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October 7, 2016

Tennessee Valley Authority
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Initial Safety Factor Assessment
Gypsum Disposal Area Stilling Pond 1
EPA Final CCR Rule
TVA Paradise Fossil Plant
Drakesboro, Kentucky

1.0 PURPOSE

This letter documents AECOM's certification of the initial safety factor assessment for the TVA Paradise Fossil Plant's Gypsum Disposal Area Stilling Pond 1. Based on this assessment, the Gypsum Disposal Area Stilling Pond 1 is in compliance with the factors of safety specified in the Final CCR Rule at 40 CFR 257.73(e)(1)(i) and (ii).

2.0 INITIALSAFETY FACTOR ASSESSMENT

The initial safety factor assessment conducted pursuant to 40 CFR 257.73(e) addresses the following factors of safety:

- Long-term, maximum storage pool loading condition;
- Maximum surcharge pool loading condition;
- Seismic factor of safety loading condition; and
- Liquefaction factor of safety loading condition.

AECOM compiled and reviewed available historical site, topographic and geotechnical data for the TVA Paradise Fossil Plant's Gypsum Disposal Area Stilling Pond 1 as of October 07, 2016. A complete listing of documents reviewed is included in the attached references.

Based upon its review of these available documents, AECOM identified a cross section which is identified as the most critical cross section. This cross sections is designated Section A-A'. It was analyzed for the loading conditions specified in 40 CFR 257.73(e)(1)(i) and (ii).

3.0 SUMMARY OF FINDINGS

The attached calculation package presents the safety factor assessment for Section A-A' for the loading conditions specified in 40 CFR 257.73(e)(1)(i) and (ii). The calculated factors of safety are shown in the following table. The results show that the calculated factors of safety for Section A-A' exceed the minimum safety factors required under 40 CFR 257.73(e)(1)(i) and (ii).

Plant	Facility	Critical Cross Section	EPA Criteria	EPA Required Factor of Safety (FOS)	Calculated FOS
PAF	Gypsum Disposal Area Stilling Pond 1	A-A'	Long-term maximum storage pool loading condition	1.50	1.90
			Maximum surcharge pool loading condition	1.40	1.89
			Seismic factor of safety loading condition	1.00	1.10
			Liquefaction factor of safety loading condition	1.20	1.55

4.0 QUALIFIED PROFESSIONAL ENGINEER CERTIFICATION

I, Nicholas S. Golden, P.E., being a Professional Engineer in good standing in the Commonwealth of Kentucky, do hereby certify, to the best of my knowledge, information, and belief:

1. that the information contained in this certification is prepared in accordance with the accepted practice of engineering;
2. that the information contained herein is accurate as of the date of my signature below; and
3. that the initial safety factor assessment for the TVA Paradise Fossil Plant's Gypsum Disposal Area Stilling Pond 1 presented in the table above meets the requirements of the factors of safety specified in 40 CFR 257.73(e)(1)(i) and (ii).

SIGNATURE ______________________ DATE 10/7/16

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ATTACHMENTS: Initial Safety Factor Assessment 40 CFR §257.73(e) for Coal Combustion Residuals (CCR); Existing Surface Impoundment-Gypsum Disposal Area Stilling Pond 1 and Stilling Pond 2; TVA Paradise Fossil Plant

STATE OF KENTUCKY
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PROFESSIONAL ENGINEER

COAL COMBUSTION PRODUCT DISPOSAL PROGRAM

TENNESSEE VALLEY AUTHORITY – GYPSUM DISPOSAL AREA STILLING PONDS 1 AND 2
TVA PARADISE FOSSIL PLANT
DRAKESBORO, KENTUCKY

INITIAL SAFETY FACTOR ASSESSMENT
40 CFR §257.73 (e)
FOR COAL COMBUSTION RESIDUALS (CCR)
EXISTING SURFACE IMPOUNDMENT

Prepared for

TVA

Tennessee Valley Authority
1101 Market Street
Chattanooga, TN 37402-2801

October 7, 2016- Rev 0

Prepared by

AECOM

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PROFESSIONAL ENGINEER

10/7/16

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1.0 Introduction

1.1 Objective

On April 17, 2015 the "Final Rule: Disposal of Coal Combustion Residuals (CCR) from Electric Utilities" (CCR Rule) was published in the Federal Register by the Environmental Protection Agency (EPA). AECOM has been contracted by TVA to analyze the Structural Integrity Criteria for the Paradise Fossil Plant (PAF) CCR surface impoundments and evaluate compliance with §257.73 of the CCR Rule.

1.2 Outline of CCR Rule Requirements

As required by §257.73 of the EPA Final CCR Rule, an initial structural integrity evaluation is to be completed by October 17, 2016 and must include an initial safety factor assessment for each existing CCR surface impoundment that meets the conditions of paragraph (b) as follows:

1. Has a height of five feet or more and a storage volume of 20 acre-feet or more or
2. Has a height of 20 feet or more.

The safety factor assessment must document whether the calculated factors of safety for each existing CCR surface impoundment perimeter dike demonstrate the minimum static and seismic safety factors specified in paragraphs (e)(1)(i) through (e)(1)(iv) of the CCR Rule for the critical cross section of the embankment.

In addition, in accordance with paragraph (f)(2), the owner or operator of the existing CCR surface impoundment may elect to use a previously completed assessment to serve as the initial assessment required by paragraph (e) of the CCR Rule provided that the previous assessment(s) was completed no earlier than 42 months prior to October of 2016 and meets the applicable requirements of paragraph (e) of the EPA Final CCR Rule.

1.3 Description of Structure

Paradise Fossil Plant (PAF) is a coal-fired, electric-generating plant. The plant is located in Muhlenburg County, Kentucky adjacent to the Green River. TVA has determined that the Gypsum Disposal Area Stilling Pond 1 and Gypsum Disposal Area Stilling Pond 2, which receive discharge and surface runoff from the Gypsum Stack Disposal Area, are CCR surface impoundments and, therefore, are subject to the CCR Rule. **Figure 1** shows the location of the Gypsum Disposal Area Stilling Pond 1 and Stilling Pond 2.

