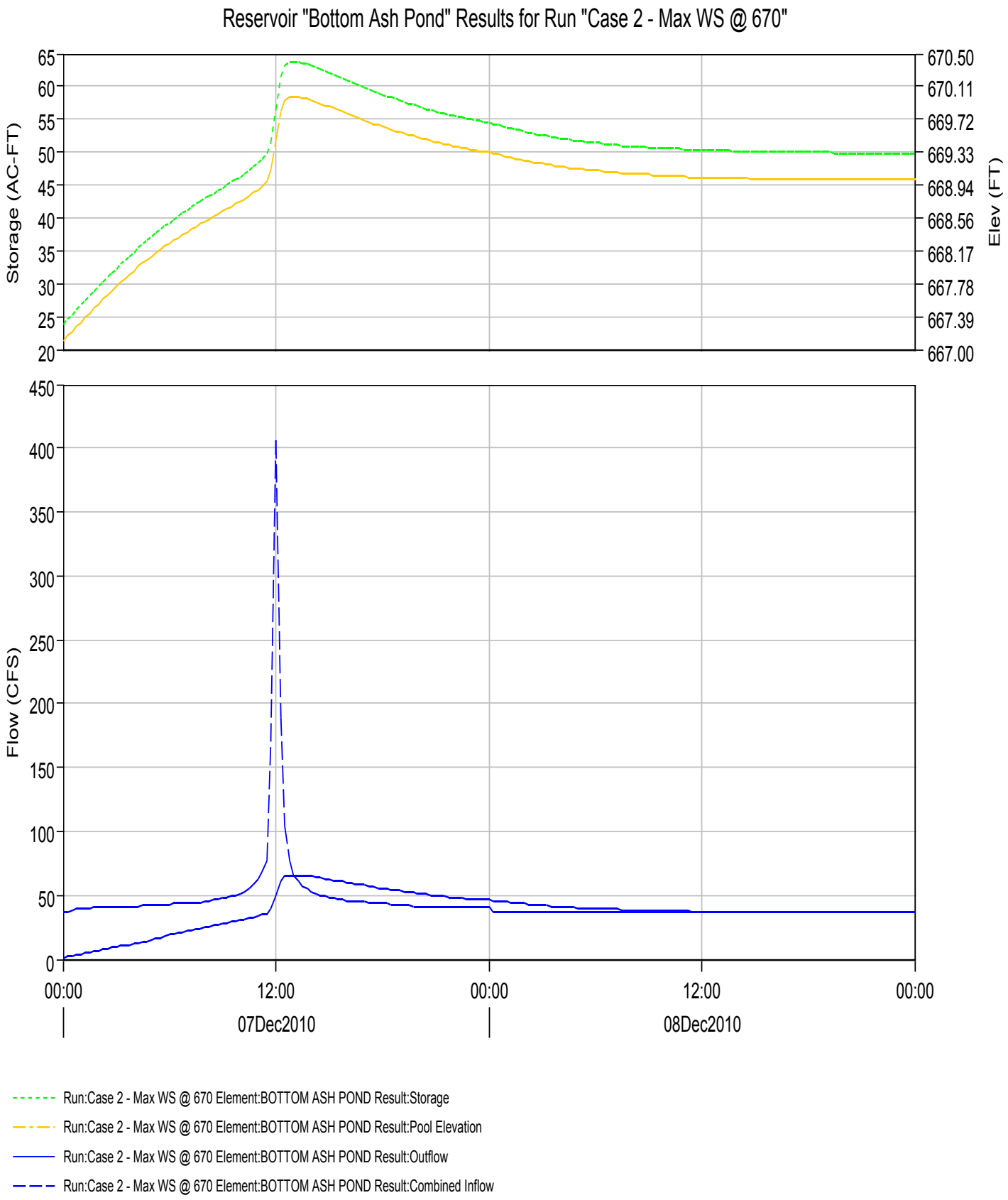
Simulation Run: Case 2 - Max WS @ 670 Reservoir: Bottom Ash Pond

Start of Run:	07Dec2010, 00:00	Basin Model:	Case 2 - Bottom Ash Pond
End of Run:	09Dec2010, 00:00	Meteorologic Model:	50 Percent PMP - 24 Hour
Compute Time:	08Dec2010, 12:34:32	Control Specifications:	Bottom Ash Pond

Volume Units: AC-FT

Computed Results

Peak Inflow :	406.2 (CFS)	Date/Time of Peak Inflow :	07Dec2010, 12:00
Peak Outflow :	66.1 (CFS)	Date/Time of Peak Outflow :	07Dec2010, 13:00
Total Inflow :	176.0 (AC-FT)	Peak Storage :	63.8 (AC-FT)
Total Outflow :	150.0 (AC-FT)	Peak Elevation :	670.0 (FT)


Reservoir "Bottom Ash Pond" Results for Run "Case 2 - Max WS @ 670"
Storage (AC-FT)
Elev (FT)
65
60
55
50
45
40
35
30
25
20
670.50
670.11
669.72
669.33
668.94
668.56
668.17
667.78
667.39
667.00
Flow (CFS)
450
400
350
300
250
200
150
100
50
0
00:00
12:00
00:00
12:00
00:00
07Dec2010
08Dec2010
Run:Case 2 - Max WS @ 670 Element:BOTTOM ASH POND Result:Storage
Run:Case 2 - Max WS @ 670 Element:BOTTOM ASH POND Result:Pool Elevation
Run:Case 2 - Max WS @ 670 Element:BOTTOM ASH POND Result:Outflow
Run:Case 2 - Max WS @ 670 Element:BOTTOM ASH POND Result:Combined Inflow

Project: Bottom Ash Pond

Simulation Run: Case 3 - NP @ 665.0 Reservoir: Bottom Ash Pond

Start of Run:	07Dec2010, 00:00	Basin Model:	Case 3 - Bottom Ash Pond
End of Run:	09Dec2010, 00:00	Meteorologic Model:	50 Percent PMP - 24 Hour
Compute Time:	08Dec2010, 12:17:34	Control Specifications:	Bottom Ash Pond

Volume Units: AC-FT

Computed Results

Peak Inflow :	406.2 (CFS)	Date/Time of Peak Inflow :	07Dec2010, 12:00
Peak Outflow :	67.7 (CFS)	Date/Time of Peak Outflow :	07Dec2010, 13:00
Total Inflow :	176.0 (AC-FT)	Peak Storage :	37.5 (AC-FT)
Total Outflow :	153.6 (AC-FT)	Peak Elevation :	668.1 (FT)

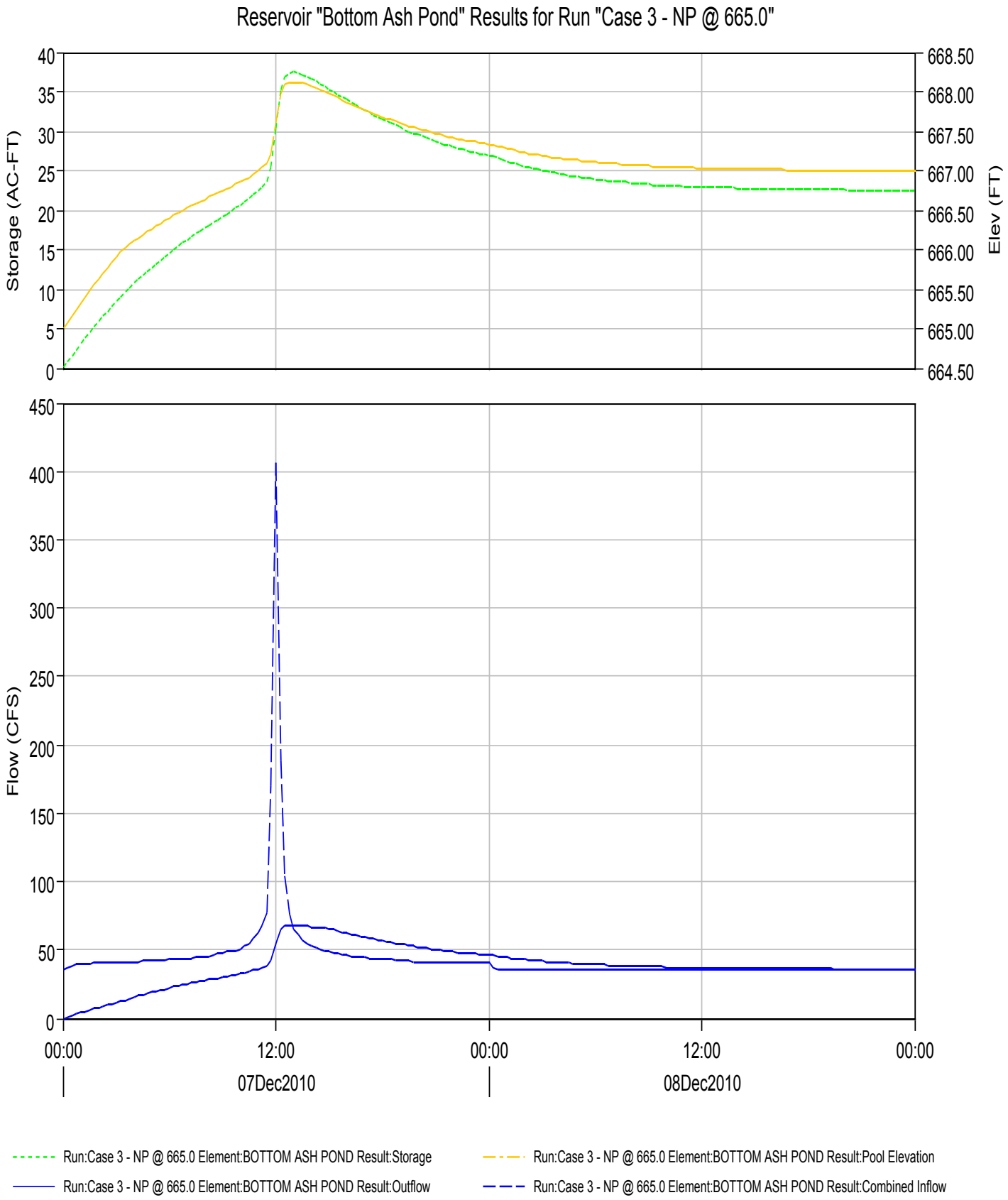

Reservoir "Bottom Ash Pond" Results for Run "Case 3 - NP @ 665.0"
Storage (AC-FT)
Elev (FT)
Flow (CFS)
0
5
10
15
20
25
30
35
40
664.50
665.00
665.50
666.00
666.50
667.00
667.50
668.00
668.50
0
50
100
150
200
250
300
350
400
450
00:00
12:00
00:00
12:00
00:00
07Dec2010
08Dec2010
Run:Case 3 - NP @ 665.0 Element:BOTTOM ASH POND Result:Storage
Run:Case 3 - NP @ 665.0 Element:BOTTOM ASH POND Result:Pool Elevation
Run:Case 3 - NP @ 665.0 Element:BOTTOM ASH POND Result:Outflow
Run:Case 3 - NP @ 665.0 Element:BOTTOM ASH POND Result:Combined Inflow

PLATE 13

Project: Bottom Ash Pond

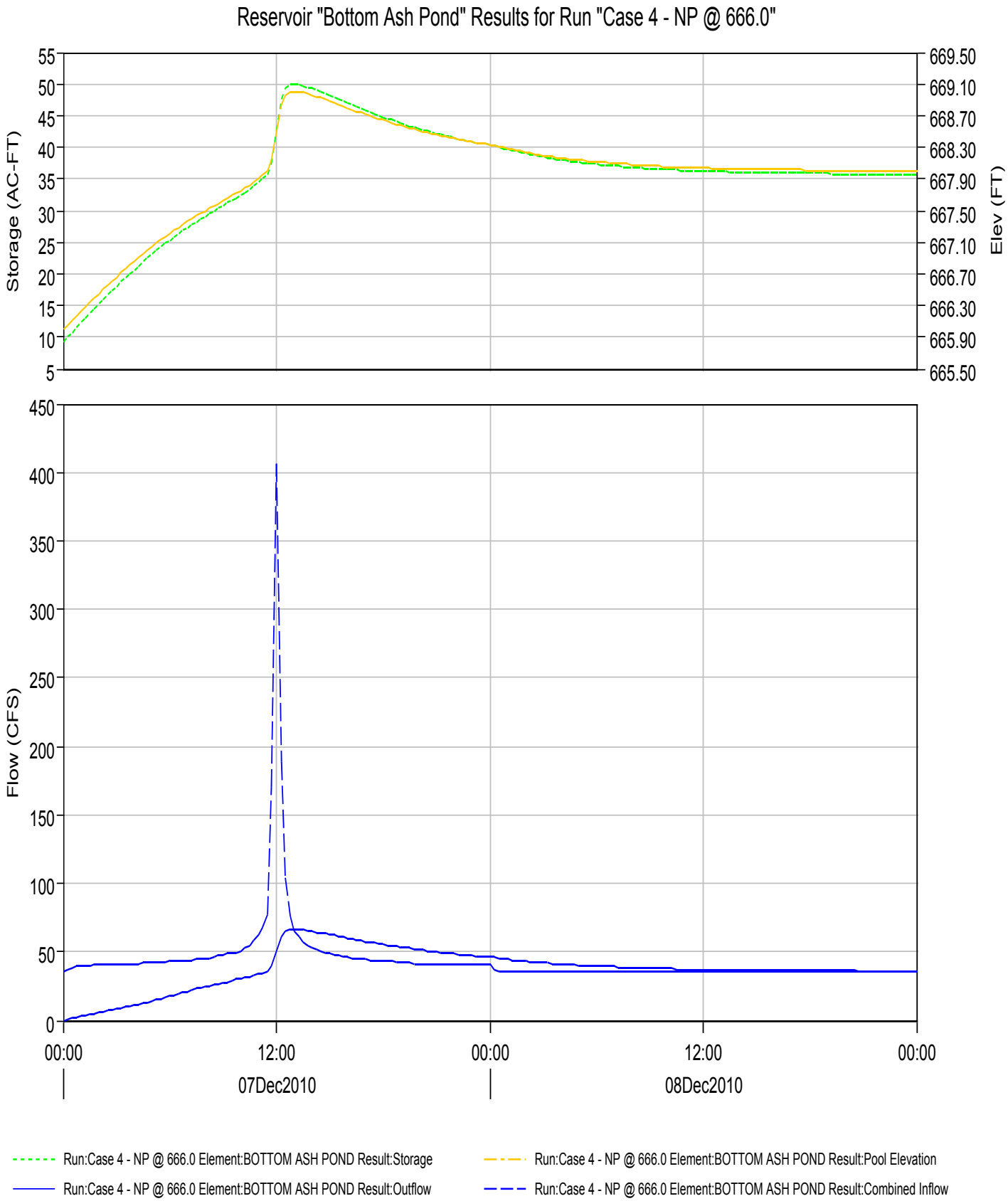
Simulation Run: Case 4 - NP @ 666.0 Reservoir: Bottom Ash Pond

Start of Run:	07Dec2010, 00:00	Basin Model:	Case 4 - Bottom Ash Pond
End of Run:	09Dec2010, 00:00	Meteorologic Model:	50 Percent PMP - 24 Hour
Compute Time:	08Dec2010, 12:21:45	Control Specifications:	Bottom Ash Pond

Volume Units: AC-FT

Computed Results

Peak Inflow :	406.2 (CFS)	Date/Time of Peak Inflow :	07Dec2010, 12:00
Peak Outflow :	66.4 (CFS)	Date/Time of Peak Outflow :	07Dec2010, 13:00
Total Inflow :	176.0 (AC-FT)	Peak Storage :	49.9 (AC-FT)
Total Outflow :	149.6 (AC-FT)	Peak Elevation :	669.0 (FT)


Reservoir "Bottom Ash Pond" Results for Run "Case 4 - NP @ 666.0"
Storage (AC-FT)
Elev (FT)
55
50
45
40
35
30
25
20
15
10
5
669.50
669.10
668.70
668.30
667.90
667.50
667.10
666.70
666.30
665.90
665.50
Flow (CFS)
450
400
350
300
250
200
150
100
50
0
00:00
12:00
00:00
12:00
00:00
07Dec2010
08Dec2010
Run:Case 4 - NP @ 666.0 Element:BOTTOM ASH POND Result:Storage
Run:Case 4 - NP @ 666.0 Element:BOTTOM ASH POND Result:Pool Elevation
Run:Case 4 - NP @ 666.0 Element:BOTTOM ASH POND Result:Outflow
Run:Case 4 - NP @ 666.0 Element:BOTTOM ASH POND Result:Combined Inflow

ATTACHMENT F

MAINTENANCE PLAN

Operation, Maintenance, and Inspection Manual for Fly Ash Dam II & Bottom Ash Ponds Complex Dikes

American Electric Power

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

Plant Ash Dam: 0105-004
Fly Ash No. 1 Dam: 0205-009
Fly Ash No. 2 Dam: 0205-010

RECEIVED
OHIO
MAR 19 2015
Soil and Water Resources
Dam Safety Program II

March 2015

STATE OF OHIO
Soil and Water Resources
DAM SAFETY REPAIR PROGRAM
APR 16 2015
APPROVED

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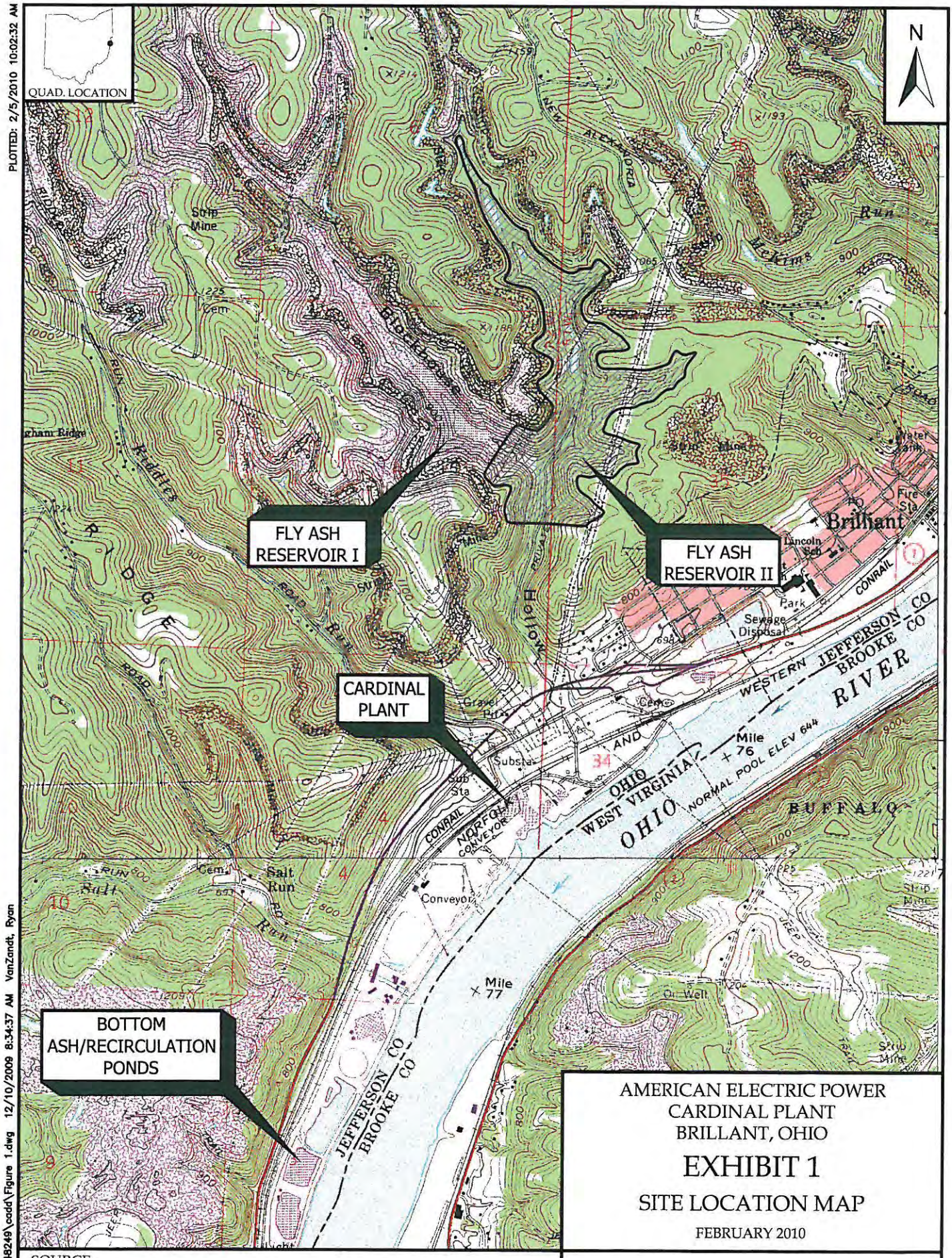
1.0 INTRODUCTION

This Operation, Maintenance, and Inspection (OM&I) Manual was prepared in accordance with Section 1501:21-15-06 of the Ohio Laws and Administrative Rules for Issuing Construction Permits for and Making Periodic Inspections of Dams, Dikes, and Levees. It is intended to assist the owner in regular operation, maintenance, and inspection activities. This manual was prepared for Cardinal Plant's Fly Ash Dam II (FAD II) and the Bottom Ash Ponds (BAP) complex conveying coal ash slurry. Exhibit 1 shows the location of the dams.

The Cardinal FAD II coal ash dam and the BAP complex dikes have been conservatively designed and carefully constructed; however, small problems can develop over time. Experience has shown that some of these small problems can become major problems if corrective measures are not promptly taken. The main intent of this manual, therefore, is to provide the guidelines for a regular operation, maintenance, and inspection program that will detect problems at an early stage so that they can then be corrected. This manual presents the procedures for the operation, maintenance and inspection of the FAD II and the BAP complex dikes.

Much of the information in this manual has been based on the requirements of publications issued by the Ohio Department of Natural Resources (ODNR), Division of Water, Dam Inspection Section. The publications are a series of Fact Sheets; copies of pertinent Fact Sheets are contained in Appendix D. In addition to providing basic recommendations for operation, maintenance, and inspection procedures, the Fact Sheets give a great deal of background information, including causes of dam failures, common problems and solutions, and reference to organizations and bureaus which can provide information and advice. The Fact Sheets are valuable publications to have as an adjunct to this manual.

This OM&I Manual supersedes any and all previous OM&I Manuals that have been used at the facility.



AMERICAN ELECTRIC POWER
CARDINAL PLANT
BRILLANT, OHIO

EXHIBIT 1

SITE LOCATION MAP

FEBRUARY 2010

SOURCE:
7.5 MINUTE TILTONSVILLE, OHIO U.S.G.S. QUADRANGLE MAP

PLOTTED: 2/5/2010 10:02:32 AM
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2.0 PROJECT DESCRIPTION

2.1 General

FAD I, FAD II, and the BAP complex are owned by AEP and Buckeye Power and operated by Cardinal Operating Company. They are located near the Cardinal Power Plant in Wells Township, Jefferson County, near Brilliant, Ohio. The Cardinal FAD I and FAD II are located approximately 1 mile northwest of the Cardinal Power Plant. The BAP complex is located at the southern part of the Cardinal power plant. The ponds were constructed for the settling/sedimentation and collection/storage of coal combustion byproducts. Exhibit 1 shows the FAD II and BAP complex in relation to the Cardinal Plant.

2.2 Fly Ash Dam I

Cardinal Fly Ash Dam I (FAD I) is the plant's original fly ash retention dam constructed in the early 1970s. The dam is an earth and rockfill dam having a final design crest elevation of 1001.5 feet. The dam has upstream (u/s) and downstream (d/s) slopes of approximately 2.5 Horizontal to 1 Vertical (2.5H:1V). As ash placement behind FAD I reached its maximum allowed level, Cardinal FAD II was constructed and began operation in the late 1980s. Fly Ash Dam I reservoir is closed, no longer receives fly ash slurry, and has no permanent pool. This area has been remitted by the Ohio Environmental Protection Agency (EPA) as a solid waste landfill (Permit to Install [PTI] Permit No. 06-07993, dated May 11, 2007) for the disposal of synthetic gypsum generated by the air pollution control equipment constructed at the Cardinal plant that captures sulfur dioxide emissions. Flow through FAR I is conveyed to FAR II via the FAD I emergency spillway.

2.3 Fly Ash Dam II

FAD II is located on Blockhouse Run, which flows directly into the Ohio River. Blockhouse Run splits into two branches, designated as the East Branch and the West Branch. The split in Blockhouse Run is approximately one mile upstream of the Ohio River. Runoff from both the east and west branch watersheds drains into the reservoir.

Fly Ash Reservoir II (FAR II), created by FAD II, is utilized for the storage of fly ash, which is discharged as slurry from six (6) 10" discharge pipes located at the upstream (north) end of the reservoir as shown on Exhibit 2. The fly ash settles out within the reservoir as the water flows toward the dam where the effluent overflows through the service spillway (overflow structure). Stop logs are placed in the discharge shaft of the overflow structure as

necessary to maintain settling action or to limit discharge. The reservoir will cover approximately 168 acres at Elevation 974, the maximum operating pool elevation.

The FAD II dam consists of a 250-foot high arched embankment with a 13 ft high MSE Wall on top of the roller compacted concrete (RCC) cap on the upper 50 feet of the upstream face and an emergency spillway on the left abutment that is an open channel cut through rock. The dam has a crest elevation of 983 feet. The dam crest has a width of 22 feet and a length of 1,645 feet. The dam is designed for a storage capacity of 11,868 acre-feet with stop logs at elevation 972.5 feet and with a corresponding maximum operating pond elevation of 974 feet. Table 1 summarizes pertinent information for FAD II.

Table 1 FAD II and BAP Complex Data

Parameter	FAD II	BAP Complex
Embankment Crest Elevation (feet)	983	670
Emergency Spillway Crest Elevation (feet)	975.5	665.5
Maximum Operating Pool Level (feet)	974.0	665
Operating Pool Freeboard (feet)	9	665
Maximum Stop Log Elevation (feet)	972.5	665.5
Surface Area (acres) at Pool Level	161	29

Table 2 includes a list of inlet and outlet structures in addition to an inventory of the works and other significant components existing at the FAD II and their location and characteristics. In addition, Appendix C includes reference information in form of water cycle Diagram, Drawings, and photos of the components.

Table 2

Features and appurtenances	Description
Embankments	Approximately 1645 ft at crest elevation of 983.
Inflow pipes	Six 10” diameter fly ash sluicing steel pipes, 12.87 MGD (EL. 962)
Spillways	Sizes 48” wide, Max elevation: 972.5, adjusted with 6” high stop logs (concrete).
Emergency spillway/overflow	Size: 110.5'x 7.5' elevation: 975.5 (Concrete)
Embankment drainage systems	Exhibit 2 and Appendix C
Monitoring weirs, flumes	Exhibit 2 and Appendix C
Piezometers and monitoring wells	Appendix C
Inclinometers	Annual monitoring, See Appendix C for location
Staff gauge & signage	Exhibit 2 and Appendix C
Settlement monuments	Annual monitoring, See Appendix C for location
Abandoned structures	Grouted in place, Exhibit 2

2.3.1 Fly Ash Dam II Service Spillway (Over Flow Structure)

The service spillway is extended with a new vertical concrete shaft structure with one side opening on top of a sloping concrete shaft structure with one side opening, four feet wide, connecting into a 54 inch diameter pre-stressed concrete cylinder pipe (PCCP).

The bottom of the sloping concrete shaft and the entire 54-inch concrete pipe were constructed within bedrock as part of the 1997 FAD II rising. Stop logs are utilized to promote settling action and control the operating pool level.

Stop logs will be incorporated into the new vertical section to continue to allow for the incremental raising of the operating pool.

2.3.2 Fly Ash Dam II Emergency Spillway

The principle spillway (or overflow structure) is located on the left abutment and is an open channel cut through rock. The flow capacity of the emergency spillway is designed to pass the Probable Maximum Flood when the reservoir reaches its maximum pond elevation, without overtopping the dam. At intermediate pool levels, floods of lesser magnitude will be discharged through the service spillway.

The fly ash dam is normally unattended and the service spillway structure has no remote controlled system to regulate the flow. Because of the nature of the pond and the design of the dam and service spillway structure, there exists sufficient freeboard to mitigate concerns of overtopping during a rainfall event.

2.3.3 Downstream Effects

There are no dams or residences located above the dam or in the east or west watershed boundaries. There are no dams located downstream that could be operated during an emergency to store flood flows. The Ohio River, Cardinal Plant, State Route 7 and the Tidd-dale subdivision of Brilliant, Ohio, all lie directly downstream of the proposed dam. Therefore, a sudden failure of the dam will likely result in loss of human life and damage to homes, high value utility installation and both a railroad and a public road.

2.4 Bottom Ash Pond Complex

The BAP Complex at the Cardinal Plant consists of a BAP (approximately 20 acres) and a Recirculation Pond (RCP) (approximately 9 acres). Flow from the BAP is discharged to the RCP. The exterior dike crest elevation varies and an overflow conduit with an inlet elevation of approximately 665.5 feet controls the maximum Recirculation Pond water

level. In 2008, plastic sheet piling was driven across the recirculation pond to modify its flow pattern in preparation of allowing the present overflow structure to discharge from the basin. The arrangement of the BAP Complex is shown in Exhibit 3 and Table 1 summarizes pertinent information for BAP Complex.

The bottom ash pond complex is located along the west bank of the river just to the south of the main plant area. The bottom ash pond complex consists of two components: the bottom ash pond and the recirculation pond (RCP). The bottom ash pond complex is utilized for the storage and collection of bottom ash, Bottom ash-laden water and other storm water is discharged via thirteen (13) pipes into the northwest corner of the bottom ash pond, the coarse bottom ash settles out closer to the discharge lines while the finer bottom ash settles out at farther locations within the pond. Near the southeast side of the bottom ash pond, Overflow Discharge structure (a drop outlet and a 36"-pipe) controls flow from the bottom ash pond into the recirculation pond. The water in the RCP is used to sluice the fly ash form the plant to FAD II via the pump station

Table 3 includes a list of inlet and outlet structures in addition to an inventory of the works existing at the BAP complex and other significant components and their location and characteristics. In addition, Appendix C includes such information in form of water cycle Diagrams, Drawings, and photos of the referenced components.

Table 3

Features and appurtenances	**Description**
Embankments	Approximately 4700 ft at crest elevation of 670.
Inflow pipes	13 10" diameter fly ash sluicing pipes
Outflow pipes	36" diameter steel pipe into to 36" diameter PVC pipe Exhibit 3 and Appendix C Pumphouse intake pipes: Two 21" diameter for ash sluicing (El 660).
Spillways	Drop inlet with stoplogs and 36" pipe;
Monitoring weirs, flumes	Exhibit 3 and Appendix C
Piezometers and monitoring wells	Annual monitoring, See Exhibit 3 for location
Staff gauge & signage	Exhibit 3
Emergency spillway/overflow	Sharp –crested 3 ft wide 10" weir at EL 665.5
Pump house	Intakes elevation 660, capacity:16.9 MGD

The BAP is located north of the RCP and they are separated by an earthen embankment. Perimeter dikes surround the bottom ash pond complex and are referred to as the BAP complex dike. The crest elevation of the embankments varies with a minimum elevation of 670 feet MSL. An overflow conduit with a variable inlet elevation and a pipe between the

BAP and the RCP controls the maximum BAP water level. The total length of the Interior embankment is approximately 2,500 feet and the total length of the exterior embankment along the Ohio River is approximately 2,000 feet. For comparison, the normal pool for this stretch of the Ohio River is El. 644. Both ponds are isolated from exterior surface water inflow. An overflow conduit with an inlet elevation of approximately 665.5 feet controls the maximum recirculation pond water level. In 2008, plastic sheet piling was driven across the recirculation pond to modify its flow pattern in preparation of allowing the present overflow structure to discharge from the basin. In 2010, the top of the BAP complex exterior dikes were re-graded to insure that the minimum elevation of 670 is applicable all over the dike. The arrangement of bottom ash complex is shown in Exhibit 3.

2.4.2 Downstream Effects

FAD II located upstream of the BAP complex dikes. The Ohio River located downstream of the BAP complex dikes. Therefore, sudden failures of the dikes will not likely result in loss of human life or damage to homes.

3.0 OPERATION OF THE RESERVOIRS

3.1 Mechanical Equipment

The mechanical equipment associated with the FAD II includes three aerators a pump station. The pump station is use to provide water for Ohio American Energy Inc's (OAEI) coal prep plant and is operated by OAEI. The aerators operated by AEP (Please see table 4 below for contact info). The aerators are necessary to mix the pond waters and maintain oxygenated conditions to promote algae bloom to consume phosphate carryover from the synthetic gypsum pollution control equipment. Therefore, the aerators should be inspected periodically to assure proper operating conditions.

The mechanical equipment associated with the BAP Complex includes the pumps located at the Pumphouse in the RCP area. Plant control room coordinator is responsible for monitoring and adjusting the pumping rates for the recirculation water. Typical and maximum flow rates are included in the Plant water cycle included in appendix C.

Table 4. Contacts List for Operating, Maintenance, and Inspecting the dams.

Name	Address	Phone	Responsibility
Eric (Randy) Sims	306 County Road 7 East Brilliant, OH 43913	(740) 314-9982	Dam safety Officer
Unit 3 Team Leader	306 County Road 7 East Brilliant, OH 43913	(740) 598-6530	Management of flow rates in and from impoundments

3.2 Outflow Measurements

Flow measurements from FAD II are measured utilizing a Parshal flume at the outlet of the impact basin immediately downstream from the dam as shown on Exhibit 2.

3.3 Drawdown Plan

There is no drain for the fly ash reservoir II due to its purpose of sedimentation. The only procedure that exists for lowering the pool elevations is the removal of the grouted stop logs in the drop inlet structures. If necessary, use alternate means to drain the pond, such as siphons or pumps. It may be necessary to excavate a hole in accumulated fly ash to enhance removal of water. All drawdown activities are to be coordinated with AEP Civil Engineering.

3.4 Safe Rate of Reservoir Drawdown

Deliberate drawdown beyond normal operational requirements shall typically not exceed 1 foot per week, except for emergency situations. Faster drawdown rates may be required under emergency conditions with the approval of the AEP Geotechnical Engineering.

3.5 Safe Dredging and temporary Stockpiling

BAP is the only pond among Cardinal Plant ponds that currently involves dredging and temporary stockpiling material above the top of dike elevation. Dredging and temporary stockpiling activities take place on regular bases to allow for the use of the bottom ash pond for settling of bottom ash. The dredged material is being beneficially used in the construction activities at the plant. Coarse bottom ash excavated closer to the sluicing point and stockpiled temporarily to allow for water draining. The finer bottom ash is usually dredged into dredging cell that exists within the BAP complex. The dredging unit is not allowed to operate next to the toe of the dam due not only to water depth requirements but also for dam safety. Once dewatered, the stockpiles are excavated and materials transported off-site for beneficial use in landfill construction.

3.6 Vandalism

"No Trespassing" signs shall be posted where appropriate. Railings or fences and warning signs shall be erected around dangerous areas.

3.7 Emergency Conditions

If any of the following conditions occur or appear imminent, the Emergency Action Plan (EAP) (separate document) shall be implemented immediately:

1. Overtopping or nearly overtopping of the embankment.
2. Piping through the embankment, spillway, or foundation.
3. A large slide in the embankment.

3.8 Records

Accurate records shall be kept of the following items:

1. Maintenance and major repairs. Appendix A contains a sample maintenance/repair log; an alternate log system may be used following plant record keeping procedures.

2. Specific observations and changes recorded and photographs taken during normal inspection periods (see Appendix B).
3. Date, hour, and maximum elevation of extreme high-water occurrences and the associated rainfall.
4. Amount, rate, and reasons for drawdown.
5. Readings made of water levels in piezometers in and near the embankment.
6. Complete and up-to-date set of as-built plans and specifications which show all changes made since the completion of the dam.
7. Visual observation of the horizontal and vertical alignment on an annual basis. If needed, the alignments should be surveyed to verify any changes.
8. Seepage location, quantity and content of flow, and size of wet area for later comparison. V-notch weirs can be used to collect and measure flow rates.
9. Erosion location and extent of erosion for later comparison.

4.0 MAINTENANCE PLAN

This section describes general maintenance procedures to be implemented at Cardinal FAD II and the BAP complex. In addition to the information provided in the following paragraphs, the ODNR has prepared a series of Fact Sheets for guidance on operation and maintenance at dams; several pertinent fact sheets are included in Appendix D for quick reference by AEP. Maintenance work to control seepage; repair cracks, slides, sloughing, damaged or deteriorated riprap; fill settled or low areas in the embankment; and repair concrete appurtenances should be performed based on the recommendations of AEP Civil Engineering.

4.1 Vegetation

1. Grassed areas shall be mown at least twice per year.
2. Paths created by pedestrian, vehicular, or animal traffic shall be minimized, and any barren areas which develop should be seeded.
3. Any cracks and/or erosion gullies which develop shall be completely filled with thoroughly compacted soil. The area shall be resodded if less than 100 square feet (sf), and reseeded if larger than 100 sf.
4. Trees and brush shall not be permitted to grow on the embankment. Tree and brush growth in the creek channel downstream of the FAD II impact basin shall be minimized. Remove any trees or brushes from the embankment and within 25 ft of the groins before they become established. The roots of any tree that is cut down should be pulled out. The resulting hole should be backfilled with tamped topsoil and reseeded. Replace areas of sparse or displaced riprap on the upstream slopes. This should be budgeted and performed annually to assure no growth of trees and brush on the embankment. ODNR Fact Sheet 94-28, Trees and Brush, in Appendix D, outlines the importance of properly maintained embankment vegetation.

4.2 Erosion

1. Promptly repair any eroded areas on the embankment to prevent more serious damage to the embankment (see Section 4.1 Vegetation). Repair erosion gullies to provide an even slope surface. Minor rills and gullies shall be filled with compacted cohesive soil, and then top soiled and seeded.
2. Erosion in large gullies can be slowed by stacking and securing bales of hay across the gully until permanent repairs can be made.
3. Causes of erosion shall be eliminated. Surface drainage should be spread out in thin layers as sheet flow.

4.3 Seepage

1. Any areas of seepage shall be noted and observed for evidence of piping erosion. Seepage containing soil is a sign of potential serious damage to the dam which may lead to failure of the dam and should be promptly addressed. Professional engineering assistance for control of any seepage problems shall be obtained.
2. Maintain written records of seepage (see Section 3.7 Records).

4.4 Cracks, Slides, Sloughing, and Settlement

1. Cracks, slides, sloughing, and settlement are signs of embankment distress and indicate that maintenance or remedial work is necessary.
2. A Professional Engineer shall determine the cause of stress before any repairs are made. Maintain written records of problems found and repairs completed (see Section 3.7 Records).

4.5 Rodent Control

1. Activities of rodents, such as groundhogs, muskrats, and beavers can endanger the structural integrity and proper performance of an embankment. Groundhogs and muskrats burrow into an embankment, thereby weakening it and creating seepage paths. Rodent control is therefore essential for a well-maintained dam. Refer to ODNR Fact Sheet 94-27, Rodent Control, in Appendix D, for further information.
2. Repair rodent burrows and implement rodent control procedures as follows:

i. Rodents may be controlled by fumigants. More detailed information on rodent control is contained in ODNR Fact Sheet 94-27, Rodent Control, in Appendix D. Fumigate rodent burrows with ignitable gas cartridges. To fumigate a burrow, light and drop an ignitable gas cartridge as deep into the burrow as possible. The burrow entrances should then be plugged with compacted soil. The procedure should be repeated at all burrow holes. The gas in the cartridge is non-poisonous. However, one should avoid inhaling the gas. Gas cartridges can be purchased at any local farm supply store.

ii. Backfill burrows by following the mud-packing method. First, place one to two lengths of metal stove or vent pipe in a vertical position over the entrance of the burrow. Mud-packing slurry should be made by adding water to a 90 percent bottom ash and 10 percent cement mixture. The slurry should then be poured into the burrow through the vertical pipe. Fly ash or bentonite may be added, as needed, to increase the flowability of slurry. After the burrow is filled, the pipe should be removed. Dry earth should be tamped into the burrow entrance and reseeded. A method for backfilling by mud packing is described in ODNR Fact Sheet 94-27, Rodent Control, in Appendix D.

4.6 Debris

Debris shall be removed from the outlet structures and their discharge pipes to allow free discharge. Caution should be used during high pond levels.

4.7 Concrete Structures

1. All deteriorated concrete surfaces (i.e., spalling, cracking, pitting, etc.) shall be repaired.
2. If sealant is observed to be missing from construction/expansion joints on the concrete outlet structures, monitor the condition and replace the sealant if necessary.

4.8 Toe Drain

1. The toe drain outlets should be inspected and observations recorded on a semiannual basis. Space to record these observations is provided in the Inspection Record form in Appendix B.

2. Areas of known seepage should be monitored for evidence of piping erosion. Seepage containing soil is a sign of potential serious damage to the dam which may lead to failure of the dam and should be promptly addressed. Professional engineering assistance for control of any seepage problems should be obtained.

3. In addition to quarterly monitoring, the toe drain outlet should be monitored during and after periods of high reservoir levels (greater than 2 foot of water over the principal spillway). If flow significantly increases at any time, contact a Professional Engineer for evaluation of the recorded data.

5.0 INSPECTION PROGRAM

5.1 Purpose

The purpose of this inspection program is to detect and document any changes in condition of the dam. AEP has an established Dam Inspection and Maintenance Program (DIMP) applicable throughout the service life of the facility. When a change in condition is detected, AEP-Civil Engineering staff and/or a Professional Engineer shall be contacted to identify any necessary remedial repair or maintenance work. The DIMP also provides a mechanism by which to activate the EAP which is made part of this Operations, Maintenance and Inspection Manual. The program consists of the following steps:

1. Conduct scheduled and unscheduled field inspections to check for signs of malfunction and to read the geotechnical instrumentation.
2. Graphically plot and interpret field measurements.
3. Investigate problems as they develop.
4. Design and implement preventive and remedial measures as required.
5. Perform regularly scheduled and routine maintenance work on the dam and its appurtenances.
6. Activate the EAP in the event that an unsafe condition is detected.

The description of the field instrumentation and the details of the DIMP are presented in the following sections.

For clear identification, a pictorial representation of potential problems and resolutions has been excerpted from Federal Emergency Management Agency (FEMA) 145, Dam Safety: An Owner's Guidance Manual, August 1987, and is contained in Appendix E for reference.

5.2 Personnel

Inspections shall be performed by a responsible person familiar with this Operation, Maintenance, and Inspection Manual. The same personnel shall perform all regular dam inspections to maintain consistency in reporting as well as familiarity with the structure. A checklist outlining the major inspection items for the dam and appurtenances is provided

in Appendix B. Plant personnel should use this checklist to inspect the dam and report the findings. Currently, Mr. Randy Sims is the plant personnel responsible for performing Dam Inspections. Copies of the inspection findings should be sent to AEP Civil Engineering for evaluation.

5.3 Periodic Inspections

a. Periodic inspection of the dams is extremely important. AEP has regularly inspected the dams on a quarterly basis. AEP shall continue quarterly inspections.

   i. Three of the quarterly inspections can be completed by Cardinal Plant personnel.

   ii. The fourth quarterly inspections shall be completed by an engineer knowledgeable in dam safety. This inspector may be either a qualified AEP engineer or an independent consulting engineer. This inspection shall be a comprehensive review of field conditions and instrumentation readings.

b. Inspection instructions and an inspection checklist to be used to record observations are found in Appendix B.

c. The inspection procedures and findings must be documented in writing. The quarterly inspection reports shall be maintained for a minimum of 10 years.

d. If problems are found during an inspection that may affect the integrity of the dam, the EAP for the dam shall be followed for the appropriate emergency condition (A, B, or C) and the identified problems shall be placed under increased surveillance and scheduled for repair as appropriate. See also Appendix E for additional guidance.

e. Problems found during an inspection which do not immediately affect the integrity of the dam shall be noted and scheduled for follow-up monitoring and repair as appropriate.

5.4 Event Inspections

A brief inspection shall be made within 24 hours of unusual event such as seismic activity or significant precipitation event (e.g., greater than 3 inch of rain in 24 hours or 6 inches of rain in seven days) or within 24 to 48 hours after placing three or more stoplogs in the drop-inlet structures to ensure that the outlet structures and their discharge pipes are unobstructed, no earth slide has occurred, no significant erosion gullies have formed, and

no seepage is present. Concentrate inspections at known problem areas; pool level; debris at outlet structure; new or increased seepage. These Inspections shall be recorded on the dam inspection checklist. Instrumentation should be recorded if new or increased seepage is detected during this inspection.

5.5 Informal Inspections

Informal inspections include both daily and weekly surveillance by Plant personnel looking for changes in conditions (slips along dam face, erosion gullies, excessive settlement, malfunctioning drains, new seepage areas, etc).

Informal inspections shall be made after every significant precipitation event (e.g., greater than 1/2 inch of rain or 3 inches of snow in 24 hours) to ensure that the outlet structures and their discharge pipes are unobstructed, no earth slide has occurred, no significant erosion gullies have formed, and no seepage is present.

These inspections shall be documented either on the checklist form or on an inspection log by indicating the date and time of the inspection, the inspector name(s), the weather conditions, any observed deficiencies or unusual change in the operating or physical conditions, and the overall physical condition of the dam or dike.

5.6 Instrumentation —Fly Ash Dam II

The following instrumentation has been installed to monitor key aspects of the dam's performance:

5.6.1 Seepage Collection/Measurement

Since the 1997 raising, seepage has been identified at three primary locations, specifically:

1. Along the right abutment of FAD II from a spring.
2. Along the left channel slope of the emergency spillway channel.
3. Above the discharge channel along the left side emerging from the bedrock
4. Additionally, a new seep was identified in June of 2013 along the right downstream abutment/dam groin. In October of 2013, an inverted filter and drain was installed. The pipe exiting the drain has been monitored at regular intervals since this time

and the seepage rate has been found to be approximately 0.25 gallons/minute and seepage itself free of fines. One last reading should be obtained within the week prior to stop log placement.

5. Any additional seeps discovered after the pool level has been raised will be added to the inspection list and monitored. If possible, collect seepage and monitor the flow through the use of a V-notch weir or a pipe.

6. Attention should be given to the area at the right groin downstream of the installed PVC sheet pile #79 to be able to trigger any seepage occurring in that area.

If seepage increases by more than 25% at any location, AEP Civil Engineering will immediately be contacted for evaluation.

AEP maintains a Drain and Seepage Zone Spreadsheet detailing drain number and location. This worksheet is included in Appendix B, Section 6 – Pipe Drains as part of the inspection checklist.

5.6.2 Piezometers/Observation Wells

1. Water levels in the piezometers shall be determined and recorded on a quarterly basis to monitor changes in the pore pressures within the dam. Water levels shall be measured to the nearest tenth of a foot. A form for recording the piezometer readings is provided in Appendix B.

2. In addition to quarterly monitoring, the piezometers shall be monitored during and after periods of high pool levels (pool level rise greater than 2 feet from a precipitation event). If piezometer water levels within the dam rise more than 2 feet during a flood event, contact AEP-Civil Engineering staff and/or a Professional Engineer for evaluation of the recorded data.

3. All piezometer monitoring must be done with regard to the safety of the personnel performing the monitoring. Personnel shall cease monitoring activities if weather conditions become hazardous (i.e., lightning), if failure of the dam is imminent, or if safe exit from the embankment will be cut off by flood flows.

5.6.3 Surface Monuments

More than 60 survey monuments have been installed on FAD II to monitor horizontal and vertical movements (See Appendix C). A monitoring plan illustration can be found in

Appendix B. Annual surveys are performed by AEP Civil Laboratory. Copies of the surveys should be sent to:

1. Cardinal Plant Manager
2. AEP Civil Engineering.

5.6.4 Slope Inclinometers

Five slope inclinometers have been installed on FAD II to monitor horizontal movements with depth along the central section of the dam (See Appendix C). Annual reading of the slope inclinometers are performed by AEP Civil Engineering Laboratory. Copies of the readings should be sent to:

1. Cardinal Plant Manager
2. AEP Civil Engineering.

6.0 EMERGENCY ACTION PLAN

The EAP for FAD II is made part of this O&M Manual but is provided as a separate document. The EAP includes the notification flowcharts of individuals/agencies that will be contacted in the event of unsafe conditions detected at any of the three dams.

6.1 Unsafe – Emergency

Each of the malfunctions listed under the UNSAFE – EMERGENCY performance corresponds to a rapid/instantaneous failure condition. Therefore, in the event that one or more of these malfunctions are detected, there may not be enough time for a thorough evaluation of the situation. Accordingly, the first action to be taken by field personnel is notifying the Team Leader who in turn should activate the EAP.

6.2 Unsafe – Non Emergency

Malfunctions under the category of UNSAFE – NON EMERGENCY corresponds to potentially hazardous conditions. These types of malfunctions should allow sufficient time for an expedient evaluation of the situation and for the implementation of remedial measures. Accordingly, the recommended immediate response in the event that one or more of these malfunctions is detected is to use an ALERT as dictated by the EAP and to upgrade the inspection and monitoring program.

6.3 Marginal Deficiency

The malfunctions in the Marginal Deficiency category do not pose a serious threat to the safety of the dam: Therefore, the appropriate field response is to alert the AEP Civil Engineering of the situation and follow up with the inspection checklist report.

6.4 Minor Deficiency

The remaining malfunctions correspond to maintenance rather than immediate safety related problems. These conditions, if detected, will not require any special immediate response other than the normal reporting required under the Dam Inspection and Maintenance Program. If appropriate, an order for maintenance work should be written and implemented by plant personnel.

INSPECTION RESPONSE TABLE

Performance Level of the Dam	Malfunctions or Undesirable Features	Actions to be Taken By Field Personnel (In Order Indicated)
UNSAFE Emergency	• Overtopping or activation of emergency spillway • Breach or slide below the waterline, which reaches the dam crest and/or seeps water. • Springs on abutment or downstream slope with muddy water and progressively increasing flow rate.	1. Notify Team Leader who in turn should issue a Notification. (See EAP) 2. Continue 24-hr. surveillance program, if possible. 3. Read all field instrumentation daily, if possible.
UNSAFE Non-emergency	• Springs on abutments or downstream face with muddy water but stable flow rate. • Pipes, cavities, or holes, which could be attributed to internal erosion, even without evidence of seepage. • Clogged drains. • Slide with no seepage and that does not reach the dam crest. • Noticeable increase in amount of foundation or abutment seepage or piezometer level.	1. Notify Team Leader who in turn should issue an Alert (see EAP). 2. Initiate a daily surveillance program. 3. Read all field instrumentation daily, if possible. 4. Report on Inspection Checklist.
MARGINAL Deficiency	• Cracks parallel or transverse to the dam. • Soft zones in downstream face or toe. • Previously undetected springs with clear water and stable flow rate on face of dam or abutments. • Excessive settlement of crest.	1. Contact AEP Civil Engineering. 2. Report on Inspection Checklist.
MINOR Deficiency	• Damaged instrumentation. • Sloughing. • Rodent burrows. • Surface or riprap erosion. • Trees and tall vegetation on embankments or spillway channel. • Poor vegetal cover.	1. Report on inspection Checklist. 2. Write repair order, if appropriate.

7.0 OWNER'S REVIEW

This Operation, Maintenance, and Inspection Manual was prepared for AEP's Cardinal facility fly ash dam II and bottom ash pond complex and supersedes all previous versions. I have read the Manual on behalf of AEP and understand the actions that will be required of AEP, and acknowledge that the information contained herein is, to the best of my knowledge, accurate as of the date of my signature.

Charles W George — 2-27-15

(Signature) Date

Charles W George
Plant Manager

APPENDIX A
DAM MAINTENANCE RECORD

CARDINAL FAD II
DAM MAINTENANCE RECORD

FOR YEAR _____

Maintenance	Date	Initials	Comments [a]
1. Cut/mow grass and clear brush			
2. Cut/mow grass and clear brush			
3. Cut/mow grass and clear brush			
4. Cut/mow grass and clear brush			
5. Remove debris from outlet structures			
6. Repair eroded areas			
7. Concrete repair (describe)			
8. Repair rodent damage			
9. Piezometers Maintenance (if required)			
10. Other (specify)			
11. Other (specify)			

[a]Use additional sheets if necessary.

_____

Signature

APPENDIX B
DAM INSPECTION INSTRUCTIONS
AND
DAM INSPECTION CHECKLIST

A. Dam Inspection Instructions

1. Dike Inspection Checklist

a. Inspectors and others should include names and affiliations.

b. Weather and site conditions should include weather conditions and the condition of the ground surface (i.e., wet, snow covered, dry, etc.), at the time of the inspection. Note, if the inspection is occurring immediately after a heavy precipitation (e.g., greater than 0.5 inch rainfall or 3 inches of snow in the preceding 24 hours)

c. Fill in the information requested. Obvious problems will require maintenance. Monitoring will be recommended if there is potential for a problem to occur in the future.

2. Comments

a. A brief description of any noted irregularities, needed maintenance, or problems for each item checked should be made. Abbreviations and short descriptions are recommended.

3. Sketches and Field Measurements

a. Explanatory sketches, measurements of cracks, settlement, and additional explanation of observations should be placed on these pages. A copy of the Cardinal Plant Dam Inspection Location Plan should be used to indicate the locations of any concerns identified during an inspection.

b. Definitions:

CW	Clear Water
BA	Bottom Ash
GPM	Gallons Per Minute
MGD	Million Gallons per Day

CARDINAL PLANT
FLY ASH DAM II
INSPECTION CHECKLIST

CARDINAL PLANT
FLY ASH DAM II
INSPECTION CHECKLIST

1. GENERAL INFORMATION

Date of Inspection	
Inspected by	
Reason for Inspection	
Weather	
Temperature	
Rainfall During Previous 7 Days	
Reservoir Elevation: Fly Ash Dam II	
Available Spillway Freeboard (974.0 - Reservoir Elevation)	
Available Dam Crest Freeboard (983.0 - Reservoir Elevation)	

2. EMBANKMENT CONDITION

Note the conditions of the overflow structures and, to the extent practicable, the discharge pipes. Signify good conditions with a checkmark, problem areas with an X in the appropriate spaces below. The FAD II Inspection Location Page shall be used to indicate malfunction locations. Place a number or letter (location code) on the plan at each problem area. Place the same letter(s) or number(s) next to appropriate malfunction. Place sketches, notes, and comments.

Malfunction	" ✔ "or "X"	Location Code	Descriptive Features
Bulges			Areal extent and elevation
Cavities or Holes			General shape, size, and elevation
Cracks			Length, width, depth and elevation
Surficial Erosion, Gullies			Length, width, depth, areal extent
Sloughing/Slides			Areal extent, vertical drop
Soft Soil			Areal extent and vegetation
Springs/Seepage/ Wetness			Flow rate, muddy or clear water, areal extent, and elevation
Rodent Burrows			Size, areal extent if clustered
Poor Vegetal Cover			Areal extent

Malfunction	" ✔ "or "X"	Location Code	Descriptive Features
Trees or Tall Vegetation			Areal extent, height, trunk size
Excessive Crest Settlement			Settlement/affected crest length
Defects in Crest Road			Size, areal extent
Clogged Drains			Color and origin of deposit/size of color
Deteriorated Rip Rap Outlet Channel			Areal extent
Other (Please specify and describe)			

Note: All malfunctions which occur within the same general area should be shown in the same descriptive sketch or narrative for that particular problem area.

3. OVERFLOW STRUCTURE

Inspect the below listed structures. Place a " ✔ "in the space if the condition is good; place an "X" in the space if a problem is found and describe the problem below. If necessary, continue description of problem on Page 12, NOTES AND COMMENTS.

Description	" ✔ " or "X"	Location Code	Descriptive Features
Does discharge flow appear normal?			
Condition of concrete at spillway shaft			
Are extra stop logs available?			
Have stop logs been added? If yes, note number, date, and new top elevation			
Obstruction: note location(s)			
Have obstructions been removed?			
Are access stairs OK?			
Are the any rusted areas in the skimmer?			
Other (please specify)			

4. OUTLET WORKS

Please note the conditions with regard to the following items. If a problem is observed, please describe it.

Does the discharge flow appear normal at the energy dissipater?	
Is the condition of concrete at energy dissipater and Parshall flume OK?	
Is the condition of the Parshall flume OK?	
Is flow through the Parshall flume without turbulence?	
Is there any erosion or riprap problem at the outlet channel?	
Is rubble from the hillside obstructing or threatening to obstruct the outlet channel?	
Other comments.	

5. EMERGENCY SPILLWAY

Please note the conditions with regard to the following items. If a problem is observed, please describe it.

Are there any trees or obstructions in the channel?	
Is there evidence of instability on the side slopes?	
Are there erosion gullies or problems with the vegetal cover in the channel?	
Other comments.	

6. PIPE DRAINS

- Using a stopwatch, determine the time in seconds it takes each of the drainage blanket pipes to fill a 1- or 5-gallon bucket.
- Calculate the pipes discharge in gallons per minute (gpm).

Discharge = 60/time in seconds or 300/time in seconds.

- Record the measurements and describe the turbidity of the discharge in the table below.
- Note: The 12″ diameter spring flow (north of the large weir) can be calculated from the large weir flow minus the sum of all other incoming flows.

Pipe	Time (Sec)	Discharge (gpm)	Description
12″ Dia. Solid E. Underdrain El. 735 (North of Large Weir)			
12″ Dia. Perf. W. Underdrain El. 734 (North of Large Weir)			
12″ Dia. Solid Spring Outlet El. 738 (North of Large Weir)	See Note Above		
4″ Dia. Solid Spring Outlet El. 867 (East Abutment Ditch)			
12″ Dia. Solid Spring Outlet El. 893 (West Abutment Ditch)			
6″ Dia. Solid E. Sprg. Outlet El. 739 (@ Energy Dissipater)			
4″ Dia. Solid W. Sprg. Outlet El. 739 (@ Energy Dissipater)			
6″ Dia. Solid E. Groin Drain El. 907 (In Emerg. Spillway)			
12″ Dia. Solid RCC Drain El. 908 (In Emerg. Spillway)			
6″ Dia. Solid Right Groin Channel. Outlet El. 943			
Other			

7. V-NOTCH WEIRS

7.1 The large 12-inch weir measures the total surface flows, spring flows, and the underdrain flows from the riprap slide repair area.

- Read the head of water acting on the large weir from the staff gauge which is attached to a lumber post located approximately 5 feet upstream of the weir.

- With this reading and the rating curve for a 90° V-notch weir shown Page 14, determine the discharge over the weir in gpm. Record the water head and discharge as follows:

Head, inches	
Discharge, gpm	
Has a significant snowmelt occurred during the last 2 days?	
Additional comments about condition of the _____	

7.2 The small 6-inch weir (located south of the large weir in a small basin) measures all of the dam internal drainage blanket flows.

- Read the head of water acting on the weir from the floor of the weir and subtract 6 inches to obtain the correct reading.

- With this reading and the rating curve for a 90° V-notch weir shown on Page 14, determine the discharge over the weir in gpm.

- Record the water head and discharge as follows:

Head, inches	
Discharge, gpm	
Has a significant snowmelt occurred during the last 2 days?	
Additional comments about condition of the _____	

8. PNEUMATIC PIEZOMETERS

8.1 Obtain water level readings at the piezometers that follow:

- Use the portable indicator to read the pressure, in psi, at each pneumatic piezometer following the procedure outlined in the Instruction Manual for Pneumatic-Pressure Transducer Model 51421102.

- Determine the pressure head in feet of water by multiplying the pressure by 2.308.

- Determine the water elevation or total head by adding the pressure head, in feet of water, to the corresponding elevation of the transducer tip (elevation head).

- Record the pressure and total head calculations in the table below.

Note: The piezometers with an asterisk (*) in front of their identification number should be read on the same schedule as the field inspections. All other piezometers should be read every three months.

PIEZOMETER RECORD

Piezometer No.	Pressure (psi)	Pressure Head (ft)	Elevation Head (ft)	Total Head (ft)	Comments
EXAMPLE	10.5	24.2	730.4	754.5	
P-1A			752.30		
P-2A			771.00		
P-3A			801.30		
P-3B			772.30		
*P-1BE			728.00		
*P-1BW			735.90		
*P-2BE			730.00		
*P-2BW			731.10		
*P-1C			714.40		
*P-2C			711.00		
*P-3C			712.30		
*P-4A			798.90		
P-5A			774.70		
P-5BR			725.30		
P-8A			802.10		
*P-8B			776.00		
*P-9			771.20		
*P-10			769.10		
*P-11			802.60		
P-11B			789.10		
P-RCC1			923.30		
P-RCC2			913.40		
P-RCC3			913.30		

Additional comments regarding piezometer readings and the condition of the terminal panel and housing structure.

9. HYDRAULIC (STANDPIPE) PIEZOMETERS

- Use a water level indicator to measure the depth to water in each hydraulic piezometer. Determine the water elevation (i.e., total head) by subtracting the depth of water from the elevation of the top of riser for the corresponding piezometers.
- Record the readings and calculations on the table below.
- The schedule for reading the hydraulic piezometers should be the same as for conducting the field inspections.

Piezometer

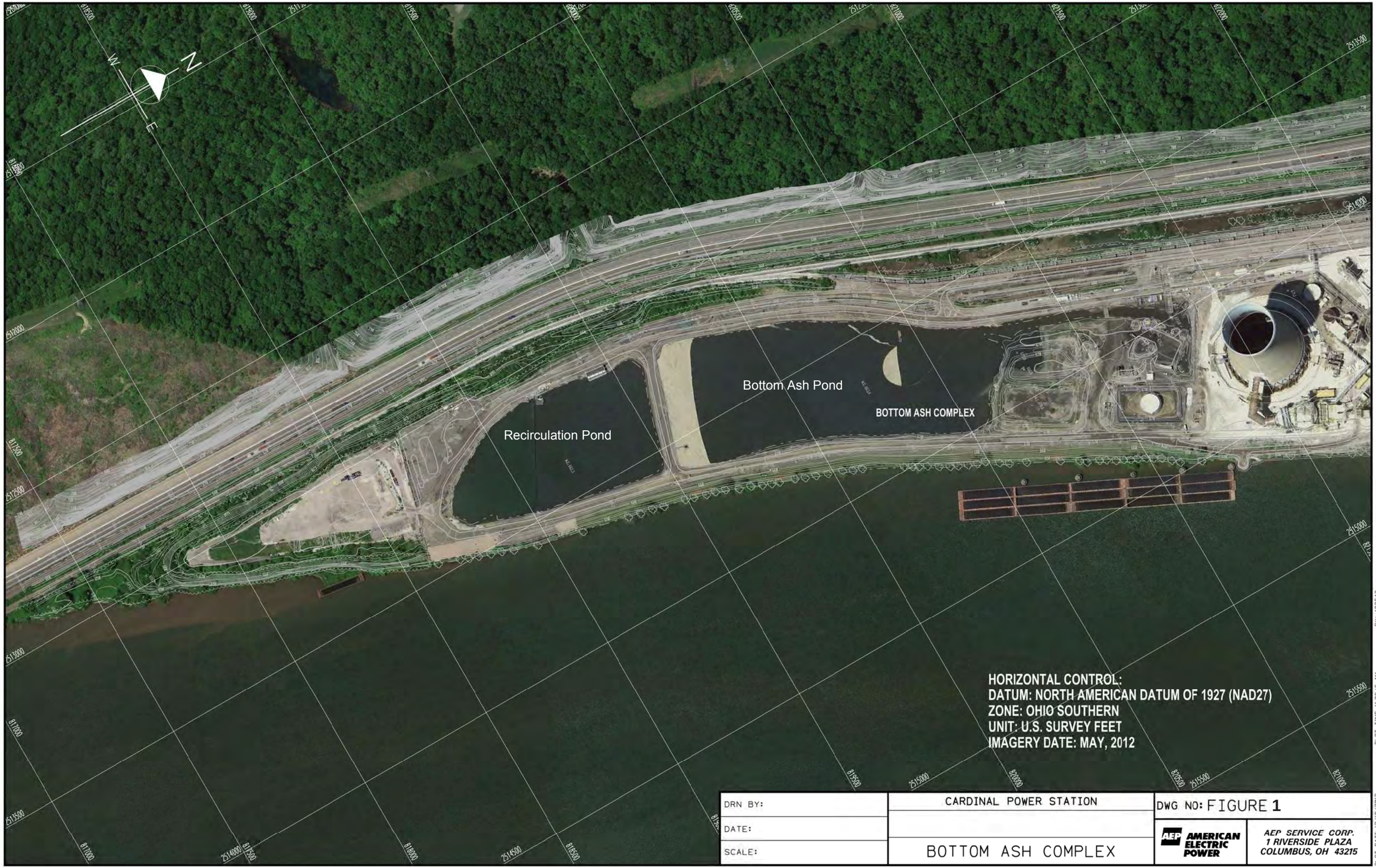
Piezometer No.	Elevation of Top of Riser	Depth to Water	Water Elevation	Comments
MW-1D	968.630			
MW-1S	968.630			
MW-5	980.205			
MW-6	980.555			
MW-7	972.500			
Additional comments regarding condition of the piezometer riser, protection casing, vented cap, etc.				

Open Bore Hole (RCC Zone)

Bore Hole No.	Elevation of Top of RCC	Depth to Water	Water Elevation	Comments
OB-1	970.205			
OB-2	970.015			
OB-3	969.950			
OB-4	696.915			
OB-5	969.890			
OB-6	696.885			
OB-7	969.865			
OB-8	969.880			
OB-9	969.935			
OB-10	970.015			
OB-11	970.035			
OB-12	961.965			
OB-13	961.240			

10. NOTES AND COMMENTS

11. REPAIR ORDERS WRITTEN AND REPAIRS DONE SINCE PREVIOUS INSPECTION



DRN BY:	CARDINAL POWER STATION	DWG NO: FIGURE 1
DATE:		AEP AMERICAN ELECTRIC POWER / AEP SERVICE CORP. 1 RIVERSIDE PLAZA COLUMBUS, OH 43215
SCALE:	BOTTOM ASH COMPLEX	

PLOT DATE: 12/18/2013 PLOT TIME: 11:38:6 AM BY: s182642

CARDINAL PLANT
BOTTOM ASH/RECLAIM DIKE
INSPECTION CHECKLIST

CARDINAL PLANT
BOTTOM ASH/RECLAIM POND AREAS
INSPECTION CHECKLIST

1. GENERAL INFORMATION

Date of Inspection	
Inspected by	
Weather	
Temperature	
Bottom Ash Pond Elevation	
Recirculation Pond Elevation	

2. EMBANKMENT CONDITION

Please refer to the Cardinal Ash Storage Areas Inspection Location Plan. Place a number or letter (Location Code) on the location plan at each problem area and place the same number(s) or letter(s) next to the appropriate malfunction below. For each problem area, provide a sketch or narrative describing the pertinent features of the malfunction(s) under NOTES and COMMENTS section.

Malfunction	" ✔ "or "X"	Location Code	Descriptive Features
Bulges			Areal extent and elevation
Cavities or Holes			General shape, size, and elevation
Cracks			Length, width, depth and elevation
Excessive Crest Settlement			Settlement/affected crest length
Rodent Burrows			Size, areal extent if clustered
Slides			Length, width, vertical drop & elevation
Sloughing			Areal extent and elevation
Springs/Seepage/ Wetness			Flow rate, muddy or clear water, areal extent, and elevation
Soft Soil			Areal extent and vegetation
Surficial Erosion			Length, width, depth, areal extent

Malfunction	" ✔ "or "X"	Location Code	Descriptive Features
Trees or Tall Vegetation			Areal extent, height, trunk size
Deteriorated Rip Rap			Areal extent
Poor Vegetal Cover			Areal extent
Other (Please specify and describe)			

Note: All malfunctions which occur within the same general area should be shown in the same descriptive sketch or narrative for that particular problem area.

3. OVERFLOW STRUCTURE

Please mark the appropriate spaces below with a checkmark if condition is good or briefly note observed problems; if necessary, continue description of problem under NOTES and COMMENTS.

Description	" ✔ " or "X"	Location Code	Descriptive Features
Does bottom ash discharge flow appear normal?			
Condition of bottom ash spillway tower.			
Condition of bottom ash skimmer.			
Are they any rusted areas in the skimmer?			
Obstructions: note location.			

Description	" ✔ " or "X"	Location Code	Descriptive Features
Have obstructions been removed?			
Are access stairs and walkway OK?			
Condition of recirculation structure.			
Does the recirculation overflow pipe have flow coming from it?			
Condition of concrete apron.			
Other (please specify)			

4. OUTLET WORKS

Please note the conditions with regard to the following items. If a problem is observed, please describe it.

Does the discharge flow appear normal at the recirculation pond?	
Other comments.	

5. EMERGENCY SPILLWAY

Both emergency spillways were removed from service in 1988 by backfilling with clay and bottom ash. The elevations are the same as the existing embankment crest. Please note the conditions with regard to the following items. If a problem is observed, please describe it.

Other comments.

6. HYDRAULIC (STANDPIPE) PIEZOMETERS

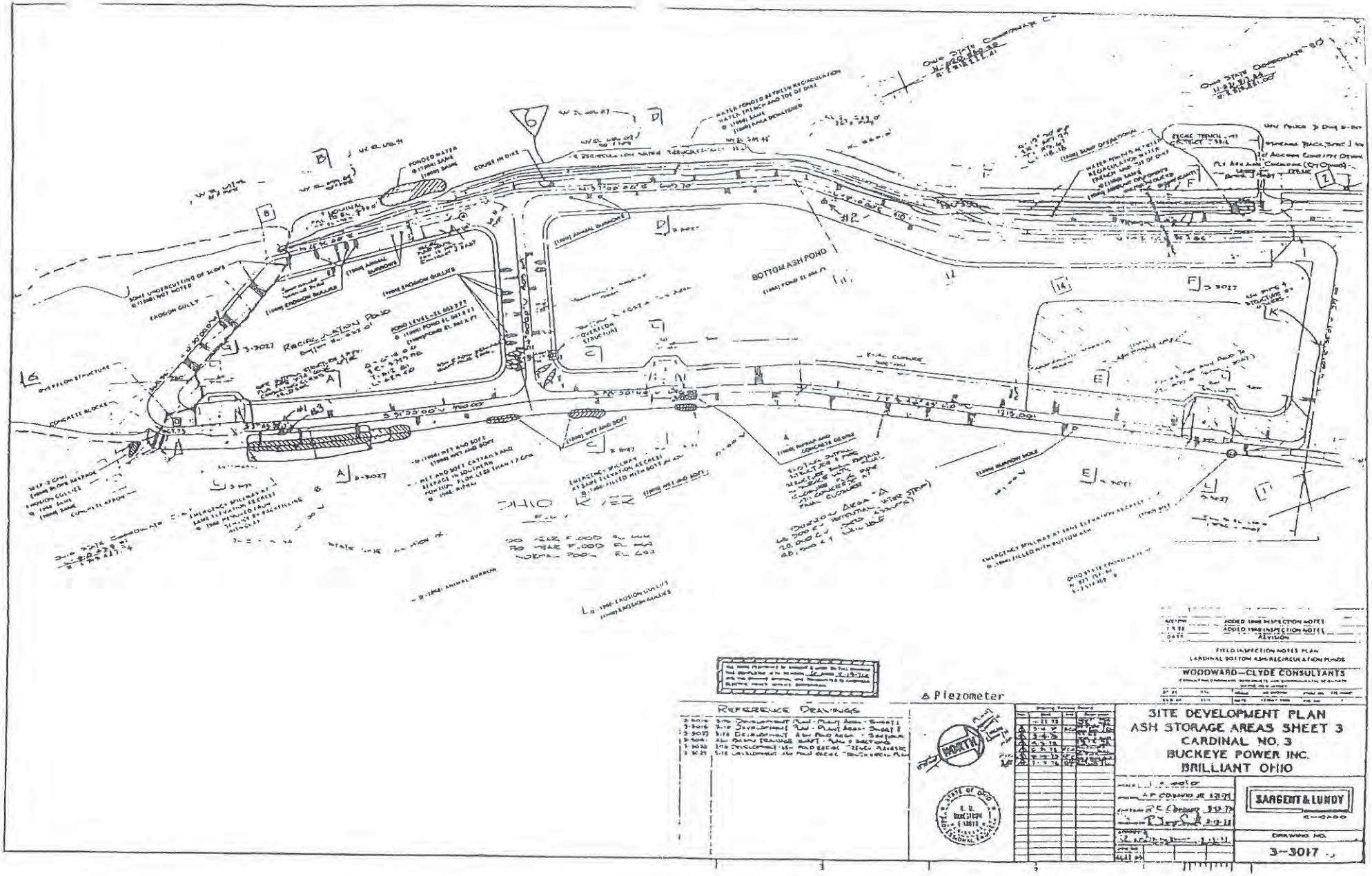
Use a water level indicator to measure the depth to water in each hydraulic piezometer. Determine the water elevation (i.e., total head) by subtracting the depth of water from the elevation of the top of riser for the corresponding piezometer. Record the readings and calculations on the table below. The schedule for reading the hydraulic piezometers should be the same as for conducting the field inspections.

