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October 7, 2016

Tennessee Valley Authority
1101 Market Street
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Initial Safety Factor Assessment
Slag Pond 2A and 2B
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 Slag Pond 2A and 2B. Based on this assessment, the Slag Pond 2A and 2B 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 Slag Pond 2A and 2B 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 C-C'. 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 C-C' 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 C-C' 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	Slag Pond 2A and 2B	C-C'	Long-term maximum storage pool loading condition	1.50	2.37
			Maximum surcharge pool loading condition	1.40	2.16
			Seismic factor of safety loading condition	1.00	1.09
			Liquefaction factor of safety loading condition	1.20	1.66

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 Slag Pond 2A and 2B 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-Slag Pond 2A and 2B, and Slag Stilling Pond 2C; TVA Paradise Fossil Plant

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COAL COMBUSTION PRODUCT DISPOSAL PROGRAM

TENNESSEE VALLEY AUTHORITY – SLAG PONDS 2A AND 2B, AND SLAG STILLING POND 2C
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

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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

PAF is a coal-fired, electric-generating plant. The plant is located in western Kentucky along the banks of the Green River, in Muhlenberg County. TVA has determined that the Slag Ponds 2A and 2B and Slag Stilling Pond 2C are CCR surface impoundments and, therefore, subject to the CCR rule. A plan view showing the Slag Ponds 2Aand 2B and Slag Stilling Pond 2C is shown in **Figure 1**.

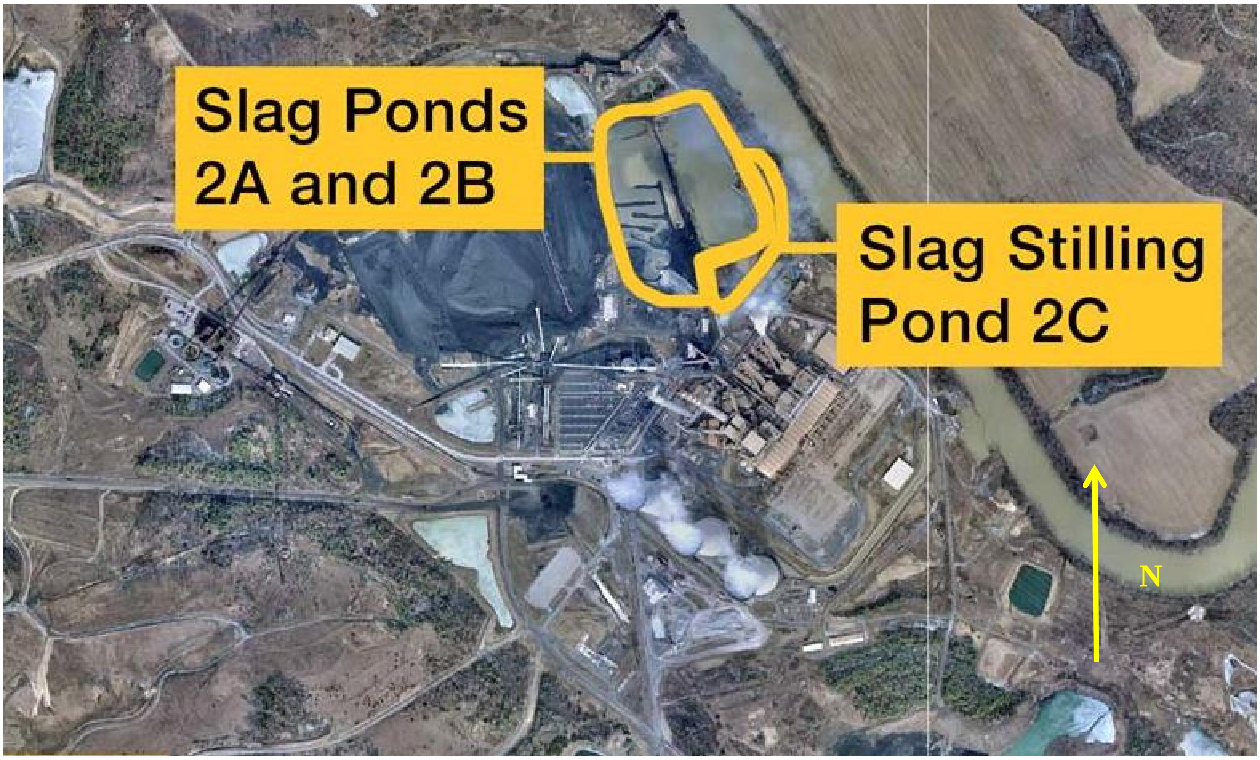


Figure 1: Aerial View of Slag Pond Complex

Slag Pond 2A is located northwest of the plant and immediately west of Slag Pond 2B. Slag Pond 2B is located northwest of the plant and immediately east of Slag Pond 2A. Slag Stilling Pond 2C is located east of Slag Pond 2A and 2B. The Slag Pond complex encompasses a total of approximately 25 acres. The Slag Pond Dike is approximately 2,500 feet in length, and extends from the northwestern corner of Slag Pond 2A to the east and south toward the plant and Red Water Pond #1. The dike is up to 34 feet in height with a gravel access road on the crest. The upstream and downstream slopes vary from approximately 2.5H:1V to 3.5H:1V in inclination.

2.0 Project Reconnaissance

2.1 Review of Existing Data

The existing data review included the following documents:

- AECOM, 2016. Report of Geotechnical Exploration, Slag Pond Complex.
- TVA, 1983. Paradise Steam Plant-Coal Receiving Facility-Soil Investigation for Ash Pond Dike Adjacent to Barge Dock Cells.
- Law Engineering 1995; Monitoring Well Installation Logs
- Stantec, 2010. Report of Geotechnical Exploration, Gypsum Stack, Paradise Fossil Plant, Muhlenberg County, Kentucky, Accessed from TVA public records.