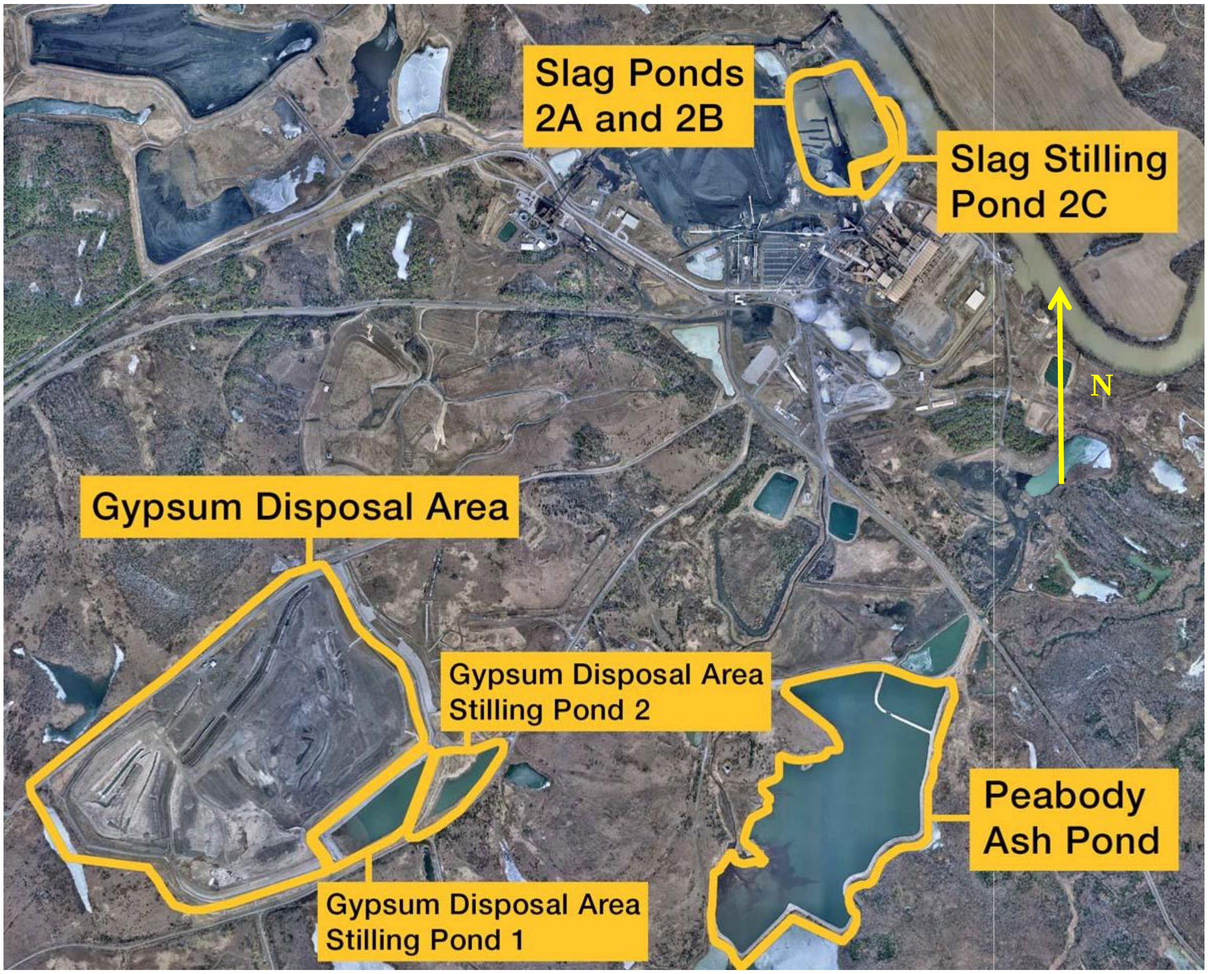


Figure 1: Aerial View of the Gypsum Disposal Area

Gypsum Disposal Area Stilling Ponds 1 and 2 are separated by a divider dike, the Gypsum Disposal Area Stilling Pond 1 Dike. The dike is approximately 2,000 feet in length and up to 34 feet in height with a gravel access along the crest. The upstream and downstream slopes are covered with grassy vegetation and inclined at approximately 3H:1V. A horizontal bench is present along the downstream slope. Gypsum Disposal Area Stilling Pond 2 is predominantly incised, but a dike is formed by the existing Haul Road to the southeast of the pond at some locations along the southeastern and northeastern edges of Gypsum Disposal Area Stilling Pond 2. The maximum height of the dike at these locations is approximately 6 feet.

2.0 Project Reconnaissance

2.1 Review of Existing Data

The existing data review included the following documents:

- AECOM Technical Services, Inc. (2016). Report of Geotechnical Exploration, Paradise Fossil Plant – Gypsum Disposal Area Stilling Pond 1 and Stilling Pond 2.
- AECOM Technical Services, Inc. (2016). Initial Inflow Design Flood Control Plan for Gypsum Disposal Area and Stilling Ponds 1 and 2. Paradise Fossil Plant. Muhlenburg County, Kentucky. Prepared for Tennessee Valley Authority.
- Stantec Consulting Services Inc. (2010). Report of Geotechnical Exploration, Paradise Fossil Plant – Gypsum Stack, Muhlenburg County, Kentucky. Prepared for Tennessee Valley Authority.
- Stantec Consulting Services Inc. (2013). Report of Mine Subsidence, Gypsum Stack Disposal Complex, Paradise Fossil Plant, Muhlenburg County, Tennessee. Prepared for Tennessee Valley Authority.
- Stantec Consulting Services Inc. (2009). Report of Phase 1 Facility Assessment, Coal Combustion Product Impoundments and Disposal Facilities, Various Locations, Paradise Fossil Plant, Muhlenburg County, Kentucky. Prepared for Tennessee Valley Authority.
- URS (2012). Intermediate Dam Safety Inspection Report, Paradise Fossil Plant, Muhlenburg County, Kentucky. Prepared for Tennessee Valley Authority.
- GEI (2015) Instrumentation Evaluation, Installation, and Abandonment, Scrubber Sludge Complex.
- Tennessee Valley Authority (1984). Paradise Steam Plant Proposed Scrubber Sludge Disposal Area Geotechnical Report, Paradise Fossil Plant, Muhlenburg County, Kentucky.
- AECOM (2016). Hydrogeologic CCR Exploration, 2016. (Review of field data only-report completion in progress).
- Stantec (2011) Monitoring Well 10-2 Installation.

2.2 Data Gaps

During review of the existing data, AECOM did not identify data gaps that would require additional geotechnical drilling, sampling, laboratory testing, or field surveying.

3.0 Summary of Field Investigations and Laboratory Testing

In 2011, Stantec (Stantec 2011) installed a monitoring well along the exterior slope of the dike between Gypsum Disposal Area Stilling Pond 1 and Gypsum Disposal Area Stilling Pond 2. Subsurface data was obtained from installation of the monitoring well.

One boring was completed by Stantec in 2013 (Stantec, 2013) on the dike between Stilling Pond 1 and Stilling Pond 2 as part of a mine subsidence report. According to the report, the dike was constructed with clayey mine spoils underlain by sandstone, coal, and durable shale.

Subsurface exploration performed by AECOM (Report of Geotechnical Exploration, 2016) along the dike between Gypsum Disposal Area Stilling Pond 1 and Gypsum Disposal Area Stilling Pond 2 included two hollow stem auger (HSA) borings, two cone penetrometer test (CPT) soundings with shear wave velocity testing and pore pressure dissipation testing, and index laboratory testing.

In addition, AECOM is in process of performing a hydrogeologic exploration at Paradise Fossil Plant. As part of the study, three monitoring wells have been installed along the Haul Road containing Gypsum Disposal Area Stilling Pond 2. The wells were installed using sonic drilling procedures with continuous sampling through the overburden. The boring logs and well installation logs generated were reviewed in order to characterize the subsurface conditions at this location.

These geotechnical explorations, laboratory testing results, and conclusions were used as the basis of this analysis and are referenced in **Section 2.1.**

4.0 Detailed Task Analysis Criteria

4.1 Material Properties

Subsurface data indicates the dikes consist of medium stiff to very stiff clayey mine spoils extending to auger refusal depths, with the exception of a 12 inch layer of filter sand within the dike between Gypsum Disposal Area Stilling Pond 1 and 2 at approximately 19 feet below ground surface. An overview of the subsurface conditions is summarized on the next page in **Table 1**. A more in-depth review is found in AECOM (2016).