Piezometer No.	Elevation of Top of Riser	Depth to Water	Water Elevation	Comments
1	671.56			Destroyed
2	672.47			
3	671.54			
B-0902	670.60			
B-0904	671.08			
B-0905	652.57			

7. NOTES AND COMMENTS

8. REPAIR ORDERS WRITTEN AND REPAIRS DONE SINCE PREVIOUS INSPECTION

Bottom Ash Complex Exhibit



	ADDED 1998 INSPECTION NOTES
	ADDED 1998 INSPECTION NOTES
DATE	REVISION

FIELD INSPECTION NOTES PLAN
CARDINAL BOTTOM ASH RECIRCULATION PONDS

WOODWARD—CLYDE CONSULTANTS

REFERENCE DRAWINGS

3-3016	Site Development Plan - Plant Area - Sheet 1
3-3017	Site Development Plan - Plant Area - Sheet 2
3-3027	Site Development Ash Pond Area - Sheet 1
3-3028	Ash Pond Drainage Sheet - Plan & Sections
3-3032	Site Development Ash Pond Area - Sheet 2
3-3033	Site Development Ash Pond Area - Sheet 3

SITE DEVELOPMENT PLAN
ASH STORAGE AREAS SHEET 3
CARDINAL NO. 3
BUCKEYE POWER INC.
BRILLIANT OHIO

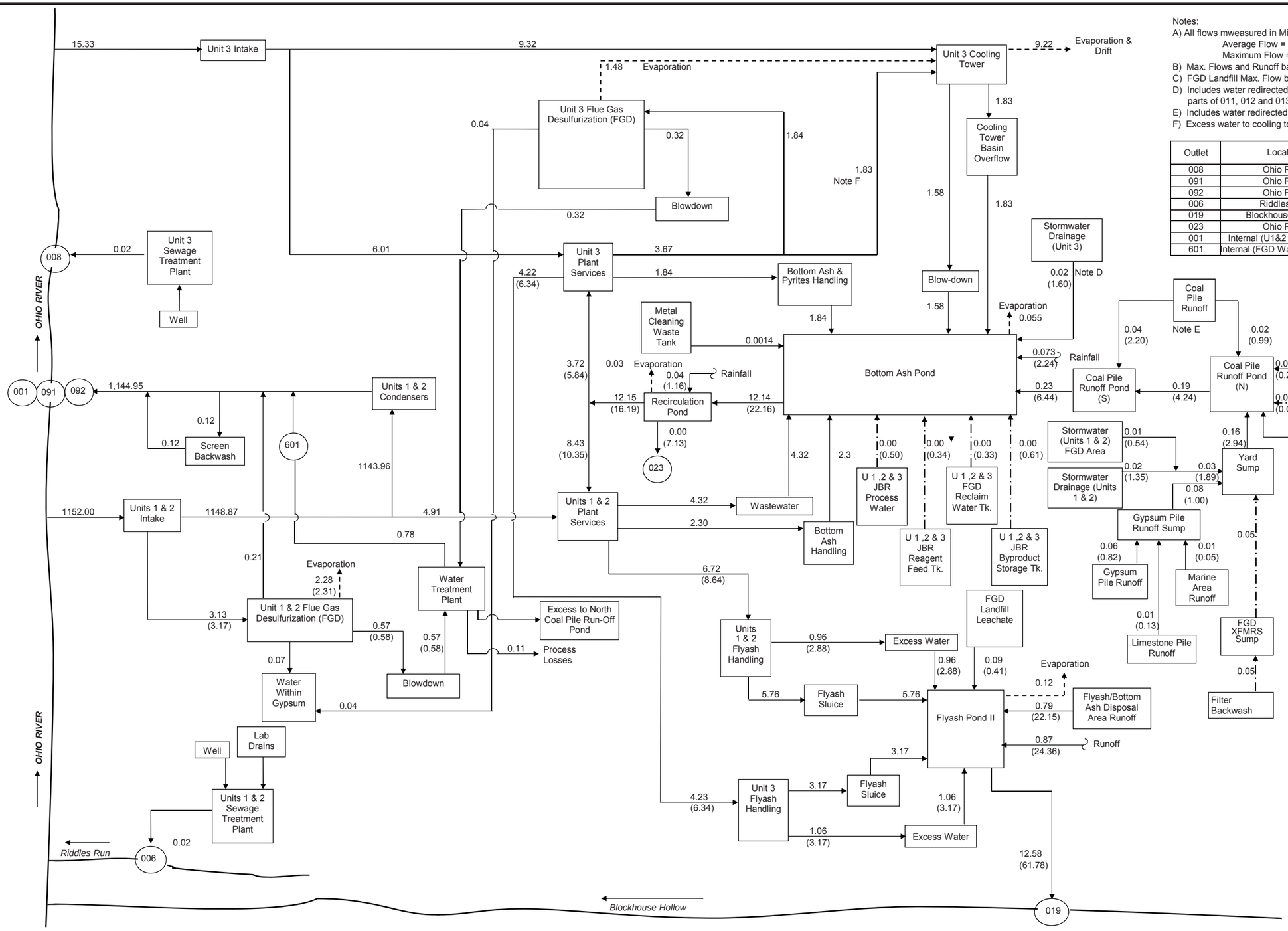
SARGENT & LUNDY

DRAWING NO.
3-3017

APPENDIX C
REFERENCE DRAWINGS AND PHOTOS

Notes:
A) All flows mweasured in Million Gallons per Day
Average Flow = MGD
Maximum Flow = (MGD)
B) Max. Flows and Runoff based on 10-yr/24-hr Storm
C) FGD Landfill Max. Flow basedon 25-yr/24-hr Storm
D) Includes water redirected from Outfalls 016, 017, and parts of 011, 012 and 013.
E) Includes water redirected from Outfall 010
F) Excess water to cooling tower.

Outlet	Location	Average Flow (MGD)
008	Ohio River	0.02
091	Ohio River	1,144.95
092	Ohio River	1,144.74
006	Riddles Run	0.02
019	Blockhouse Hollow	12.58
023	Ohio River	0.00
001	Internal (U1&2 Condensers)	1,143.96
601	Internal (FGD Water Treatment	0.78



Process water or Storm Water
Evaporation
Intermittent Flow
XXX - Outlet

12/10/2011

Cardinal Operating Company
Cardinal Plant

Average Flow - MGD
Maximum Flow - (MGD)

Water Balance Diagram

Water & Ecological Resource Services

AEP

EXHIBIT B

Bottom Ash Retrofit Project – Design Drawings

Sitework & Civil Drawings:

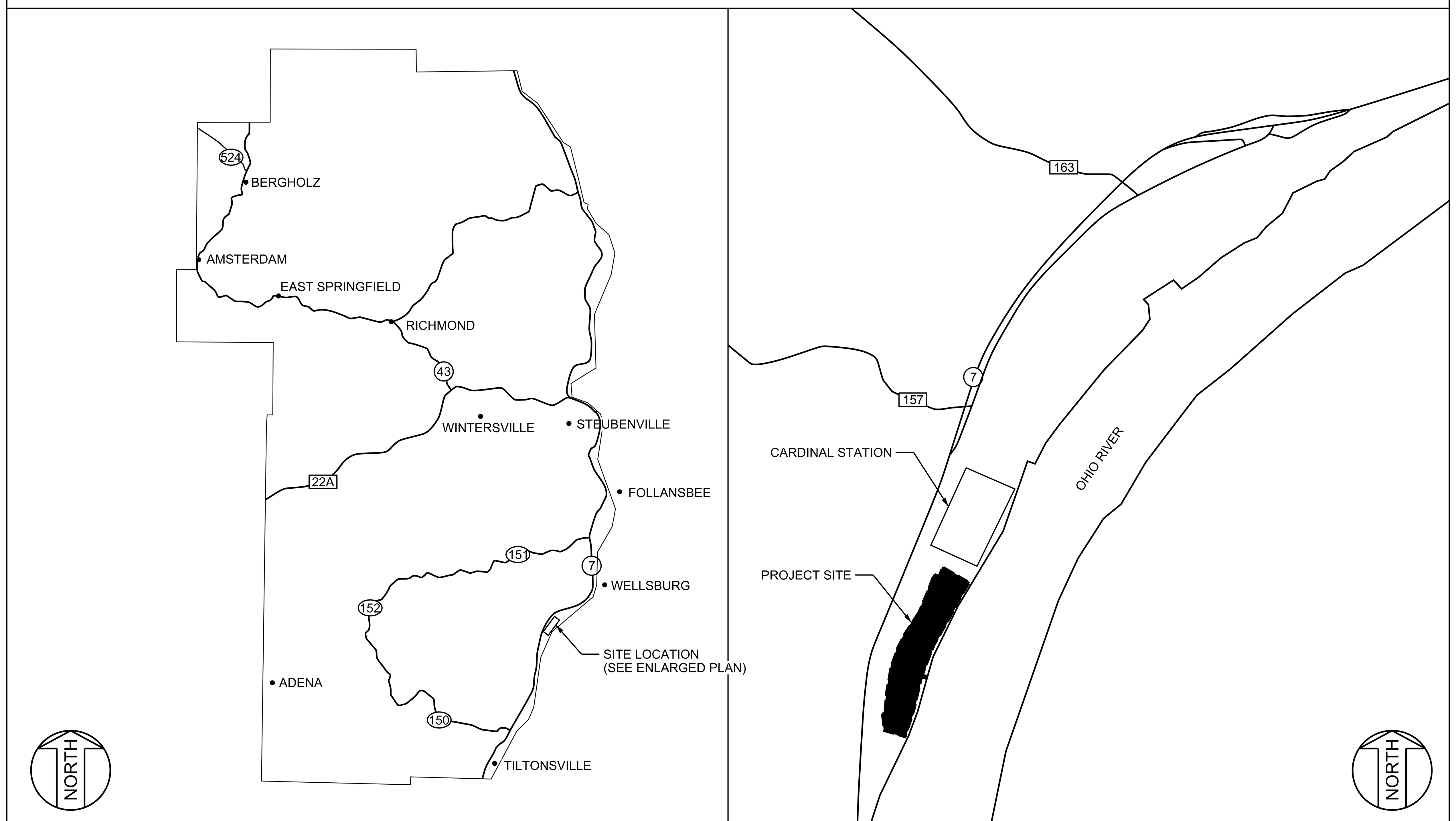
DRAWING NO.	TITLE
13-33482	TITLE SHEET AND VICINITY MAP
13-33483	CIVIL GENERAL NOTES, ABBREVIATIONS, AND SYMBOLS
13-33486	OVERALL KEY PLAN
13-33487	SOUTH POND – EXISTING CONDITIONS PLAN
13-33488	SOUTH POND – EXCAVATION – PLAN
13-33489	SOUTH POND – EXCAVATION – SECTION VIEWS
13-33490	SOUTH POND – TOP OF LINER PROTECTION – PLAN
13-33491	SOUTH POND – TOP OF LINER PROTECTION – SECTION VIEWS
13-33492	SOUTH POND - TOP OF LINER PROTECTION – SECTION AND DETAILS – SHEET 1
13-33493	SOUTH POND - TOP OF LINER PROTECTION – SECTION AND DETAILS – SHEET 2
13-33494	SOUTH POND – BOTTOM ASH DEWATERING AND STAGING AREA – PLAN VIEW
13-33495	SOUTH POND – SUB-LINER TRENCH DRAIN SYSTEM
13-33496	SOUTH POND – SUB-LINER TRENCH DRAIN SYSTEM SECTION VIEWS

Foundation and Structural Steel Drawings:

DRAWING NO.	TITLE
13-33470	BOTTOM ASH STORAGE AREA – PIPE SUPPORT LOCATION PLAN
13-33471	BOTTOM ASH STORAGE AREA – PIPE SUPPORT SECTIONS AND DETAILS
13-33472	RECIRCULATION PUMP HOUSE – BULKHEADS MODIFICATION
13-33475	BOTTOM ASH PIPE DISCHARGE SUPPORT – PLAN, SECTIONS & DETAILS

CARDINAL OPERATING COMPANY
CARDINAL POWER PLANT - BRILLIANT, OHIO
BOTTOM ASH CLOSURE AND LINING PROJECT

VICINITY MAP



JEFFERSON COUNTY MAP (N.T.S) | SITE LOCATION ENLARGED PLAN (N.T.S)

SITEWORK DRAWING LIST

33482	TITLE SHEET AND VICINITY MAP
33483	CIVIL GENERAL NOTES, ABBREVIATIONS, AND SYMBOLS
33484	TEMPORARY EROSION AND SEDIMENT CONTROL PLAN
33485	TEMPORARY EROSION AND SEDIMENT CONTROL DETAILS
33486	OVERALL KEY PLAN
33487	SOUTH POND - EXISTING CONDITIONS PLAN
33488	SOUTH POND - EXCAVATION - PLAN
33489	SOUTH POND - EXCAVATION - SECTION VIEWS
33490	SOUTH POND - TOP OF LINER PROTECTION - PLAN
33491	SOUTH POND - TOP OF LINER PROTECTION - SECTION VIEWS
33492	SOUTH POND - TOP OF LINER PROTECTION - SECTIONS AND DETAILS - SHEET 1
33493	SOUTH POND - TOP OF LINER PROTECTION - SECTIONS AND DETAILS - SHEET 2
33494	SOUTH POND - BOTTOM ASH DEWATERING AND STAGING AREA - PLAN VIEW
33495	SOUTH POND - SUB-LINER TRENCH DRAIN SYSTEM
33496	SUB-LINER TRENCH DRAIN SYSTEM SECTION VIEWS
33500	NORTH POND - EXISTING CONDITIONS PLAN
33501	NORTH POND - EXCAVATION AND CLOSURE PLAN - SHEET 1
33502	NORTH POND - EXCAVATION AND CLOSURE PLAN - SHEET 2
33503	NORTH POND - EXCAVATION AND CLOSURE - SECTION VIEWS
33505	NORTH POND - TOP OF LINER PLAN - SHEET 1
33506	NORTH POND - TOP OF LINER PLAN - SHEET 2
33507	NORTH POND - TOP OF LINER - SECTION VIEWS
33508	NORTH POND - TOP OF LINER - SECTIONS AND DETAILS
33511	NORTH POND - OUTFALL MODIFICATION
33512	NORTH POND - OUTFALL MODIFICATION - SECTIONS AND DETAILS
33514	NORTH AND SOUTH POND - CHAIN LINK FENCE DETAILS
33515	NORTH POND - TEMPORARY LOW VOLUME WASTE IMPOUNDMENT

5

STRUCTURAL DRAWING LIST

3041	ASH BASIN DRAINAGE SHAFT - PLANS & SECTIONS
33470	BOTTOM ASH STORAGE AREA - PIPE SUPPORT LOCATION PLAN
33471	BOTTOM ASH STORAGE AREA - PIPE SUPPORT SECTIONS & DETAILS
33472	RECIRCULATION PUMP HOUSE - BULKHEADS MODIFICATION
33473	PIPE TRENCH ROAD CROSSING PLANS & SECTIONS
33474	PIPE TRENCH CROSSINGS DETAILS
33475	BOTTOM ASH PIPE DISCHARGE SUPPORT - PLAN, SECTIONS & DETAILS
33476	MISCELLANEOUS PIPING SUPPORT FOUNDATIONS
33477	MISCELLANEOUS PIPING SUPPORT STEEL

DEMOLITION DRAWING LIST

15301-DEMO	DEMOLITION - ELECT. DUCT BANKS & MANHOLE - ASH WATER RECIRC. POND TRANSFER
31000-DEMO	DEMOLITION - AWRP PUMP PLATFORM - STEEL PLAN - CHEMICAL MIXING AREA
31001-DEMO	DEMOLITION - UNIT 1 THRU 3 CHEMICAL MIXING AREA - AWRP PUMP, STEEL
32007-DEMO	DEMOLITION - CONCRETE PLAN - VALVE PIT, SAFETY SHOWER & ASSORTED FOUNDATIONS
32008-DEMO	DEMOLITION - AWRP PUMP PLATFORM - CHEMICAL MIXING AREA - CONCRETE PLAN
BW-1-DEMO	DEMOLITION - BAFFLE WALL
SKS-CD-BA-01-DEMO	SOUTH POND AREA
123-5350-DEMO	DEMOLITION - YARD PIPING - METAL CLEANING WASTE TREATMENT FACILITY
4001-DEMO	DEMOLITION - METAL CLEANING WASTE TREATMENT FACILITY - PUMPHOUSE PLAN, ELEV.
MSK-CA-81789-DEMO	DEMOLITION - 1,000,000 GAL. METAL CLEANING WASTE TREATMENT TANK
SKS-CA-BA-02-DEMO	NORTH POND AREA

DATE	NO.	DESCRIPTION	APPD.

REVISIONS

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CARDINAL OPERATING COMPANY

CARDINAL PLANT

BRILLIANT OHIO

BOTTOM ASH CLOSURE AND LINING PROJECT
TITLE SHEET AND VICINITY MAP

CARDINAL PLANT
BUCKEYE POWER INC.

STATE OF OHIO
JAMES T. PERRY
PE.84615
REGISTERED
PROFESSIONAL ENGINEER

James Perry:A01410D00000178409B375B00006B30
Digitally signed by James Perry:A01410D00000178409B375B00006B30
Date: 2021.10.11 15:26:24 -05'00'

PROFESSIONAL ENGINEER'S STAMP

Sargent & Lundy

CONTRACTOR/INSTALLER SHALL TAKE ALL APPROPRIATE PRECAUTIONS TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE, INCLUDING CONTRACTOR'S/INSTALLER'S PERSONNEL (OR THAT OF ITS SUBCONTRACTOR(S) PERFORMING THE WORK

REV	DATE RELEASED	PURPOSE	PREPARED / REVIEWED / APPROVED
3	02-25-2021	ISSUED FOR CONSTRUCTION	MR / JF / JC
2	12-30-2020	ISSUED FOR BIDS AND FOR PERMIT REVIEW	MR / JF / JC
5	10-11-2021	ISSUED FOR CONSTRUCTION REVISION	AP / JF / JP
4	04-13-2021	ISSUE FOR CONSTRUCTION REVISION	MR / JF / JP

DRAWING RELEASE RECORD

UNIT:	DRAWING NUMBER:	REV:
13	33482	5

SCALE: NONE
ENGINEERING DIVISION
DR: AP
CH: JF
SUP: --
ENG: --
DATE: 10-19-2020
APPROVED BY

CARDINAL OPERATING COMPANY

CARDINAL OPERATING CO.
306 COUNTY ROAD 7E
BRILLIANT, OH 43913

PLOT DATE: DD-MMM-YYYY
PLOT TIME: HOUR:MINUTE
BY: USERPLOT

CROSS REFS:

DRAWING NUMBER
33482

CM 1 2 3 4 5 6 7 | 1/16 INCH 4 8 12 16 | TENTHS 10 20 30 | INCHES 1 2 3

CROSS REFS:

GENERAL NOTES

1. ALL WORK SHALL BE PERFORMED ACCORDING TO THE REQUIREMENTS OF SPECIFICATION C-5413 UNLESS OTHERWISE NOTED ON THE DESIGN DRAWINGS.
2. THE CONTRACTOR SHALL BE SOLELY RESPONSIBLE FOR AND HAVE CONTROL AND CHARGE OF CONSTRUCTION MEANS, METHODS, TECHNIQUES, WORK SEQUENCING, AND PROCEDURES IN CONNECTION WITH THE WORK. THE CONTRACTOR SHALL CARRY OUT THE WORK IN ACCORDANCE WITH THE CONTRACT DOCUMENTS, COMPOSED OF THE DESIGN DRAWINGS AND SPECIFICATIONS.
3. ALL WORK DONE BY CONTRACTOR/INSTALLER PURSUANT TO THESE DRAWINGS SHALL: (A) CONFORM TO THE GOVERNING CONTRACT DOCUMENTS; (B) BE PERFORMED EXCLUSIVELY BY ITS TRAINED, COMPETENT PERSONNEL OR, WHERE PERMITTED, THAT OF ITS SUBCONTRACTOR(S); AND (C) COMPLY WITH ALL APPLICABLE SAFETY LAWS, REGULATIONS, PROGRAMS AND PRACTICES TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE, INCLUDING THE CONTRACTOR'S /INSTALLER'S PERSONNEL (OR THAT OF ITS SUBCONTRACTOR(S)) PERFORMING THE WORK.
4. THE CONTRACTOR SHALL PERFORM INSTALLATION AND REMOVAL WORK IN A NEAT AND SKILLFUL MANNER, CAREFULLY TERMINATING WORK NEAR MATERIAL TO REMAIN IN PLACE. PRECAUTIONS SHALL BE TAKEN NOT TO DAMAGE OR DEFACE WORK, EXISTING FACILITIES, AND/OR MATERIAL TO REMAIN IN PLACE. THE CONTRACTOR SHALL BE RESPONSIBLE FOR ANY SUCH DAMAGE OR REPAIR THEREOF.
5. ALL WORK SHALL BE DONE IN ACCORDANCE WITH THE REQUIREMENTS OF FEDERAL, STATE OR LOCAL CODES, STANDARDS AND SPECIFICATIONS.
6. EXISTING CONDITIONS:
   A. DIMENSIONS OF EXISTING WORK SHALL BE VERIFIED BY THE CONTRACTOR PRIOR TO THE START OF WORK IN ACCORDANCE WITH THE SPECIFICATION AS FIELD CONDITIONS MAY VARY FROM INFORMATION SHOWN ON THE DESIGN DRAWING. DIMENSIONS NOTED FOR REFERENCE (REF) INDICATE NOMINAL DIMENSIONS FOR THE EXISTING STRUCTURE, UTILITY, ETC. NEW WORK SHALL NOT BE LOCATED BASED ON THE REFERENCED DIMENSIONS.
   B. PRIOR TO COMMENCING WORK, THE CONTRACTOR SHALL EXAMINE THE AREAS AND CONDITIONS UNDER WHICH THE CLOSURE AND RETROFIT WORK IS TO TAKE PLACE, ESPECIALLY THE LOCATION OF OVERHEAD TRANSMISSION LINES AND ADJACENT RAILROAD RIGHT OF WAY, AND NOTIFY THE OWNER IN WRITING OF CONDITIONS WHICH MAY IMPACT THE PROPER AND TIMELY COMPLETION OF THE WORK.
   C. UNDERGROUND OR EMBEDDED UTILITIES MAY EXIST WITHIN THE AREA OF AND ADJACENT TO THE LIMITS OF THE WORK. THE LOCATION OR IDENTIFICATION OF SUCH UTILITIES HAS NOT BEEN VERIFIED BY THE OWNER OR BY S&L. CONTRACTOR/INSTALLER IS RESPONSIBLE FOR FIELD LOCATING AND IDENTIFYING UNDERGROUND OR EMBEDDED UTILITIES AND ANY OTHER UNDERGROUND OR EMBEDDED UTILITY DIMENSIONS.
   D. REFERENCES USED HAVE BEEN IDENTIFIED ON EXCAVATION/FOUNDATION /DEMOLITION DRAWINGS AND HAVE BEEN PROVIDED TO ASSIST THE CONTRACTOR/INSTALLER IN THE FIELD LOCATING EXISTING UTILITIES AND OTHER POTENTIAL UNDERGROUND OR EMBEDDED INTERFERENCES. THESE REFERENCES ONLY SHOW THE APPROXIMATE LOCATION OF POTENTIAL UNDERGROUND OR EMBEDDED UTILITIES AND MAY NOT INDICATE OR REFLECT ALL EXISTING UNDERGROUND OR EMBEDDED UTILITIES OR THEIR ACTUAL LOCATIONS.
   E. REFERENCES IDENTIFIED SHALL NOT SUBSTITUTE FOR THE CONTRACTOR'S /INSTALLER'S OBLIGATION TO FIELD LOCATE ANY UNDERGROUND OR EMBEDDED UTILITIES OR INTERFERENCES THAT MAY AFFECT THE WORK.
   F. DUE CAUTION SHALL BE TAKEN DURING ANY EXCAVATION/FOUNDATION/DEMOLITION WORK WITHIN THE AREA OF, AND ADJACENT TO THE LIMITS OF THE WORK DUE TO POSSIBLE INTERFERENCES THAT MAY NOT BE REFLECTED ON THE REFERENCES IDENTIFIED.
   G. THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE PRESERVATION AND RESTORATION OF THE EXISTING UTILITIES IF DAMAGED DURING CONSTRUCTION AT NO ADDITIONAL COST TO THE OWNER.
7. CONCRETE
   CONCRETE FOR ROADS AND PAVED AREAS SHALL HAVE A MINIMUM 28-DAYS COMPRESSIVE STRENGTH OF 4000 PSI UNLESS NOTED OTHERWISE. CONCRETE SHALL BE FURNISHED AND INSTALLED IN ACCORDANCE WITH ACI 301. REINFORCING STEEL BARS SHALL CONFORM TO ASTM A615 GRADE 60 UNLESS NOTED OTHERWISE. WELDED WIRE FABRIC FOR REINFORCING SHALL CONFORM TO ASTM A185 (FY=65 KSI) UNLESS NOTED OTHERWISE.
8. COMPACTION:
   THE FILL, BEDDING MATERIAL AND THE AGGREGATE BASE SHALL BE COMPACTED TO 95% OF THE MAXIMUM DRY DENSITY AS DETERMINED BY ASTM D1557, MODIFIED PROCTOR TEST, UNLESS NOTED OTHERWISE.
9. SOIL EROSION AND SEDIMENTATION CONTROL:
   PROPER SOIL EROSION AND SEDIMENTATION CONTROL MEASURES SHALL BE INTALLED TO MEET THE APPLICABLE REGULATORY CODES AND THE PERMIT REQUIREMENTS.
10. CONSTRUCTION QUALITY ASSURANCE:
    ANY WORK FOUND DEFECTIVE OR NOT IN COMPLIANCE WITH THE REQUIREMENTS OF THE PROJECT SPECIFICATIONS OR THE DESIGN DRAWINGS SHALL BE REPLACED/FIXED AT NO ADDITIONAL COST TO THE OWNER.
11. COORDINATES:
    THE PLANT COORDINATE SYSTEM SHOWN ON THE DESIGN DRAWINGS IS BASED ON THE CARDINAL UNIT 3 PLANT GRID.
12. HORIZONTAL AND VERTICAL CONTROL:
    A. THE BASIS FOR HORIZONTAL CONTROL IS AS DESCRIBED IN NOTE 11.
    B. THE BASIS FOR VERTICAL CONTROL IS THE NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD88).
    C. PERMANENT MONUMENTS FOR HORIZONTAL AND VERTICAL CONTROL HAVE BEEN ESTABLISHED BY CARDINAL.
    D. CONTRACTORS ARE RESPONSIBLE FOR SETTING ADDITIONAL MONUMENTS AND CONTROL POINTS THAT THEY MAY DEEM NECESSARY FOR COMPLETION OF WORK.
13. TOPOGRAPHIC MAPS;
    THE TOPOGRAPHIC MAP OF THE PLANT SITE (USED ON THE DESIGN DRAWINGS) WAS PREPARED BY LABELLA ASSOCIATES, D.P.C.COMPLETED IN AUGUST 30, 2020.
14. GEOTECHNICAL WORK:
    A SAFETY FACTOR ASSESSMENT FOR THE BOTTOM ASH COMPLEX WAS PREPARED BY S&ME, DATED DECEMBER 30, 2015. SITE SPECIFIC SOIL DATA AND GEOTECHNICAL RECOMMENDATIONS ARE PROVIDED WITHIN.

ABBREVIATIONS

ROAD AND GRADING

T/RD	TOP OF ROAD ELEVATION
EL OR ELEV	GRADE ELEVATION
INV	INVERT ELEVATION
HP	HIGH POINT
LP	LOW POINT
HPFS	HIGH POINT FINISH SURFACING
BC	BEGINNING OF CURVE (HORIZONTAL CURVE)
EC	END OF CURVE (HORIZONTAL CURVE)
PI	POINT OF INTERSECTION (HORIZONTAL CURVE)
PT	POINT OF TANGENT
PC	POINT OF CURVE
STA	STATION
VC	VERTICAL CURVE
BVC	BEGINNING OF VERTICAL CURVE
EVC	END OF VERTICAL CURVE
PIVC	POINT OF INTERSECTION OF VERT. CURVE
PRC	POINT OF REVERSE CURVE
PCC	POINT OF COMPOUND CURVE
R	RADIUS
T	TANGENT
L	LENGTH OF CURVE
D	DEGREE OF CURVE
I	INTERIOR/DEFLECTION ANGLE OF CURVE
UN	UNLESS NOTED
ROW	RIGHT OF WAY
OHL	OVERHEAD LINE
OC	ON CENTER
WL	WATER LEVEL
HWL	HIGH WATER LEVEL
LWL	LOW WATER LEVEL
YR	YEAR
DS	DOWNSTREAM
US	UPSTREAM
CL	CENTERLINE
AC	ACRE
N.T.S.	NOT TO SCALE

SEWERS AND UNDERGROUND PIPE

CB	CATCH BASIN
CO	CLEANOUT
MH	MANHOLE
RE	RIM ELEVATION
INV	INVERT ELEVATION
℄	CENTERLINE
S	SLOPE
BOP	BOTTOM OF PIPE
PVC	POLY VINYL CHLORIDE PIPE
HDPE	HIGH DENSITY POLYETHYLENE PIPE
RCP	REINFORCED CONCRETE PIPE
CMP	CORRUGATED METAL PIPE
CHDPE	CORRUGATED HIGH DENSITY POLYETHYLENE PIPE
CISP	CAST IRON SOIL PIPE
DIWP	DUCTILE IRON WATER PIPE
STL	CARBON STEEL PIPE
IP	IN PLACE
SWS	STORM WATER SEWER
OWS	OILY WATER SEWER
SAN	SANITARY SEWER
PWS	PROCESS WASTE SEWER
C.S.	CARBON STEEL
CLSM	CONTROLLED LOW STRENGTH MATERIAL

2

TRAFFIC SIGNS

MUTCD	MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES

SYMBOLS

Symbol	Description
	CENTERLINE OF NATURAL DRAINAGE PATTERN
	VALLEY LINE OR "V" DITCH
	SWALE
	CENTERLINE OF TRAPEZOIDAL DRAINAGE DITCH WITH 2' BOTTOM WIDTH
	TRAPEZOIDAL DRAINAGE DITCH WITH BOTTOM WIDTH GREATER THAN 2'. BOTTOM WIDTH AND SIDE SLOPE SHOWN ON PLAN OR DETAIL
	RIPRAP EROSION PROTECTION
C-1	PIPE CULVERT CULVERT NUMBER SHOWN
DOWN	TOP OF EMBANKMENT SLOPE OR DITCH SIDE SLOPE AND DIRECTION OF SLOPE
3:1	HORIZONTAL TO VERTICAL SLOPE WHEN SLOPE IS CONSTANT
SLOPE VARIES	SLOPE IS NOT CONSTANT
1%	DIRECTION OF ROAD OR AREA SLOPE. PERCENT OF SLOPE SHOWN WHERE APPLICABLE
	TOP OF DIKE
R=50'	RADIUS OF CURVATURE
1	SECTION NUMBER
	CHAIN LINK FENCE
PLAN SECTION	WATER LINE
G G	BURIED GAS LINE
E E	BURIED ELECTRICAL CABLE
	INDEX CONTOUR
	INTERMEDIATE CONTOUR
405	ELEVATION CONTOUR
	EXISTING DEPRESSION
X 408.8	SPOT ELEVATION
X	VERTICAL CONTROL POINT
	HORIZONTAL CONTROL POINT
	EXISTING FIRE HYDRANT
	EXISTING UTILITY POLE
	EXISTING UTILITY POLE WITH GUY
	WOOD OR BRUSH OUTLINE
	GRATING
	SINGLE SIGN ON POST
	DOUBLE SIGN ON POST
	GUARD POST
MW-BAP-1	MONITORING WELL LOCATION

SYMBOLS

EROSION CONTROL SYMBOLS

Symbol	Description
S	SILT FENCE
IP	INLET PROTECTION
	ROCK CHECK

ROAD, PAVEMENT AND SURFACING SYMBOLS

Symbol	Description
	ASPHALT OR CONCRETE PAVED ROAD. OUTER LINES SHOW OVERALL WIDTH. INTERIOR LINES SHOW EDGES OF PAVEMENT.
	ROCK SURFACED ROAD
I	ISOLATION JOINT
IT	THICKENED EDGE ISOLATION JOINT
TE	THICKENED EDGE EXPANSION JOINT
T	PAVEMENT THICKENED EDGE
C	CONTRACTION JOINT
	CONCRETE
	GRAVEL OR CRUSHED ROCK SURFACING
	RIPRAP SURFACING
	ASPHALT PAVEMENT
	COMPACTED BOTTOM ASH
	FABRIC FORMED CONCRETE

DATE	NO.	DESCRIPTION	APPD.

REVISIONS

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CARDINAL OPERATING COMPANY

CARDINAL PLANT

BRILLIANT OHIO

BOTTOM ASH CLOSURE AND LINING PROJECT
CIVIL GENERAL NOTES, ABBREVIATIONS, AND SYMBOLS
CARDINAL PLANT
BUCKEYE POWER INC.

UNIT:	DRAWING NUMBER:	REV:
13	33483	2

SCALE: NONE — ENGINEERING DIVISION
DR: AP
CH: JF
SUP: --
ENG: --
DATE: 10-19-2020
APPROVED BY

STATE OF OHIO — JAMES T. PERRY PE.84615 — REGISTERED PROFESSIONAL ENGINEER

James Perry:A01410D00000178409B375B00006B30
Digitally signed by James Perry:A01410D00000178409B375B00006B30 Date: 2021.04.09 10:49:35 -05'00'

PROFESSIONAL ENGINEER'S STAMP

Sargent & Lundy

CONTRACTOR/INSTALLER SHALL TAKE ALL APPROPRIATE PRECAUTIONS TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE, INCLUDING CONTRACTOR'S/ INSTALLER'S PERSONNEL (OR THAT OF ITS SUBCONTRACTOR(S) PERFORMING THE WORK

REV	DATE RELEASED	PURPOSE	PREPARED / REVIEWED / APPROVED
2	04-09-2021	ISSUED FOR CONSTRUCTION REVISION	MR / JF / JP
1	02-25-2021	ISSUED FOR CONSTRUCTION	MR / JF / JC
1	12-30-2020	ISSUED FOR BIDS AND FOR PERMIT REVIEW	MR / JF / JC
0	10-19-2020	ISSUE FOR PERMIT REVIEW	AP / JF / JC

DRAWING RELEASE RECORD

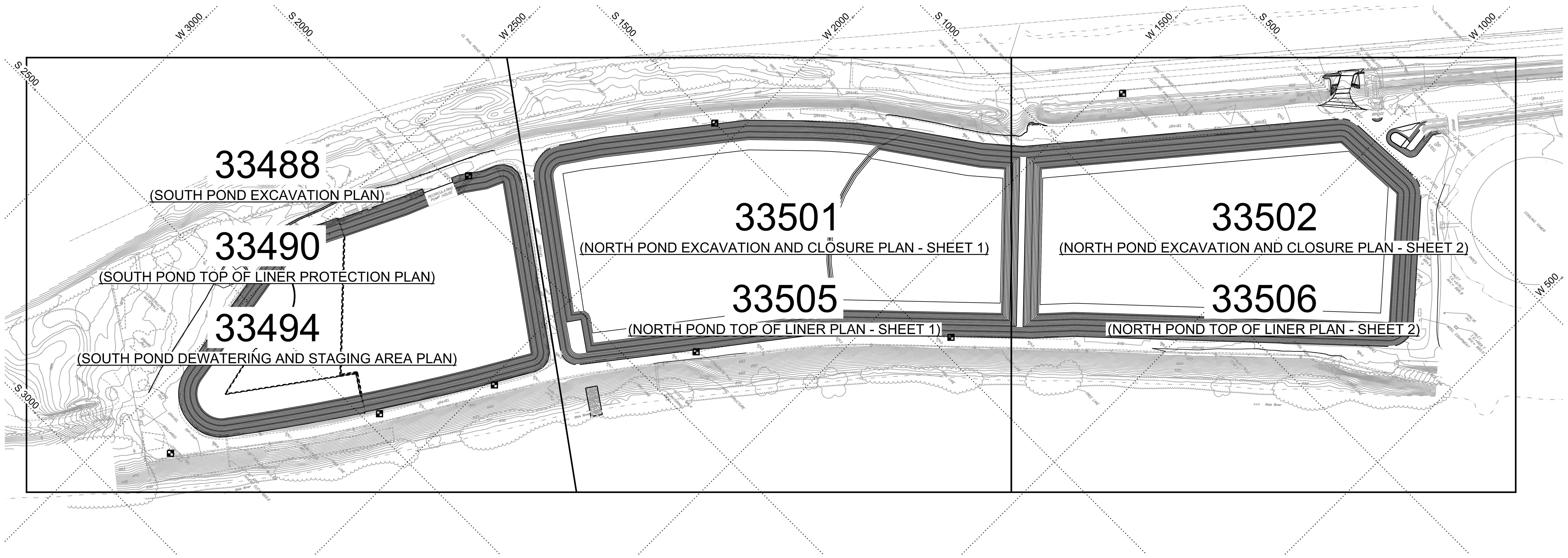
CARDINAL OPERATING COMPANY

CARDINAL OPERATING CO. 306 COUNTY ROAD 7E BRILLIANT, OH 43913

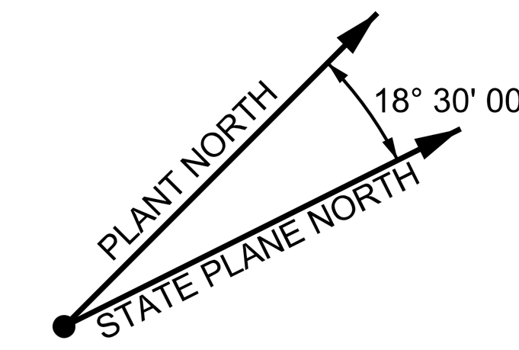
PLOT DATE: DD-MMM-YYYY PLOT TIME: HOUR:MINUTE BY: USERPLOT

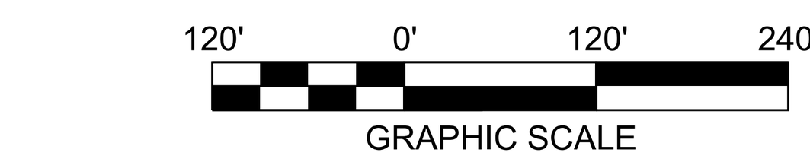
CROSS REFS:

DRAWING NUMBER 33486



OVERALL KEY PLAN





NOTES

1. FOR CIVIL GENERAL NOTES, ABBREVIATIONS, AND SYMBOLS, SEE DRAWING 33483.
2. ALL WORK SHOWN ON THIS DRAWING SHALL BE FURNISHED AND INSTALLED BY SPECIFICATION C-5413 UNLESS NOTED OTHERWISE.

REFERENCE DRAWINGS

33488	SOUTH POND - EXCAVATION PLAN
33490	SOUTH POND - TOP OF LINER PROTECTION - PLAN
33494	SOUTH POND - BOTTOM ASH DEWATERING AND STAGING AREA - PLAN VIEW
33501	NORTH POND - EXCAVATION AND CLOSURE PLAN - SHEET 1
33502	NORTH POND - EXCAVATION AND CLOSURE PLAN - SHEET 2
33505	NORTH POND - TOP OF LINER PLAN - SHEET 1
33506	NORTH POND - TOP OF LINER PLAN - SHEET 2

UNDERGROUND OR EMBEDDED UTILITIES MAY BE LOCATED WITHIN OR ADJACENT TO THE AREA IN WHICH EXCAVATION, DEMOLITION, FOUNDATION, OR MODIFICATION WORK IS TO BE PERFORMED.

REFERENCES RELATING TO THE UNDERGROUND OR EMBEDDED UTILITIES ARE PROVIDED TO ASSIST THE CONTRACTOR/INSTALLER IN THE FIELD LOCATING THOSE UTILITIES AND OTHER POSSIBLE UNDERGROUND OR EMBEDDED INTERFERENCES WITH THE WORK.

THE CONTRACTOR/INSTALLER SHALL EXERCISE DUE CAUTION DURING ALL EXCAVATION/FOUNDATION/DEMOLITION WORK.

DATE	NO.	DESCRIPTION	APPD.

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CARDINAL OPERATING COMPANY

CARDINAL PLANT

BRILLIANT OHIO

BOTTOM ASH CLOSURE AND LINING PROJECT
OVERALL KEY PLAN

CARDINAL PLANT
BUCKEYE POWER INC.

UNIT:	DRAWING NUMBER:	REV:
13	33486	3

SCALE: NONE | ENGINEERING DIVISION
DR: AP
CH: JF
SUP: --
ENG: --
DATE: 10-19-2020
APPROVED BY

REV	DATE RELEASED	PURPOSE	PREPARED / REVIEWED / APPROVED
3	04-12-2021	ISSUED FOR CONSTRUCTION REVISION	MR / JF / JP
2	02-25-2021	ISSUED FOR CONSTRUCTION	MR / JF / JC
1	12-30-2020	ISSUED FOR BIDS AND FOR PERMIT REVIEW	MR / JF / JC
0	10-19-2020	ISSUE FOR PERMIT REVIEW	AP / JF / JC

DRAWING RELEASE RECORD

STATE OF OHIO
JAMES T. PERRY
PE.84615
REGISTERED PROFESSIONAL ENGINEER

James Perry:A01410D00000178409B375B00006B30
Digitally signed by James Perry:A01410D00000178409B375B00006B30
Date: 2021.04.12 07:39:05 -05'00'

PROFESSIONAL ENGINEER'S STAMP

Sargent & Lundy

CONTRACTOR/INSTALLER SHALL TAKE ALL APPROPRIATE PRECAUTIONS TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE, INCLUDING CONTRACTOR'S/INSTALLER'S PERSONNEL (OR THAT OF ITS SUBCONTRACTOR(S) PERFORMING THE WORK

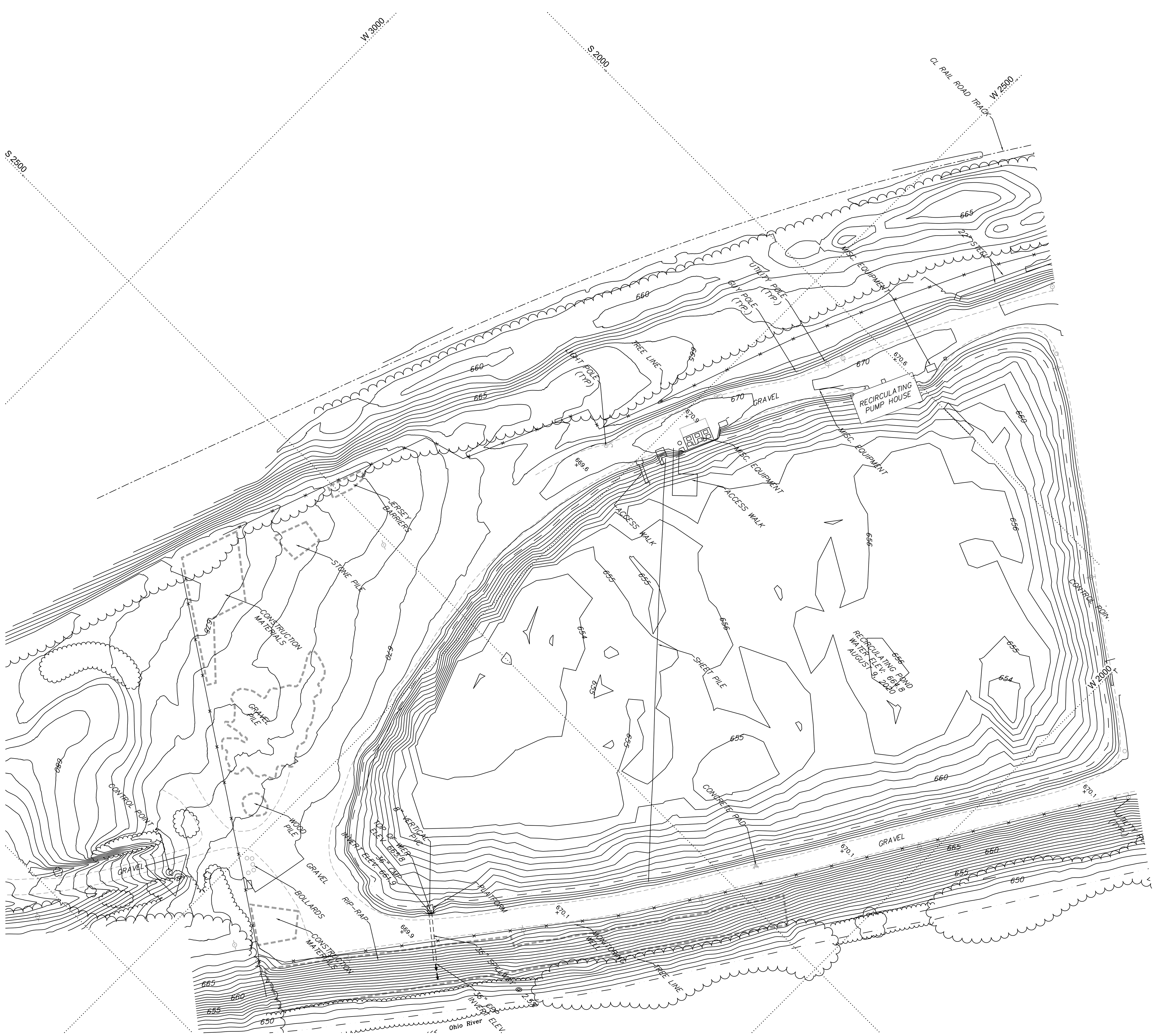
CARDINAL OPERATING COMPANY

CARDINAL OPERATING CO.
306 COUNTY ROAD 7E
BRILLIANT, OH 43913

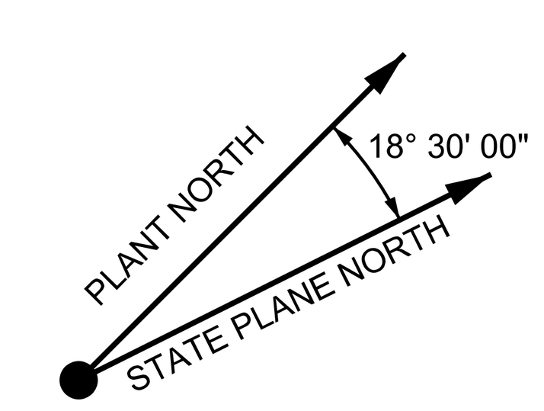
PLOT DATE: DD-MMM-YYYY
PLOT TIME: HOUR:MINUTE
BY: USERPLOT

CROSS REFS:

DRAWING NUMBER 33487



SOUTH POND - EXISTING CONDITIONS PLAN



50' 0' 50' 100'
GRAPHIC SCALE

LEGEND

670	MAJOR CONTOUR
670	MINOR CONTOUR
	FENCE LINE
N.250 ... N.250	GRID LINE
	GRAVEL
	TREE LINE
	CL RAIL ROAD TRACK
	WALL
	WATER
	MISC. PIPE
	GUARD RAIL
	GUY WIRE
	UTILITY POLE
	BOLLARD
669.3 ×	SPOT ELEVATION
	INLET
	LIGHT POST
	MISC. STRUCTURES
	MISC. EQUIPMENT
CPP	CORRUGATED PLASTIC PIPE
CMP	CORRUGATED METAL PIPE
SLCPP	SMOOTH LINED CORRUGATED PLASTIC PIPE
PVC	POLYVINYL CHLORIDE PIPE
HDPE	HIGH-DENSITY POLYETHYLENE PIPE
	MONITORING WELL

NOTES

1. FOR CIVIL GENERAL NOTES, ABBREVIATIONS, AND SYMBOLS, SEE DRAWING 33483.
2. TOPOGRAPHIC INFORMATION SHOWN ON THIS DRAWING, WAS PREPARED BY LABELLA ASSOCIATES, D.P.C. COMPLETED ON AUGUST 30, 2020.

REFERENCE DRAWINGS

112302008 SHT 1 THRU 6	BATHYMETRIC AND TOPOGRAPHIC SURVEY

UNDERGROUND OR EMBEDDED UTILITIES MAY BE LOCATED WITHIN OR ADJACENT TO THE AREA IN WHICH EXCAVATION, DEMOLITION, FOUNDATION, OR MODIFICATION WORK IS TO BE PERFORMED.

REFERENCES RELATING TO THE UNDERGROUND OR EMBEDDED UTILITIES ARE PROVIDED TO ASSIST THE CONTRACTOR/INSTALLER IN THE FIELD LOCATING THOSE UTILITIES AND OTHER POSSIBLE UNDERGROUND OR EMBEDDED INTERFERENCES WITH THE WORK.

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REV	DATE RELEASED	PURPOSE	PREPARED / REVIEWED / APPROVED
1	02-25-2021	ISSUED FOR CONSTRUCTION	MR / JF / JC
1	12-30-2020	ISSUED FOR BIDS AND FOR PERMIT REVIEW	MR / JF / JC
0	10-19-2020	ISSUE FOR PERMIT REVIEW	AP / JF / JC

DRAWING RELEASE RECORD

STATE OF OHIO JOSEPH P. CHARLES PE.80469 REGISTERED PROFESSIONAL ENGINEER
25-Feb-2021
PROFESSIONAL ENGINEER'S STAMP

Sargent & Lundy

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DATE	NO.	DESCRIPTION	APPD.

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CARDINAL OPERATING COMPANY

CARDINAL PLANT

BRILLIANT OHIO

BOTTOM ASH CLOSURE AND LINING PROJECT
SOUTH POND EXISTING CONDITIONS PLAN

CARDINAL PLANT
BUCKEYE POWER INC.

UNIT:	DRAWING NUMBER:	REV:
13	33487	1

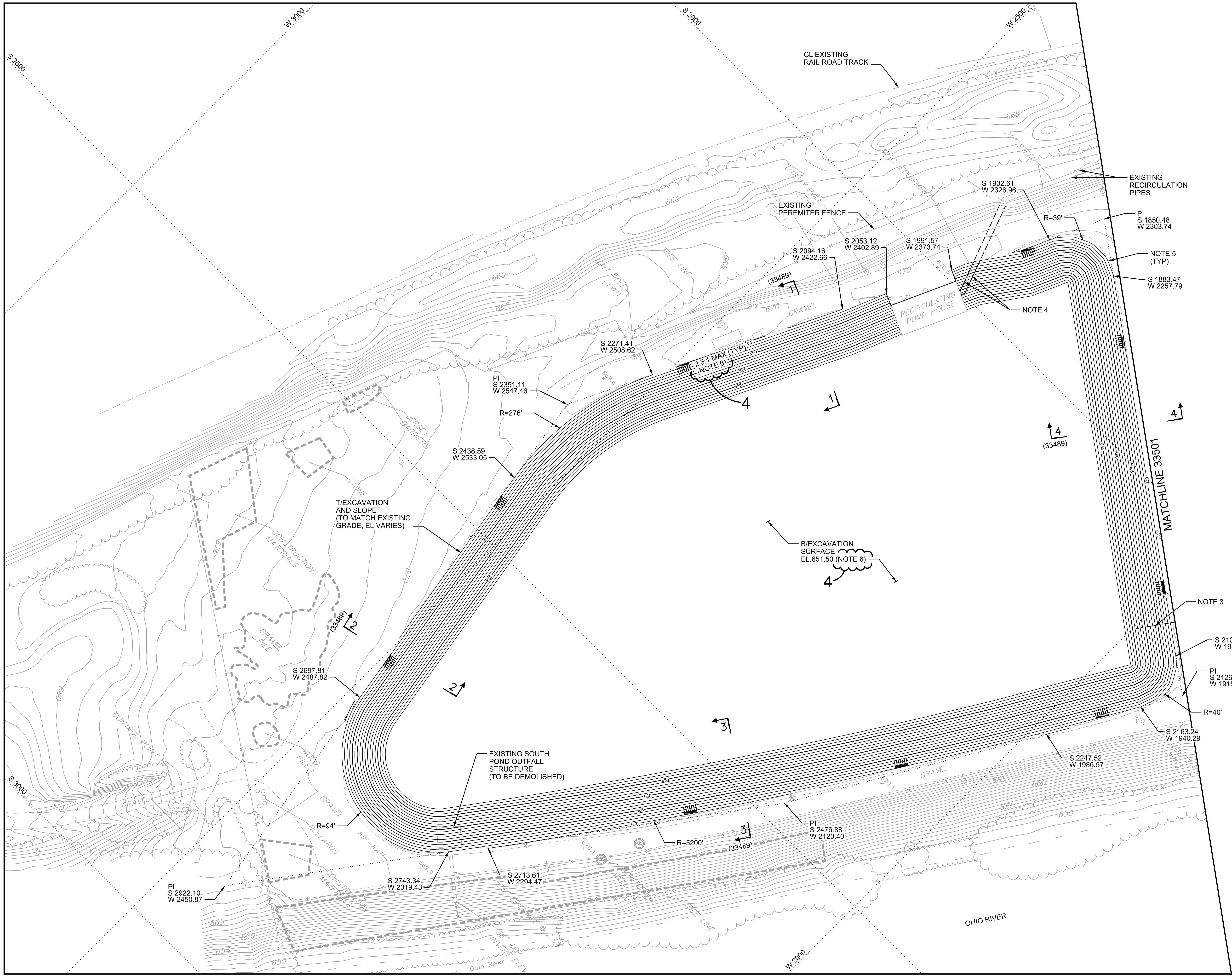
SCALE: NONE
DR: AP
CH: JF
SUP: --
ENG: --
DATE: 10-19-2020
ENGINEERING DIVISION
APPROVED BY

CARDINAL OPERATING COMPANY

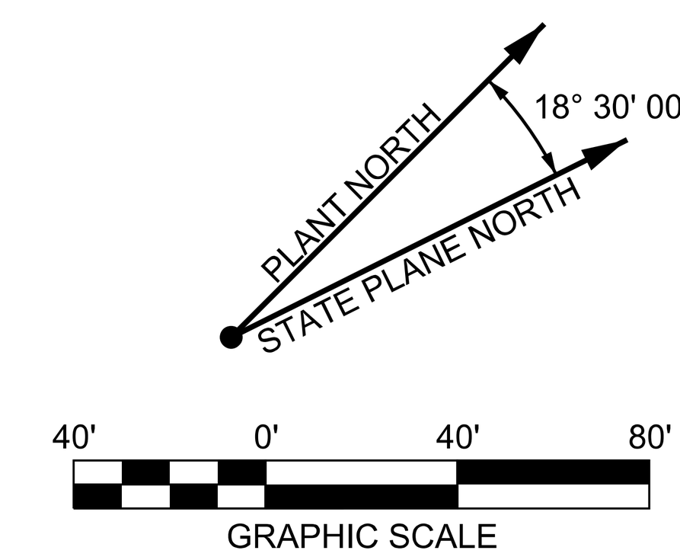
CARDINAL OPERATING CO.
306 COUNTY ROAD 7E
BRILLIANT, OH 43913

PLOT DATE: DD-MMM-YYYY
PLOT TIME: HOUR:MINUTE
BY: USERPLOT

CROSS REFS:



SOUTH POND - EXCAVATION PLAN



NOTES

1. FOR CIVIL GENERAL NOTES, ABBREVIATIONS, AND SYMBOLS, SEE DRAWING 33483.
2. ALL WORK SHOWN ON THIS DRAWING SHALL BE FURNISHED AND INSTALLED BY SPECIFICATION C-5413 UNLESS NOTED OTHERWISE.
3. EXISTING ASH BASIN DRAINAGE SHAFT DISCHARGE PIPE SHALL BE COMPLETELY REMOVED AND BACKFILLED WITH CLSM UP TO EL.660.00 AND APPROVED COMPACTED MATERIALS UP TO THE DESIGN GRADES.
4. SEE DRAWING 33470 FOR RECIRCULATION PIPING SUPPORT.
5. PRECAUTION SHALL BE TAKEN TO NOT DAMAGE EXISTING ELECTRICAL POLES DURING EXCAVATION AND LINER INSTALLATION.
6. CONTOURS SHOWN ON THIS DRAWING ARE BASED ON THE ORIGINAL POND DESIGN DRAWINGS AND OTHER HISTORICAL INFORMATION; HOWEVER, THESE CONTOURS MAY NOT ACCURATELY REFLECT THE CURRENT FLOOR AND SIDE SURFACES OF THE POND. SEE NOTE 3 ON DRAWING 33489 FOR MORE INFORMATION.

REFERENCE DRAWINGS

112302008 SHT 1 THRU 6	BATHYMETRIC AND TOPOGRAPHIC SURVEY
3041	ASH BASIN DRAINAGE SHAFT PLAN AND SECTIONS
33470	BOTTOM ASH STORAGE AREA PIPE SUPPORT LOCATION PLAN
33489	SOUTH POND EXCAVATION SECTION VIEWS

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DATE	NO.	DESCRIPTION	APPD.

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CARDINAL OPERATING COMPANY

CARDINAL PLANT

BRILLIANT OHIO

BOTTOM ASH CLOSURE AND LINING PROJECT
SOUTH POND
EXCAVATION PLAN
CARDINAL PLANT
BUCKEYE POWER INC.

UNIT:	DRAWING NUMBER:	REV:
13	33488	4

SCALE: NONE | ENGINEERING DIVISION
DR: AP
CH: JF
SUP: --
ENG: --
DATE: 10-19-2020
APPROVED BY

STATE OF OHIO
JAMES T. PERRY PE.84615
REGISTERED PROFESSIONAL ENGINEER

James Perry:A01410D00000178409B375B00006B30
Digitally signed by James Perry:A01410D00000178409B375B00006B30
Date: 2021.10.11 15:27:56 -05'00'

PROFESSIONAL ENGINEER'S STAMP

Sargent & Lundy

CONTRACTOR/INSTALLER SHALL TAKE ALL APPROPRIATE PRECAUTIONS TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE, INCLUDING CONTRACTOR'S/INSTALLER'S PERSONNEL (OR THAT OF ITS SUBCONTRACTOR(S) PERFORMING THE WORK

CARDINAL OPERATING COMPANY

CARDINAL OPERATING CO.
306 COUNTY ROAD 7E
BRILLIANT, OH 43913

REV	DATE RELEASED	PURPOSE	PREPARED	REVIEWED	APPROVED
3	06-01-2021	ISSUED FOR CONSTRUCTION REVISION	AP	JF	JP
2	02-25-2021	ISSUED FOR CONSTRUCTION	MR	JF	JC
1	12-30-2020	ISSUED FOR BIDS AND FOR PERMIT REVIEW	AP	JF	JC
4	10-11-2021	ISSUE FOR CONSTRUCTION REVISION	AP	JF	JP

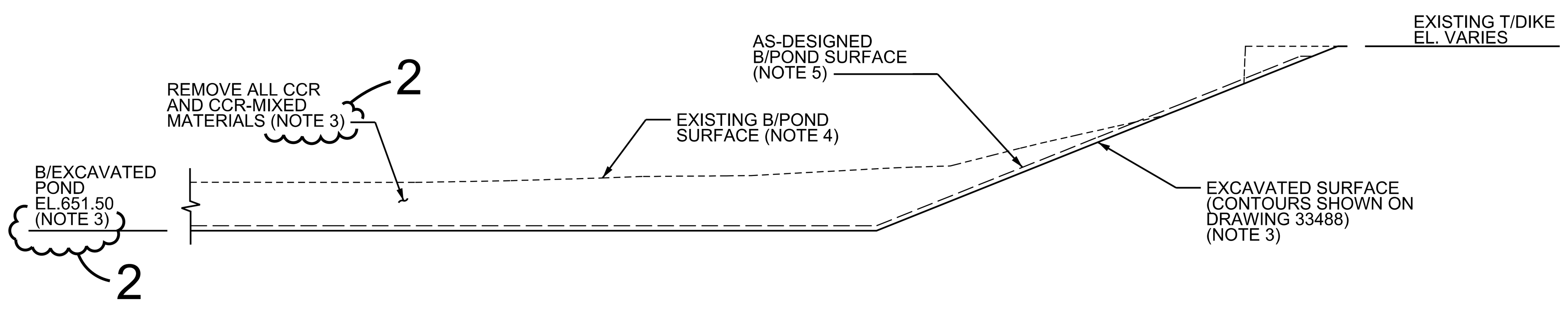
DRAWING RELEASE RECORD

PLOT DATE: DD-MMM-YYYY
PLOT TIME: HOUR:MINUTE
BY: USERPLOT

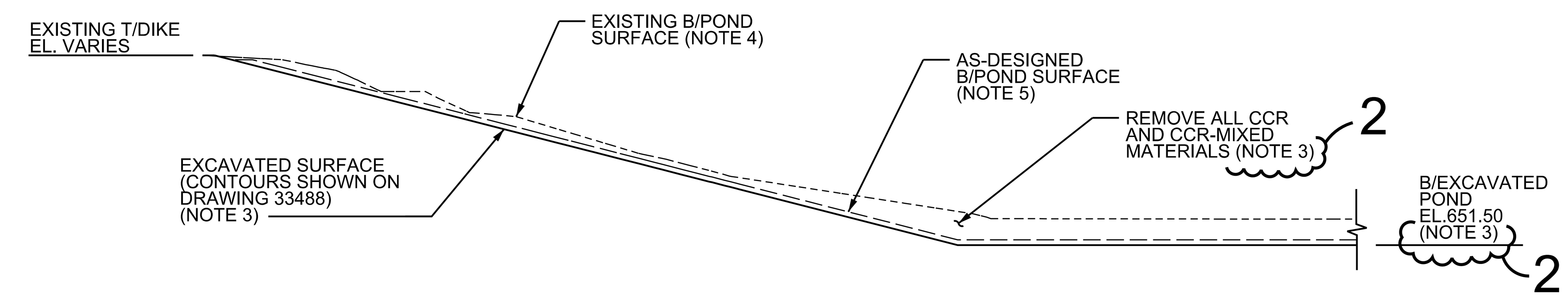
CROSS REFS:

CROSS REFS:

DRAWING NUMBER 33489



SECTION 1



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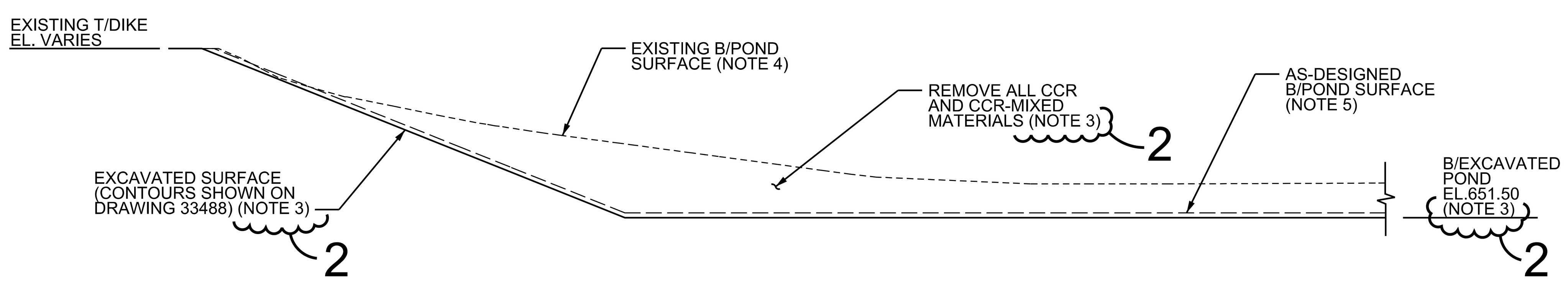
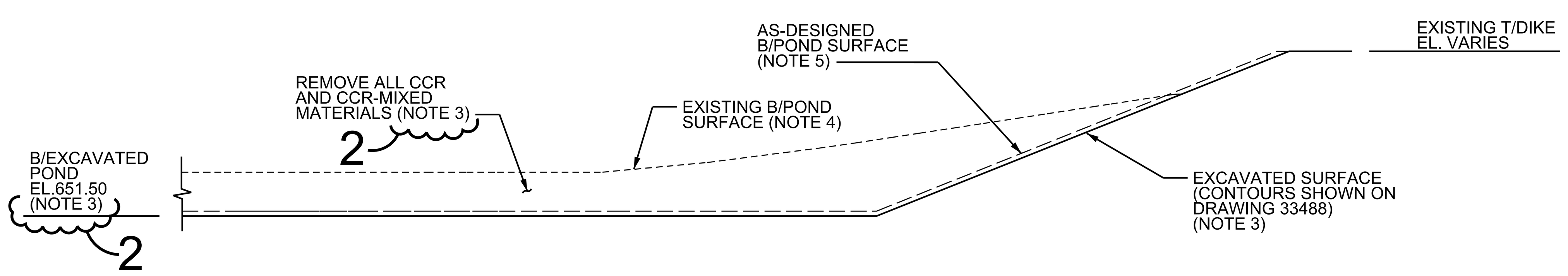


SECTION 3



SECTION 4

NOTES

1. FOR CIVIL GENERAL NOTES, ABBREVIATIONS, AND SYMBOLS, SEE DRAWING 33483.
2. ALL WORK SHOWN ON THIS DRAWING SHALL BE FURNISHED AND INSTALLED BY SPECIFICATION C-5413 UNLESS NOTED OTHERWISE.
3. CONTRACTOR SHALL REMOVE ALL CCR AND CCR-MIXED MATERIALS FROM THE SOUTH POND IN ACCORDANCE WITH THE CCR RULE AND THE FOLLOWING SPECIFICATIONS:
   - CONTOURS SHOWN ON DRAWING 33488 ARE BASED ON THE ORIGINAL POND DESIGN DRAWINGS AND OTHER HISTORICAL INFORMATION; HOWEVER, THESE CONTOURS MAY NOT ACCURATELY REFLECT THE CURRENT FLOOR AND SIDE SURFACES OF THE POND.
   - IF THE CONTRACTOR EXCAVATES TO A DEPTH LESS THAN THE SPECIFIED CONTOURS ON DRAWING 33488 AND ENCOUNTERS CCR-FREE SOILS, THE CONTRACTOR SHALL REVIEW THE SURFACE OF THE POND WITH REPRESENTATIVES OF THE STATION AND CERTIFYING ENGINEER FOR APPROVAL TO CEASE EXCAVATION IN THAT AREA.
   - IF THE CONTRACTOR REACHES THE SPECIFIED CONTOURS AND OBSERVES CCR OR CCR-MIXED MATERIALS, THE CONTRACTOR SHALL REVIEW THE SURFACE OF THE POND WITH REPRESENTATIVES OF THE STATION FOR APPROVAL TO REMOVE ADDITIONAL MATERIAL BEYOND THE SPECIFIED CONTOURS TO COMPLY WITH THE CCR RULE REGULATIONS. THE STATION REPRESENTATIVE MAY DIRECT THE CONTRACTOR TO RESTORE THE BOTTOM OF POND SURFACE WITH CLEAN FILL MATERIAL.
4. EXISTING BOTTOM OF POND SURFACE REPRESENTS THE FLOOR AND SIDE SURFACES OF THE POND THAT WERE RECORDED WITH TOPOGRAPHIC AND BATHYMETRIC MAPPING, AUGUST 2020.
5. THE AS-DESIGNED BOTTOM OF POND SURFACE REPRESENTS THE FLOOR AND SIDE SURFACES OF THE POND THAT ARE ASSUMED TO HAVE BEEN INSTALLED AT THE TIME OF COMMISSIONING BASED ON THE ORIGINAL POND DESIGN DRAWINGS AND OTHER HISTORICAL INFORMATION.

2

REFERENCE DRAWINGS

112302008 SHT 1 THRU 6	BATHYMETRIC AND TOPOGRAPHIC SURVEY
3-3017-6	SITE DEVELOPMENT PLAN ASH STORAGE AREAS SHEET 3
3-3027-3	SITE DEVELOPMENT ASH STORAGE AREAS SECTIONS
33488	SOUTH POND EXCAVATION PLAN

UNDERGROUND OR EMBEDDED UTILITIES MAY BE LOCATED WITHIN OR ADJACENT TO THE AREA IN WHICH EXCAVATION, DEMOLITION, FOUNDATION, OR MODIFICATION WORK IS TO BE PERFORMED.

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THE CONTRACTOR/INSTALLER SHALL EXERCISE DUE CAUTION DURING ALL EXCAVATION/FOUNDATION/DEMOLITION WORK.

DATE	NO.	DESCRIPTION	APPD.

REVISIONS

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CARDINAL OPERATING COMPANY

CARDINAL PLANT

BRILLIANT OHIO

BOTTOM ASH CLOSURE AND LINING PROJECT
SOUTH POND
EXCAVATION SECTION VIEWS
CARDINAL PLANT
BUCKEYE POWER INC.

REV	DATE RELEASED	PURPOSE	PREPARED / REVIEWED / APPROVED
2	10-11-2021	ISSUED FOR CONSTRUCTION REVISION	AP / JF / JP
1	02-25-2021	ISSUED FOR CONSTRUCTION	MR / JF / JC
1	12-30-2020	ISSUED FOR BIDS AND FOR PERMIT REVIEW	MR / JF / JC
0	10-19-2020	ISSUE FOR PERMIT REVIEW	AP / JF / JC

DRAWING RELEASE RECORD

STATE OF OHIO JAMES T. PERRY PE.84615 REGISTERED PROFESSIONAL ENGINEER

James Perry:A01410D00000178409B375B00006B30
Digitally signed by James Perry:A01410D00000178409B375B00006B30
Date: 2021.10.11 15:29:05 -05'00'

PROFESSIONAL ENGINEER'S STAMP

Sargent & Lundy

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UNIT:	DRAWING NUMBER:	REV:
13	33489	2

SCALE: NONE | ENGINEERING DIVISION
DR: AP
CH: JF
SUP: --
ENG: --
DATE: 10-19-2020
APPROVED BY

CARDINAL OPERATING COMPANY

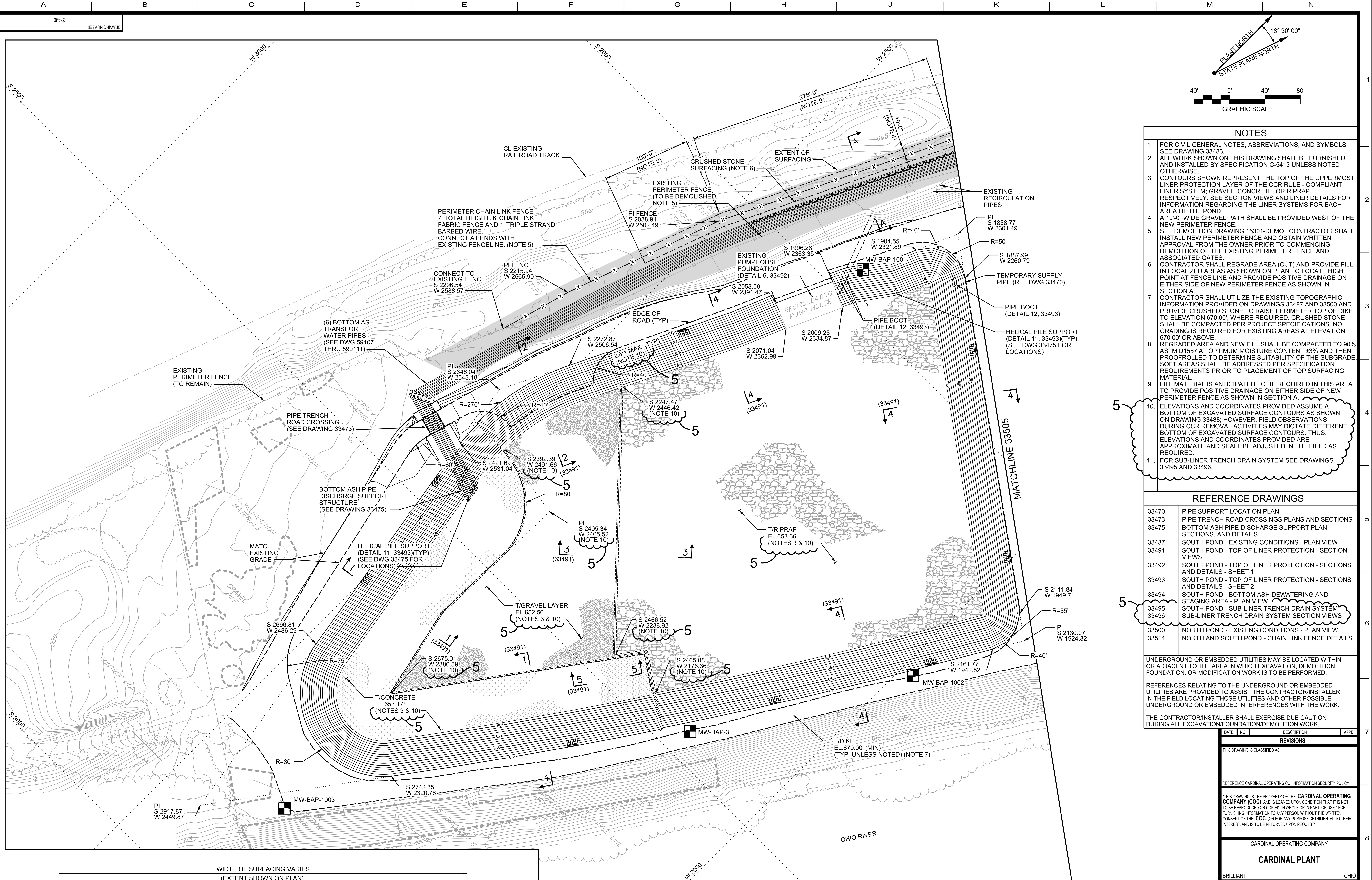
CARDINAL OPERATING CO.
306 COUNTY ROAD 7E
BRILLIANT, OH 43913

PLOT DATE: DD-MMM-YYYY
PLOT TIME: HOUR:MINUTE
BY: USERPLOT

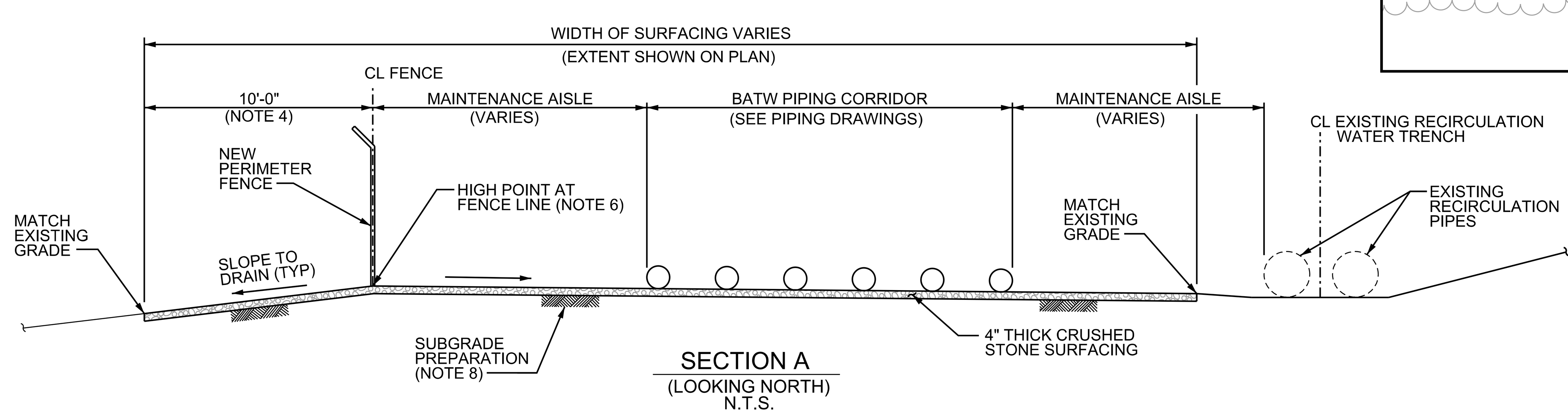
CROSS REFS:

CROSS REFS:

DRAWING NUMBER 33490



SOUTH POND - TOP OF LINER PROTECTION PLAN



SECTION A
(LOOKING NORTH)
N.T.S.

