Stantec Consulting Services Inc.
10509 Timberwood Circle, Suite 100, Louisville, KY 40223-5308

October 12, 2021
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Revision 0

Tennessee Valley Authority
1101 Market Street
Chattanooga, Tennessee 37402

RE: Periodic Seismic Safety Factor Assessment
East Ash Disposal Area
EPA CCR Rule
TVA Allen Fossil Plant
Memphis, Tennessee

1.0 PURPOSE

This letter documents certification that the East Ash Disposal Area at the Tennessee Valley Authority (TVA) Allen Fossil Plant is in compliance with the seismic safety factor requirements set forth in 40 CFR 257.73(e)(1)(iii)&(iv) of the EPA CCR Rule. The EPA CCR Rule requires periodic safety factor assessments, certified by a professional engineer, every five years. The initial certification of seismic safety factor was placed in the operating record on October 14, 2016.

2.0 INITIAL SEISMIC SAFETY FACTOR ASSESSMENT

The initial seismic safety factor assessment (Geocomp 2016) is attached. The assessment calculated the seismic factors of safety for the following loading conditions:

- Seismic (i.e., Pseudo-seismic); and
- Liquefaction (i.e., Post-earthquake).

Geocomp compiled and reviewed available historical site, topographic, and geotechnical data for the East Ash Disposal Area as part of the initial assessment and identified Section E-E' as the most critical cross section. The critical section was analyzed for the loading conditions specified in 40 CFR 257.73(e)(1)(iii) and (iv). The result of the initial assessment was that East Ash Disposal Area complied with 40 CFR 257.73(e)(1)(iii) and (iv).

3.0 CURRENT SEISMIC SAFETY FACTOR ASSESSMENT

Stantec reviewed the result of the initial seismic safety factor assessment and the changes in site conditions that have occurred in the past five years. The following items summarize changes that have occurred:

1. East Ash Disposal Area ceased receiving CCR and non-CCR waste streams. The main spillway has been temporarily plugged, and a drawdown/dewatering pump system has been installed that discharges to the Mississippi River.

2. East Ash Disposal Area operating pool level has decreased from El. 225.7 ft to El. 219.6 ft which improves the stability by reducing pore water pressures.

3. Cross-sectional geometry of the perimeter dike system has not changed.

4. Annual and weekly inspections conducted since 2015 were reviewed as part of this assessment. No areas of interest were identified that would warrant remediation of seismic stability conditions.

5. Monthly instrumentation (i.e., piezometer) monitoring conducted since 2015 has been reviewed and the phreatic condition at the critical cross section has reduced or remained consistent.

6. Ground motion parameters (i.e., uniform hazard response spectrum) were compared to the initial seismic assessment using the USGS unified hazard tool website. The current parameters are representative of those used in the initial seismic assessment.

Based on our review, there are no conditions that have changed in the past five years that would cause the result of the initial seismic stability assessment to have changed.

4.0 SUMMARY OF ASSESSMENT

Based on review of the initial seismic safety factor assessment and the items listed in Section 3.0, the result of this periodic seismic safety factor assessment is that the East Ash Disposal Area at the Allen Fossil Plant meets the requirements of §257.73(e)(1)(iii)&(iv) of the EPA CCR Rule.

Re: **Periodic Seismic Safety Factor Assessment**
East Ash Disposal Area
EPA CCR Rule
TVA Allen Fossil Plant
Memphis, Tennessee

5.0 QUALIFIED PROFESSIONAL ENGINEER CERTIFICATION

I, Stephen H. Bickel, being a Professional Engineer in good standing in the State of Tennessee, 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 this periodic seismic safety factor assessment for the TVA Allen Fossil Plant's East Ash Disposal Area meets the requirements of 40 CFR 257.73(e)(1)(iii) and (iv).

SIGNATURE [signature] DATE 10/12/2021

ADDRESS: Stantec Consulting Services Inc.
10509 Timberwood Circle, Suite 100
Louisville, Kentucky 40223-5308

TELEPHONE: (502) 212-5075

ATTACHMENTS: Initial Seismic Safety Factor Assessment Report

References:

Stantec Consulting Services Inc. (2016). Initial Safety Factor Assessment, Allen Fossil Plant, East Ash Disposal Area, Memphis, Tennessee. Prepared for Tennessee Valley Authority, October 6

Geocomp (2016). Initial Seismic Safety Factor Assessment, EPA Final CCR Rule, TVA Allen Fossil Plant East Ash Disposal Area, Memphis, Tennessee; October 14

STEPHEN H. BICKEL
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INITIAL SEISMIC SAFETY FACTOR ASSESSMENT

Revision 0. October 14, 2016

Geocomp
Technologies to manage risk for infrastructure

October 14, 2016

Tennessee Valley Authority
1101 Market Street
Chattanooga, TN 37402

RE: Initial Seismic Safety Factor Assessment
EPA Final CCR Rule
TVA Allen Fossil Plant East Ash Disposal Area
Memphis, Tennessee

Dear Sir/Madam:

TVA retained Geocomp Corporation (Geocomp) to prepare a seismic and liquefaction factor of safety assessment to meet the EPA's requirements under the HAZARDOUS AND SOLID WASTE MANAGEMENT SYSTEM; DISPOSAL OF COAL COMBUSTION RESIDUALS FROM ELECTRIC UTILITIES; FINAL RULE [RIN-2050-AE81; FRL-9919-44-OSWER]. This letter provides a brief project background, summary of findings, limitations, and certification.

1.0 BACKGROUND

As required by §257.73 of the EPA Final CCR Rule, within 18 months of the published date (April 17, 2015), an initial structural integrity evaluation for seismic loading is required and must include initial assessments of seismic factor of safety and liquefaction factor of safety 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 seismic and liquefaction factor of safety assessments must document whether the calculated factors of safety for the critical cross section(s) of each existing CCR surface impoundment achieve the minimum factors of safety specified in paragraphs (e)(1)(iii) and (e)(1)(iv) of §257.73 in the EPA Final CCR Rule. 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 EPA Final CCR Rule provided that the previously completed 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.

In support of the above assessment, Geocomp completed a subsurface and laboratory investigation, seismic stability evaluation, and liquefaction assessment for the East Ash Disposal Area at the Allen Fossil Plant in Memphis, Tennessee. Information gathered through the subsurface and laboratory investigation, completed in October of 2015, was used to supplement data collected by Stantec in 2010 and 2011, Geocomp in 2013, and Stantec in 2013. The above information was provided in the Stantec report titled "Report of Geotechnical Exploration and Evaluation of Slope Stability, Eastern Perimeter Dike, East Stilling Pond, Allen Fossil Plant, Shelby County, Tennessee" dated February 4, 2010; Stantec report titled "Report of Geotechnical Exploration Report and Evaluation of Slope Stability, Northern Perimeter Dike East Active Ash Pond, Allen Fossil Plant, Shelby County, Tennessee" dated March 25, 2010; Stantec Report Titled "Results of Seismic Slope Stability Analysis Active CCP Disposal Facilities – Allen Fossil Plant" dated October 3, 2011; Geocomp report titled "Tennessee Valley Authority EPA Seismic Assessment Supplemental Exploration, Allen Fossil Plant" dated March 29, 2013 and Stantec report titled "Preliminary Seismic Risk Assessment – DRAFT Temporary Conditions at CCP Storage Facilities TVA Fossil Plant, Various Locations" dated March 29, 2013. A complete listing of documents reviewed and utilized as part of this assessment is included in the Attachment.