- Stantec, 2013. Report of Mine Subsidence, Gypsum Stack Disposal Complex.
- Stantec, 2009. Report of Phase 1 Facility Assessment, Coal Combustion Product Impoundments and disposal Facilities, Various Locations, Kentucky, Accessed from TVA public records.
- URS, 2011. TVA Four-Plant Dewatering Paradise Fossil Plant Site 1.
- URS, 2012. Intermediate Dam Safety Inspection Report. Accessed from internal files.
- URS, 2013. Jet Filter Facility Geotechnical Report. Accessed from internal files.

2.2 Data Gaps

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

3.0 Summary of Field Investigations and Laboratory Testing

TVA (1983) performed a subsurface exploration and study along the Slag Pond 2A and 2B and Slag Stilling Pond 2C dike crest and exterior toe. The exploration included advancing eight hollow stem auger borings. Standard penetration testing and laboratory testing was performed.

Law Engineering (1995) installed monitoring wells along the Stilling Pond 2A and 2B and Slag Stilling Pond 2C dike. Three monitoring wells were installed, standard penetration testing was performed, and initial water levels were obtained.

A geotechnical exploration (AECOM, 2016) has been performed which included advancing 7 hollow stem auger (HSA) borings and 6 seismic cone penetration test ($SCPT_u$) soundings at the crest and downstream slopes of the Slag Pond 2A and 2B and Slag Stilling Pond 2C dike. The borings were located to provide good geo-spatial coverage of the dike, and the soundings were located immediately adjacent or very near the borings as companions. In addition, 10 individual vibrating wire transducers were installed at multiple boring locations.

Upon encountering the bedrock surface, each boring was advanced into bedrock. Four of the borings were advanced 0.5 to 25 feet into bedrock using the tri-cone roller bit. In addition, three borings were advanced ten feet into bedrock by means of coring with NQ-sized barrel. Core samples were logged by the geotechnical engineer and recovery and rock quality were documented.

The purpose of the HSA exploration was to explore and document the subsurface conditions and obtain undisturbed samples for laboratory testing. The purpose of the CPT soundings was to confirm the findings of the HSA borings, provide additional, continuous subsurface data at these locations, and obtain seismic data for use in seismic stability analysis. Ultimately, the combined subsurface data was used to construct cross sections to assess stability.

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

Recent topographic and bathymetric data was provided by TVA (Tuck Mapping Solutions, Inc., 2014).

4.0 Detailed Task Analysis Criteria

4.1 Material Properties

Based upon the results of the subsurface exploration, the subsurface materials that make up the Slag Pond Dike system are summarized below in **Table 1**. A more in-depth review is found in AECOM Report of Geotechnical Exploration (2016).

Table 1: Generalized Subsurface Conditions

Materials	Approximate Depth (feet below ground surface)	Consistency or Relative Density
Mine Spoils- generally consisting of lean clay (CL), clayey sand (SC), or clayey gravel (GC) with varying quantities of gravel sized rock fragments.	15 to 30	Very Stiff
Clayey Alluvium- generally consisting of moist, silty, lean clay (CL) with an irregular interval of sandy alluvium (discussed in detail below).	30 to 65	Medium Stiff
Alluvial Sand- generally consisting of fine to coarse grained silty sand (SM) to poorly graded sand (SP).	Varying depths; thickness 4 to 9 feet.	Medium Dense to Dense
Residuum-generally consisting of silty, sandy, lean clay (CL).	37 to 84	Stiff to Very Stiff
Sandstone – Fine to coarse grained, thinly bedded with occasional shale and clay seams.	47 to 94	Moderately Hard
Shale - Dark gray, thinly bedded, laminated with occasional clay seams.	47 to 94	Durable

Shear strength parameters for the stability analysis were primarily based upon triaxial shear strength testing previously performed as part of this study in conjunction with the historic TVA data. Failure criteria was taken to be maximum obliquity for drained conditions and the maximum deviator stress for undrained conditions. In either case, failure was assigned at no more than 15 percent strain. Comparison was also made to published correlations to shear strength parameters, and for the undrained condition, the unconsolidated, undrained triaxial laboratory test results. Individual test points from the consolidated undrained, triaxial shear strength testing results were plotted on p-q diagrams as recommended by USACE Engineering Manual EM 1110-2-1902. Multiple triaxial tests were plotted together and a single best fit line was applied such that approximately two thirds of the data points fall above the line. The shear strength parameters developed by AECOM were used 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 Parameters		Total Stress Strength Parameters	
		c' (psf)	ϕ' (degrees)	c (psf)	ϕ (degrees)
Fill Mine Spoils	126	0	29	200	21
Clayey Alluvium	123	0	32	1,260	11
Sandy Alluvium	127	0	32	0	20
Residuum	123	0	32	350	18
Bedrock (Shale or Sandstone)	Impenetrable				

4.2 Critical Cross Section Selection

Upon determination of the subsurface conditions, AECOM (2016) generated cross sections based upon existing geometries and selected to be representative of the most critical cross sections, such as the maximum embankment height, the steepest embankment slopes, and the least resisting force at and beyond the downstream toe. The number and location of cross sections also reflects engineering judgment to obtain appropriate geo-spatial coverage of the dike. A total of six cross sections were constructed for these analyses as described below.

- **Section A-A'** represents the central portion of the dike and shows a cross section through Slag Stilling Pond 2C into the discharge channel.
- **Section B-B'** represents the southern portion of the dike and shows a cross section through Slag Pond 2B, Slag Stilling Pond 2C and downstream to the Green River.
- **Section C-C'** represents the northern portion of the dike and shows a cross section through Slag Pond2B and the existing embankment and downstream bench to the Green River.
- **Section D-D'** represents the northern portion of the dike and shows a cross section extending from Slag Pond 2B through the dike crest northeast toward the Green River.
- **Section E-E'** represents the northern portion of the dike and shows a cross section extending from Slag Pond 2A through Red Water Pond #2.
- **Section F-F'** represents the northern portion of the dike and shows a cross section extending from Slag Pond 2B through Red Water Pond #2. HSA boring SP-B2 was advanced in this area, and the cross-sectional geometry is based on the SPT boring data.