NOTES

1. FOR CIVIL GENERAL NOTES, ABBREVIATIONS, AND SYMBOLS, SEE DRAWING 33483.
2. ALL WORK SHOWN ON THIS DRAWING SHALL BE FURNISHED AND INSTALLED BY SPECIFICATION C-5413 UNLESS NOTED OTHERWISE.
3. CONTOURS SHOWN REPRESENT THE TOP OF THE UPPERMOST LINER PROTECTION LAYER OF THE CCR RULE - COMPLIANT LINER SYSTEM; GRAVEL, CONCRETE, OR RIPRAP RESPECTIVELY. SEE SECTION VIEWS AND LINER DETAILS FOR INFORMATION REGARDING THE LINER SYSTEMS FOR EACH AREA OF THE POND.
4. A 10'-0" WIDE GRAVEL PATH SHALL BE PROVIDED WEST OF THE NEW PERIMETER FENCE.
5. SEE DEMOLITION DRAWING 15301-DEMO. CONTRACTOR SHALL INSTALL NEW PERIMETER FENCE AND OBTAIN WRITTEN APPROVAL FROM THE OWNER PRIOR TO COMMENCING DEMOLITION OF THE EXISTING PERIMETER FENCE AND ASSOCIATED GATES.
6. CONTRACTOR SHALL REGRADE AREA (CUT) AND PROVIDE FILL IN LOCALIZED AREAS AS SHOWN ON PLAN TO LOCATE HIGH POINT AT FENCE LINE AND PROVIDE POSITIVE DRAINAGE ON EITHER SIDE OF NEW PERIMETER FENCE AS SHOWN IN SECTION A.
7. CONTRACTOR SHALL UTILIZE THE EXISTING TOPOGRAPHIC INFORMATION PROVIDED ON DRAWINGS 33487 AND 33500 AND PROVIDE CRUSHED STONE TO RAISE PERIMETER TOP OF DIKE TO ELEVATION 670.00', WHERE REQUIRED. CRUSHED STONE SHALL BE COMPACTED PER PROJECT SPECIFICATIONS. NO GRADING IS REQUIRED FOR EXISTING AREAS AT ELEVATION 670.00' OR ABOVE.
8. REGRADED AREA AND NEW FILL SHALL BE COMPACTED TO 90% ASTM D1557 AT OPTIMUM MOISTURE CONTENT ±3% AND THEN PROOFROLLED TO ENSURE SUITABILITY OF THE SUBGRADE. SOFT AREAS SHALL BE REPLACED PER SPECIFICATION REQUIREMENTS PRIOR TO PLACEMENT OF TOP SURFACING MATERIAL.
9. FILL MATERIAL IS ANTICIPATED TO BE REQUIRED IN THIS AREA TO PROVIDE POSITIVE DRAINAGE ON EITHER SIDE OF NEW PERIMETER FENCE AS SHOWN IN SECTION A.
10. ELEVATIONS AND COORDINATES PROVIDED ASSUME A BOTTOM OF EXCAVATED SURFACE CONTOURS AS SHOWN ON DRAWING 33488; HOWEVER, FIELD OBSERVATIONS DURING CCR REMOVAL ACTIVITIES MAY DICTATE DIFFERENT BOTTOM OF EXCAVATED SURFACE CONTOURS. THUS, ELEVATIONS AND COORDINATES PROVIDED ARE APPROXIMATE AND SHALL BE ADJUSTED IN THE FIELD AS REQUIRED.
11. FOR SUB-LINER TRENCH DRAIN SYSTEM SEE DRAWINGS 33495 AND 33496.

REFERENCE DRAWINGS

33470	PIPE SUPPORT LOCATION PLAN
33473	PIPE TRENCH ROAD CROSSINGS PLANS AND SECTIONS
33475	BOTTOM ASH PIPE DISCHARGE SUPPORT PLAN, SECTIONS, AND DETAILS
33487	SOUTH POND - EXISTING CONDITIONS - PLAN VIEW
33491	SOUTH POND - TOP OF LINER PROTECTION - SECTION VIEWS
33492	SOUTH POND - TOP OF LINER PROTECTION - SECTIONS AND DETAILS - SHEET 1
33493	SOUTH POND - TOP OF LINER PROTECTION - SECTIONS AND DETAILS - SHEET 2
33494	SOUTH POND - BOTTOM ASH DEWATERING AND STAGING AREA - PLAN VIEW
33495	SOUTH POND - SUB-LINER TRENCH DRAIN SYSTEM
33496	SUB-LINER TRENCH DRAIN SYSTEM SECTION VIEWS
33500	NORTH POND - EXISTING CONDITIONS - PLAN VIEW
33514	NORTH AND SOUTH POND - CHAIN LINK FENCE DETAILS

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REVISIONS

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CARDINAL OPERATING COMPANY

CARDINAL PLANT

BRILLIANT OHIO

BOTTOM ASH CLOSURE AND LINING PROJECT
SOUTH POND
TOP OF LINER PROTECTION PLAN
CARDINAL PLANT
BUCKEYE POWER INC.

UNIT:	DRAWING NUMBER:	REV:
13	33490	5

SCALE: NONE — ENGINEERING DIVISION
DR: AP
CH: JF
SUP: --
ENG: --
DATE: 10-19-2020

REV	DATE RELEASED	PURPOSE	
3	02-25-2021	ISSUED FOR CONSTRUCTION	MR / JF / JC
2	12-30-2020	ISSUED FOR BIDS AND FOR PERMIT REVIEW	AP / JF / JC
5	10-11-2021	ISSUE FOR CONSTRUCTION REVISION	AP / JF / JP
4	04-09-2021	ISSUE FOR CONSTRUCTION REVISION	MR / JF / JP
			PREPARED / REVIEWED / APPROVED

DRAWING RELEASE RECORD

STATE OF OHIO — JAMES T. PERRY — PE-84615 — REGISTERED PROFESSIONAL ENGINEER

James Perry:A01410D000001784093758000068300
Digitally signed by James Perry:A01410D000001784093758000068300 Date: 2021.10.11 15:30:59 -05'00'

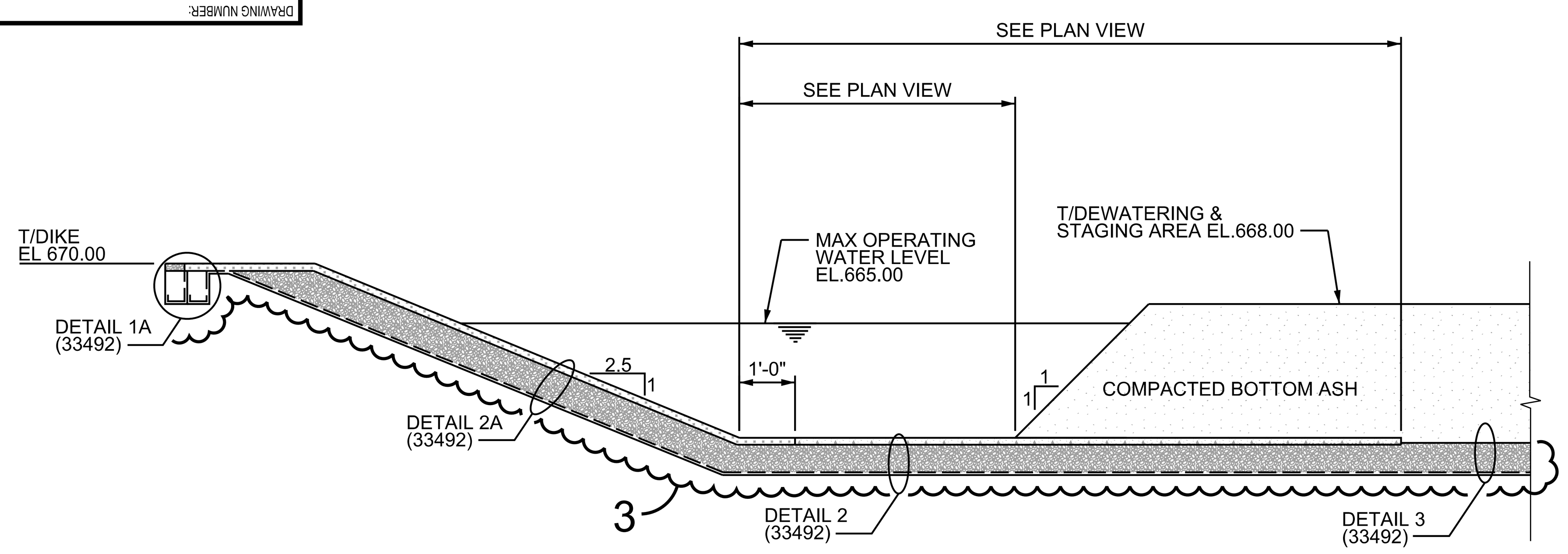
PROFESSIONAL ENGINEER'S STAMP

Sargent & Lundy

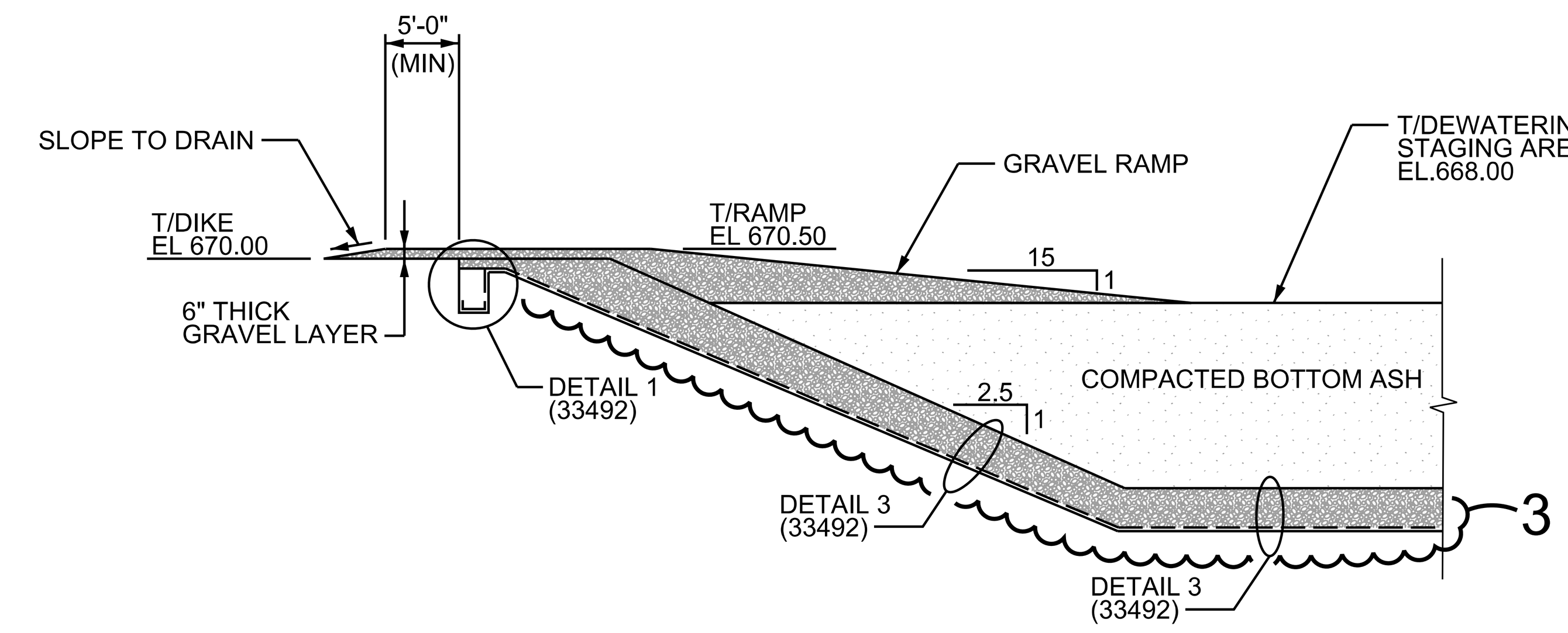
CARDINAL OPERATING COMPANY

CARDINAL OPERATING CO.
306 COUNTY ROAD 7E
BRILLIANT, OH 43913

CROSS REFS:



SECTION 1



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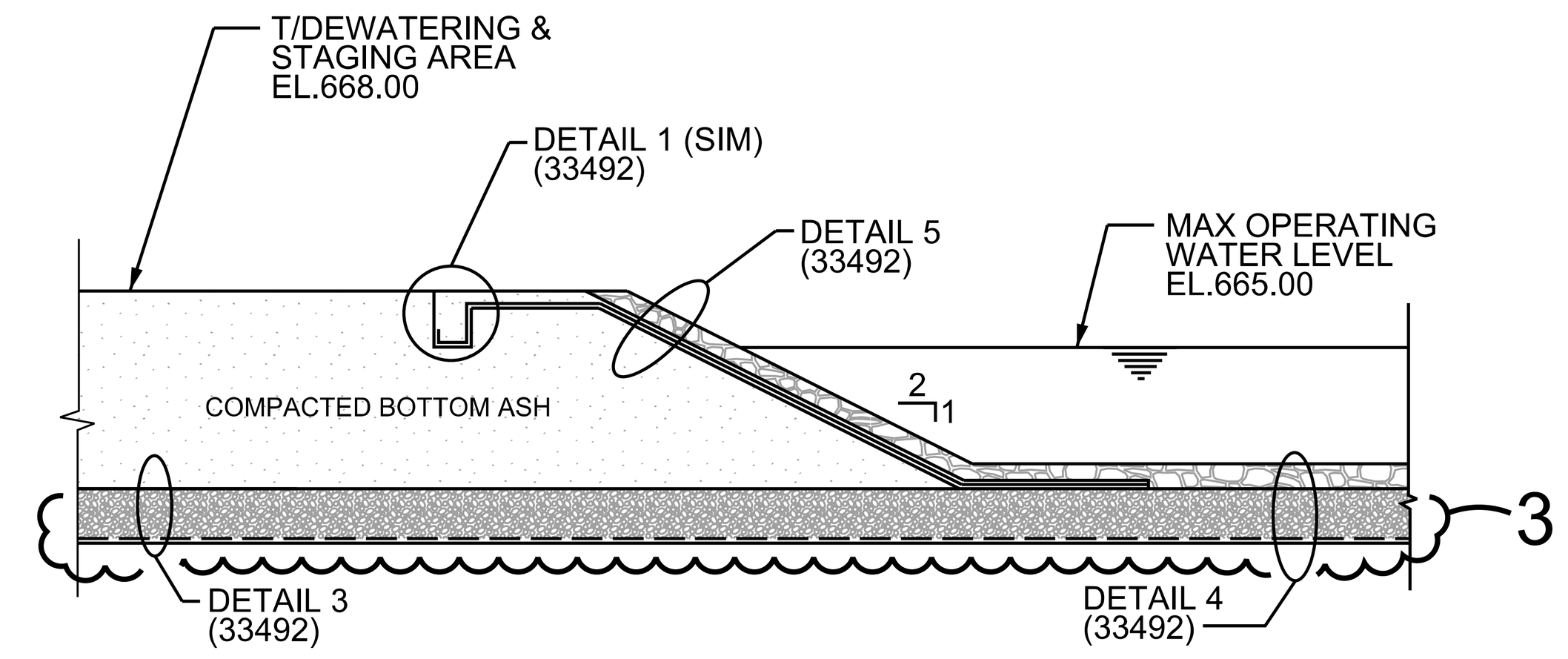
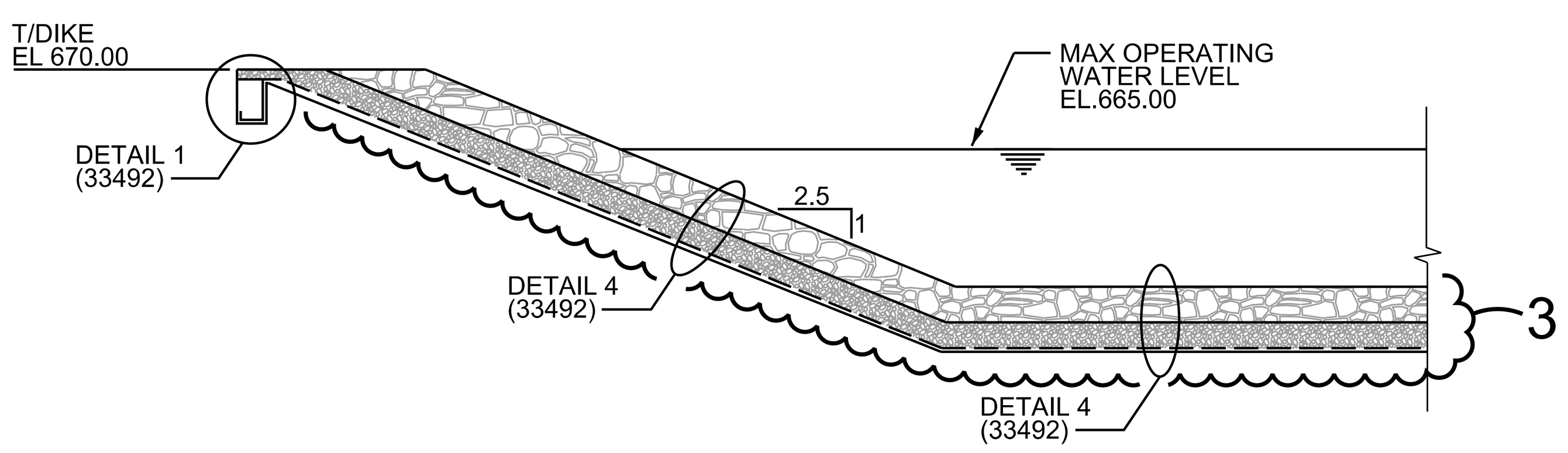


SECTION 3



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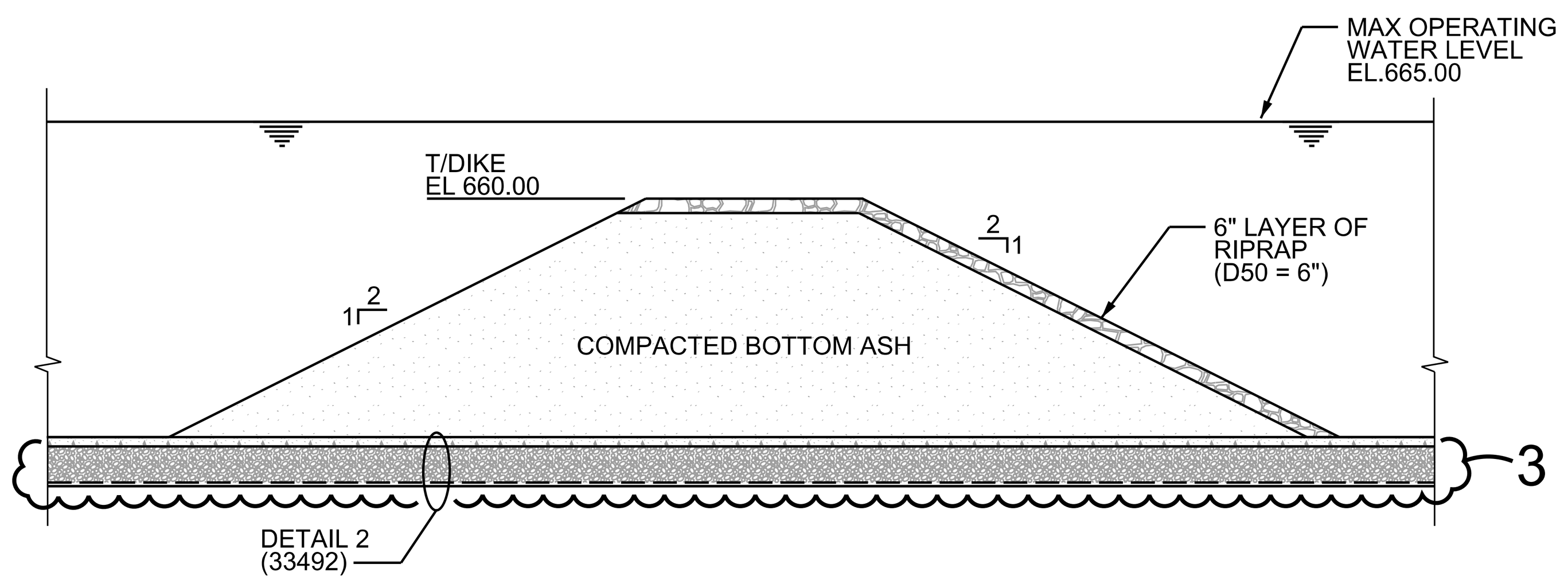

SECTION 5

3

NOTES

1. FOR CIVIL GENERAL NOTES, ABBREVIATIONS, AND SYMBOLS, SEE DRAWING 33483.
2. ALL WORK SHOWN ON THIS DRAWING SHALL BE FURNISHED AND INSTALLED BY SPECIFICATION C-5413 UNLESS NOTED OTHERWISE.

3

REFERENCE DRAWINGS

33490	SOUTH POND - TOP OF LINER PROTECTION - PLAN

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DATE	NO.	DESCRIPTION	APPD.

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CARDINAL OPERATING COMPANY

CARDINAL PLANT

BRILLIANT OHIO

BOTTOM ASH CLOSURE AND LINING PROJECT
SOUTH POND TOP LINER PROTECTION
SECTION VIEWS
CARDINAL PLANT
BUCKEYE POWER INC.

UNIT:	DRAWING NUMBER:	REV:
13	33491	3

SCALE: NONE — ENGINEERING DIVISION
DR: AP
CH: JF
SUP: --
ENG: --
DATE: 10-19-2020
APPROVED BY:

REV	DATE RELEASED	PURPOSE	
3	04-09-2021	ISSUED FOR CONSTRUCTION REVISION	MR / JF / JP
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			PREPARED / REVIEWED / APPROVED

DRAWING RELEASE RECORD

STATE OF OHIO — JAMES T. PERRY PE.84615 — REGISTERED PROFESSIONAL ENGINEER

James Perry:A01410D00000178409B375B00006830 — Digitally signed by James Perry:A01410D00000178409B375B00006830 Date: 2021.04.09 10:53:01 -05'00'

PROFESSIONAL ENGINEER'S STAMP

Sargent & Lundy

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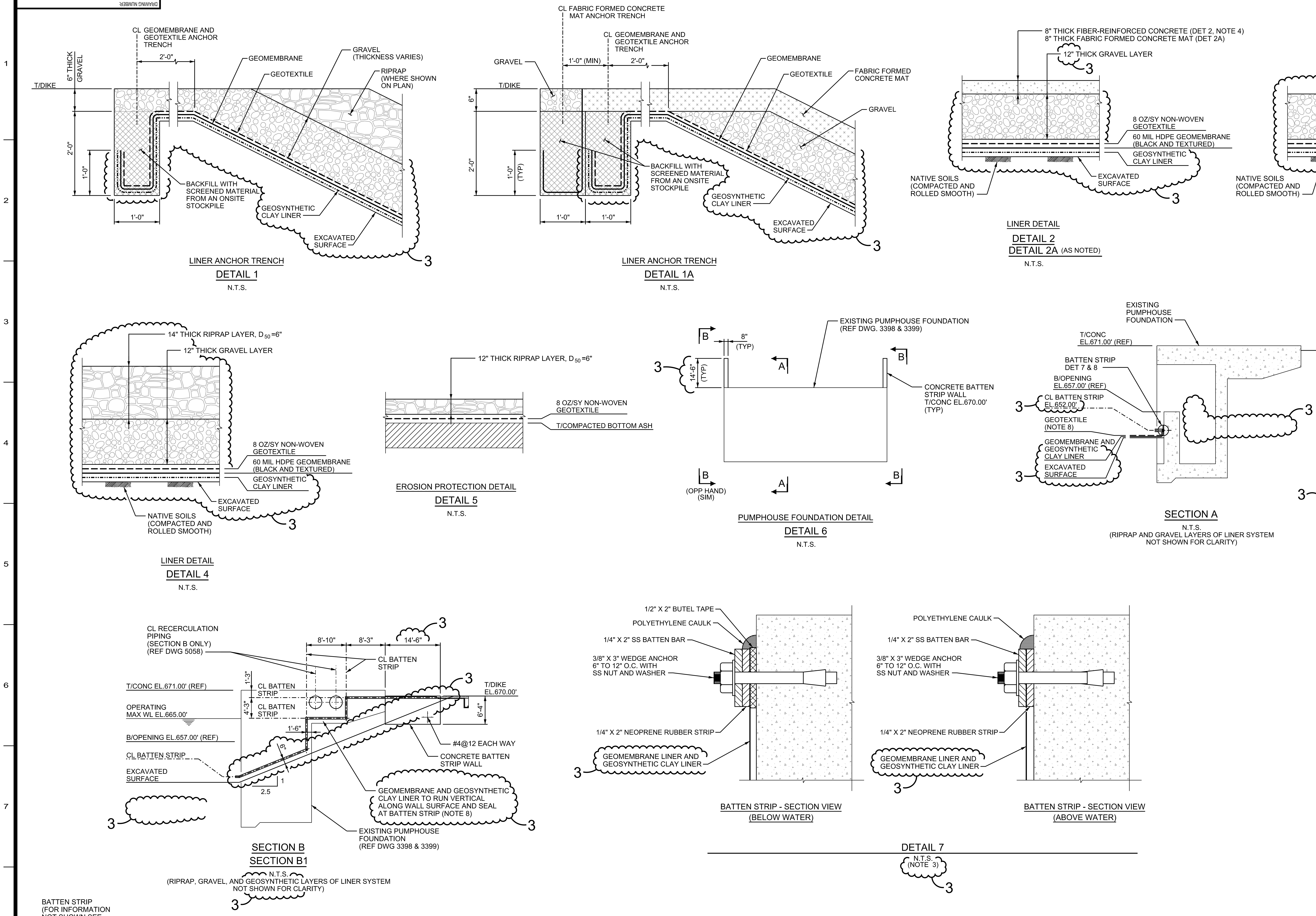
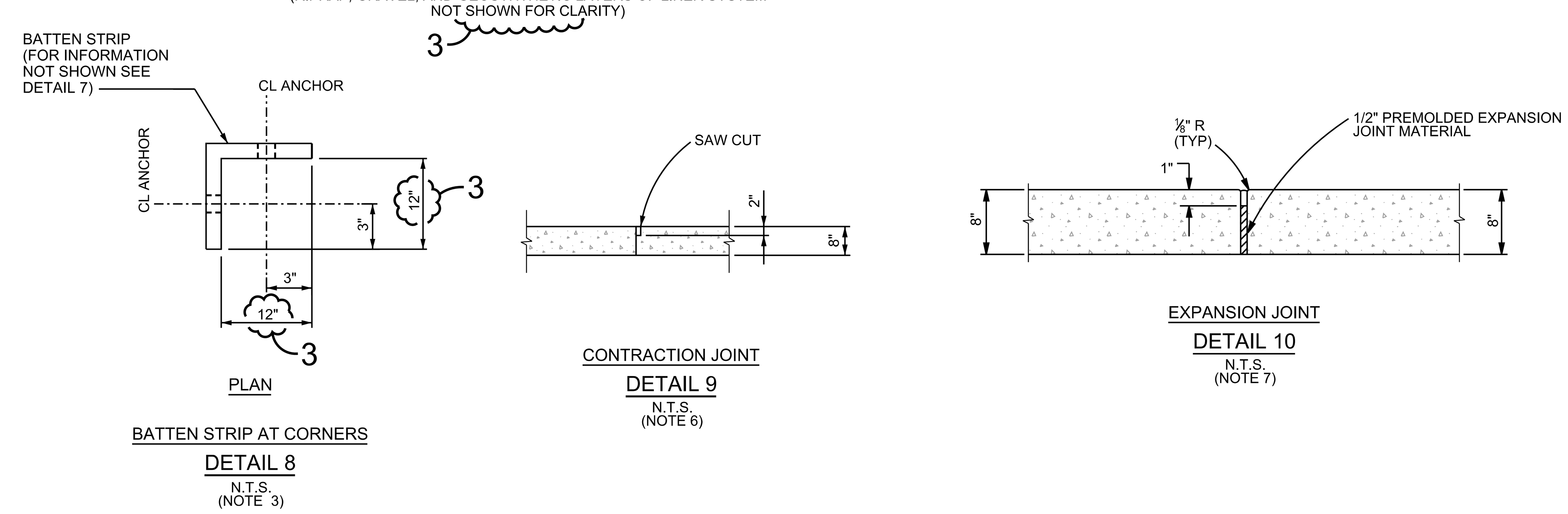
CARDINAL OPERATING COMPANY

CARDINAL OPERATING CO.
306 COUNTY ROAD 7E
BRILLIANT, OH 43913

CROSS REFS:





NOTES

1. FOR CIVIL GENERAL NOTES, ABBREVIATIONS, AND SYMBOLS, SEE DRAWING 33483.
2. ALL WORK SHOWN ON THIS DRAWING SHALL BE FURNISHED AND INSTALLED BY SPECIFICATION C-5413 UNLESS NOTED OTHERWISE.
3. LOOSE GRANULAR SODIUM BENTONITE OR BENTONITE PASTE SHALL BE LIBERALLY APPLIED AT CORNERS AND AREAS WHERE THE BENTONITE MAY NOT BE CONTINUOUSLY IN DIRECT CONTACT WITH THE STRUCTURE OR SUBGRADE.
4. CONCRETE MIXTURE SHALL INCLUDE 6LB/CY SYNTHETIC STRUX 90/40 MACRO-FIBER FROM GCP APPLIED TECHNOLOGIES OR APPROVED EQUAL. CONTRACTOR SHALL APPLY THE FIBERS IN STRICT ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS. FURTHERMORE, PRECAUTION SHALL BE TAKEN WHEN PREPARING CONCRETE FORMWORK SUCH THAT THE HDPE LINER IS NOT DAMAGED. STAKING OF THE FORMWORK IS NOT PERMITTED.
5. THE AS-DESIGNED BOTTOM OF POND SURFACE REPRESENTS THE FLOOR AND SIDE SURFACES OF THE POND THAT ARE ASSUMED TO HAVE BEEN INSTALLED AT THE TIME OF COMMISSIONING BASED ON THE ORIGINAL POND DESIGN DRAWINGS AND OTHER HISTORICAL INFORMATION.
6. FOR ALL FIBER REINFORCED CONCRETE, CONTRACTION JOINTS SHALL BE FIELD LOCATED AND APPLIED AT 20'-0" (MAX) ON CENTER, EACH DIRECTION.
7. FOR ALL FIBER REINFORCED CONCRETE, EXPANSION JOINTS SHALL BE FIELD LOCATED AND APPLIED AT 60'-0" MAXIMUM ON CENTER, EACH DIRECTION.
8. GEOTEXTILE SHALL ALSO RUN VERTICLE ALONG WALL SURFACE AND TERMINATE A MINIMUM OF 4" BEYOND THE TOP OF THE RIPRAP LAYER OF THE LINER SYSTEM.

REFERENCE DRAWINGS

3398	RECIRCULATING PUMP HOUSE PLAN & SECTIONS SHEET - 1
3399	RECIRCULATING PUMP HOUSE PLAN & SECTIONS SHEET - 2
5058	RECIRCULATING PUMPHOUSE AT ASH POND
33490	SOUTH POND - TOP OF LINER PROTECTION - PLAN

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REV	DATE RELEASED	PURPOSE	
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			PREPARED / REVIEWED / APPROVED

DRAWING RELEASE RECORD

STATE OF OHIO — JAMES T. PERRY — PE.84615 — REGISTERED PROFESSIONAL ENGINEER

James Perry:A01410D0000017840 9B375B00006830

Digitally signed by James Perry:A01410D000001784 09B375B00006830 Date: 2021.04.09 10:54:30 -05'00'

PROFESSIONAL ENGINEER'S STAMP

Sargent & Lundy

DATE	NO.	DESCRIPTION	APPD.

REVISIONS

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CARDINAL OPERATING COMPANY

CARDINAL PLANT

BRILLIANT OHIO

BOTTOM ASH CLOSURE AND LINING PROJECT
SOUTH POND TOP OF LINER PROTECTION
SECTIONS AND DETAILS - SHEET 1
CARDINAL PLANT
BUCKEYE POWER INC.

UNIT:	DRAWING NUMBER:	REV:
13	33492	3

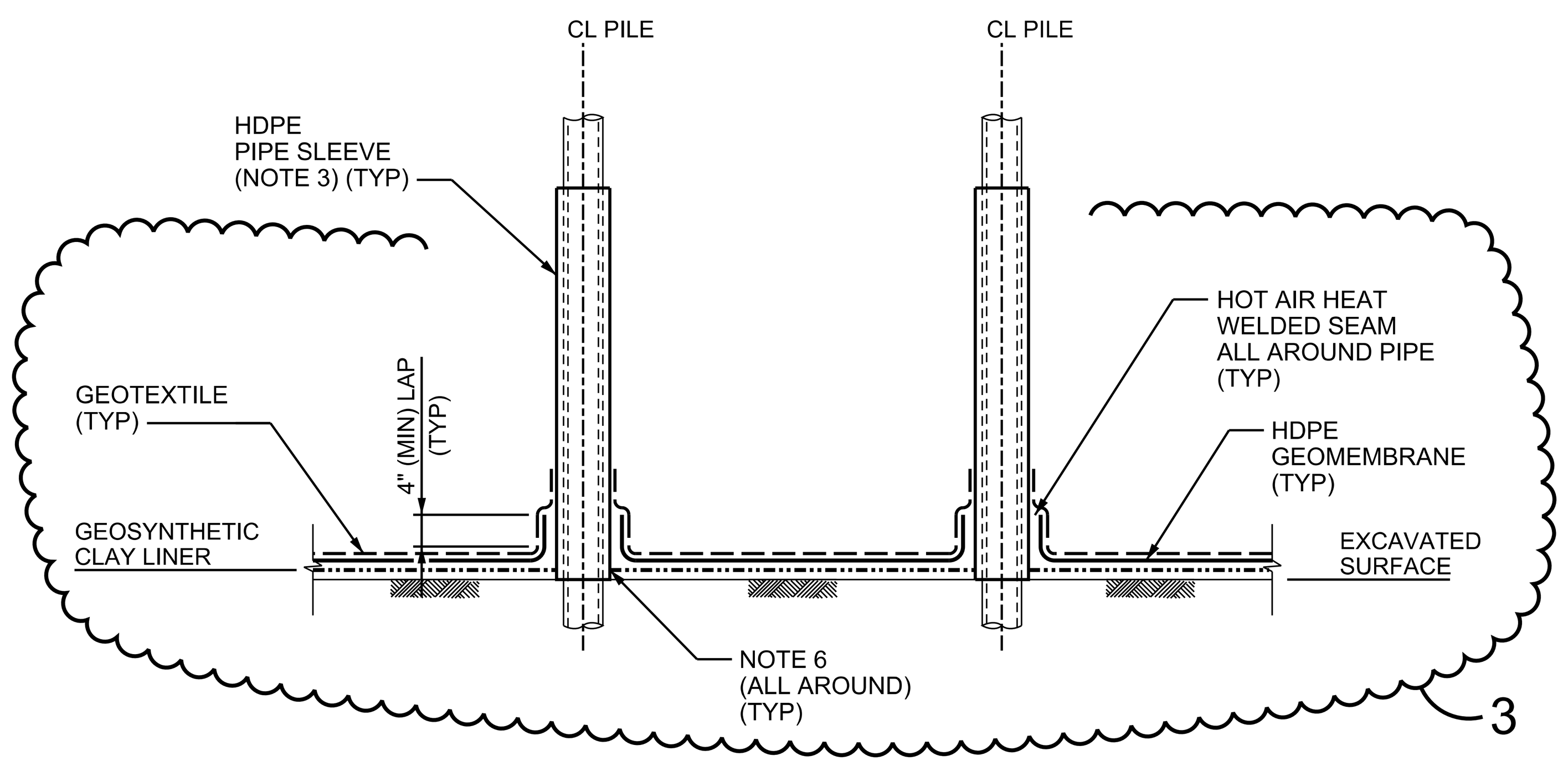
SCALE: NONE — ENGINEERING DIVISION
DR: AP
CH: JF
SUP: --
ENG: --
DATE: 10-19-2020
APPROVED BY

CARDINAL OPERATING COMPANY
CARDINAL OPERATING CO.
306 COUNTY ROAD 7E
BRILLIANT, OH 43913

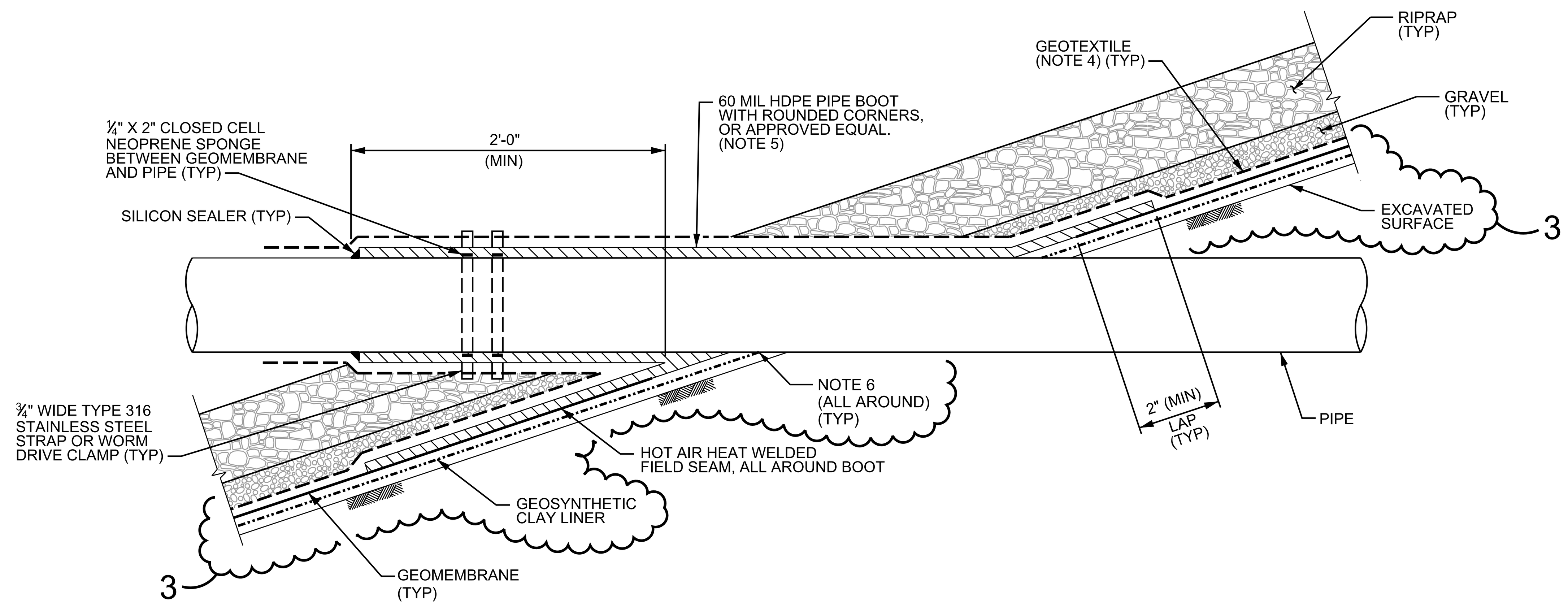
DRAWING NUMBER 33492

CROSS REFS:

DRAWING NUMBER
33493



DETAIL 11
N.T.S.
(FOR LOCATION OF PILES SEE DRAWINGS 33470 AND 33475)
(GRAVEL, CONCRETE, AND RIPRAP LAYERS OF THE LINER SYSTEM ARE NOT SHOWN FOR CLARITY)



LINER CONNECTION AT PIPE
PENETRATION THROUGH LINER
DETAIL 12
N.T.S.

NOTES

1. FOR CIVIL GENERAL NOTES, ABBREVIATIONS, AND SYMBOLS, SEE DRAWING 33483.
2. ALL WORK SHOWN ON THIS DRAWING SHALL BE FURNISHED AND INSTALLED BY SPECIFICATION C-5413 UNLESS NOTED OTHERWISE.
3. THE HDPE SLEEVES SHALL BE INSTALLED OVER THE PILES BEFORE THE BEARING PLATE CAPS ARE INSTALLED. AFTER THE POND IS CLEANED AND CLOSED THE SLEEVE SHALL BE CENTERED ON THE PILE AND THE ANNULAR SPACE FILLED WITH BENTONITE PELLETS AND REHYDRATED PRIOR TO THE LINER COMPACTED SOIL INSTALLATION. THE SLEEVE SHALL BE WELDED TO THE HDPE GEOMEMBRANE AS SHOWN.
4. GEOTEXTILE SHALL DRAPE OVER AND COVER PIPE BOOT AND SILICON SEALER.
5. CONTRACTOR MAY FIELD FABRICATE A 60 MIL HDPE PIPE BOOT BY HEAT WELDING A LONGITUDINAL SEAM ALONG THE PIPE WITH A MINIMUM OVERLAP OF 2". TESTING OF THE LONGITUDINAL WELD SHALL ADHERE TO SPECIFICATION REQUIREMENTS.
6. LOOSE GRANULAR SODIUM BENTONITE OR BENTONITE PASTE SHALL BE LIBERALLY APPLIED AT INTERFACE BETWEEN GEOSYNTHETIC CLAY LINER AND PIPE PENETRATIONS. (3)

REFERENCE DRAWINGS

33470	PIPE SUPPORT LOCATION PLAN
33475	BOTTOM ASH PIPE DISCHARGE SUPPORT PLAN, SECTIONS, AND DETAILS
33490	SOUTH POND - TOP OF LINER PROTECTION - PLAN

UNDERGROUND OR EMBEDDED UTILITIES MAY BE LOCATED WITHIN OR ADJACENT TO THE AREA IN WHICH EXCAVATION, DEMOLITION, FOUNDATION, OR MODIFICATION WORK IS TO BE PERFORMED.

REFERENCES RELATING TO THE UNDERGROUND OR EMBEDDED UTILITIES ARE PROVIDED TO ASSIST THE CONTRACTOR/INSTALLER IN THE FIELD LOCATING THOSE UTILITIES AND OTHER POSSIBLE UNDERGROUND OR EMBEDDED INTERFERENCES WITH THE WORK.

THE CONTRACTOR/INSTALLER SHALL EXERCISE DUE CAUTION DURING ALL EXCAVATION/FOUNDATION/DEMOLITION WORK.

DRAWING RELEASE RECORD

REV	DATE RELEASED	PURPOSE	PREPARED / REVIEWED / APPROVED
3	04-09-2021	ISSUED FOR CONSTRUCTION REVISION	MR / JF / JP
2	02-25-2021	ISSUED FOR CONSTRUCTION	MR / JF / JC
1	12-30-2020	ISSUED FOR BIDS AND FOR PERMIT REVIEW	AP / JF / JC
0	10-19-2020	ISSUE FOR PERMIT REVIEW	AP / JF / JC

STATE OF OHIO — JAMES T. PERRY — PE.84615 — REGISTERED PROFESSIONAL ENGINEER

James Perry:A01410D0000017840 9B375B00006B30
Digitally signed by James Perry:A01410D0000017840 9B375B00006B30 Date: 2021.04.09 10:56:28 -05'00'

PROFESSIONAL ENGINEER'S STAMP

Sargent & Lundy

DATE	NO.	DESCRIPTION	APPD.

REVISIONS

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REFERENCE CARDINAL OPERATING CO. INFORMATION SECURITY POLICY

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CARDINAL OPERATING COMPANY

CARDINAL PLANT

BRILLIANT OHIO

BOTTOM ASH CLOSURE AND LINING PROJECT
SOUTH POND TOP OF LINER PROTECTION
SECTIONS AND DETAILS - SHEET 2
CARDINAL PLANT
BUCKEYE POWER INC.

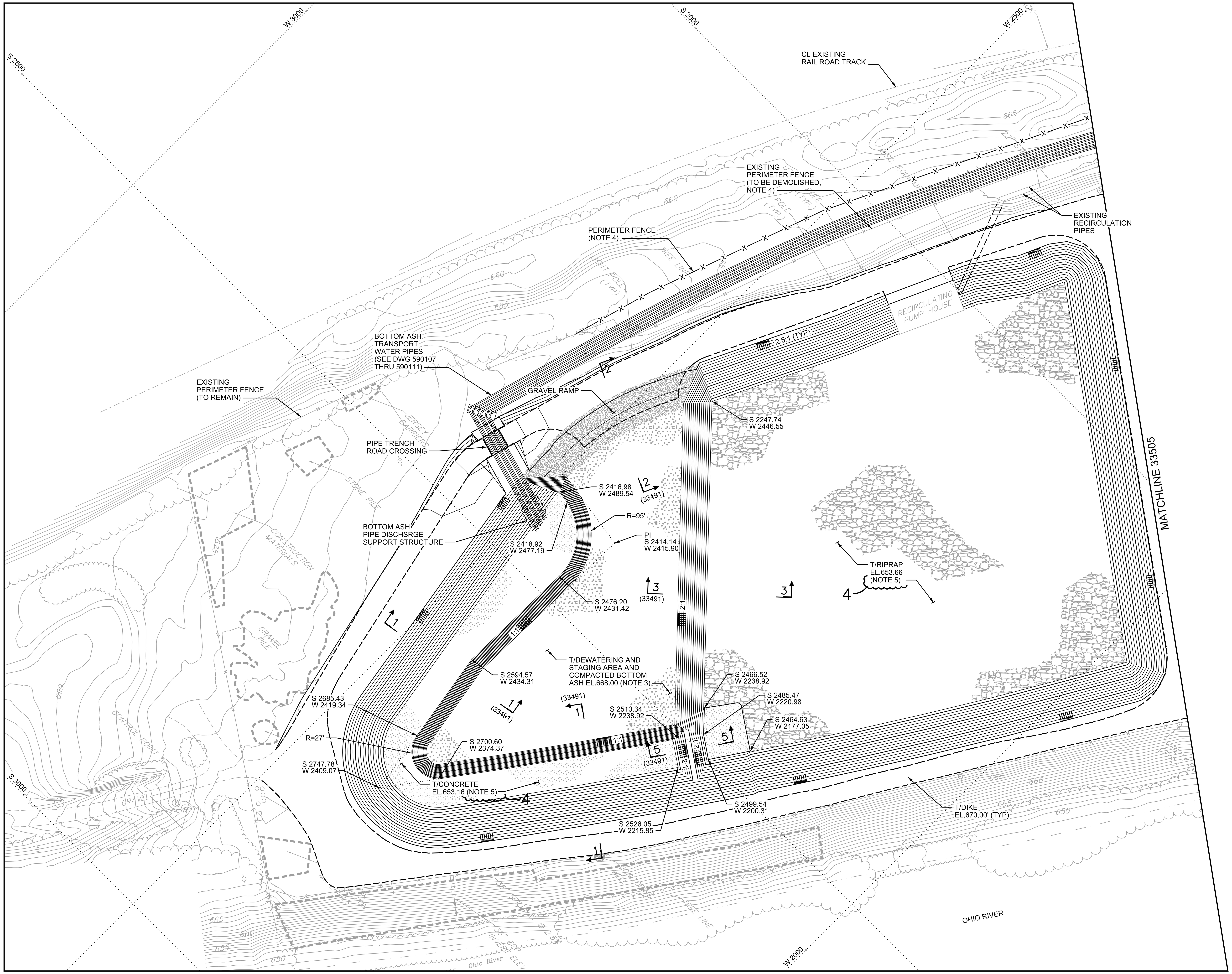
UNIT: 13 | DRAWING NUMBER: 33493 | REV: 3

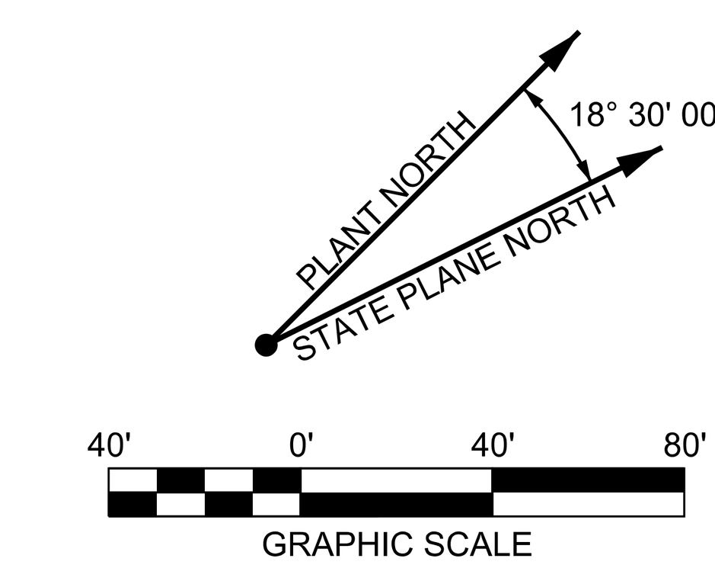
SCALE: NONE — ENGINEERING DIVISION
DR: AP
CH: JF
SUP: --
ENG: --
DATE: 10-19-2020
APPROVED BY

CARDINAL OPERATING COMPANY

CARDINAL OPERATING CO.
306 COUNTY ROAD 7E
BRILLIANT, OH 43913

CROSS REFS:





SOUTH POND - BOTTOM ASH DEWATERING AND STAGING AREA PLAN

(NOTE 5)

NOTES

1. FOR CIVIL GENERAL NOTES, ABBREVIATIONS, AND SYMBOLS, SEE DRAWING 33483.
2. ALL WORK SHOWN ON THIS DRAWING SHALL BE FURNISHED AND INSTALLED BY SPECIFICATION C-5413 UNLESS NOTED OTHERWISE.
3. FOOTPRINT, SIDE SLOPES, AND SURFACE OF DEWATERING AND STAGING AREA SHOWN REPRESENT THE INITIAL CONFIGURATION TO BE INSTALLED BY SPECIFICATION C-5413. AFTER THE POND BEGINS TO RECEIVE WASTE WATER STREAMS THE FUTURE ASH MANAGEMENT CONTRACTOR MAY PROPOSE ALTERATIONS TO THE DEWATERING AND STAGING AREA FOR OWNER'S REVIEW AND APPROVAL TO OPTIMIZE THE AREA FOR BOTTOM ASH EXCAVATION AND/OR HYDRAULIC DREDGING ACTIVITIES AND SUIT THE AVAILABLE EQUIPMENT.
4. SEE DEMOLITION DRAWING 15301-DEMO. CONTRACTOR SHALL INSTALL NEW PERIMETER FENCE AND OBTAIN WRITTEN APPROVAL FROM THE OWNER PRIOR TO COMMENCING DEMOLITION OF THE EXISTING PERIMETER FENCE AND ASSOCIATED GATES.
5. ELEVATIONS AND COORDINATES PROVIDED ON THIS DRAWING ASSUME A BOTTOM OF EXCAVATED SURFACE CONTOURS AS SHOWN ON DRAWING 33488; HOWEVER, FIELD OBSERVATIONS DURING CCR REMOVAL ACTIVITIES MAY DICTATE DIFFERENT BOTTOM OF EXCAVATED SURFACE CONTOURS. THUS, ELEVATIONS AND COORDINATES PROVIDED ARE APPROXIMATE AND SHALL BE ADJUSTED IN THE FIELD AS REQUIRED.

REFERENCE DRAWINGS

33490	SOUTH POND - TOP OF LINER PROTECTION - PLAN
33491	SOUTH POND - TOP OF LINER PROTECTION - SECTION VIEWS
33492	SOUTH POND - TOP OF LINER PROTECTION - SECTIONS AND DETAILS - SHEET 1
33493	SOUTH POND - TOP OF LINER PROTECTION - SECTIONS AND DETAILS - SHEET 2

UNDERGROUND OR EMBEDDED UTILITIES MAY BE LOCATED WITHIN OR ADJACENT TO THE AREA IN WHICH EXCAVATION, DEMOLITION, FOUNDATION, OR MODIFICATION WORK IS TO BE PERFORMED.

REFERENCES RELATING TO THE UNDERGROUND OR EMBEDDED UTILITIES ARE PROVIDED TO ASSIST THE CONTRACTOR/INSTALLER IN THE FIELD LOCATING THOSE UTILITIES AND OTHER POSSIBLE UNDERGROUND OR EMBEDDED INTERFERENCES WITH THE WORK.

THE CONTRACTOR/INSTALLER SHALL EXERCISE DUE CAUTION DURING ALL EXCAVATION/FOUNDATION/DEMOLITION WORK.

DATE	NO.	DESCRIPTION	APPD

REVISIONS

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CARDINAL OPERATING COMPANY

CARDINAL PLANT

BRILLIANT OHIO

BOTTOM ASH CLOSURE AND LINING PROJECT
SOUTH POND
BOTTOM ASH DEWATERING AND STAGING AREA PLAN
CARDINAL PLANT
BUCKEYE POWER INC.

UNIT:	DRAWING NUMBER:	REV:
13	33494	4

SCALE: NONE — ENGINEERING DIVISION
DR: AP
CH: JF
SUP: --
ENG: --
DATE: 10-19-2020
APPROVED BY

REV	DATE RELEASED	PURPOSE	PREPARED / REVIEWED / APPROVED
3	04-09-2021	ISSUED FOR CONSTRUCTION REVISION	MR / JF / JP
2	02-25-2021	ISSUED FOR CONSTRUCTION	MR / JF / JC
1	12-30-2020	ISSUED FOR BIDS AND FOR PERMIT REVIEW	AP / JF / JC
4	10-11-2021	ISSUED FOR CONSTRUCTION REVISION	AP / JF / JP

DRAWING RELEASE RECORD

STATE OF OHIO — JAMES T. PERRY PE.84615 — REGISTERED PROFESSIONAL ENGINEER

James Perry:A01410D00000178409B375B00006B30
Digitally signed by James Perry:A01410D00000178409B375B00006B30 Date: 2021.10.11 15:32:33 -05'00'

PROFESSIONAL ENGINEER'S STAMP

Sargent & Lundy

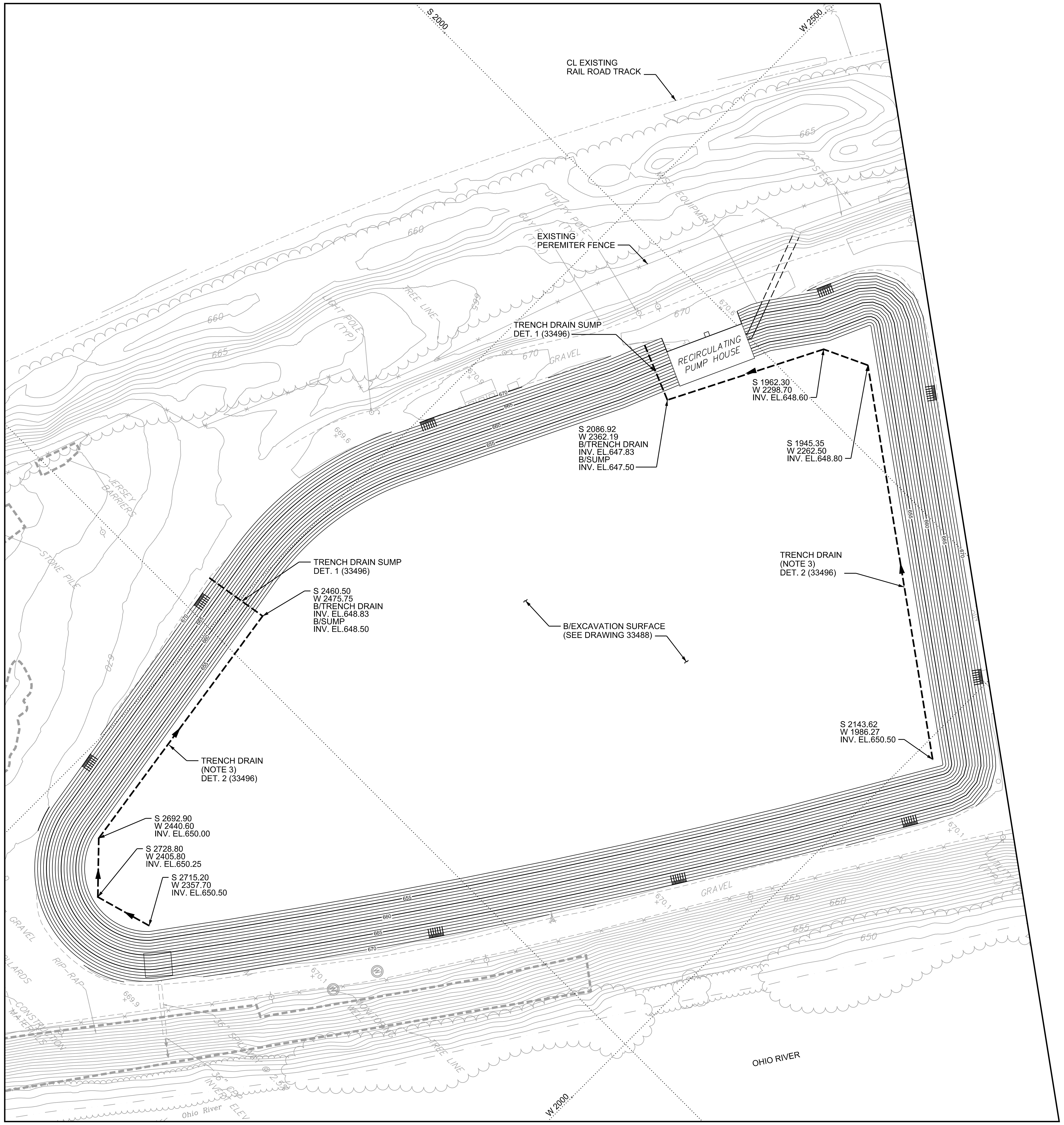
CONTRACTOR/INSTALLER SHALL TAKE ALL APPROPRIATE PRECAUTIONS TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE, INCLUDING CONTRACTOR'S/ INSTALLER'S PERSONNEL (OR THAT OF ITS SUBCONTRACTOR(S) PERFORMING THE WORK

CARDINAL OPERATING COMPANY

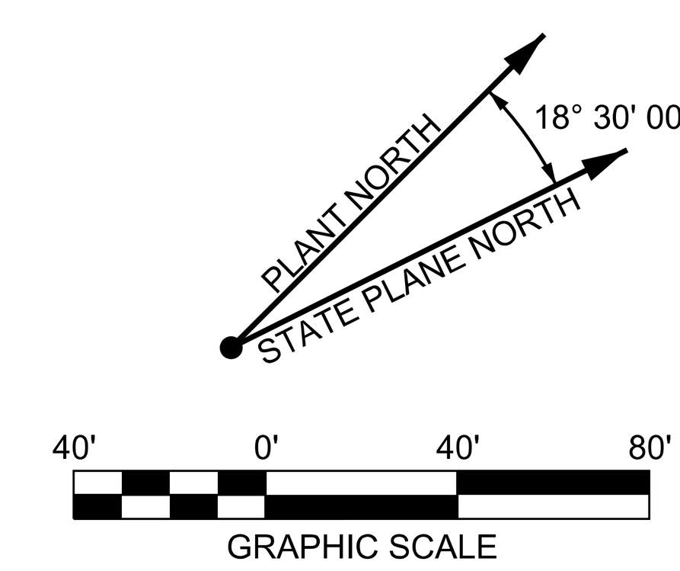
CARDINAL OPERATING CO.
306 COUNTY ROAD 7E
BRILLIANT, OH 43913

PLOT DATE: DD-MMM-YYYY
PLOT TIME: HOUR:MINUTE
BY: USERPLOT

CROSS REFS:



SOUTH POND - SUB-LINER TRENCH DRAIN SYSTEM
(NOTE 3)



NOTES

1. FOR CIVIL GENERAL NOTES, ABBREVIATIONS, AND SYMBOLS, SEE DRAWING 33483.
2. ALL WORK SHOWN ON THIS DRAWING SHALL BE FURNISHED AND INSTALLED BY SPECIFICATION C-5413 UNLESS NOTED OTHERWISE.
3. CONTRACTOR SHALL ADJUST TRENCH DRAIN COORDINATES AND INVERT ELEVATIONS BASED ON FIELD CONDITIONS TO PROMOTE POSITIVE DRAINAGE AS REQUIRED TO INSTALL THE POND LINER SYSTEM. AN AS-BUILT OF THE TRENCH DRAIN SYSTEM SHALL BE SUBMITTED TO THE OWNER UPON COMPLETION OF THE INSTALLATION.
4. ADDITIONAL TRENCH DRAINS AND TRENCH DRAIN SUMPS MAY BE INSTALLED USING DETAILS PROVIDED TO ADDRESS UNFORSEEN FIELD CONDITIONS IF WRITTEN APPROVAL IS RECEIVED FROM THE STATION REPRESENTATIVE PRIOR TO INSTALLATION.
5. AFTER CONFIRMATION AND DOCUMENTATION OF CCR REMOVAL, FREE-DRAINING ROUNDED GRAVEL MAY BE PLACED ON THE POND FLOOR AS REQUIRED AND APPROVED BY THE STATION REPRESENTATIVE TO ASSURE DRY PLACEMENT OF THE GCL.

REFERENCE DRAWINGS

33488	SOUTH POND - EXCAVATION PLAN
33489	SOUTH POND - EXCAVATION-SECTION VIEWS
33491	SOUTH POND - TOP LINER PROTECTION SECTION VIEWS
33496	SUB-LINER TRENCH DRAIN SYSTEM SECTION VIEWS

UNDERGROUND OR EMBEDDED UTILITIES MAY BE LOCATED WITHIN OR ADJACENT TO THE AREA IN WHICH EXCAVATION, DEMOLITION, FOUNDATION, OR MODIFICATION WORK IS TO BE PERFORMED.

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THE CONTRACTOR/INSTALLER SHALL EXERCISE DUE CAUTION DURING ALL EXCAVATION/FOUNDATION/DEMOLITION WORK.

DATE	NO.	DESCRIPTION	APPD.

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CARDINAL OPERATING COMPANY

CARDINAL PLANT

BRILLIANT OHIO

BOTTOM ASH CLOSURE AND LINING PROJECT
SOUTH POND
SUB-LINER TRENCH DRAIN SYSTEM
CARDINAL PLANT
BUCKEYE POWER INC.

UNIT:	DRAWING NUMBER:	REV:
13	33495	0

SCALE: NONE — ENGINEERING DIVISION
DR: AP
CH: JF
SUP: --
ENG: --
DATE: 10-19-2020
APPROVED BY

STATE OF OHIO — JAMES L. PERRY — PE.84615 — REGISTERED PROFESSIONAL ENGINEER

James Perry:A01410D0000017840983758000068 30
Digitally signed by James Perry:A01410D0000017840983758000068 30 Date: 2021.10.11 15:36:59 -05'00'

PROFESSIONAL ENGINEER'S STAMP

Sargent & Lundy

CONTRACTOR/INSTALLER SHALL TAKE ALL APPROPRIATE PRECAUTIONS TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE INCLUDING CONTRACTOR'S/INSTALLER'S PERSONNEL OR THAT OF ITS SUBCONTRACTOR(S) PERFORMING THE WORK.

REV	DATE RELEASED	PURPOSE		
0	10-11-2021	ISSUE FOR CONSTRUCTION	AP / JF / JP	PREPARED / REVIEWED / APPROVED

DRAWING RELEASE RECORD

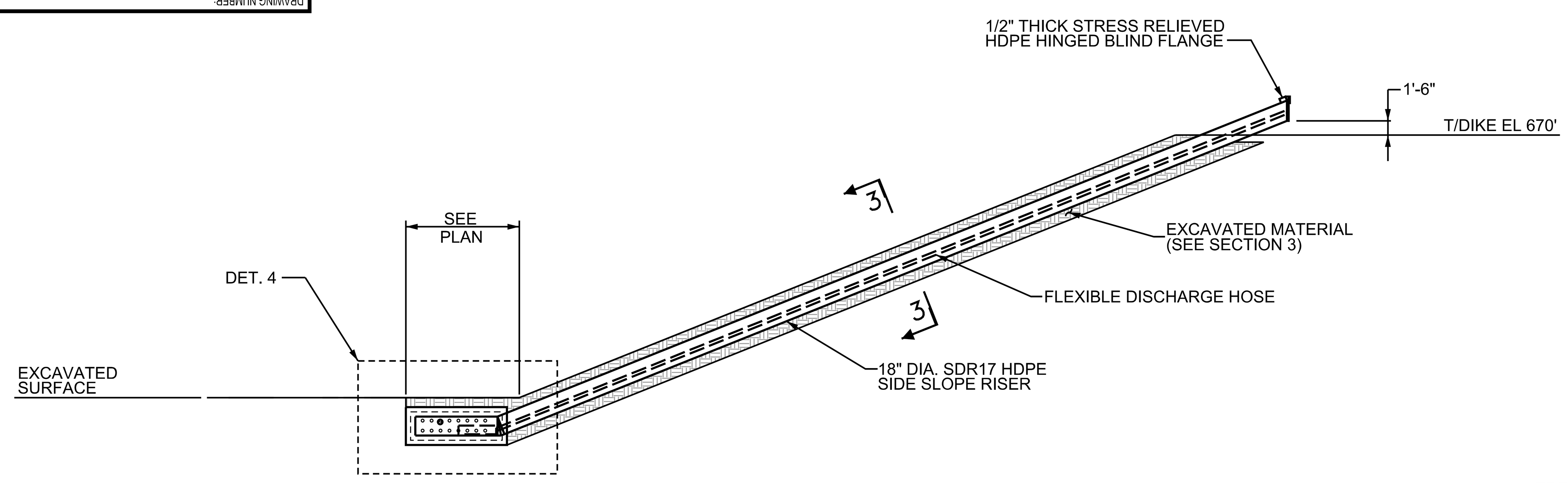
CARDINAL OPERATING COMPANY

CARDINAL OPERATING CO.
306 COUNTY ROAD 7E
BRILLIANT, OH 43913

CROSS REFS:

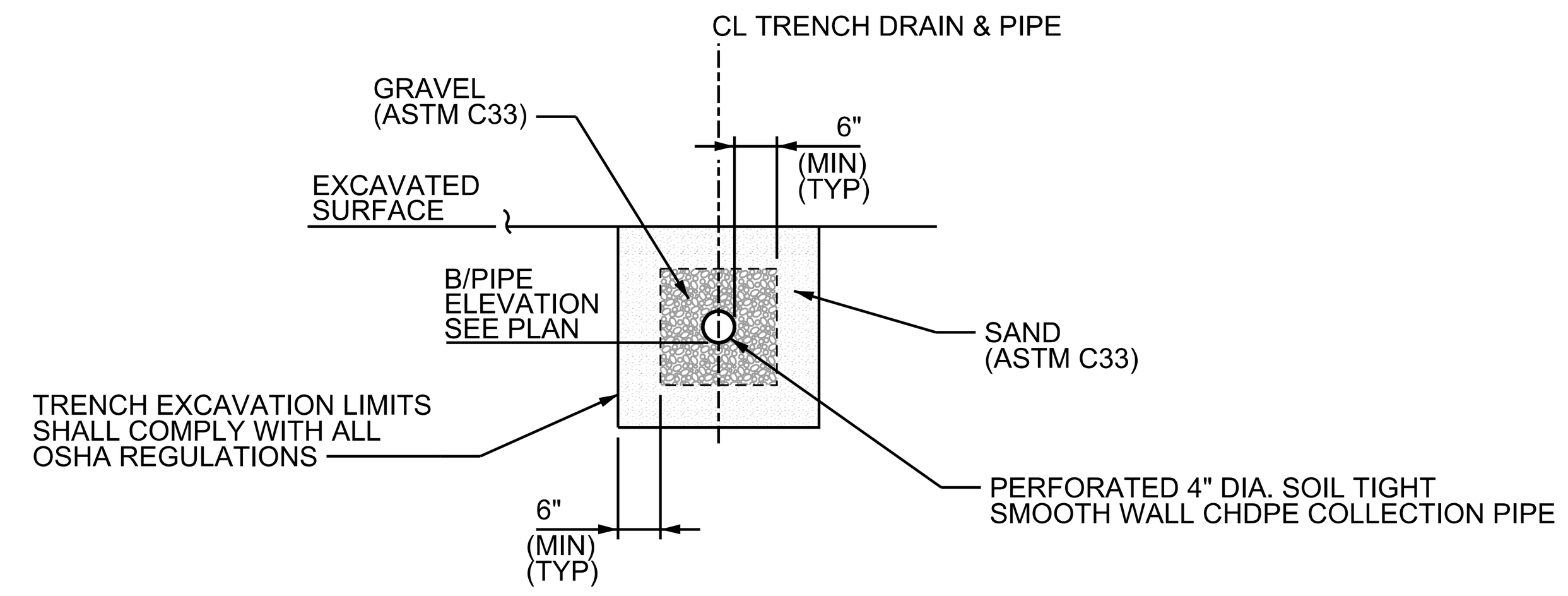
CROSS REFS:

DRAWING NUMBER 33496



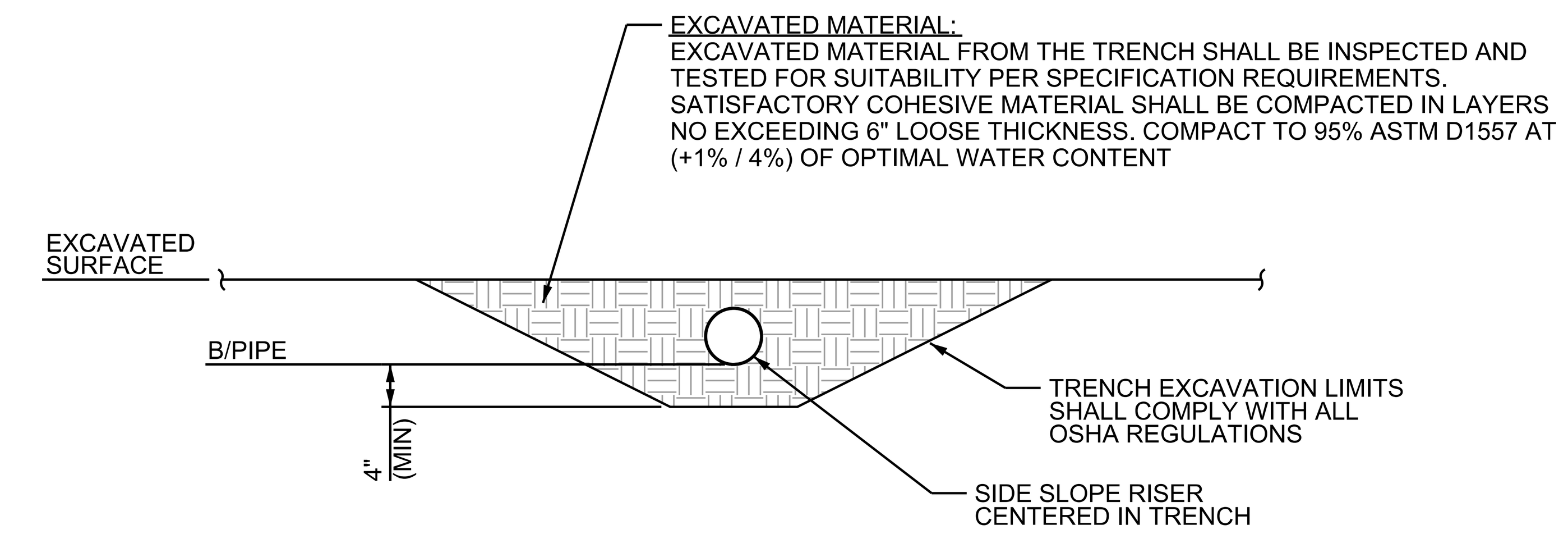
TRENCH DRAIN SUMP
ELEVATION VIEW

DETAIL 1
N.T.S.
LINER SYSTEM NOT SHOWN FOR CLARITY. FOR LINER SYSTEM INFORMATION SEE SECTION VIEWS ON DRAWING 33491.