2.0 SUMMARY OF FINDINGS

Based upon a review of the available information from documents listed in the Attachment and Geocomp's seismic stability evaluations associated with the East Ash Disposal Area, Cross Section E-E' was selected as the critical cross section at the East Ash Disposal Area of the Allen Fossil Plant. Table 1 below provides a summary of the safety factors for the critical cross section.

Table 1. Summary of Safety Factors for Critical Cross Section

Plant	Facility	Critical Cross Section	EPA Criteria	CCR Rule Reference	EPA Required FOS	Factor of Safety (FOS)
ALF	East Ash Disposal Area	E-E'	Seismic Factor of Safety (Pseudo-Static Stability)	§257.73(e)(1)(iii)	1.00	1.73
			Liquefaction Factor of Safety (Post-Earthquake Stability)	§257.73(e)(1)(iv)	1.20	1.50

Based upon the information presented in Table 1, it is Geocomp's opinion that the above factors of safety meet or exceed the requirements of those specified in the EPA CCR Final Rule § 257.73 paragraphs (e)(1)(iii) and (e)(1)(iv). Analyses supporting these safety factors are presented in Geocomp's report to TVA entitled "Tennessee Valley Authority EPA Seismic Assessment Supplemental Site Exploration Allen Fossil Plant East Ash Disposal Area Final Report" dated October, 2016.

3.0 LIMITATIONS

The signature of Geocomp's authorized representative on this document represents that to the best of Geocomp's knowledge, information, and belief in the exercise of its professional judgment, Geocomp's professional opinion is that the aforementioned information is accurate as of the date of such signature. Any opinion or decisions by Geocomp are made on the basis of this information, the engineering analyses, and Geocomp's experience, qualifications, and professional judgment and are not to be construed as warranties or guaranties. In addition, opinions relating to environmental, geologic, and geotechnical conditions or other estimates are based on available data and the actual conditions may vary from those encountered at the times and locations where data were obtained, despite the use of due care.

4.0 CERTIFICATION

I, W. Allen Marr, being a Registered Professional Engineer in the State of Tennessee do hereby certify to the best of my knowledge, information and belief that the information contained in this report is true and correct and has been prepared in accordance with the accepted engineering practice.

SIGNATURE W. Allen Marr DATE Oct 14, 2016

ADDRESS: Geocomp Corporation, 125 Nagog Park, Acton, MA 01720

TELEPHONE: 978-635-0012

ATTACHMENTS: Demonstration Document for Seismic Factor of Safety and Liquefaction Factor of Safety for TVA Allen Fossil Plant, East Ash Disposal Area, Memphis, TN.

Geocomp

Attachment:

Demonstration Document for Seismic Factor of Safety and Liquefaction Factor of Safety for TVA Allen Fossil Plant East Ash Disposal Area Memphis, TN.

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Appendix A: Slope Stability Analysis Results for Critical Cross Section

1.0 INTRODUCTION

1.1 OBJECTIVE

On April 17, 2015 the "Final Rule: Disposal of Coal Combustion Residuals (CCR) from Electric Utilities" (Environmental Protection Agency, 2015) was published in the Federal Register. Geocomp Corporation (Geocomp) was contracted by the Tennessee Valley Authority (TVA) to analyze the Structural Integrity Criteria for the Allen Fossil Plant (ALF) CCR surface impoundments and to evaluate compliance with §257.73(e)(1) (iii) and (iv) of the Environmental Protection Agency (EPA) Final CCR Rule.

1.2 OUTLINE OF RULE REQUIREMENTS

As required by §257.73(e)(1) (iii) and (iv) of the EPA Final CCR Rule, an initial structural integrity evaluation is required by October 17, 2016 and must include an initial seismic and liquefaction factor of safety assessment for each existing CCR surface impoundment that meets the conditions of paragraph (b) as follows:

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

§257.53 requires seismic stability assessments of CCR impoundments consider a seismic event with 2 Percent Probability of Exceedance in 50 years (i.e. probable earthquake within approximately 2,500 years) and a Horizontal Spectral Response Acceleration for 1.0-Second Period (5 Percent of Critical Damping). The safety factor assessment must document whether the calculated factors of safety for each existing CCR surface impoundment perimeter dike demonstrate the minimum seismic and liquefaction factors of safety specified in paragraphs (e)(1)(iii) and (e)(1)(iv) of the EPA Final CCR Rule for the critical cross section of the embankment.

As mandated by the EPA, TVA is required to evaluate all of its active CCR impoundment facilities for seismic factors of safety and liquefaction factors of safety. The EPA established requirements for the minimum "seismic factor of safety" and the minimum "liquefaction factor of safety". Geocomp interprets what the EPA Final CCR Rule calls "seismic factor of safety" to be what geotechnical engineers call "pseudo-static factor of safety". Geocomp interprets what the EPA's final rule calls "liquefaction factor of safety" to be what geotechnical engineers call "post-earthquake" or "post-shaking" factor of safety. The EPA Final CCR Rule requirements for seismic and liquefaction factors of safety are summarized in Table 1.1.

Table 1.1: Factor of Safety Criteria

CCR Rule Criteria	CCR Rule Factor of Safety Requirements	CCR Rule Reference
Seismic Factor of Safety	≥ 1.00	§257.73(e)(1)(iii)
Liquefaction Factor of Safety	≥ 1.20	§257.73(e)(1)(iv)

1.3 DESCRIPTION OF FACILITY

Allen Fossil Plant (ALF) is a coal-fired, electric-generating plant. The ALF facility is at 2574 Plant Road in the city of Memphis, Shelby County, Tennessee. It is situated along the southern shore of Lake McKellar and on the eastern bank of the Mississippi River, approximately 8 miles southwest of downtown Memphis, Tennessee. Figure 1.1 shows a plan view of the Allen Fossil Plant. The impoundment evaluated at the Allen Fossil Plant is the East Ash Disposal Area. The facility is located approximately 1.0 miles east of the main power plant. Earthen dikes form the entire perimeter of the impoundment. TVA has determined that the East Ash Disposal Area is a CCR surface impoundment and, therefore, is subject to the EPA Final CCR Rule.