Cross sections B-B', C-C', and D-D' were selected as critical cross sections based on their geometry and having the Green River as tailwater. Each cross section constructed and analyzed for Slag Pond 2A and 2B and Slag Stilling Pond 2C is shown in plan view in **Figure 2.**

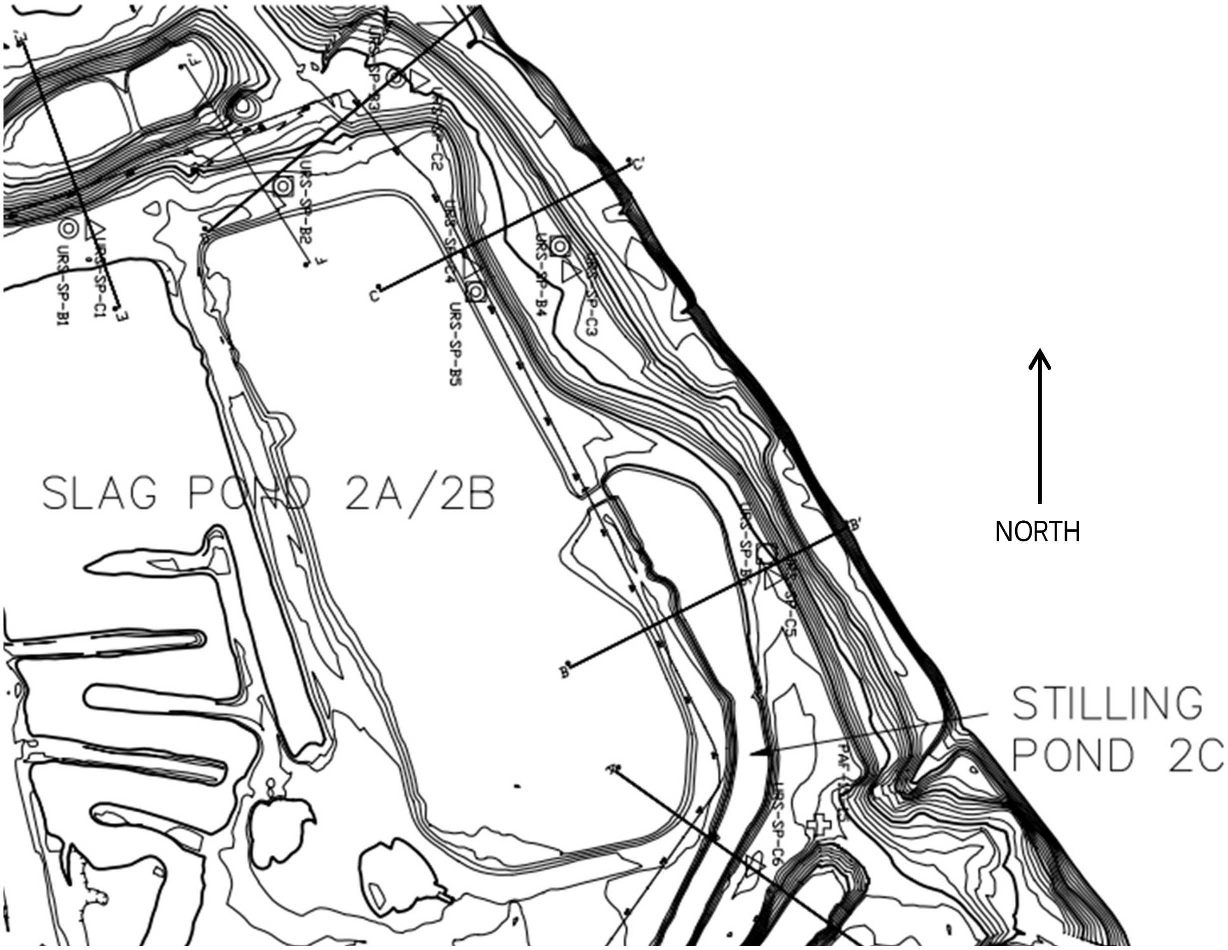


Figure 2: Plan View of Cross Sections

The summary of the historic stability analyses are provided below in **Table 3**.

Table 3: Historic Slope Stability Results

Cross Section	CCR Unit	CCR Rule Loading Condition	Factor of Safety (Global Failure, Exterior Slope)	Reference
B-B’	Slag Stilling Pond 2C	Long Term Maximum Storage Pool	1.68	AECOM (2016)
		Maximum Surcharge Pool	1.67	AECOM (2016)
		Seismic Factor of Safety	1.14	AECOM (2016)
		Liquefaction Factor of Safety	1.56	AECOM (2016)
C-C’	Slag Pond 2A and 2B	Long Term Maximum Storage Pool	2.37	AECOM (2016)
		Maximum Surcharge Pool	2.16	AECOM (2016)
		Seismic Factor of Safety	1.09	AECOM (2016)
		Liquefaction Factor of Safety	1.66	AECOM (2016)
D-D’	Slag Pond 2A and 2B	Long Term Maximum Storage Pool	2.36	AECOM (2016)
		Maximum Surcharge Pool	1.87	AECOM (2016)
		Seismic Factor of Safety	1.29	AECOM (2016)
		Liquefaction Factor of Safety	1.79	AECOM (2016)

As demonstrated in **Table 3**, Section C-C’ resulted in the lowest factors of safety when analyzed under global static and seismic conditions for Slag Pond 2A and 2B. Section B-B’ was selected to be the critical cross section for Slag Stilling Pond 2C as it represented the most direct failure path for CCR material to reach the Green River.

4.3 Water Levels

In consideration of the Initial Inflow Design Flood analysis performed by AECOM (2016), the water elevations for Slag Pond 2A/2B and Slag Stilling Pond 2C 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 Slag Pond 2A and 2B and Slag Stilling Pond 2C, while the Maximum Surcharge Pool is the pool level determined based on the 1,000 year, 6-hour storm event modeled as part of the IDF. The pond elevations proposed for the slope analyses are summarized below in **Table 4**.