Table 1: Generalized Subsurface Conditions

Materials	Approximate Depth (feet MSL)	Consistency or Relative Density
Clayey Mine Spoils – consists of lean clay and gravel sized rock fragments	Elevation 484 to Elevation 383	Medium stiff to very stiff
Filter Sand – consists of finely graded sand	Elevation 465 to Elevation 464	Loose

The 2010 geotechnical exploration performed at the adjacent Gypsum Disposal Area by Stantec included a laboratory testing program consisting of natural moisture content testing, sieve and hydrometer analysis, Atterberg Limits, specific gravity, consolidated-undrained triaxial compression tests, and permeability testing. Stantec used the laboratory test results to determine shear strength parameters for the subsurface materials. Additional exploration, instrumentation installation, lab testing, and analysis was performed by GEI in 2015 at the Gypsum Disposal Area. The results of the index testing performed by AECOM in 2016 indicate the clayey mine spoils at the dike between Gypsum Disposal Area Stilling Pond 1 and 2 are similar to those explored and tested at the Gypsum Disposal Area. Accordingly, the drained shear strength parameters previously developed by Stantec and GEI were determined appropriate for the analysis of Gypsum Disposal Area Stilling Pond 1 and Gypsum Disposal Area Stilling Pond 2. AECOM assessed undrained shear strength parameters for stability analysis by constructing p-q plots from historic laboratory testing as described in Appendix D of the United States Corps of Engineers Engineer Manual EM-1110-2-1902 “Slope Stability”, and CPT data. The shear strength parameters used by AECOM for this analysis and are summarized in **Table 2**.

Table 2: Strength Parameters for Stability Analysis

Soil Horizon	Wet Unit Weight (pcf)	Effective Stress Strength		Total Stress Strength Parameters	
		c’ (psf)	ϕ’ (degrees)	c (psf)	ϕ (degrees)
Clayey Mine Spoils	120	0	28	340	19
Chimney and Finger Drain	127	0	35	0	35
Bedrock	Impenetrable				

4.2 Critical Cross Section Selection

Slope stability analyses were evaluated at three cross sections by AECOM (2016). The locations of the three cross sections labeled A-A’, B-B’ and C-C’ are shown on the next page in a plan view of the Gypsum Disposal Area Stilling Pond 1 and Gypsum Disposal Area Stilling Pond 2 in **Figure 2**.

Figure 2: Plan View of Cross Sections

Sections A-A' and B-B' represent the geometry through the dike between Gypsum Disposal Area Stilling Pond 1 and Gypsum Disposal Area Stilling Pond 2. Section C-C' represents the geometry through the Gypsum Disposal Area Stilling Pond 2 perimeter dike at a non-incised location.

The summary of the static slope stability performed by AECOM (2016) are presented on the next page in **Table 3**.

Table 3: Historic Slope Stability Results

Cross Section	CCR Unit	CCR Rule Loading Condition	Exterior Slope (Global Failure, Exterior Scope)	Reference
A-A'	Gypsum Disposal Area Stilling Pond 1	Long-Term Maximum Storage Pool	1.90	AECOM (2016)
		Maximum Surcharge Pool	1.89	
		Seismic Factor of Safety	1.10	
		Liquefaction Factor of Safety	1.55	
B-B'	Gypsum Disposal Area Stilling Pond 1	Long-Term Maximum Storage Pool	2.01	
		Maximum Surcharge Pool	1.96	
		Seismic Factor of Safety	1.12	
		Liquefaction Factor of Safety	1.59	
C-C'	Gypsum Disposal Area Stilling Pond 2	Long-Term Maximum Storage Pool	3.09	
		Maximum Surcharge Pool	3.08	
		Seismic Factor of Safety	1.36	
		Liquefaction Factor of Safety	2.55	

As shown in **Table 3**, Section A-A' (Gypsum Disposal Area Stilling Pond 1) and Section C-C' (Gypsum Disposal Area Stilling Pond 2) resulted in the lowest factor of safety when analyzed under static conditions. Therefore, these sections were selected as the critical cross sections.

4.3 Water Levels

In consideration of the Initial Inflow Design Flood analysis performed by AECOM (2016), the water elevation for Gypsum Disposal Area Stilling Pond 1 and Gypsum Disposal Area Stilling Pond 2 were defined to meet the requirements of the EPA CCR Rule [§257.82(a)]. The long term maximum storage pool elevation is the normal operating pool of Gypsum Disposal Area Stilling Pond 1 and Gypsum Disposal Area Stilling Pond 2, while the Maximum Surcharge Pool is the pool level determined for the 1,000 year, 6-hour storm event modeled as part of the IDF. Gypsum Disposal Area Stilling Pond 2 is the tailwater for Gypsum Disposal Area Stilling Pond 1. The pond elevations used for the static slope analyses are summarized in **Table 4**.

Table 4: PAF Gypsum Disposal Area Stilling Pond 1 and 2 Water Elevations for Stability Modeling

Loading Condition	Gypsum Disposal Area Stilling Pond 1 (feet, MSL)	Gypsum Disposal Area Stilling Pond 2 (feet, MSL)
Long-term Maximum Storage Pool	474.4	450.3
Maximum Surcharge Pool	481.3	452.7

There is an offsite lagoon downstream of Gypsum Disposal Area Stilling Pond 2 to the southeast. The water elevations are not known for the lagoon but were estimated based on the existing topography and aerial maps. Based on the limits of the lagoon as shown in the aerial displays, the water elevation for the lagoon is estimated at 434 feet. This lagoon was taken to be the tailwater for the analysis of Gypsum Disposal Area Stilling Pond 2.

4.4 Analysis Methodology

AECOM performed the static and seismic slope stability analyses using the GeoStudio 2012, Version 8.15.5.11777 software package developed by Geoslope, Inc. of Calgary, Alberta, Canada. The analysis was performed using the boundary conditions provided in Table 4. This package includes the SLOPE/W module for slope stability analysis. The analyses were performed in accordance with the guidelines in USACE Design Manuals EM 1110-2-1902 “Slope Stability” (United States Army Corps of Engineers, 2003).

The phreatic surface used in each stability analysis was based on a seepage analysis model performed using the SEEP/W module of the above referenced GeoStudio software. Seepage analysis parameters were determined from information published by the United States Bureau of Reclamation and historic laboratory testing. Values were then adjusted to calibrate the seepage models to the monitoring well and field CPT dissipation data. The calibration process was completed until parameters were determined which yielded a reasonable correlation to field readings.

4.4.1 Long-Term Maximum Storage Pool §257.73(e)(1)(i)

A drained, effective stress analysis was performed for this load case to evaluate slope stability in the downstream direction. This assessment used a phreatic surface based on the seepage analysis discussed in Section **4.4** and data provided in Table **4** and Section **4.3**.The required minimum factor of safety corresponds to the entry for “Long-Term Maximum Storage Pool” in **Table 5**.

4.4.2 Maximum Surcharge Pool §257.73(e)(1)(ii)

The maximum surcharge pool load condition is created by a rapid pool level rise during a flood. It is a temporary water level, higher than the normal pool, which does not last long enough to develop steady-state seepage within the impoundment embankment and foundation (USACE, 2003). The pool is assumed to rise faster than water can flow in or out of fine-grained soils, and the surcharge pressure may cause shear-induced, excess pore pressures in the saturated zones. This assumption is based on the significance of the surcharge pressure with respect to the size of the dike. Surcharge pressures are discussed further in **Section 5.0**.

Materials below the phreatic surface were considered saturated and modeled using undrained material properties. The partially saturated zones above the phreatic surface were modeled using drained material properties. This assessment used a phreatic surface based on the seepage analysis discussed in Section **4.4** and data provided in Table **4** and Section **4.3**.The required minimum factor of safety corresponds to the entry for “Maximum Surcharge Pool” loading condition in **Table 5**.