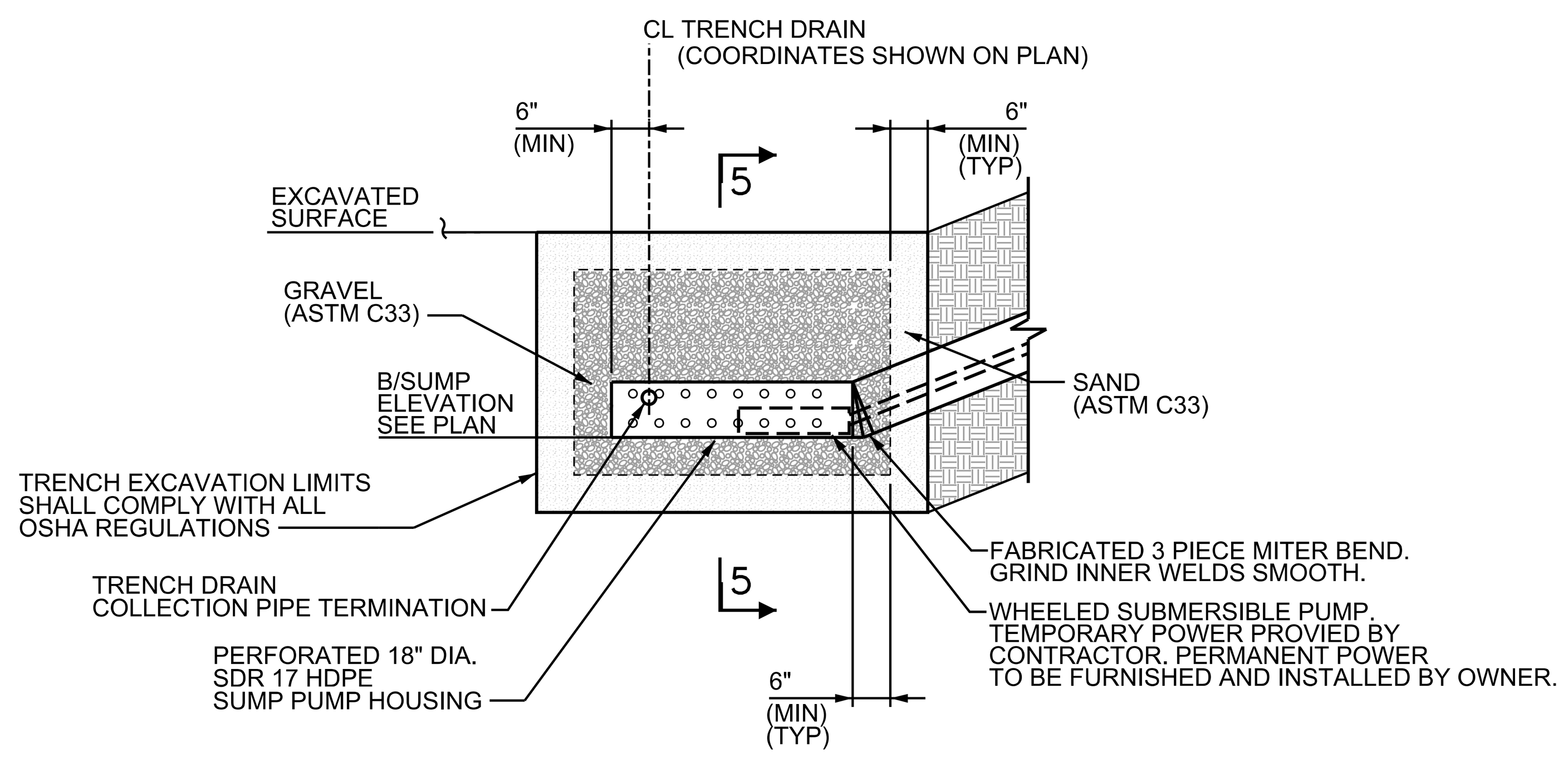
TRENCH DRAIN
ELEVATION VIEW

DETAIL 2
N.T.S.
LINER SYSTEM NOT SHOWN FOR CLARITY. FOR LINER SYSTEM INFORMATION SEE SECTION VIEWS ON DRAWING 33491.

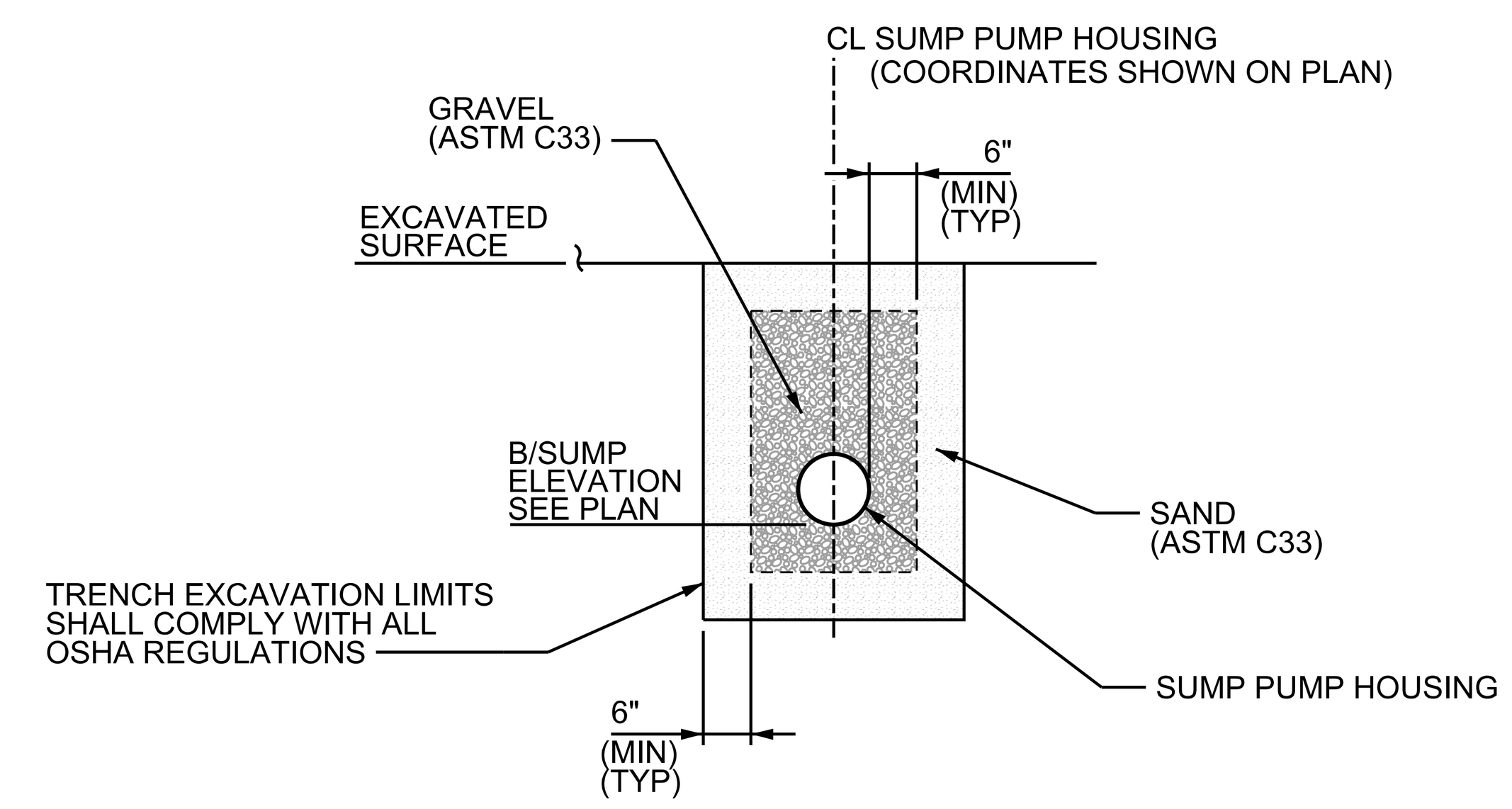


TRENCH DRAIN

SECTION 3
N.T.S.
LINER SYSTEM NOT SHOWN FOR CLARITY. FOR LINER SYSTEM INFORMATION SEE SECTION VIEWS ON DRAWING 33491.



DETAIL 4
N.T.S.



SUMP PUMP HOUSING
ELEVATION VIEW

SECTION 5
N.T.S.
LINER SYSTEM NOT SHOWN FOR CLARITY. FOR LINER SYSTEM INFORMATION SEE SECTION VIEWS ON DRAWING 33491.

NOTES

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2. ALL WORK SHOWN ON THIS DRAWING SHALL BE FURNISHED AND INSTALLED BY SPECIFICATION C-5413 UNLESS NOTED OTHERWISE.

REFERENCE DRAWINGS

33491	SOUTH POND - TOP LINER PROTECTION SECTION VIEWS
33495	SOUTH POND - SUB-LINER TRENCH DRAIN SYSTEM

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THE CONTRACTOR/INSTALLER SHALL EXERCISE DUE CAUTION DURING ALL EXCAVATION/FOUNDATION/DEMOLITION WORK.

DATE	NO.	DESCRIPTION	APPD.

REVISIONS

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CARDINAL OPERATING COMPANY

CARDINAL PLANT

BRILLIANT OHIO

BOTTOM ASH CLOSURE AND LINING PROJECT
SUB-LINER TRENCH DRAIN SYSTEM
SECTION VIEWS
CARDINAL PLANT
BUCKEYE POWER INC.

UNIT:	DRAWING NUMBER:	REV:
13	33496	0

SCALE: NONE — ENGINEERING DIVISION
DR: AP
CH: JF
SUP: --
ENG: --
DATE: 10-19-2020
APPROVED BY

STATE OF OHIO — JAMES T. PERRY PE.84615 — REGISTERED PROFESSIONAL ENGINEER

James Perry:A01410D00000178409B375B00006B30
Digitally signed by James Perry:A01410D00000178409B375B00006B30 Date: 2021.10.11 15:38:14 -05'00'

PROFESSIONAL ENGINEER'S STAMP

Sargent & Lundy

CONTRACTOR/INSTALLER SHALL TAKE ALL APPROPRIATE PRECAUTIONS TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE, INCLUDING CONTRACTOR'S/ INSTALLER'S PERSONNEL (OR THAT OF ITS SUBCONTRACTOR(S) PERFORMING THE WORK

REV	DATE RELEASED	PURPOSE	PREPARED	REVIEWED	APPROVED
0	10-11-2021	ISSUED FOR CONSTRUCTION	AP	JF	JP

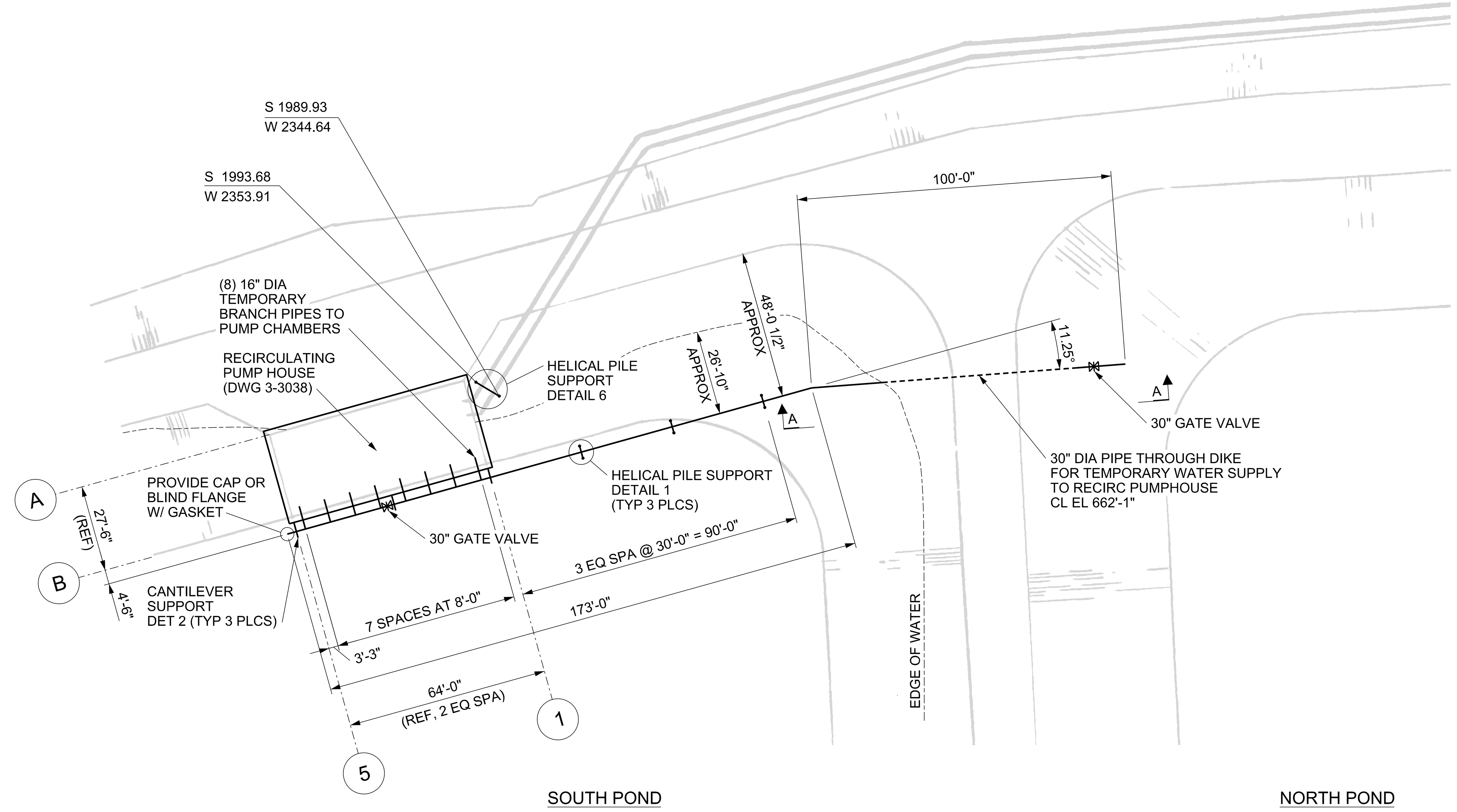
DRAWING RELEASE RECORD

CARDINAL OPERATING COMPANY

CARDINAL OPERATING CO. 306 COUNTY ROAD 7E BRILLIANT, OH 43913

PLOT DATE: DD-MMM-YYYY
PLOT TIME: HOUR:MINUTE
BY: USERPLOT

CROSS REFS:



BOTTOM ASH STORAGE AREA PIPE SUPPORT LOCATION PLAN
SCALE: NONE

NOTES

1. ALL WORK SHOWN ON THIS DRAWING SHALL BE FURNISHED AND INSTALLED IN ACCORDANCE WITH SPECIFICATION C-5413.
2. FOR BOTTOM ASH STORAGE AREA PIPE SUPPORT SECTIONS AND DETAILS SEE DRAWING 13-33471.

REFERENCE DRAWINGS

DATE	NO.	DESCRIPTION	APPD.

REVISIONS

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CARDINAL OPERATING COMPANY

CARDINAL PLANT

BRILLIANT OHIO

BOTTOM ASH CLOSURE & LINING PROJECT
BOTTOM ASH STORAGE AREA
PIPE SUPPORT LOCATION PLAN
CARDINAL PLANT
BUCKEYE POWER INC

UNIT:	DRAWING NUMBER:	REV:
13	33470	2

SCALE: AS NOTED — ENGINEERING DIVISION
DR: DZ
CH: JC
SUP: JC
ENG: JC
DATE: 02-25-2021
APPROVED BY

REV	DATE RELEASED	PURPOSE	PREPARED / REVIEWED / APPROVED
2	02-25-2021	FOR CONSTRUCTION SPEC C-5413	DZ / BB / JC
1	12-31-2020	FOR PERMIT REVIEW AND BID SPEC C-5413	DZ/SC / BB / JC
0	10-19-2020	FOR PERMIT REVIEW	DZ / JC / JC

DRAWING RELEASE RECORD

STATE OF OHIO — JOSEPH P. CHARLES PE.80469 — REGISTERED PROFESSIONAL ENGINEER
25-Feb-2021
PROFESSIONAL ENGINEER'S STAMP

Sargent & Lundy

CONTRACTOR/INSTALLER SHALL TAKE ALL APPROPRIATE PRECAUTIONS TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE, INCLUDING CONTRACTOR'S/ INSTALLER'S PERSONNEL (OR THAT OF ITS SUBCONTRACTOR(S) PERFORMING THE WORK

CARDINAL OPERATING COMPANY

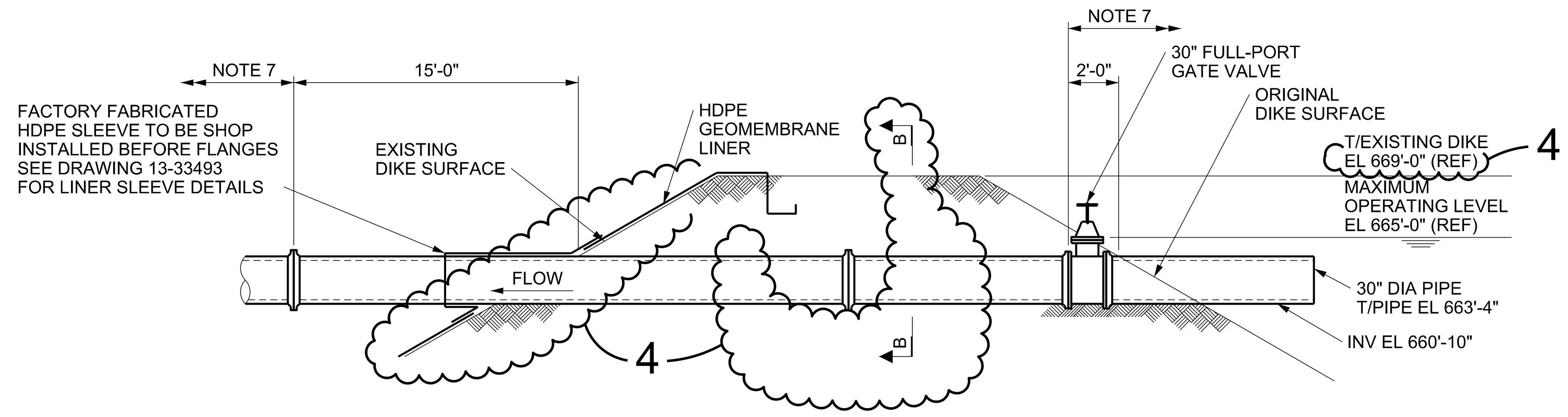
CARDINAL OPERATING CO. 306 COUNTY ROAD 7E BRILLIANT, OH 43913

PLOT DATE: DD-MMM-YYYY PLOT TIME: HOUR:MINUTE BY: USERPLOT

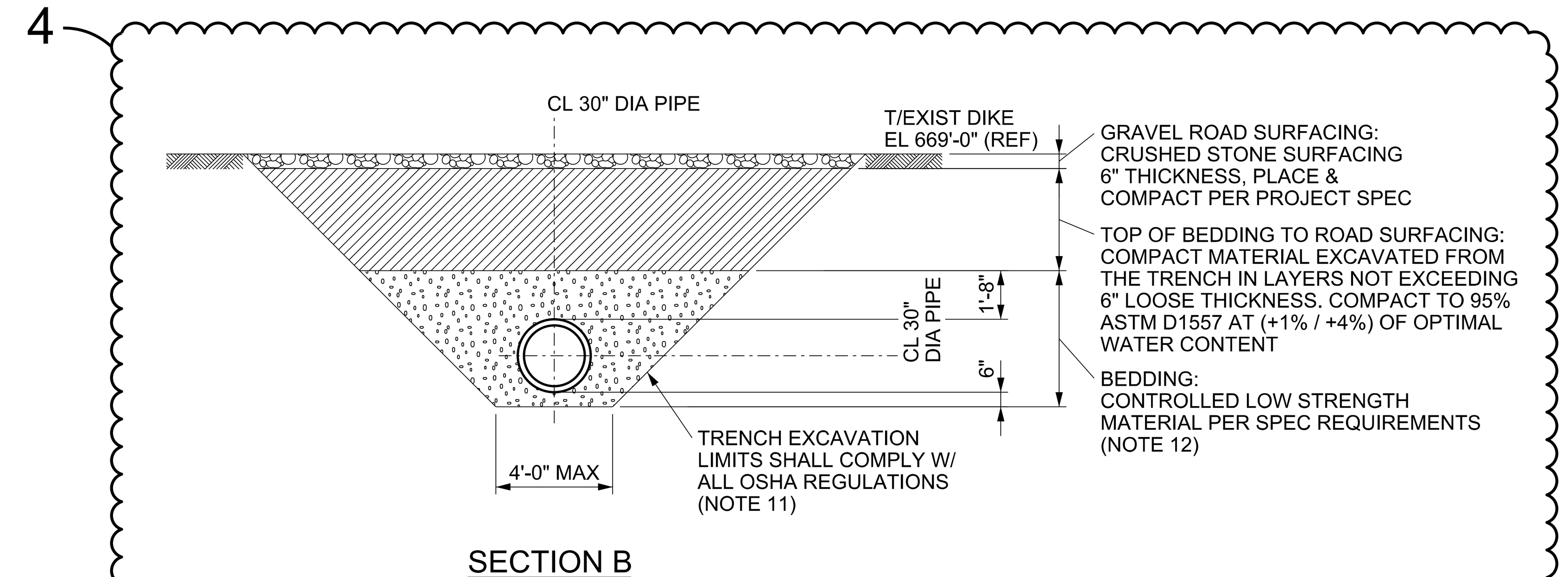
CROSS REFS:

DRAWING NUMBER: 33470

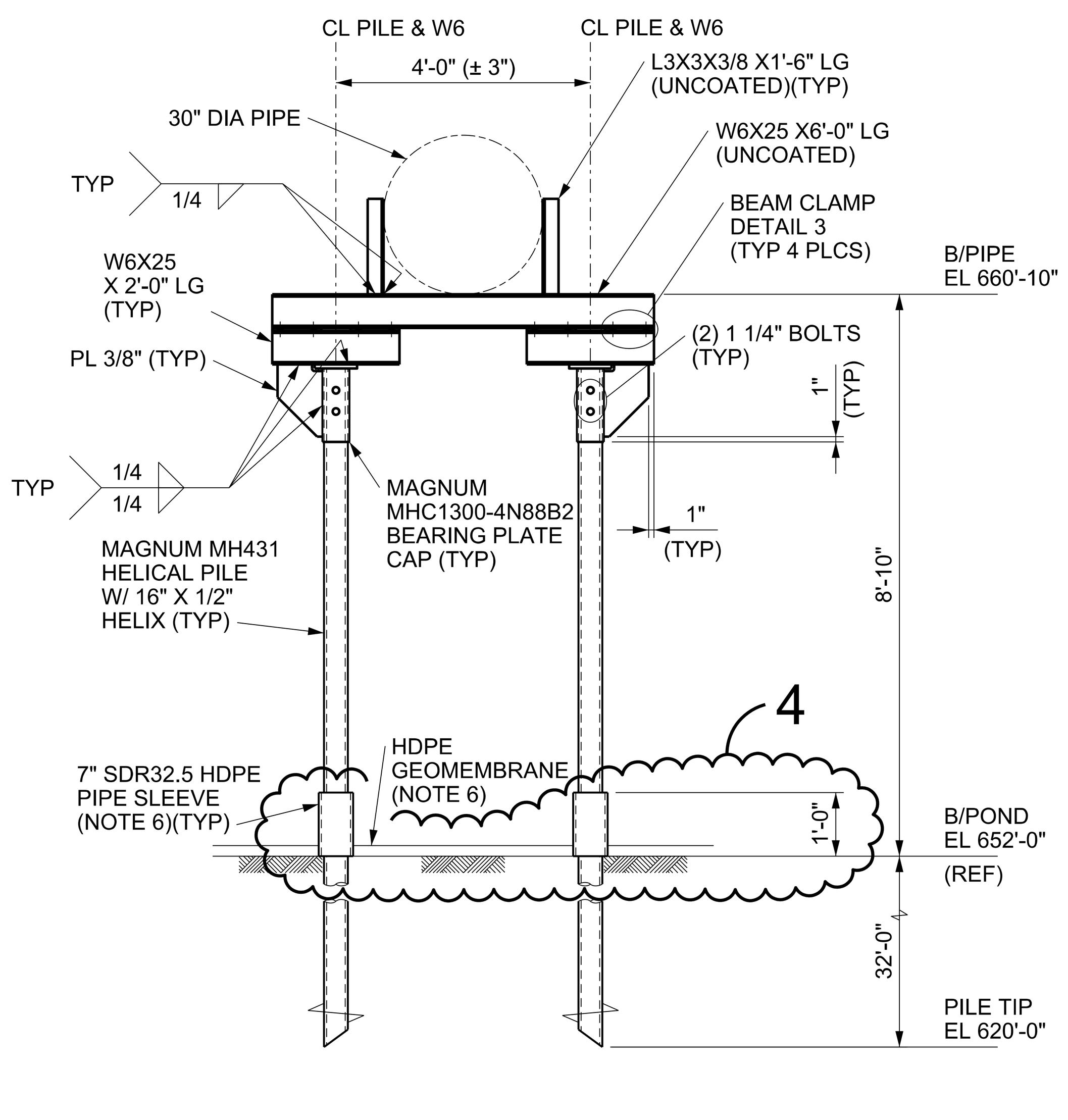
DRAWING NUMBER 33471



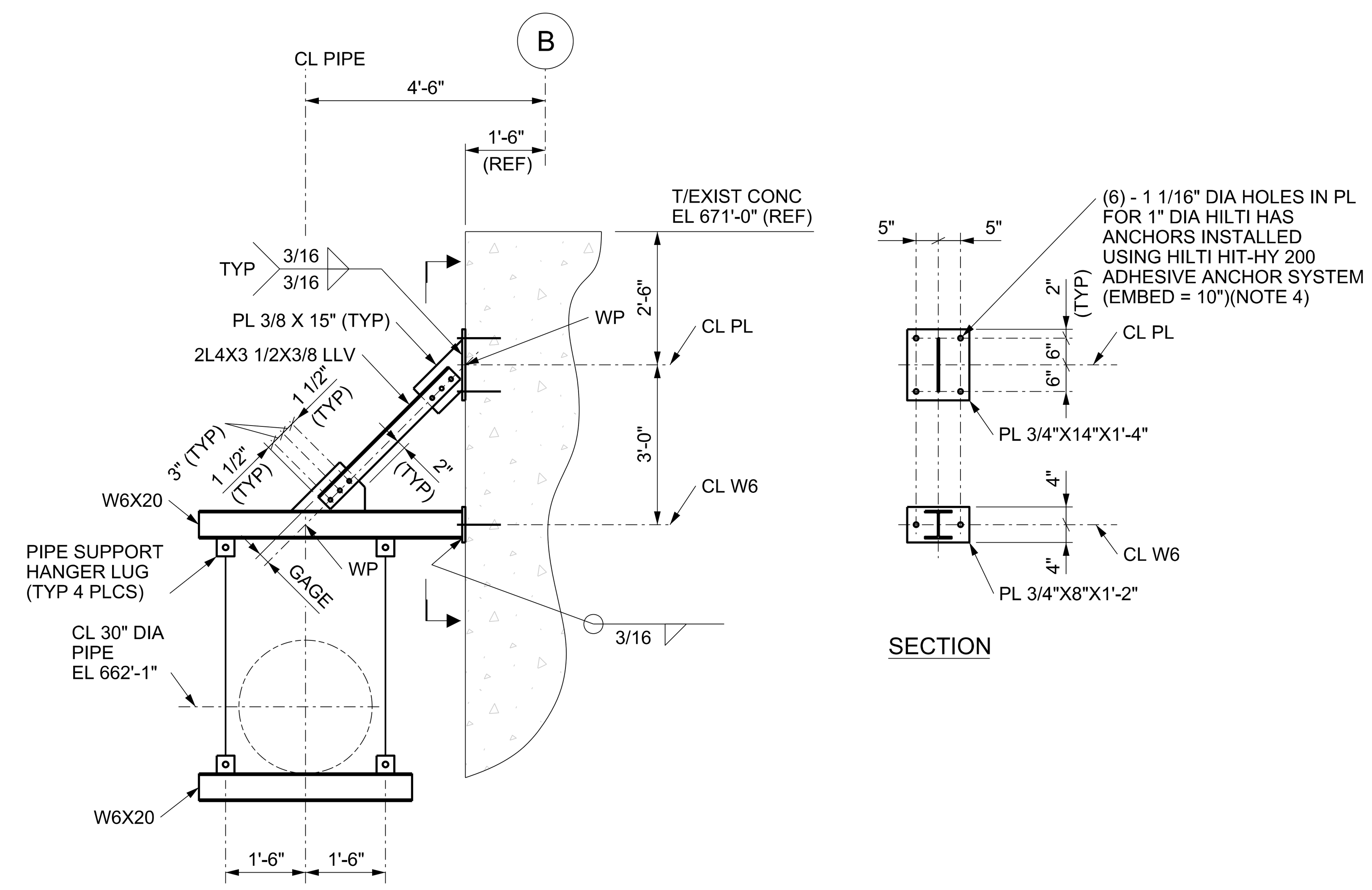
SECTION A
SCALE: NONE



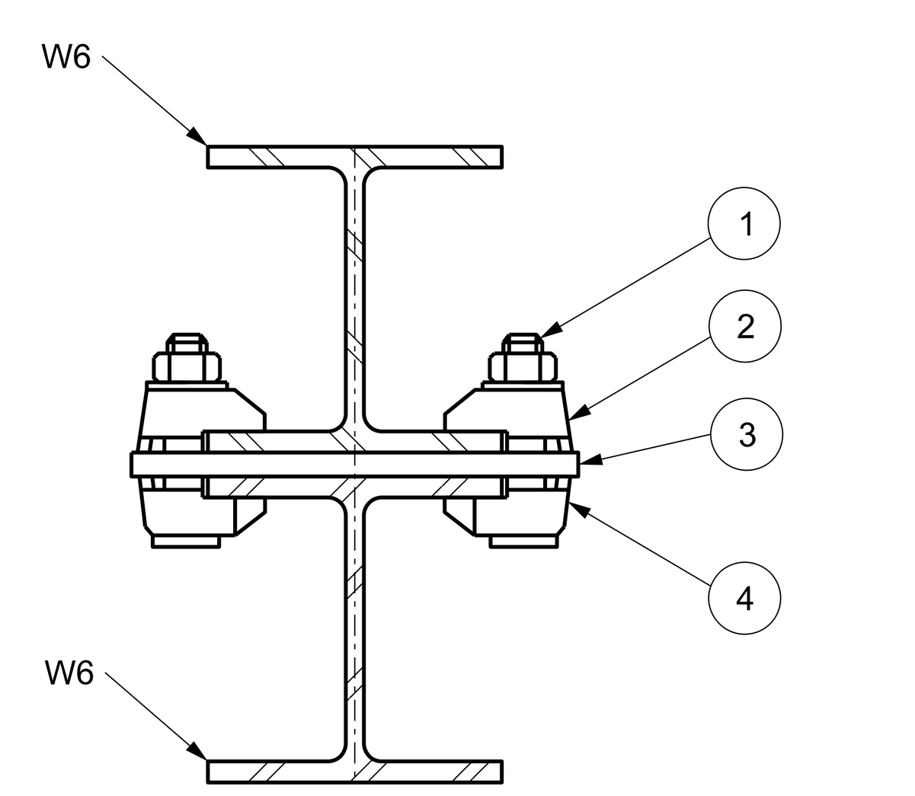
SECTION B
SCALE: NONE



DETAIL 1
SCALE: 1/2"=1'-0"



DETAIL 2
SCALE: 1/2"=1'-0"



BILL OF MATERIALS

ITEM #	QTY	DESCRIPTION
1	4	GRADE 5 BOLT COMPLETE WITH NUT AND FLAT WASHER 3/4" DIA X 4" LG
2	4	UPPER COMPONENT(S) (INCLUDING ANY PACKING BB1G20 & BH1Z20
3	1	LOCATION PLATE 9 5/16" X 9 5/16" X 1/2" THICK
4	4	LOWER COMPONENT(S) (INCLUDING ANY PACKING) BA1G20 & BH1Z20

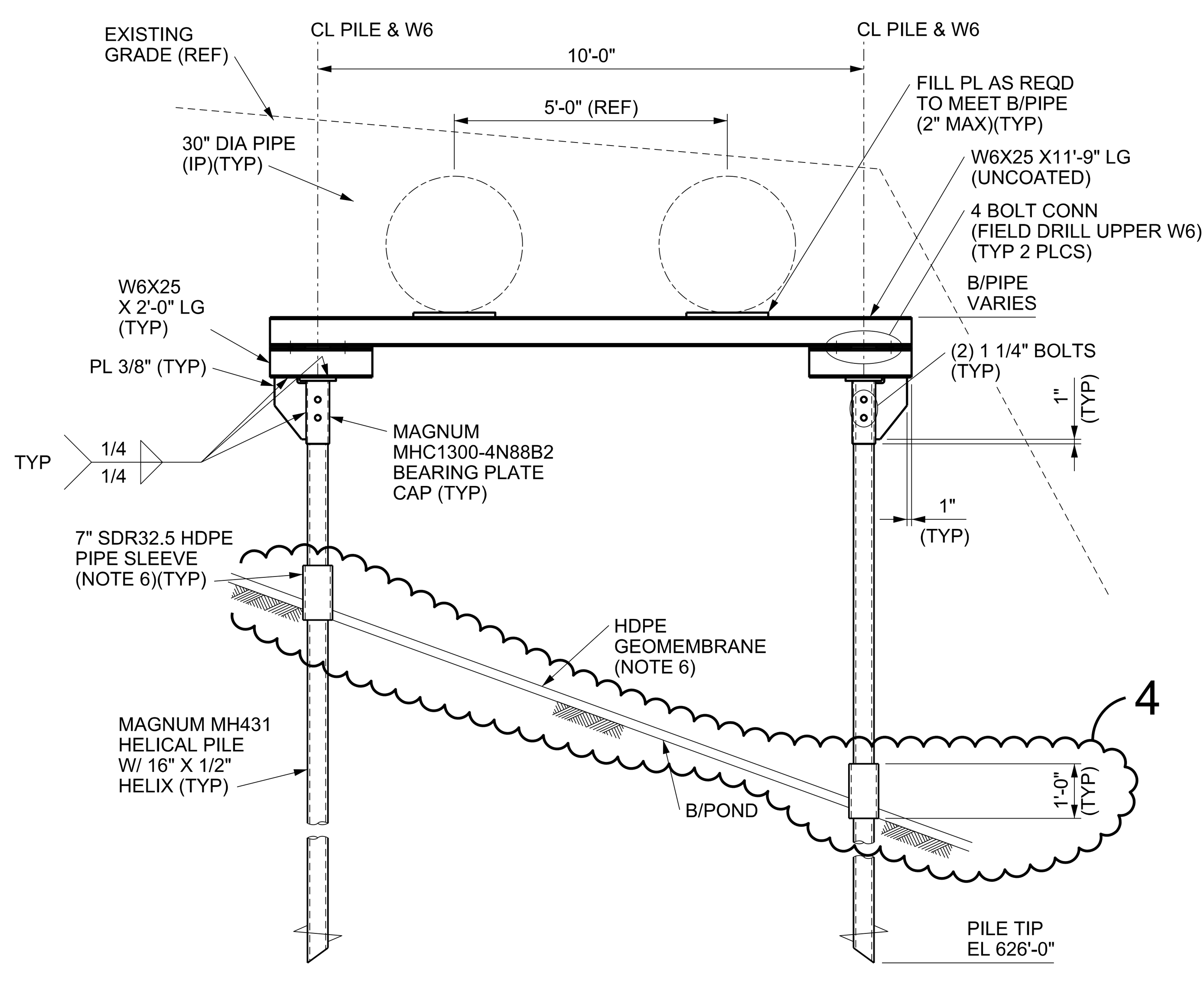
DETAIL 3
SCALE: NONE
TYPICAL BEAM CLAMP
(BEAM CLAMP BY LNA OR APPROVED EQUAL)

NOTES

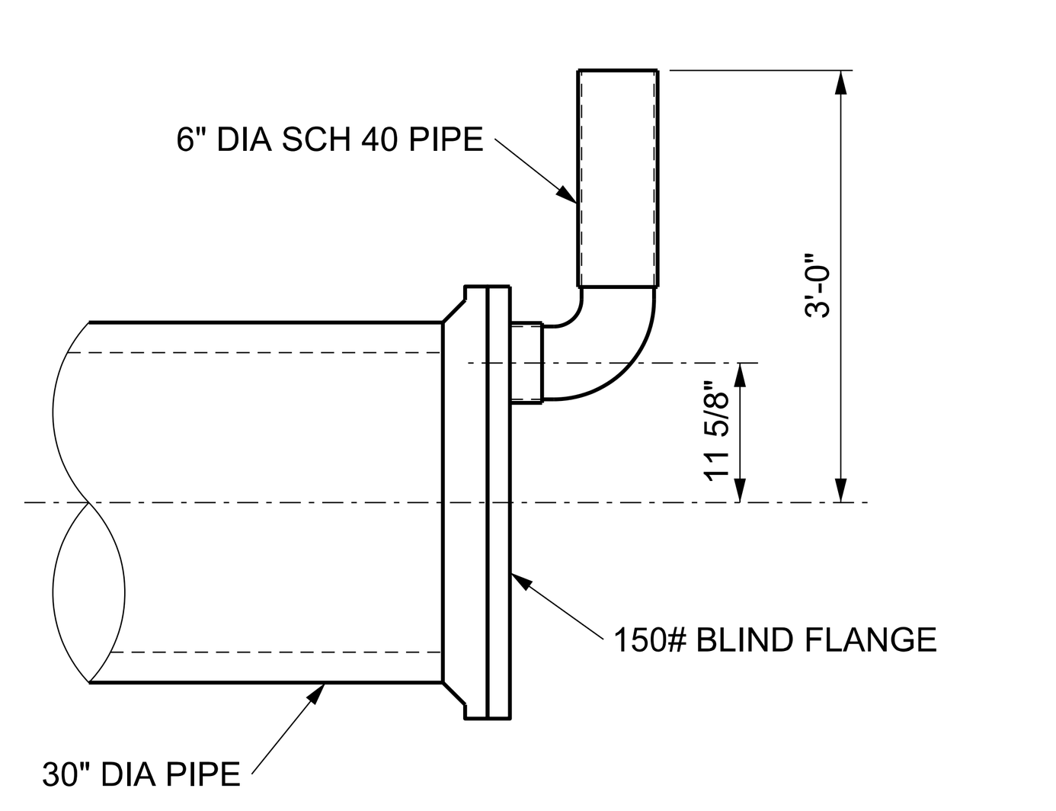
1. ALL WORK SHOWN ON THIS DRAWING SHALL BE FURNISHED AND INSTALLED IN ACCORDANCE WITH SPECIFICATION C-5413.
2. UNLESS NOTED, ALL W SECTIONS SHALL BE ASTM A992 AND ALL PLATE AND OTHER SHAPES SHALL BE ASTM A36.
3. UNLESS NOTED, ALL BOLTED CONNECTIONS SHALL USE 7/8" DIA A325 BEARING TYPE BOLTS.
4. ALL HORIZONTALLY ORIENTED ADHESIVE ANCHORS SHALL BE INSTALLED BY AN ACI-CERTIFIED ADHESIVE ANCHOR INSTALLER.
5. PROVIDE A 30" BLIND FLANGE AT THE SOUTH END OF THE PIPE AND USE 10" GROUT/VENT PIPES TO FILL THE 30" DIA PIPE WITH GROUT (NOTE 10).
6. THE HDPE SLEEVES SHALL BE INSTALLED OVER THE PILE BEFORE THE BEARING PLATE CAPS ARE INSTALLED. AFTER THE POND IS CLEANED AND CLOSED THE SLEEVE SHALL BE CENTERED ON THE PILE AND THE ANNULAR SPACE FILLED WITH BENTONITE PELLETS AND REHYDRATED PRIOR TO THE GEOSYNTHETIC CLAY LINER INSTALLATION. THE SLEEVE SHALL BE WELDED TO THE HDPE GEOMEMBRANE IN ACCORDANCE WITH THE LINER INSTALLATION DETAILS ON DRAWING 13-33493.
7. PIPE AND VALVES TO BE REMOVED AFTER SOUTH POND IS LINED AND BACK IN SERVICE BEFORE SOUTH POND LEVEL IS RAISED TO NORMAL OPERATING LEVEL. DETAIL 4 SHALL THEN BE INSTALLED AND THE REMAINING PIPE FILLED WITH GROUT (NOTE 10).
8. ALL SUPPORT STEEL AND PILES SHOWN ON THIS DRAWING SHALL BE GALVANIZED UNLESS NOTED OTHERWISE.
9. CONTRACTOR SHALL MINIMIZE THE AMOUNT OF SOIL REMOVAL REQUIRED FOR INSTALLATION OF THIS PIPE SUPPORT. EXISTING PIPES SHALL REMAIN SUPPORTED BY SOIL ON THE NORTHWEST SIDE OF THE NEW PIPE SUPPORT UNTIL INSTALLATION OF THE PIPE SUPPORT IS COMPLETE.
10. CONTRACTOR SHALL SUBMIT A PLAN FOR REVIEW AND APPROVAL PRIOR TO GROUTING THE TEMPORARY SUPPLY PIPE. THE PLAN SHALL INCLUDE A NARRATIVE FOR THE MEANS AND METHODS, THE MIX DESIGN, BULKHEAD DESIGN, VENT DESIGN AND MAXIMUM PRESSURES.
11. CONTRACTOR SHALL SLOPE THE EXCAVATION WALLS, TRENCH BOX IS NOT PERMITTED. FURTHERMORE, THE EXCAVATED SLOPE SHALL BE BENCHED PRIOR TO BACKFILLING WITH EXCAVATED MATERIAL. BENCHES SHALL MATCH THE COMPACTED LIFT THICKNESS. DRY SOIL ALONG SLOPES OR AT THE BOTTOM OF THE EXCAVATION MUST BE REMOVED OR MOISTENED PRIOR TO BACKFILLING.
12. PROVISIONS SHALL BE MADE TO PREVENT FLOATING OF THE PIPE DURING CLSM PLACEMENT. ADDITIONALLY, CONTRACTOR SHALL PROVIDE CONCRETE OR SOIL CRADLE SUPPORTS AT A MAXIMUM OF THREE LOCATIONS TO SUPPORT THE PIPE FROM BELOW DURING CLSM PLACEMENT.

REFERENCE DRAWINGS

13-33493	SOUTH POND - TOP OF LINER - DETAILS & SECTIONS



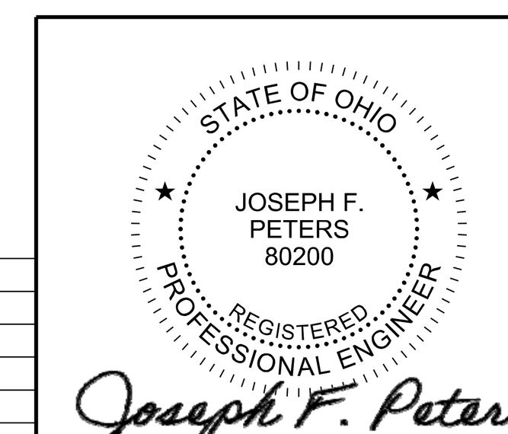
DETAIL 6
SCALE: 1/2"=1'-0"



DETAIL 4
SCALE: 3/4"=1'-0"
TYPICAL GROUT PORT

REV	DATE RELEASED	PURPOSE	PREPARED / REVIEWED / APPROVED
3	04-05-2021	FOR CONSTRUCTION REVISION SPEC C-5413	DZ / BB / JP
2	02-25-2021	FOR CONSTRUCTION SPEC C-5413	DZ / BB / JC
1	12-31-2020	FOR PERMIT REVIEW AND BID SPEC C-5413	DZ/SC / BB / JC
4	04-21-2021	FOR CONSTRUCTION REVISION SPEC C-5413	DZ / JF / JP

DRAWING RELEASE RECORD



Joseph F. Peters
Apr 21, 2021
PROFESSIONAL ENGINEER'S STAMP

Sargent & Lundy

CONTRACTOR/INSTALLER SHALL TAKE ALL APPROPRIATE PRECAUTIONS TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE INCLUDING CONTRACTOR'S/INSTALLER'S PERSONNEL (OR THAT OF ITS SUBCONTRACTORS) PERFORMING THE WORK.

DATE	NO.	DESCRIPTION	APPD.

REVISIONS

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CARDINAL OPERATING COMPANY

CARDINAL PLANT

BRILLIANT OHIO

BOTTOM ASH CLOSURE & LINING PROJECT
BOTTOM ASH STORAGE AREA
PIPE SUPPORT SECTIONS & DETAILS
CARDINAL PLANT
BUCKEYE POWER INC

UNIT:	DRAWING NUMBER:	REV:
13	33471	4

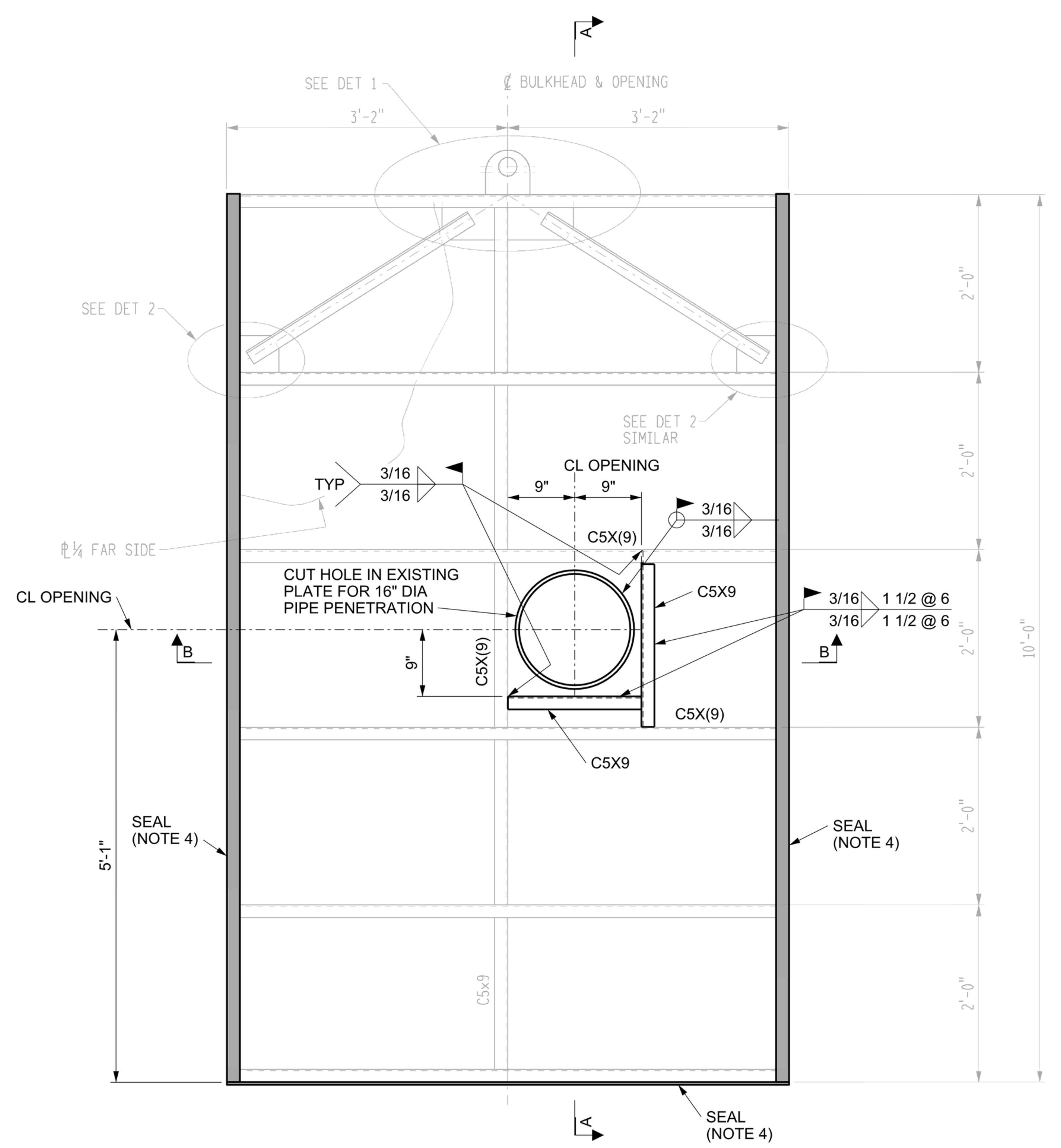
SCALE: AS NOTED — ENGINEERING DIVISION
DR: DZ
CH: JF
SUP: JP
ENG: JF
DATE: 04-21-2021
APPROVED BY:

CARDINAL OPERATING COMPANY

CARDINAL OPERATING CO.
306 COUNTY ROAD 7E
BRILLIANT, OH 43913

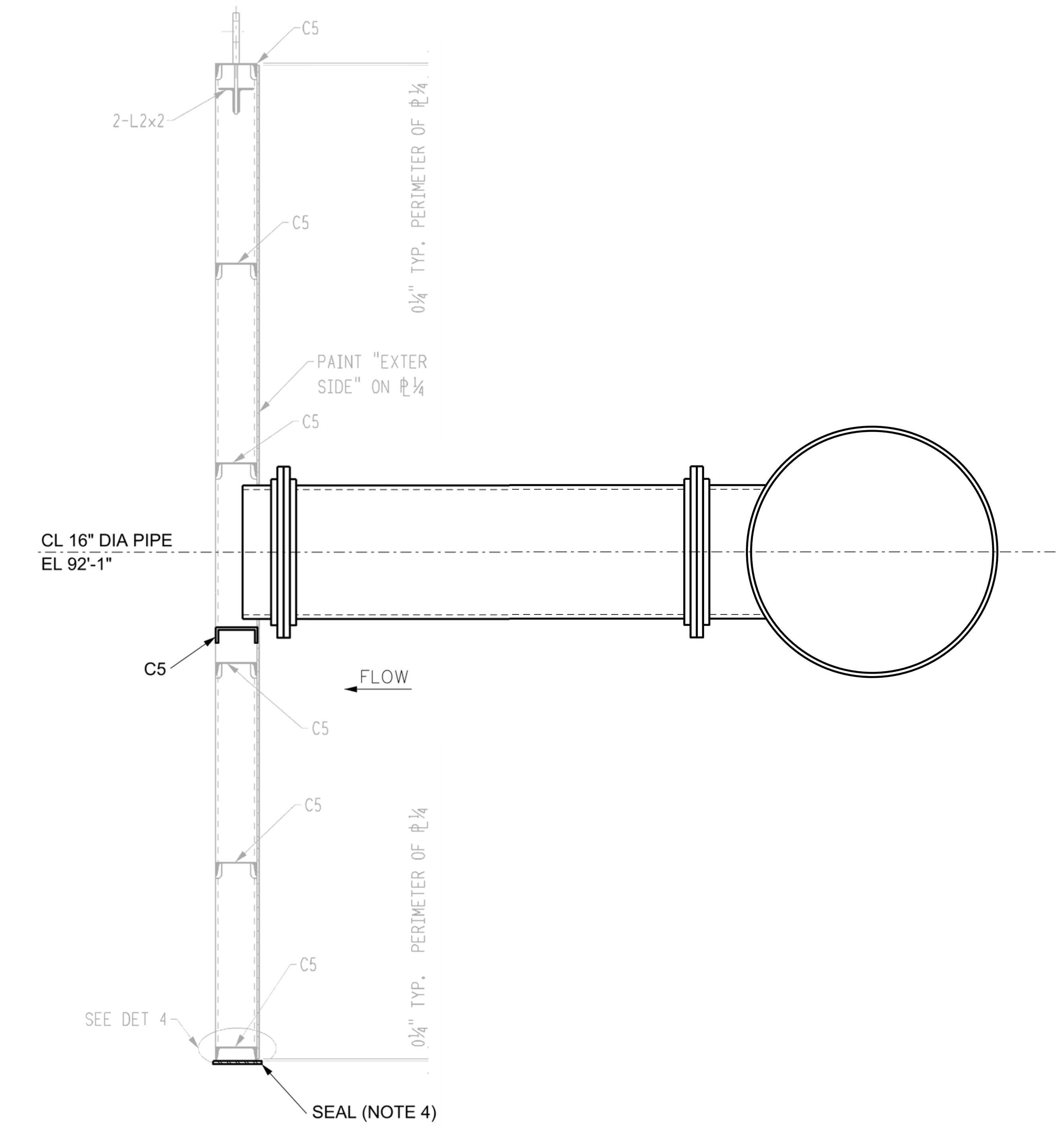
CROSS REFS:

DRAWING NUMBER: 33472



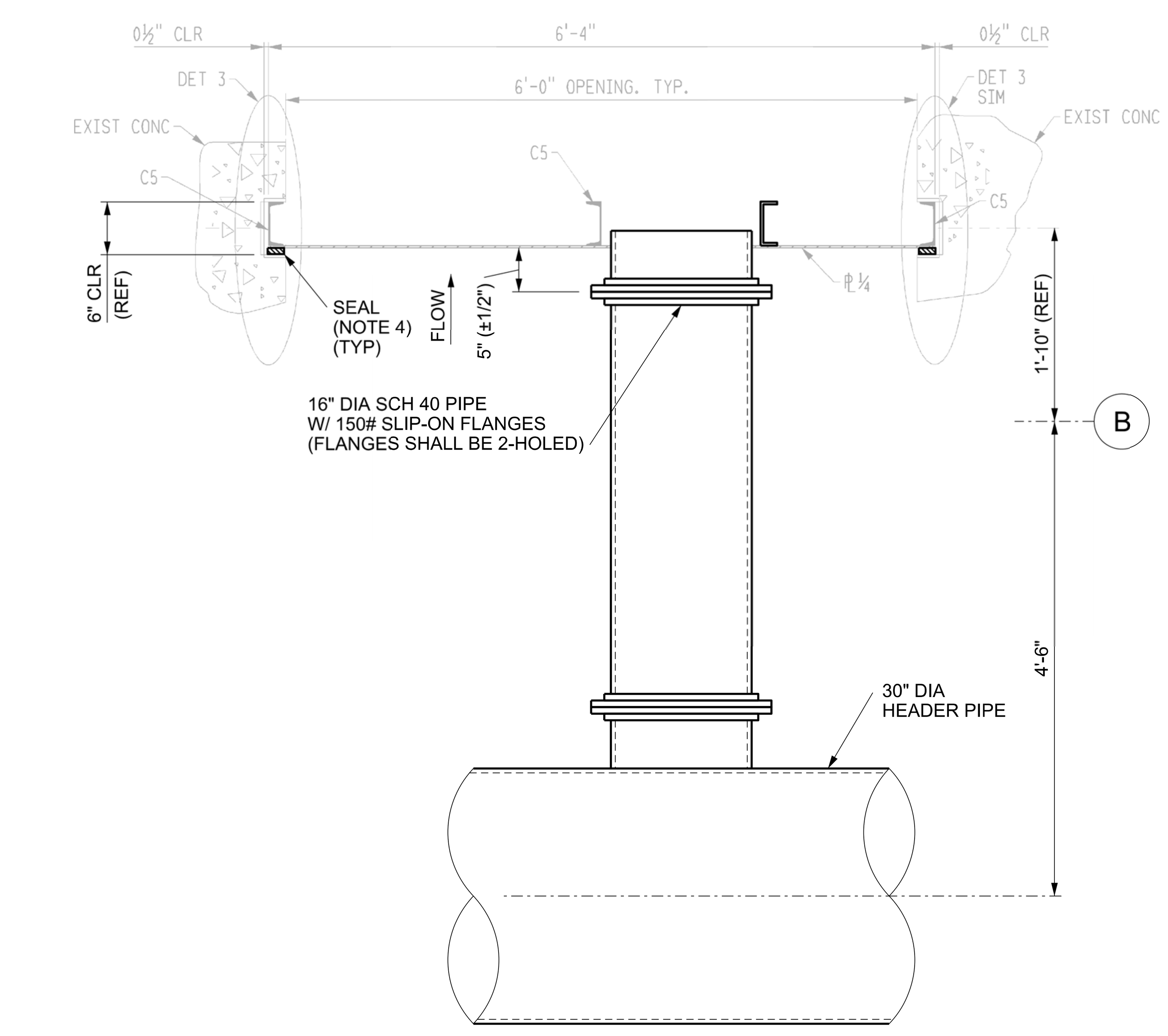
TYPICAL RECIRCULATION PUMPHOUSE BULKHEAD

SCALE: 1" = 1'-0"



SECTION A

SCALE: 1" = 1'-0"



SECTION B

SCALE: 1" = 1'-0"

NOTES

1. ALL WORK SHOWN ON THIS DRAWING SHALL BE FURNISHED AND INSTALLED IN ACCORDANCE WITH SPECIFICATION C-5413.
2. FOR INFORMATION NOT SHOWN SEE DRAWING 3-3399B.
3. TWO EXISTING BULKHEADS ARE TO BE MODIFIED BY ADDING THE 16" NOZZLE AND ADDING THE TWO C5 STIFFENERS AROUND THE OPENING. SIX NEW BULKHEADS WITH 16" NOZZLES SHALL BE FABRICATED IN ACCORDANCE WITH DETAILS ON DRAWING 3-3399B AND SHALL INCLUDE THE 16" NOZZLE DETAILS SHOWN ON THIS DRAWING.
4. SEAL BULKHEAD TO PREVENT LEAKAGE OUT OF THE PUMPHOUSE. PROVIDE 1/2" THICK CLOSED CELL NEOPRENE FOAM STRIPS AND USE WOOD WEDGES ON VERTICAL EDGES TO COMPRESS THE SEAL BETWEEN THE BULKHEAD AND THE GUIDE.

REFERENCE DRAWINGS

	BUCKEYE POWER INC
3-3399B	RECIRCULATING PUMP HOUSE BULKHEADS PLAN, SECTIONS & DETAILS

DATE	NO.	DESCRIPTION	APPD.

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CARDINAL PLANT

BRILLIANT OHIO

BOTTOM ASH CLOSURE & LINING PROJECT
RECIRCULATING PUMP HOUSE
BULKHEADS MODIFICATION
CARDINAL PLANT
BUCKEYE POWER INC

UNIT:	DRAWING NUMBER:	REV:
13	33472	1

SCALE: AS NOTED — ENGINEERING DIVISION

DR: DZ
CH: JC
SUP: JC
ENG: JC
DATE: 02-25-2021
APPROVED BY

REV	DATE RELEASED	PURPOSE	PREPARED / REVIEWED / APPROVED
1	02-25-2021	FOR CONSTRUCTION SPEC C-5413	DZ / BB / JC
0	10-19-2020	FOR PERMIT REVIEW	DZ / JC / JC

DRAWING RELEASE RECORD

STATE OF OHIO — JOSEPH P. CHARLES PE.80469 — REGISTERED PROFESSIONAL ENGINEER
25-Feb-2021
PROFESSIONAL ENGINEER'S STAMP

Sargent & Lundy

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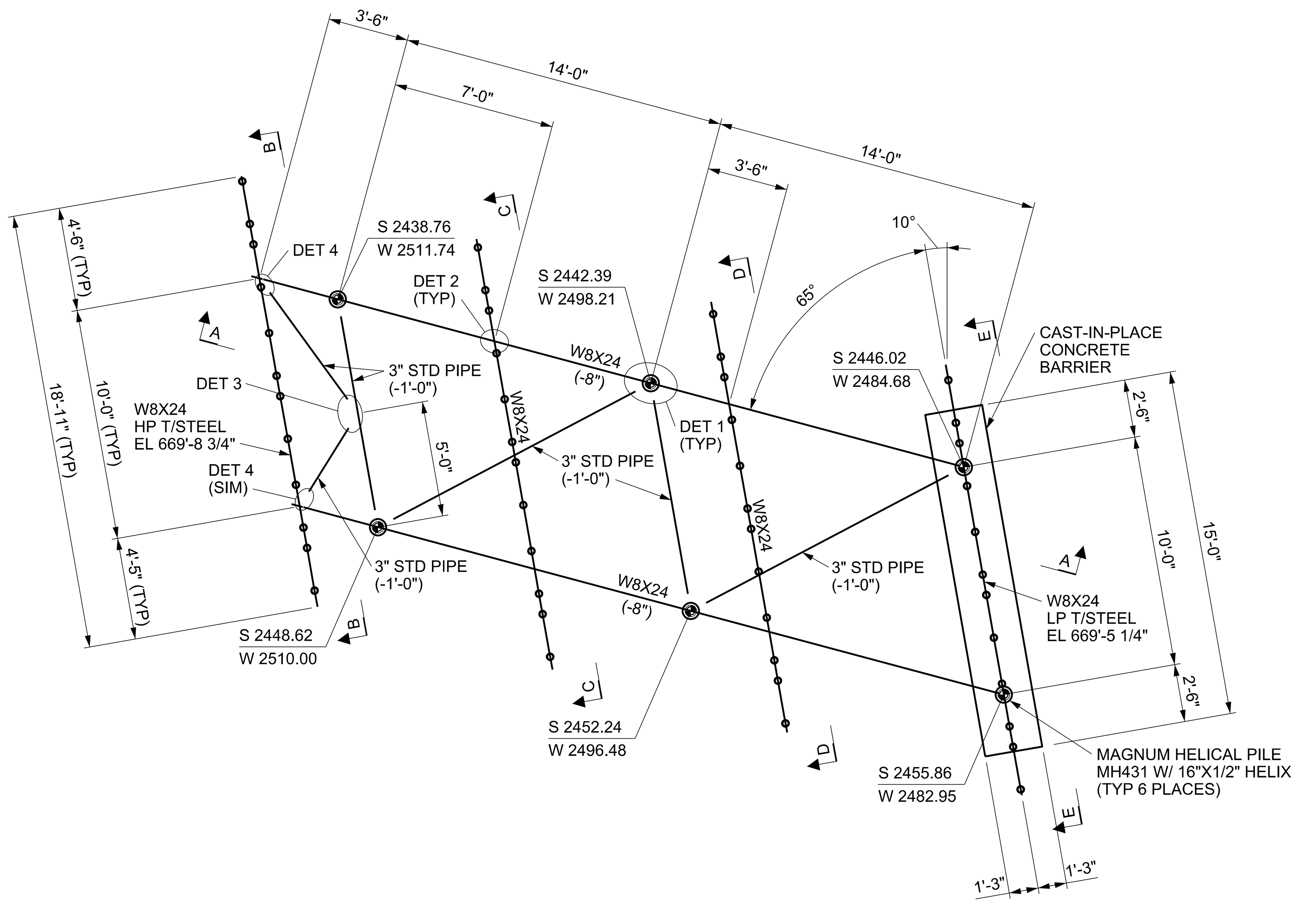
CARDINAL OPERATING COMPANY

CARDINAL OPERATING CO.
306 COUNTY ROAD 7E
BRILLIANT, OH 43913

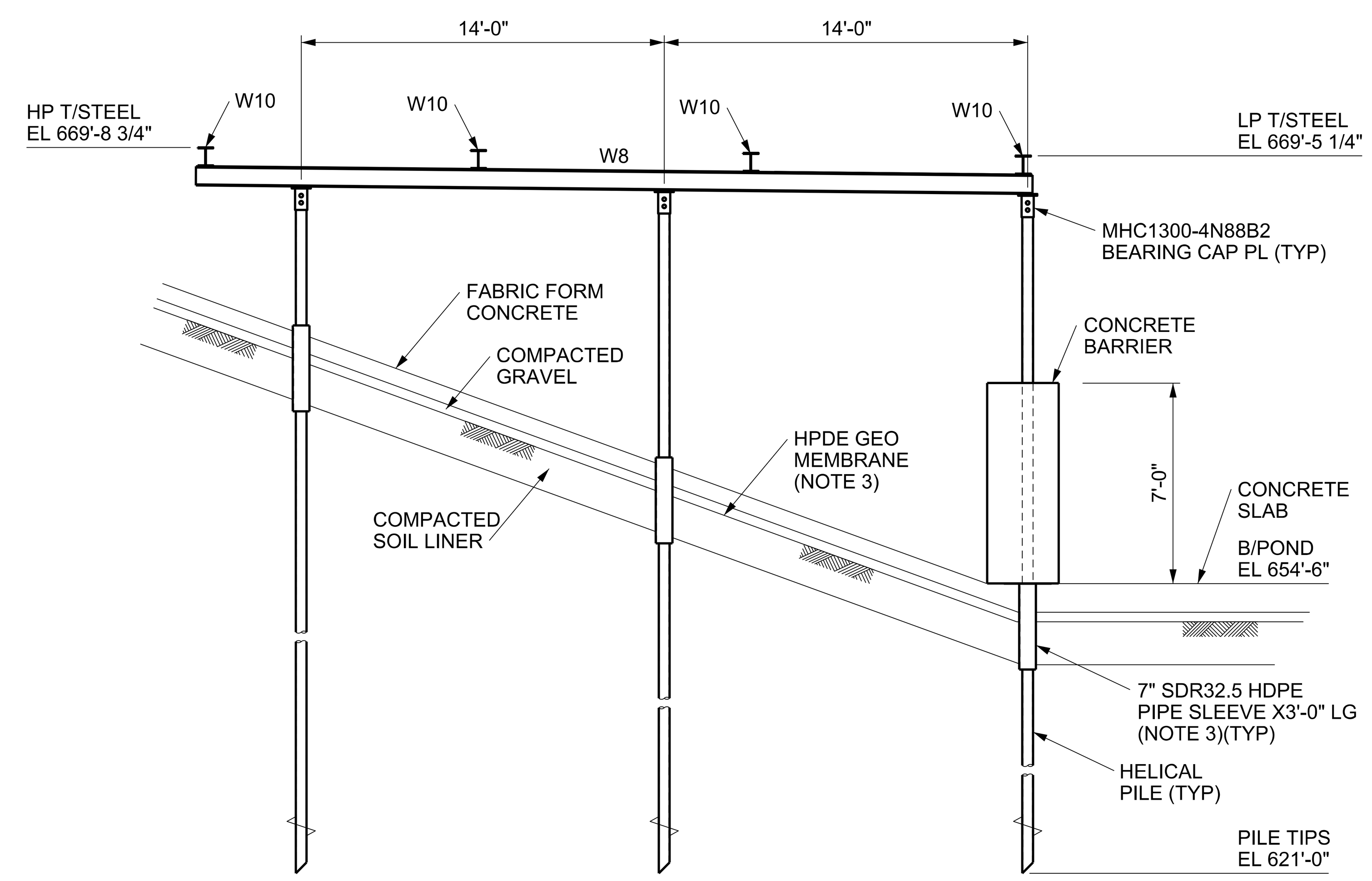
PLOT DATE: DD-MMM-YYYY
PLOT TIME: HOUR:MINUTE
BY: USERPLOT

CROSS REFS:

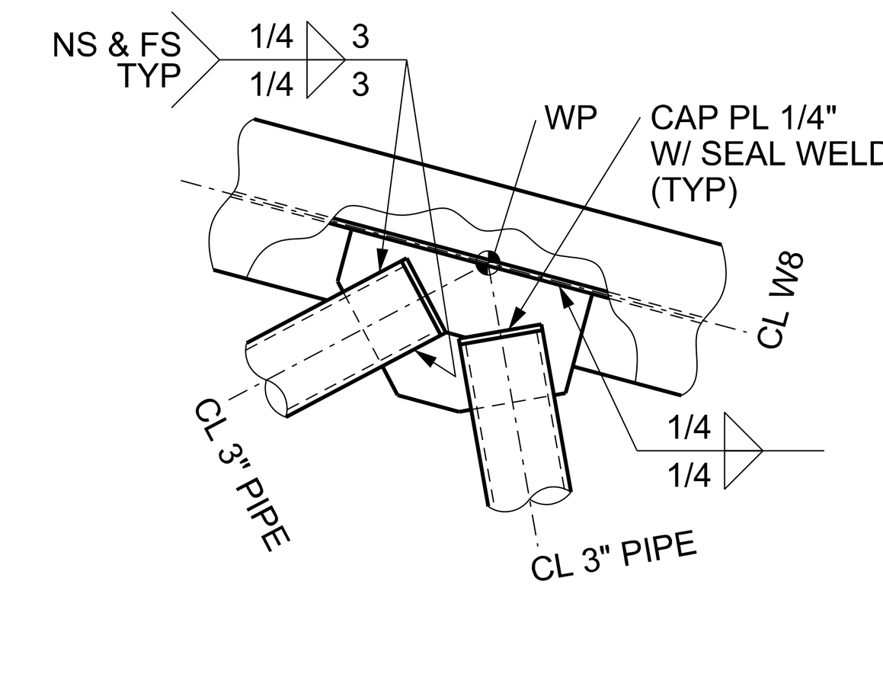
DRAWING NUMBER 33475



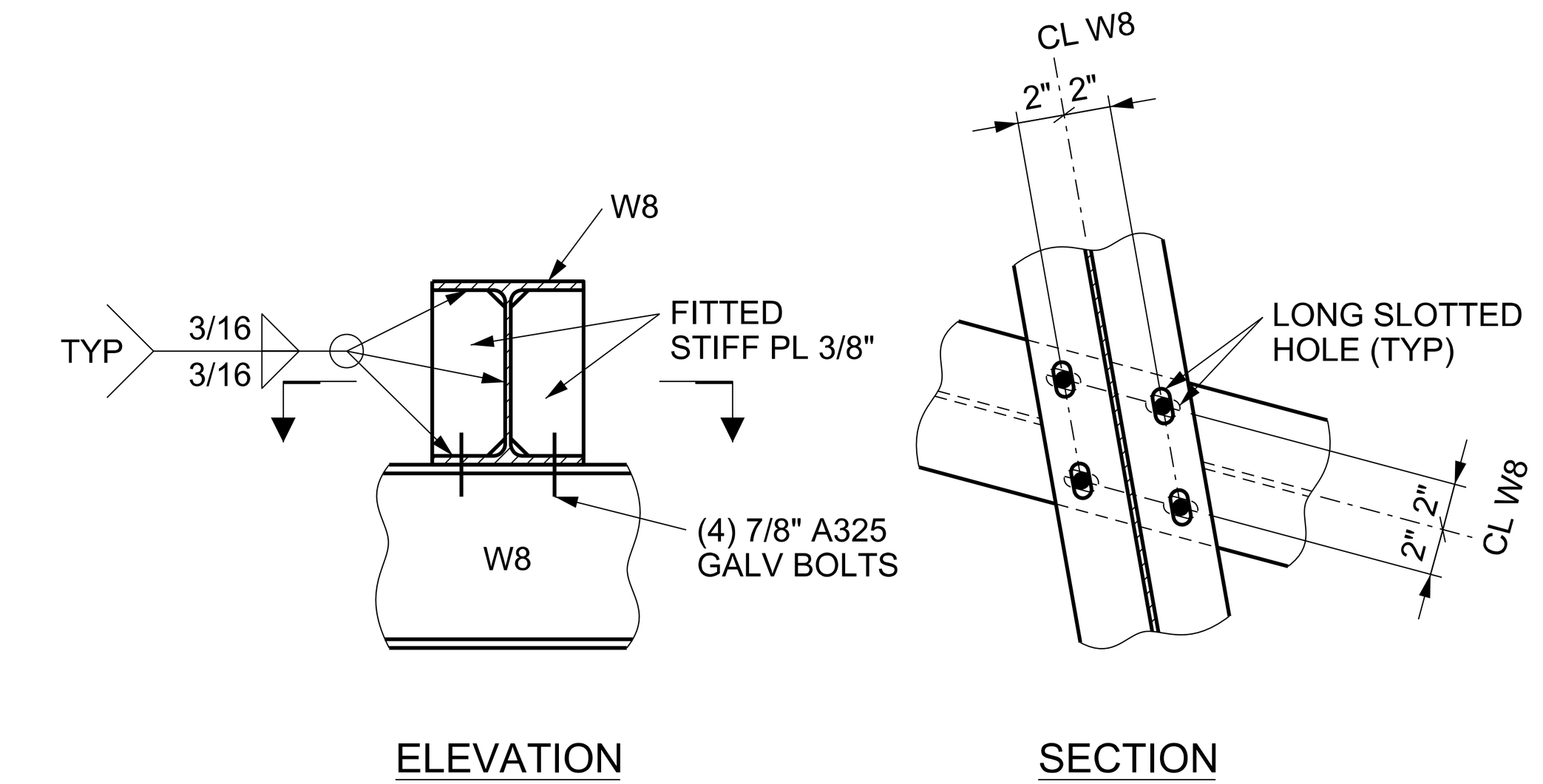
PIPE DISCHARGE SUPPORT PLAN
SCALE: 1/4"=1'-0"
T/STEEL VARIES