Table 4: PAF Slag Pond 2A and 2B and Slag Stilling Pond 2C Water Elevations for Stability Modeling

Loading Condition	Slag Pond 2A Elevation (feet, MSL)	Slag Pond 2B Elevation (feet, MSL)	Slag Stilling Pond 2C Elevation (feet, MSL)
Long-term Maximum Storage Pool	412.09	411.62	407.17
Maximum Surcharge Pool	413.4	412.6	407.7

The Green River flows along the northeastern side of the downstream toe of the Slag Stilling Pond 2C and Slag Pond 2A and 2B. Based on published USGS flooding data, the Green River has a normal pool elevation of approximately 370 feet and a flood pool elevation of 386 feet. For each of the three cross sections considered in the analysis, the Green River served as the tailwater.

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 vibrating wire piezometer 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)(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)(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)(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)(iv)

The purpose of post-liquefaction stability is to access 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	1.00	§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 Slag Pond 2A and 2B and Slag Stilling Pond 2C.
- 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 Slag Pond 2A and 2B and Slag Stilling Pond 2C. 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 normal 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 Slag Pond 2A and 2B or Slag Stilling Pond 2C.
- 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 static safety factor evaluation results at the Slag Pond 2A and 2B critical cross section (Section C-C') and Slag Stilling Pond 2C critical section (Section B-B') is provided below 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
Slag Pond 2A and 2B	C-C'	Long-Term Maximum Storage Pool [§257.73(e)(1)(i)]	1.5	2.37
	C-C'	Maximum Surcharge Pool [§257.73(e)(1)(ii)]	1.4	2.16
	C-C'	Seismic Factor of Safety [§257.73(e)(1)(iii)]	1.0	1.09
	C-C'	Liquefaction Factor of Safety [§257.73(e)(1)(iv)]	1.2	1.66
Slag Stilling Pond 2C	B-B'	Long-Term Maximum Storage Pool [§257.73(e)(1)(i)]	1.5	1.68
	B-B'	Maximum Surcharge Pool [§257.73(e)(1)(ii)]	1.4	1.67
	B-B'	Seismic Factor of Safety [§257.73(e)(1)(iii)]	1.0	1.14
	B-B'	Liquefaction Factor of Safety [§257.73(e)(1)(iv)]	1.2	1.56

7.0 Conclusions

This report documents the safety factor evaluation of PAF's Slag Pond 2A and 2B and Slag Stilling Pond 2C. The evaluation was performed in accordance with section §257.73(e) of the CCR Rule.

The initial safety factor results for Slag Pond 2A and 2B and Slag Stilling Pond 2C 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 Slag Pond 2A and 2B and Slag Stilling Pond 2C meet the initial safety factor requirements of EPA 40 CFR §257.73(e).

8.0 References

1. Stantec, 2009. Report of Phase 1 Facility Assessment, Coal Combustion Product Impoundments and disposal Facilities, Various Locations, Kentucky, June 24, 2009, Accessed from TVA public records.
2. URS, 2012. Intermediate Dam Safety Inspection Report. Accessed from internal files.
3. USACE, 2005. ETL 1110-2-569. Design Guidance for Levee Under-seepage, Department of the Army, May 1, 2005.
4. USACE, 2003. EM 1110-2-1902. Slope Stability. Engineering and Design. October 31, 2003.
5. TVA, 1995. Ash Disposal Area and Stilling Pond Extension Plan Details, 10W3274 Drawings 1-5.
6. University of Kentucky Geological Survey, 2015. Online Geologic Interactive Map Accessed at: http://kgs.uky.edu/kgsmap/kgsgeoserver/viewer.asp on January 21, 2015.
7. Kentucky Mine Mapping Service, 2015. Online Interactive Mine Mapping Accessed at: http://eppcgis.ky.gov/flexviewers/minemapping/ on January 21, 2015.
8. Robertson, Guide to Cone Penetration Testing for Geotechnical Engineering 6th Edition, Gregg Drilling & Testing, Inc., December 2014.
9. Mitchell & Katti, Soil Improvement: State of the Art Report. June, 1981.
10. Bureau of Reclamation (2014), Design Standards No. 13, Embankment Dams, Chapter 8, Seepage.
11. AECOM, 2016. Report of Geotechnical Exploration, Slag Pond Complex. March, 2016.
12. TVA, 1983. Paradise Steam Plant-Coal Receiving Facility-Soil Investigation for Ash Pond Dike Adjacent to Barge Dock Cells.
13. Law Engineering 1995; Monitoring Well Installation Logs
14. Stantec, 2010. Report of Geotechnical Exploration, Gypsum Stack, Paradise Fossil Plant, Muhlenberg County, Kentucky, Accessed from TVA public records.
15. Stantec, 2013. Report of Mine Subsidence, Gypsum Stack Disposal Complex.
16. Stantec, 2009. Report of Phase 1 Facility Assessment, Coal Combustion Product Impoundments and disposal Facilities, Various Locations, Kentucky, Accessed from TVA public records.
17. URS, 2011. TVA Four-Plant Dewatering Paradise Fossil Plant Site 1.
18. URS, 2012. Intermediate Dam Safety Inspection Report. Accessed from internal files.
19. URS, 2013. Jet Filter Facility Geotechnical Report. Accessed from internal files.