4.4.3 Seismic Factor of Safety §257.73(e)(1)(iii)

The seismic factor of safety loading condition considers stability during horizontal seismic loading induced by the Maximum Design Earthquake, defined by the EPA CCR Rule as an event that produces a level of shaking with a probability of exceedance of 2% in 50 years, or a 2,500 year return period. Online United States Geologic Survey (USGS) seismic hazard mapping software (http://geohazards.usgs.gov/hazardtool/application.php) was used to obtain the spectral acceleration at a period of 1 second for the above referenced return period. This value, the peak transverse base acceleration taken at the base of the unit, was found to be 0.16g for this project site. The peak transverse base acceleration was amplified through the embankment to obtain the peak transverse crest acceleration based on data developed by Idriss (2008, personal communication based on Harder et. al (1998).

The horizontal seismic coefficient k_h used in the seismic factor of safety analysis was calculated using the method outlined by Makdisi-Seed (1978), which states that k_h is calculated by multiplying the peak transverse crest acceleration (determined as described above) by the ratio of maximum average acceleration for a potential sliding mass. K_h was calculated to be 0.136g for this project.

The seismic factor of safety analysis was performed with saturated and unsaturated, fine grained materials modeled using undrained shear strength parameters. The analysis was performed at Long-Term Maximum Storage Pool elevations and phreatic conditions described in

Section 4.4. The required minimum factor of safety corresponds to the entry for "Seismic Factor of Safety" in **Table 5**.

4.4.4 Liquefaction Factor of Safety §257.73(e)(1)(iv)

The purpose of post-liquefaction stability is to assess stability conditions immediately following the design seismic event. Liquefaction triggering was performed using project SPT and CPT data. The SPT-based liquefaction procedure is based on the revised methodology by Youd et al. (2001) updated by Idriss and Boulanger (2008, 2014). The CPT based liquefaction procedure is based on Youd et al. (2001) and Idriss and Boulanger (2014). Both procedures consider a stress-based approach to evaluate the potential for liquefaction triggering, and compare the earthquake-induced cyclic stress ratios (CSR) with the cyclic resistance ratios (CRR) to obtain a factor of safety. Materials with a factor of safety against liquefaction less than 1.1 were considered to undergo liquefaction. Assumptions regarding the potential for materials to liquefy are provided in **Section 5.0**.

Liquified materials were assigned a residual strength based on SPT and CPT data using a data figure from Idriss and Boulanger (2008). Saturated fine grained and coarse grained soils were assumed to undergo cyclic softening resulting in a reduction to 80% of peak undrained strength. Unsaturated, fine grained materials were modeled at peak, undrained strength. The analysis was performed at Long-Term, Maximum Storage Pool elevations and phreatic conditions described in **Section 4.4**. The required minimum factor of safety corresponds to the entry for "Liquefaction Factor of Safety" in **Table 5**.

4.5 Acceptance Criteria

The following summary is taken from the EPA's CCR Rule §257.73(e). The factor of safety assessment criteria are outlined in **Table 5** below.

Table 5: Factor of Safety Criteria

Loading Condition	CCR Rule Required Factor of Safety	CCR Rule Reference
Long-Term Maximum Storage Pool	1.50	§257.73(e)(1)(i)
Maximum Surcharge Pool	1.40	§257.73(e)(1)(ii)
Seismic Factor of Safety	1.0	§257.73(e)(1)(iii)
Liquefaction Factor of Safety	1.20	§257.73(e)(1)(iv)

5.0 Analysis Assumptions

The following assumptions apply to this analysis.

- The goal of the analyses was to identify failures which would likely result in the release of ash. Therefore, incipient motion in the downstream direction was considered, and upstream directional failures were not included.

- The long-term maximum storage pool elevation is the normal operating pool elevation for Gypsum Disposal Area Stilling Pond 1 and 2.
- The maximum surcharge pool elevations were applied to the model based on the flood pool level determined for the 6-hour, 1,000 year storm for Gypsum Disposal Area Stilling Ponds 1 and 2. The surcharge pool was assumed not to last long enough for steady-state conditions to develop. Therefore, the phreatic surface obtained from the seepage analysis for the long-term maximum storage pool analysis was utilized within the embankment. A surcharge pressure was applied to the slow-draining soils along the ground surface, reflecting the difference in elevation between the flood pool and normal pool.
- During maximum surcharge pool loading analysis, the tailwater was conservatively maintained at the long term maximum pool or normal pool elevation, neglecting potential added resistance at the toe resulting from short term, surcharge loading conditions
- The slope stability assessments presented in this report are focused on the potential for slope failures of significant mass, which could directly impact potential release of water and CCR materials from Gypsum Disposal Area Stilling Ponds 1 and 2.
- The search for a critical slip surface in the slope stability assessments was therefore restricted to consider only potential surfaces where the depth (measured at the base of at least one slice) is more than 10 feet vertically below the ground surface.
- For the Seismic Factor of Safety analyses, it was assumed that undrained conditions were induced for saturated and unsaturated fine grained soils.
- For purposes of the liquefaction triggering analysis, the following materials were considered unsusceptible to liquefaction:
    - Well compacted, medium plasticity soils in the dam embankment.
    - Riprap materials.
    - Compacted drains or filter zones comprised of clean gravel or rock fill.
    - Unsaturated granular soils.
    - Saturated, sand-like soils that exhibit dilative behavior over the anticipated range of confining stresses.
    - Clay-like soils with high plasticity (see Seed et al. 2003; Bray and Sancio 2006; MSHA 2010).
    - Clay-like soils that exhibit dilative behavior over the anticipated range of confining stresses (MSHA 2010).

- For the Liquefaction Factor of Safety analysis, it was assumed that saturated fine grained soils would be softened from cyclic loading to 80% of the peak, undrained strength.

6.0 Analysis Results

A summary of the initial safety factor assessment results at Gypsum Disposal Area Stilling Pond 1 and Gypsum Disposal Area Stilling Pond 2 critical sections (Section A-A' and Section C-C') is presented on the next page in **Table 6**.

Table 6: Initial Factor of Safety Assessment Results

Facility	Critical Cross Section	Loading Condition	CCR Rule Required Factor of Safety	Calculated Factor of Safety
PAF Gypsum Disposal Area Stilling Pond 1	A-A'	Long-term maximum storage pool [§257.73(e)(1)(i)]	1.5	1.90
		Maximum surcharge pool [§257.73(e)(1)(ii)]	1.4	1.89
		Seismic Factor of Safety [§257.73(e)(1)(iii)]	1.0	1.10
		Liquefaction Factor of Safety [§257.73(e)(1)(iv)]	1.2	1.55
PAF Gypsum Disposal Area Stilling Pond 2	C-C'	Long-term maximum storage pool [§257.73(e)(1)(i)]	1.5	3.09
		Maximum surcharge pool [§257.73(e)(1)(ii)]	1.4	3.08
		Seismic Factor of Safety [§257.73(e)(1)(iii)]	1.0	1.36
		Liquefaction Factor of Safety [§257.73(e)(1)(iv)]	1.2	2.55

7.0 Conclusions

This report documents the static and seismic safety factor evaluation of PAF's Gypsum Disposal Area Stilling Pond 1 and Gypsum Disposal Area Stilling Pond 2. The evaluation was performed in accordance with section §257.73(e) of the CCR Rule.

The initial safety factor results for the Gypsum Disposal Area Stilling Pond 1 and Gypsum Disposal Area Stilling Pond 2 met or exceeded the required safety factors at each cross section and at the critical cross sections evaluated for the long-term maximum storage pool [§257.73(e)(1)(i)], the maximum surcharge pool [§257.73(e)(1)(ii)], the seismic factor of safety [§257.73(e)(1)(iii)], and the liquefaction factor of safety [§257.73(e)(1)(iv)] loading conditions. These results demonstrate that Gypsum Disposal Area Stilling Pond 1 and Gypsum Disposal Area Pond 2 meet the initial safety factor requirements of EPA 40 CFR §257.73(e).