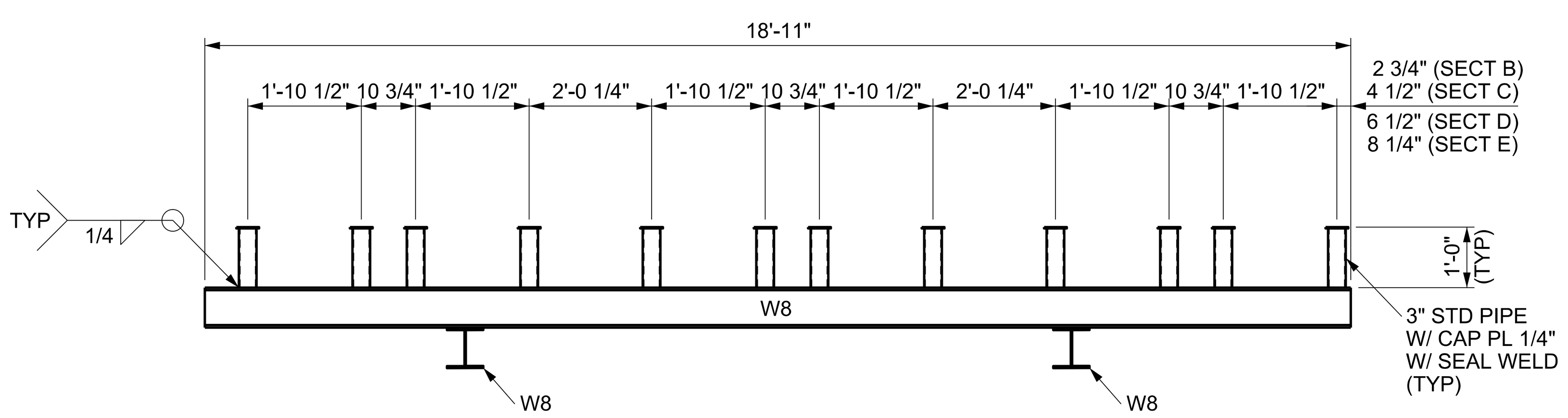
SECTION A
SCALE: 1/4"=1'-0"



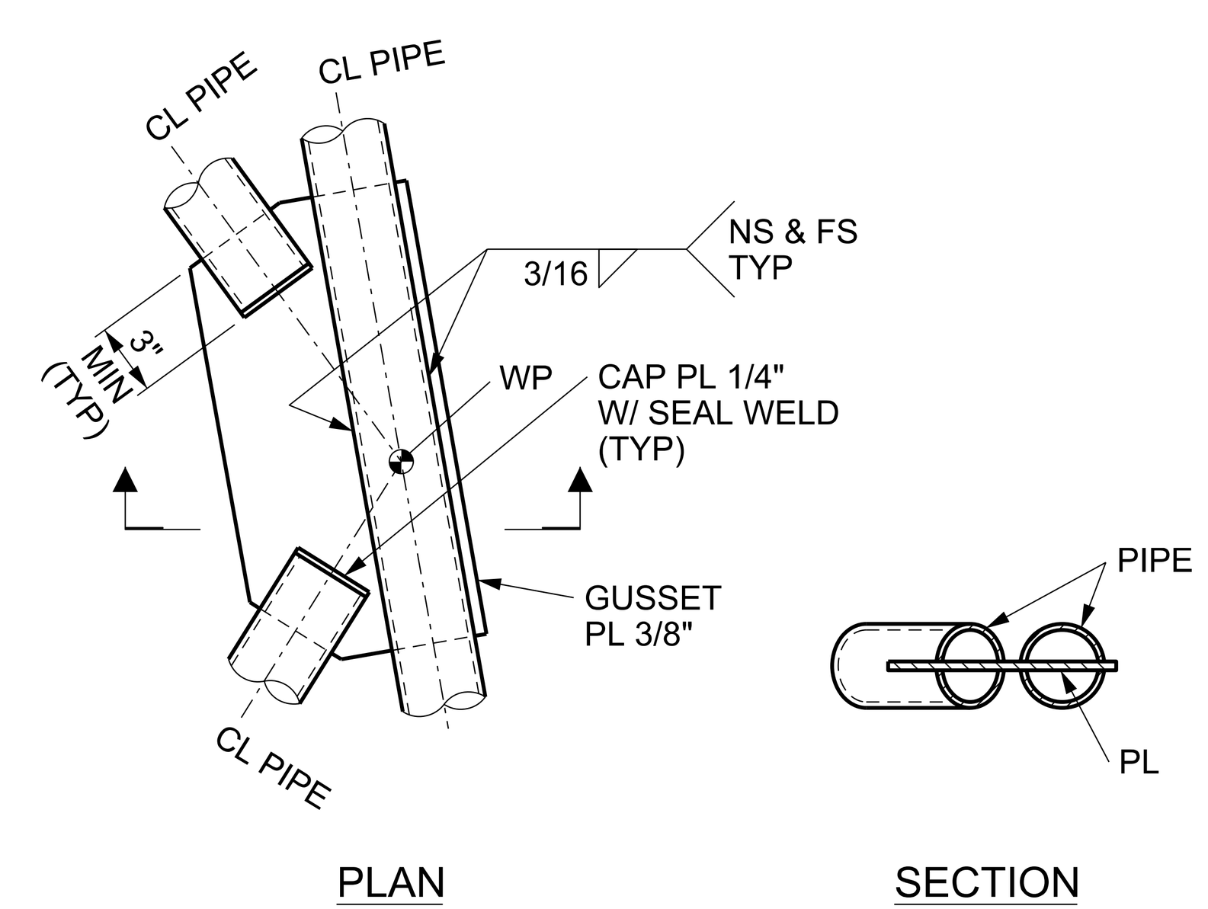
DETAIL 1
SCALE: 1 1/2"=1'-0"



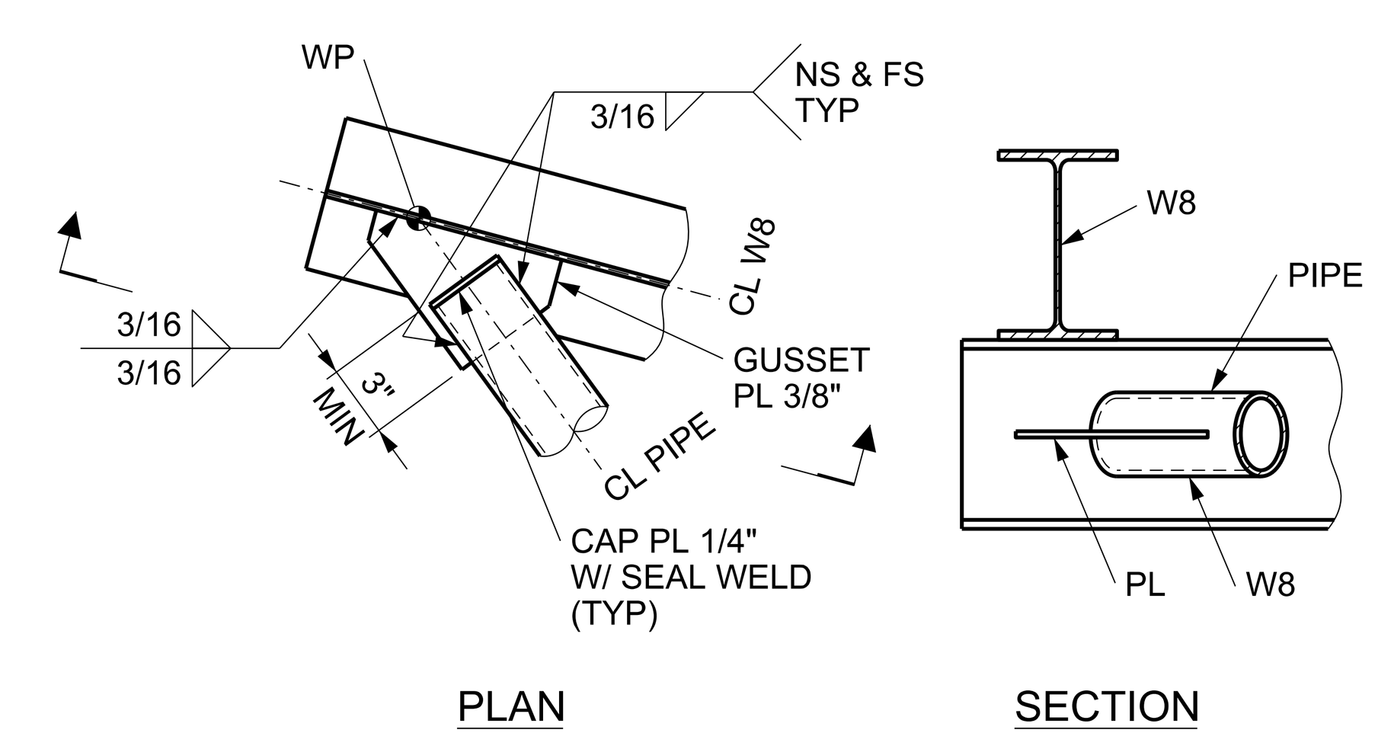
DETAIL 2
SCALE: 1 1/2"=1'-0"



SECTION B, C, D, E
SCALE: 1/2"=1'-0"



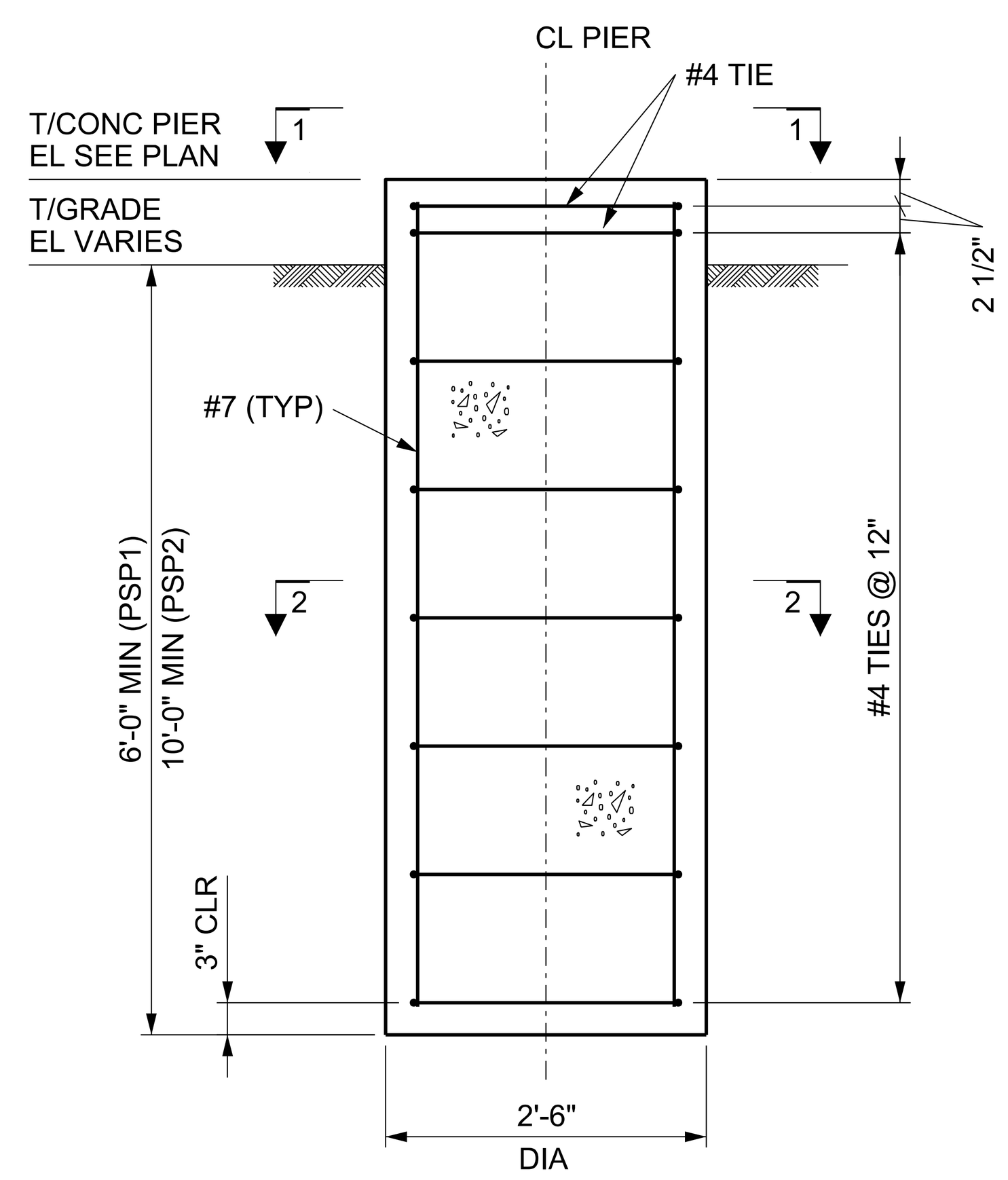
DETAIL 3
SCALE: 1 1/2"=1'-0"



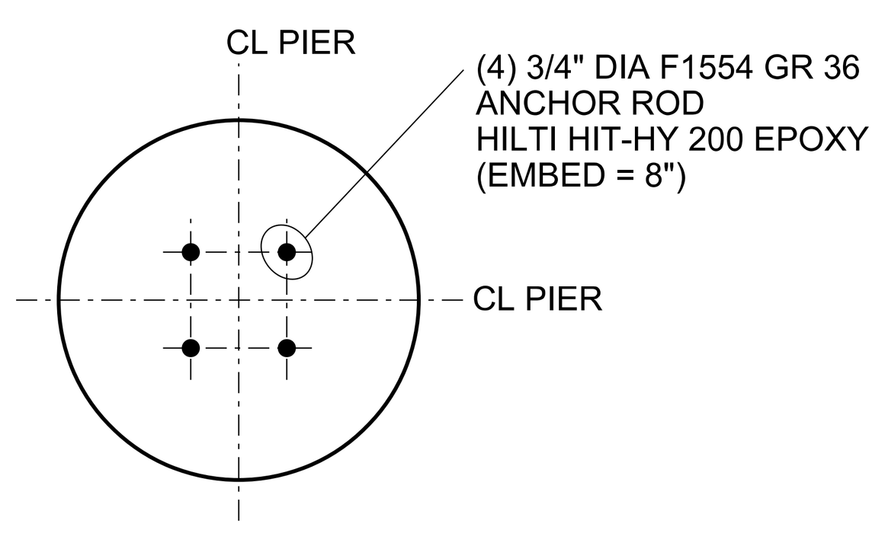
DETAIL 4
SCALE: 1 1/2"=1'-0"

	NOTES
1	FOR STRUCTURAL STEEL GENERAL NOTES SEE DRAWING 13-33438.
2	ALL WORK SHOWN ON THIS DRAWING SHALL BE FURNISHED AND INSTALLED IN ACCORDANCE WITH SPECIFICATION C-5413.
3	THE HDPE SLEEVES SHALL BE INSTALLED OVER THE PILE BEFORE THE BEARING PLATE CAPS ARE INSTALLED. AFTER THE POND IS CLEANED AND CLOSED THE SLEEVE SHALL BE CENTERED ON THE PILE AND THE ANNULAR SPACE FILLED WITH BENTONITE PELLETS AND REHYDRATED PRIOR TO THE LINER COMPACTED SOIL INSTALLATION. THE SLEEVE SHALL BE WELDED TO THE HDPE GEOMEMBRANE IN ACCORDANCE WITH THE LINER INSTALLATION DETAILS ON DRAWING 13-33493.

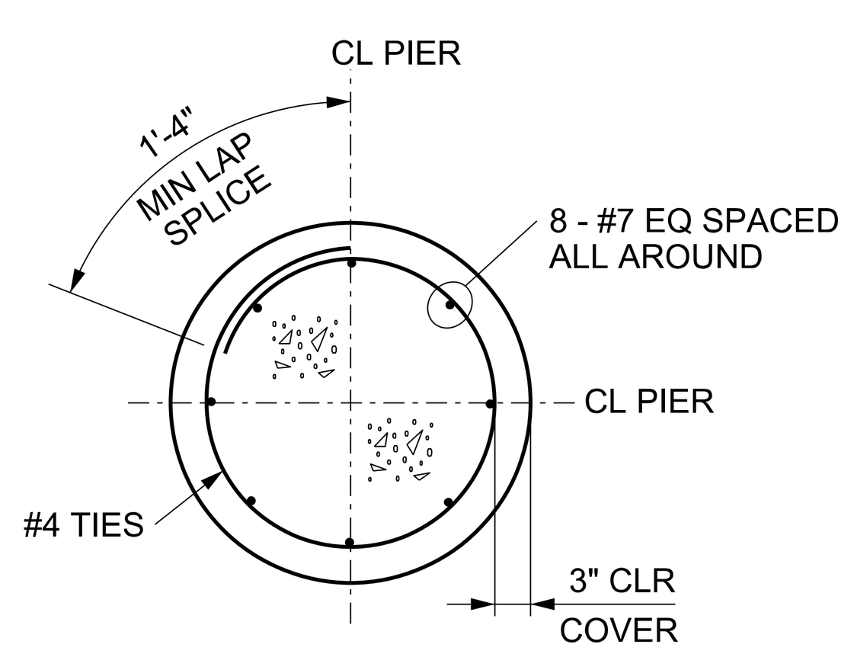
REFERENCE DRAWINGS



ELEVATION

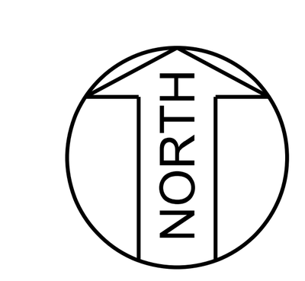


SECTION 1

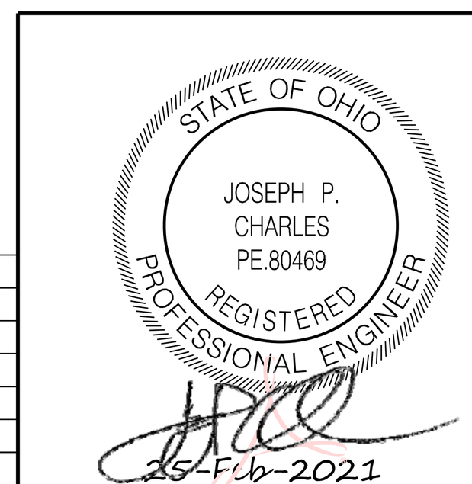


SECTION 2

PIPE SUPPORT PIER FOUNDATIONS PSP1, PSP2
SCALE: 3/4"=1'-0"
3



PLANT



PROFESSIONAL ENGINEER'S STAMP

Sargent & Lundy

REV	DATE RELEASED	PURPOSE	
3	02-25-2021	FOR CONSTRUCTION SPEC C-5413	DZ / BB / JC
2	01-22-2021	FOR BID ADDENDUM SPEC C-5413	DZ / BB / JC
1	12-31-2020	FOR PERMIT REVIEW AND BID SPEC C-5413	DZ/SC / BB / JC
0	10-19-2020	FOR PERMIT REVIEW	DZ / JC / JC
			PREPARED / REVIEWED / APPROVED

DRAWING RELEASE RECORD

CONTRACTOR/INSTALLER SHALL TAKE ALL APPROPRIATE PRECAUTIONS TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE INCLUDING CONTRACTOR'S/INSTALLER'S PERSONNEL OR THAT OF ITS SUBCONTRACTOR(S) PERFORMING THE WORK.

DATE	NO.	DESCRIPTION	APPD.

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CARDINAL OPERATING COMPANY

CARDINAL PLANT

BRILLIANT OHIO

BOTTOM ASH CLOSURE & LINING PROJECT
BOTTOM ASH PIPE DISCHARGE
SUPPORT PLAN, SECTIONS & DETAILS
CARDINAL PLANT
BUCKEYE POWER INC

UNIT:	DRAWING NUMBER:	REV:
13	33475	3

SCALE: AS NOTED
ENGINEERING DIVISION
DR: DZ
CH: JC
SUP: JC
ENG: JC
DATE: 02-25-2021
APPROVED BY

CARDINAL OPERATING COMPANY

CARDINAL OPERATING CO.
306 COUNTY ROAD 7E
BRILLIANT, OH 43913

CROSS REFS:

CM 1 2 3 4 5 6 7 | 16 INCH 4 8 12 16 | TENTHS 10 20 30 | INCHES 1 2 3

EXHIBIT C

Bottom Ash Pond Closure and Lining Project – Technical Specifications

- Section 311521 Non-woven Geotextiles
- Section 313524 Fabric Formed Concrete Mats
- Section 313716 Riprap and Bedding
- Section 319005 Earthwork for a Clay Lined Impoundment
- Section 319022 HDPE Geomembrane Liner
- Section 319025 Geosynthetic Clay Liner

SECTION 311521

NON-WOVEN GEOTEXTILES

PART 1 - GENERAL

101. EXTENT

101.1 This Specification Section defines the minimum requirements for the material and installation of non-woven geotextiles in accordance with the design drawings and as specified herein for the following uses:

a. Geotextile soil separator between drainage material and geosynthetic material.

b. Geotextile bedding for riprap.

c. Protective layer beneath or over a geomembrane liner inside a spill containment area or pond.

101.2 The Work shall include, but not be limited to, the following items:

a. Furnishing all materials.

b. Handling and storage.

c. Preparation of bearing areas as necessary.

d. Placement, splicing and anchorage.

e. Repair of holes or tears.

f. Cleanup.

102. RELATED WORK SPECIFIED IN OTHER SECTIONS

102.1 The work specified in this Section shall be coordinated with work specified in the following related Sections:

a. Section 313716 – Riprap.

b. Section 319005 – Earthwork for a Clay Lined Impoundment

103. REFERENCE DOCUMENTS

103.1 Standards, Specifications, manuals, codes and other publications of nationally recognized organizations and association are referenced herein. Methods, equipment and materials specified herein shall comply with the specified and applicable portions of the referenced documents, in addition to federal, state or local codes having jurisdiction.

103.2 References to these documents are to the latest issue date of each document, unless otherwise indicated, together with the latest additions, addenda, amendments, supplements, etc., thereto, in effect as of the date of Contract for the Work.

103.3 Abbreviations listed indicate the form used to identify the reference documents in the Specification text.

103.4 ASTM - ASTM International:

a. D 4355 - Standard Test Method for Deterioration of Geotextiles by Exposure to Light, Moisture and Heat in a Xenon Arc Type Apparatus.

b. D 4491 - Standard Test Methods for Water Permeability of Geotextiles by Permitivity.

c. D 4533 - Standard Test Method for Trapezoid Tearing Strength of Geotextiles.

d. D 4632 - Standard Test Method for Grab Breaking Load and Elongation of Geotextiles.

e. D 4716 - Standard Test Method for Determining the (In-Plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head.

f. D 4751 - Standard Test Method for Determining Apparent Opening Size of a Geotextile.

g. D 4873 - Standard Guide for Identification, Storage and Handling of Geosynthetic Rolls and Samples.

h. D 4884 - Standard Test Method for Strength of Sewn or Thermally Bonded Seams of Geotextiles.

i. D 5261 - Standard Test Method for Measuring Mass per Unit Area of Geotextiles.

j. D 6241 – Standard Test Method for the Static Puncture Strength of Geotextiles and Geotextile-Related Products Using a 50mm Probe.

103.5 ODOT - Ohio Department of Transportation:

a. Construction and Material Specifications

103.6 FHWA - Federal Highway Administration:

a. Report No. FHWA HI-95-038 - Geosynthetic Design and Construction Guidelines.

103.7 IFAI - Industrial Fabrics Association International.

a. Field Sewing of Geotextiles by V. Diaz and B. Myles, 1989.

104. SUBMITTALS

104.1 Contractor shall submit drawings and data as indicated below at least 30 days prior to use. Contractor's drawings and data shall be submitted via electronic medium in a format compatible for importing into Owner's information systems specified by Owner.

104.2 Contractor shall submit the following data:

a. Manufacturer's literature providing Specifications on the geotextile(s) that will be supplied.

b. Manufacturer's certification that geotextile(s) to be supplied comply with the requirements of this technical Specification.

c. Manufacturer's Quality Control (MQC) and Construction Quality Control Plans. The MQC plan shall state the frequency that index tests are performed on the geotextile during manufacturing.

d. If requested by Owner, four samples of each geotextile suitable for testing.

105. QUALITY ASSURANCE

105.1 Materials and construction procedures shall be subject to inspection and testing by an Independent Testing Service employed by the Owner. Such inspections and tests will not relieve the Contractor of responsibility for providing materials and installation in compliance with specified requirements.

105.2 Contractor shall give Owner reasonable notice of starting new Work. Work shall not be done outside the agreed regular working hours without prior approval by Owner.

105.3 The Owner reserves the right, at any time before final acceptance, to reject materials or workmanship not complying with specified requirements. The Contractor shall correct the deficiencies which the inspections and tests have indicated are not in compliance to the specifications.

105.4 QA activities for pond liner construction shall be performed as described in Section 014302, Construction Quality Assurance Plan for a Geomembrane Lined Pond.

PART 2 - PRODUCTS

201. ACCEPTABLE MANUFACTURERS

201.1 Products of the following manufacturers meet the requirements of this section:

a. US Fabrics, Inc., 3904 Virginia Ave., Cincinnati, OH 45227.
(Products: US205NW – 8oz/SY, US250NW – 10oz/SY, US300NW – 12oz/SY, US160NW – 6oz/SY)

b. Carthage Mills, 4243 Hunt Road, Cincinnati, OH 45242.
(Products: FX-60HS – 6oz/SY, FX-80HS – 8oz/SY, FX100HS – 10oz/SY, FX-120HS – 12oz/SY)

c. Mirafi (TenCate Geosynthetics), 365 S. Holland Dr., Pendergrass, GA 30567.
(Products: S600 – 6oz/SY, S800 – 8oz/SY, S1000 – 10oz/SY, S1200 – 12oz/SY, S1600 – 16oz/SY, S2000 – 20oz/SY)

d. Propex Operating Company, LLC, 6025 Lee Highway, Chattanooga, TN 37422.
(Products: GEOTEX 601 – 6oz/SY, GEOTEX 801 – 8oz/SY, GEOTEX 1001 – 10oz/SY, GEOTEX 1201 – 10oz/SY)

e. Thrace-Linq Inc., 2550 W. 5th North St., Summerville, SC 29483.
(Products: 150EX – 6oz/SY, 180EX – 8oz/SY, 245EX – 10oz/SY, 275EX – 12oz/SY)

f. Others as approved by Owner.

202. GEOTEXTILE MATERIALS

202.1 Geotextiles shall be non-woven, spun bonded fabric manufactured from long chain polymeric filaments, yarns, staple fibers, or other structural components of polyester or polypropylene formed into a stable network (mesh).

202.2 The geotextile shall be colored (non-white) or otherwise treated to prevent the occurrence of snow blindness of handling personnel.

202.3 Non-woven geotextile shall meet the requirements of ODOT Item 712.09 Type B.

203. ANCHORING PINS

203.1 Anchoring Pins shall not be used.

204. PACKAGING AND IDENTIFICATION REQUIREMENTS

204.1 Packaging:

a. Deliver geotextiles to the project site in rolls each wrapped securely with a protective covering installed at the manufacturing facility. The covering shall prevent the entrance of water, vermin and dirt, and shall be adequate for protection against ultraviolet exposure.

b. The packaging shall not interfere with handling of the rolls either by slings or by using the central core upon which the geotextile is wound.

204.2 Protective Cover: Attach or adhere a tag to the protective cover identifying the following:

a. Manufacturer and product name/number.

b. Date of manufacture of geotextile.

c. Roll identification number.

d. Contractor's order number (matching Bill of Lading).

e. Mass per unit area of geotextile.

f. Width, length and square yard area of the roll.

204.3 Labeling:

a. Manufacturer shall include a label on the inside of the roll core specifying/indicating manufacturer, product name, and roll identification number.

b. Details of labeling rolls shall comply with ASTM D 4873.

PART 3 - EXECUTION

301. ACCEPTANCE AND STORAGE AT THE PROJECT SITE

301.1 Handling of Rolls:

a. The method of off-loading the geotextiles at the project site shall not cause any damage to the geotextile, its core, nor its protective covering.

b. Any protective covering that is accidentally damaged or stripped off of a roll shall be immediately repaired or the roll shall be moved to an enclosed facility until the repair can be made.

301.2 Storage at the Project Site:

a. Owner will provide on-site storage space in a location near where the geotextile will be placed such that on-site transportation and handling are minimized. The Contractor shall be responsible for protecting the stored material from theft and vandalism.

b. Rolls of geotextile shall be stored in such a manner that cores are not crushed, the geotextile not damaged, and as required to provide protection from exposure to ultraviolet light, inundation, mud, dirt, dust, puncture, cutting, or any other damaging or deleterious condition.

301.3 Inspection upon Delivery:

a. Upon delivery of the materials to the project site, the Contractor shall conduct a visual inspection of all rolls of geotextile for damage or defects. This inspection shall be done without unrolling any rolls unless damage to the inside of a roll is found or suspected.

b. Any damage or defects shall be noted and immediately reported to Owner, the Manufacturer and the carrier that transported the material. Any roll, or portion thereof, which, in the judgment of Owner, is seriously damaged, shall be removed from the project site and replaced with complying material at no additional cost to Owner.

302. GENERAL PLACEMENT REQUIREMENTS

302.1 The Contractor shall not remove the protective covering from the geotextile rolls to be deployed until immediately prior to deployment to ensure that geotextiles are not excessively exposed to ultraviolet degradation.

302.2 During handling, the geotextiles shall be handled in such a manner that the material is not damaged in any way. Damaged material shall not be used.

302.3 All necessary precautions shall be taken to prevent damage to the subsoil or underlying layers upon which the geotextile is to be placed. For subsoil layer, construction equipment can be used provided that excess rutting is not created. The maximum allowable rut depth is one inch.

302.4 On slopes, the geotextile shall be securely anchored at the top and then rolled down the slope in such a manner as to continually keep the geotextile sheet in tension and keep the geotextile free of wrinkles and folds.

302.5 All deployed geotextile shall be weighted with sand bags, old tires, or the equivalent to provide resistance to wind uplift. Such weights shall be installed during deployment and shall remain until replaced with cover material. Uplifted material can be reused only if approved by Owner.

302.6 Geotextiles shall only be cut using an upward cutting hook blade. If geotextiles are cut in place, special care shall be taken to protect other geosynthetics from damage which could be caused by cutting the geotextiles.

302.7 During placement of geotextiles, care shall be taken not to entrap, in or beneath the geotextile, stones, excessive dust, or moisture that could damage the geomembrane or cause clogging of drains or filters, or hamper subsequent splicing.

302.8 Unused portions of rolls or cut sections shall be protected from the elements by recovering with the protective covering. Geotextiles exposed to the elements for more than 14 days shall be removed from the Project Site.

303. INSTALLATION OF GEOTEXTILE FOR RIPRAP BEDDING

303.1 Preparation of Bearing Surface:

a. Compact, trim, and dress the slope, ditch cross section, shoreline, or other surface to receive riprap.

b. Immediately prior to placing geotextile, inspect bearing area and correct unacceptable conditions, i.e., debris, loose earth, protruding or loose stones or rocks, dips, or soft spots.

c. Obtain Owner's acceptance of bearing surface before placing geotextile.

303.2 Type and Placement of Geotextile:

a. Type of Geotextile: Refer to Section 313716, Riprap, for the weight of geotextile to be used beneath each class of riprap.

b. Material of Geotextile: Refer to design drawings for material of geotextile to be used for installation. If no material is specified then both polyester and polypropylene are acceptable.

c. The terminal ends of geotextile placed on a slope shall be anchored in trenches or aprons at the crest of a slope.

303.3 Splicing of Geotextile:

a. The geotextile shall be spliced by either sewing or overlapping. All splices shall be subject to the approval of Owner.

b. If splicing by overlapping is used, adjacent rolls of geotextile shall be shingle overlapped a minimum of 12 inches in the downslope or downstream direction.

c. Small rips, tears, or holes in the geotextile shall be patched by the Contractor. The patch shall be placed over the damaged area and extend a minimum of 3 feet beyond the perimeter of the hole, tear, or damage.

d. Sewn splices shall be acceptable if the overlap is a minimum of 6 inches and the seam grab tensile strength is equal to the minimum value specified in Table 1.

e. Do not place more geotextile than can be covered with riprap or gravel on the same day as placed. Until completion of the total installation, a strip 24 inches wide shall be left uncovered to allow for splicing on the next working day.

303.4 Backfill or Covering:

a. Soil cover or riprap placement shall be done within 24 hours of placing geotextile.

b. The overlying material shall be deployed in such a manner that excess tensile stress is not placed on the geotextile.

c. If an aggregate bedding layer is to cover the geotextiles, the placement of the aggregate bedding shall be done in such a manner that the geotextile is not shifted from its intended position and underlying materials are not exposed or damaged. On side slopes, this requires aggregate bedding backfill to proceed from the bottom of the slope upward.

d. Riprap shall be placed as specified in Section 313716, Riprap.

304. INSTALLATION OF GEOTEXTILES FOR PROTECTION OF A GEOMEMBRANE INSIDE A SPILL CONTAINMENT AREA OR POND

304.1 Geotextile used for Separation and Protection:

a. Seaming on the floor: Successive panels of the geotextile shall be continuously sewn (i.e., spot seaming is not allowed) or continuously heat bonded in accordance with Manufacturer's recommendations on the floor and interior slopes flatter than 10H:1V (10 percent).

b. Seaming on side slopes: On slopes steeper than 10H:1V (10 percent), all geotextiles shall be continuously sewn (i.e., spot sewing and heat bonding are not allowed). All seams shall be vertical (parallel with the slope). No horizontal seams (across the slope) shall be permitted on side slopes.

304.2 Sewing:

a. Sewing shall be done using polyester or heat-set UV stabilized polypropylene sewing thread with chemical and ultraviolet light resistance properties equal to or exceeding the values specified in Table 1. The thread color shall contrast with the color of the geotextile to assist in inspection of the seam. Tex size or denier number of the thread shall be specified by the Contractor.

b. Seams shall be "prayer" or "flat" seams. Seams shall be formed by mating the edges of the geotextile panels and sewing the panels together with continuous stitches located a minimum of four inches from the mated edges.

c. Sewing procedures shall conform to the latest procedures recommended by the geotextile Manufacturer.

d. For geotextiles used for bedding beneath riprap placed on the interior side slopes of a pond, stitching shall be two rows (SSa-2) of stitching using a 01 two-thread locking chain stitch as described in Industrial Fabrics Association International (IFAI) with 6 to 10 stitches per inch. Thread strength shall be such field seam strength will be a minimum of 90 percent of the tensile strength of the geotextile.

e. For geotextiles used elsewhere in a pond for separation or geomembrane protection, stitching shall be one row (SSa-1) of stitching using a Type 401 two-thread locking chain stitch as described in the IFAI with a minimum of 5 stitches per inch or the seam shall be heat bonded. Thread strength shall be selected by the Contractor.

304.3 Seam Tests:

a. For geotextiles used for bedding beneath riprap within a containment area or pond, seam samples shall be prepared prior to starting field work and tested in accordance with ASTM D 4884 to establish that the specified field seam strength will be met. Samples of field seams shall be taken at intervals stipulated in ASTM D 4884 and tested in the laboratory per ASTM D 4884 to check that field seam strengths are as specified. All other tests specified in Table 1 shall also be applied.

b. For geotextiles used elsewhere in a pond, visual examinations shall be conducted to ensure that 100 percent of the seams are sewn or heat bonded as required. Seam sampling and testing is not required.

304.4 Repair of Holes or Tears:

a. All holes or tears in a geotextile shall be repaired by patching.

b. The patch material shall be the same geotextile material as the damaged geotextile.

c. Care shall be taken to remove any soil, object, and/or other material which penetrated or tore the geotextile.

304.5 Patches on Slopes:

a. On slopes, a patch made from the same geotextile shall be sewn into place. Should any tear exceed 10 percent of the width of the roll, that roll shall be removed from the slope and replaced.

304.6 Patches on the Floor:

a. On the floor, a patch shall be sewn into place.

304.7 Requirements for Sewn Patches:

a. The patch shall extend a minimum of 12 inches beyond any portion of the damaged geotextile.

b. The patch shall be sewn by hand or machine so as not to accidentally shift out of position or be moved during any backfilling or covering.

c. The thread shall be the same as specified for sewing seams.

d. The repair shall be made to the satisfaction of the Owner.

304.8 Inspection After Installation:

a. After installation is complete, a visual examination of the geotextile shall be carried out over the entire surface of the geotextile to verify that no potentially harmful foreign objects, such as broken needles, are present.

b. When sewing seams, the Contractor shall perform continuous inspection during the seaming process using an in-line metal detector with an adequate sweep rate to determine the presence of broken needles. If the presence of broken needles is indicated, a needle removal system using magnets shall be implemented.

304.9 Backfill or Covering:

a. Soil backfilling, riprap placement, or covering of the geotextile by another geosynthetic material shall be done within the time limit specified by the Manufacturer.

b. The overlying material shall be deployed in such a manner that excessive tensile stress is not placed on the geotextile.

c. If soil is to cover the geotextiles, the placement of the soil shall be done in such a manner that the geotextile is not shifted from its intended position and underlying materials are not exposed or damaged. On side slopes, this requires soil backfill to proceed from the bottom of the slope upward.

d. Riprap shall be placed as specified in Section 313716, Riprap.

e. If a geosynthetic material is to cover the geotextile, both the geotextile and the newly deployed geosynthetic material shall not be damaged in the process.

END OF SECTION

SECTION 313524

FABRIC FORMED CONCRETE MATS

PART 1 - GENERAL

101. EXTENT

101.1 This Specification Section defines the requirements for the installation of fabric formed concrete mats as protection on pond slopes as specified herein and indicated on the design drawings.

101.2 The work shall consist of the following:

a. Preparing and grading surfaces to receive fabric mats.

b. Excavation of anchor trenches.

c. Placing and anchoring a geotextile prior to placing the fabric mats.

d. Placing fabric mats and filling them with a pumpable sand/cement slurry to form a stable erosion protection system.

e. Backfill of anchor trenches.

f. Offsite disposal of excess or unsuitable materials and debris.

102. RELATED WORK SPECIFIED IN OTHER SECTIONS

102.1 The work specified in this Section shall be coordinated with work specified in the following related Sections:

a. Section 311521 – Geotextiles

103. REFERENCE DOCUMENTS

103.1 Standards, specifications, manuals, codes and other publications of nationally recognized organizations and associations are referenced herein. Methods, equipment and materials specified herein shall comply with the specified and applicable portions of the referenced documents, in addition to federal, state or local codes having jurisdiction.

103.2 References to these documents are to the latest issue date of each document, unless otherwise indicated, together with the latest additions, addenda, amendments, supplements, etc., thereto, in effect as of the date of contract for the work

103.3 Abbreviations listed indicate the form used to identify the reference documents in the Specification text.

103.4 ASTM – ASTM International:

a. C 31 – Practice for Making and Curing Concrete Test Specimens in the Field.

b. C 39 – Test Method for Compressive Strength of Cylindrical Concrete Specimens.

c. C 143 – Standard Test Method for Slump of Hydraulic Cement Concrete.

d. C 172 – Standard Practice for Sampling Freshly Mixed Concrete.

e. C 173 – Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method.

f. C231 – Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method.

g. C1064 – Standard Test Method for Temperature of Freshly Mixed Portland - Cement Concrete.

h. D543 – Test Method for Resistance of Plastics to Chemical Reagents.

i. D751 – Test Methods for Coated Fabrics.

j. D792 – Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement.

k. D1777 – Test Method for Thickness of Textile Materials.

l. D2101 – Test Method for Tensile Properties of Single Man-Made Textile Fibers Taken from Yarns and Tows.

m. D3776 – Test Methods for Mass per Unit Area (Weight) of Fabric.

n. D3786 – Test Method for Hydraulic Bursting Strength of Knitted Goods and Non-Woven Fabrics: Diaphragm Bursting Strength Tester Method.

o. D3787 – Test Method for Bursting Strength of Knitted Goods: Constant-Rate-of-Traverse (CRT) Ball Burst Test.

p. D4157 – Test Methods for Abrasion Resistance of Textile Fabrics (Oscillatory Cylinder Method).

q. D4355 – Test Method for Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus).

r. D4491 – Test Methods for Water Permeability of Geotextiles by Permittivity.

s. D4553 – Test Method for Trapezoid Tearing Strength of Geotextiles.

t. D4632 – Test Method for Grab Breaking Load and Elongation of Geotextiles.

u. D5034 – Test Method for Breaking Strength and Elongation of Textile Fabrics (Grab Test).

v. D5035 – Test Method for Breaking Strength and Elongation of Textile Fabrics (Strip Method).

104. SUBMITTALS

104.1 Submit the following documents to the Owner for review not less than 30 days prior to scheduled delivery of materials.

a. Manufacturer’s literature providing specifications on the fabric mats that will be supplied.

b. Manufacturer’s certification that the fabric mats to be supplied comply with the requirements of this Technical Specification.

c. Manufacturer’s Quality Control and Construction Quality Control Plans. The MQC Plan shall state the frequency that index tests are performed on the fabric mat during manufacturing.

d. If requested by the Owner, four samples of each fabric mat suitable for testing.

e. Certification that the mat and fabric material to be used meets the requirements of Articles 201 and 202 of this Section.

f. Slurry mix designs and data for constituent materials.

g. Results of the strength tests for the proposed slurry mix 4 weeks prior to use in the Work.

104.2 Results of the strength tests performed on the production concrete grout within 30 days of the completion of the work.

105. CONSTRUCTION QUALITY ASSURANCE

105.1 The Contractor shall examine the areas and conditions under which the work is to be installed and notify Owner in writing of conditions detrimental to the proper and timely completion of the work, that have changed from the time of the Bidder's walkdown.

105.2 Material and installation procedures are subject to inspection and tests conducted by a Testing Service employed by the Owner. Such inspections and tests will not relieve the Contractor of responsibility for providing material and installation procedures in compliance with specified requirements. Owner reserves the right, at any time before final acceptance, to reject material not complying with the specified requirements.

105.3 The Contractor shall correct deficiencies in the work which inspections and laboratory test reports have indicated to be not in compliance with requirements. Perform additional tests, at the Contractor's expense, as may be necessary to reconfirm any noncompliance of the original work, and as may be necessary to show compliance of corrected work.

105.4 The Contractor shall promptly correct errors or flaws in material or placement of the erosion protection mats discerned during construction. The Contractor shall make immediate substitution of non-complying component or make field changes to make the non-complying component acceptable. Whether the correction is made by substitution or field correction, it shall be performed without cost to the Owner.

PART 2 – PRODUCTS

201. MATERIAL

201.1 Fabric Design:

a. Fabric-forming material shall consist of double-layer, open-selvage fabric joined in a mat configuration. The fabric shall be woven of 100% continuous multi-filament nylon fiber of which 50% by weight shall be bulk textured fiber. The use of staple yarns will be permitted.

b. The fabric shall be woven in such a manner as to provide interwoven points of attachment on spaced centers. These points of attachment shall serve to control the thickness of the finished product and to also act as a filter point to provide relief of hydrostatic uplift pressure beneath the completed revetment. The fabric shall be woven in a basket or other open pattern to provide permeability at the filter points and the main fabric field.

c. The spacing of the filter points is indicated on the design drawings. This spacing will result in an average revetment thickness that is consistent with the average thickness published by the manufacturer for the designated style specified.

d. Fabric design shall produce an eight inch (8") finished thickness.

202. FIBER AND FABRIC MATERIAL

202.1 The warp fiber shall be 1260 Denier Nylon, 18.5 ends/inch per single layer and the fill fiber shall be 1900 Denier Nylon, 14 picks/inch per single layer. The fiber and fabric material shall meet the minimum requirements listed in Table 1.

TABLE 1

MATERIAL PROPERTIES

Property	ASTM Test Method	Minimum Test Value
Fiber count	-	0.164 g/m
Trapezoidal tear breaking force on the warp fiber at 70% elongation	D 4553	80 lbs./in.
Trapezoidal tear breaking force on the fill fiber at 70% elongation	D 4553	40 lbs./in.
Density	D 792	1.00 g/cm^3
Fiber dry breaking strength at 48% elongation	D 2101	20 lbs.
Fiber wet breaking strength at 53% elongation (soaked in water for 2 hours)	D 2101	19 lbs.
Tensile strength in the warp direction after exposure to 300 hours of Ca (OH) at a pH of 10	D 543	180 lbs./in.
Tensile strength in the warp direction after exposure to 300 hours of H_2SO_4.	D 543	170 lbs./in.
Tensile breaking strength in the warp direction on a strip of the fabric at 39% elongation (1)	D 5034 D 5035	160 lbs./in.
Tensile breaking strength in the fill direction on a strip of the fabric at 34% elongation (1)	D 5034 D-5035	190 lbs./in.
Mass/unit area for a single layer of fabric	D 3776	7.8 oz./sqyd.
Thickness of a single layer of fabric	D 1777	31 mils
Falling head permittivity of two layers of fabric woven together	D 4491	0.28 s^{-1} 0.04 cm/s (4)
Falling head permittivity of a single layer of fabric	D 4491	1.3 s^{-1} 0.12 cm/s
Seam strength (2)	D 751	35 lbs./in.

Property	ASTM Test Method	Minimum Test Value
Wyzenbeek abrasion resistance in the warp direction (3)	D 4157	160 lbs./in.
Grab strength in the warp direction at 31% elongation	D 4632	350 lbs.
Grab strength in the fill direction at 41% elongation	D 4632	275 lbs.
Breaking strength in the warp direction after exposure to 500 hours of UV light	D 4355	190 lbs./in.
Mullen burst test	D 3786	750 psi
Puncture test	D 3787	80 lbs.

Notes for Table 1:

(1) 3" x 8" sample gripped along full width of the specimen with 3" of separation between grips. Strip test to be performed on single layer of fabric at cross-head speed of 5 inches per minute.

(2) Seam centered between grips 3" apart and gripped the full width of the specimen.

(3) 95% of the strip tensile breaking strength retained; 25 cycles using fine grade energy cloth; 3.5 pound head weight; 5.0 pound tension weight.

(4) Applies to Filter Points only.

203. FABRIC ASSEMBLY

203.1 Adjacent fabric panels shall be connected by sewing or by means of zippers.

203.2 The two top layers of fabric and the two bottom layers of fabric shall be joined separately permitting full mat thickness between the two parallel seams. A single seam in which all four layers of the fabric are joined at one point will not be permitted.

203.3 If required, grout stops may be installed parallel to and in between individual mill widths at predetermined intervals to regulate the flow of the concrete fill. Grout stops shall be so designed as to produce full mat thickness along the full length of the grout stop.

204. CONCRETE GROUT

204.1 The concrete grout shall consist of a mixture of Portland cement, fine aggregate and water, proportional and mixed as to provide a readily pumpable slurry.

204.2 Admixtures and/or a pozzolan may be used with the approval of the Owner. The use of superplasticizers and/or silica fume require special precautions and the approval of the Owner.

204.3 The hardened concrete shall exhibit a minimum compressive strength of 4000 psi at 28 days when specimens are made and tested in accordance with the provisions of ASTM C 31 and ASTM C 39.

205. GEOTEXTILE

205.1 Geotextile for placement on the subgrade prior to placement of fabric mats shall be an 8 oz/sy geotextile meeting the requirements of Section 311521, Geotextiles.

206. APPROVED PRODUCTS AND MANUFACTURERS

206.1 Type and Manufacture as follows:

a. Fabriform Filter Point Fabric as manufactured by Construction Techniques, Inc., Cleveland, Ohio.

b. Other approved by Owner.

207. TESTING

207.1 An independent Testing Service shall perform the following:

a. Test material for the concrete slurry fill and prepare initial test cylinders in accordance with the requirements specified herein.

b. Prepare test cylinders and determine the compressive strength of job concrete fill test cylinders.

207.2 Obtaining and testing concrete slurry shall be by the Testing Service in accordance with the following specifications:

a. Sampling freshly mixed slurry shall be done in accordance with ASTM C 172.

b. Making and curing concrete test specimens shall be in accordance with ASTM C 31.

c. Slump test shall be in accordance with ASTM C 143.

d. Air content tests shall be in accordance with ASTM C 173 or ASTM C 231.

e. Tests for the temperature of the freshly mixed concrete slurry shall be in accordance with ASTM C 1064.

f. Compressive strength test shall be in accordance with ASTM C 39.

207.3 The frequency of testing shall be as directed by Owner as follows:

a. At least one test shall be made for each day's placement of concrete grout, but not less than once for each 100 cubic yards or part thereof placed.

b. A test shall consist of a minimum of four 6" x 12" cylinders taken from the same truck. If 4" X 8" cylinders are used, a minimum of five cylinders shall be taken. One 7-day and two 6"x 12" or three 4"x 8" 28-day tests shall be performed by the laboratory with results submitted to the Owner as soon as possible. One spare cylinder shall be made and used as directed by the Owner

c. A slump test and air content test shall be performed on every 100 cubic yards of concrete grout.

d. The temperature of each 100 cubic yards shall be recorded in the field prior to placement. If the concrete grout temperature is in excess of 100°F, the concrete shall be rejected.

207.4 Submit test results to the Owner for review.

PART 3 – EXECUTION

301. ACCEPTANCE AND STORAGE AT THE PROJECT SITE

301.1 Handling of Rolls:

a. The method of off-loading the fabric at the project site shall not cause any damage to the fabric, its core, nor its protective covering.

b. If any protective covering is accidentally damaged or stripped off of a pallet or roll and the pallet or roll cannot be immediately installed, the protective covering shall be immediately repaired or the pallet or roll shall be moved to an enclosed facility until the repair can be made or the material can be installed.

301.2 Storage and Field Site:

a. The Owner shall provide on-site storage space in a location near where the fabric will be placed such that on-site transportation and handling are minimized. The Contractor shall be responsible for protecting the stored material from theft and vandalism.

b. Rolls or pallets of fabric shall be stored in such a manner that cores are not crushed, the fabric not damaged, and as required to provide protection from exposure to ultraviolet light, innundation, mud, dirt, dust, puncture, cutting or any other damaging or deleterious condition.

c. Duration of outdoor storage of rolls or pallets shall not exceed the manufacturer's recommendations or be more than six months, whichever is less.

301.3 Inspection upon Delivery:

a. Upon delivery of the materials to the site, the Contractor shall conduct a visual inspection of all rolls of fabric for damage or defects. This inspection shall be done without unrolling any rolls unless damage to the inside of a roll is found or suspected.

b. Any damage or defects shall be noted and immediately reported to the Owner, the Manufacturer and the carrier that transported the material. Any roll, portion thereof, which, in the judgement of the Owner, is seriously damaged, shall be removed from the project site and replaced with complying material at no additional cost to the Owner.

302. FABRIC PLACEMENT

302.1 Prior to concrete injection, the fabric shall be positioned over a geotextile as indicated on the design drawings making appropriate allowances for contraction of the fabric mats as a result of injecting the concrete grout. The geotextile shall be installed as specified in Section 311521, Geotextiles.

302.2 Anchoring of fabric shall be as shown on the design drawings.

302.3 Fabric panels may be factory assembled in predetermined sizes and joined together side-by-side at the job site by field sewing or by means of zipper closures attached to the upper and lower layers of the fabric. In no case will simple unattached butt joints between panels be allowed. Overlapping shall be allowed only if approved by Owner.

303. CONCRETE INJECTION

303.1 Following placement of the fabric mats over the geotextile, the specified concrete grout shall be injected between the top and bottom layers of the fabric through small slits cut in the upper layer

of the fabric. The injection pipe shall be wrapped tightly at the point of injection with a strip of burlap, or similar material, during pumping to seal the joint between the injection pipe and the slit. After pumping, the burlap shall be pushed into the slit as the injection pipe is withdrawn in order to minimize spillage of the concrete slurry onto the surface of the revetment.

303.2 The sequence of concrete slurry injection shall be such as to ensure complete filling of the revetment-forming fabric to average thickness indicated by the manufacturer for the designated style specified on the design drawings.

303.3 Foot traffic will not be permitted on the freshly pumped mat since such traffic will cause permanent indentations in the mat surface. Walk boards shall be used where necessary.

303.4 Excess concrete slurry which has been inadvertently spilled on the mat surface shall be cleaned up with a broom and shovel. The use of a water hose to remove spillage from the surface of a freshly pumped mat will not be permitted.

303.5 During concrete slurry injection, the mat thickness shall be measured by inserting a short piece of stiff wire through the crowns of the mats midway between the filter points at several locations from the crest to the toe of the slope. Any mat measurement less than 90% of the average of all thickness measurements shall be re-injected until the average thickness indicated for the style specified has been attained.

END OF SECTION

SECTION 313716

RIPRAP

PART 1 - GENERAL

101. EXTENT

101.1 This Specification Section defines the material and installation requirements for riprap.

101.2 The Work shall include, but not be limited to, the following items:

a. Surveying for alignment and grade.

b. Furnishing all materials from offsite sources, including transportation to the site.

c. Installation of materials.

102. RELATED WORK SPECIFIED IN OTHER SECTIONS

102.1 The work specified in this Section shall be coordinated with work specified in the following related Sections:

a. Section 311521 – Non-Woven Geotextiles

103. REFERENCE DOCUMENTS

103.1 Standards, Specifications, manuals, codes and other publications of nationally recognized organizations and associations are referenced herein. Methods, equipment and materials specified herein shall comply with the specified and applicable portions of the referenced documents, in addition to federal, state or local agencies having jurisdiction.

103.2 References to these documents are to the latest issue date of each document, unless otherwise indicated, together with the latest additions, addenda, amendments, supplements, etc., thereto, in effect as of the date of Contract for the Work.

103.3 ASTM - ASTM International:

a. C88 – Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate.

b. C131 – Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine.

c. C136 – Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates.

d. C142 – Standard Test Method for Clay Lumps and Friable Particles in Aggregates.

e. C535 – Standard Test Method for Resistance to Degradation of Large-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine.

f. D448 – Standard Classification for Sizes of Aggregate for Road and Bridge Construction.

g. D5519 – Standard Test Methods for Particle Size Analysis of Natural and Man-Made Riprap Materials.

h. D5821 – Standard Test Method for Determining the Percentage of Fractured Particles in Coarse Aggregate.

i. D6473 – Standard Test Method for Specific Gravity and Absorption of Rock for Erosion Control.

j. D6825 – Standard Guide for Placement of Riprap Revetments.

103.4 AASHTO – American Association of State Highway and Transportation Officials:

a. T103 – Standard Method of Test for Soundness of Aggregates by Freezing and Thawing.

104. SUBMITTALS

104.1 Contractor shall submit drawings and data listed below. Contractor's Drawings and data shall be submitted via electronic medium in a format compatible with Owner's information systems and as specified by Owner.

104.2 Data shall be submitted a minimum of 30 days prior to use.

104.3 Riprap:

a. Material Certificates signed by the material producer certifying that the following items comply with or exceed Specifications:

Property	ASTM Test	Data Required
Sieve analysis	C136 and D5519	Percent Passing Selected Sieves
Soundness of aggregates by use of sodium sulfate or magnesium sulfate	C88	Percent Loss
Percent Crushed Faces	D5821	Percent
Bulk Specific Gravity	D6473	Bulk Specific Gravity
Color	–	Note color

104.4 Riprap Aggregate Bedding Material:

a. Material Certificates signed by the material producer certifying that the following items comply with or exceed Specifications:

Property	ASTM Test	Data Required
Sieve analysis	C136 and D5519	Percent Passing Selected Sieves
Soundness of aggregates by use of sodium sulfate or magnesium sulfate	C88	Percent Loss
Resistance to degradation of large size coarse aggregate by abrasion and impact in the Los Angeles machine	C131 or C535	Percent Loss
Clay lumps and friable particles in aggregate	C142	Percent

104.5 Proposed Source of Riprap and Bedding Material:

a. Proposed source of riprap and bedding material, including material producer's name, address and phone number.

104.6 Submit Samples:

a. Submit samples when requested by Owner.

105. QUALITY ASSURANCE

105.1 Material and placing procedures shall be subject to inspections, audits and tests conducted by a Testing Service hired by Owner. Such inspections and tests will not relieve the Contractor of responsibility for providing materials and installation in compliance with specified requirements.

105.2 Contractor shall cooperate with Owner's Testing Service and allow reasonable and necessary opportunities and facilities for setting points and making measurements, and shall not proceed with any Work until it has made timely demand upon Owner's Testing Service for, and received from him, such points and instruction for the testing as may be necessary as Work progresses. Work shall be done in strict conformity with such points and instruction.

105.3 Contractor shall give Owner reasonable notice of starting new Work. Work shall not be done outside the agreed regular working hours without prior approval of Owner.

PART 2 - PRODUCTS

201. MATERIALS

201.1 Rock for Riprap:

a. Riprap material sizes and gradations are indicated in Table 1 by class of riprap.

b. The shortest dimension of any stone (width or thickness) shall be not more than 1/3 of the length of the stone.

c. Riprap shall consist of quarried or crushed stone with 100% of all faces angular or crushed, free from structural defects, laminations, seams, weak cleavage planes, and undesirable effects of weathering. Stone containing shale, unsound sandstone or any other material, which will readily disintegrate under handling and placing or weathering, shall not be used. All material shall be clean and free from deleterious material and impurities, including earth, clay, or refuse.

d. Any stone, which is free from incipient fractures and seams and has given evidence of ability to withstand weathering after long exposure to the elements, shall be considered suitable for this purpose. Upon presentation of satisfactory evidence of the ability to withstand weathering, such stone may be used without laboratory testing.

e. Riprap shall be subjected to the sodium sulfate or magnesium sulfate soundness test (ASTM C88) and shall show a loss, after five cycles, of not more than 18% with magnesium sulfate or 15% with sodium sulfate. A material failing this test may be approved by Owner if, when subjected to 50 cycles of freezing and thawing, it has a loss not greater than 15% (AASHTO T103).

f. The bulk specific gravity of the riprap shall not be less than 2.55 (ASTM D6473) (approximate unit weight of 160 pounds per cubic foot.

g. Riprap color shall be gray unless otherwise approved by Owner.

TABLE 1

RIPRAP GRADATION

RIPRAP GRADATION													
CLASS		PERCENT LARGER THAN, BY WEIGHT											
D50 WEIGHT, lb. (2)	D50 SIZE, In. (APPROX.)	WEIGHT OF STONE (POUNDS) – DRY SPECIFIC WEIGHT ≥ 160#/FT^3											
		1	5	10	25	50	75	100	150	200	300	1/4 TON	1/2 TON
		APPROXIMATE EQUIVALENT DIAMETER (INCHES) (1)											
		2 ½	4 ½	6	8	10	---	12	15	---	18	21	27
5	4”	95-100	50-100	0-5	---	---	---	---	---	---	---	---	---
10	6”	95-100	---	50-100	0-5	---	---	---	---	---	---	---	---
25	8”	---	95-100	---	50-100	---	0-5	---	---	---	---	---	---
50	10”	---	---	---	95-100	50-100	---	---	0-5	---	---	---	---
100	12”	---	---	---	---	95-100	---	50-100	---	---	0-5	---	---
150	15”	---	---	---	---	---	95-100	---	50-100	---	---	0-5	---
300	18”	---	---	---	---	---	---	---	95-100	---	50-100	---	0-5

NOTES:

1) $D = \left[\frac{6W}{\pi\lambda_s}\right]^{1/3}$ *or* $W = \frac{\pi\lambda_s D^3}{6}$

2) $\lambda_s = 160\,\#/FT^3$ is assumed

201.2 Aggregate Bedding Layer Material:

a. Aggregate bedding layer material shall be used as specified on the design drawings.

b. Aggregate bedding layer material gradations shall be as specified in Table 2.

c. The material shall be well-graded crushed gravel, crushed rock or crushed concrete conforming to the specification gradation limits without significant deficiency in any size or group of sizes between the coarsest and finest particles. The material shall be reasonably free from flat, thin, or elongated pieces.

d. The material shall be relatively free from organic matter, shale, clay lumps, coal, lignite or other objectionable matter. The total maximum percent deleterious material shall not exceed 6% (ASTM C142).

e. The material shall show a loss of not more than 15% when subjected to five cycles of the Sodium Sulfate Soundness Test (ASTM C88).

f. The material shall show a loss of not more than 50% when subjected to the Los Angeles Abrasion Test (ASTM C31).

TABLE 2

AGGREGATE BEDDING LAYER MATERIAL GRADATION

BEDDING LAYER MATERIAL GRADATION														
Size Number ASTM D448	Nominal Size SQUARE OPENING	U.S. STANDARD SIEVE PERCENT PASSING, BY WEIGHT												
		4”	3 1/2”	3”	2 1/2”	2”	1 1/2”	1”	3/4”	1/2”	3/8”	#4	#8	#16
1	3 1/2” – 1 1/2”	100	90-100	---	25-60	---	0-15	---	0-5	---	---	0	---	---
24	2 1/2” – 3/4”	---	---	100	90-100	---	25-60	---	0-10	0-5	---	0	---	---

PART 3 - EXECUTION

301. INSTALLATION

301.1 Riprap Thickness and Bedding Layer Requirements:

a. Riprap thickness and bedding layer requirements shall be in accordance with Table 3. The class of riprap to use for each installation shall be as specified on the design drawings.

TABLE 3

RIPRAP THICKNESS AND BEDDING REQUIREMENTS

RIPRAP			BEDDING LAYER	ALTERNATE TO BEDDING LAYER(5)		
CLASS		MINIMUM THICKNESS (2)	GEOTEXTILE BEDDING LAYER (4)	GEOTEXTILE BEDDING LAYER	AGGREGATE BEDDING LAYER GRADATION NO. (3)	AGGREGATE BEDDING LAYER THICKNESS
D50 WEIGHT, LB. (1)	D50 SIZE, IN. (APPROX.)					
5	4”	6”	8.0 OZ/SY	None	None	None
10	6”	9”	8.0 OZ/SY	None	None	None
25	8”	12”	8.0 OZ/SY	None	None	None
50	10”	15”	10.0 OZ/SY	None	None	None
100	12”	18”	10.0 OZ/SY	8.0 OZ/SY	24	6”
150	15”	24”	10.0 OZ/SY	8.0 OZ/SY	1	8”
300	18”	30”	N/A Use Alternate	8.0 OZ/SY	1	8”

Notes:

(1) See Table 1 for gradation of riprap.

(2) Provide minimum thickness shown in table unless shown otherwise on design drawings.

(3) See Table 2 for gradation of aggregate bedding layer.

(4) Geotextile material as specified in Section 311521, Non-Woven Geotextiles.

(5) Alternate bedding layer shall only be used with Owner and Engineer approval.

301.2 Placement of Geotextile Bedding:

a. Place geotextile over properly prepared bearing surface. Refer to Section 311521, Non-Woven Geotextiles.

301.3 Placement of Aggregate Bedding Layer (when required by Table 3):

a. Place aggregate bedding course to the full thickness indicated in Table 3 in one operation using methods which will not cause segregation of particle sizes.

b. Compaction of the bedding course is not required; however, the surface shall be reasonably even and free from mounds or wind rows.

c. Aggregate bedding material shall not be dropped onto the geotextile bedding material from a height exceeding three feet.

d. Granular bedding material placed underwater shall be deposited directly on the foundation by means of a bucket or similar container. Discharging the material from above the surface of the water is not permitted.

e. The material placement shall begin at the toe of the slope and proceed up the slope.

301.4 Placement of Riprap:

a. Riprap shall be placed in general accordance with the methods listed in ASTM D6825 in designated areas to the lines, grades, and the minimum thicknesses indicated in Table 3 unless specified otherwise on the design drawings. Riprap shall be placed to the full thickness in one operation, and thickness shall not be less than the minimum at any point.

b. Riprap shall be placed by dragline, clamshell or similar equipment, which shall be operated so as to place each load of material in approximately its final position without reworking and without excessive height of drop. Placing riprap in layers shall not be permitted. Placing stones by dumping into chutes or other methods, which cause segregation of the various sizes, shall not be permitted.

c. Placement operations, including handling, stockpiling and transporting, shall be accomplished in such a manner as to produce a reasonably well graded mass of rock with minimum percentage of voids, free from objectionable pockets of small stone and clusters of large stones. The larger stones shall be well distributed and the entire mass of stones in their final position shall be roughly graded to conform to the gradation specified.

d. Riprap shall not be dropped onto the geotextile or aggregate bedding from a height of more than 1 foot. Any geotextile damaged during placement shall be repaired or replaced at the Contractor's expense.

e. Stone placement shall begin at the toe of the slope and proceed up the slope and stone shall be placed such that the greater portion of their weight is carried by earth bedding and not by the adjacent stones.

301.5 Thickness Tolerance:

a. Thickness determination of riprap and aggregate bedding material shall be made at points selected by Owner. When the average constructed thickness is less than 100% of the thickness specified

on the design drawings, additional material shall be added to obtain the specified thickness at no additional cost to the Owner.

END OF SECTION 313716

SECTION 319005

EARTHWORK AND CLAY LINING FOR A CLAY/GEOMEMBRANE COMPOSITE LINED POND

PART 1 - GENERAL

101. EXTENT

101.1 This Specification Section defines the material and installation requirements for earthwork and clay lining for ponds in accordance with the design drawings and as specified herein.

101.2 The work shall include, but not be limited to, the following items:

a. Installation of sediment and erosion control facilities prior to the start of construction and maintenance of the facilities during construction.

b. Dust Control during the construction period.

c. Earth excavation.

d. Preparation of the subgrade to receive fill, including clearing and grubbing.

e. Placement and compaction of general and structural fills.

f. Placement and compaction of dike fills.

g. Supply of clay liner materials from an onsite borrow area.

h. Placement and compaction of the clay liner.

i. Preparation of the clay liner to be geomembrane lined.

j. Excavation and backfill of anchor trenches for geomembrane lining.

k. Placement and compaction of prepared protective cover material (gravel as shown on the design drawings).

l. Permanent erosion protection for slopes.

m. Fine Finishing of completed slopes and embankments.

n. Disposal of excess or unsuitable excavated material, if required.

o. Placement of rock surfacing on the top of the dikes.

p. Closure and seeding of borrow areas.

q. Onsite disposal of excess or unsuitable excavated earthen material and debris.

102. RELATED WORK SPECIFIED IN OTHER SECTIONS

102.1 The work specified in this Section shall be coordinated with work specified in the following related Sections:

a. Section 311010 – Temporary Sediment Control During Construction

b. Section 313716 – Riprap

c. Section 319022 – High Density Polyethylene Geomembrane Liner for a Single Lined Pond

103. REFERENCE DOCUMENTS

103.1 Standards, specifications, manuals, codes and other publications of nationally recognized organizations and associations are referenced herein. Methods, equipment and materials specified herein shall comply with the specified and applicable portions of the referenced documents, in addition to federal, state or local codes having jurisdiction.

103.2 References to these documents are to the latest issue of each document, unless otherwise indicated, together with the latest additions, addenda, amendments, supplements, etc., thereto, in effect as of the date of the Contract for the Work.

103.3 Abbreviations listed indicate the form used to identify the reference documents in the Specification.

103.4 ASTM – ASTM International:

a. D422 – Test Method for Particle Size Analysis of Soils.

b. D698 – Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort.

c. D1140 – Test Method for Amount of Material in Soils Finer than the No. 200 Sieve.

d. D2487 – Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System).

e. D4318 – Test Method for Liquid Limit, Plastic Limit and Plasticity Index of Soils.

f. D5084 – Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials using a Flexible Wall Permeameter.

g. D5321 – Standard Test Method for Determining the Shear Strength of Soil-Geosynthetic and Geosynthetic-Geosynthetic Interfaces by Direct Shear

104. SUBMITTALS

104.1 Contractor shall submit drawings and data as specified. Contractor's Drawings and Data shall be submitted via electronic medium in a format compatible for importing into the Owner's information systems specified by the Owner.

104.2 Data required to be submitted by the CQA Engineer is specified in Section 014362 – Quality Assurance for Installation of Earthwork and Clay Lining for a Clay Lined Pond.

104.3 The Contractor shall submit for the Owner's review catalog data on all compaction equipment and proofrolling equipment he plans to use on the project.

105. QUALITY ASSURANCE

105.1 Inspection before Working: The Contractor shall examine the areas and conditions under which earthwork is to be done and notify the Owner in writing of conditions detrimental to the proper and timely completion of the Work.

105.2 Material, placing procedures and installations are subject to inspection and tests conducted by an Independent Testing Service hired by Owner. Such inspections and tests shall not relieve Contractor of responsibility for providing material and placement in compliance with this specification. The Owner reserves the right, at any time before final acceptance, to reject material not complying with the specified requirements.

105.3 The Contractor shall correct all deficiencies in earthwork and liner installation which inspections and laboratory and field tests have indicated are not in compliance with the specifications. The Contractor shall perform additional tests, at his expense, as may be necessary to reconfirm any noncompliance of the original work, and as may be necessary to show compliance of corrected work.

105.4 The Contractor shall promptly correct errors or flaws in the work or material identified during construction and which prevent proper installation. The Contractor shall make immediate substitution of the noncomplying material or shall make field changes to make the noncomplying material acceptable. The correction or substitution shall be performed at no cost to the Owner.

106. GEOTECHNICAL DATA AND TOPOGRAPHY

106.1 Geotechnical Data:

a. Reference drawings in the geotechnical report indicate location of the borings taken at the Project Site and the boring logs indicate the character of the soil. This information is available and, on request, will be furnished to the Contractor for his convenience and use. The Owner assumes no responsibility for the accuracy of information provided.

106.2 The Contractor may be permitted to make his own soil investigations. If permitted, investigations shall be performed at no cost to the Owner.

106.3 Topography:

a. A topographical survey was prepared by the Owner. The design drawings indicate contour lines, elevations and dimensions of existing ground. This information is furnished for Contractor's convenience and use. The Owner assumes no responsibility for the accuracy of information provided.

b. The Contractor may be permitted to make his own topography assessment or check the existing survey data. Any additional surveying of the project site shall be at no cost to the Owner.

107. LINE AND GRADES

107.1 The Contractor shall lay out lines and grades from the existing monuments and bench marks on the Project Site. Design drawings show the location of existing monuments, or this information is available from the Owner.

107.2 The Owner reserves the right to verify correctness of lines and grades during progress of the Work. Such verification by Owner shall not relieve the Contractor of responsibility as herein specified.

107.3 The Contractor shall notify the Owner of any difference in location of existing construction and conditions from those indicated wherever such difference may affect his work.

107.4 The Contractor shall preserve and maintain bench marks and reference points established on the Project site. Should Contractor, during prosecution of the Work, destroy or remove any bench mark or reference point established by the Owner, the cost of reestablishing the bench mark or reference point shall be borne by the Contractor.

108. DUST CONTROL

108.1 The Contractor shall be responsible for controlling dust caused by the grading operation in compliance with any dust control permit obtained by the Owner. Water shall be applied uniformly and lightly to prevent muddy, slippery or other hazardous conditions. The application shall be frequent enough to adequately control the dust nuisance. However, excessive application that would affect compacting operations shall be avoided.

109. TEMPORARY SEDIMENT CONTROL DURING CONSTRUCTION

109.1 The Contractor shall be responsible for providing temporary facilities for the control of sediment in site area runoff during construction.

109.2 Silt fences, straw bale dikes and other temporary facilities shall be provided in accordance with Section 311010.

110. EROSION CONTROL

110.1 The Contractor shall be responsible for temporary protection of graded areas against erosion and for correction of erosion, which occurs.

110.2 Temporary seeding or application of topsoil and permanent seeding or other erosion control measures specified on the design drawings shall be applied to completed slopes, ditches and other disturbed areas not subject to additional construction activities within 30 days of completion of the grading activity.

110.3 Slopes, ditches or other disturbed areas, which will be exposed for more than 30 days without a permanent cover because they will be subject to additional future construction activities, shall be provided with temporary seeding. Included are cut and fill slopes, pond dikes, and spoils disposal areas.

PART 2 - PRODUCTS

201. DESCRIPTION OF EARTHWORK

201.1 Earthwork for the ponds includes, excavating the pond area, and lining the interior of the dikes with clay obtained from a borrow area. The clay liner will be covered with a geomembrane, geotextile, a protective gravel layer, riprap and in some cases concrete in accordance with the design drawings.

202. MATERIAL GENERAL AND STRUCTURAL FILLS

202.1 Definitions:

a. "General Fill" is fill, which does not support structures. "General Fill" includes fill around the inlet and discharge structure where it is not part of the dikes.

b. "Structural Fill" is fill placed beneath equipment, walls, retaining walls, inlet and outlet structures, pump stations, and other similar structures sensitive to settlement. "Structural Fill" is also fill placed in the upper 3 feet beneath roads, fill supporting buried structures such as drainage manholes, electrical manholes and vaults where they are not incorporated in the dikes.

202.2 Satisfactory Fill Material:

a. Granular Material:

a1. Granular material is suitable for use as "General Fill" and "Structural Fill" if it contains not more than 1 percent organic or other deleterious material, is free of excess moisture, and has a maximum particle size of 3 inches.

a2. Acceptable granular material comes from soils which are classified as coarse-grained soils in the Unified Soil Classification System, ASTM D 2487. Classifications are GW, GP, GM, GC, SW, SP, SM or SC, or combinations of these such as SP-SC.

a3. Restrictions on the use of poorly graded sand (SP) or silty sand (SM) material are as follows: No material with a silt content of greater than 15 percent shall be used for "Structural Fill" nor shall it be used for fill behind retaining walls or within 12 inches of the surface of ditches or slopes.

b. Cohesive Material:

b1. Cohesive material is suitable for use as "General Fill" and "Structural Fill" if it contains not more than 1 percent organic or other deleterious material, has a maximum particle size of 3 inches, has a liquid limit of less than 45 and a plasticity index of less than 25.

b2. Acceptable cohesive material comes from soils which are classified as fine-grained soils in the Unified Soil Classification System, ASTM D2487. Classification is CL.