20. AECOM (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, September 30.

APPENDIX A

SLOPE STABILITY ANALYSIS

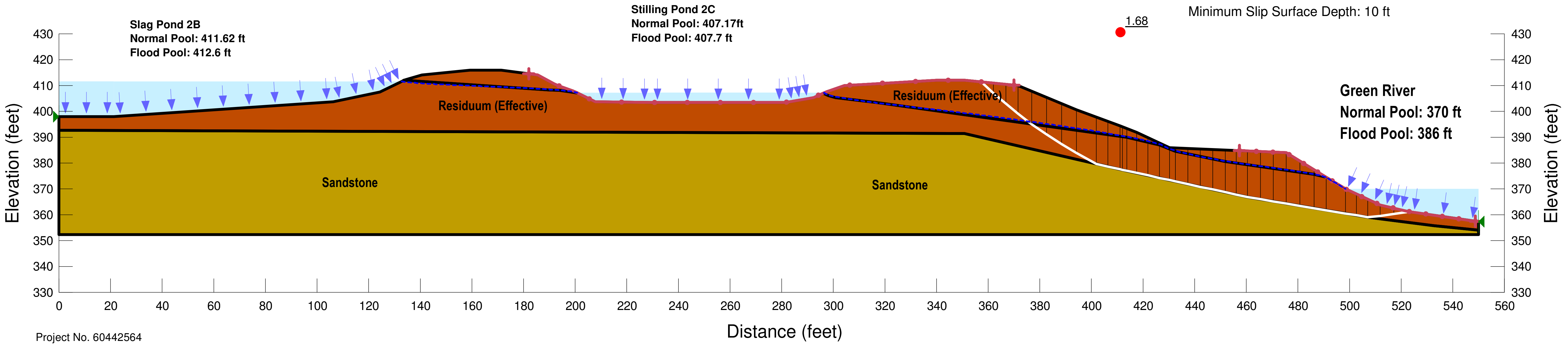
Tennessee Valley Authority
Paradise Fossil Plant - Slag Pond Complex
Paradise, Kentucky
Cross Section B-B'

Long Term, Maximum Storage Pool Loading Condition

Note: The results of the analysis shown here are based on laboratory test results and approximate soil properties.
The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the same time of drilling.
No warranties can be made regarding the continuity of subsurface conditions
Bathymetry for Slag Pond 2B, Stilling Pond 2C and the Green River are assumed.

Material	Model	Unit Weight (pcf)	Cohesion (psf)	Phi (deg.)
Residuum (Effective)	Mohr-Coulomb	123	0	32
Sandstone	Bedrock (Impenetrable)	--		

Method: Spencer
F of S: 1.68
Center: (490.12222, 551.01264) ft
Radius: 192.68001 ft
Minimum Slip Surface Depth: 10 ft



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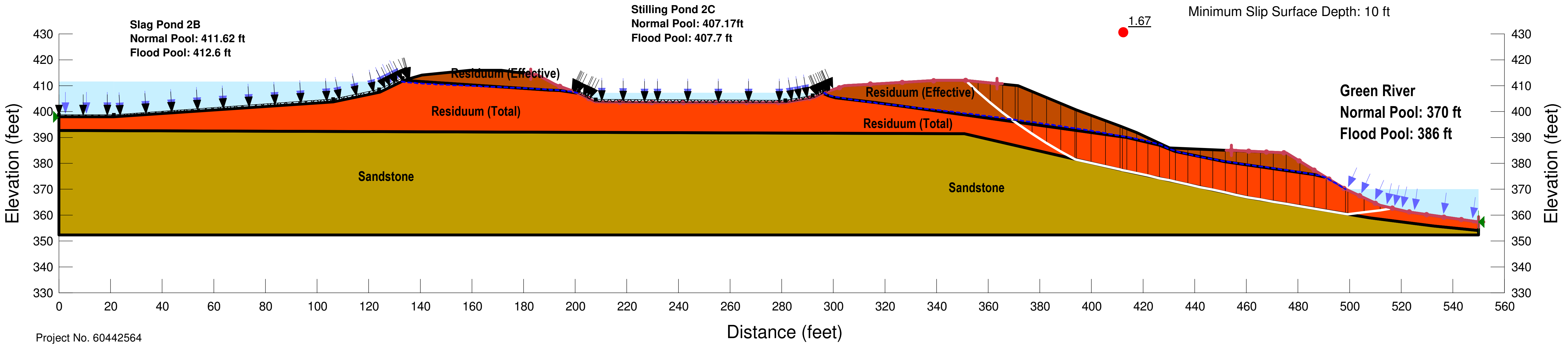
Tennessee Valley Authority
Paradise Fossil Plant - Slag Pond Complex
Paradise, Kentucky
Cross Section B-B'

Maximum Surcharge Pool Loading Condition

Note: The results of the analysis shown here are based on laboratory test results and approximate soil properties.
The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the same time of drilling.
No warranties can be made regarding the continuity of subsurface conditions
Bathymetry for Slag Pond 2B, Stilling Pond 2C and the Green River are assumed.

Material	Model	Unit Weight (pcf)	Cohesion (psf)	Phi (deg.)
Residuum (Effective)	Mohr-Coulomb	123	0	32
Sandstone	Bedrock (Impenetrable)	--		
Residuum (Total)	Mohr-Coulomb	123	350	18

Method: Spencer
F of S: 1.67
Center: (482.63222, 550.7806) ft
Radius: 191.14163 ft
Minimum Slip Surface Depth: 10 ft



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Tennessee Valley Authority
Paradise Fossil Plant - Slag Pond Complex
Paradise, Kentucky
Cross Section B-B'