8.0 References

1. AECOM, 2016. Geotechnical Exploration for CCR Compliance. Gypsum Disposal Area Stilling Pond. Paradise Fossil Plant. Muhlenberg County, Kentucky. Prepared for Tennessee Valley Authority, September 26.
2. AECOM, 2016. Initial Inflow Design Flood Control Plan for Gypsum Disposal Area and Stilling Ponds 1 and 2. Paradise Fossil Plant. Muhlenberg County, Kentucky. Prepared for Tennessee Valley Authority, September 30.
3. Environmental Protection Agency (2015). “Final Rule: Disposal of Coal Combustion Residuals from Electric Utilities”, Feeral Register, April 17.
4. GEO-SLOPE International, Ltd (2012). GeoStudio 2012, Version 8.15. Calgary, Alberta, Canada. www.geo-slope.com.
5. Stantec Consulting Services Inc. (2009). Report of Phase 1 Facility Assessment, Coal Combustion Product Impoundments and Disposal Facilities. Various Locations. Kentucky. Prepared for Tennessee Valley Authority, June 24.
6. Stantec Consulting Services Inc. (2010). Report of Geotechnical Exploration. Gypsum Stack, Paradise Fossil Plant, Muhlenberg County, Kentucky. Prepared for Tennessee Valley Authority, February 9.
7. Stantec Consulting Services Inc. (2013). Report of Mine Subsidence. Gypsum Stack Disposal Complex. Paradise Fossil Plant. Muhlenberg County, Kentucky. Prepared for Tennessee Valley Authority, August 26.
8. United States Army Corps of Engineers (USACE) (2005). ETL 1110-2-1902. Design Guidance for Levee Under-Seepage, Department of the Army. May 1
9. United States Army Corps of Engineers (USACE) (2003). Engineering and Design. Slope Stability. Engineering Manual EM 1110-2-1902, Department of the Army. October 3.
10. URS, 2012. Intermediate Dam Safety Inspection Report. Paradise Fossil Plant, Muhlenberg County, Kentucky. Prepared for Tennessee Valley Authority, February 4.

APPENDIX A
SLOPE STABILITY ANALYSIS

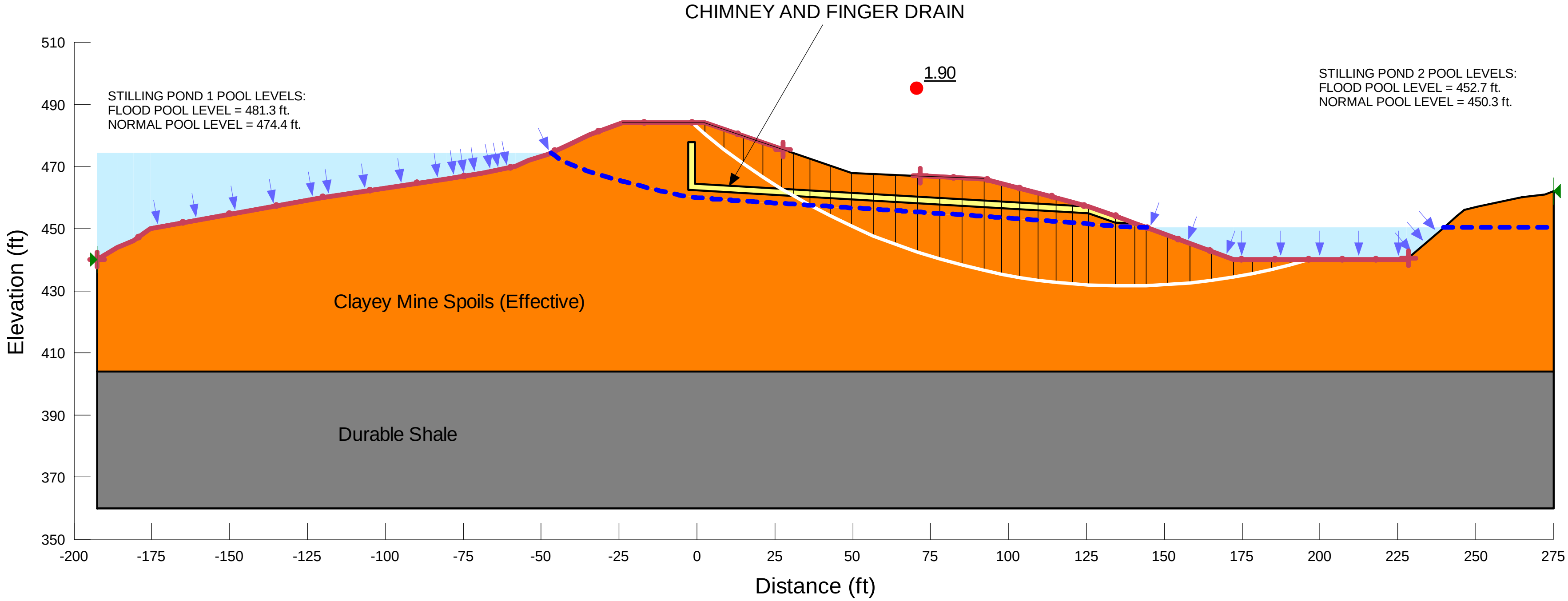
TVA PARADISE FOSSIL PLANT (PAF)
GYPSUM DISPOSAL AREA STILLING POND 1 AND STILLING POND 2
CROSS-SECTION A-A'
Slope Stability Long-term Maximum Storage Pool

Factor of Safety: 1.90
Method: Spencer
Center: (137.51709, 642.12851) ft
Radius: 210.55509 ft

Notes:

Cross section stratigraphy corresponds to boring GSSP-1. Circles correspond to water levels observed during CPT testing or from piezometer data obtained at Monitoring Well 10W-9.

Material	Unit Weight (pcf)	Cohesion (psf)	Friction Angle (deg.)
Clayey Mine Spoils (Effective)	120	0	28
Chimney and Finger Drain	127	0	35



Project No. 60444361

TVA PARADISE FOSSIL PLANT (PAF)
GYPSUM DISPOSAL AREA STILLING POND 1 AND STILLING POND 2
CROSS-SECTION A-A'
Slope Stability Maximum Surcharge Pool