202.3 Unsatisfactory Fill Material:

a. Material unsatisfactory for use as either a "General Fill" or a "Structural Fill" is as follows:

a1. Soils classified as silt or organic soils in the Unified Soil Classification System, ASTM D 2487. Classifications are ML, MH, PT, OL and OH.

a2. Clay soils classified as CH with a liquid limit greater than 50.

a3. Rock material without a soil matrix in which nesting of rocks could occur.

b. Material classified as CL-ML (Plasticity Index of 4 to 7) may be blended with CL material to meet the limits of cohesive material listed above and used for "General Fill."

203. MATERIAL FOR CLAY LINER

203.1 Satisfactory Material:

a. Materials for the clay liner shall be clay, silty clay, sandy clay, or clayey sand classified as CL soils in the Unified Soil Classification System, ASTM D 2487. Clay liner material shall meet requirements shown below.

No.	Test	Item	ASTM	Requirement
1	Atterberg Limits	Liquid Limit (LL)	D4318	LL < 45, and
		Plasticity Index (PI)	D4318	PI < 25
2	Gradation	Passing No. 200 sieve (0.074mm size)	D1140	50% minimum
		Passing 2 micron (0.002mm) size	D422	30% minimum
		Retained on the 3/8 inch sieve	D422	10% maximum
3	Permeability	Permeability	D5084	$1x10^{-7}$ cm/sec maximum

b. Clay shall be free from trash, vegetation, organic matter, hard lumps of earth, and frozen, corrosive or perishable material.

c. Clay shall not contain any earth particles or pieces of rock greater than 3/4 inch in any dimension.

d. Soils amended with additives such as bentonite, cement, or asphalt shall not be used as liner materials.

203.2 Source of Liner Material:

a. Clay for use as liner material shall be obtained from an approved borrow source.

b. Materials shall not be borrowed from any source until it has been qualified for use by the Owner.

204. RESTRICTIONS ON THE USE OF MATERIAL FOR ANY PURPOSE

204.1 Any material, which is frozen, contains an excessive amount of organic material or trash, or contains large rocks, shall be considered unsatisfactory for use as fill.

204.2 Fill and backfill soils placed by previous construction shall be considered unsatisfactory for use as fill unless they meet the requirements for satisfactory material.

205. PROTECTIVE GRAVEL MATERIAL

205.1 Source and Preparation:

a. Material for the gravel layer shall be obtained from off-site sources, screened as required to remove oversize material, washed as required to remove excess silt size material, and stockpiled. Samples for gradation tests required by the Testing Service shall be obtained from the stockpile. The material shall be qualified by testing prior to being placed.

205.2 Material Requirements:

a. The protective gravel layer shall be composed of reasonably well-graded rounded gravel free of organics, trash, clay balls, or other deleterious material. The material shall be classified as GW, or GP material in the Unified Soil Classification System, ASTM D2487.

b. No sharp edged stones, stones larger than ¾ inches in any dimension, or hard objects shall be acceptable. If the material must be screened to remove coarse material, then all material larger than ½ inches shall be removed.

c. No material with a silt content greater than 10% shall be acceptable.

d. Material provided shall have a friction angle of at least 33 degrees and be capable of generating an interface friction angle of at least 30 degrees with the underlying non-woven geotextile when tested in accordance with ASTM D5321.

206. RIPRAP

206.1 Material shall be placed in accordance with the design drawings and as specified in Section 313716, Riprap.

206.2 Submittals of Certificates of riprap materials shall be as specified in Section 313716, Riprap.

PART 3 - EXECUTION

301. EXCAVATION

301.1 Classification of Excavation:

a. Excavation is classified as follows:

a1. Earth Excavation.

a2. Rock Excavation.

b. Earth excavation shall consist of removal of all material encountered which can be excavated using common earthmoving equipment.

c. Rock excavation shall consist of the excavation of boulders 1/2 cubic yard in volume or greater, all rock in ledges, and bedded and conglomerated deposits so firmly cemented that they cannot be removed by common earthmoving equipment.

301.2 Earth Excavation:

a. After topsoil removal has been completed, excavation within the limits of grading shall be performed to the lines and grades indicated on the design drawings.

b. Excavated material shall be used for fill unless it is classified as unsatisfactory.

c. Excavations shall not be carried below grades indicated on the design drawings without approval of the Owner. Over excavations shall be refilled with compacted satisfactory fill material to the proper grade at the Contractor's expense.

d. If unsatisfactory material is encountered at the bottom of an excavation, this material shall be removed to a depth as directed by the Owner and backfilled to the proper grade with compacted satisfactory fill material.

e. Excavation shall be performed in a sequence which will provide proper drainage at all times. Excavations shall be kept free of standing water while construction is in progress.

301.3 Rock Excavation:

a. No rock excavation is anticipated for this project.

301.4 Stockpile of Select Material:

a. No stockpiling of excavated material suitable for a specialized use is anticipated for this project.

301.5 Disposal of Excess Material:

a. Excess excavated material shall be placed in a designated onsite stockpile or disposal area as directed by Owner. Material may be removed from the stockpile or disposal area as directed by the Owner.

b. After completion of earthwork operations, all disposal and stockpile areas shall be dressed to drain properly and control erosion and seeded or removed from the site as directed by the Owner.

302. PREPARATION OF SUBGRADE TO RECEIVE FILL

302.1 Removal of Unsatisfactory Material Beneath Dikes:

a. Any material which is unsatisfactory for use for dike construction shall be removed and placed in a disposal area. The subgrade soils shall be inspected and approved by the Owner prior to the start of dike construction.

302.2 Preparation of Sloping Areas and Hillsides:

a. If fill is to be placed on an original hillside or an existing embankment with a slope of between 5 and 20 percent, the original ground shall be scarified to provide a bond between the ground and the fill to be placed thereon and the first layer of fill shall be placed, blended and compacted.

302.3 Compaction and Proofrolling:

a. Extent: The subgrade of areas to receive fill shall be compacted and proofrolled prior to placing the fill. The subgrade shall be compacted to a minimum degree of compaction specified in Table 1. Compaction shall be performed using suitable equipment for the type of soil present. Proofrolling shall consist of furnishing and operating heavy pneumatic tired compaction equipment for testing the stability of subgrade prior to receiving the fill. The intent is to locate any unstable areas. Compaction and proofrolling shall be performed in the presence of the Testing Service to allow for observation of unstable areas.

b. Proofrolling Equipment: The compaction equipment used for proofrolling shall be equipment such as a fully loaded water wagon having a gross weight of not less than 25 tons or a pneumatic-tired roller having not less than 4 pneumatic wheels. Under working conditions the roller shall deliver a compression of not less than 150 pounds per square inch of tire tread.

c. Operation: Compact the surface of the subgrade to be proofrolled. Proofroll the surface by making a minimum of two coverages with the compaction equipment at a speed of not greater than 5 mph. Each succeeding trip of the proofroller shall be offset by not greater than one tire width. Make additional passes over areas of suspected instability.

d. Failure: The subgrade shall be considered failed if, under the action of proofrolling, the subgrade yields, pumps, or is otherwise unstable. Yielding is defined as rutting of more than 1 inch measured from the top of the construction grade to the bottom of the rut.

e. Remedial Action: Remove all failed areas a minimum depth of 1 foot or deeper as directed by the Owner and replace with satisfactory fill compacted as specified in Table 1.

303. PLACEMENT OF GENERAL AND STRUCTURAL FILLS

303.1 Material Sources:

a. Borrow material from an onsite cut or an onsite borrow area shall be used for obtaining material for this purpose.

303.2 Moisture Content of Fill Material:

a. If the material is too dry, cut areas shall be pre-wetted to raise the moisture content. If the material is too wet, both cut and fill areas may require wind rowing or blending to dry the material. The moisture content of dike fill shall be within the range of (+) 1 to (+) 4 percent of optimum moisture content at the time of compaction. The moisture content of structural fill material shall be within $\pm$2 percent of optimum moisture content at the time of compaction. The moisture content of general fill material shall be within $\pm$3 percent of optimum moisture content at the time of compaction.

b. Fill material, which contains excessive moisture, shall not be compacted unless the material has dried and the moisture content is within the specified limits.

c. Fill material, which is too dry, shall have moisture added and then be blended so that the moisture content is uniform throughout the thickness prior to compaction.

d. Moisture control shall be applied to the upper 6 inches of the undercut subgrade soils.

303.3 Thickness:

a. Fill shall be placed in horizontal layers in thicknesses compatible with the material being placed, equipment being used and the compaction requirements.

b. Unless otherwise approved by the Owner the loose thickness shall not exceed the following:

b1. 8 inches maximum loose lift thickness for compaction by self-propelled equipment.

b2. 3 inches maximum loose lift thickness for compaction by hand-operated equipment.

b3. These lift thicknesses may be increased if the results of a test section prove that a thicker loose lift can be compacted to the required specified densities. The maximum loose lift thickness shall be 12 inches.

303.4 Placement of General and Structural Fills:

a. Each layer of fill shall be evenly spread and moistened or aerated as required to achieve the required moisture content.

b. Large continuous areas shall be uniformly filled to cover the entire length and width of the area to be filled before the next higher layer of material is placed.

c. The top surface of each layer shall be approximately level but shall have sufficient crown or cross fall to provide adequate drainage of water at all times during the construction period. The crown or crossfall shall be at least 1 in 50 (2 percent) but no greater than 1 in 20 (5 percent).

d. Fill slopes steeper than 20 percent (i.e., 5 horizontal to 1 vertical) shall be overfilled a minimum of 6 inches beyond the face of the slope, measured horizontally, and then cut back and trimmed to the required line and grade to expose a smooth surface uniformly compacted to the required density. Installing the fill slope to lines and grades shown on the design drawings and then running over the surface with compaction equipment is not acceptable.

303.5 Compacting Fills:

a. Equipment:

a1. Each layer of fill shall be compacted by tamping, sheepsfoot roller, pneumatic-tired roller, smooth drum steel-wheeled roller or other mechanical means acceptable to the Owner that will produce the specified compaction.

a2. At locations where it would be impractical because of inaccessibility to use self-propelled compacting equipment, fill layers shall be compacted using hand directed compaction equipment.

a3. When soils are used that develop a densely packed surface as a result of spreading or compacting equipment, the surface of each layer of fill shall be sufficiently roughened after compaction to ensure bonding of the succeeding layer.

b. Inspection and Testing:

b1. All work is subject to inspection and testing by an Independent Testing Service. The Testing Service shall have access to the work at all times. Testing shall be in accordance with Section 014362, “Quality Assurance for Installation of Earthwork and Clay Lining for a Clay Lined Pond”.

b2. Each layer of compacted fill shall be tested before proceeding with the next layer.

b3. It is the Contractor’s responsibility to request inspection prior to proceeding with further work that would make parts of the work inaccessible for inspection.

b4. If the fill material fails to meet the required density, the material shall be removed and replaced or reworked, altering the construction method as necessary to obtain the required density and compaction. Sufficient time shall be allotted between lifts for the necessary testing of the soils.

c. Compaction Densities:

c1. The degree of compaction shall be expressed as a percentage of the maximum laboratory dry density obtained at optimum moisture content in accordance with ASTM D 698.

c2. Compaction requirements are specified in Table 1.

304. PLACEMENT OF THE CLAY LINER

304.1 Excavation:

a. In-Place Material:

a1. Acceptable in-place liner materials SHALL NOT be compacted in-place. They shall be excavated and stockpiled or conditioned as specified herein before being placed and compacted.

a2. Liner material to be excavated from within the area to be lined may be stockpiled within the area to be lined as determined by the Contractor. Stockpiles outside of the area to be lined shall be approved by the Owner prior to stockpiling.

a3. Stockpile areas shall be properly prepared by clearing, grubbing and stripping.

a4. The Contractor shall provide and maintain suitable drainage in stockpile areas to prevent excessive wetting of the material. Stockpiled material shall be placed with a sufficient slope to assure rapid runoff of rainfall.

b. Borrow:

b1. Borrow areas shall first be cleared, grubbed and stripped before proceeding with borrow excavation of the liner material.

b2. The Contractor shall be responsible for maintenance of proper drainage and erosion control within the borrow area until the area is closed.

b3. Upon closure, all borrow areas shall be graded to drain and seeded or surfaced in accordance with final landscaping plans.

304.2 Blending and Conditioning of Material:

a. Selection and Blending:

a1. Selective use of material or blending of clay materials may be required to produce the required quality and uniformity. The soil shall be mixed and blended as it is excavated to produce as homogeneous a soil as possible. Methods such as cutting across zones of stratification and sieving out and crushing large clods shall be followed as necessary during excavation.

b. Conditioning:

b1. If a change in moisture content is required then conditioning shall be as follows:

b1.1 If a change of less than 2% is required then the change may be accomplished after the soil is in-place at the site, but before it is compacted.

b1.2 If a change of more than 2% is required then conditioning to adjust the moisture content to within 2% of moisture content required for compaction shall be done at the borrow source. Corrective moisture content of more than 2% IS NOT PERMITTED at the site.

b2. If a substantial change in moisture content is required it shall be done so that moistening or drying occurs uniformly throughout the soil. Materials shall be mixed and blended with discs or harrows as necessary so that the soil is uniform and homogeneous as to material and moisture content and so that clods are thoroughly wetted.

304.3 Preparation of the Subgrade to Receive Clay Liner Material:

a. The top 12 inches of subgrade shall be compacted to the degree of compaction specified in Table 1 and then proofrolled using equipment specified in Paragraph 303.3 to determine suitability of the

subgrade. Proofrolling shall be performed in the presence of the Owner to allow for observance of deflection, pumping, or rutting. The Owner shall make the determination of unsuitable areas. Soft spots shall be excavated a minimum depth of 1 foot by the Contractor and backfilled with suitable material compacted per the requirements listed in Table 1.

b. Prior to placement of the liner, the Contractor and the Owner shall inspect the subgrade for the following:

b1. Moisture seeps in the base or side slopes of the ponds.

b2. Side slope or base softening or failure due to moisture seeps.

b3. Presence of zones of high permeability that could present a pathway for seepage. Zones of high permeability can be fissures or fractures in the base or side slope or pockets of high permeability gravel or rock.

c. The Owner shall define the regions of high permeability requiring sealing. The Contractor shall seal all regions of high permeability identified by the Owner by over excavating a minimum of 2 feet and backfilling the over excavation with material meeting the requirements for satisfactory clay liner material compacted per the requirements listed in Table 1. This type of work shall be performed in the presence of the Owner.

d. The Owner shall define the work required to eliminate moisture seeps and/or repair damage due to moisture seeps.

304.4 Weather Related Restrictions on Placement:

a. Placement and compaction operations during periods of rainfall, snowfall, high winds, or when the air temperature drops below 30°F IS NOT PERMITTED.

b. Liner material shall not be placed on frozen ground or on surfaces having visual signs of ponded water, frost or snow.

c. Frozen material shall not be incorporated into liner fill.

d. Before resumption or liner placement after freezing weather the surfaces to receive liner fill shall be scarified to the depth of frost penetration and recompacted to the specification requirements. The surfaces to receive fill shall be approved by the Owner prior to placement of a new lift.

e. After a prolonged shutdown the surfaces to receive liner fill shall be scarified and moistened to a minimum depth of 6 inches or as directed by the Owner and recompacted to the required density.

304.5 Placement of Lifts:

a. On the bottom crowned or sloped sections, the liner material shall be placed and compacted in nearly horizontal lifts.

b. On side slopes 2-1/2 horizontal to 1 vertical and flatter, the liner material shall be placed and compacted in lifts parallel to the slope.

304.6 Material Placement and Conditioning:

a. Prior to compaction, the moisture content of the clay shall be adjusted to between +1% and +4% WET of the optimum moisture content.

b. Changes in moisture content of up to 2% may be accomplished at the site. If substantial changes are required, see Paragraph 305.2.

c. The maximum size of hard clods prior to compaction shall be 3/4 inch. This shall be determined by visual inspection. If the maximum clod size exceeds 3/4 inch, additional mixing and blending shall be provided as required to reduce clods to that size or the larger clods shall be sieved out.

d. The maximum loose thickness of a lift shall be 9 inches or the length of the compaction sheepsfoot roller feet, whichever is less. The maximum thickness of a compacted lift shall be 6 inches.

304.7 Compacting Clay Liner Material:

a. Compaction Equipment:

a1. Sheepsfoot Roller: The Contractor shall use sheepsfoot rollers of adequate weight to achieve compaction densities specified herein and to achieve the kneading action necessary to break down clods blended in liner materials, and eliminate interclod voids. Sheepsfoot rollers shall conform to the following:

a1.1 Have long thin feet capable of fully penetrating a loose lift and blending and compacting the bottom of the lift directly into the top of the previous lift. The minimum preferable length of the feet is 8 inches.

a1.2 Have a roller weight of not less than 50,000 lb. and a minimum weight of 3000 lb. per linear foot of roller. A roller with a weight of 4,000 to 5,000 lb. per linear foot is preferred.

a1.3 The area of each foot shall be such that the foot contact pressure is not less than 300 psi, preferably 400-500 psi.

a2. Breakdown Roller: The Breakdown Roller used for fine finishing shall be a heavy wheel roller with 18,000 to 25,000 lb. wheel loads and tire inflation pressures in excess of 65 psi.

a3. Smooth Drum Roller: The Smooth Drum Roller used for compaction and fine finishing shall be a 3-axle tandem roller with a minimum weight in the range of 15 to 20 tons. Heavy rollers with a weight over 20 tons are acceptable.

b. Compaction:

b1. Compaction shall be accomplished using heavy sheepsfoot rollers.

b2. Compaction equipment shall pass over the soil liner a sufficient number of times to maximize compaction. Each lift shall receive a minimum of 5 passes of a footed roller. Additional passes shall be made as necessary to blend the soil, break up clods, and obtain the specified degree of compaction.

b3. The clay shall be compacted to at least the minimum dry density specified in Table 1.

b4. If a compacted lift fails to meet the specified density, the clay shall either be compacted further or removed and replaced. If a density/moisture content test of the clay fails to meet specifications, the clay shall be scarified, the moisture content adjusted, and the material recompacted for an area extending from the failed test to one-half the distance to the nearest passing tests, in all directions. The Contractor shall alter compaction methods of subsequent work as necessary to obtain the specified compaction. The recompacted area shall then be retested for conformance with specifications.

b5. Compaction of bottom crowned sections shall start by rolling at the sides and proceed toward the center of the crowned section.

b6. Compaction of sloped areas shall start longitudinally at the low side and proceed toward the high side.

b7. Alternate trips of rollers shall be slightly different in length and shall overlap on successive trips by at least one-half of the width of the roller unit.

b8. After compaction of a lift is completed, the surface shall be smoothed using a rubber-tired breakdown roller or a heavy steel smooth drum roller to provide protection against over moistening during a rainfall and provide a smooth surface so that Construction Quality Control Tests can be made.

304.8 Fine Finishing of the Lining Surface:

a. After the lining has been brought to its final thickness and lift compaction is complete, the surface of the lining shall be fine finished as follows:

a1. Visually inspect the surface, remove clods and stones that would be retained on a 3/4 inch sieve.

a2. Irregularities such as desiccation cracks and holes shall be corrected. Soil from irregularities, which cannot be corrected in-place, shall be removed and replaced with acceptable material.

a3. Shape the lining and form a flat uniform working surface free of bumps, ridges, gullies, holes, ruts, desiccation cracks or pockets of non-cohesive material.

a4. Compact the surface using a heavy rubber-tired roller or a heavy smooth steel drum roller to obtain a smooth, uniform surface. The last two passes of the surface shall be made using a heavy smooth steel drum roller.

b. The finished compacted surface of the clay liner shall be placed to the locations and elevations shown on the design drawings. Tolerances shall be as shown in Table 2.

304.9 Protection of Liner:

a. The Contractor shall make provisions to protect the liner until the geomembrane is in place. Protection shall be provided against over-moistening or erosion during rainfall or cracking resulting from desiccation or freezing.

b. If soft spots, subsidence or cracks larger than 1 inch wide or 2 inches deep occur in the clay liner prior to placement of the protective cover, the Contractor shall be responsible for blading down the lining material to the unaffected soil and then preparing and recompacting the disturbed soil to meet the requirements specified herein.

305. PREPARATION OF SUBGRADE BENEATH GEOMEMBRANE LINER

305.1 Intersections Between Planes:

a. Intersections between planes shall be rounded as specified below to provide a firm bearing without abrupt change:

	Intersection of Slope	Radius of Rounding
a1.	Side slope and bottom plane	3 feet minimum
a2.	Side slope and top of dike or grade	6 inch minimum
a3.	Intersection of 2 bottom planes (planes sloped at 10% or less)	Straight line is acceptable

305.2 Responsibility:

a. The Contractor shall be responsible for preparing the surface of the subgrade beneath a geomembrane liner prior to placement of the liner. The subgrade is subject to inspection and acceptance by the Owner and the Geomembrane Liner Contractor prior to installation of the liner.

305.3 Inspection:

a. When requested by the Contractor, the Owner and the Geomembrane Liner Contractor shall inspect and document the following:

a1. Lines, grades and slopes are in conformance with the design drawings.

a2. Surface has been graded and rolled such that it is free of irregularities, protrusions, loose soil and abrupt changes in grade.

a3. The surface is free of debris, clods, stones, roots and organic material.

a4. That no settlement has occurred.

a5. That there are no side slope failures.

a6. That there are no moisture seeps, puddling or ponding.

a7. That there are no soft spots.

305.4 Certification:

a. The Geomembrane Liner Contractor shall provide written certification that the surface is acceptable. The acceptance shall be recorded and copies of the certification given to both the Contractor and the Owner.

b. Only as much surface as will be lined the following day shall be inspected, certified and documented as acceptable.

305.5 Geomembrane Liner Contractor's Responsibility:

a. After the surface has been accepted by the Geomembrane Liner Contractor, it becomes its responsibility and changes or repair work are this Contractor's responsibility. Requests for

changes or repair work to the subgrade by the Geomembrane Liner Contractor may be made through the Owner. The expense of such work shall be by the Geomembrane Liner Contractor.

306. ANCHOR TRENCH EXCAVATION AND BACKFILLING

306.1 Excavation and Shaping:

a. The anchor trench shall be excavated by the Contractor to the lines and widths shown on the design drawings, prior to geomembrane liner system placement.

b. A slightly rounded corner shall be provided in the trench where the geomembrane adjoins the trench to avoid sharp bends in the geomembrane. The radius of rounding is shown on the design drawings. No loose soil shall be allowed to underlie the geomembrane in the anchor trench.

c. The anchor trench shall be adequately drained to prevent ponding or otherwise softening of the adjacent soils while the trench is open.

306.2 Backfilling:

a. The anchor trench shall be backfilled by the Contractor after the geomembrane is in place.

b. Backfilling of the anchor trench shall occur during the morning or during extended periods of overcast skies when the liner is at its most contracted state.

c. Backfill shall be placed in layers not exceeding 6 inches loose thickness and compacted using hand compaction equipment to a minimum of 95 percent of the maximum dry density as determined by ASTM D698 at a recommended moisture content of optimum water content ±3%.

d. The material used for backfilling the first 8 inches of the anchor trench may be screened material from an onsite stockpile or material excavated from the trench which has a maximum size stone of 2 inches. The material used to backfill the remainder of the trench shall be material excavated from the trench which has a maximum stone size of 2 inches.

307. INSTALLATION OF PROTECTIVE GRAVEL LAYER

307.1 General Requirements:

a. Material for the protective cover shall be placed to the thickness shown on the design drawings.

b. Acceptable placement methods include:

b1. Using a crane to place material from outside of the pond.

b2. Transporting material into the pond to the point of dumping using trucks or scrapers.

c. Placement utilizing transportation of materials into the pond:

c1. Under no circumstance shall there be direct equipment travel over a geomembrane.

c2. A temporary ramp constructed with the protective gravel material shall be constructed into the pond at a location selected by the Contractor.

d. The ramp inside of the pond shall be constructed by craning-in sand to the base of the pond and spreading the material up the side slope, never down.

e. Trucks used to transport material inside of a pond over a lining shall be loaded such that a tandem axle load does not exceed 34,000 pounds or a tri-axle load does not exceed 42,500 pounds. Scrapers used to transport material inside of a pond shall have a maximum capacity of 15 cubic yards. The inflation pressure of tires on a scraper shall be reduced to the minimum pressure recommended by the manufacturer to maximize the tire contact area.

f. The minimum protective cover between a truck and the geomembrane liner shall be 24-inches on the bottom of the cell and 48-inches on the side slopes. The minimum depth of protective gravel layer between a 15 cubic yard scraper and the geomembrane liner shall be 36 inches on the bottom of the pond and 48 inches on the side slopes.

g. Trucks shall avoid hard braking on ramps and avoid sharp turns or quick stops that could pinch or tear the geomembrane.

h. The material shall be placed by the "dump and spread" method. Lightweight bulldozers or motor graders with low ground pressure shall be used for spreading material (Caterpillar D3 or wide track D6 or lighter).

i. No travel over piping shall be allowed without sufficient protection of the piping.

j. Material placement over the geomembrane liner during periods of warm weather can cause wrinkling in the liner. The wrinkling effect can cause damage to the liner. Placement of the protective gravel material shall be halted when the air temperature is greater than 85°F or less than 40°F.

k. When the protective gravel material is being placed, a worker shall walk alongside earthmoving equipment spreading the material to spot and remove all rocks, stones, roots, and other debris that remain in the material and that could cause damage to the liner.

307.2 Final Grading:

a. The protective gravel material shall be fine graded using equipment with low ground pressure.

b. Horizontal and vertical tolerances for the material shall be as specified in Table 2.

307.3 Report Damage:

a. If damage occurs in the geomembrane while placing the soil cover, the Contractor shall report it to the Owner immediately so that repairs can be performed without delay.

b. Repairs to a geomembrane shall be made by the Geomembrane Liner Contractor as specified in Section 319022, High Density Polyethylene Geomembrane Liner for a Single Lined Pond.

c. The Contractor shall be responsible for completion of all repair work at no additional cost to the Owner.

308. GRADING TOLERANCES

308.1 The acceptable deviation from lines and grades indicated on the design drawings shall be as shown in Table 2.

308.2 Slopes shall be finished in conformance with the lines and grades shown on the design drawings. When completed, the average plane of a slope shall conform to the slope indicated on the design

drawings and no point on the completed slope shall vary from the designated plane by more than 6 inches measured at right angles to the slope.

309. CLEAN-UP

309.1 All waste, excess materials and debris shall be disposed of in an onsite disposal area as directed by the Owner.

TABLE 1

MINIMUM DEGREE OF COMPACTION	
AREA	**ASTM D698 (percent)**
Subgrade Beneath Fills, Dikes and Clay Lining	95
Pond Dike	95
Clay Liner	95
General Site Fills	95

Notes:

(1) Structures include items such as equipment, buildings, pump structures, inlet and outlet structures, walls, and retaining walls and any other structures or equipment that are sensitive to settlement.

TABLE 2

ACCEPTABLE DEVIATION		
Type of Installation Excavation or Fill	**Maximum Acceptable Deviation From Line (Feet)**	**Maximum Acceptable Deviation From Grade(l) (Feet)**
General Earthwork		
Pond Dike and Top Edge of Excavated Ponds	±0.5	+0.25 to -0.0
Pond Bottom (Top of Liner) (2)	±0.3	±0.0 to ±0.l
General Site Area	±0.3	±0.2

Notes:

(1) After initial settlement has taken place. Initial settlement is that settlement that will occur up to the time of determination and acceptance of final grade elevation as approved by Owner.

(2) Zero minus tolerance for thickness.

END OF SECTION

SECTION 319022

HIGH DENSITY POLYETHYLENE GEOMEMBRANE LINER FOR A POND

PART 1 - GENERAL

101. EXTENT

101.1 This Specification Section defines the minimum requirements for material and installation of High Density Polyethylene (HDPE) Textured Geomembrane to be used as part of a composite liner system for the bottom and side slopes of a pond, all in accordance with the design drawings and as specified herein.

101.2 Work Included:

101.3 The Work shall include, but not be limited to, the following items:

a. Manufacture, shipping, handling, and storage of geomembrane materials.

b. Inspection and approval of surfaces to be lined.

c. Placement and field seaming of geomembrane.

d. Crest anchorage and attachment of the geomembrane to structures and penetrations.

e. Non-destructive field testing of geomembrane seams.

f. Removal of samples of geomembrane seams and transportation to an independent third-party laboratory for destructive testing.

g. Repair of defective geomembrane seams.

h. Repair of defects in the geomembrane and locations where samples were taken.

i. Visual inspection of the completed geomembrane liner.

101.4 Definition of Terms:

a. The following definition of terms shall apply throughout this section.

a1. Owner: Cardinal Operating Company

a2. Earthwork Contractor: The Earthwork Contractor is responsible for earthwork for the facility and for excavation and backfill of crest anchorage trenches.

a3. Geomembrane Contractor: The Geomembrane Contractor is responsible for supply and installation of all geomembrane and geotextile materials and unloading and storage of the materials.

a4. Construction Quality Assurance (CQA) Contractor: The Contractor who is responsible for all CQA work.

a5. Construction Quality Assurance (CQA) Geomembrane Inspector: An inspector who works for the CQA Contractor and is responsible for inspection of the Geomembrane Contractor's work.

a6. Manufacturer: The Manufacturer who is responsible for manufacture of materials and for transporting materials to the site.

101.5 Qualifications:

a. Manufacturer:

a1. The Manufacturer shall be approved by the Owner.

b. Geomembrane Contractor:

b1. The Geomembrane Contractor shall be approved by the geomembrane Manufacturer for installation of the Manufacturer's products.

b2. The Geomembrane Contractor shall be approved by the Owner.

102. RELATED WORK SPECIFIED IN OTHER SECTIONS

102.1 The work specified in this Section shall be coordinated with work specified in the following related Sections:

a. Section 311521 – Non-Woven Geotextiles.

b. Section 319005 – Earthwork and Clay Lining for a Clay/Geomembrane Composite Lined Pond.

103. REFERENCE DOCUMENTS

103.1 Standards, specifications, manuals, codes and other publications of nationally recognized organizations and associations are referenced herein. Methods, equipment and materials specified herein shall comply with the specified and applicable portions of the referenced documents, in addition to federal, state or local agencies having jurisdiction.

103.2 References to these documents are to the latest issue date of each document, unless otherwise indicated, together with the latest additions, addenda, amendments, supplements, etc., thereto, in effect as of the date of Contract for the Work.

103.3 Abbreviations listed indicate the form used to identify the reference documents in the Specification Section text.

103.4 ASTM – ASTM International:

a. A276 - Specification for Stainless Steel Bars and Shapes.

b. B633 - Specification for Electrodeposited Coatings of Zinc on Iron and Steel.

c. D638 - Test Method for Tensile Properties of Plastics.

d. D698 - Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort.

e. D792 - Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement.

f. D1004 - Test Method for Tear Resistance of Plastic Film and Sheeting.

g. D1505 - Test Method for Density of Plastics by the Density-Gradient Technique.

h. D1603 - Test Method for Carbon Black Content in Olefin Plastics.

i. D3895 - Test Method for Oxidative-Induction Time in Polyolefins by Differential Scanning Calorimetry.

j. D4218 - Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique.

k. D4833 - Test Method for Index Puncture Resistance of Geomembranes and Related Products.

l. D5397 - Test Method for Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Test.

m. D5596 - Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics.

n. D5641 - Standard Practice for Geomembrane Seam Evaluation by Vacuum Chamber.

o. D5721 - Standard Practice for Air-Oven Aging of Polyolefin Geomembranes.

p. D5820 - Standard Practice for Pressurized Air Channel Evaluation of Dual Seamed Geomembranes.

q. D5885 - Test Method for Oxidative Induction Time of Polyolefin Geosynthetics by High-Pressure Differential Scanning Calorimetry.

r. D5994 - Test Method for Measuring Core Thickness of Textured Geomembrane.

s. D6392 - Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods.

t. D7238 - Test Method for Effect of Exposure of Unreinforced Polyolefin Geomembrane Using Fluorescent UV Condensation Apparatus.

u. D 7466 - Test Method for Measuring Asperity Height of Textured Geomembranes.

103.5 GRI – Geosynthetic Research Institute:

a. GM 6 – Pressurized Air Channel Test for Dual Seamed Geomembrane.

b. GM 10 – The Stress Crack Resistance of HDPE Geomembrane Sheet.

c. GM 13 – Test Methods, Test Properties and Testing Frequency for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes.

d. GM 14 – Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using the Method of Attributes.

104. SUBMITTALS

104.1 Contractor shall submit the drawings and data as specified below within 30 days prior to use. Contractor's drawings and data shall be submitted via electronic medium in a format compatible for importing into the Owner's information systems specified by the Owner.

104.2 Contractor shall submit status reports at regular intervals as specified by the Owner. The reports shall indicate the status of the schedule. The reports shall be submitted via electronic medium in a format compatible for importing into the Owner's information system specified by the Owner.

104.3 Submittals with the Bid Proposal:

a. HDPE Geomembrane Material:

a1. Certification of Compliance from the Manufacturer of the HDPE geomembrane sheeting signed by its authorized representative, indicating that the material meets the criteria specified herein.

a2. One representative sample of each type of geosynthetic material.

a3. Manufacturer's Quality Control and Quality Assurance Policies and Procedures.

b. Warranty:

b1. Written warranties from the Manufacturer and the Geomembrane Contractor covering the quality of the material and workmanship as specified.

b2. The minimum period of warranty for materials shall be 20 years with first year non-prorated. The minimum period of warranty for installation shall be 5 years with the first year non-prorated.

b3. Warranty conditions proposed, including limits of liability, will be evaluated by the Owner in approving the liner Manufacturer and the Geomembrane Contractor.

c. Geomembrane Contractor:

c1. Geomembrane Contractor's name, address and telephone number.

c2. Geomembrane Contractor's qualifications.

c3. Installer's qualifications if the Geomembrane Contractor is proposing to subcontract installation work.

d. Testing Laboratory:

d1. Name, address, and telephone number of the off-site, independent third-party laboratory that will perform destructive testing on cut samples of field seams.

d2. Laboratory's qualifications.

104.4 Submittals After Award of the Contract:

a. Geomembrane Resin:

a1. Manufacturer's signed Certificate that the resin meets specification requirements.

a2. Manufacturer's signed Certification of the origin of the resin and that all resin is from the same manufacturer (Contractor's name, identification brand name, and number).

a3. Copies of Manufacturer and resin suppliers' QA/QC certificates. Certificates shall include a summary report of test results conducted to verify the quality of the resin used in each batch used to manufacture geomembrane for this project. As a minimum, the report shall include tests on specific gravity, melt flow index and percent carbon black.

b. Geomembrane Sheeting:

b1. Signed certification that the properties of the manufactured sheeting meet specification requirements and are guaranteed by the Manufacturer.

b2. Statement certifying that no post consumer resin (PCR) has been added to the formulation.

b3. Copy of all of the geomembrane Manufacturer's Quality Assurance certificates. The certificates shall include documents of test results.

c. Extrudate Resins or Rod for Seaming Geomembranes:

c1. Certification that all extrudate is the same resin type as the geomembrane and was obtained from the same resin supplier as the resin used to manufacture the geomembranes.

d. Installation Data:

d1. Manufacturer's proposed geomembrane panel layout for each installation.

d2. Manufacturer's recommended procedures for making and testing seams if different from this specification.

d3. Manufacturer's recommended procedures for repairing damaged geomembrane sections and seams if different from this specification.

d4. Manufacturer's details of geomembrane liner anchorage, and attachment to structures and penetrations if different from this specification and the details on the design drawings.

104.5 Submittals After Construction is Complete:

a. Geomembrane Contractor:

a1. As-built panel layout.

a2. Drawing showing location of repairs and type of repairs made.

a3. Location of destructive tests.

a4. Results of destructive tests.

a5. Results of non-destructive tests.

105. QUALITY ASSURANCE

105.1 Materials and construction procedures shall be subject to inspection by a Construction Quality Assurance (CQA) Testing Service employed by the Owner.

PART 2 - PRODUCTS

201. HIGH DENSITY POLYETHYLENE GEOMEMBRANE

201.1 Manufacturers of HDPE Geomembrane Products:

a. The products of the following manufacturers meeting the requirements herein are acceptable:

a1. Agru America Manufacturing, Inc., 500 Garrison Road, Georgetown, SC 29440, Tel.: 800-373-2478.

a2. Poly-Flex, 2000 W. Marshall Drive, Grand Prairie, TX 75051, Tel.: 888-765-9359.

a3. GSE Lining Technology, Inc., 19103 Gundle Road, Houston, TX 77073, Tel.: 281-443-8564 or 800-435-2008.

a4. Other as approved by the Owner.

201.2 HDPE Geomembrane - General Requirements:

a. The HDPE geomembrane shall be manufactured from first quality, virgin resin. Blending of resins shall not be allowed. No recycled or reworked geomembrane may be used except edge trim generated during the manufacturing process (no more than 10%). No post consumer resin (PCR) of any type shall be added to the formulation

b. The resin used to produce the geomembrane shall be formulated to be resistant to chemical and ultraviolet degradation.

c. The geomembrane shall be free of plasticizers.

d. The geomembrane shall be free of leachable additives.

e. During manufacture, each roll of geomembrane shall be continuously monitored across the width to assure uniformity of thickness. Thickness measurements shall meet the requirements of Table 1 for Textured Geomembrane.

f. The geomembrane shall be free of factory seams.

g. The geomembrane shall be free from dirt, oil, foreign matter, scratches, cracks, creases, bubbles, blisters, pits, tears, holes, pores, pinholes, voids, undispersed raw material, any sign of contamination or other defects that may affect serviceability, and shall be uniform in color, thickness and surface texture.

h. The geomembrane shall be capable of being seamed in the field to yield seams that are as resistant to waste liquids as the sheeting.

i. The geomembrane shall be manufactured in the United States or Canada.

201.3 HDPE Textured Geomembrane:

a. HDPE Textured Geomembrane shall meet the requirements of Table 1.

b. The location of HDPE Textured Geomembrane to be used for each installation shall be as shown on the design drawings.

c. The textured liner shall be manufactured using a co-extrusion process.

d. The textured coating shall be applied to both sides of the base sheet.

e. Textured geomembrane shall have uniform texturing appearance. It shall be free from agglomerated texturing material and such defects that would affect the specified properties of the geomembrane.

f. Each roll shall have 6-inch-wide smooth edges to provide suitable seaming surfaces. Textured geomembrane without smooth edges may be provided if approved by the Owner.

201.4 Smooth HDPE Geomembrane:

a. Smooth HDPE Geomembrane shall meet the requirements for HDPE Textured Geomembrane and the requirements of Table 1 with the exception of requirements associated with D7466 - asperity height.

b. The location of Smooth HDPE Geomembrane to be used for each installation shall be as shown on the design drawings.

TABLE 1

HIGH DENSITY POLYETHYLENE TEXTURED GEOMEMBRANE REQUIREMENTS[1]

Property	Test Method	Polyethylene Base Compound	GEOMEMBRANE MINIMUM AVERAGE ROLL VALUE	Testing Frequency
Nominal thickness, mil	--	--	60	---
Resin Properties				
Oxidative Induction Time (OIT), minimum average minutes			--	
Standard OIT or	D3895	100		200,000 lbs. of Resin
High Pressure OIT	D5885	400	--	200,000 lbs. of Resin
Oven Aging at 85° C	D5721	--	--	
Standard OIT (min avg), percent retained after 90 days or	D3895	55	--	one per formulation
High Pressure OIT (min avg), percent retained after 90 days	D5885	80	--	one per formulation
High Pressure OIT (min avg), percent retained after 1600 hrs.	D5885	50	--	one per formulation
Analytical Properties				
Density of base resin, g/cc minimum	D1505/D792	0.932	--	200,000 lbs. of Resin
Carbon black content, %	D1603 or D4218	2.0-3.0	--	20,000 lbs. of Resin
Carbon black dispersion for 10 different views	D5596	All 10 in Categories 1,2 & 3	--	45,000 lbs. of Resin
Mechanical Properties				
Thickness, mils	D5994	--	--	One per roll
Minimum Average		--	51	
Lowest individual for 8 out of 10 values		--	54	
Lowest individual for 10 out of 10 values		--	51	
Asperity Height, mils (min avg)	D7466	--	10	Every second roll
Tensile properties, in each direction (minimum average)	D638 (Type IV Specimen at 2 ipm)			
Tensile stress at yield, ppi minimum		--	126	20,000 lbs. of Resin
Elongation at yield, % minimum		--	12	20,000 lbs. of Resin
Tensile stress at break, ppi minimum		--	90	20,000 lbs. of Resin
Elongation at break, % minimum 2" gage length		--	100	20,000 lbs. of Resin
Tear resistance, lb. (minimum avg)	D1004	--	42	45,000 lbs. of Resin
Puncture resistance, lb. (minimum avg)	D4833	--	90	45,000 lbs. of Resin
Bonded seam strength[2]	D6392	--	--	
Shear strength, ppi		--	121	
Peel adhesion (fusion), ppi		--	98	
Peel adhesion (extrusion), ppi		--	78	
Environmental and Aging				
Effect on Properties				
Stress Crack Resistance, hours (min)	D5397	--	200	per GRI GM 10

Notes:

1. Requirements shown in this table meet the minimum requirements of GRI Standard GM 13, April 11, 2011 except for bonded seam strength.
2. Seam requirements.

201.5 Panel Layout:

a. Prior to manufacture of the geomembrane, a panel layout of the surface to be lined shall be made. Each panel to be used for the installation shall be given a numeric or alphanumeric identification number.

b. The panel identification number shall be related in writing to the manufacturing roll number that identifies the resin type, batch number, and date of manufacturer.

c. The panel layout shall be made considering the following requirements:

c1. Panel lengths shall include slope gain and anchorage.

c2. Perpendicular tie-ins shall be made a minimum of 5 feet beyond the toe of the slope.

c3. A minimum of 6-inch overlap shall be allowed at double fusion welded seams.

c4. All field seams on slopes shall be oriented parallel to the slope (oriented along, not across the slope).

c5. The number of seams in corners or odd shaped geometric locations shall be minimized.

201.6 Packaging and Shipping:

a. The geomembrane shall be shipped to the project site in rolls. No material shall be folded.

b. A label shall be attached or adhered to each roll of the geomembrane identifying the following:

b1. Manufacturer.

b2. Product Identification, which can be traced back to the origin of the base material (resin supplier's name, resin production plant, resin brand name type, resin brand number, and production date of the resin).

b3. Date of manufacture of the geomembrane.

b4. Roll identification number.

b5. Geomembrane thickness and type.

b6. Roll dimensions (length and width).

b7. Batch number.

b8. Order number.

b9. Panel number.

201.7 Packaging and Transportation:

a. Packaging and transportation shall be the responsibility of the Manufacturer, who shall retain responsibility until the geomembrane is accepted at the site by the Geomembrane Contractor.

202. MATERIALS FOR ATTACHMENT OF GEOMEMBRANE TO CONCRETE

202.1 Batten Strip:

a. Batten strip material shall be hot rolled, annealed and pickled Type 306 L stainless steel in accordance with ASTM A276.

b. Strips shall be ¼ inch thick by 2 inches wide. Random lengths are acceptable.

202.2 Expansion Anchors:

a. Expansion anchors shall be stud type with a single piece three section wedge and zinc plated in accordance with ASTM B633. Wedges shall be manufactured from ANSI Type 304 stainless steel. Hilti Kwik Bolt 3 Expansion Anchors, or equal, are acceptable.

b. Minimum yield strength of 60,000 psi for wedge-type anchors and a minimum tensile strength of 65,000 psi for stud type anchors.

c. Anchors shall be 3/8 inch diameter by 3 1/2 inch long.

d. Washers for anchors shall be Type 18-8 stainless steel flat washers for 3/8 inch bolt size.

202.3 Neoprene Gasket:

a. Neoprene gaskets shall be 1/4 inch-thick by 2-inches wide closed cell neoprene sponge sealing strips. Operating temperature range of neoprene shall be –40°F to +220°F.

b. Neoprene gaskets placed against concrete shall have a pressure sensitive adhesive on the side of the gasket placed against the concrete.

202.4 Mechanical Anchorage:

a. Extruded HDPE mechanical anchorage, set in cast-in-place concrete structures for liner attachment, shall be per Manufacturer's standard.

PART 3 - EXECUTION

301. ONSITE HANDLING AND STORAGE

301.1 Receipt/Unloading:

a. Unloading and storage of materials shall be the responsibility of the Manufacturer.

b. The unloading and other handling of materials shall be performed by the Manufacturer to ensure that the material is handled with care and not damaged.

301.2 Storage:

a. The Contractor shall provide on-site storage space in a location near the area to be lined such that on-site transportation and handling are minimized. The Manufacturer shall be responsible for protecting stored material from theft and vandalism.

b. The rolls of geomembrane shall be placed on a smooth surface free of rocks and standing water.

301.3 Inspection:

a. Upon delivery of the material to the project site, the Geomembrane Contractor shall conduct a visual inspection of all rolls of geomembrane for damage or defects. This inspection shall be done without unrolling any rolls unless damage to the inside of a roll is found or suspected.

b. Any damage or defects shall be noted and immediately reported to the Owner, the Manufacturer and to the carrier that transported the material. Any roll or portion thereof, which, in the judgement of the Owner, is seriously damaged, shall be removed from the project site and replaced with complying material at no additional cost to the Owner.

302. PREPARATION OF SURFACES TO BE LINED

302.1 General:

a. The Earthwork Contractor shall be responsible for preparing and maintaining the surfaces to be lined as specified in Section 319005, Earthwork and Clay Lining for a Clay/Geomembrane Composite Lined Pond, prior to placement of the geomembrane.

b. The Geomembrane Contractor shall confirm the conditions of the finished surfaces to be lined prior to placement of the liner.

302.2 Grading Requirements:

a. The subgrade surface on which a lining is to be placed shall be graded to elevations shown on the design drawings. Tolerances shall be as specified in Section 319005, Earthwork and Clay Lining for a Clay/Geomembrane Composite Lined Pond.

302.3 Preparation of Concrete Surfaces:

a. All portions of concrete walls, curbs and foundations that will come in contact with a geomembrane shall be free of sharp edges or rough spots that can puncture or abrade the geomembrane. Where necessary, the concrete shall be ground smooth by the Earthwork Contractor. Where specified on the design drawings, one or more layers of geomembrane scuff strips shall be placed between the concrete and the geomembrane to act as a protective layer for the liner.

302.4 Subgrade Acceptance:

a. See Section 319005, Earthwork and Clay Lining for a Clay/Geomembrane Composite Lined Pond, regarding inspection and acceptance of surfaces to be lined.

302.5 Geotextile:

a. See Section 311521, Non-Woven Geotextiles, regarding installation, inspection, and acceptance of a geotextile used to protect the geomembrane liner.

303. FIELD PLACEMENT OF THE GEOMEMBRANE LINER

303.1 General Requirements:

a. Placement Procedure: The placement procedure used for the geomembrane liner shall include the conditions listed below.

b. Weather:

b1. Geomembrane shall not be placed when the air temperature is above 104°F or below 41°F unless it can be demonstrated to the approval of the Owner by trial welds that acceptable welds can be made at the prevailing temperature. Trial welds shall be as described in Paragraph 303.2.c.

b2. Geomembrane shall not be placed when there is any rainfall or snowfall, in the presence of excessive moisture due to fog or dew, in ponded water, on a frozen subgrade, or during high winds.

c. Panel Layout:

c1. The panels shall be placed in accordance with the Manufacturer's panel layout drawing to ensure that they are placed in the proper direction for seaming.

c2. If panels are installed in a location other than indicated on the panel layout drawing, the revised location shall be indicated on an "as-built" layout drawing. The "as-built" record drawing shall be submitted to the Owner at the completion of the project.

d. Panel Deployment:

d1. Only the panels that can be anchored and seamed together in one shift shall be unrolled.

d2. Unroll and layout panels in as close to the final position as possible. Pulling geomembrane panels should be minimized to reduce the chance of permanent tension.

d3. The methods and equipment used to deploy the panels shall not damage the geomembrane or the supporting surface.

d4. Wrinkles shall be minimized. However, enough slack shall be provided in both directions so that there will be no tension in the geomembrane at the lowest expected operating temperature.

e. Precautions to Prevent Wind Damage:

e1. If possible, work shall be oriented in the direction of the prevailing wind.

e2. Provide adequate temporary loading and/or anchoring of the geomembrane by the use of sandbags, tires or other means which will not damage the geomembrane, to prevent uplift of the geomembrane by wind.

f. Other Precautions to Prevent Damage:

f1. Protection of the geomembrane from damage due to foot traffic on the slopes shall be provided.

f2. Provisions of facilities for safe entrance and egress of employees from sloped depressions is required.

g. Replacement of Damaged Geomembrane:

g1. Any area of a panel, which, in the judgement of the Owner, becomes seriously damaged (torn, twisted, or crimped permanently) shall be replaced at no additional cost to the Owner.

303.2 Field Seaming:

a. Method of Seaming:

a1. The primary welding procedure for seams shall be double wedge fusion welding.

a2. Extrusion welding shall be used only for repairs, detail work, and for seaming where double wedge fusion welding is not possible.

a3. The rods used for extrusion welding shall be the same type of resin as the geomembrane, unless otherwise approved by the Owner.

a4. The use of solvents or adhesives is not permitted.

b. General Requirements for Seaming:

b1. On slopes steeper than 10 horizontal to 1 vertical, seams shall be oriented parallel to the line of maximum slope (oriented up and down, not across the slope) when possible. No seams oriented across the slope shall be used unless approved by the Owner.

b2. Seams parallel to the toe of the slope shall be located a minimum of 5 feet from the toe.

b3. Seams parallel to the crest of the slope shall be located a minimum of 2 feet from the crest.

b4. Seams on the floor of the pond shall be overlapped so that the upslope sheet is positioned above the downslope sheet.

b5. Seaming shall extend to the outside edge of panels to be placed in the anchor trench. Seams at sheet corners of three or four sheets shall be completed with a patch having a minimum dimension of 24 inches, and extrusion welded to the parent sheets.

b6. All cross seams between the two rows of seamed panels shall be welded during the coolest time of the day to allow for contraction of geomembrane.

c. Trial Welds Prior to Beginning Seaming:

c1. Trial welds are required for pre-qualification of personnel, equipment and procedures for making seams on identical geomembrane material under the same climatic conditions as the actual field production seams will be made.

c2. Trial welds shall be made as follows:

c2.1 Prior to each seaming period.

c2.2 Every 4 to 5 hours.

c2.3 Whenever personnel or equipment are changed.

c2.4 When climatic conditions result in wide changes in geomembrane temperature.

c2.5 When requested by CQA Geomembrane Inspector for any seaming crew or piece of welding equipment if problems are suspected.

c3. Once qualified by passing a trial weld, welding technicians shall not change parameters without performing another trial weld.

c4. Trial welds shall be made on both double wedge fusion welds and on extrusion welds.

c5. A test strip shall be prepared by joining two pieces of geomembrane, each piece shall be at least 6 inches wide. The length of double wedge fusion welded seams shall be a minimum of 10 feet long. The length of an extrusion welded seam shall be a minimum of 4 feet long. The CQA Geomembrane Inspector shall witness the fabrication of each test strip.

c6. All test welds shall be tested by destructive testing. Testing can be done as soon as the seam cools.

c7. A minimum of three (3) one (1) inch wide sample strips shall be cut from each test strip, one from each end and one from the middle. The location of each sample shall be selected by the CQA Geomembrane Inspector. The test strips shall be tested in peel at 2 inches per minute using a field tensiometer. The CQA Geomembrane Inspector shall witness all tests.

c8. If any of the test specimens fail, a new test strip shall be fabricated and the tests repeated for the new strip. If additional specimens fail, the seaming apparatus and the seamer shall not be accepted and shall not be used for seaming until the deficiencies are corrected and successful trial welds have been achieved.

c9. The trial weld is considered acceptable if, when tested for peel adhesion using the field tensiometer, all three specimens meet the criteria specified in Table 1 for both peel and shear under Bonded Seam Strength, or the three specimens exhibit Film Tear Bond (FTB) (yielding of the parent material before seam failure). In the case of double wedge fusion welded seams, both welds must pass in order to be considered acceptable.

c10. If the specimens pass the tests, production seaming operations can begin.

c11. The Contractor shall document all data on each trial weld, including:

c11.1 Date.

c11.2 Time.

c11.3 Operator.

c11.4 Machine number.

c11.5 Ambient temperature.

c11.6 Operating temperature.

c11.7 Speed setting.

c11.8 Pass/Fail designation.

d. Preparation for Seaming:

d1. Prior to seaming, the surface of the geomembrane shall be wiped with a clean cloth to ensure that it is clean and free from moisture, grease, dust, dirt, and debris of any kind before seam welding is started.

d2. The panels shall be adjusted so that the seams are aligned to eliminate wrinkles and fish mouths. Where necessary, fish mouths and wrinkles shall be cut to achieve flat overlap.

e. Seaming:

e1. Seaming shall be performed in accordance with the Manufacturer's accepted procedure.

e2. Double Wedge Fusion Welds:

e2.1 The panels shall be overlapped a minimum of 6 inches prior to welding.

e2.2 Vehicle mounted automated hot wedge welding apparatus shall be used to make the seam.

e3. Extrusion Fillet Welding:

e3.1 Geomembrane overlap shall be a minimum of 3 inches for extrusion welding.

e3.2 Geomembrane panels shall be temporarily bonded using a hot air device prior to extrusion welding.

e3.3 The edge of the geomembrane to be fillet welded shall be pre-beveled before heat-tacking the seam in place.

e3.4 The seam overlap shall be ground (abraded) no more than one hour prior to welding.

e3.5 Grinding shall be performed in accordance with the Manufacturer’s instructions in a manner that does not damage the geomembrane.

e3.6 Grinding shall not extend more than 1/4 inch past the area to be covered with extrudate during welding.

e3.7 All grind marks shall be covered with extrudate.

e3.8 Geomembrane overlap shall be a minimum of 3 inches for extrusion welding.

303.3 Non-Destructive Field Testing – Geomembrane:

a. General:

a1. All non-destructive field testing shall be performed and documented by the Geomembrane Contractor.

a2. The CQA Geomembrane Inspector shall observe all non-destructive test procedures.

a3. One hundred percent (100%) of the seam length shall be tested using non-destructive procedures to check the continuity of the field seams. Non-destructive testing is not meant to qualify seam strength.

a4. Air pressure testing shall be performed in accordance with ASTM D5820 and GRI GM 6.

a5. Vacuum Box testing shall be performed in accordance with ASTM D5641 and as specified herein.

a6. Continuity testing shall be performed as seaming progresses or as soon as a suitable length of seam is available, not at the completion of all field seaming.

b. Double Wedge Fusion Welded Seams:

b1. Double fusion welded seams shall be tested using air pressure testing.

b2. The procedure for testing shall be as specified in GRI GM 6 for the type and thickness of geomembrane in use.

b3. The following test pressures are applicable to both smooth and textured HDPE. After an initial 2-minute pressure stabilization period, the pressure shall be maintained between 24 and 30 psi for 40 mil HDPE, 27 and 30 psi for 60 mil HDPE, and 30 and 35 psi for 80 and 100 mil HDPE. The pressure shall be sustained for a minimum of 5 minutes. The loss of pressure shall not exceed a maximum of 3 psi in 5 minutes. If the pressure does not stabilize in the first two minutes or the pressure loss exceeds the loss specified, the seam test shall be considered a failure.

b4. The leak or suspected leak shall be located and repaired.

b5. The repaired seam shall be re-tested as required until all leaks are identified, and repaired, and the seam passes a subsequent air pressure test.

b6. When the geometry of a double wedge fusion weld makes air testing impossible or impractical, vacuum testing may be used to test the seam.

c. Extrusion Welded Seams:

c1. Extrusion welded seams shall be tested using vacuum chamber testing in accordance with ASTM D5641.

c2. The completed seam shall exhibit no leakage when tested between 4 and 8 psi minimum vacuum for approximately 10 seconds.

c3. If leaks are discovered during testing, they shall be located, marked, and repaired.

c4. The repaired area shall be re-tested and exhibit no leakage.

d. Inaccessible Seams:

d1. Where extrusion welded seam locations make use of vacuum box testing impractical, then the electric wire method of testing shall be used or the seam shall be cap stripped as approved by the Owner.

d2. If cap stripping is approved by the Owner, the seams shall be cap stripped as described in Paragraph 304.4, with strips of the same type and thickness of geomembrane being installed. The cap stripping shall be performed in the presence of the Owner.

d3. The electric wire test method shall consist of placing a 24-gauge copper wire 1/8 inch beneath the top sheet overlap of the two sheets prior to welding with the extruder. The wire shall be imbedded in the seam. After welding, a holiday spark detector, operating at 20,000 volts, shall be connected

to one end of the wire and slowly moved over the length of the seam. A seam defect between the probe and the embedded wire shall result in an audible alarm indicating where the defect is located.

e. Test Reports:

e1. Test reports for all air pressure tests shall contain all data specified in ASTM D5820 and GRI GM 6.

e2. Test reports for vacuum box testing shall contain all the data specified in ASTM D5641.

e3. Test reports for other types of non-destructive tests shall contain as a minimum for each test:

e3.1 Location.

e3.2 Type of test.

e3.3 Test parameters.

e3.4 Test data.

e3.5 Test number.

e3.6 Name of tester.

e3.7 Outcome of the test.

303.4 Destructive Testing – Geomembrane:

a. Testing:

a1. Destructive testing shall be performed by an independent third-party laboratory employed by the Geomembrane Contractor on samples cut from production welds in the field by the Geomembrane Contractor.

a2. Samples shall be taken by the Geomembrane Contractor to the third-party laboratory and tested for shear strength and peel adhesion. For double wedge seam samples, both welds shall be tested for peel adhesion.

a3. The third-party laboratory that will perform testing shall be identified by the Geomembrane Contractor with the bid proposal and agreed-to in writing by the Owner.

b. Location and Frequency:

b1. Test locations shall be determined after seaming. The location where the test samples shall be taken shall be marked by the CQA Geomembrane Inspector. Locations may be prompted by the appearance of excessive heating, contaminations, offset welds, or a suspected defect. Destructive test samples shall be taken at a minimum average frequency of one per every 500 linear feet of seam length.

b2. The Method of Attributes described in GRI GM 14 may be exercised to minimize the number of test samples taken if more than 100 destructive seam samples will be required based on the sampling strategy given in Paragraph 303.4.b1.

b3. Each sample location shall be numbered and marked with permanent identification and the location of the sample and the locations shall be indicated on a plan drawing prepared and maintained by the Geomembrane Contractor. The following shall be recorded for each sample:

b3.1 Date and Time.

b3.2 Ambient Temperature.

b3.3 Seam Number and Location.

b3.4 Welding Apparatus Used.

b3.5 Name of Master Seamer.

b3.6 Reason for Taking the Sample.

b3.7 Size of Sample.

b3.8 Test Results.

b3.9 Name of Tester.

b4. Samples shall be cut by the Geomembrane Contractor. The CQA Geomembrane Inspector shall witness test sample cutting.

b5. Test samples shall be cut every shift and taken by the Geomembrane Contractor to the third-party laboratory the same day that the sample is prepared.

c. Sample Size:

c1. The minimum sample size shall be 12 inches wide with a seam 16 inches long centered length wise in the sample. As agreed to with Owner, a sample may be increased in size to accommodate the requirements of the testing laboratory.

d. Field Testing:

d1. A one-inch wide specimen shall be cut from each end of each sample for field testing.

d2. Each one-inch wide specimen shall be tested with a field tensiometer for peel adhesion.

d3. The CQA Geomembrane Inspector shall witness each field test.

d4. A test is considered acceptable if a specimen meets the criteria specified in Table 1 for both peel and shear under Bonded Seam Strength or, exhibits Film Tear Bond (FTB). For double wedge fusion welds, both welds must pass the test. If either sample fails the field test, it shall be assumed that the seam will not pass the specified laboratory testing and the sample shall be given a fail designation.

e. Laboratory Testing:

e1. Full size (12-inch minimum length) samples shall be taken to an independent third-party laboratory for testing.

e2. Samples shall be tested for shear strength and peel adhesion in accordance with ASTM D6392. Five specimens shall be tested for each test method. All samples shall meet minimum requirements for shear strength and peel adhesion given in Table 1 under Bonded Seam Strength.

f. Test Results:

f1. Verbal test results shall be given to the Geomembrane Contractor within 24 hours of receipt of the samples. Written results shall follow within one week.

f2. All test locations shall be marked with a pass/fail designation on the liner and on the drawings maintained by the Geomembrane Contractor for submittal to the Owner after construction is complete.

g. Re-Testing if Failure Occurs:

g1. If a seam fails testing, one additional sample shall be taken 10 feet on each side of the location of the failed test. Additional samples shall continue to be taken at 10-foot intervals until tests show that seam strength is adequate and the zone in which the seam requires reconstruction is identified.

g2. All passing seams shall be bounded by two locations from which samples passing laboratory destructive tests have been taken.

g3. The entire seam length failing strength tests shall be reconstructed at no additional cost to the Owner.

g4. If the length of reconstructed seam exceeds 150 feet, a sample shall be taken of the reconstructed seam every 150 feet and shall pass destructive testing.

303.5 Inspection – Geomembrane:

a. After seaming is complete, the Geomembrane Contractor and the CQA Geomembrane Inspector shall conduct a detailed walk-down to visually check all seams and non-seam areas of the geomembrane.

b. All defects, holes, blisters, tears, signs of damage during installation, areas of undispersed carbon and holes from destructive or non-destructive testing shall be marked and repaired.

304. <u>REPAIR OF DEFECTS AND SEAMS - GEOMEMBRANE</u>

304.1 Patching:

a. Patching shall be used to repair large holes, tears and destructive sample locations.

b. All patches shall be round, oval, or shall have rounded corners.

c. All patches shall be made of the base geomembrane material and shall extend a minimum of 6 inches beyond the edges of the defect, or to the manufacturer’s recommended length.

d. Patches shall be extrusion welded to the base sheet.

304.2 Grinding and Welding:

a. Grinding and welding shall be used to repair sections of extruded fillet seams with small defects.

304.3 Spot Welding:

a. Spot welding shall be used to repair small tears, pinholes, or other minor localized flaws.

304.4 Capping:

a. When approved by the Owner, capping shall be used to repair lengths of extrusion welded seams with large defects and to repair double wedge fusion welded seams.

b. Cap strips shall be made with strips of the same type and thickness of geomembrane being installed. Strips shall extend a minimum of 6 inches beyond the weld, and shall have rounded corners.

c. Cap strips shall be extrusion welded to the base sheet.

304.5 Cut Out and Replacement:

a. When approved by the Owner, a length of defective seam may be cut out and replaced with a strip of new material seamed into place.

304.6 Verification of Repairs:

a. All repairs shall be non-destructive tested using one of the procedures described in Paragraph 303.3.

b. Repairs, which pass the non-destructive test, shall be deemed acceptable.

c. Repairs of a seam in excess of 150 feet in length shall have one destructive seam test per 150 feet in length.

305. CREST ANCHOR TRENCH EXCAVATION AND BACKFILLING

305.1 Excavation and Shaping:

a. Unless specified otherwise on the design drawings, the geomembrane liner shall be anchored in an anchor trench at the top of the slope. The anchor trench shall be excavated by the Earthwork Contractor to the lines and widths shown on the design drawings prior to placement of the liner.

b. A slightly rounded corner shall be provided in the trench where the geomembrane adjoins the trench to avoid sharp bends in the geomembrane. No loose soil shall be allowed to underlie the geomembrane in the anchor trench.

c. The anchor trench shall be adequately drained to prevent ponding or otherwise softening of the adjacent soils while the trench is open.

305.2 Backfilling:

a. Anchor trench backfill shall be placed as shown on the design drawings by the Earthwork Contractor.

b. Backfilling of the anchor trench shall occur during the morning or during extended periods of overcast skies when the liners are at their most contracted state.

c. Backfill shall be placed in layers not exceeding 4 inches loose thickness and compacted using hand compaction equipment to a minimum of 95% of the maximum dry density as determined by ASTM D698 at optimum water content ± 2%.

306. ATTACHMENT TO CONCRETE

306.1 Geomembrane shall be attached to concrete using batten strips in accordance with details on the design drawings.

307. ATTACHMENT TO PIPE PENETRATIONS

307.1 Geomembrane shall be attached to pipe penetrations through the lining in accordance with details on the design drawings.

307.2 Prefabricated or field fabricated HDPE sleeves (pipe boots) used for attaching the geomembrane to the pipe shall be supplied by the Manufacturer.

END OF SECTION

SECTION 319025

GEOSYNTHETIC CLAY LINER (GCL)

PART 1 – GENERAL

101. EXTENT

101.1 This technical specification section is applicable only if the Contractor proposes and the Owner accepts geosynthetic clay liner (GCL) as an alternate liner material.

101.2 The Contractor may propose use of GCL in lieu of the compacted clay liner component of the composite liner in the south impoundment. Any proposed use of GCL shall comply with this technical specification and be approved by the Owner.

101.3 This Specification Section defines the minimum requirements for material and installation of a GCL in accordance with the design drawings and as specified herein.

101.4 Work Included:

a. The work shall include, but not be limited to, the following items:

a1. Manufacturing, shipping, handling and storage of GCL.

a2. Preparation and inspection of surfaces to be lined.

a3. Placement and seaming of GCL.

a4. Sealing around penetrations.

a5. Patching and repairs.

a6. Visual inspection of the completed GCL.

102. DEFINITIONS, QUALIFICATIONS AND WARRANTY

102.1 Definition of Terms:

a. The following definitions of terms shall apply throughout this specification:

a1. Owner/Owner: Cardinal Operating Company

a2. Earthwork Contractor: The Contractor who will be responsible for earthwork, preparation of the subgrade, and excavation and backfill of anchorage trenches.

a3. GCL Contractor: The Contractor who is responsible for supply and installation of the geosynthetic clay liner.

a4. Testing Service: The Contractor who is responsible for all CQA work.

a5. Manufacturer: The Manufacturer who is responsible for manufacture of material and for transporting materials to the site.

102.2 Qualifications:

a. Manufacturer:

a1. The Manufacturer shall be compliant with the requirements of ASTM D5889 and be approved by the Owner.

b. GCL Contractor:

b1. The GCL Contractor shall be approved by the Geosynthetic Clay Liner Manufacturer for installation of the Manufacturer's products.

b2. The GCL Contractor shall be approved by the Owner.

c. Installer:

c1. The Installer shall be approved by the GCL Manufacturer if the GCL Contractor is subcontracting the installation work.

102.3 Warranty:

a. Written warranties from the Manufacturer and the GCL Contractor covering the quality of the material and workmanship as applicable.

b. The minimum period of warranty for materials shall be 5 years.

c. Warranty conditions proposed, including limits of liability, will be evaluated by the Owner in approving the GCL Manufacturer and the GCL Contractor.

103. RELATED WORK SPECIFIED IN OTHER SECTIONS

103.1 The work specified in this Section shall be coordinated with work specified in the following related Sections:

a. Section 311521 – Non-Woven Geotextiles.

b. Section 313716 – Riprap.

c. Section 319005 – Earthwork and Clay Lining for a Clay/Geomembrane Composite Lined Pond.

d. Section 319022 – High Density Polyethylene Geomembrane Liner for a Single Lined Pond.

104. REFERENCE DOCUMENTS

104.1 Standards, specifications, manuals, codes and other publications of nationally recognized organizations and associations are referenced herein. Methods, equipment and materials specified herein shall comply with the specified and applicable portions of the referenced documents, in addition to federal, state or local codes having jurisdiction.

104.2 References to these documents are to the latest issue date of each document, unless otherwise indicated, together with the latest additions, addenda, amendments, supplements, etc., thereto, in effect as of the date of Contract for the Work.

104.3 Abbreviations listed indicate the form used to identify the reference documents in the specification text.

104.4 ASTM – ASTM International:

a. D4643 – Standard Test Method for Determination of Water (Moisture) Content of Soil by Microwave Oven Method.

b. D5261 – Standard Test Method for Measuring Mass per Unit Area of Geotextiles.

c. D5887 – Standard Test Method for Measurement of Index Flux through Saturated Geosynthetic Clay Liner Specimens using a Flexible Wall Permeameter.

d. D5889 – Standard Practice for Quality Control of Geosynthetic Clay Liners.

e. D5890 – Standard Test Method for Swell Index of Clay Mineral Component of Geosynthetic Clay Liners.

f. D5891 – Standard Test Method for Fluid Loss of Clay Component of Geosynthetic Clay Liners.

g. D5993 – Standard Test Method for Measuring Mass per Unit of Geosynthetic Clay Liners.

h. D6243 – Standard Test Method for Determining the Internal and Interface Shear Resistance of Geosynthetic Clay Liner by Direct Shear Method.

i. D6496 – Standard Test Method for Determining Average Bonding Peel Strength Between Top and Bottom Layers of Needle-Punched Geosynthetic Clay Liners

j. D6768 – Standard Test Method for Tensile Strength of Geosynthetic Clay Liners

105. SUBMITTALS

105.1 Contractor shall submit drawings and data. Contractor's drawings and data shall be submitted via electronic medium in a format compatible for importing into the Owner's information systems specified by the Owner.

105.2 Submittals with Bid Proposal:

a. GCL Material:

a1. Documentation that the product proposed provides equal or better performance than the required clay liner component of a composite liner system in a Coal Combustion Residual surface impoundment.

a2. Copies of the Manufacturer's catalog data describing the GCL material proposed for use on this project.

a3. Copies of Manufacturer's QA certificates on tests performed on the material and a summary of results after the tests.

a4. Certification of Compliance from the Manufacturer of the GCL, signed by its authorized representative, stating that the liner material meets the specification requirements and that those requirements are guaranteed by the Manufacturer.

a5. Manufacturer's Quality Control and Quality Assurance Policies and Procedures.

b. GCL Contractor

b1. GCL Contractor's name, address and telephone number.

b2. GCL Contractor's qualifications.

b3. Installer's qualifications if the GCL Contractor is proposing to subcontract installation work.

105.3 Submittals Upon Shipment:

a. Four representative samples of the GCL.

b. Manufacturer's QA/QC certificates with each shipment of GCL. The QA/QC certificates shall include:

b1. GCL lot and roll numbers with corresponding shipping information.

b2. Manufacturer's test data for raw materials used in GCL production, including at a minimum, mass per unit area data and tensile test data.

b3. Manufacturer's test data for the finished GCL product, including at a minimum, clay mass per unit area data and tensile testing data.

b4. Certificates of analyses for the bentonite clay used in GCL production.

105.4 Submittals After Construction is Complete:

a1. Drawing showing location of repairs and type of repairs made.

a2. Executed warrantee documents.

106. QUALITY ASSURANCE

106.1 Materials and construction procedures shall be subject to inspection and testing by a Testing Service employed by the Owner. Such inspections and tests will not relieve GCL Contractor of the responsibility for providing materials and placing procedures in compliance with the contract requirements.

PART 2 - PRODUCTS

201. GEOSYNTHETIC CLAY LINER (GCL)

201.1 Approved GCL Manufacturers:

a. The products of the following manufacturers that meeting the requirements herein are acceptable:

a1. Colloid Environmental Technologies Co. (CETCO), Arlington Heights, IL.

a2. SOLMAX, Inc., Houston, TX.

a3. Others as approved by the Owner.

201.2 GCL General Requirements:

a. The GCL shall be a needle punched GCL. The GCL shall be manufactured by placing a uniform layer of high-swell sodium bentonite encapsulated between two geotextiles and then needle punching through both layers of the geotextile and the bentonite to push fibers from the non-woven geotextile cap through the bentonite layer and embed them in the geotextile scrim on the other side.

b. The upper and lower support materials shall protect the bentonite but shall be sufficiently porous to allow bentonite flow-through to create a positive bentonite-to-bentonite seal at the seams.

c. The support materials used in the manufacturing shall not interfere with the swelling, self-healing or low permeability characteristics of the GCL.

d. The GCL shall be fabricated such that bentonite will not be displaced when the liner is cut.

e. Six inch and nine or twelve inch overlap marks shall be marked longitudinally on both edges of the geotextile cap by the Manufacturer to assist in obtaining the proper overlap. The lines shall be printed in easily visible, non-toxic ink.

201.3 GCL Material Specifications:

a. The GCL materials shall meet the requirements listed below:

a1. Sodium Bentonite: The bentonite utilized in the manufacture of the GCL, as well as any accessory bentonite provided for seaming and detail work, shall be Wyoming-grade sodium bentonite with the properties listed below:

Property (2)	Test Method	Value	Min Testing Frequency (1)
Free Swell	ASTM D5890	24 ml/2g min	1/100,000 lb
Fluid Loss	ASTM D5891	18 ml (max A.R.V.)	1/100,000 lb
Moisture Content	ASTM D4643	12% max	1/100,000 lb

NOTES:

(1) In accordance with ASTM D 5889.

(2) Properties of the base bentonite prior to incorporation into the final GCL product.

a2. Geosynthetic Clay Liner: The finished GCL manufactured using a non-woven cap and a woven scrim shall have the following properties:

Property	ASTM Method	Value	Min Testing Frequency (1)
Geotextile Properties			
Non-Woven Cap	D5261	6.0 oz/yd^2	1/200,000 SF
Woven Scrim	D5261	3.1 oz/yd^2	1/200,000 SF
Finished GCL Properties			
Bentonite Mass/Area (psf)	D5993	0.75 lb/ft^2 (3.6 kg/m^2) MARV at 0% moisture	1/40,000 SF
Hydrated Internal Shear Strength	D6243	500 psf (24 kPa) typical	Periodic
Tensile Strength	D6768	30 lbs	1/40,000 SF
Peel Strength (2)	D6496	3.5 lb/in (6.1 N/cm)	1/40,000 SF

Property	ASTM Method	Value	Min Testing Frequency (1)
Index Flux at 5 psi maximum effective confining stress and 2 psi head	D5887	$1x10^{-8}$ $m^3/m^2/sec$ maximum	1/week
Hydraulic Conductivity (5 psi effective confining stress and 2 psi head)	D5887	$\leq 1x10^{-9}$ cm/sec maximum	1/week

NOTES:

(1) In accordance with ASTM D5889.