Figure 1.1: Allen Fossil Plant

2.0 PROJECT RECONNAISSANCE

2.1 REVIEW OF EXISTING AND READILY AVAILABLE DATA

Geocomp's review of existing and readily available data included the following documents:

- Atkinson, G., & Beresnev, I. (2002, April). Ground Motions at Memphis and St. Louis from M7.5-8.0 Earthquakes in the New Madrid Seismic Zone. Bulletin of the Seismological Society of America, 92(3), 1015-1024.
- Cramer, C., Gomberg, J., Schweig, E., Waldron, B., & Tucker, K. (n.d.). The Memphis, Shelby County, Tennessee, Seismic Hazard Maps. U.S. Geological Survey Open-File Report 04-1294.
- Geocomp Corporation, Inc. (2013). Tennessee Valley Authority EPA Seismic Assessment Supplemental Site Exploration, Allen Fossil Plant.
- Stantec Consulting Services, Inc. (2010a). Report of Geotechnical Exploration and Evaluation of Slope Stability. Eastern Perimeter Dike, East Stilling Pond, Allen Fossil Plant, Shelby County, Tennessee.
- Stantec Consulting Services, Inc. (2010b). Report of Geotechnical Exploration Report and Evaluation of Slope Stability, Northern Perimeter Dike, East Active Ash Pond, Allen Fossil Plant, Shelby County, Tennessee.

- Stantec Consulting Services, Inc. (2011). Results of Seismic Slope Stability Analysis Active CCP Disposal Facilities - Allen Fossil Plant.
- Stantec Consulting Services, Inc. (2013). Preliminary Seismic Risk Assessment – DRAFT, Temporary Conditions at CCP Storage Facilities, TVA Fossil Plants, Various Locations. Letter No. let_012_175551015.
- Stantec Consulting Services, Inc. (September 2014). Instrumentation Progress Report (Rev. 0), Instrumentation Program, Allen Fossil Plant, Shelby County, Tennessee.

3.0 APPROACH TO SEISMIC ASSESSMENT

Geocomp's general approach to assess the likely performance of a CCR impoundment seismic conditions is summarized in Figure 3.1 Please refer to Geocomp (2016) for a detailed discussion of the seismic assessment approach.

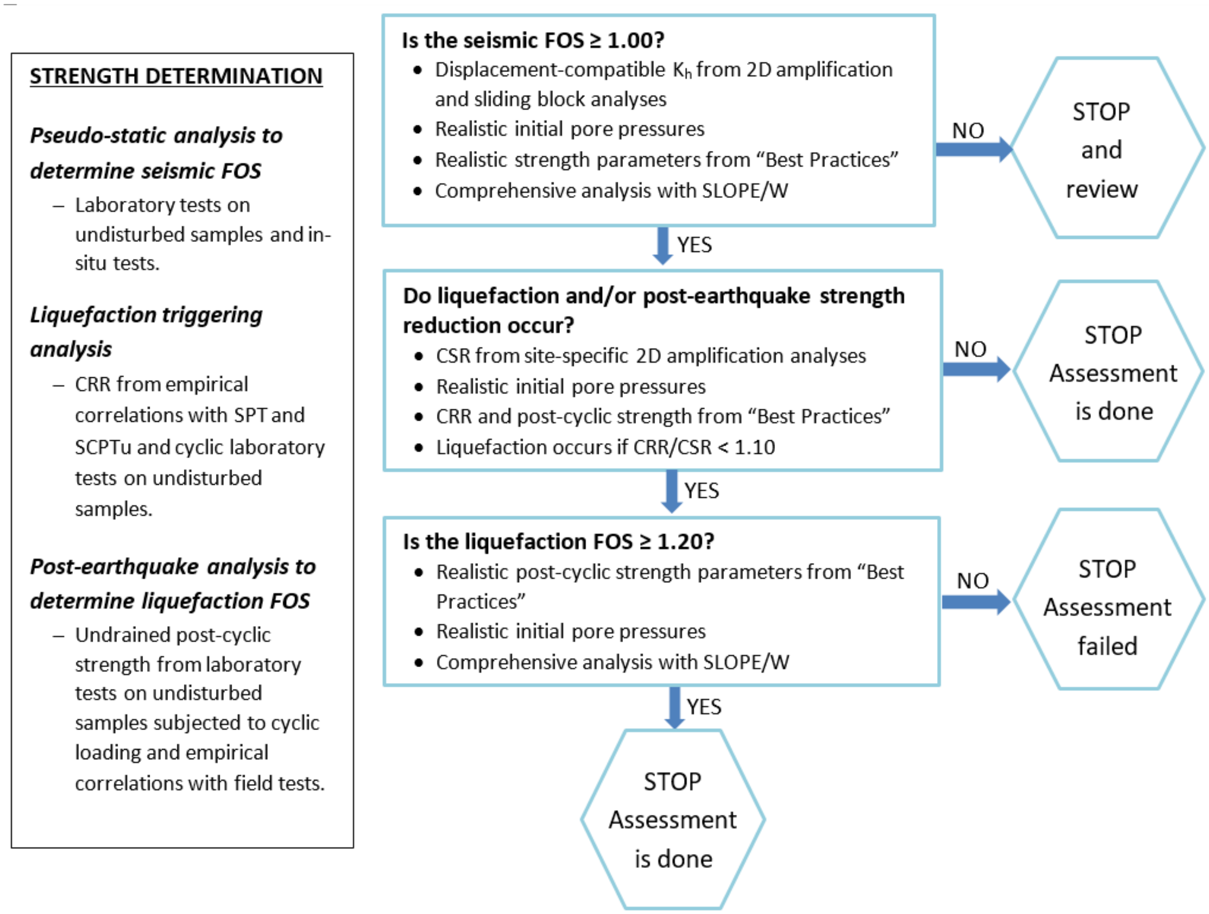

Figure 3.1: Summary of Technical Approach for Seismic Assessment

4.0 SEISMIC ASSESSMENT

4.1 SEISMICITY

The ALF facility is located at the northern end of a thick sequence of Cretaceous period deposits in an area known as the Mississippi Embayment. These thick deposits of sediments have a significant effect on earthquake ground motions. While damaging earthquakes in central Tennessee are only moderately likely, ground motions are dominated by events originating in the New Madrid Seismic Zone. This zone is defined by a clustered pattern of earthquake hypocenters between 5 and 15 km deep. The ALF facility is located approximately 45 km from the center of this seismic zone. Figure 4.1 shows the peak and spectral accelerations at a period of 1 second for a 2% probability of exceedance in 50 years, equivalent to a return period of approximately 2,500 years, for ALF obtained from the USGS website (http://geohazards.usgs.gov/hazardtool/application.php last accessed 04/01/16). The seismic design criteria are summarized in Table 4.1. The 2,500-yr ground motion levels at the ALF facility are dominated by earthquakes generated in the New Madrid Fault Zone.