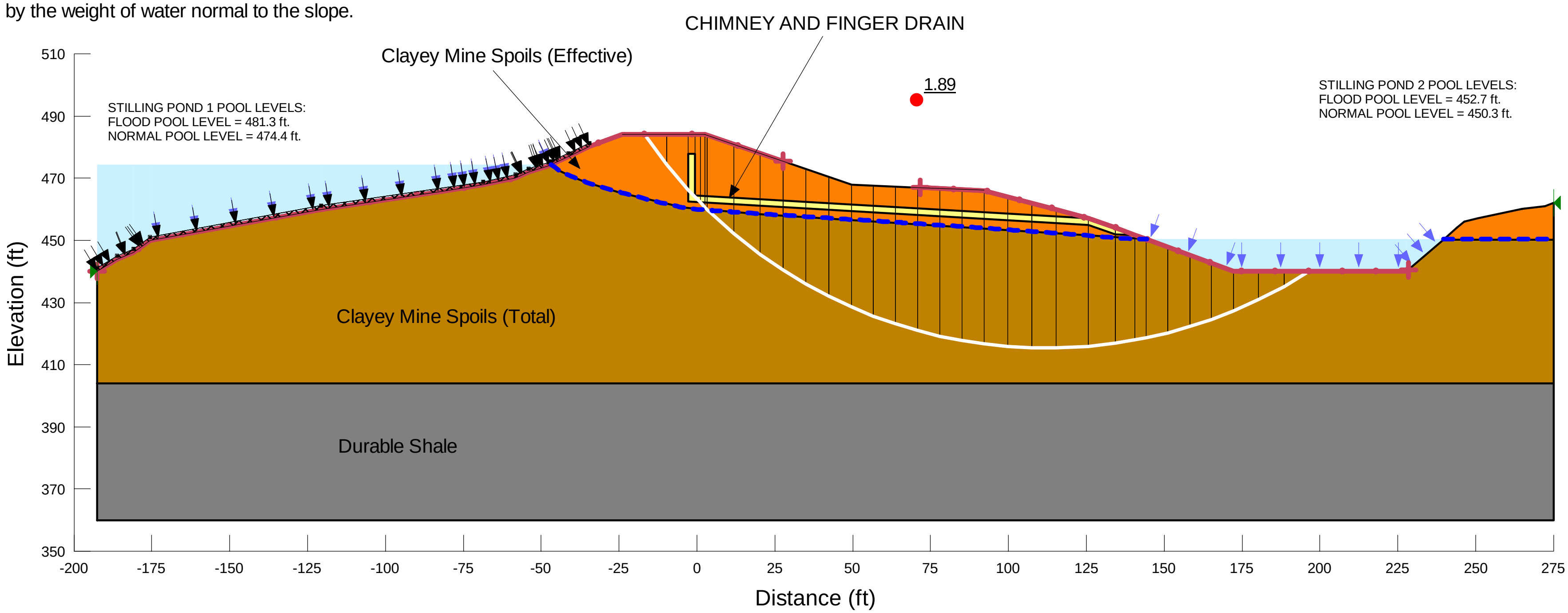
Factor of Safety: 1.89
Method: Spencer
Center: (112.38272, 571.15423) ft
Radius: 155.80452 ft

Notes:

Cross section stratigraphy corresponds to boring GSSP-1. Circles correspond to water levels observed during CPT testing or from piezometer data obtained at Monitoring Well 10W-9.

Material	Unit Weight (pcf)	Cohesion (psf)	Friction Angle (deg.)
Clayey Mine Spoils (Effective)	120	0	28
Clayey Mine Spoils (Total)	120	340	19
Chimney and Finger Drain	127	0	35

Flood pool elevation modeled at 481.3 feet. Flood pool loading modeled as a surcharge caused by the weight of water normal to the slope.



Project No. 60444361

TVA PARADISE FOSSIL PLANT (PAF)
GYPSUM DISPOSAL AREA STILLING POND 1 AND STILLING POND 2
CROSS-SECTION A-A'
Seismic Factor of Safety Stability (Downstream)

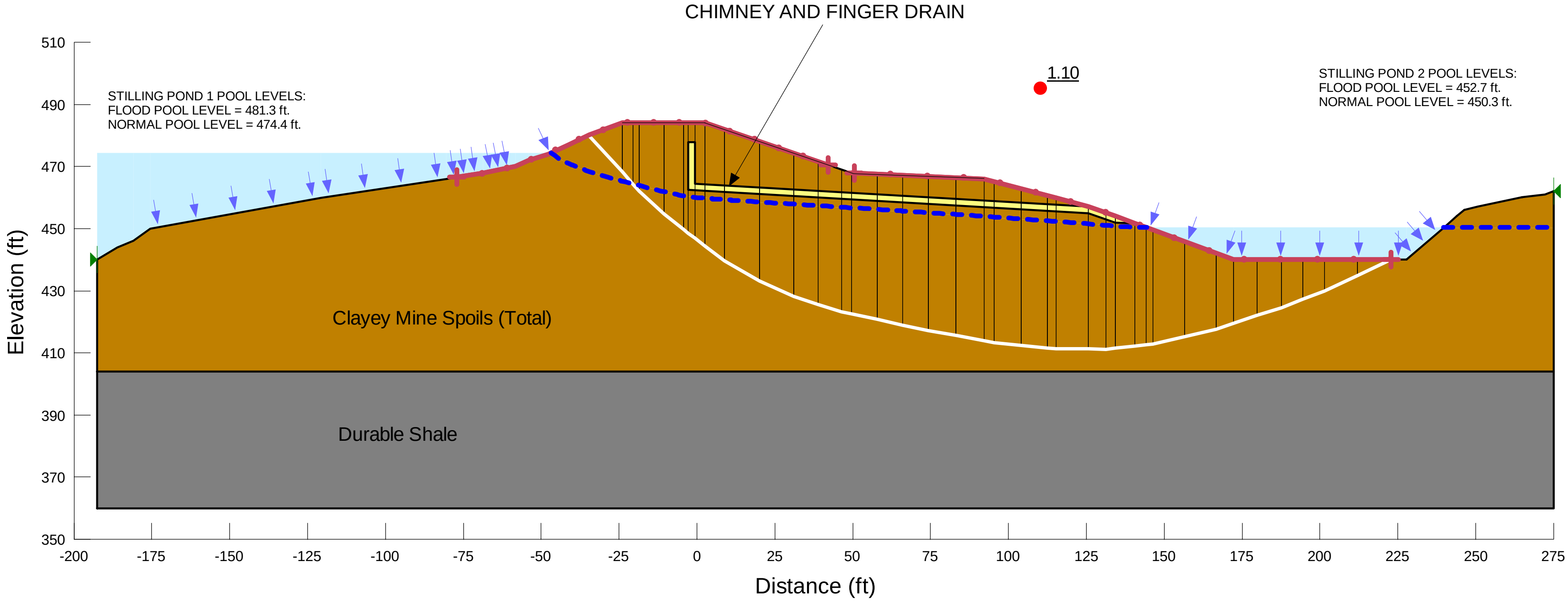
Factor of Safety: 1.10
Method: Spencer
Center: (116.42307, 620.45204) ft
Radius: 114.75035 ft

Notes:

Cross section stratigraphy corresponds to boring GSSP-1. Circles correspond to water levels observed during CPT testing or from piezometer data obtained at Monitoring Well 10W-9.

Material	Unit Weight (pcf)	Cohesion (psf)	Friction Angle (deg.)
Clayey Mine Spoils (Total)	120	340	19
Chimney and Finger Drain	127	0	35