Seismic Factor of Safety Stability

Note: The results of the analysis shown here are based on laboratory test results and approximate soil properties.
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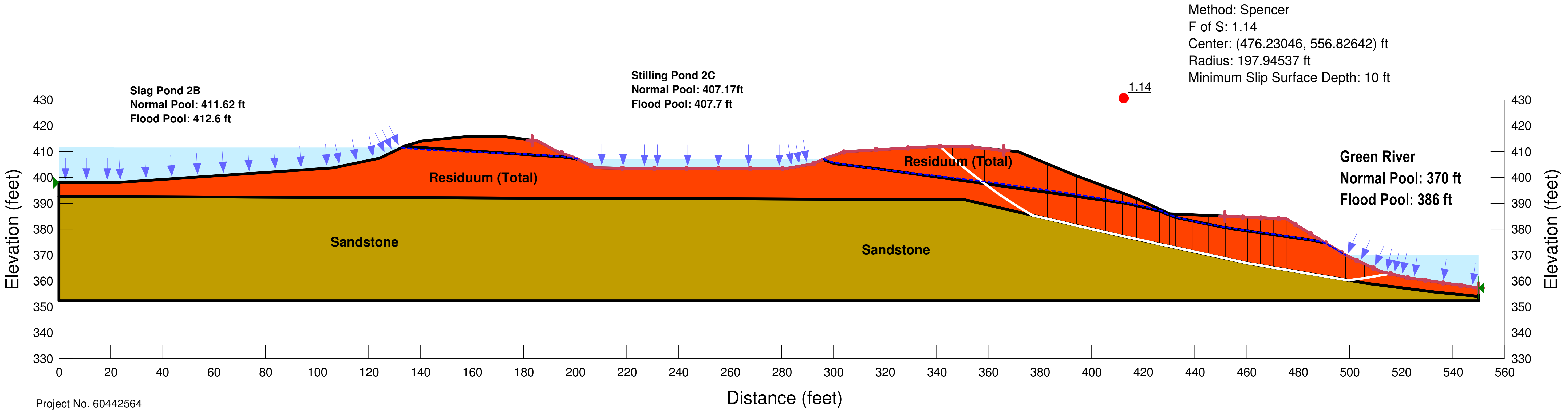
No warranties can be made regarding the continuity of subsurface conditions
Bathymetry for Slag Pond 2B, Stilling Pond 2C and the Green River are assumed.

Material	Model	Unit Weight (pcf)	Cohesion (psf)	Phi (deg.)
Sandstone	Bedrock (Impenetrable)	----------	----------	----------
Residuum (Total)	Mohr-Coulomb	123	350	18

Horz Seismic Coef.: 0.136



Method: Spencer
F of S: 1.14
Center: (476.23046, 556.82642) ft
Radius: 197.94537 ft
Minimum Slip Surface Depth: 10 ft

Slag Pond 2B
Normal Pool: 411.62 ft
Flood Pool: 412.6 ft

Stilling Pond 2C
Normal Pool: 407.17ft
Flood Pool: 407.7 ft

Green River
Normal Pool: 370 ft
Flood Pool: 386 ft

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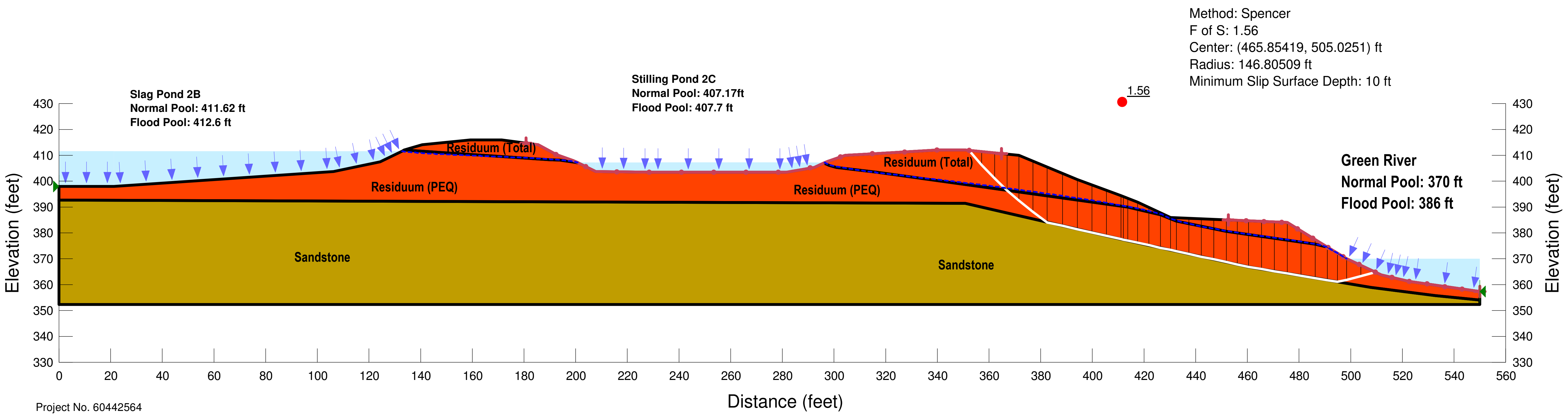
Tennessee Valley Authority
Paradise Fossil Plant - Slag Pond Complex
Paradise, Kentucky
Cross Section B-B'

Liquefaction Factor of Safety Stability

Note: The results of the analysis shown here are based on laboratory test results and approximate soil properties.
The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the same time of drilling.
No warranties can be made regarding the continuity of subsurface conditions
Bathymetry for Slag Pond 2B, Stilling Pond 2C and the Green River are assumed.

Material	Model	Unit Weight (pcf)	Cohesion (psf)	Phi (deg.)
Sandstone	Bedrock (Impenetrable)			
Residuum (Total)	Mohr-Coulomb	123	350	18
Residuum (PEQ)	Mohr-Coulomb	123	360	14.4


Method: Spencer
F of S: 1.56
Center: (465.85419, 505.0251) ft
Radius: 146.80509 ft
Minimum Slip Surface Depth: 10 ft