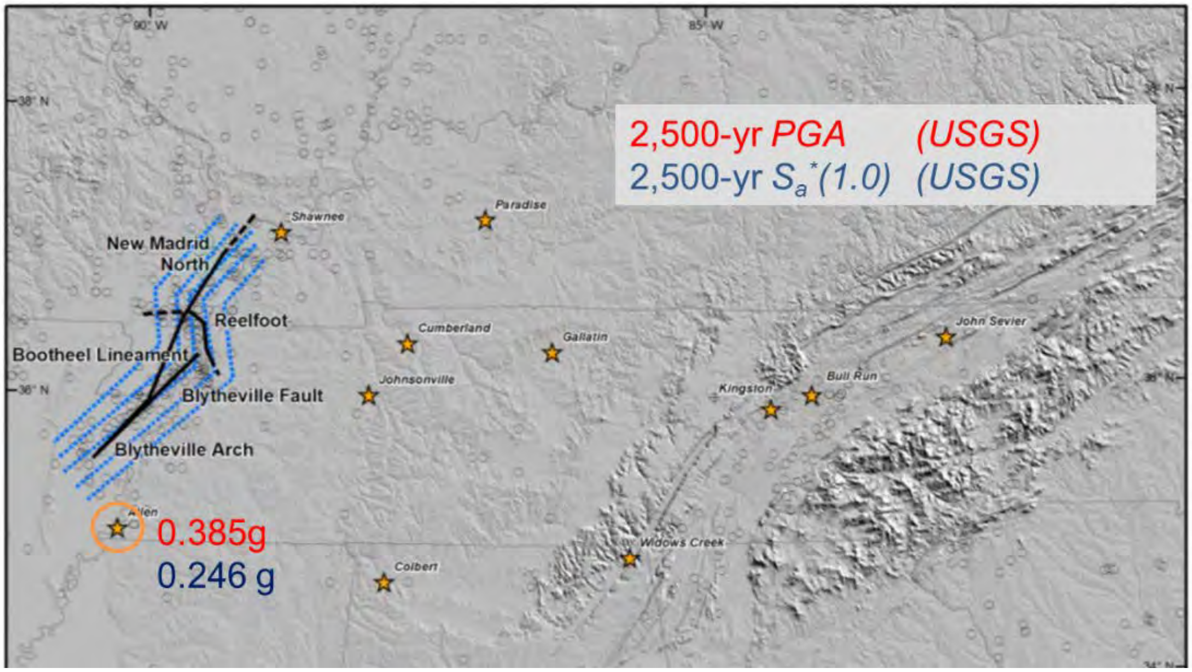

Figure 4.1: Peak Acceleration Values 2500-yr Return Periods at ALF

Table 4.1: Allen Fossil Site Summary of Seismic Design Parameters

Parameter	Value
Uniform Hazard Peak Ground Acceleration – Hard Rock (A)	0.385g
Design Peak Ground Acceleration – Hard (A)	0.451g(1)
Design Peak Ground Acceleration – Soil Class (D)	0.562g(1)
Uniform Hazard Spectral Acceleration at a period of 1.0 second	0.246g
Uniform Hazard Spectral Acceleration at a period of 0.2 second	0.640g
Mean Moment Magnitude	M7.19
Mean distance to seismic event	44.6 km
Uniform Hazard Response Spectra	See Figure 4.2

(1) Design PGA values from the 2015 NEHRP Provisions (FEMA 2015).

The site-specific seismic amplification analyses used seven ground motion time histories that have spectral contents that match the uniform hazard response spectrum (UHRS) shown in Figure 4.2. The development of these input ground motions started with the selection of recorded earthquake time histories that approximate the design criteria. These motions have response spectra with shapes similar to that of the UHRS and ground motion durations within the range expected for the deaggregated mean magnitude. The recorded motions were then modified by adding and subtracting wavelets using the software SeismoMatch (SeismoSoft 2016) until the resulting response spectra closely match the UHRS.

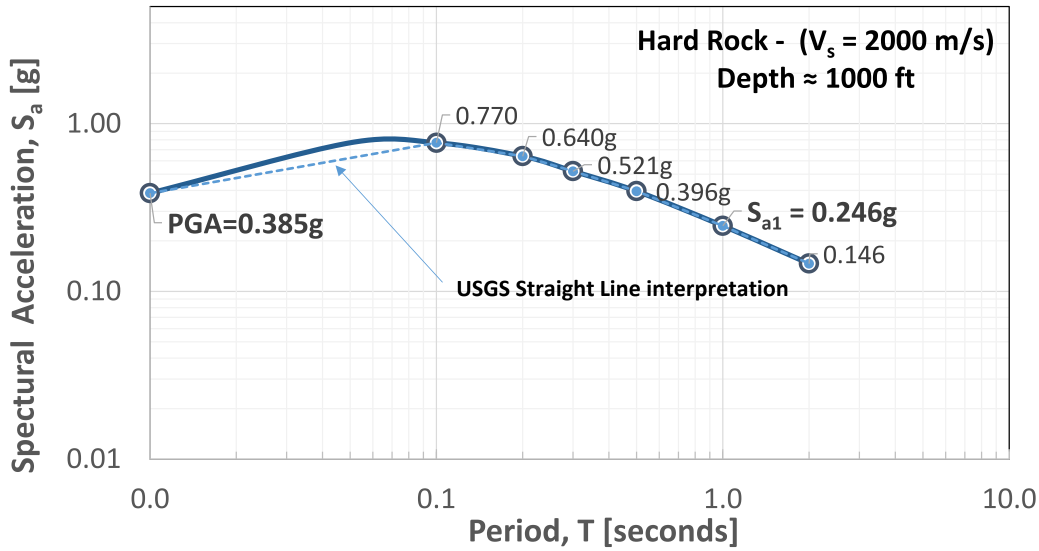

Figure 4.2: USGS Uniform Hazard Response Spectra (UHRS)

The site specific seismic study conducted for ALF is based on the design response spectra developed by USGS as required by the new EPA rules and summarized in Figure 4.2. Table 4.2 summarizes the seven time history records selected for the site-specific amplification analysis.

Table 4.2: Time Histories Used in the Analysis

Motion	Earthquake	Arias Intensity [cm/sec]	Significant Duration [sec]	Spectral Acceleration at 1s Sa(1s) [g]
Motion 1	Synthetic Bootheel	198	41	0.148
Motion 2	Synthetic Reelfoot	35	22	0.112
Motion 3	Quintay Long, Chile 1985	125	39	0.130
Motion 4	SanFelipe 080, Chile 1985	306	32	0.173
Motion 5	ValpoUFSM 160, Chile 1985	71	42	0.078
Motion 6	SanFern EW, Chile 1985	201	26	0.456
Motion 7	Chi-Chi CHY010 ROTD50, Taiwan 1999	65	28	0.180

4.2 SELECTION OF CROSS SECTIONS FOR ASSESSMENT

Geocomp's review of existing and readily available information resulted in the selection of two cross sections as potential critical cross sections for further evaluation. These cross sections are each located on the Eastern Perimeter Dike and Northern Perimeter Dike at the Allen Fossil Plant. Additional site subsurface explorations were planned and conducted to fill data gaps.

In February/March 2010, Stantec Consulting Services, Inc. (Stantec) completed two reports (Stantec 2010a and Stantec 2010b) which presented results of geotechnical explorations and subsequent slope stability analyses for the Eastern Perimeter Dike and Northern Perimeter Dike at the Allen Fossil Plant. The site exploration performed by Stantec for their evaluation consisted of drilling 14 borings and installing 14 piezometers at five cross-sections at the East Ash Disposal Area. Stantec found cross sections to have static factors of safety between 1.03 to 2.30. The reports did not include seismic stability assessments.