Horizontal Seismic Coefficient.: 0.136g



Project No. 60444361

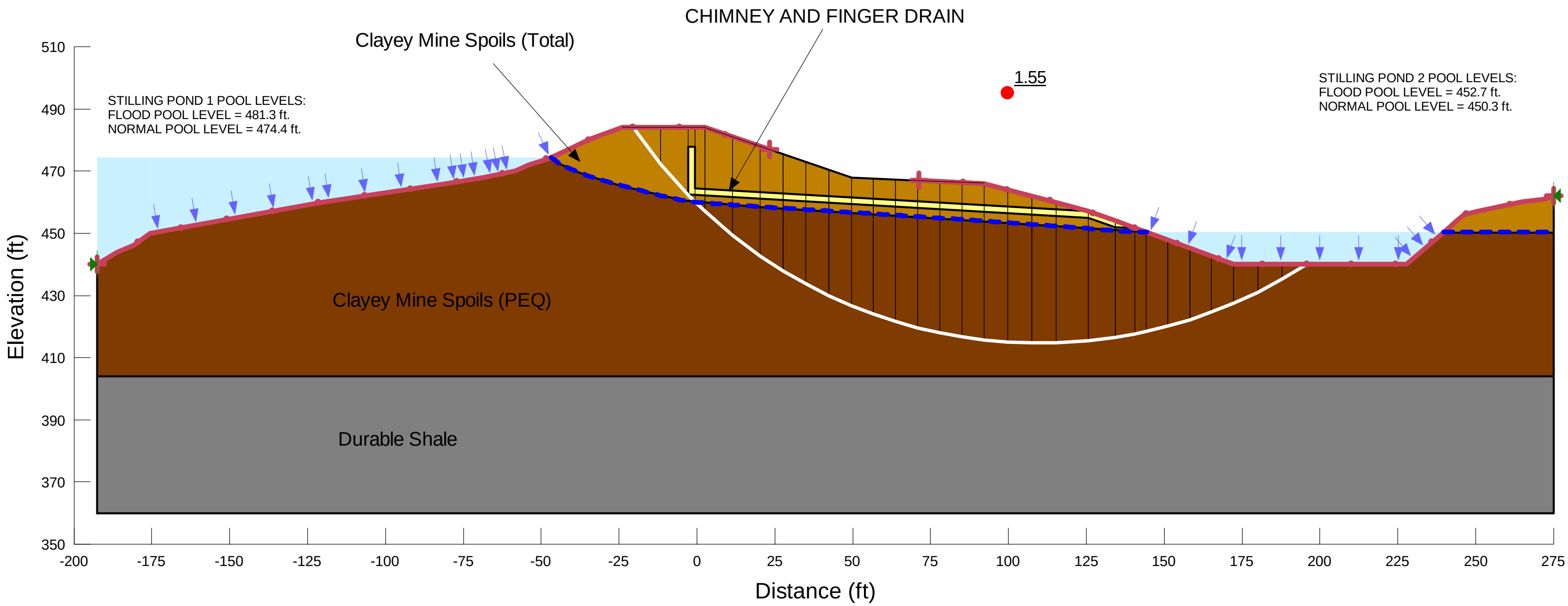
TVA PARADISE FOSSIL PLANT (PAF)
GYPSUM DISPOSAL AREA STILLING POND 1 AND STILLING POND 2
CROSS-SECTION A-A'
Liquefaction Factor of Safety Stability (Downstream)

Factor of Safety: 1.55
Method: Spencer
Center: (110.10698, 572.25149) ft
Radius: 157.58346 ft

Notes:

Cross section stratigraphy corresponds to boring GSSP-1. Circles correspond to water levels observed during CPT testing or from piezometer data obtained at Monitoring Well 10W-9.

Material	Unit Weight (pcf)	Cohesion (psf)	Friction Angle (deg.)
Clayey Mine Spoils (Total)	120	340	19
Clayey Mine Spoils (PEQ)	120	272	15.4
Chimney and Finger Drain	127	0	35

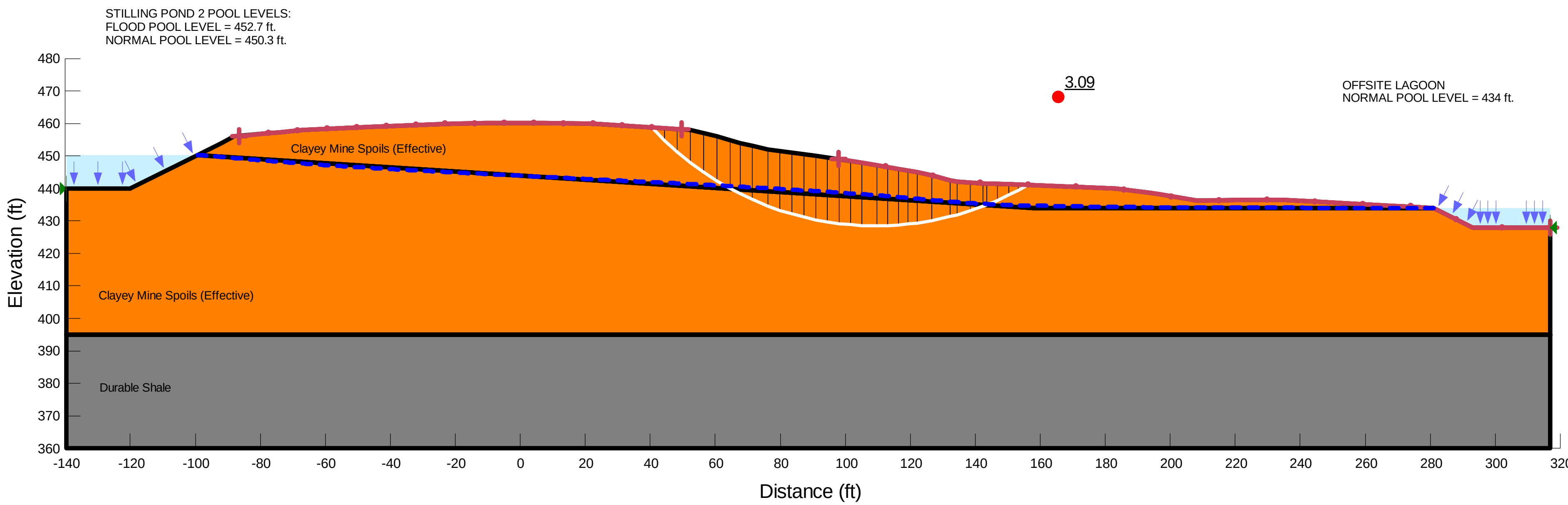


Project No. 60444361

TVA PARADISE FOSSIL PLANT (PAF)
GYPSUM DISPOSAL AREA STILLING POND 2
CROSS-SECTION C-C'
Slope Stability Long-term Maximum Storage Pool

Factor of Safety: 3.09
Method: Spencer
Center: (109.39038, 521.91771) ft
Radius: 93.419667 ft

Material	Unit Weight (pcf)	Cohesion (psf)	Friction Angle (deg.)
Clayey Mine Spoils (Effective)	120	0	28



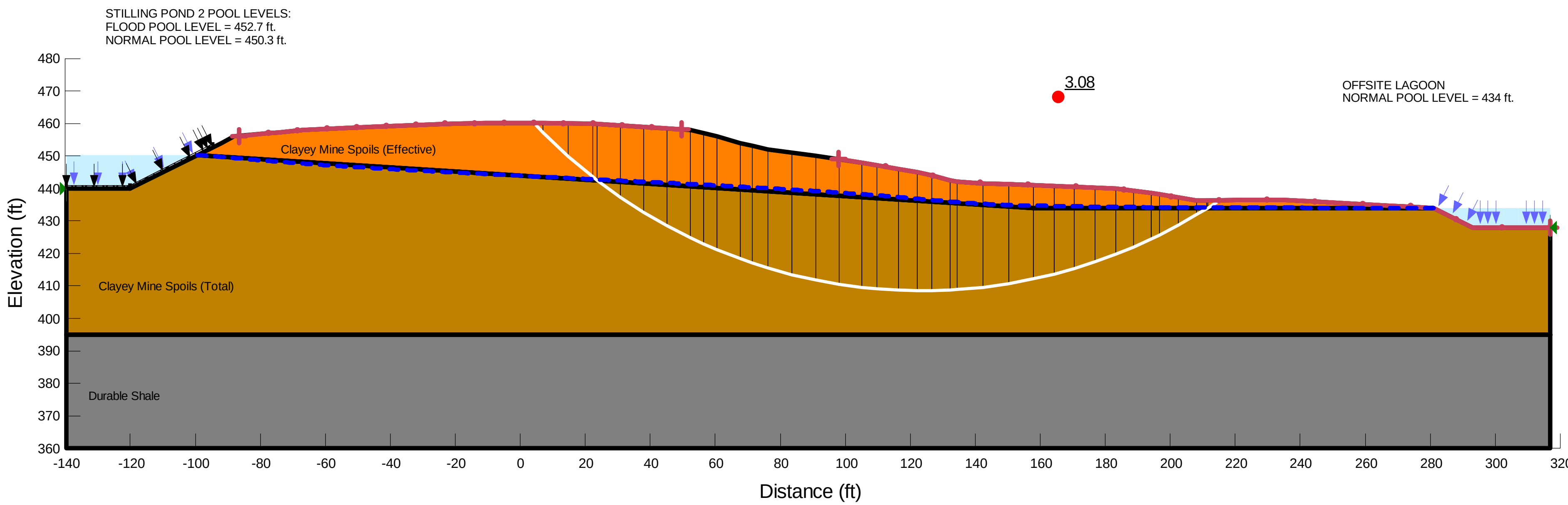
Project No. 60444361

TVA PARADISE FOSSIL PLANT (PAF)
GYPSUM DISPOSAL AREA STILLING POND 2
CROSS-SECTION C-C'
Slope Stability Maximum Surcharge Pool