(2) Machine (warp) direction of primary backing.

a3. Geosynthetic Clay Liner: The finished GCL manufactured using both a non-woven cap and a non-woven scrim shall have the following properties:

Property	ASTM Method	Value	Min Testing Frequency (1)
Geotextile Properties			
Non-Woven Cap	D5261	6.0 oz/yd^2	1/200,000 SF
Non-Woven Scrim	D5261	6.0 oz/yd^2	1/200,000 SF
Finished GCL Properties			
Bentonite Mass/Area (psf)	D 5993	0.75 lb/ft^2 (3.6 kg/m^2) MARV at 0% moisture	1/40,000 SF
Hydrated Internal Shear Strength	D6243	500 psf (24 kPa) typical	Periodic
Tensile Strength	D6768	45 lbs	1/40,000 SF
Peel Strength	D6496	3.5 lb/in (6.1 N/cm)	1/40,000 SF
Index Flux at 5 psi maximum effective confining stress and 2 psi head	D5887	$1x10^{-8}$ $m^3/m^2/sec$ maximum	1/week
Hydraulic Conductivity (5 psi effective confining stress and 2 psi head)	D5887	$\leq 1x10^{-9}$ cm/sec maximum	1/week

NOTES:

(1) In accordance with ASTM D5889.

201.4 Packing and Shipping:

a. The finished GCL shall be completely wrapped and adequately secured with a durable polyethylene protective cover in order to provide protection from ultraviolet degradation of the Primary Backing Material (PBM) and excessive loss of moisture during shipping and storage.

b. The GCL shall be shipped to the project site in rolls.

c. A label shall be attached or adhered to each roll of the GCL identifying the following:

c1. Manufacturer.

c2. Product Identification (brand name, product code).

c3. Date of Manufacture.

c4. Roll Identification Number.

c5. Panel Number.

c6. GCL Thickness.

c7. Roll Dimensions (length, width and height).

c8. Lot Number.

c9. Order Number.

d. The GCL shall be stenciled throughout each roll with the product name and name of the Manufacturer, which can be cross-referenced to the roll number marked on the label and to the production and quality control data sheets.

202. BENTONITE SEALING COMPOUND (BSC) AND GRANULAR BENTONITE (GB)

202.1 The BSC and GB shall be supplied by the Manufacturer and shall be comprised of the same bentonite used in the manufacturing of the GCL. The BSC shall be a mixture of non-aqueous liquid suspension agents which creates a paste-like texture. The GB shall be furnished in 50 lb bags.

202.2 The suspension agents used in the manufacture of the BSC shall be non-toxic, water-soluble and shall not restrict the bentonite's ability to swell and absorb water upon hydration.

PART 3 - EXECUTION

301. ONSITE HANDLING AND STORAGE

301.1 Unloading:

a. Handling and unloading shall be the responsibility of the GCL Contractor.

b. Upon arrival at the site, the rolls of the GCL shall be carefully unloaded by the GCL Contractor in accordance with Manufacturer's recommendations.

301.2 Storage:

a. The Owner shall provide on-site storage space in a location near the area to be lined such that on-site transportation and handling are minimized. The GCL Contractor shall be responsible for protection of materials from theft and vandalism.

b. The rolls of GCL shall be stored horizontally in their original, unopened, wrapped cover in a clean, dry area. The material shall be stored off the ground on pallets or plywood in small stacks not to exceed five (5) rolls in height. The rolls shall be covered with a heavy, protective tarpaulin or plastic sheeting or enclosed within a storage facility. Care shall be used to keep the GCL clean and free from debris prior to installation.

c. Rolls shall be stacked in a manner recommended by the Manufacturer that prevents them from sliding or rolling from the stacks.

d. Any rolls that come in contact with moisture while in storage shall be set aside by the GCL Contractor to await examination by the Owner. Damaged rolls shall also be set aside and inspected to determine suitability of the material for use.

301.3 Inspection:

a. Upon delivery of the material to the project site, the GCL Contractor shall conduct a visual inspection of the polyethylene sleeves of all rolls of GCL for damage or rips or tears. Sleeve damage shall be repaired immediately with tape or additional plastic sheeting.

b. Any damage shall be noted and immediately reported to the Owner, the Manufacturer and to the carrier that transported the material. Any roll or portion thereof, which, in the judgement of the Owner, is seriously damaged, shall be removed from the project site and replaced with complying material at no additional cost to the Owner.

302. PREPARATION OF SURFACE TO BE LINED

302.1 The Earthwork Contractor shall be responsible for the initial preparing and maintaining of the surfaces to be lined as specified in the Section 319005, Earthwork and Clay Lining for a Clay/Geomembrane Composite Lined Pond, prior to placement of the GCL.

302.2 The GCL Contractor shall provide written certification to both the Earthwork Contractor and the Owner that the surface on which the GCL is to be installed is acceptable. The surface then becomes the responsibility of the GCL Contractor.

302.3 The surface upon which the GCL is to be placed shall be free of standing water and maintained in a firm, clean and smooth condition during liner installation.

303. FIELD PLACEMENT OF THE GEOSYNTHETIC CLAY LINER

303.1 Weather:

a. A GCL shall not be placed during a rainfall or snowfall, in ponded water or during high winds.

303.2 Panel Layout:

a. The panels shall be placed in accordance with the Manufacturer's panel layout drawing to ensure that they are placed in the proper direction for overlapping.

b. If panels are installed in a location other than indicated on the panel layout drawing, the revised location shall be indicated on an "as-built" layout drawing prepared by the GCL Contractor. The as-built record drawing of the panel layout shall be submitted to the Owner at the completion of the project.

304. PANEL DEPLOYMENT

304.1 The rolls of GCL shall be brought to the area to be lined with a front-end loader and support pipes set up such that the GCL roll is fully supported across its length and freely suspended so that it can unroll freely. The core bar and spreader bar shall not flex or bend excessively when a full roll is lifted.

304.2 Deploy only as much GCL as can be covered by the end of the day or in a reasonably short time in the event of precipitation.

304.3 The cap material (non-woven geotextile) shall face upwards, toward the Installer. The GCL shall be placed over the prepared surface in such a manner as to assure minimum handling. If the GCL is to be anchored, the anchor trench for the area to be lined shall be excavated before installation of the GCL begins.

304.4 Installation shall begin at a high elevation and proceed to a low elevation.

304.5 Pulling GCL panels shall be minimized to reduce the chance of permanent tension.

304.6 Wrinkles shall be minimized. However, enough slack shall be provided in both directions so that there will be no tension in the GCL at the lowest expected operating temperature.

305. PRECAUTIONS TO PREVENT WIND DAMAGE

305.1 If possible, work shall be oriented in the direction of the prevailing wind.

305.2 Provide adequate temporary anchoring of the edges of the exposed sheets using sandbags, tires or other means which will not damage the GCL to prevent uplift of the GCL by wind.

306. OTHER PRECAUTIONS TO PREVENT DAMAGE

306.1 Protection of the GCL from damage due to foot traffic on the slopes shall be provided.

306.2 Provisions of facilities for safe entrance and egress of employees from sloped depressions shall be provided.

307. FIELD SEAMING

307.1 General Requirements for Seaming:

a. Horizontal seams shall be located not less than five (5) feet from the toe of the slope.

b. On slopes, all runs shall be continuous with the long dimension of all panels oriented parallel to the slope.

c. Panels placed on the bottom require no particular orientation.

d. Once the first run has been laid, adjoining runs shall be laid with a six (6) inch minimum overlap on the longitudinal seams and twenty-four (24) inch overlap on end seams.

e. The edges of GCL panels shall be adjusted to smooth out wrinkles, creases or “fishmouths” in order to maximize contact with the underlying panel.

f. If the air temperature is higher than 85°F and the humidity is low, contraction may occur soon after placement when no confining stress has been placed over the GCL. To allow for the possibility of contraction under these conditions, the seam overlap shall be increased to a minimum of twelve (12) inches on longitudinal seams and thirty-six (36) inches on end seams, or to 4% of the distance to the next parallel seams, whichever is greater.

307.2 Seaming:

a. Seaming shall be performed in accordance with the Manufacturer's accepted procedure.

b. All seams shall be formed by executing a bentonite-enhanced overlap to ensure that a continuous seal is achieved.

c. The side of the overlying panel shall be pulled back to expose and examine the overlap areas. Seam overlap areas shall be clean and free from moisture, free from dust and debris of any kind before seaming is started. Any contamination shall be removed.

d. A fillet of dry granular bentonite shall be poured in a continuous manner along the overlap zone (between the edge of the panel and the six-inch line) at a rate of at least one-quarter pound per linear foot.

e. Seam overlap on the bottom shall be placed such that the direction of flow is from the top sheet to the bottom sheet to form a shingle effect and prevent flow into the seam.

308. INSPECTION

308.1 After seaming is complete, the GCL Contractor and the Owner shall conduct a detailed walkdown to visually check all seams and non-seam areas of the GCL.

308.2 All defects, holes, blisters, tears and signs of damage during installation shall be marked for repair.

309. PATCHING AND REPAIRS

309.1 Patching shall be used to repair small defects, blisters, holes and tears.

309.2 All dirt and debris present in the patched area shall be removed.

309.3 All patches shall be round, oval or shall have rounded corners.

309.4 All patches shall be made of the base GCL and shall extend a minimum of twelve (12) inches beyond the edges of the defect. Accessory bentonite shall be placed around the perimeter of the affected area at a rate of one-half pound per lineal foot prior to placing the patch. Adhesive, such as wood glue, may be used if necessary to secure the patch.

310. PROTECTIVE COVER

310.1 The GCL shall be covered the same day with protective geomembrane.

310.2 To prevent premature hydration or contraction, only the amount of GCL that can be installed, inspected, repaired and covered in the same day shall be installed.

310.3 Any leading edge or panels of GCL left unprotected shall be covered with a heavy, waterproofing tarp which is adequately secured and protected with sand bags or other ballast.

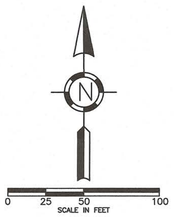
311. ACTIVATION OF GCL

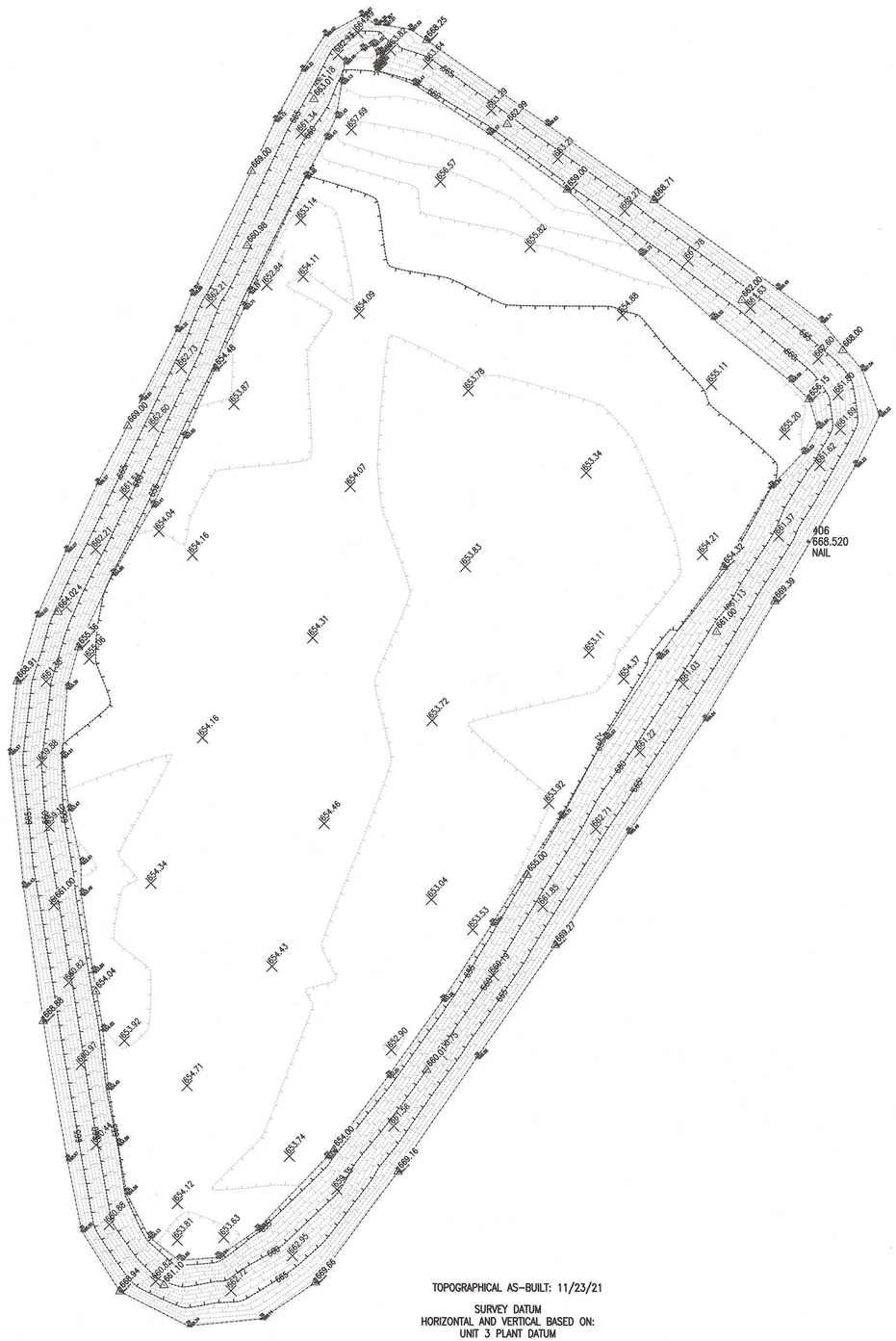
311.1 Hydration by the Earthwork or GCL Contractor is not required. Ground moisture is sufficient to hydrate the GCL.

END OF SECTION 319025

EXHIBIT D

Bottom Ash Retrofit Project – As-Built Drawings





TOPOGRAPHICAL AS-BUILT: 11/23/21

SURVEY DATUM
HORIZONTAL AND VERTICAL BASED ON:
UNIT 3 PLANT DATUM

OHIO811.org Before You Dig

12/8/2021 12:04 PM F:\clients\active\wh\wh001\survey\wh001_topo surface_final.dwg bbutler

HULL
Environment / Energy / Infrastructure

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Suite 200
Dublin, OH 43016
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Fax: (614) 360-0023
www.hullinc.com

Professional Seal:

STATE OF OHIO
JEREMY LEWIS VAN OSTRAN
8283
REGISTERED SURVEYOR

Date: 12/08/21

Project Title:

TOPOGRAPHICAL AS-BUILT
CARDINAL PLANT BOTTOM ASH POND CLOSURE
WELLS TOWNSHIP
JEFFERSON COUNTY, OHIO

Owner:

306 COUNTY ROAD 7E
BRILLIANT, OH 43913

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Mark	Description	Date
	FOR AS-BUILT	11/23/21

Project No.:	SEI001
Plot Date:	12/08/21
Layout By:	BDB
Drawn By:	BDB
Check By:	JLV
Scale:	AS NOTED
Issue Date:	DECEMBER 2021

Sheet Title:

AS-BUILT

Sheet Number: 01 OF 01

FIGURE 2

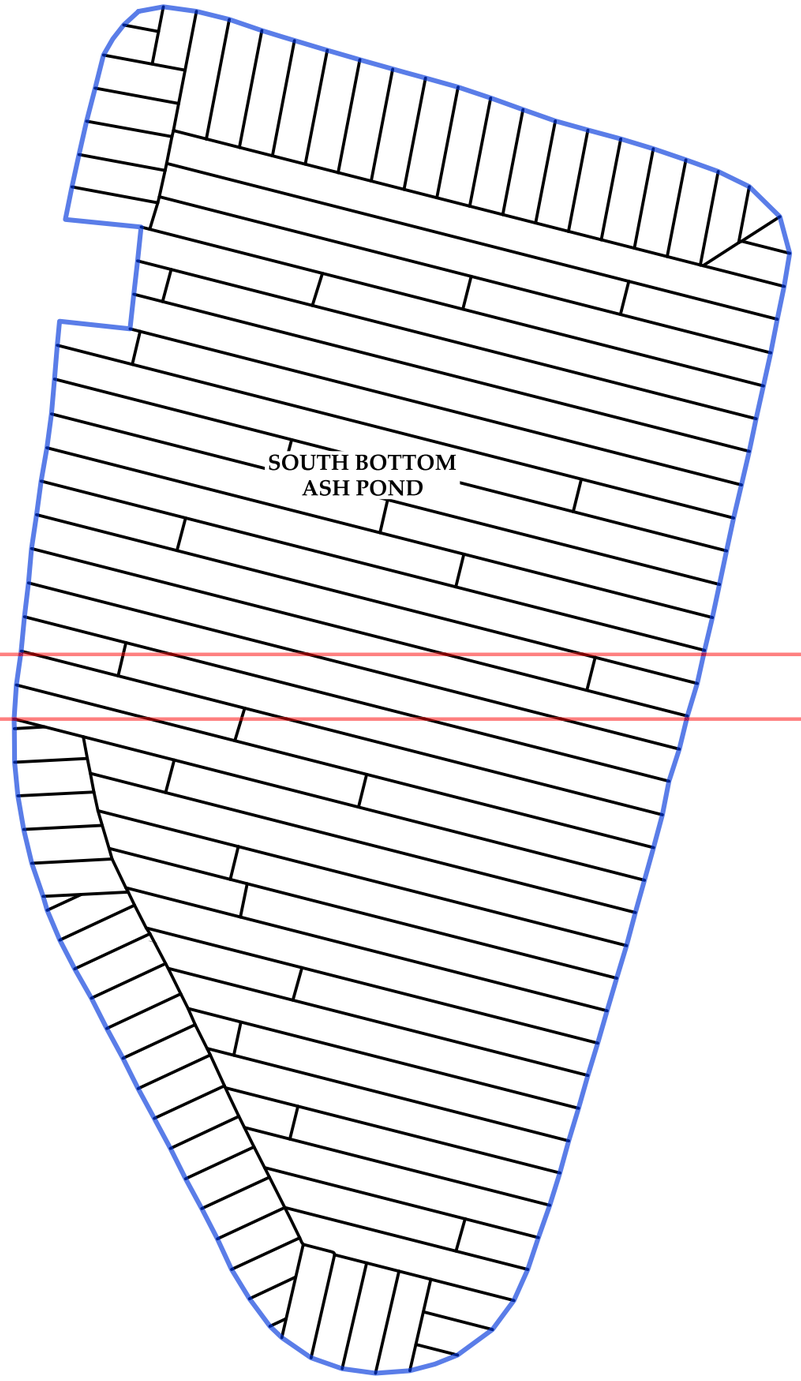


FIGURE 3

N

GEOMEMBRANE LINER AS-BUILT PANEL LAYOUT FOR THE SOUTH BOTTOM ASH POND COMPLETED ON 12/16/2021 BY CHESAPEAKE CONTAINMENT SYSTEMS, INC.

0 100 200

GRAPHIC SCALE (IN FEET)

SHEET INDEX

SOUTH BOTTOM ASH POND - AS BUILT GEOMEMBRANE LINER
CARDINAL POWER PLANT
BRILLIANT, OH

SCALE:
GRAPHIC

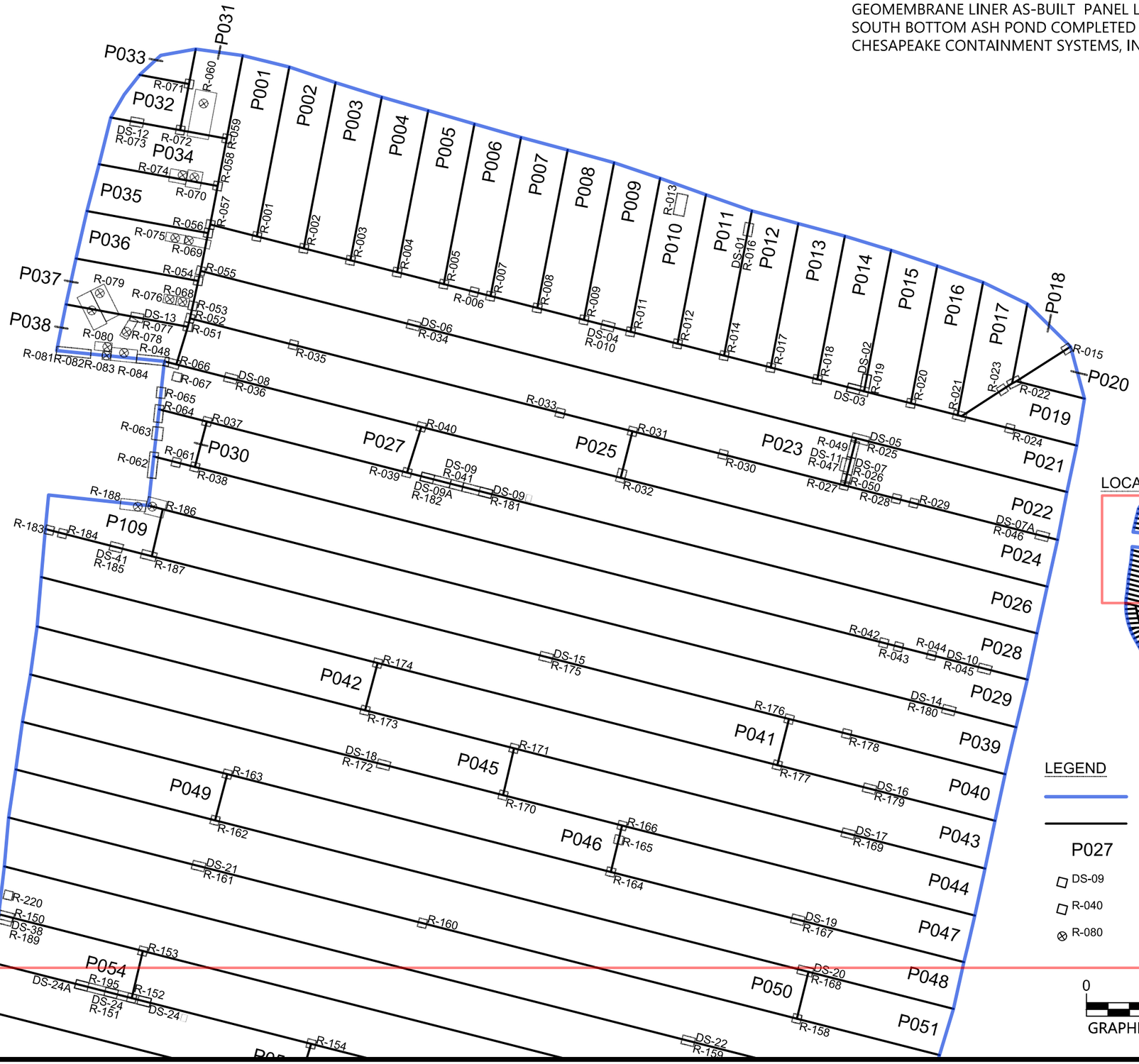
DATE:
1/18/2022

PROJECT NUMBER
211387

FIGURE NO.
1

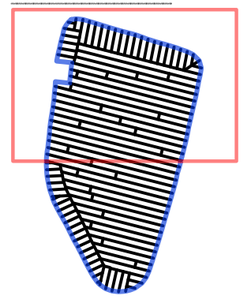
Drawing path: T:\Energy\Projects\2021\211387 Cardinal Power Plant Lined Bottom Ash Pond CQA_Brilliant OH\CAD\Construction\211387_Cardinal BAP As-Built Liner_12-16-21.dwg

GEOMEMBRANE LINER AS-BUILT PANEL LAYOUT FOR THE SOUTH BOTTOM ASH POND COMPLETED ON 12/16/2021 BY CHESAPEAKE CONTAINMENT SYSTEMS, INC.



N

LOCATION MAP



LEGEND

- ANCHOR TRENCH
- PANEL BOUNDARY
- P027 — PANEL NUMBER
- DS-09 — DESTRUCT LOCATION
- R-040 — REPAIR LOCATION
- R-080 — BOOT LOCATION

0 50 100

GRAPHIC SCALE (IN FEET)

PANEL LAYOUT - PLAN (1 OF 2)

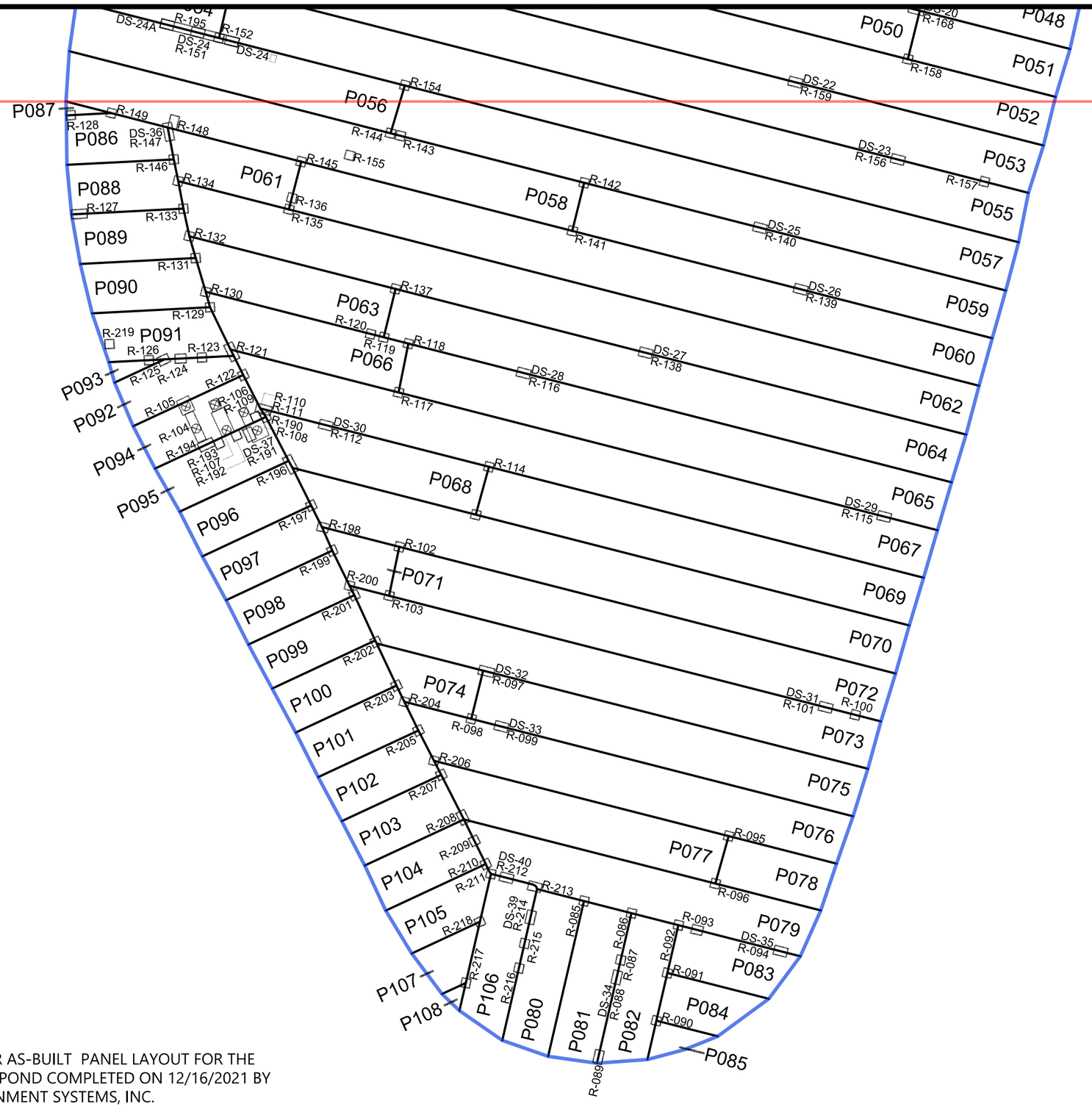
SOUTH BOTTOM ASH POND - AS BUILT GEOMEMBRANE LINER
CARDINAL POWER PLANT
BRILLIANT, OH

SCALE:	GRAPHIC
DATE:	1/18/2022
PROJECT NUMBER	211387
FIGURE NO.	2

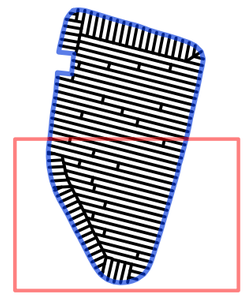
FIGURE 2
FIGURE 3

Drawing path: T:\Energy\Projects\2021\211387 Cardinal Power Plant Lined Bottom Ash Pond CQA_Brilliant OH\CAD\Construction\211387_Cardinal BAP As-Built Liner_12-16-21.dwg

FIGURE 2
FIGURE 3



LOCATION MAP



LEGEND

- ANCHOR TRENCH
- PANEL BOUNDARY
- P027 PANEL NUMBER
- DS-09 DESTRUCT LOCATION
- R-040 REPAIR LOCATION
- R-080 BOOT LOCATION

0 50 100
GRAPHIC SCALE (IN FEET)

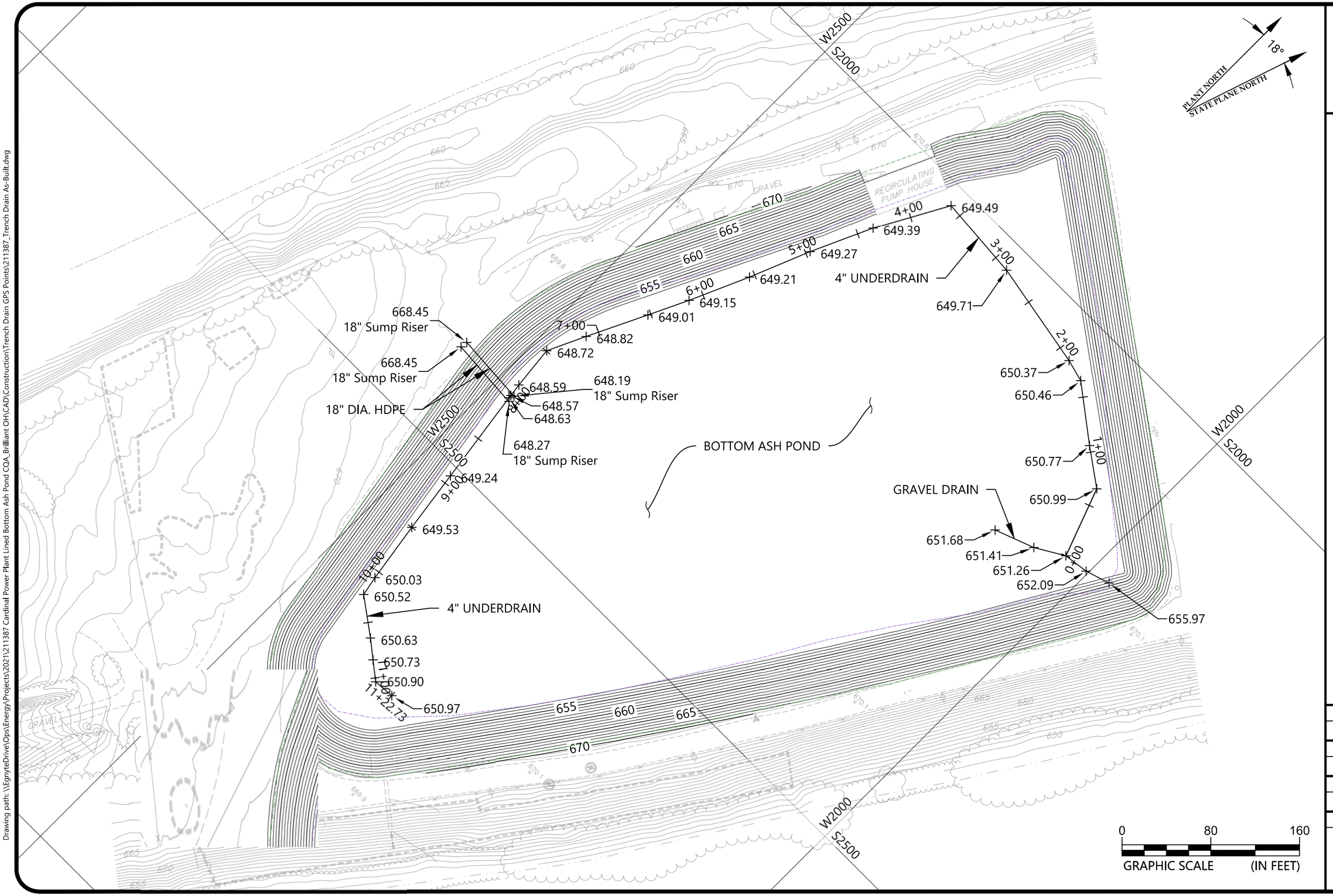
GEOMEMBRANE LINER AS-BUILT PANEL LAYOUT FOR THE SOUTH BOTTOM ASH POND COMPLETED ON 12/16/2021 BY CHESAPEAKE CONTAINMENT SYSTEMS, INC.

PANEL LAYOUT - PLAN (2 OF 2)

SOUTH BOTTOM ASH POND - AS BUILT GEOMEMBRANE LINER
CARDINAL POWER PLANT
BRILLIANT, OH

SCALE: GRAPHIC
DATE: 1/18/2022
PROJECT NUMBER: 211387
FIGURE NO.: 3

Drawing path: T:\Energy\Projects\2021\211387 Cardinal Power Plant Lined Bottom Ash Pond CQA_Brilliant OH\CAD\Construction\211387_Cardinal BAP As-Built Liner_12-16-21.dwg

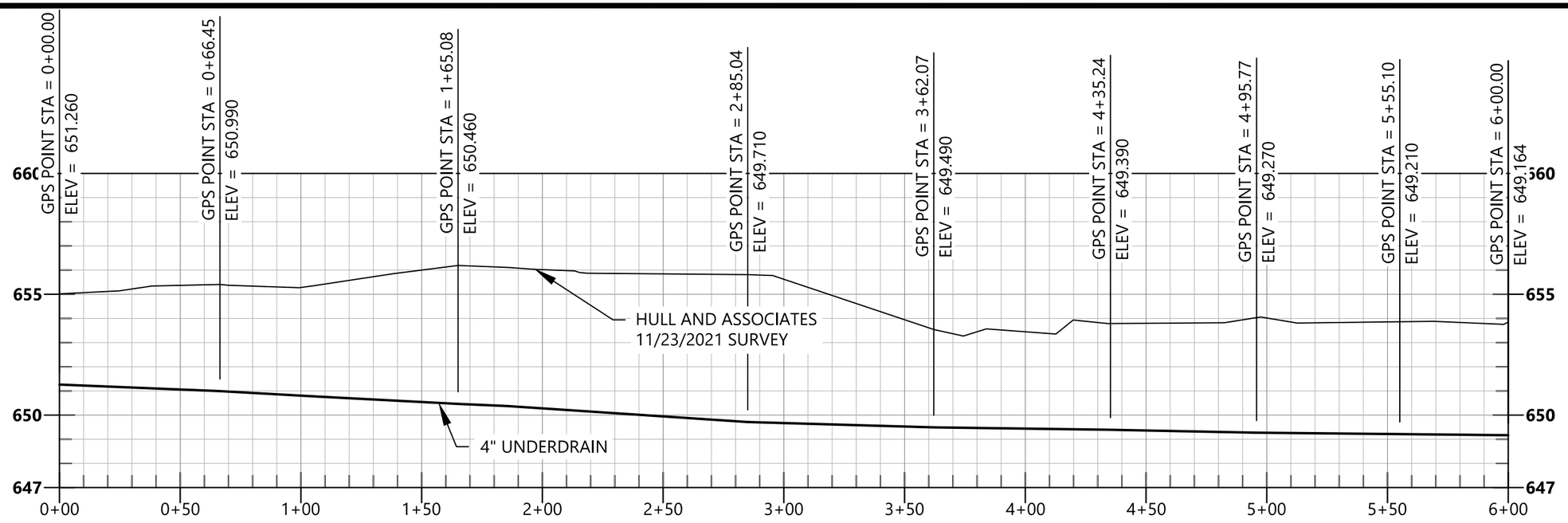


SITE PLAN

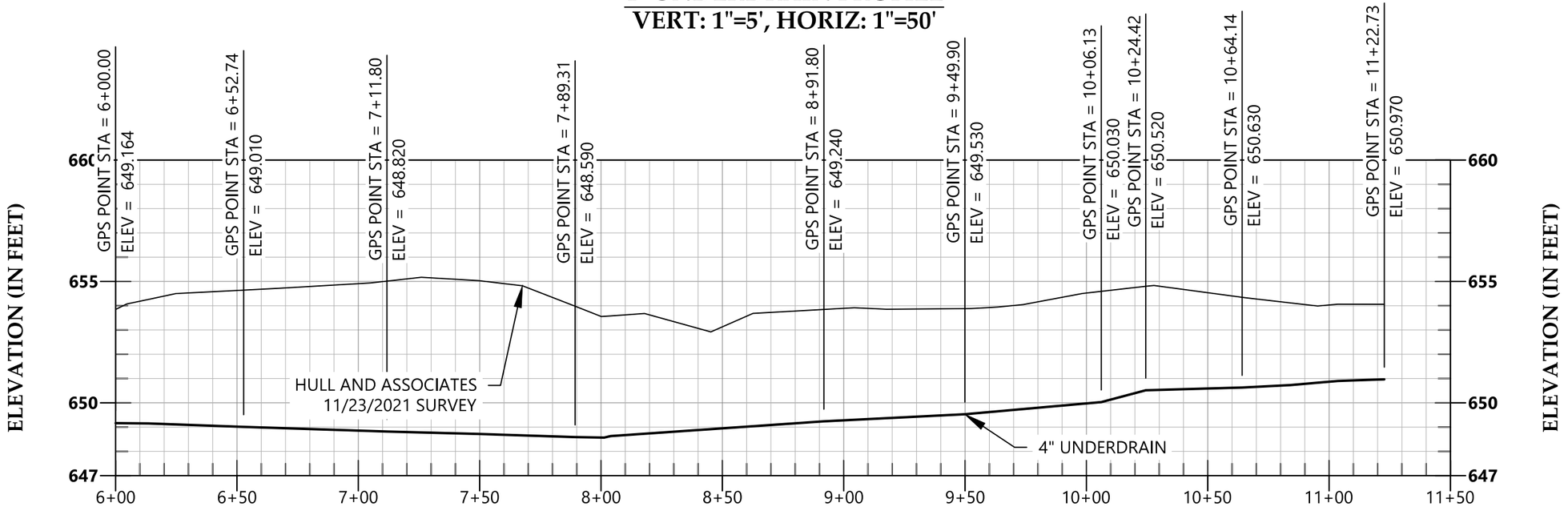
BOTTOM ASH POND UNDERDRAIN
CARDINAL POWER PLANT
BRILLIANT, OHIO

SCALE:	GRAPHIC
DATE:	1/10/2022
PROJECT NUMBER	211387
FIGURE NO.	1

Drawing path: \\EgnyteDrive\Ops\Energy\Projects\2021\211387 Cardinal Power Plant Lined Bottom Ash Pond CQA_Brilliant OH\CAD\Construction\Trench Drain GPS Points\211387_Trench Drain As-Built.dwg



4" UNDERDRAIN PROFILE
VERT: 1"=5', HORIZ: 1"=50'



4" UNDERDRAIN PROFILE
VERT: 1"=5', HORIZ: 1"=50'

0 50 100
GRAPHIC SCALE (IN FEET)

SITE PLAN

BOTTOM ASH POND UNDERDRAINDRAIN
CARDINAL POWER PLANT
BRILLIANT, OHIO

SCALE:	GRAPHIC
DATE:	1/10/2022
PROJECT NUMBER	211387
FIGURE NO.	2

Drawing path: \\EgnyteDrive\Ops\Energy\Projects\2021\211387 Cardinal Power Plant Lined Bottom Ash Pond CQA_Brilliant OH\CAD\Construction\Trench Drain GPS Points\211387_Trench Drain As-Built.dwg

EXHIBIT E

Hydrology and Hydraulic Analysis After Retrofit

Sargent & Lundy LLC

ISSUE SUMMARY
Form SOP-0402-07

DESIGN CONTROL SUMMARY

CLIENT: CARDINAL OPERATING COMPANY UNIT NO.: 1, 2, 3 PAGE NO.: 1

PROJECT NAME: CARDINAL PLANT

PROJECT NO.: 13770-005/6

CALC. NO.,.: CRD-BAP-C-002

S&L NUCLEAR QA PROGRAM
APPLICABLE ☐ YES ☒ NO

TITLE: HYDROLOGY & HYDRAULICS CALCULATION FOR RETROFITTEED BOTTOM ASH POND

EQUIPMENT NO.: N/A

IDENTIFICATION OF PAGES ADDED/REVISED/SUPERSEDED/VOIDED & REVIEW METHOD

ISSUE SUMMARY
CALC. PAGES: 2-9
ATTACHMENTS: 8.1-8.5
TOTAL PAGES: 59

INPUTS/ ASSUMPTIONS
☒ VERIFIED
☐ UNVERIFIED

REVIEW METHOD: DETAILED REV.: 2

STATUS: ☒ APPROVED ☐ SUPERSEDED BY CALCULATION NO. ☐ VOID DATE FOR REV.: 12/22/2021

PREPARER: SHELLI HERRING Shelli Herring Digitally signed by Shelli Herring Date: 2021.12.22 16:20:20 -06'00' DATE: 12/22/2021

REVIEWER: DARREL PACKARD Darrel Packard Digitally signed by Darrel Packard Date: 2021.12.22 16:34:35 -06'00' DATE: 12/22/2021

APPROVER: DARREL PACKARD Darrel Packard Digitally signed by Darrel Packard Date: 2021.12.22 16:34:59 -06'00' DATE: 12/22/2021

IDENTIFICATION OF PAGES ADDED/REVISED/SUPERSEDED/VOIDED & REVIEW METHOD

INPUTS/ ASSUMPTIONS
☐ VERIFIED
☐ UNVERIFIED

REVIEW METHOD: DETAILED REV.:

STATUS: ☐ APPROVED ☐ SUPERSEDED BY CALCULATION NO. ☐ VOID DATE FOR REV.:

PREPARER: DATE:

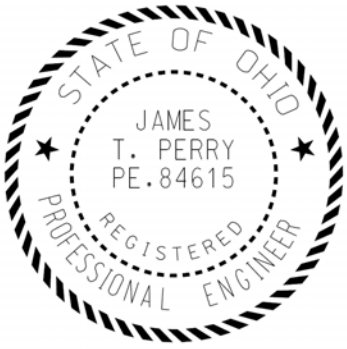
REVIEWER: DATE:

APPROVER: DATE:

SEAL FOR REVISION 0

NOTE: PRINT AND SIGN IN THE SIGNATURE AREA

Table of Contents



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Date: 2022.01.05 08:01:31 -06'00'

1. PURPOSE AND SCOPE

The Cardinal Operating Company is currently in the process of repurposing its Bottom Ash Pond in the Bottom Ash Complex pursuant to the liner requirements in 40 CFR Part 257 Subpart D ("the EPA CCR Rule"). The new name for this surface impoundment evaluated by this calculation will be the "South Pond" and it will handle CCR wastestreams from Units 1, 2 and 3 at the Cardinal Station. A hydrologic and hydraulics evaluation for the North Pond, which manages low volume wastewater only, is covered in a separate calculation.

The purpose of this calculation is to verify that the pond can manage the regulatory design storm event and will not overtop the surrounding dikes during a storm event specified by 40 CFR 257 and the Ohio Administrative Code in section 1501:21-13-02 (A) (2), as seen in Reference 7.1.

2. DESIGN INPUT

2.1 Topographic and Bathymetric Survey Information

Topographic surveying for the site was provided by Labella in August 2020. The survey indicates the existing contours, existing outfalls, etc. for the site.

2.2 Ohio Dam Classification

Pursuant to the Ohio Administrative Code in section 1501:21-13-01 (Ref. 7.1), a dam can be classified as Class I, II, III, and IV. When reviewing the different class options, Class II was chosen as the classification for the South Pond at the Cardinal Plant. The definition of a Class II dam is listed below:

"Dams having a total storage volume greater than five hundred acre-feet or a height of greater than forty feet shall be placed in Class II. A dam shall be placed in Class II when sudden failure of the dam would result in at least one of the following conditions, but loss of human life is not probable.
(a) Disruption of a public water supply or wastewater treatment facility, release of health hazardous industrial or commercial waste, or other health hazards.
(b) Flooding of residential, commercial, industrial, or publicly owned structures. At the request of the dam owner, the chief may exempt dams from the criterion of this paragraph if the dam owner owns the potentially affected property.
(c) Flooding of high-value property. At the request of the dam owner, the chief may exempt dams from the criterion of this paragraph if the dam owner owns the potentially affected property.
(d) Damage or disruption to major roads including but not limited to interstate and state highways, and the only access to residential or other critical areas such as hospitals, nursing homes, or correctional facilities as determined by the chief.
(e) Damage or disruption to railroads or public utilities."

2.3 Rainfall Data

As stated above, the design storm event required was specified by the Ohio Administrative Code in section 1501:21-13-02 (A) (2). This section states that "Class II dams, fifty percent of the probable maximum flood or the critical flood." For this calculation, the design storm considered was fifty percent of the probable maximum flood (PMF), which was determined by first routing the probable maximum flood using the probable maximum precipitation, and then reducing the runoff by 50 percent to obtain the design runoff values: this was then compared to an alternative approach that routed the runoff from 50 percent of the maximum probable precipitation.

The probable maximum flood information was taken from the Hydrometeorological Report No. 51 (HMR 51), titled "Probable Maximum Precipitation Estimates, United States East of the l05th Meridian." (Ref. 7.2) Using Figure 20, the PMP estimated for the Cardinal site was 33 inches over a 24-hour period.

The US EPA CCR Rule specified a 1000-year, 24-hour storm even to be considered for surface impoundments that have a significant hazard potential. The 1000-year, 24-hour rainfall value is 6.98 inches per NOAA Atlas 14 (Attachment 8.2). Consequently, the more stringent ½ PMF value as required by the state of Ohio will be used.

2.4 Drainage Areas

The drainage areas accounted for the calculation was the perimeter dike road around the site. This area equated to 2.1 acres.

2.5 Curve Number

The curve number for gravel is 85 per Reference 7.3, while the curve number for the pond utilized was 100 per Reference 7.4. A combined curve number of 99 was used for the entire drainage area.

2.6 Pond Characteristics

Per the as-built documents, the top of dike is set at 670.0 feet and the normal water elevation is at 665.0 feet. The South Pond area is approximately 7.11 acres and the pond bottom elevation is at 652.0 feet. Water is pumped out of the South Pond through the Recirculation Pumphouse.

2.6 Recycle Pumphouse Characteristics

Per the design basis in Attachment 8.1, there are 8 existing pumps that pump water out of the South Pond at a capacity of 3,900 GPM each, and regulate the water level during a large rainfall event.

2.7 Bottom Ash Transport Water

The BATW flow rate into the pond is 4.14 MGD from Units 1, 2 and 3 per Attachment 8.1. The 4.14 MGD equates to 6.41 cfs.

3. ASSUMPTIONS

No assumptions were used in this calculation.

4. METHODOLOGY AND ACCEPTANCE CRITERIA

4.1 Methodology

Using the design event obtained from using the Ohio Administrative Code and HMR 51, the water levels in the South Pond were analyzed. In order to properly understand how the design storm will affect the water levels, the different flows entering the pond were considered. The three flows entering the pond are the runoff from the perimeter roads, the direct rainfall and the BATW flows into the pond. The flow rate of the BATW into the pond is a constant 4.14 MGD, while the other flow rates are based upon the design storm event. The design storm pursuant to HMR 51 is 16.5 inches over a 24-hour period.

In order to regulate the water levels in the pond and account for various storms, the South Pond has a Recirculation Pumphouse. The Recirculation Pumphouse has 8 pumps that work to regulate the water levels in the pond by recycling the water back into plant operations. These pumps have a capacity of 3,900 GPM or 8.69 cfs each.

In order to analyze the design storm event as specified by the ODNR, the Probable Maximum Flood was considered. As a comparison, the peak runoff during the Probable Maximum Flood was halved and compared to 50 percent of the Probable Maximum Precipitation. Fifty percent of the Probable Maximum Precipitation was analyzed using a hydraulic model, PondPack. When the two results were compared, both events resulted in similar water levels in the South Pond, primarily due to much of the site drainage area. This is the result of negligible drainage area runoff into the pond. Within these conditions, routing the 50 percent PMF is taken as being equivalent to routing 50 percent of the PMP runoff.

A pond modeling software, PondPack, was utilized to evaluate the flows into the South Pond using the full PMF. The design inputs from Section 2 were entered into the modeling software to model the total inflow into the South Pond. Once the maximum inflow into the pond was entered into PondPack using the full PMF event, the software calculated the maximum water level in the pond. The value was then divided in half to represent 50 percent PMF per the OHIO DNR requirements as identified in Section 2.2.

The following computer program was used as a technical aide in the preparation of this calculation:

PondPack Version V8i
S&L Program No. 08.11.01.56

The computer software listed above, accessed on the S&L LAN, has been validated per S&L Software Verification and Validation procedures for the program functions used in the calculation. The program was run on S&L PC#ZL11791.

4.2 Acceptance Criteria

4.2.1 The maximum water level in the pond should not overtop the top of dike elevation of 670.0 feet.

4.2.2 The additional rain must be pumped out of the South Pond within 10 days following the design flood peak per 1501:21-13-04 of the Ohio Administrative Code.

4.2.3 There must be five feet of freeboard between the maximum operating level and the top of the dike.

5. Calculation

The Recirculation Pumphouse within the South Pond contains 8 pumps with a capacity of 3,900 GPM. The BATW flows into the pond will be a constant 4.14 MGD over the 24-hour storm event. All of the water that enters the South Pond from the BATW flows will be pumped out of the pond by the pumps in the Recirculation Pumphouse and recycled back into Plant operations. The pumps will be used to maintain the normal operating water level of 665.0 feet.

When the design storm or the 16.5 inches of water over a 24-hour period begins over the 9 acre area (the pond and the perimeter road), approximately 16.5 inches of water will either fall into the pond directly or enter the pond as runoff from the perimeter road. The pumps from the Recirculation Pumphouse will begin working in order to make sure normal operating water level in the pond is maintained. Because of the availability of all 8 pumps and the 5 feet of freeboard within the pond, there will be no threat of overtopping the dike during the design storm event.

In order to calculate the maximum water surface elevation of the South Pond, a PondPack model was used. As shown in Attachment 8.5, the layout of the model was comprised of three catchment areas, the South Pond and the pumphouse. The three catchment areas represented the constant 6.41 cfs flow of the BATW generated by the Plant, the runoff from the design storm onto the perimeter road surrounding the South Pond, and also the direct rainfall from the design storm into the South Pond, respectively. Because the BATW was a constant flow and not an actual area within the site capable of runoff, the BATW design input was solely the 6.41 cfs.

For the remaining catchment areas, the design inputs were as follows:

	Area (Acres)	Curve Number	Time of Concentration (Minutes)
Perimeter Road	2.10	85	5
South Pond	7.11	99	5

In order to satisfy the ODNR requirements for the 50 percent PMF, the full PMF must be routed through PondPack. The results of this analysis using PondPack to route the full PMF design storm, the BATW flow and the direct runoff from the perimeter road entering the South Pond are summarized below:

	Hydrograph Volume (Ac-ft)	Time to Peak (min)	Peak Flow (cfs)	Maximum Water Surface Elevation (ft)	Maximum Pond Storage (Ac-ft)
BATW Flows	12.71	0.00	6.41	N/A	N/A
South Pond Direct Rainfall	19.47	720.00	415.54	N/A	N/A
Perimeter Road Runoff	5.42	720.00	121.28	N/A	N/A
South Pond Total Inflow	37.60	720.00	543.23	667.65	80.54
South Pond Pumphouse	N/A	645.00	17.00	N/A	N/A

Once obtaining the results for the full PMF storm event, the 50 percent PMF event can be calculated using half of the peak value of the PMF hydrograph. The results of this analysis using PondPack to route the 50 percent PMF design storm, the BATW flow and the direct runoff from the perimeter road entering the South Pond are summarized below:

	Hydrograph Volume (Ac-ft)	Time to Peak (min)	Peak Flow (cfs)	Maximum Water Surface Elevation (ft)	Maximum Pond Storage (Ac-ft)
BATW Flows	12.71	0.00	6.41	N/A	N/A
South Pond Direct Rainfall	9.70	72**0**.00	207.74	N/A	N/A
Perimeter Road Runoff	2.55	720.00	58.91	N/A	N/A
South Pond Total Inflow	24.96	720.00	273.06	666.26	71.32
South Pond Pumphouse	N/A	714.00	17.00	N/A	N/A

For the full results from PondPack including stage storage tables and hydrograph information, see Attachment 8.3 and 8.4.

6. CONCLUSION

The flows and direct rainfall entering the South Pond per the design storm specified by the Ohio Administrative Code will raise the water level in the pond about 1.26 feet above the normal operating water level of 665.0 feet. With a top of dike at 670.0 feet, the water level in the South Pond will not overtop the dike for the design storm analyzed. Based upon the analyzed flows into the pond, the 8 pumps in the recirculation pumphouse should be able to handle the additional water entering into the South Pond within 10 days per the ODNR requirement. During regular operation, the maximum operating level at 665.00 will provide five feet of freeboard to the top of the dike elevation at 670.00’.

7. References

7.1 Classification of Dams. Lawriter Ohio Laws and Rules. http://codes.ohio.gov/oac/1501:21-13-01v1/, Accessed 10/29/2020.

7.2 Hydrometeorological Report No. 51 (HMR 51), titled “Probable Maximum Precipitation Estimates, United States East of the l05th Meridian.” US Department of Commerce, Washington, D.C. 1978.

8. Attachments

8.1 Design Basis

8.2 NOAA Atlas 14

8.3 PondPack Modeling Results for PMF Event

8.4 PondPack Modeling Results for 50 Percent PMF Event

8.5 PondPack Modeling Layout

	Category	Attribute	Design Basis/Criteria		Verified
	General	Plant Design Life	25 years (Units 2 and 3)		
			10 years (to 2030) (Unit 1)		
		In-Service Date	31-Dec-21		
		Plant Capacity Factor	62 percent		
		Bottom Ash Make Rates	Design Value	Actual (w/Capacity Factor applied)	
		Unit 1	4.2 T/hr	2.6 T/hr	7/11/2018 - 8/1/2018
		Unit 2	4.2 T/hr	2.6 T/hr	7/11/2018 - 8/1/2018
		Unit 3	4.8 T/hr	3.0 T/hr	7/11/2018 - 8/1/2018
		Bottom Ash Total	13.2 T/hr	8.2 T/hr	
		BA Uncompacted Density	60 pcf		Assumed
		BA Compacted Density	75 pcf		Assumed
		Ohio River 100-year Flood Elevation	664 feet NAVD 1988		FIRM 39081C0356D
		Hazard Potential	Significant		CCR Haz. Class. Doc
		Precipitation Frequency Data:			
		1-year, 24-hour Rainfall	2.01 inches		NOAA Atlas 14
		2-year, 24-hour Rainfall	2.40 inches		NOAA Atlas 14
		5-year, 24-hour Rainfall	2.94 inches		NOAA Atlas 14
		10-year, 24-hour Rainfall	3.38 inches		NOAA Atlas 14
		25-year, 24-hour Rainfall	4.00 inches		NOAA Atlas 14
		50-year, 24-hour Rainfall	4.50 inches		NOAA Atlas 14
		100-year, 24-hour Rainfall	5.03 inches		NOAA Atlas 14
		1000-year, 24-hour Rainfall	6.98 inches		NOAA Atlas 14
		Current BAP Dredging Cycle	Once per month		Cardinal Station
		Future South Pond Dredging Cycle	Once per month or as needed as determined by Cardinal Station		Cardinal Station
		Bottom Ash Particle Distribution	50 micron to 5000 micron		Engineering Judgement
		Bottom Ash Particle Density	144.21 pcf		Sample S-7 of Cardinal grainsize distribution test
		Applicable Environmental Regulation for CCR Impoundment	Federal: 40 CFR Part 257, CCR Rule, current revision 40 CFR Part 423, Effluent Limitations Guidelines		
			Ohio: OAC 3745-42-03 and OAC 1501:21-5		

	Category	Attribute	Design Basis/Criteria		Verified
	N. / S. Pond Parameters	Top of North/South Dike Elevation	670 ft MSL (Original Constr T/Dike was 658 ft MSL)		HoC CCR Doc
		Bottom of Elevation of North Pond	648 ft MSL		Dwg 3-3017
		Bottom of Elevation of South Pond	652 ft MSL		Dwg 3-3017
		Normal Water Level Elevation North Pond	665 ft MSL		HoC CCR Doc
		Normal Water Level Elevation South Pond	664 ft MSL		
		Elevation Conversion	Mean Sea Level (MSL) is assumed to be equivalent to the NGVD 1929.		
		North Pond Surface Area	13.13 acres Water Area (19 acres total with dredging fill) (TBV Later with Survey)		S&L Measurement
		South Pond Surface Area	7.73 acres (TBV Later with Survey)		S&L Measurement
		North Pond Volume Capacity	242 acre-ft (TBV Later with Survey)		S&L Measurement
		South Pond Volume Capacity	117 acre-ft (TBV Later with Survey)		S&L Measurement
		North Pond Ash Depth	8 to 11 feet	Use 10 feet	2018 Insp. Report
		South Pond Ash Depth	(TBD Later with Survey)	Use 1 foot	Assumed

	Category	Attribute	Design Basis/Criteria		Verified
	North Pond Water Inflow	Unit 1 & 2 BA Transport (CCR)	2.30 MGD	1597 gpm	Per Baseline Case Water Balance, MSK-CAR-WB-001, Rev. 1
	(Existing Condition)	Unit 3 BA Transport (CCR)	1.84 MGD	1278 gpm	
		Direct Rainfall (CCR)	0.07 MGD avg / 2.24 MGD max	49 gpm / 1556 gpm	
		Unit 1 & 2 Wastewater (LVW)	4.32 MGD	3000 gpm	Per Baseline Case Water Balance, MSK-CAR-WB-001, Rev. 1
		Coal Pile Runoff Pond (LVW)	0.23 MGD avg / 6.44 MGD max	160 gpm / 4472 gpm	
		Unit 3 Storm Water	0.02 MGD avg / 1.60 MGD max	14 gpm / 1111 gpm	
		Unit 3 Cooling Tower Blowdown (LVW)	1.58 MGD	1097 gpm	
		Unit 3 Cooling Tower Basin Overflow (LVW)	1.83 MGD	1271 gpm	
		Unit 1, 2, 3 JBR Process Water (LVW)	0.00 MGD avg / 0.50 MGD max	0 gpm / 347 gpm	
		Unit 1, 2, 3 JBR Reagent Feed Tank (LVW)	0.00 MGD avg / 0.34 MGD max	0 gpm / 236 gpm	
		Unit 1, 2, 3 JBR Reclaim Water Tank (LVW)	0.00 MGD avg / 0.33 MGD max	0 gpm / 229 gpm	
		Unit 1, 2, 3 JBR Byproduct Storage Tank (LVW)	0.00 MGD avg / 0.61 MGD max	0 gpm / 424 gpm	
		Inflow Summary			
		Design CCR	4.21 MGD avg / 6.38 MGD max	2924 gpm / 4431 gpm	Summary of CCR
		Design LVW	7.98 MGD avg / 17.55 MGD max	5542 gpm / 12188 gpm	Summary of LVW
		Design Total	12.19 MGD avg / 23.93 MGD max	8465 gpm / 16618 gpm	
		Actual CCR	2.61 MGD avg / 3.96 MGD max	1813 gpm / 2750 gpm	Capacity Factor Applied
		Actual LVW	4.95 MGD avg / 10.88 MGD max	3438 gpm / 7556 gpm	Capacity Factor Applied
		Actual Total	7.56 MGD avg / 14.84 MGD max	5250 gpm / 10306 gpm	Capacity Factor Applied
	South Pond Water Inflow	North Pond Discharge	12.14 MGD avg / 22.16 MGD max	8431 gpm / 15389 gpm	Per Water Balance, MSK-CAR-WB-001, Rev. 1
	(Existing Condition)	Direct Rainfall	0.04 MGD avg / 1.16 MGD max	28 gpm / 806 gpm	
		Recycle Flow Summary	12.15 MGD avg / 16.19 MGD max	8438 gpm / 11243 gpm	Per Water Balance, MSK-CAR-WB-001, Rev. 1
		Outfall 023 Discharge Summary	0.00 MGD avg / 7.13 MGD max	0 gpm / 4951 gpm	
			Discharges through Outfall 023 shall adhere to the requirements of the current NPDES Permit (OIB0009 Effective January 1, 2019)		

	Category	Attribute	Design Basis/Criteria		Verified
	North Pond Water Inflow	Unit 1 & 2 Wastewater (LVW)	4.32 MGD	3000 gpm	Per Water Balance, MSK-CAR-WB-002, Rev. 2
	(Final Condition)	Coal Pile Runoff Pond (LVW)	0.23 MGD avg / 6.44 MGD max	160 gpm / 4472 gpm	
		Unit 3 Storm Water	0.02 MGD avg / 1.60 MGD max	14 gpm 1111 gpm	
		Unit 3 Cooling Tower Blowdown (LVW)	1.58 MGD	1097 gpm	
		Unit 3 Cooling Tower Basin Overflow (LVW)	3.66 MGD	2542 gpm	
		Unit 1, 2, 3 JBR Process Water (LVW)	0.00 MGD avg / 0.50 MGD max	0 gpm / 347 gpm	
		Unit 1, 2, 3 JBR Reagent Feed Tank (LVW)	0.00 MGD avg / 0.34 MGD max	0 gpm / 236 gpm	
		Unit 1, 2, 3 JBR Reclaim Water Tank (LVW)	0.00 MGD avg / 0.33 MGD max	0 gpm / 229 gpm	
		Unit 1, 2, 3 JBR Byproduct Storage Tank (LVW)	0.00 MGD avg / 0.61 MGD max	0 gpm / 424 gpm	
		Direct Rainfall	0.073 MGD avg / 2.24 MGD max	51 gpm / 1556 gpm	
		Unit 3 Pyrites Handling	0.35 MGD	243 gpm	
		Discharge Summary (Outfall 023)	10.18 MGD avg / 21.57 MGD max	7069 gpm / 14979 gpm	Per Water Balance, MSK-CAR-WB-002, Rev. 2
			Discharges through Outfall 023 shall adhere to the requirements of the current NPDES Permit		
	South Pond Water Inflow	Unit 1 & 2 BA Transport (CCR)	2.30 MGD	1597 gpm	Per Water Balance, MSK-CAR-WB-002, Rev. 2
	(Final Condition)	Unit 3 BA Transport (CCR)	1.83 MGD	1271 gpm	
		Direct Rainfall	0.04 MGD avg / 1.16 MGD max	28 gpm / 806 gpm	
		Recycle Flow Summary	4.14 MGD avg / 5.61 MGD max	2875 gpm / 3896 gpm	Per Water Balance, MSK-CAR-WB-002, Rev. 2
		Recycle Water Quality Limits	200 ppm / 50 micron size per cycle - These are Target Values		S&L Mechanical
			20,000 ppm maximum / 50 micron size - These are Target Values		S&L Mechanical

	Category	Attribute	Design Basis/Criteria	Verified
	Electrical & Controls	Controls	The current station DCS is from ABB using Harmony series controllers and I/O. The workstations use S+ Engineering version 3.2. PLCs and local controllers shall be avoided.	S&L I&C
		Instrumentation	New instrumentation shall be manufactured by Rosemount, if applicable and if required.	S&L I&C
		Motors	New or replacement motors will match the existing voltage of the Unit (13.2kV, 6.6kV, 575V, 460V). Minimum service factor will be specified to be 1.15.	S&L Electrical
	Structural	Building Code	OBC 2017 (IBC 2015 and ASCE 7-10 with Ohio exemptions)	
		Ladders, walkways, stairs	Will meet the requirements of OSHA in effect at the time of the design.	
		Stability of Existing Sheetpile wall against ash loads	Wall to be modified or replaced to allow ash storage without excessive deformation	
		Stablility of Center Dike between North and South Ponds, when subject to unequal pond levels.	To be considered in comparision to existing perimter dikes.	
	Mechanical	Piping	New Bottom Ash - Steel, Basalt lined, Flanged Bottom Ash Recirculation Water/Blowdown - Carbon Steel, A53 ERW Underground Water - Carbon steel, A53 ERW, wrapped for Corrosion / HDPE Aboveground Water - Carbon Steel, A53 ERW	
		Recirculation System (Existing)	Utilize existing ARP Water Return system: - 8 pumps - Pump Design (Vertical, 3,900 GPM at 162 ft TDH) Piping: - 30"at pumphouse - 24" header up to Unit 2 - 16" header to Unit 1	

	Category	Attribute	Design Basis/Criteria	Verified
	Mechanical (continued)	Bottom Ash System (Existing)	Utilize existing Bottom Ash pumps: - 2x100% per Unit - Unit 1 (3,000 gpm at 600 ft TDH) - Unit 2 (3,000 gpm at 600 ft TDH) - Unit 3 (3,600 gpm at 360 ft TDH) Utilize existing Bottom Ash piping to greatest extent, then reroute as required to South pond - 12" last year was worseNominal Basalt Lined, Flanged - 11.4" ID	
		Piping System Design - General	ASME B31.1	
		Fluid Velocity	Water - 7 to 10 ft/s Bottom Ash Sluice - 8 ft/s	
		Piping Insulation		
		Personnel Protection	- For process piping system surfaces >140°F - 7'-6" above walkways - 36" horizontally beyond accessible areas	
		Heat Tracing	To maintain process piping above freezing	
		Bottom Ash Piping	Insulation not provided	
		Potable water system for Eyewash stations	Not required	
		Demolition	Abandon in place, cut and cap as required for piping, equipment and components	

	Category	Attribute	Design Basis/Criteria		Verified
	Civil	Site Grading	Where necessary, stable, erosion-resistant earthen side slopes may be constructed. Permanent cut and fill slopes shall be maximum 3H:1V.		
			Site grading shall be adequate for surface drainage to drain the plant area without flooding.		
		Erosion Control	Temporary facilities shall be provided for control of erosion and turbid runoff during earthwork operations and from graded areas until they are surfaced or grass turf is established. Temporary erosion control measures shall include geotextile silt fences, velocity check dams in ditches, inlet protection using straw bales or geotextile covers, or other approved measures in compliance with the approved Construction Storm Water Pollution Prevention Plan Permit.		
			Permanent erosion control measures such as riprap, turf reinforcing, and crushed stone surfacing shall be provided for ditches, slopes, and other open areas, as required.		
		Stormwater Sewer System	The stormwater system shall be designed to discharge a 10-year storm runoff without flooding the road side ditches and a 50-year storm runoff without flooding the roads and equipment foundations.		
			New stormwater culverts will use double walled CHDPE pipe and fittings		
		General Surfacing	Disturbed areas will be restored in-kind (grass for grass; gravel for gravel; etc.)		
			Type:	Min. Thickness	
			Permanent Seeding on Topsoil	4 inches	
			Crushed Rock Area Surfacing	6 inches	
		Roads	Roadway alterations will be kept to a minimum unless directed by Owner.		
			Where required, disturbed roadways will be repaired with a 12" thick compacted gravel layer over an 8 oz/sy geotextile		

	Category	Attribute	Design Basis/Criteria	Verified
	Civil (continued)	Lining Systems		
		For South Pond (Future BA Pond):	Composite Liner in accordance with CFR 257.72(a) and 257.70(b)	
		High Frequency Dredging Canal (From top surface down)	Daily dredging anticipated in this area of the pond.	
		Liner protection from dredging activities:	8" thick fiber reinforced concrete above a 4" thick layer of gravel	
		Liner protection from gravel layer:	8 oz/sy non-woven geotextile	
		Upper component - geomembrane:	60-mil textured HDPE geomembrane (black)	
		Lower component - imported clay:	24" thick layer of imported and compacted soil	
		Compacted base:	Rolled and compacted native soils	
		Hydraulic conductivity of lower component:	No greater than the liquid flow rate through two feet of compacted soil with a hydraulic conductivity of 1x10-7 cm/sec. (Shall be field verified)	
		Below Dewatering and Staging Area (From top surface down)	No future dredging activities anticipated in this area of the pond.	
		Liner protection from compacted bottom ash:	8" thick layer of gravel	
		Liner protection from gravel layer:	8 oz/sy non-woven geotextile	
		Upper component - geomembrane:	60-mil textured HDPE geomembrane (black)	
		Lower component - imported clay:	24" thick layer of imported and compacted soil	
		Compacted base:	Rolled and compacted native soils	
		Hydraulic conductivity of lower component:	No greater than the liquid flow rate through two feet of compacted soil with a hydraulic conductivity of 1x10-7 cm/sec. (Shall be field verified)	
		Low Frequency Dredging Area (From top surface down)	Hydraulic dredging is anticipated to be required once every 3 years.	
		Liner protection from dredging activities:	18" thick layer of riprap above 8" thick layer of gravel	
		Liner protection from top gravel layer:	8 oz/sy non-woven geotextile	
		Upper component - geomembrane:	60-mil textured HDPE geomembrane (black)	
		Lower component - imported clay:	24" thick layer of imported and compacted soil	
		Compacted base:	Rolled and compacted native soils	
		Hydraulic conductivity of lower component:	No greater than the liquid flow rate through two feet of compacted soil with a hydraulic conductivity of 1x10-7 cm/sec. (Shall be field verified)	
		For North Pond (Future LVW Pond):	Ohio EPA NPDES compliant liner system	
		(From top surface down)		
		Geomembrane:	60-mil smooth HDPE geomembrane (black)	
		Geotextile:	8 oz/sy non-woven geotextile	
		Compacted base:	Rolled and compacted native soils	

Attachment 8.2

NOAA Atlas 14, Volume 2, Version 3
Location name: Brilliant, Ohio, USA*
Latitude: 40.2527°, Longitude: -80.6526°
Elevation: 729.28 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	**0.320** (0.284-0.363)	**0.382** (0.339-0.434)	**0.463** (0.410-0.524)	**0.524** (0.462-0.592)	**0.603** (0.531-0.681)	**0.663** (0.582-0.747)	**0.720** (0.629-0.811)	**0.779** (0.679-0.878)	**0.858** (0.743-0.965)	**0.915** (0.789-1.03)
10-min	**0.497** (0.441-0.564)	**0.597** (0.529-0.677)	**0.719** (0.637-0.814)	**0.808** (0.714-0.914)	**0.922** (0.812-1.04)	**1.00** (0.882-1.13)	**1.08** (0.947-1.22)	**1.16** (1.01-1.31)	**1.26** (1.09-1.42)	**1.33** (1.15-1.50)
15-min	**0.610** (0.540-0.691)	**0.730** (0.647-0.828)	**0.883** (0.782-1.00)	**0.994** (0.878-1.13)	**1.14** (1.00-1.29)	**1.24** (1.09-1.40)	**1.35** (1.18-1.52)	**1.45** (1.26-1.63)	**1.57** (1.36-1.77)	**1.67** (1.44-1.87)
30-min	**0.807** (0.715-0.914)	**0.977** (0.866-1.11)	**1.21** (1.07-1.37)	**1.38** (1.22-1.56)	**1.61** (1.42-1.82)	**1.78** (1.56-2.01)	**1.94** (1.70-2.19)	**2.11** (1.84-2.38)	**2.33** (2.02-2.62)	**2.50** (2.15-2.81)
60-min	**0.985** (0.873-1.12)	**1.20** (1.06-1.36)	**1.52** (1.34-1.72)	**1.76** (1.55-1.99)	**2.09** (1.84-2.36)	**2.34** (2.06-2.64)	**2.60** (2.27-2.93)	**2.87** (2.50-3.23)	**3.23** (2.79-3.63)	**3.51** (3.02-3.94)
2-hr	**1.13** (0.995-1.30)	**1.37** (1.21-1.58)	**1.74** (1.52-1.99)	**2.02** (1.77-2.31)	**2.41** (2.10-2.75)	**2.72** (2.37-3.11)	**3.05** (2.64-3.46)	**3.38** (2.92-3.84)	**3.85** (3.29-4.36)	**4.21** (3.58-4.78)
3-hr	**1.20** (1.07-1.40)	**1.46** (1.29-1.69)	**1.84** (1.63-2.13)	**2.14** (1.89-2.47)	**2.56** (2.25-2.95)	**2.90** (2.54-3.33)	**3.25** (2.83-3.73)	**3.63** (3.13-4.15)	**4.14** (3.55-4.74)	**4.55** (3.88-5.21)
6-hr	**1.44** (1.29-1.64)	**1.73** (1.54-1.97)	**2.16** (1.93-2.46)	**2.52** (2.24-2.86)	**3.02** (2.67-3.42)	**3.42** (3.01-3.87)	**3.85** (3.37-4.35)	**4.31** (3.75-4.85)	**4.95** (4.26-5.56)	**5.47** (4.67-6.13)
12-hr	**1.70** (1.53-1.90)	**2.03** (1.83-2.27)	**2.52** (2.26-2.81)	**2.91** (2.61-3.24)	**3.49** (3.11-3.86)	**3.96** (3.52-4.37)	**4.47** (3.94-4.91)	**5.00** (4.39-5.49)	**5.77** (5.01-6.32)	**6.40** (5.51-6.97)
24-hr	**2.01** (1.88-2.18)	**2.41** (2.24-2.60)	**2.94** (2.74-3.18)	**3.38** (3.14-3.64)	**4.00** (3.70-4.30)	**4.51** (4.15-4.83)	**5.03** (4.62-5.39)	**5.58** (5.10-5.97)	**6.36** (5.77-6.79)	**6.98** (6.30-7.44)
2-day	**2.37** (2.21-2.54)	**2.82** (2.63-3.03)	**3.41** (3.19-3.67)	**3.90** (3.63-4.18)	**4.56** (4.24-4.89)	**5.11** (4.73-5.46)	**5.66** (5.23-6.05)	**6.24** (5.73-6.65)	**7.03** (6.42-7.49)	**7.65** (6.95-8.15)
3-day	**2.53** (2.38-2.71)	**3.01** (2.83-3.22)	**3.62** (3.40-3.87)	**4.12** (3.86-4.40)	**4.81** (4.49-5.12)	**5.35** (4.98-5.70)	**5.92** (5.49-6.30)	**6.49** (6.00-6.90)	**7.29** (6.69-7.74)	**7.91** (7.22-8.40)
4-day	**2.70** (2.55-2.87)	**3.20** (3.02-3.41)	**3.84** (3.61-4.08)	**4.35** (4.09-4.62)	**5.05** (4.73-5.36)	**5.60** (5.24-5.95)	**6.17** (5.75-6.55)	**6.75** (6.27-7.16)	**7.55** (6.96-7.99)	**8.16** (7.49-8.66)
7-day	**3.24** (3.07-3.43)	**3.84** (3.63-4.06)	**4.55** (4.30-4.82)	**5.11** (4.83-5.41)	**5.88** (5.54-6.21)	**6.47** (6.08-6.84)	**7.08** (6.64-7.48)	**7.69** (7.18-8.12)	**8.50** (7.90-8.98)	**9.12** (8.44-9.64)
10-day	**3.74** (3.55-3.94)	**4.41** (4.18-4.66)	**5.17** (4.91-5.46)	**5.77** (5.48-6.09)	**6.58** (6.23-6.94)	**7.21** (6.81-7.60)	**7.83** (7.38-8.26)	**8.46** (7.95-8.92)	**9.27** (8.67-9.78)	**9.89** (9.21-10.4)
20-day	**5.24** (4.99-5.50)	**6.15** (5.86-6.48)	**7.12** (6.78-7.49)	**7.88** (7.50-8.28)	**8.88** (8.43-9.32)	**9.63** (9.14-10.1)	**10.4** (9.81-10.9)	**11.1** (10.5-11.7)	**12.0** (11.3-12.6)	**12.7** (11.9-13.4)
30-day	**6.57** (6.26-6.92)	**7.69** (7.32-8.11)	**8.82** (8.40-9.29)	**9.71** (9.23-10.2)	**10.9** (10.3-11.4)	**11.7** (11.1-12.3)	**12.6** (11.9-13.2)	**13.4** (12.6-14.1)	**14.4** (13.6-15.2)	**15.2** (14.2-16.0)
45-day	**8.41** (8.03-8.80)	**9.81** (9.37-10.3)	**11.1** (10.6-11.6)	**12.1** (11.6-12.7)	**13.4** (12.8-14.0)	**14.3** (13.7-15.0)	**15.2** (14.5-15.9)	**16.1** (15.3-16.8)	**17.1** (16.2-18.0)	**17.8** (16.9-18.7)
60-day	**10.1** (9.72-10.6)	**11.8** (11.3-12.3)	**13.2** (12.7-13.8)	**14.3** (13.7-15.0)	**15.7** (15.1-16.4)	**16.7** (16.0-17.5)	**17.7** (16.9-18.4)	**18.5** (17.7-19.3)	**19.6** (18.6-20.4)	**20.3** (19.3-21.2)

[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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PondPack Results for PMF Event

Subsection: Master Network Summary

Catchments Summary

Label	Scenario	Return Event (years)	Hydrograph Volume (ac-ft)	Time to Peak (min)	Peak Flow (ft³/s)
BATW	Base	1	12.714	0.0	6.41
Perimeter Roads	Base	1	5.417	720.0	121.28
South Pond Direct Rainfall	Base	1	19.472	720.0	415.54

Node Summary

Label	Scenario	Return Event (years)	Hydrograph Volume (ac-ft)	Time to Peak (min)	Peak Flow (ft³/s)
Outlet	Base	1	25.508	645.0	17.00

Pond Summary

Label	Scenario	Return Event (years)	Hydrograph Volume (ac-ft)	Time to Peak (min)	Peak Flow (ft³/s)	Maximum Water Surface Elevation (ft)	Maximum Pond Storage (ac-ft)
South Pond (IN)	Base	1	37.603	720.0	543.23	(N/A)	(N/A)
South Pond (OUT)	Base	1	25.508	645.0	17.00	667.65	80.544

PondPack Results for PMF Event

Subsection: Time-Depth Curve
Label: Time-Depth - 1
Scenario: Base

Return Event: 1 years
Storm Event: PMP

Time-Depth Curve: PMP	
Label	PMP
Start Time	0.0 min
Increment	5.0 min
End Time	1,440.0 min
Return Event	1 years

CUMULATIVE RAINFALL (in)
Output Time Increment = 5.0 min
Time on left represents time for first value in each row.