In 2013, Geocomp analyzed Cross Section B-B' along the Northern Perimeter Dike for seismic stability under an earthquake event with a return period of 2,500 years. This cross section was selected at that time based on a previous assessment performed by Stantec who selected Cross Section B-B' as the critical cross section along the Northern Perimeter Dike in terms of seismic factor of safety (Stantec 2011). The seismic factor of safety reported by Stantec was 0.7 for this cross section. Geocomp's 2013 assessment resulted in seismic and liquefaction factors of safety of 0.72 and 0.98, respectively.

In a subsequent study performed in 2013, Stantec selected Cross Section B-B' as the critical cross section in terms of liquefaction factor of safety. This assessment resulted in a liquefaction factor of safety between 0.6 and 0.8 for this cross section under a seismic event with a return period of 660 years for the New Madrid Seismic Zone as the source (Stantec 2013). The liquefiable materials at this cross section, as reported by Stantec, were the alluvial sands and silts.

For the current study, Geocomp selected Cross Sections B-B' and E-E' as the potential critical cross sections at the East Ash Disposal Area.

Cross Section B-B' was selected based on the following information:

- According to Geocomp (2013), the seismic and liquefaction factors of safety were less than 1.00. This was mainly because these results relied heavily on the results of Standard Penetration Tests performed in the four borings at this cross section.
- The liquefaction factor of safety was strongly dependent on a zone between EL. 130 ft. and EL. 135 ft. within the native silty sand layer which had relatively low SPT-N values. Only one boring (at the toe of the slope) extended below this depth. This layer had a factor of safety of less than 1 against liquefaction triggering and therefore was assigned a low undrained residual shear strength. For post-earthquake stability, this layer has a significant effect on the computed factor of safety value as a major part of the failure surface passed through this relatively weak zone.
- The closer proximity of Cross Section B-B' to the northwestern side of the East Ash Disposal Area compared to Cross Section A-A' which is the remaining available cross section along the dike. It should be noted that generally similar subsurface conditions were encountered at Cross Sections A-A' and B-B'.
- The loss of containment in the vicinity of Cross Section B-B' at the East Ash Disposal Area could result in direct uncontrolled discharge of CCR materials into Lake McKellar and the Mississippi River.

The basis for the selection of Cross Section E-E' as a potential critical cross section are Stantec's 2010 and 2013 analyses of static factors of safety for long term conditions for three cross sections, i.e. Cross Sections C-C', D-D' and E-E', as well as preliminary evaluations of field investigation data provided to Geocomp by Stantec when field work for the current study was ongoing in 2015. Stantec's 2013 analyses resulted in factors of safety of 1.82, 1.71, and 1.61 for Cross Sections C-C', D-D' and E-E', respectively (Stantec 2013b). In selecting the potential critical cross section from among Cross Sections C-C', D-D' and E-E' for the current study, Geocomp adopted the following approach:

- Perform two SCPTu at each of the three cross-sections (Cross Sections C-C', D-D' and E-E'), one at the crest and one at the toe.

- Based on preliminary review of the draft SCPTu results made available to Geocomp while field investigations for the current study are underway, select the potential critical cross section for subsequent drilling and sampling, installation of piezometers, cross hole seismic measurements, and seismic analysis.

The draft SCPTu data provided to Geocomp by Stantec during the ongoing 2015 field investigations as well as subsurface information obtained from Stantec (2010b) cross sections showed the following:

- The native materials underlying the site were generally similar between Cross Sections C-C', D-D' and E-E'.
- The dike materials at Cross Section E-E' were weaker than the dike materials at Cross Sections C-C' and D-D' as indicated by the lower SCPTu tip resistance and shear wave velocities measured at Cross Section E-E' compared to the other two cross sections.
- Within the top 30 ft of the native materials underlying the dikes at the three cross sections, Cross Section E-E' appears have more significant presence of materials that could be susceptible to liquefaction.

Based on the Stantec cross sections (Stantec 2010a and 2010b), Stantec (2013) stability analysis results, and preliminary review of the draft 2015 SCPTu data, Geocomp selected Cross-Section E-E' as a potential critical cross at the East Ash Disposal Area.

We also determined from the review that some of the prior field measurements of SPT values were suspect due to improper test procedures and that some of the prior analyses made overly conservative assumptions about strength parameters of critical materials. These findings warranted a further field investigation program, laboratory testing to quantify static and cyclic strength of these critical materials and updated analyses.

4.3 FIELD INVESTIGATIONS

The field investigation for the current assessment included 7 borings with standard penetration testing, undisturbed sampling and 11 seismic cone penetration testing with pore pressure measurements (SCPTu). Geophysical testing was performed at two of the cross sections including seismic cross-hole testing and gamma density logging. The subsurface conditions encountered at the critical cross section at the East Ash Disposal Area are summarized in Table 4.3. A more in-depth presentation of the field investigation is found in Geocomp (2016).

Table 4.3: Generalized Subsurface Conditions at Cross Section E-E'

ALF Cross Section E-E'		
Soil Layer	**Approximate Elevation (ft)**	**General Consistency/Density**
Sandy Silt (Dike)	236-207	Medium dense to dense non-plastic sandy SILT with layers of lean Clay with Sand and Silt with average PI=10
Upper Clay	207-191	Medium stiff to stiff fat CLAY with average PI=39
Sandy Silt	191-189	Medium dense non-plastic sandy SILT
Lower Clay	189-179	Medium stiff to stiff fat CLAY with average PI=40
Silt with interbedded layers of SM and CL	179-166	Loose to medium dense non-plastic SILT with interbedded layers of silty Sand and lean Clay with average PI=15

ALF Cross Section E-E’		
Soil Layer	Approximate Elevation (ft)	General Consistency/Density
Silty Sand	166-157	Medium dense to dense non-plastic silty SAND
Sand	157-110	Dense poorly graded and well graded SAND with Silt

During the 2016 geotechnical explorations, Geocomp performed a laboratory testing program consisting of index parameters including natural moisture content, sieve and hydrometer analyses, Atterberg limits, specific gravity and bulk density. The laboratory testing program also included constant rate of strain consolidation tests, direct simple shear tests, cyclic direct simple shear with post cyclic monotonic strength measurement, modulus and damping versus strain using fixed-based resonant column and shear wave measurements using bender element sensors. Geocomp (2016) provides detailed results of the laboratory testing program.

4.4 WATER CONDITIONS

4.4.1 Surface Water

This section discusses the surface water conditions for the critical cross section at the East Ash Disposal Area. For this impoundment, a water level of El. 230 feet was used for the analyses. This is based on the information contained in the February 2013 final report prepared by Dewberry Consultants, LLC. (Dewberry 2013). For the East Stilling pond, a water level of El. 225 feet was used for the analyses. This is based on readings collected from automatic water level gauge “ALF_Pond_PL” located at the East Stilling Pond between February 14, 2012 and November 4, 2015. For Lake McKellar, a water level of El. 185.0 feet was used for the analyses. This is based on river gauges located nearby in the Mississippi River and confirmed by values used by others (Stantec 2010). Table 4.4 summarizes the surface water levels used in the seismic assessment of the critical cross section at the East Ash Disposal Area.