Factor of Safety: 3.08
Method: Spencer
Center: (123.6782, 572.71084) ft
Radius: 164.19026 ft

Material	Unit Weight (pcf)	Cohesion (psf)	Friction Angle (deg.)
Clayey Mine Spoils (Effective)	120	0	28
Clayey Mine Spoils (Total)	120	340	19

Flood pool elevation modeled at 452.7 feet. Flood pool loading modeled as a surcharge caused by the weight of water normal to the slope.



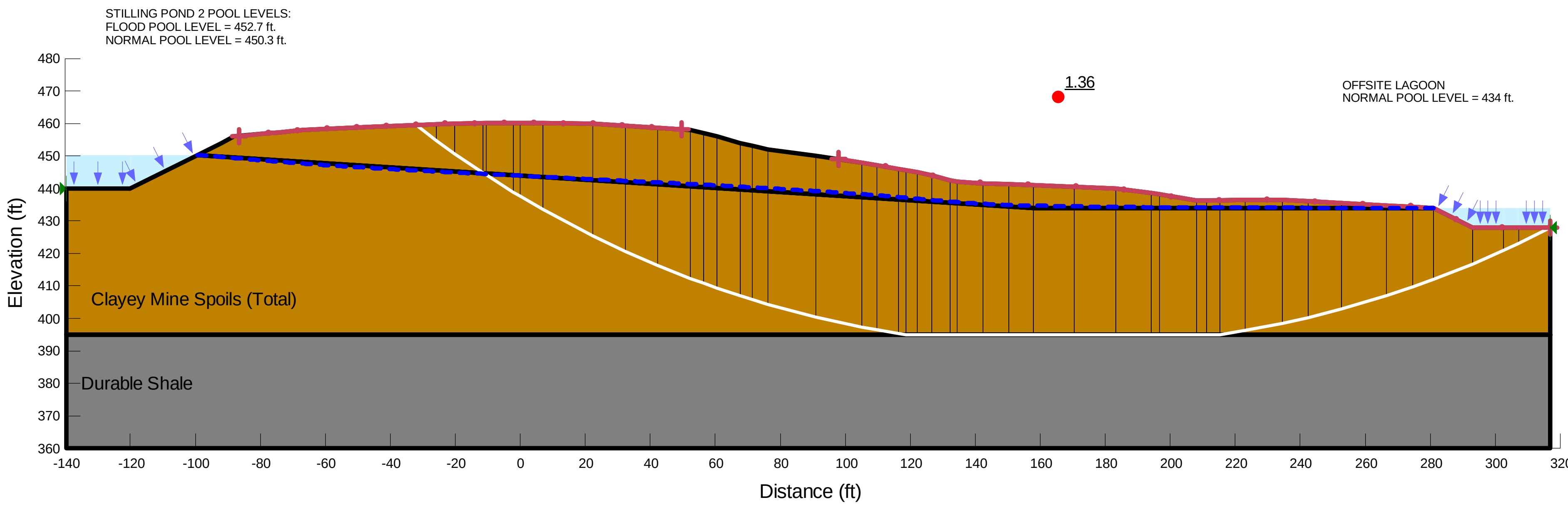
Project No. 60444361

TVA PARADISE FOSSIL PLANT (PAF) GYPSUM DISPOSAL AREA STILLING POND 2 CROSS-SECTION C-C'
Seismic Factor of Safety Stability (Downstream)

Factor of Safety: 1.36
Method: Spencer
Center: (167.03372, 716.61579) ft
Radius: 325.2262 ft

Material	Unit Weight (pcf)	Cohesion (psf)	Friction Angle (deg.)
Clayey Mine Spoils (Total)	120	340	19

Horizontal Seismic Coefficient.: 0.136g

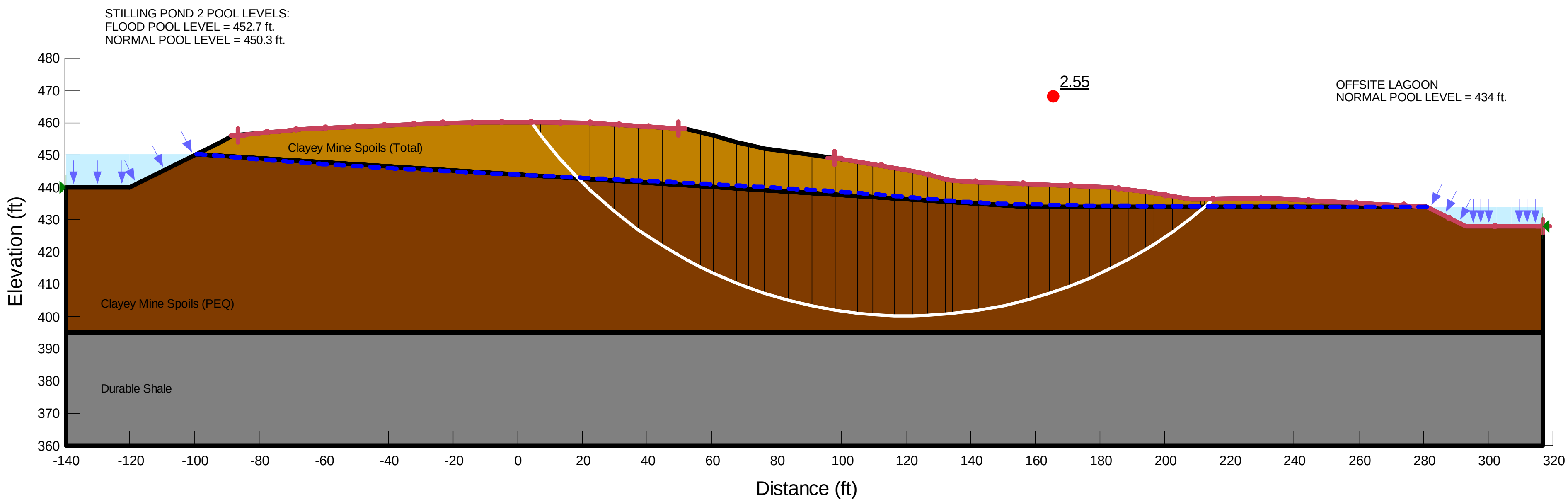


Project No. 60444361

TVA PARADISE FOSSIL PLANT (PAF) GYPSUM DISPOSAL AREA STILLING POND 2 CROSS-SECTION C-C'
Liquefaction Factor of Safety Stability (Downstream)

Factor of Safety: 2.55
Method: Spencer
Center: (120.27914, 542.58005) ft
Radius: 142.39799 ft

Material	Unit Weight (pcf)	Cohesion (psf)	Friction Angle (deg.)
Clayey Mine Spoils (Total)	120	340	19
Clayey Mine Spoils (PEQ)	120	272	15.4



Project No. 60444361