Time (min)	Depth (in)	Depth (in)	Depth (in)	Depth (in)	Depth (in)
0.0	0.000	0.017	0.035	0.052	0.069
25.0	0.087	0.104	0.122	0.139	0.156
50.0	0.174	0.191	0.208	0.226	0.243
75.0	0.260	0.278	0.295	0.313	0.330
100.0	0.347	0.365	0.382	0.399	0.417
125.0	0.434	0.451	0.469	0.486	0.503
150.0	0.521	0.538	0.556	0.573	0.590
175.0	0.608	0.625	0.642	0.660	0.677
200.0	0.694	0.712	0.729	0.747	0.764
225.0	0.781	0.799	0.816	0.833	0.851
250.0	0.868	0.885	0.903	0.920	0.938
275.0	0.955	0.972	0.990	1.007	1.024
300.0	1.042	1.059	1.076	1.094	1.111
325.0	1.128	1.146	1.163	1.181	1.198
350.0	1.215	1.233	1.250	1.306	1.361
375.0	1.417	1.472	1.528	1.583	1.639
400.0	1.694	1.750	1.806	1.861	1.917
425.0	1.972	2.028	2.083	2.139	2.194
450.0	2.250	2.306	2.361	2.417	2.472
475.0	2.528	2.583	2.639	2.694	2.750
500.0	2.806	2.861	2.917	2.972	3.028
525.0	3.083	3.139	3.194	3.250	3.398
550.0	3.547	3.695	3.843	3.992	4.140
575.0	4.288	4.437	4.585	4.733	4.882
600.0	5.030	5.178	5.327	5.475	5.623
625.0	5.772	5.920	6.068	6.217	6.365
650.0	6.513	6.662	6.810	6.958	7.107
675.0	7.255	7.403	7.552	7.700	8.418
700.0	9.137	9.855	11.198	12.878	18.778
725.0	20.458	21.802	23.145	23.863	24.582
750.0	25.300	25.448	25.597	25.745	25.893
775.0	26.042	26.190	26.338	26.487	26.635
800.0	26.783	26.932	27.080	27.228	27.377
825.0	27.525	27.673	27.822	27.970	28.118

PondPack Results for PMF Event

Subsection: Time-Depth Curve
Label: Time-Depth - 1
Scenario: Base

Return Event: 1 years
Storm Event: PMP

CUMULATIVE RAINFALL (in)
Output Time Increment = 5.0 min
Time on left represents time for first value in each row.

Time (min)	Depth (in)	Depth (in)	Depth (in)	Depth (in)	Depth (in)
850.0	28.267	28.415	28.563	28.712	28.860
875.0	29.008	29.157	29.305	29.453	29.602
900.0	29.750	29.806	29.861	29.917	29.972
925.0	30.028	30.083	30.139	30.194	30.250
950.0	30.306	30.361	30.417	30.472	30.528
975.0	30.583	30.639	30.694	30.750	30.806
1,000.0	30.861	30.917	30.972	31.028	31.083
1,025.0	31.139	31.194	31.250	31.306	31.361
1,050.0	31.417	31.472	31.528	31.583	31.639
1,075.0	31.694	31.750	31.767	31.785	31.802
1,100.0	31.819	31.837	31.854	31.872	31.889
1,125.0	31.906	31.924	31.941	31.958	31.976
1,150.0	31.993	32.010	32.028	32.045	32.063
1,175.0	32.080	32.097	32.115	32.132	32.149
1,200.0	32.167	32.184	32.201	32.219	32.236
1,225.0	32.253	32.271	32.288	32.306	32.323
1,250.0	32.340	32.358	32.375	32.392	32.410
1,275.0	32.427	32.444	32.462	32.479	32.497
1,300.0	32.514	32.531	32.549	32.566	32.583
1,325.0	32.601	32.618	32.635	32.653	32.670
1,350.0	32.688	32.705	32.722	32.740	32.757
1,375.0	32.774	32.792	32.809	32.826	32.844
1,400.0	32.861	32.878	32.896	32.913	32.931
1,425.0	32.948	32.965	32.983	33.000	(N/A)

PondPack Results for PMF Event

Subsection: Read Hydrograph
Label: BATW
Scenario: Base

Return Event: 1 years
Storm Event: PMP

Peak Discharge	6.41 ft³/s
Time to Peak	480.0 min
Hydrograph Volume	12.714 ac-ft

HYDROGRAPH ORDINATES (ft³/s)
Output Time Increment = 60.0 min
Time on left represents time for first value in each row.

Time (min)	Flow (ft³/s)	Flow (ft³/s)	Flow (ft³/s)	Flow (ft³/s)	Flow (ft³/s)
0.0	6.41	6.41	6.41	6.41	6.41
300.0	6.41	6.41	6.41	6.41	6.41
600.0	6.41	6.41	6.41	6.41	6.41
900.0	6.41	6.41	6.41	6.41	6.41
1,200.0	6.41	6.41	6.41	6.41	6.41

PondPack Results for PMF Event

Subsection: Unit Hydrograph Summary
Label: Perimeter Roads
Scenario: Base

Return Event: 1 years
Storm Event: PMP

Storm Event	PMP
Return Event	1 years
Duration	1,440.0 min
Depth	33.000 in
Time of Concentration (Composite)	5.0 min
Area (User Defined)	2.100 acres

Computational Time Increment	0.7 min
Time to Peak (Computed)	721.3 min
Flow (Peak, Computed)	127.91 ft³/s
Output Increment	3.0 min
Time to Flow (Peak Interpolated Output)	720.0 min
Flow (Peak Interpolated Output)	121.28 ft³/s

Drainage Area	
SCS CN (Composite)	85.000
Area (User Defined)	2.100 acres
Maximum Retention (Pervious)	1.765 in
Maximum Retention (Pervious, 20 percent)	0.353 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	30.973 in
Runoff Volume (Pervious)	5.420 ac-ft

Hydrograph Volume (Area under Hydrograph curve)	
Volume	5.417 ac-ft

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	5.0 min
Computational Time Increment	0.7 min
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670

PondPack Results for PMF Event

Subsection: Unit Hydrograph Summary
Label: Perimeter Roads
Scenario: Base

Return Event: 1 years
Storm Event: PMP

SCS Unit Hydrograph Parameters	
Unit peak, qp	28.55 ft³/s
Unit peak time, Tp	3.3 min
Unit receding limb, Tr	13.3 min
Total unit time, Tb	16.7 min

PondPack Results for PMF Event

Subsection: Unit Hydrograph Summary
Label: South Pond Direct Rainfall
Scenario: Base

Return Event: 1 years
Storm Event: PMP

Storm Event	PMP
Return Event	1 years
Duration	1,440.0 min
Depth	33.000 in
Time of Concentration (Composite)	5.0 min
Area (User Defined)	7.110 acres

Computational Time Increment	0.7 min
Time to Peak (Computed)	721.3 min
Flow (Peak, Computed)	437.65 ft³/s
Output Increment	3.0 min
Time to Flow (Peak Interpolated Output)	720.0 min
Flow (Peak Interpolated Output)	415.54 ft³/s

Drainage Area	
SCS CN (Composite)	99.000
Area (User Defined)	7.110 acres
Maximum Retention (Pervious)	0.101 in
Maximum Retention (Pervious, 20 percent)	0.020 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	32.879 in
Runoff Volume (Pervious)	19.481 ac-ft

Hydrograph Volume (Area under Hydrograph curve)	
Volume	19.472 ac-ft

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	5.0 min
Computational Time Increment	0.7 min
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670

PondPack Results for PMF Event

Subsection: Unit Hydrograph Summary
Label: South Pond Direct Rainfall
Scenario: Base

Return Event: 1 years
Storm Event: PMP

SCS Unit Hydrograph Parameters	
Unit peak, qp	96.67 ft³/s
Unit peak time, Tp	3.3 min
Unit receding limb, Tr	13.3 min
Total unit time, Tb	16.7 min

PondPack Results for PMF Event

Subsection: Time vs. Elevation
Label: South Pond (OUT)
Scenario: Base

Return Event: 1 years
Storm Event: PMP

Time vs. Elevation (ft)

Output Time increment = 3.0 min
Time on left represents time for first value in each row.

Time (min)	Elevation (ft)	Elevation (ft)	Elevation (ft)	Elevation (ft)	Elevation (ft)
0.0	665.00	665.00	665.01	665.01	665.02
15.0	665.02	665.02	665.03	665.03	665.04
30.0	665.04	665.04	665.05	665.05	665.05
45.0	665.06	665.06	665.07	665.07	665.07
60.0	665.08	665.08	665.08	665.09	665.09
75.0	665.09	665.09	665.10	665.10	665.10
90.0	665.11	665.11	665.11	665.11	665.12
105.0	665.12	665.12	665.12	665.13	665.13
120.0	665.13	665.13	665.13	665.14	665.14
135.0	665.14	665.14	665.14	665.15	665.15
150.0	665.15	665.15	665.15	665.16	665.16
165.0	665.16	665.16	665.16	665.16	665.16
180.0	665.17	665.17	665.17	665.17	665.17
195.0	665.17	665.17	665.18	665.18	665.18
210.0	665.18	665.18	665.18	665.18	665.18
225.0	665.19	665.19	665.19	665.19	665.19
240.0	665.19	665.19	665.19	665.19	665.19
255.0	665.20	665.20	665.20	665.20	665.20
270.0	665.20	665.20	665.20	665.20	665.20
285.0	665.20	665.20	665.21	665.21	665.21
300.0	665.21	665.21	665.21	665.21	665.21
315.0	665.21	665.21	665.21	665.21	665.21
330.0	665.21	665.21	665.21	665.22	665.22
345.0	665.22	665.22	665.22	665.22	665.22
360.0	665.22	665.22	665.22	665.22	665.23
375.0	665.23	665.23	665.23	665.24	665.24
390.0	665.24	665.24	665.25	665.25	665.25
405.0	665.25	665.26	665.26	665.26	665.26
420.0	665.26	665.27	665.27	665.27	665.27
435.0	665.27	665.28	665.28	665.28	665.28
450.0	665.28	665.29	665.29	665.29	665.29
465.0	665.29	665.29	665.29	665.30	665.30
480.0	665.30	665.30	665.30	665.30	665.30
495.0	665.31	665.31	665.31	665.31	665.31
510.0	665.31	665.31	665.31	665.31	665.32
525.0	665.32	665.32	665.32	665.32	665.32
540.0	665.32	665.32	665.33	665.33	665.34
555.0	665.35	665.36	665.36	665.37	665.37
570.0	665.38	665.39	665.39	665.40	665.40
585.0	665.41	665.42	665.42	665.43	665.43

PondPack Results for PMF Event

Subsection: Time vs. Elevation
Label: South Pond (OUT)
Scenario: Base

Return Event: 1 years
Storm Event: PMP

Time vs. Elevation (ft)

Output Time increment = 3.0 min
Time on left represents time for first value in each row.

Time (min)	Elevation (ft)	Elevation (ft)	Elevation (ft)	Elevation (ft)	Elevation (ft)
600.0	665.44	665.44	665.45	665.45	665.46
615.0	665.46	665.46	665.47	665.47	665.48
630.0	665.48	665.49	665.49	665.49	665.50
645.0	665.50	665.50	665.51	665.51	665.52
660.0	665.52	665.52	665.53	665.53	665.53
675.0	665.54	665.54	665.54	665.55	665.55
690.0	665.56	665.57	665.60	665.64	665.68
705.0	665.72	665.77	665.85	665.94	666.07
720.0	666.31	666.61	666.83	666.96	667.05
735.0	667.14	667.22	667.28	667.33	667.37
750.0	667.41	667.45	667.47	667.47	667.48
765.0	667.48	667.49	667.49	667.49	667.50
780.0	667.50	667.50	667.51	667.51	667.52
795.0	667.52	667.52	667.53	667.53	667.53
810.0	667.54	667.54	667.54	667.55	667.55
825.0	667.56	667.56	667.56	667.57	667.57
840.0	667.57	667.58	667.58	667.58	667.59
855.0	667.59	667.60	667.60	667.60	667.61
870.0	667.61	667.61	667.62	667.62	667.62
885.0	667.63	667.63	667.64	667.64	667.64
900.0	667.65	667.65	667.65	667.65	667.64
915.0	667.64	667.64	667.64	667.63	667.63
930.0	667.63	667.62	667.62	667.62	667.62
945.0	667.61	667.61	667.61	667.61	667.60
960.0	667.60	667.60	667.60	667.59	667.59
975.0	667.59	667.58	667.58	667.58	667.58
990.0	667.57	667.57	667.57	667.57	667.56
1,005.0	667.56	667.56	667.55	667.55	667.55
1,020.0	667.55	667.54	667.54	667.54	667.54
1,035.0	667.53	667.53	667.53	667.53	667.52
1,050.0	667.52	667.52	667.51	667.51	667.51
1,065.0	667.51	667.50	667.50	667.50	667.50
1,080.0	667.49	667.49	667.49	667.48	667.47
1,095.0	667.47	667.46	667.46	667.45	667.45
1,110.0	667.44	667.44	667.43	667.43	667.42
1,125.0	667.42	667.41	667.41	667.40	667.39
1,140.0	667.39	667.38	667.38	667.37	667.37
1,155.0	667.36	667.36	667.35	667.35	667.34
1,170.0	667.34	667.33	667.33	667.32	667.31
1,185.0	667.31	667.30	667.30	667.29	667.29
1,200.0	667.28	667.28	667.27	667.27	667.26

PondPack Results for PMF Event

Subsection: Time vs. Elevation
Label: South Pond (OUT)
Scenario: Base

Return Event: 1 years
Storm Event: PMP

Time vs. Elevation (ft)

Output Time increment = 3.0 min
Time on left represents time for first value in each row.

Time (min)	Elevation (ft)	Elevation (ft)	Elevation (ft)	Elevation (ft)	Elevation (ft)
1,215.0	667.26	667.25	667.24	667.24	667.23
1,230.0	667.23	667.22	667.22	667.21	667.21
1,245.0	667.20	667.20	667.19	667.19	667.18
1,260.0	667.18	667.17	667.16	667.16	667.15
1,275.0	667.15	667.14	667.14	667.13	667.13
1,290.0	667.12	667.12	667.11	667.11	667.10
1,305.0	667.10	667.09	667.08	667.08	667.07
1,320.0	667.07	667.06	667.06	667.05	667.05
1,335.0	667.04	667.04	667.03	667.03	667.02
1,350.0	667.02	667.01	667.00	667.00	666.99
1,365.0	666.99	666.98	666.98	666.97	666.97
1,380.0	666.96	666.96	666.95	666.95	666.94
1,395.0	666.93	666.93	666.92	666.92	666.91
1,410.0	666.91	666.90	666.90	666.89	666.89
1,425.0	666.88	666.87	666.87	666.86	666.86
1,440.0	666.85	(N/A)	(N/A)	(N/A)	(N/A)

PondPack Results for PMF Event

Subsection: Time vs. Volume
Label: South Pond
Scenario: Base

Return Event: 1 years
Storm Event: PMP

Time vs. Volume (ac-ft)

Output Time increment = 3.0 min
Time on left represents time for first value in each row.

Time (min)	Volume (ac-ft)	Volume (ac-ft)	Volume (ac-ft)	Volume (ac-ft)	Volume (ac-ft)
0.0	63.131	63.157	63.183	63.208	63.233
15.0	63.258	63.283	63.309	63.334	63.359
30.0	63.384	63.409	63.434	63.458	63.481
45.0	63.505	63.527	63.550	63.572	63.594
60.0	63.615	63.636	63.657	63.677	63.697
75.0	63.716	63.735	63.754	63.772	63.790
90.0	63.808	63.825	63.842	63.858	63.874
105.0	63.890	63.906	63.921	63.936	63.950
120.0	63.965	63.979	63.993	64.006	64.019
135.0	64.032	64.045	64.058	64.070	64.082
150.0	64.094	64.105	64.117	64.128	64.139
165.0	64.149	64.160	64.170	64.180	64.190
180.0	64.200	64.209	64.218	64.227	64.236
195.0	64.245	64.254	64.262	64.270	64.278
210.0	64.286	64.294	64.302	64.309	64.317
225.0	64.324	64.331	64.338	64.344	64.351
240.0	64.357	64.364	64.370	64.376	64.382
255.0	64.388	64.394	64.399	64.405	64.410
270.0	64.416	64.421	64.426	64.431	64.436
285.0	64.441	64.446	64.450	64.455	64.459
300.0	64.463	64.468	64.472	64.476	64.480
315.0	64.484	64.488	64.492	64.495	64.499
330.0	64.503	64.506	64.510	64.513	64.517
345.0	64.520	64.523	64.526	64.529	64.532
360.0	64.535	64.541	64.553	64.570	64.588
375.0	64.605	64.622	64.639	64.656	64.672
390.0	64.688	64.704	64.719	64.734	64.749
405.0	64.764	64.778	64.792	64.806	64.819
420.0	64.833	64.846	64.858	64.871	64.883
435.0	64.895	64.907	64.919	64.930	64.941
450.0	64.952	64.963	64.974	64.984	64.994
465.0	65.004	65.014	65.023	65.033	65.042
480.0	65.051	65.060	65.068	65.077	65.085
495.0	65.093	65.101	65.109	65.117	65.125
510.0	65.132	65.139	65.146	65.153	65.160
525.0	65.167	65.173	65.180	65.186	65.192
540.0	65.198	65.212	65.243	65.285	65.330
555.0	65.374	65.417	65.460	65.501	65.542
570.0	65.583	65.622	65.660	65.698	65.735
585.0	65.771	65.807	65.841	65.875	65.909

PondPack Results for PMF Event

Subsection: Time vs. Volume
Label: South Pond
Scenario: Base

Return Event: 1 years
Storm Event: PMP

Time vs. Volume (ac-ft)

Output Time increment = 3.0 min
Time on left represents time for first value in each row.

Time (min)	Volume (ac-ft)	Volume (ac-ft)	Volume (ac-ft)	Volume (ac-ft)	Volume (ac-ft)
600.0	65.942	65.973	66.005	66.035	66.066
615.0	66.095	66.124	66.152	66.180	66.207
630.0	66.234	66.260	66.285	66.310	66.334
645.0	66.358	66.382	66.405	66.429	66.453
660.0	66.477	66.500	66.524	66.547	66.571
675.0	66.595	66.619	66.643	66.666	66.690
690.0	66.714	66.787	66.969	67.229	67.508
705.0	67.792	68.131	68.594	69.189	70.036
720.0	71.642	73.644	75.053	75.902	76.554
735.0	77.142	77.663	78.062	78.376	78.670
750.0	78.958	79.197	79.323	79.372	79.402
765.0	79.428	79.453	79.477	79.502	79.526
780.0	79.551	79.575	79.600	79.624	79.648
795.0	79.673	79.697	79.721	79.746	79.770
810.0	79.795	79.819	79.843	79.868	79.892
825.0	79.917	79.941	79.965	79.990	80.014
840.0	80.039	80.063	80.087	80.112	80.136
855.0	80.161	80.185	80.210	80.234	80.259
870.0	80.283	80.307	80.332	80.356	80.381
885.0	80.405	80.430	80.454	80.478	80.503
900.0	80.527	80.544	80.542	80.528	80.511
915.0	80.493	80.475	80.456	80.438	80.420
930.0	80.402	80.384	80.366	80.347	80.329
945.0	80.311	80.293	80.275	80.257	80.239
960.0	80.221	80.202	80.184	80.166	80.148
975.0	80.130	80.111	80.093	80.075	80.057
990.0	80.039	80.021	80.003	79.985	79.967
1,005.0	79.948	79.930	79.912	79.894	79.876
1,020.0	79.858	79.839	79.821	79.803	79.785
1,035.0	79.767	79.749	79.731	79.713	79.695
1,050.0	79.677	79.659	79.640	79.622	79.604
1,065.0	79.586	79.568	79.550	79.531	79.513
1,080.0	79.495	79.473	79.444	79.410	79.374
1,095.0	79.339	79.303	79.267	79.231	79.195
1,110.0	79.159	79.123	79.087	79.052	79.016
1,125.0	78.980	78.944	78.908	78.872	78.836
1,140.0	78.800	78.764	78.729	78.693	78.657
1,155.0	78.621	78.585	78.549	78.514	78.478
1,170.0	78.442	78.406	78.370	78.334	78.299
1,185.0	78.263	78.227	78.191	78.155	78.119
1,200.0	78.084	78.048	78.012	77.976	77.940

PondPack Results for PMF Event

Subsection: Time vs. Volume
Label: South Pond
Scenario: Base

Return Event: 1 years
Storm Event: PMP

Time vs. Volume (ac-ft)

Output Time increment = 3.0 min
Time on left represents time for first value in each row.

Time (min)	Volume (ac-ft)	Volume (ac-ft)	Volume (ac-ft)	Volume (ac-ft)	Volume (ac-ft)
1,215.0	77.905	77.869	77.833	77.797	77.762
1,230.0	77.726	77.690	77.654	77.619	77.583
1,245.0	77.547	77.512	77.476	77.440	77.404
1,260.0	77.369	77.333	77.297	77.261	77.226
1,275.0	77.190	77.154	77.118	77.083	77.047
1,290.0	77.012	76.976	76.940	76.905	76.869
1,305.0	76.833	76.797	76.762	76.726	76.691
1,320.0	76.655	76.619	76.584	76.548	76.512
1,335.0	76.477	76.441	76.405	76.370	76.334
1,350.0	76.299	76.263	76.228	76.192	76.156
1,365.0	76.120	76.084	76.048	76.012	75.976
1,380.0	75.940	75.904	75.868	75.832	75.796
1,395.0	75.761	75.725	75.689	75.653	75.617
1,410.0	75.581	75.545	75.509	75.474	75.438
1,425.0	75.402	75.366	75.330	75.294	75.259
1,440.0	75.223	(N/A)	(N/A)	(N/A)	(N/A)

PondPack Results for PMF Event

Subsection: Outlet Input Data
Label: Composite Outlet Structure - 1
Scenario: Base

Return Event: 1 years
Storm Event: PMP

Requested Pond Water Surface Elevations	
Minimum (Headwater)	655.00 ft
Increment (Headwater)	0.50 ft
Maximum (Headwater)	670.00 ft

Outlet Connectivity

Structure Type	Outlet ID	Direction	Outfall	E1 (ft)	E2 (ft)
User Defined Table	User Defined Rating Table - 1	Forward	TW	655.00	670.00
Tailwater Settings	Tailwater			(N/A)	(N/A)

PondPack Results for PMF Event

Subsection: Outlet Input Data
Label: Composite Outlet Structure - 1
Scenario: Base

Return Event: 1 years
Storm Event: PMP

Structure ID: User Defined Rating Table - 1
Structure Type: User Defined Table

Elevation (ft)	Flow (ft³/s)
0.00	0.00
10.00	0.00
10.01	17.00
15.00	17.00

Structure ID: TW
Structure Type: TW Setup, DS Channel

Tailwater Type	Free Outfall

Convergence Tolerances	
Maximum Iterations	30
Tailwater Tolerance (Minimum)	0.01 ft
Tailwater Tolerance (Maximum)	0.50 ft
Headwater Tolerance (Minimum)	0.01 ft
Headwater Tolerance (Maximum)	0.50 ft
Flow Tolerance (Minimum)	0.001 ft³/s
Flow Tolerance (Maximum)	10.000 ft³/s

PondPack Results for PMF Event

Subsection: Elevation-Volume-Flow Table (Pond)
Label: South Pond
Scenario: Base

Return Event: 1 years
Storm Event: PMP

Infiltration	
Infiltration Method (Computed)	No Infiltration

Initial Conditions	
Elevation (Water Surface, Initial)	665.00 ft
Volume (Initial)	63.131 ac-ft
Flow (Initial Outlet)	0.00 ft³/s
Flow (Initial Infiltration)	0.00 ft³/s
Flow (Initial, Total)	0.00 ft³/s
Time Increment	3.0 min

Elevation (ft)	Outflow (ft³/s)	Storage (ac-ft)	Area (acres)	Infiltration (ft³/s)	Flow (Total) (ft³/s)	2S/t + O (ft³/s)
653.00	0.00	0.000	0.000	0.00	0.00	0.00
653.50	0.00	0.129	0.773	0.00	0.00	62.38
654.00	0.00	1.031	3.093	0.00	0.00	499.06
654.50	0.00	2.819	4.081	0.00	0.00	1,364.41
655.00	0.00	5.135	5.205	0.00	0.00	2,485.33
655.50	0.00	7.752	5.263	0.00	0.00	3,752.07
656.00	0.00	10.399	5.322	0.00	0.00	5,032.88
656.50	0.00	13.074	5.380	0.00	0.00	6,327.82
657.00	0.00	15.779	5.439	0.00	0.00	7,636.95
657.50	0.00	18.513	5.498	0.00	0.00	8,960.31
658.00	0.00	21.277	5.557	0.00	0.00	10,297.96
658.50	0.00	24.070	5.616	0.00	0.00	11,649.95
659.00	0.00	26.893	5.676	0.00	0.00	13,016.35
659.50	0.00	29.746	5.736	0.00	0.00	14,397.19
660.00	0.00	32.629	5.796	0.00	0.00	15,792.54
660.50	0.00	35.542	5.856	0.00	0.00	17,202.44
661.00	0.00	38.485	5.917	0.00	0.00	18,626.96
661.50	0.00	41.459	5.977	0.00	0.00	20,066.15
662.00	0.00	44.463	6.038	0.00	0.00	21,520.05
662.50	0.00	47.497	6.099	0.00	0.00	22,988.72
663.00	0.00	50.562	6.161	0.00	0.00	24,472.22
663.50	0.00	53.658	6.222	0.00	0.00	25,970.60
664.00	0.00	56.785	6.284	0.00	0.00	27,483.92
664.50	0.00	59.943	6.346	0.00	0.00	29,012.22
665.00	0.00	63.131	6.409	0.00	0.00	30,555.56
665.50	17.00	66.351	6.471	0.00	17.00	32,131.00
666.00	17.00	69.602	6.534	0.00	17.00	33,704.58
666.50	17.00	72.885	6.596	0.00	17.00	35,293.27
667.00	17.00	76.198	6.658	0.00	17.00	36,897.03

PondPack Results for PMF Event

Subsection: Elevation-Volume-Flow Table (Pond)
Label: South Pond
Scenario: Base

Return Event: 1 years
Storm Event: PMP

Elevation (ft)	Outflow (ft³/s)	Storage (ac-ft)	Area (acres)	Infiltration (ft³/s)	Flow (Total) (ft³/s)	2S/t + O (ft³/s)
667.50	17.00	79.543	6.720	0.00	17.00	38,515.79
668.00	17.00	82.918	6.782	0.00	17.00	40,149.48
668.50	17.00	86.332	6.875	0.00	17.00	41,801.89
669.00	17.00	89.793	6.968	0.00	17.00	43,476.82
669.50	17.00	93.295	7.039	0.00	17.00	45,171.66
670.00	0.00	96.832	7.110	0.00	0.00	46,866.74
670.50	0.00	100.387	7.110	0.00	0.00	48,587.47
671.00	0.00	103.943	7.110	0.00	0.00	50,308.19
671.50	0.00	107.498	7.110	0.00	0.00	52,028.89
672.00	0.00	111.053	7.110	0.00	0.00	53,749.59
672.50	0.00	114.608	7.110	0.00	0.00	55,470.27
673.00	0.00	118.163	7.110	0.00	0.00	57,190.94
673.50	0.00	121.718	7.110	0.00	0.00	58,911.60
674.00	0.00	125.273	7.110	0.00	0.00	60,632.25
674.50	0.00	128.828	7.110	0.00	0.00	62,352.89
675.00	0.00	132.383	7.110	0.00	0.00	64,073.51

PondPack Results for PMF Event

Subsection: Level Pool Pond Routing Summary
Label: South Pond (IN)
Scenario: Base

Return Event: 1 years
Storm Event: PMP

Infiltration	
Infiltration Method (Computed)	No Infiltration

Initial Conditions	
Elevation (Water Surface, Initial)	665.00 ft
Volume (Initial)	63.131 ac-ft
Flow (Initial Outlet)	0.00 ft³/s
Flow (Initial Infiltration)	0.00 ft³/s
Flow (Initial, Total)	0.00 ft³/s
Time Increment	3.0 min

Inflow/Outflow Hydrograph Summary			
Flow (Peak In)	543.23 ft³/s	Time to Peak (Flow, In)	720.0 min
Flow (Peak Outlet)	17.00 ft³/s	Time to Peak (Flow, Outlet)	645.0 min

Elevation (Water Surface, Peak)	667.65 ft
Volume (Peak)	80.544 ac-ft

Mass Balance (ac-ft)	
Volume (Initial)	63.131 ac-ft
Volume (Total Inflow)	37.603 ac-ft
Volume (Total Infiltration)	0.000 ac-ft
Volume (Total Outlet Outflow)	25.508 ac-ft
Volume (Retained)	75.152 ac-ft
Volume (Unrouted)	-0.074 ac-ft
Error (Mass Balance)	0.2 %

PondPack Results for PMF Event

Subsection: Pond Inflow Summary
Label: South Pond (IN)
Scenario: Base

Return Event: 1 years
Storm Event: PMP

Summary for Hydrograph Addition at 'South Pond'

Upstream Link	Upstream Node
<Catchment to Outflow Node>	Perimeter Roads
<Catchment to Outflow Node>	BATW
<Catchment to Outflow Node>	South Pond Direct Rainfall

Node Inflows

Inflow Type	Element	Volume (ac-ft)	Time to Peak (min)	Flow (Peak) (ft³/s)
Flow (From)	Perimeter Roads	5.417	720.0	121.28
Flow (From)	BATW	12.714	0.0	6.41
Flow (From)	South Pond Direct Rainfall	19.472	720.0	415.54
Flow (In)	South Pond	37.603	720.0	543.23

PondPack Results for PMF Event

Subsection: Master Network Summary

Catchments Summary

Label	Scenario	Return Event (years)	Hydrograph Volume (ac-ft)	Time to Peak (min)	Peak Flow (ft³/s)
BATW	Base	14	12.714	0.0	6.41
Perimeter Roads	Base	14	2.546	720.0	58.91
South Pond Direct Rainfall	Base	14	9.700	720.0	207.74

Node Summary

Label	Scenario	Return Event (years)	Hydrograph Volume (ac-ft)	Time to Peak (min)	Peak Flow (ft³/s)
Outlet	Base	14	22.978	714.0	17.00

Pond Summary

Label	Scenario	Return Event (years)	Hydrograph Volume (ac-ft)	Time to Peak (min)	Peak Flow (ft³/s)	Maximum Water Surface Elevation (ft)	Maximum Pond Storage (ac-ft)
South Pond (IN)	Base	14	24.960	720.0	273.06	(N/A)	(N/A)
South Pond (OUT)	Base	14	22.978	714.0	17.00	666.26	71.322

PondPack Results for PMF Event

Subsection: Time-Depth Curve
Label: Time-Depth - 1
Scenario: Base

Return Event: 14 years
Storm Event: HalfPMF

Time-Depth Curve: HalfPMF	
Label	HalfPMF
Start Time	0.0 min
Increment	5.0 min
End Time	1,440.0 min
Return Event	14 years

CUMULATIVE RAINFALL (in)
Output Time Increment = 5.0 min
Time on left represents time for first value in each row.

Time (min)	Depth (in)	Depth (in)	Depth (in)	Depth (in)	Depth (in)
0.0	0.000	0.009	0.017	0.026	0.035
25.0	0.043	0.052	0.061	0.069	0.078
50.0	0.087	0.095	0.104	0.113	0.122
75.0	0.130	0.139	0.148	0.156	0.165
100.0	0.174	0.182	0.191	0.200	0.208
125.0	0.217	0.226	0.234	0.243	0.252
150.0	0.260	0.269	0.278	0.286	0.295
175.0	0.304	0.313	0.321	0.330	0.339
200.0	0.347	0.356	0.365	0.373	0.382
225.0	0.391	0.399	0.408	0.417	0.425
250.0	0.434	0.443	0.451	0.460	0.469
275.0	0.477	0.486	0.495	0.503	0.512
300.0	0.521	0.530	0.538	0.547	0.556
325.0	0.564	0.573	0.582	0.590	0.599
350.0	0.608	0.616	0.625	0.653	0.681
375.0	0.708	0.736	0.764	0.792	0.819
400.0	0.847	0.875	0.903	0.931	0.958
425.0	0.986	1.014	1.042	1.069	1.097
450.0	1.125	1.153	1.181	1.208	1.236
475.0	1.264	1.292	1.319	1.347	1.375
500.0	1.403	1.431	1.458	1.486	1.514
525.0	1.542	1.569	1.597	1.625	1.699
550.0	1.773	1.848	1.922	1.996	2.070
575.0	2.144	2.218	2.293	2.367	2.441
600.0	2.515	2.589	2.663	2.738	2.812
625.0	2.886	2.960	3.034	3.108	3.183
650.0	3.257	3.331	3.405	3.479	3.553
675.0	3.628	3.702	3.776	3.850	4.209
700.0	4.568	4.928	5.599	6.439	9.389
725.0	10.229	10.901	11.573	11.932	12.291
750.0	12.650	12.724	12.798	12.873	12.947
775.0	13.021	13.095	13.169	13.243	13.318
800.0	13.392	13.466	13.540	13.614	13.688
825.0	13.763	13.837	13.911	13.985	14.059

PondPack Results for PMF Event

Subsection: Time-Depth Curve
Label: Time-Depth - 1
Scenario: Base

Return Event: 14 years
Storm Event: HalfPMF

CUMULATIVE RAINFALL (in)
Output Time Increment = 5.0 min
Time on left represents time for first value in each row.

Time (min)	Depth (in)	Depth (in)	Depth (in)	Depth (in)	Depth (in)
850.0	14.133	14.208	14.282	14.356	14.430
875.0	14.504	14.578	14.653	14.727	14.801
900.0	14.875	14.903	14.931	14.958	14.986
925.0	15.014	15.042	15.069	15.097	15.125
950.0	15.153	15.181	15.208	15.236	15.264
975.0	15.292	15.319	15.347	15.375	15.403
1,000.0	15.431	15.458	15.486	15.514	15.542
1,025.0	15.569	15.597	15.625	15.653	15.681
1,050.0	15.708	15.736	15.764	15.792	15.819
1,075.0	15.847	15.875	15.884	15.892	15.901
1,100.0	15.910	15.918	15.927	15.936	15.944
1,125.0	15.953	15.962	15.970	15.979	15.988
1,150.0	15.997	16.005	16.014	16.023	16.031
1,175.0	16.040	16.049	16.057	16.066	16.075
1,200.0	16.083	16.092	16.101	16.109	16.118
1,225.0	16.127	16.135	16.144	16.153	16.161
1,250.0	16.170	16.179	16.188	16.196	16.205
1,275.0	16.214	16.222	16.231	16.240	16.248
1,300.0	16.257	16.266	16.274	16.283	16.292
1,325.0	16.300	16.309	16.318	16.326	16.335
1,350.0	16.344	16.352	16.361	16.370	16.378
1,375.0	16.387	16.396	16.405	16.413	16.422
1,400.0	16.431	16.439	16.448	16.457	16.465
1,425.0	16.474	16.483	16.491	16.500	(N/A)

PondPack Results for PMF Event

Subsection: Read Hydrograph
Label: BATW
Scenario: Base

Return Event: 14 years
Storm Event: HalfPMF

Peak Discharge	6.41 ft³/s
Time to Peak	480.0 min
Hydrograph Volume	12.714 ac-ft

HYDROGRAPH ORDINATES (ft³/s)
Output Time Increment = 60.0 min
Time on left represents time for first value in each row.

Time (min)	Flow (ft³/s)	Flow (ft³/s)	Flow (ft³/s)	Flow (ft³/s)	Flow (ft³/s)
0.0	6.41	6.41	6.41	6.41	6.41
300.0	6.41	6.41	6.41	6.41	6.41
600.0	6.41	6.41	6.41	6.41	6.41
900.0	6.41	6.41	6.41	6.41	6.41
1,200.0	6.41	6.41	6.41	6.41	6.41

PondPack Results for PMF Event

Subsection: Unit Hydrograph Summary
Label: Perimeter Roads
Scenario: Base

Return Event: 14 years
Storm Event: HalfPMF

Storm Event	HalfPMF
Return Event	14 years
Duration	1,440.0 min
Depth	16.500 in
Time of Concentration (Composite)	5.0 min
Area (User Defined)	2.100 acres

Computational Time Increment	0.7 min
Time to Peak (Computed)	721.3 min
Flow (Peak, Computed)	62.32 ft³/s
Output Increment	3.0 min
Time to Flow (Peak Interpolated Output)	720.0 min
Flow (Peak Interpolated Output)	58.91 ft³/s

Drainage Area	
SCS CN (Composite)	85.000
Area (User Defined)	2.100 acres
Maximum Retention (Pervious)	1.765 in
Maximum Retention (Pervious, 20 percent)	0.353 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	14.556 in
Runoff Volume (Pervious)	2.547 ac-ft

Hydrograph Volume (Area under Hydrograph curve)	
Volume	2.546 ac-ft

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	5.0 min
Computational Time Increment	0.7 min
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670

PondPack Results for PMF Event

Subsection: Unit Hydrograph Summary
Label: Perimeter Roads
Scenario: Base

Return Event: 14 years
Storm Event: HalfPMF

SCS Unit Hydrograph Parameters	
Unit peak, qp	28.55 ft³/s
Unit peak time, Tp	3.3 min
Unit receding limb, Tr	13.3 min
Total unit time, Tb	16.7 min

PondPack Results for PMF Event

Subsection: Unit Hydrograph Summary
Label: South Pond Direct Rainfall
Scenario: Base

Return Event: 14 years
Storm Event: HalfPMF

Storm Event	HalfPMF
Return Event	14 years
Duration	1,440.0 min
Depth	16.500 in
Time of Concentration (Composite)	5.0 min
Area (User Defined)	7.110 acres

Computational Time Increment	0.7 min
Time to Peak (Computed)	721.3 min
Flow (Peak, Computed)	218.80 ft³/s
Output Increment	3.0 min
Time to Flow (Peak Interpolated Output)	720.0 min
Flow (Peak Interpolated Output)	207.74 ft³/s

Drainage Area	
SCS CN (Composite)	99.000
Area (User Defined)	7.110 acres
Maximum Retention (Pervious)	0.101 in
Maximum Retention (Pervious, 20 percent)	0.020 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	16.379 in
Runoff Volume (Pervious)	9.705 ac-ft

Hydrograph Volume (Area under Hydrograph curve)	
Volume	9.700 ac-ft

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	5.0 min
Computational Time Increment	0.7 min
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670

PondPack Results for PMF Event

Subsection: Unit Hydrograph Summary
Label: South Pond Direct Rainfall
Scenario: Base

Return Event: 14 years
Storm Event: HalfPMF

SCS Unit Hydrograph Parameters	
Unit peak, qp	96.67 ft³/s
Unit peak time, Tp	3.3 min
Unit receding limb, Tr	13.3 min
Total unit time, Tb	16.7 min

PondPack Results for PMF Event

Subsection: Time vs. Elevation
Label: South Pond (OUT)
Scenario: Base

Return Event: 14 years
Storm Event: HalfPMF

Time vs. Elevation (ft)

Output Time increment = 3.0 min
Time on left represents time for first value in each row.

Time (min)	Elevation (ft)	Elevation (ft)	Elevation (ft)	Elevation (ft)	Elevation (ft)
0.0	665.00	665.00	665.01	665.01	665.02
15.0	665.02	665.02	665.03	665.03	665.03
30.0	665.04	665.04	665.04	665.05	665.05
45.0	665.05	665.06	665.06	665.06	665.07
60.0	665.07	665.07	665.08	665.08	665.08
75.0	665.08	665.09	665.09	665.09	665.09
90.0	665.10	665.10	665.10	665.10	665.11
105.0	665.11	665.11	665.11	665.11	665.12
120.0	665.12	665.12	665.12	665.12	665.13
135.0	665.13	665.13	665.13	665.13	665.13
150.0	665.14	665.14	665.14	665.14	665.14
165.0	665.14	665.14	665.15	665.15	665.15
180.0	665.15	665.15	665.15	665.15	665.15
195.0	665.16	665.16	665.16	665.16	665.16
210.0	665.16	665.16	665.16	665.16	665.17
225.0	665.17	665.17	665.17	665.17	665.17
240.0	665.17	665.17	665.17	665.17	665.17
255.0	665.17	665.18	665.18	665.18	665.18
270.0	665.18	665.18	665.18	665.18	665.18
285.0	665.18	665.18	665.18	665.18	665.18
300.0	665.18	665.19	665.19	665.19	665.19
315.0	665.19	665.19	665.19	665.19	665.19
330.0	665.19	665.19	665.19	665.19	665.19
345.0	665.19	665.19	665.19	665.19	665.19
360.0	665.19	665.19	665.20	665.20	665.20
375.0	665.20	665.20	665.20	665.20	665.21
390.0	665.21	665.21	665.21	665.21	665.21
405.0	665.21	665.21	665.22	665.22	665.22
420.0	665.22	665.22	665.22	665.22	665.22
435.0	665.22	665.22	665.23	665.23	665.23
450.0	665.23	665.23	665.23	665.23	665.23
465.0	665.23	665.23	665.23	665.23	665.24
480.0	665.24	665.24	665.24	665.24	665.24
495.0	665.24	665.24	665.24	665.24	665.24
510.0	665.24	665.24	665.24	665.24	665.25
525.0	665.25	665.25	665.25	665.25	665.25
540.0	665.25	665.25	665.25	665.26	665.26
555.0	665.26	665.27	665.27	665.27	665.27
570.0	665.28	665.28	665.28	665.29	665.29
585.0	665.29	665.29	665.30	665.30	665.30

PondPack Results for PMF Event

Subsection: Time vs. Elevation
Label: South Pond (OUT)
Scenario: Base

Return Event: 14 years
Storm Event: HalfPMF

Time vs. Elevation (ft)

Output Time increment = 3.0 min
Time on left represents time for first value in each row.

Time (min)	Elevation (ft)	Elevation (ft)	Elevation (ft)	Elevation (ft)	Elevation (ft)
600.0	665.31	665.31	665.31	665.31	665.31
615.0	665.32	665.32	665.32	665.32	665.33
630.0	665.33	665.33	665.33	665.33	665.34
645.0	665.34	665.34	665.34	665.34	665.34
660.0	665.35	665.35	665.35	665.35	665.35
675.0	665.35	665.36	665.36	665.36	665.36
690.0	665.36	665.37	665.38	665.40	665.42
705.0	665.44	665.46	665.50	665.54	665.60
720.0	665.72	665.87	665.97	666.03	666.08
735.0	666.12	666.16	666.18	666.20	666.22
750.0	666.24	666.26	666.26	666.26	666.26
765.0	666.26	666.26	666.26	666.26	666.25
780.0	666.25	666.25	666.25	666.25	666.25
795.0	666.25	666.24	666.24	666.24	666.24
810.0	666.24	666.24	666.23	666.23	666.23
825.0	666.23	666.23	666.23	666.23	666.22
840.0	666.22	666.22	666.22	666.22	666.22
855.0	666.22	666.21	666.21	666.21	666.21
870.0	666.21	666.21	666.21	666.20	666.20
885.0	666.20	666.20	666.20	666.20	666.19
900.0	666.19	666.19	666.19	666.18	666.18
915.0	666.17	666.17	666.16	666.16	666.16
930.0	666.15	666.15	666.14	666.14	666.13
945.0	666.13	666.12	666.12	666.11	666.11
960.0	666.10	666.10	666.09	666.09	666.08
975.0	666.08	666.07	666.07	666.07	666.06
990.0	666.06	666.05	666.05	666.04	666.04
1,005.0	666.03	666.03	666.02	666.02	666.01
1,020.0	666.01	666.00	666.00	665.99	665.99
1,035.0	665.99	665.98	665.98	665.97	665.97
1,050.0	665.96	665.96	665.95	665.95	665.94
1,065.0	665.94	665.93	665.93	665.92	665.92
1,080.0	665.91	665.91	665.90	665.90	665.89
1,095.0	665.88	665.88	665.87	665.87	665.86
1,110.0	665.85	665.85	665.84	665.84	665.83
1,125.0	665.82	665.82	665.81	665.81	665.80
1,140.0	665.79	665.79	665.78	665.77	665.77
1,155.0	665.76	665.76	665.75	665.74	665.74
1,170.0	665.73	665.73	665.72	665.71	665.71
1,185.0	665.70	665.70	665.69	665.68	665.68
1,200.0	665.67	665.66	665.66	665.65	665.65

PondPack Results for PMF Event

Subsection: Time vs. Elevation
Label: South Pond (OUT)
Scenario: Base

Return Event: 14 years
Storm Event: HalfPMF

Time vs. Elevation (ft)

Output Time increment = 3.0 min
Time on left represents time for first value in each row.

Time (min)	Elevation (ft)	Elevation (ft)	Elevation (ft)	Elevation (ft)	Elevation (ft)
1,215.0	665.64	665.63	665.63	665.62	665.62
1,230.0	665.61	665.60	665.60	665.59	665.59
1,245.0	665.58	665.57	665.57	665.56	665.55
1,260.0	665.55	665.54	665.54	665.53	665.52
1,275.0	665.52	665.51	665.51	665.50	665.49
1,290.0	665.49	665.48	665.48	665.47	665.46
1,305.0	665.46	665.45	665.45	665.44	665.44
1,320.0	665.43	665.43	665.43	665.42	665.42
1,335.0	665.41	665.41	665.40	665.40	665.40
1,350.0	665.39	665.39	665.38	665.38	665.38
1,365.0	665.37	665.37	665.37	665.36	665.36
1,380.0	665.36	665.35	665.35	665.35	665.35
1,395.0	665.34	665.34	665.34	665.33	665.33
1,410.0	665.33	665.33	665.33	665.32	665.32
1,425.0	665.32	665.32	665.31	665.31	665.31
1,440.0	665.31	(N/A)	(N/A)	(N/A)	(N/A)

PondPack Results for PMF Event

Subsection: Time vs. Volume
Label: South Pond
Scenario: Base

Return Event: 14 years
Storm Event: HalfPMF

Time vs. Volume (ac-ft)

Output Time increment = 3.0 min
Time on left represents time for first value in each row.

Time (min)	Volume (ac-ft)	Volume (ac-ft)	Volume (ac-ft)	Volume (ac-ft)	Volume (ac-ft)
0.0	63.131	63.157	63.183	63.208	63.232
15.0	63.256	63.280	63.303	63.326	63.349
30.0	63.371	63.393	63.415	63.436	63.457
45.0	63.478	63.498	63.518	63.538	63.557
60.0	63.576	63.595	63.613	63.631	63.649
75.0	63.666	63.683	63.699	63.716	63.732
90.0	63.747	63.762	63.777	63.792	63.807
105.0	63.821	63.834	63.848	63.861	63.874
120.0	63.887	63.899	63.912	63.924	63.935
135.0	63.947	63.958	63.969	63.980	63.990
150.0	64.001	64.011	64.021	64.030	64.040
165.0	64.049	64.058	64.067	64.076	64.085
180.0	64.093	64.101	64.109	64.117	64.125
195.0	64.132	64.140	64.147	64.154	64.161
210.0	64.168	64.175	64.181	64.187	64.194
225.0	64.200	64.206	64.212	64.217	64.223
240.0	64.229	64.234	64.239	64.244	64.249
255.0	64.255	64.260	64.264	64.269	64.273
270.0	64.278	64.283	64.287	64.291	64.295
285.0	64.299	64.303	64.307	64.311	64.315
300.0	64.318	64.322	64.326	64.329	64.333
315.0	64.336	64.339	64.342	64.346	64.349
330.0	64.351	64.354	64.357	64.360	64.363
345.0	64.366	64.368	64.371	64.374	64.376
360.0	64.378	64.382	64.389	64.398	64.407
375.0	64.416	64.424	64.433	64.442	64.450
390.0	64.458	64.467	64.474	64.482	64.490
405.0	64.497	64.505	64.512	64.520	64.527
420.0	64.534	64.540	64.547	64.553	64.560
435.0	64.566	64.573	64.578	64.584	64.590
450.0	64.596	64.602	64.607	64.613	64.618
465.0	64.624	64.629	64.634	64.639	64.644
480.0	64.649	64.653	64.658	64.662	64.667
495.0	64.671	64.676	64.680	64.684	64.688
510.0	64.692	64.696	64.700	64.704	64.708
525.0	64.711	64.715	64.718	64.722	64.725
540.0	64.728	64.735	64.750	64.771	64.793
555.0	64.814	64.836	64.856	64.877	64.897
570.0	64.916	64.936	64.955	64.973	64.991
585.0	65.009	65.027	65.044	65.061	65.078

PondPack Results for PMF Event

Subsection: Time vs. Volume
Label: South Pond
Scenario: Base

Return Event: 14 years
Storm Event: HalfPMF

Time vs. Volume (ac-ft)

Output Time increment = 3.0 min
Time on left represents time for first value in each row.

Time (min)	Volume (ac-ft)	Volume (ac-ft)	Volume (ac-ft)	Volume (ac-ft)	Volume (ac-ft)
600.0	65.094	65.110	65.125	65.141	65.156
615.0	65.171	65.185	65.199	65.213	65.227
630.0	65.240	65.253	65.266	65.279	65.291
645.0	65.303	65.315	65.327	65.338	65.349
660.0	65.360	65.371	65.382	65.392	65.402
675.0	65.412	65.422	65.432	65.441	65.450
690.0	65.459	65.491	65.577	65.699	65.827
705.0	65.956	66.109	66.319	66.590	66.986
720.0	67.760	68.734	69.415	69.815	70.117
735.0	70.388	70.626	70.802	70.937	71.061
750.0	71.182	71.279	71.319	71.322	71.315
765.0	71.306	71.296	71.287	71.277	71.267
780.0	71.257	71.247	71.238	71.228	71.218
795.0	71.208	71.199	71.189	71.180	71.170
810.0	71.160	71.150	71.140	71.131	71.121
825.0	71.111	71.102	71.092	71.082	71.073
840.0	71.063	71.053	71.043	71.034	71.024
855.0	71.014	71.005	70.995	70.985	70.976
870.0	70.966	70.956	70.946	70.937	70.927
885.0	70.917	70.908	70.898	70.888	70.879
900.0	70.869	70.855	70.833	70.804	70.773
915.0	70.742	70.711	70.680	70.649	70.618
930.0	70.587	70.556	70.525	70.494	70.463
945.0	70.432	70.402	70.371	70.340	70.309
960.0	70.278	70.247	70.216	70.185	70.154
975.0	70.124	70.093	70.062	70.031	70.000
990.0	69.969	69.938	69.907	69.876	69.846
1,005.0	69.815	69.784	69.753	69.722	69.691
1,020.0	69.660	69.629	69.598	69.567	69.536
1,035.0	69.505	69.474	69.443	69.412	69.381
1,050.0	69.349	69.318	69.287	69.256	69.225
1,065.0	69.194	69.163	69.132	69.100	69.069
1,080.0	69.038	69.005	68.969	68.930	68.890
1,095.0	68.850	68.810	68.771	68.731	68.691
1,110.0	68.651	68.611	68.571	68.532	68.492
1,125.0	68.452	68.412	68.372	68.332	68.292
1,140.0	68.253	68.213	68.173	68.134	68.094
1,155.0	68.054	68.014	67.974	67.935	67.895
1,170.0	67.855	67.815	67.775	67.736	67.696
1,185.0	67.656	67.616	67.577	67.537	67.497
1,200.0	67.458	67.418	67.378	67.339	67.299

PondPack Results for PMF Event

Subsection: Time vs. Volume
Label: South Pond
Scenario: Base

Return Event: 14 years
Storm Event: HalfPMF

Time vs. Volume (ac-ft)

Output Time increment = 3.0 min
Time on left represents time for first value in each row.

Time (min)	Volume (ac-ft)	Volume (ac-ft)	Volume (ac-ft)	Volume (ac-ft)	Volume (ac-ft)
1,215.0	67.259	67.219	67.180	67.140	67.101
1,230.0	67.061	67.021	66.981	66.942	66.902
1,245.0	66.862	66.823	66.783	66.744	66.704
1,260.0	66.665	66.625	66.585	66.546	66.506
1,275.0	66.466	66.427	66.387	66.348	66.308
1,290.0	66.270	66.232	66.195	66.159	66.123
1,305.0	66.089	66.055	66.022	65.989	65.958
1,320.0	65.927	65.897	65.867	65.838	65.809
1,335.0	65.782	65.754	65.728	65.702	65.676
1,350.0	65.651	65.627	65.603	65.580	65.557
1,365.0	65.535	65.513	65.491	65.470	65.450
1,380.0	65.430	65.411	65.392	65.373	65.354
1,395.0	65.336	65.319	65.302	65.285	65.269
1,410.0	65.252	65.237	65.221	65.206	65.192
1,425.0	65.177	65.163	65.149	65.136	65.122
1,440.0	65.109	(N/A)	(N/A)	(N/A)	(N/A)

PondPack Results for PMF Event

Subsection: Outlet Input Data
Label: Composite Outlet Structure - 1
Scenario: Base

Return Event: 14 years
Storm Event: HalfPMF

Requested Pond Water Surface Elevations	
Minimum (Headwater)	655.00 ft
Increment (Headwater)	0.50 ft
Maximum (Headwater)	670.00 ft

Outlet Connectivity

Structure Type	Outlet ID	Direction	Outfall	E1 (ft)	E2 (ft)
User Defined Table	User Defined Rating Table - 1	Forward	TW	655.00	670.00
Tailwater Settings	Tailwater			(N/A)	(N/A)

PondPack Results for PMF Event

Subsection: Outlet Input Data
Label: Composite Outlet Structure - 1
Scenario: Base

Return Event: 14 years
Storm Event: HalfPMF

Structure ID: User Defined Rating Table - 1
Structure Type: User Defined Table

Elevation (ft)	Flow (ft³/s)
0.00	0.00
10.00	0.00
10.01	17.00
15.00	17.00

Structure ID: TW
Structure Type: TW Setup, DS Channel

Tailwater Type	Free Outfall

Convergence Tolerances	
Maximum Iterations	30
Tailwater Tolerance (Minimum)	0.01 ft
Tailwater Tolerance (Maximum)	0.50 ft
Headwater Tolerance (Minimum)	0.01 ft
Headwater Tolerance (Maximum)	0.50 ft
Flow Tolerance (Minimum)	0.001 ft³/s
Flow Tolerance (Maximum)	10.000 ft³/s

PondPack Results for PMF Event

Subsection: Elevation-Volume-Flow Table (Pond)
Label: South Pond
Scenario: Base

Return Event: 14 years
Storm Event: HalfPMF

Infiltration	
Infiltration Method (Computed)	No Infiltration

Initial Conditions	
Elevation (Water Surface, Initial)	665.00 ft
Volume (Initial)	63.131 ac-ft
Flow (Initial Outlet)	0.00 ft³/s
Flow (Initial Infiltration)	0.00 ft³/s
Flow (Initial, Total)	0.00 ft³/s
Time Increment	3.0 min

Elevation (ft)	Outflow (ft³/s)	Storage (ac-ft)	Area (acres)	Infiltration (ft³/s)	Flow (Total) (ft³/s)	2S/t + O (ft³/s)
653.00	0.00	0.000	0.000	0.00	0.00	0.00
653.50	0.00	0.129	0.773	0.00	0.00	62.38
654.00	0.00	1.031	3.093	0.00	0.00	499.06
654.50	0.00	2.819	4.081	0.00	0.00	1,364.41
655.00	0.00	5.135	5.205	0.00	0.00	2,485.33
655.50	0.00	7.752	5.263	0.00	0.00	3,752.07
656.00	0.00	10.399	5.322	0.00	0.00	5,032.88
656.50	0.00	13.074	5.380	0.00	0.00	6,327.82
657.00	0.00	15.779	5.439	0.00	0.00	7,636.95
657.50	0.00	18.513	5.498	0.00	0.00	8,960.31
658.00	0.00	21.277	5.557	0.00	0.00	10,297.96
658.50	0.00	24.070	5.616	0.00	0.00	11,649.95
659.00	0.00	26.893	5.676	0.00	0.00	13,016.35
659.50	0.00	29.746	5.736	0.00	0.00	14,397.19
660.00	0.00	32.629	5.796	0.00	0.00	15,792.54
660.50	0.00	35.542	5.856	0.00	0.00	17,202.44
661.00	0.00	38.485	5.917	0.00	0.00	18,626.96
661.50	0.00	41.459	5.977	0.00	0.00	20,066.15
662.00	0.00	44.463	6.038	0.00	0.00	21,520.05
662.50	0.00	47.497	6.099	0.00	0.00	22,988.72
663.00	0.00	50.562	6.161	0.00	0.00	24,472.22
663.50	0.00	53.658	6.222	0.00	0.00	25,970.60
664.00	0.00	56.785	6.284	0.00	0.00	27,483.92
664.50	0.00	59.943	6.346	0.00	0.00	29,012.22
665.00	0.00	63.131	6.409	0.00	0.00	30,555.56
665.50	17.00	66.351	6.471	0.00	17.00	32,131.00
666.00	17.00	69.602	6.534	0.00	17.00	33,704.58
666.50	17.00	72.885	6.596	0.00	17.00	35,293.27
667.00	17.00	76.198	6.658	0.00	17.00	36,897.03

PondPack Results for PMF Event

Subsection: Elevation-Volume-Flow Table (Pond)
Label: South Pond
Scenario: Base

Return Event: 14 years
Storm Event: HalfPMF

Elevation (ft)	Outflow (ft³/s)	Storage (ac-ft)	Area (acres)	Infiltration (ft³/s)	Flow (Total) (ft³/s)	2S/t + O (ft³/s)
667.50	17.00	79.543	6.720	0.00	17.00	38,515.79
668.00	17.00	82.918	6.782	0.00	17.00	40,149.48
668.50	17.00	86.332	6.875	0.00	17.00	41,801.89
669.00	17.00	89.793	6.968	0.00	17.00	43,476.82
669.50	17.00	93.295	7.039	0.00	17.00	45,171.66
670.00	0.00	96.832	7.110	0.00	0.00	46,866.74
670.50	0.00	100.387	7.110	0.00	0.00	48,587.47
671.00	0.00	103.943	7.110	0.00	0.00	50,308.19
671.50	0.00	107.498	7.110	0.00	0.00	52,028.89
672.00	0.00	111.053	7.110	0.00	0.00	53,749.59
672.50	0.00	114.608	7.110	0.00	0.00	55,470.27
673.00	0.00	118.163	7.110	0.00	0.00	57,190.94
673.50	0.00	121.718	7.110	0.00	0.00	58,911.60
674.00	0.00	125.273	7.110	0.00	0.00	60,632.25
674.50	0.00	128.828	7.110	0.00	0.00	62,352.89
675.00	0.00	132.383	7.110	0.00	0.00	64,073.51

PondPack Results for PMF Event

Subsection: Level Pool Pond Routing Summary
Label: South Pond (IN)
Scenario: Base

Return Event: 14 years
Storm Event: HalfPMF

Infiltration	
Infiltration Method (Computed)	No Infiltration

Initial Conditions	
Elevation (Water Surface, Initial)	665.00 ft
Volume (Initial)	63.131 ac-ft
Flow (Initial Outlet)	0.00 ft³/s
Flow (Initial Infiltration)	0.00 ft³/s
Flow (Initial, Total)	0.00 ft³/s
Time Increment	3.0 min

Inflow/Outflow Hydrograph Summary			
Flow (Peak In)	273.06 ft³/s	Time to Peak (Flow, In)	720.0 min
Flow (Peak Outlet)	17.00 ft³/s	Time to Peak (Flow, Outlet)	714.0 min

Elevation (Water Surface, Peak)	666.26 ft
Volume (Peak)	71.322 ac-ft

Mass Balance (ac-ft)	
Volume (Initial)	63.131 ac-ft
Volume (Total Inflow)	24.960 ac-ft
Volume (Total Infiltration)	0.000 ac-ft
Volume (Total Outlet Outflow)	22.978 ac-ft
Volume (Retained)	65.067 ac-ft
Volume (Unrouted)	-0.047 ac-ft
Error (Mass Balance)	0.2 %

PondPack Results for PMF Event

Subsection: Pond Inflow Summary
Label: South Pond (IN)
Scenario: Base

Return Event: 14 years
Storm Event: HalfPMF

Summary for Hydrograph Addition at 'South Pond'

Upstream Link	Upstream Node
<Catchment to Outflow Node>	Perimeter Roads
<Catchment to Outflow Node>	BATW
<Catchment to Outflow Node>	South Pond Direct Rainfall

Node Inflows

Inflow Type	Element	Volume (ac-ft)	Time to Peak (min)	Flow (Peak) (ft³/s)
Flow (From)	Perimeter Roads	2.546	720.0	58.91
Flow (From)	BATW	12.714	0.0	6.41
Flow (From)	South Pond Direct Rainfall	9.700	720.0	207.74
Flow (In)	South Pond	24.960	720.0	273.06

South Pond Modeling Layout

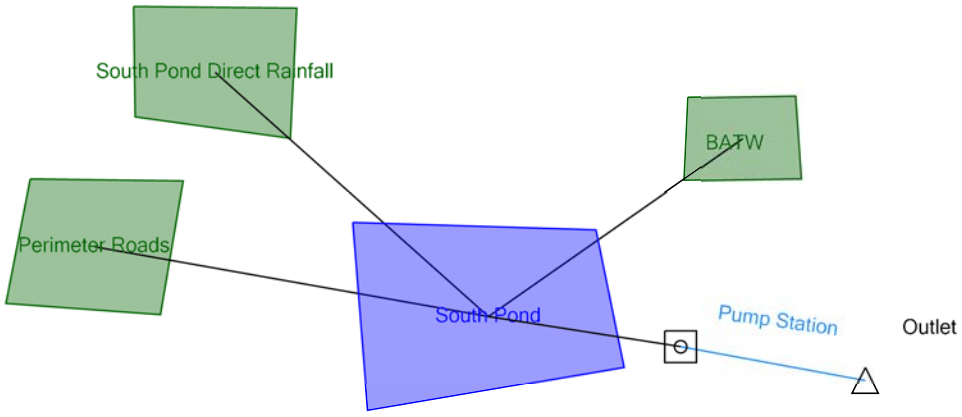
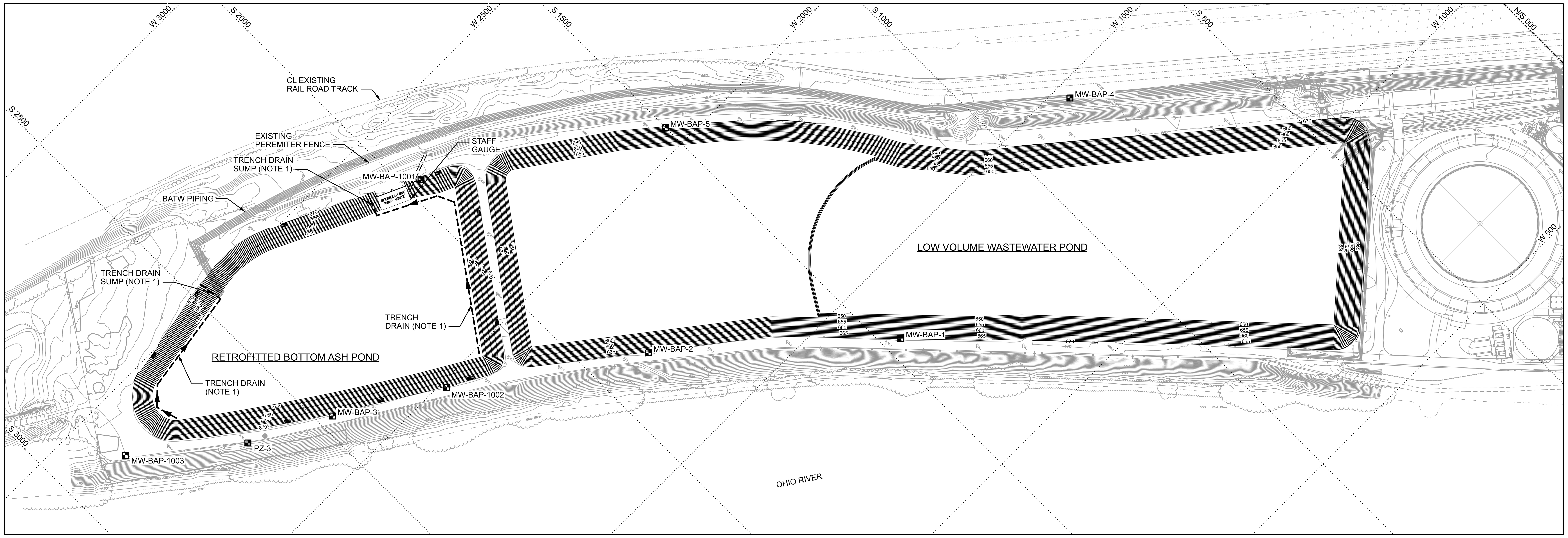


EXHIBIT F

Retrofitted Bottom Ash Pond Instrumentation Sketch

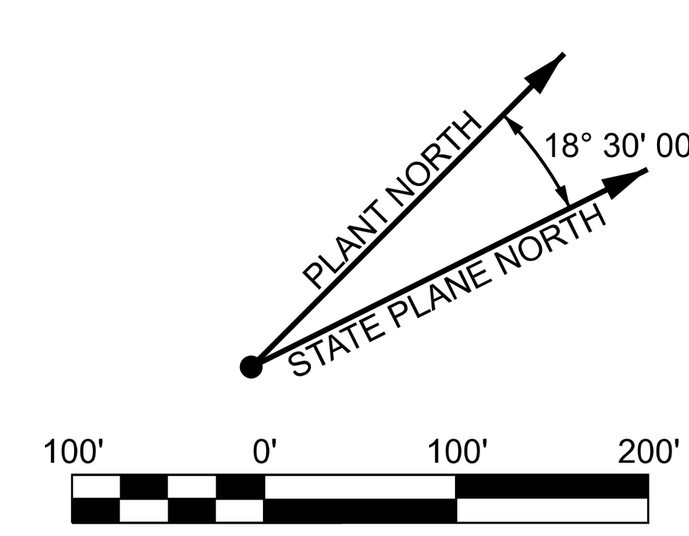


RETROFITTED BOTTOM ASH POND INSTRUMENTATION

WELL/PIEZOMETER	STATE PLANE		PLANT		GROUND ELEVATION
	NORTHING	EASTING	SOUTH	WEST	
MW-BAP-1	820309.50	2513925.00	1461.64	1353.74	670.00
MW-BAP-2	819797.40	2513705.00	1877.47	1724.86	670.00
MW-BAP-3	819112.00	2513519.40	2468.56	2118.36	670.01
MW-BAP-4	820884.30	2513614.00	823.33	1465.06	660.00
MW-BAP-5	820057.10	2513275.00	1500.29	2049.46	670.00
MW-BAP-1001	819518.79	2513139.98	1962.40	2349.09	670.31
MW-BAP-1002	819365.09	2513575.13	2246.24	1985.20	670.06
MW-BAP-1003	818664.12	2513392.95	2853.17	2380.38	670.08
PZ-3	818918.36	2513488.78	2642.75	2208.47	668.98

NOTES:

1. FOR TRENCH DRAIN AND TRENCH DRAIN SUMP COORDINATES AND INVERT ELEVATIONS, SEE AS-BUILT DRAWING: S&ME, SITE PLAN, BOTTOM ASH POND UNDERDRAIN, FIGURE 1.



REV	DATE RELEASED	PURPOSE	PREPARED	REVIEWED	APPROVED
A	03-07-2022	ISSUE FOR INFORMATION	AP	JF	JP

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RETROFITTED BOTTOM ASH POND INSTRUMENTATION

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SCALE: NONE
ENGINEERING DIVISION
DR: AP
CH: JF
SUP: --
ENG: --
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CARDINAL OPERATING CO.
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BRILLIANT, OH 43913

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