Table 4.4: Surface Water Levels at the East Ash Disposal Area

Surface Water Levels	
Pond	Total Head (ft)
East Ash Pond Level	230.0
East Stilling Pond Level	225.0
Lake McKellar(1)	185.0

(1) Lake McKellar water level fluctuates. Average water level values were used in our stability analysis.

4.4.2 Pore Water

The pore water conditions at the East Ash Disposal Area are based on recent piezometer data. They show a decrease in total head within the foundation materials. This indicates downward flow and pore water conditions below the phreatic surface that are less than hydrostatic. Table 4.5 summarizes the piezometric conditions used in the analyses at the critical cross section at the East Ash Disposal Area.

Table 4.5: Summary of Total Head Data at Cross Section E-E'

ALF Cross Section E-E’ Total Head		
Soil Layer	Total Head at Crest (ft)	Total Head at Toe (ft)
Sandy Silt (Dike)	222.8	212.6

ALF Cross Section E-E' Total Head		
Soil Layer	Total Head at Crest (ft)	Total Head at Toe (ft)
Upper Clay	203.0-222.8	202.0-212.6
Sandy Silt	201.0-203.0	200.0-202.0
Lower Clay	190.0-201.0	192.7-200.0
Silt with interbedded layers of SM and CL	184.0-190.0	186.1-192.7
Silty Sand	183.1-184.0	186.1-186.6
Sand	183.1	186.6

4.5 MATERIAL PARAMETERS

Table 4.6 summarizes the material parameters used in the site-specific amplification analyses and for the calculation of seismic factors of safety at the critical cross section at the East Ash Disposal Area. Table 4.7 summarizes the material parameters used for the calculations of liquefaction factors of safety at the critical cross section at the East Ash Disposal Area. Please refer to Geocomp (2016) for details of the soil parameter development.

Table 4.6: Parameters used for Amplification Analyses and Calculation of Seismic Factor of Safety at Cross Section E-E'

Soil Layers	Strength Parameters			Amplification Parameters			
	Unit Weight (pcf)	Friction Angle, ϕ' (deg)	Undrained Shear Strength (psf)	V_s(1) (ft/s)	G_{max} (2) (psf)	G_o(3) (psf)	n(4)
Sandy Silt (Dike) (Crest)	118	37	---	622	1.42E+06	2.14E+06	0.1
Sandy Silt (Dike) (Toe)	118	37	---	749	2.06E+06	2.14E+06	0.1
Hydraulic Ash	100	28	---	555	1.15E+06	1.15E+06	0.1
Upper Clay (Crest 1)	113	---	2,500	559	1.10E+06	9.60E+05	0.5
Upper Clay (Toe 1)	113	---	1,200	470	7.77E+05	9.60E+05	0.5
Upper Clay (Crest 2)	113	---	1,200	559	1.10E+06	9.60E+05	0.5
Upper Clay (Toe 2)	113	---	1,200	470	7.77E+05	9.60E+05	0.5
Upper Clay (Crest 3)	113	---	1,500	559	1.10E+06	9.60E+05	0.5
Upper Clay (Toe 3)	113	---	1,000	470	7.77E+05	9.60E+05	0.5
Upper Clay (Crest 4)	113	---	1,500	559	1.10E+06	9.60E+05	0.5
Upper Clay (Toe 4)	113	---	1,000	470	7.77E+05	9.60E+05	0.5
Sandy Silt (Crest)	115	28	---	589	1.24E+06	1.15E+06	0.8
Sandy Silt (Toe)	115	28	---	522	9.73E+05	1.15E+06	0.8
Lower Clay (Crest 1)	113	---	2,500	589	1.22E+06	5.43E+05	1
Lower Clay (Toe 1)	113	---	1,000	425	6.36E+05	5.43E+05	1
Lower Clay (Crest 2)	113	---	1,400	589	1.22E+06	5.43E+05	1
Lower Clay (Toe 2)	113	---	1,000	425	6.36E+05	5.43E+05	1

Soil Layers	Strength Parameters			Amplification Parameters			
	Unit Weight (pcf)	Friction Angle, ϕ' (deg)	Undrained Shear Strength (psf)	V_s [1] (ft/s)	G_{max} [2] (psf)	G_o [3] (psf)	n [4]
Clayey Silt (Crest)	115	28	---	648	1.50E+06	8.97E+05	0.8
Clayey Silt (Toe)	115	28	---	547	1.07E+06	8.97E+05	0.8
Silty Sand (Crest)	118	35	---	725	2.71E+06 – 2.76E+06	1.48E+06	0.5
Silty Sand (Toe)	118	35	---	737	2.06E+06 – 2.88E+06	1.48E+06	0.5
Sand (Crest)	125	40	---	806 - 1027	3.82E+06 – 4.10E+06	2.02E+06	0.5
Sand (Toe)	125	40	---	840 - 1171	2.97E+06 – 5.33e+06	2.02E+06 – 2.25E+06	0.5 – 0.7

(1) V_s = shear wave velocity values selected from field SCPTu tests
(2) G_{max} = Low strain shear modulus
(3) G_o = Reference low strain shear modulus at atmospheric pressure (1 atm)
(4) n = Exponent on normalized initial mean effective stress

Table 4.7: Parameters used for Calculation of Liquefaction Factor of Safety at Cross Section E-E'

Soil Layers	Static Strength Parameters			Post-Earthquake Strength Parameters		
				Sand-Like Materials	Clay-Like Materials	
	Unit Weight (pcf)	Friction Angle, ϕ' (deg)	Undrained Shear Strength (psf)	Undrained Residual Shear Strength S_r/σ'_v	Undrained Shear Strength (psf)	Post-Cyclic Strength Reduction (%)
Sandy Silt (Dike) (Crest)	118	37	---	Static Strength	---	---
Sandy Silt (Dike) (Toe)	118	37	---	0.24	---	---
Hydraulic Ash	100	28	---	0.06	---	---
Upper Clay (Crest 1)	113	---	2,500	---	1,875	25
Upper Clay (Toe 1)	113	---	1,200	---	840	30
Upper Clay (Crest 2)	113	---	1,200	---	1,080	10
Upper Clay (Toe 2)	113	---	1,200	---	840	30
Upper Clay (Crest 3)	113	---	1,500	---	1,200	20
Upper Clay (Toe 3)	113	---	1,000	---	750	25
Upper Clay (Crest 4)	113	---	1,500	---	1,500	0
Upper Clay (Toe 4)	113	---	1,000	---	750	25
Sandy Silt (Crest)	115	28	---	0.26	---	---
Sandy Silt (Toe)	115	28	---	0.26	---	---