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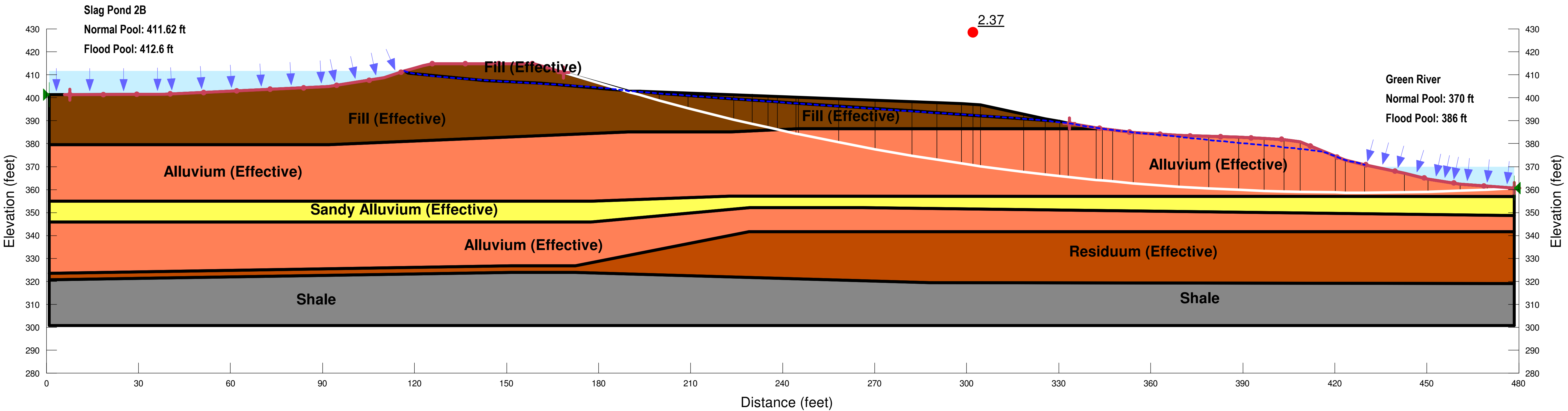
Tennessee Valley Authority
Paradise Fossil Plant -Slag Pond Complex
Paradise, Kentucky
Cross Section C-C'

Long Term, Maximum Storage Pool Loading Condition

Note: The results of the analysis shown here are based on laboratory test results and approximate soil properties.
The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the same time of drilling.
No warranties can be made regarding the continuity of subsurface conditions.
Bathymetry for Slag Pond 2B and the Green River are assumed.

Material	Model	Unit Weight (pcf)	Cohesion (psf)	Phi (deg.)
Fill	Mohr-Coulomb	126	0	29
Alluvium	Mohr-Coulomb	123	0	32
Residuum	Mohr-Coulomb	123	0	32
Sandy Alluvium	Mohr-Coulomb	127	0	32
Shale	Bedrock (Impenetrable)	--		

Method: Spencer
Contour parameter: Pore-Water Pressure
F of S: 2.37
Center: (427.85449, 1,027.5744)
Radius: 668.85978
Minimum Slip Surface Depth: 10



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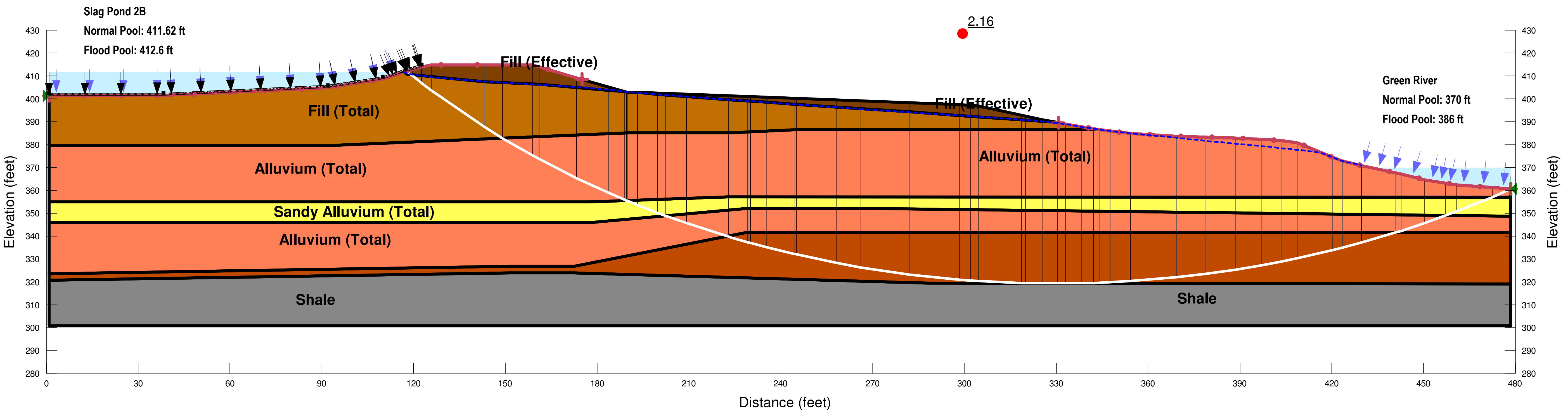
Tennessee Valley Authority
Paradise Fossil Plant -Slag Pond Complex
Paradise, Kentucky
Cross Section C-C'

Maximum Surcharge Pool Loading Condition

Note: The results of the analysis shown here are based on laboratory test results and approximate soil properties.
The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the same time of drilling.
No warranties can be made regarding the continuity of subsurface conditions.
Bathymetry for Slag Pond 2B and the Green River are assumed.

Material	Model	Unit Weight (pcf)	Cohesion (psf)	Phi (deg.)
Fill	Mohr-Coulomb	126	0	29
Shale	Bedrock (Impenetrable)	---		
Alluvium (Total)	Mohr-Coulomb	123	1,260	11
Fill (Total)	Mohr-Coulomb	126	200	21
Residuum (Total)	Mohr-Coulomb	123	350	18
Sandy Alluvium (Total)	Mohr-Coulomb	127	0	20

Method: Spencer
Contour parameter: Pore-Water Pressure
F of S: 2.16
Center: (329.68323, 607.86816)
Radius: 288.58717
Minimum Slip Surface Depth: 10



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Tennessee Valley Authority
Paradise Fossil Plant -Slag Pond Complex
Paradise, Kentucky
Cross Section C-C'