Soil Layers	Static Strength Parameters			Post-Earthquake Strength Parameters		
				Sand-Like Materials	Clay-Like Materials	
	Unit Weight (pcf)	Friction Angle, ϕ' (deg)	Undrained Shear Strength (psf)	Undrained Residual Shear Strength S_r/σ'_v	Undrained Shear Strength (psf)	Post-Cyclic Strength Reduction (%)
Lower Clay (Crest 1)	113	---	2,500	---	2,500	0
Lower Clay (Toe 1)	113	---	1,000	---	900	10
Lower Clay (Crest 2)	113	---	1,400	---	1,400	0
Lower Clay (Toe 2)	113	---	1,000	---	900	10
Clayey Silt (Crest)	115	28	---	Static Strength	---	---
Clayey Silt (Toe)	115	28	---	Static Strength	---	---
Silty Sand (Crest)	118	35	---	0.11	---	---
Silty Sand (Toe)	118	35	---	0.11	---	---
Sand (Crest)	125	40	---	0.14	---	---
Sand (Toe)	125	40	---	0.14	---	---

4.6 SEISMIC ANALYSES

4.6.1 Site-Specific Amplification

Site-specific two-dimensional amplification analyses were performed to model the seismic response of the soil profile at the East Ash Disposal Area. Two-dimensional non-linear amplification analyses were performed using the finite element program OpenSees and the results were verified with the finite difference program FLAC. Dynamic models and analyses with OpenSees were carried out by the University of Washington team led by Professors Arduino and Kramer. Geocomp was responsible for the verification of OpenSees results using FLAC models.

The results of these analyses were used to determine displacement-compatible accelerations used in the pseudo-static slope stability analyses to calculate the seismic factor of safety. The results of these analyses were also used to determine cyclic shear stresses for cyclic laboratory testing to measure post-cyclic strengths for the post-earthquake slope stability analyses to calculate the liquefaction factor of safety. Geocomp (2016) provides details for the site-specific amplification analyses.

4.6.2 Seismic Factor of Safety

The seismic stability factor of safety of the dike cross sections was evaluated under pseudo-static loading conditions using pond levels and piezometric surfaces determined by existing instrumentation and survey data provided by TVA. The pseudo-static loading conditions were determined from applied displacement-compatible accelerations. The applied displacement-compatible accelerations were selected from results of the sliding block analyses described in detail in Geocomp (2016). These use an allowable seismic displacement of 18 inches to determine the equivalent horizontal earthquake coefficient for pseudo-static stability.

4.6.3 Liquefaction Triggering

The assessment of the factor of safety against liquefaction of discrete materials and layers within the soil profiles at each cross section was performed using a combination of the stress-based approach proposed by Idriss and Boulanger (2008) and updates to the approach proposed by Boulanger and Idriss (2014). The stress-based approach was used to calculate the Cyclic Resistance Ratio (CRR) through the soil profile. The results of the site-specific two-dimensional amplification analysis are used to obtain the Cyclic Stress ratio (CSR) through the soil profile. The factor of safety against liquefaction for discrete materials and layers is then calculated as CRR/CSR. If this value is less than 1.10 then the specific material or layer evaluated is considered potentially liquefiable for the maximum design earthquake and its post-cyclic undrained residual strength is evaluated for use in the post-earthquake stability analysis.

4.6.4 Liquefaction Factor of Safety

The liquefaction factor of safety was calculated to evaluate the stability of the cross sections under post-earthquake conditions. For the purposes of liquefaction hazard evaluation, soils are often described as exhibiting “sand-like” or “clay-like” behavior. Sand-like soils typically have plasticity indices less than 7, and are considered susceptible to liquefaction. Clay-like soils have higher plasticity indices and are not considered susceptible to liquefaction, although they may experience some degree of strength loss from cyclic loading. Under these conditions, the sand-like materials that could potentially liquefy are modeled with undrained residual strengths. Sand-like materials that are not expected to liquefy are modeled with static strength parameters. Clay-like materials are modeled with reduced undrained shear strengths if they are expected to exhibit post-cyclic softening; otherwise these materials are modeled with undrained strength parameters. Piezometric conditions were kept the same for all seismic and post-earthquake stability analyses.

4.7 SELECTION OF CRITICAL CROSS SECTIONS

According to the results of pseudo-static and post-earthquake slope stability analyses on two cross sections chosen as potential critical cross sections, Cross Section E-E’ is the critical cross section at the East Ash Disposal Area in terms of seismic and liquefaction factors of safety.

5.0 ANALYSIS RESULTS

The slope stability results were obtained with the two-dimensional limit equilibrium program Slope/W. The seismic and liquefaction factors of safety for the critical cross section at East Ash Disposal Area are summarized in Table 5.1. The minimum factors of safety reported in this table correspond to slip surfaces that could potentially result in the uncontrolled release of water and CCR materials from within the impoundments during or after the maximum design earthquake. Results of these stability analyses using the limit equilibrium slope stability method are presented in Appendix A of this report. Geocomp (2016) gives details of the slope stability analyses at the East Ash Disposal Area at the Allen Fossil Plant.

Table 5.1: Summary of Seismic Assessment Results at Critical Cross Section E-E'

Plant	Facility	Cross Section	EPA Criteria	EPA Final CCR Rule Required Factor of Safety	Calculated Minimum Factor of Safety
ALF	East Ash Disposal Area	E-E'	Seismic Factor of Safety	≥ 1.00	1.73
			Liquefaction Factor of Safety	≥ 1.20	1.50

6.0 CONCLUSION

This report documents the evaluation of seismic and liquefaction factors of safety of Allen Fossil Plant's East Ash Disposal Area. The evaluation was performed in accordance with section §257.73(e) of the CCR Rule.

The seismic assessment at the East Ash Disposal Area at the Allen Fossil Plant resulted in a seismic factor of safety of 1.73 [§257.73(e)(1)(iii)] and a liquefaction factor of safety of 1.50 [§257.73(e)(1)(iv)]. These results meet or exceed the minimum required seismic factor of safety of 1.00 and liquefaction factor of safety of 1.20.

7.0 REFERENCES

Note: These references were used for the described work and are cited in the Geocomp 2016 report. They are not all cited in this summary report.

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Appendix A

Slope Stability Analysis Results for Critical Section

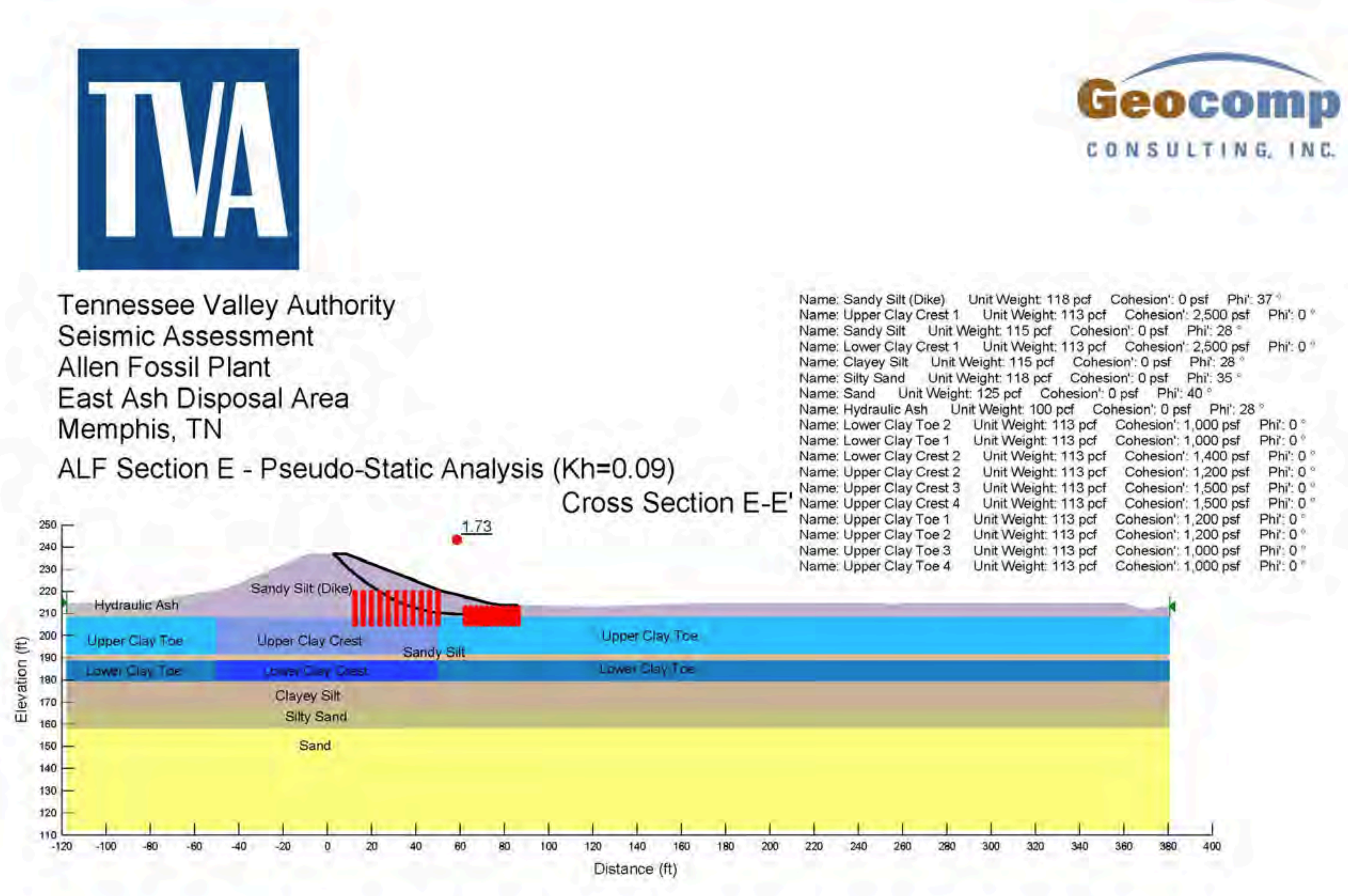

Figure A. 1: Seismic Factor of Safety by Pseudo-Static Slope Stability Analysis at Cross Section E-E'

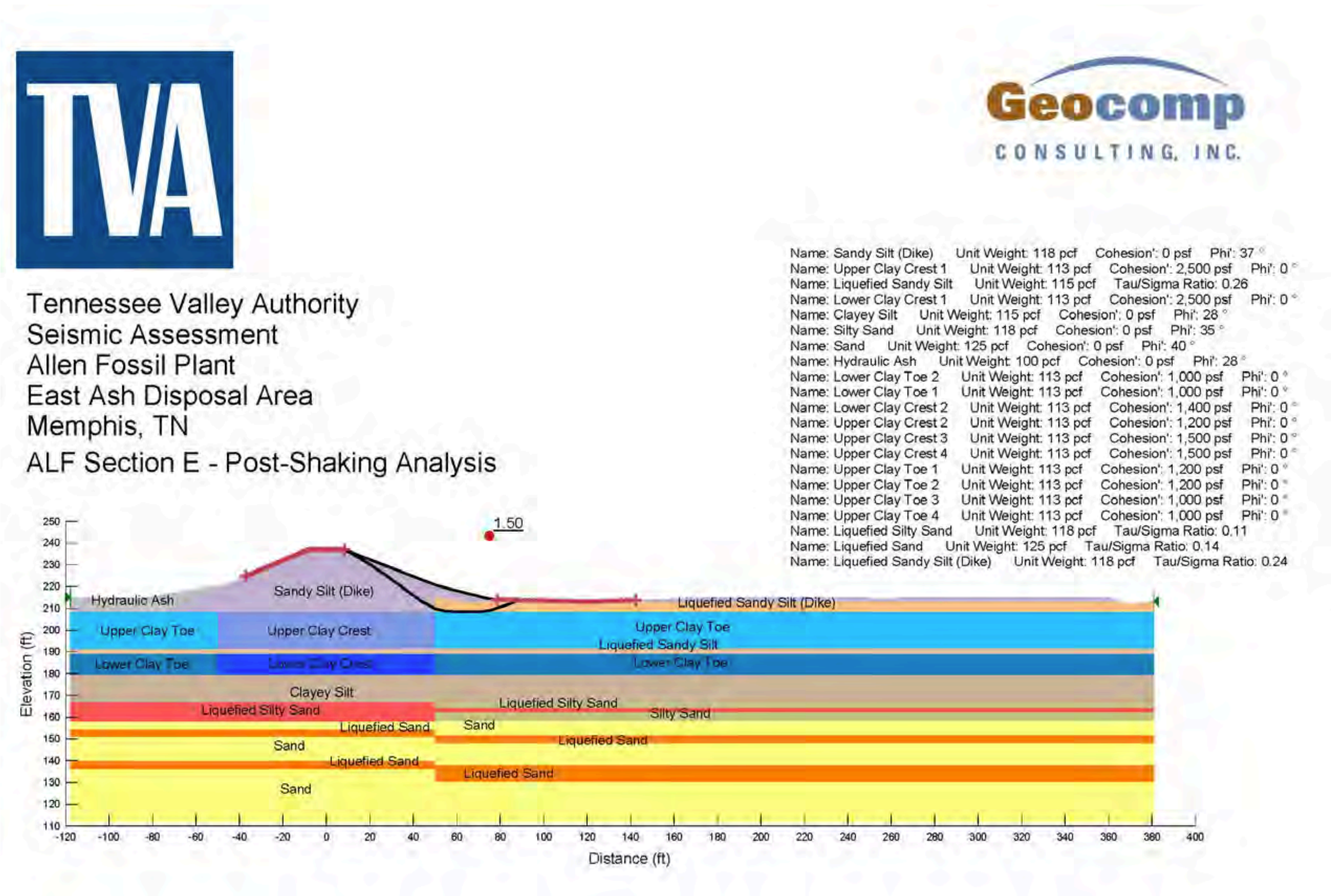

Figure A. 2: Liquefaction Factor of Safety by Post-Earthquake Slope Stability Analysis at Cross Section E-E'