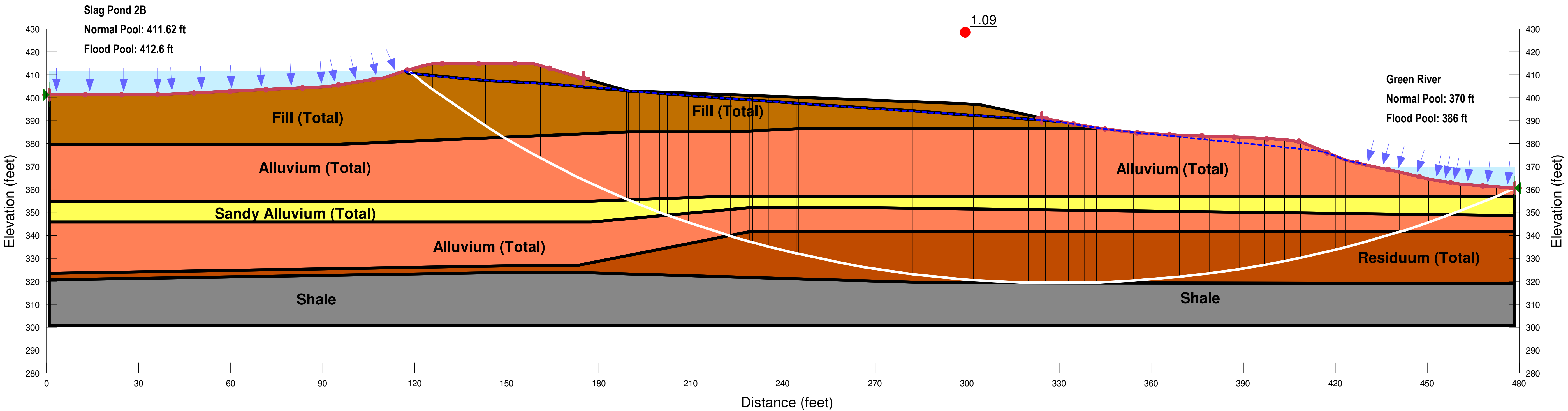
Pseudostatic Stability

Note: The results of the analysis shown here are based on laboratory test results and approximate soil properties.
The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the same time of drilling.
No warranties can be made regarding the continuity of subsurface conditions.
Bathymetry for Slag Pond 2B and the Green River are assumed.

Material	Model	Unit Weight (pcf)	Cohesion (psf)	Phi (deg.)
Shale	Bedrock (Impenetrable)	--		
Alluvium (Total)	Mohr-Coulomb	123	1,260	11
Fill (Total)	Mohr-Coulomb	126	200	21
Residuum (Total)	Mohr-Coulomb	123	350	18
Sandy Alluvium (Total)	Mohr-Coulomb	127	0	20

Horz Seismic Coef.: 0.136

Method: Spencer
Contour parameter: Pore-Water Pressure
F of S: 1.09
Center: (329.68323, 607.86816)
Radius: 288.58717
Minimum Slip Surface Depth: 10



Project No. 60442564

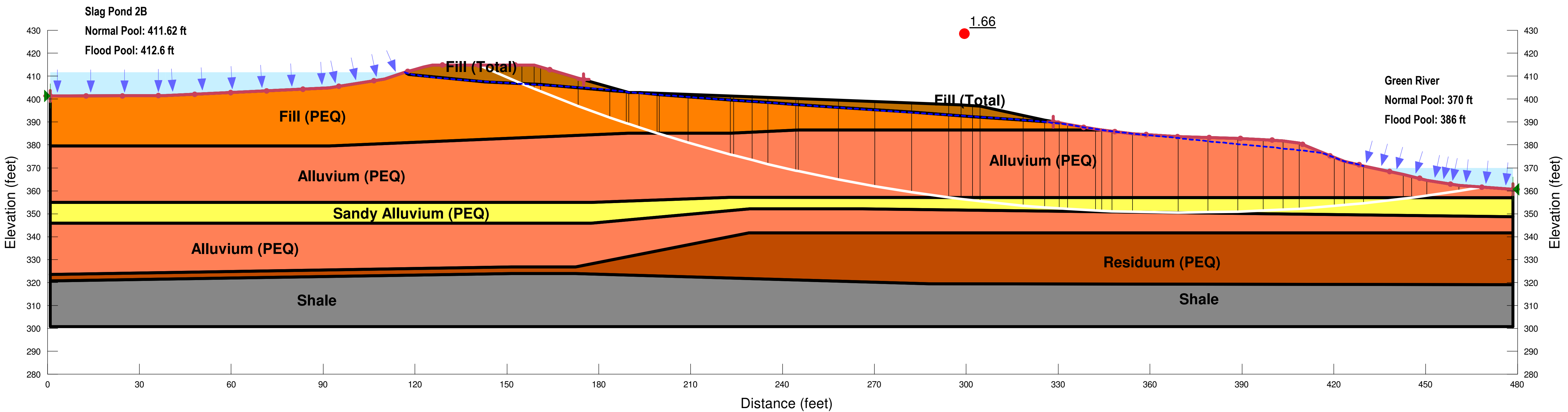
Tennessee Valley Authority
Paradise Fossil Plant -Slag Pond Complex
Paradise, Kentucky
Cross Section C-C'

Post Earthquake Stability

Note: The results of the analysis shown here are based on laboratory test results and approximate soil properties.
The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the same time of drilling.
No warranties can be made regarding the continuity of subsurface conditions.
Bathymetry for Slag Pond 2B and the Green River are assumed.

Material	Model	Unit Weight (pcf)	Cohesion (psf)	Phi (deg.)
Shale	Bedrock (Impenetrable)	---		
Alluvium (PEQ)	Mohr-Coulomb	123	1,008	8.8
Fill (Total)	Mohr-Coulomb	126	200	21
Fill (PEQ)	Mohr-Coulomb	126	160	16.8
Residuum (PEQ)	Mohr-Coulomb	123	360	14.4
Sandy Alluvium (PEQ)	S=f(overburden)	127	Tau/Sigma Ratio: 0.17	

Method: Spencer
Contour parameter: Pore-Water Pressure
F of S: 1.66
Center: (369.99124, 790.76827)
Radius: 440.22825
Minimum Slip Surface Depth: 10



Project No. 60442564