US EPA ARCHIVE DOCUMENT

US EPA ARCHIVE DOCUMENT

EPA Comments

SUBJECT: Comments on "DRAFT REPORT - Dam Safety Assessment of CCW Impoundments: TVA Cumberland Fossil Plant"

DATE: August 31, 2012

COMMENTS:

1. In Section 2.3 "Size and Hazard Classification," it should be noted that the Dry Ash Stack (although not an impoundment) and gypsum storage areas are "intermediate" sized structures. The text does not define either one, leaving ambiguity between a classification of "Small" or "Intermediate." Additionally, it should be noted here if the size classification has any bearing in later analyses and what classification was used, i.e., design flood for H&H analysis.
2. In Section 4.1.3 "Significant Repairs/Rehabilitation since Original Construction," were any repairs performed on the internal gypsum dike that failed, mentioned in Section 3.3 "Summary of Spill/Release Incidents."
3. Section 5 photos. The resolution/clarity on all the photos is poor. Can this be corrected?
4. On page 5-1, section 5.1, third paragraph, the report states: "The overall assessment of the dam was that it was in fair condition and no significant findings were noted." There don't appear to be any language in section 5 that indicate anything other than impoundments in satisfactory condition. Nothing is stated that rates the inference of "fair."
5. In Section 6.2 "Adequacy of Supporting Technical Documentation," please note if Dewberry feels that the lack of H&H analysis for the remainder of the CCR complex outside of the Ash Pond is acceptable. It is inferred from text but would be advantageous if outright stated.
6. In Section 7.1.2 "Design Parameters and Dam Materials," 2nd paragraph, 2nd sentence, there appears to be missing a word between "relatively….deposit." Please rectify.
7. On page 8-1, section 8.3.1, add a period at the end of the sentence.
8. Please indicate the location of the Bottom Ash Pond in Appendix A, Document 2.
9. Appendix A, Doc 5 is unreadable. Please correct.
10. Appendix A, Doc 16 is missing. Please add in following the header page.
11. Appendix B, Document 18, remove page 11.
12. Appendix B, Document 19, remove page 12.
13. Appendix B, Document 20, remove page 11.

Stantec Consulting Services Inc.
1901 Nelson Miller Parkway
Louisville KY 40223-2177
Tel: (502) 212-5000
Fax: (502) 212-5055

US EPA ARCHIVE DOCUMENT

October 16, 2012 let_010_175551015_rev_0

Mr. John C. Kammeyer, PE
Vice President
Tennessee Valley Authority
1101 Market Street, LP 5G
Chattanooga, Tennessee 37402

Re: Response to Recommendations
USEPA CCR Impoundment Assessment DRAFT Report
Cumberland Fossil Plant (CUF)
Cumberland City, Tennessee

Dear Mr. Kammeyer:

As requested, Stantec has reviewed the report *Coal Combustion Residue Impoundment Dam Assessment Report, Cumberland Fossil Plant, Tennessee Valley Authority, Cumberland City, Tennessee,* dated August 2012 prepared by Dewberry and Davis, LLC (Dewberry) for the United States Environmental Protection Agency (USEPA). The purpose of this letter is to address Dewberry's conclusions and recommendations pertaining to structural stability, hydrologic/hydraulic capacity, and technical documentation; and to provide additional supporting information relative to ongoing plant improvements, further analysis, and planned activities where applicable. Dewberry's recommendations and Stantec's corresponding responses are listed below. Please note that additional seismic analysis is being conducted for the Dry Fly Ash Stack; therefore, the corresponding Dewberry recommendations for that facility will be addressed under a future submittal.

Dewberry Report Section 1.2.1 1) – Ash Pond: *Install Stantec's recommended remedial measures for increasing the factor of safety against piping failure to the acceptable margin. If the driven sheet-pile wall is selected as the remedial measure, close attention should be paid to sheet-wall alignment location and depth to achieve maximum benefit in lengthening the seepage path to reduce exit gradients; the sheet-wall alignment should generally be at or upstream of the centerline of the dike crest.*

Stantec Response: Since the time of Dewberry's assessment, the operating pool level for this pond has been lowered from El. 384.2 to El. 378.0 (6.2 feet). Stantec has revised the seepage analysis for Sections P, Q and R based on the lowered pool level and recent piezometer data. Piping factors of safety (FS) have increased to 3.5, 3.5 and 4.0 for Sections P, Q and R, respectively (see attached results). Piping FS's for these sections are now satisfactory because they are greater than the Cedergren FS criterion of 2.5 to 3 (that is referenced in USCACE's EM 1110-2-1901, *Engineering and Design-Seepage Analysis and Control for Dams*). No remedial measures are deemed necessary.

Dewberry Report Section 1.2.1 2) – Gypsum Disposal Area: *Install the planned lined ponds in the Gypsum Disposal Area as soon as possible for receiving and settling the gypsum slurry that must be sluiced to the Gypsum Disposal Area whenever the dewatering facility has an outage. Reevaluate the piping potential factor of safety after the lined ponds have been in place for about a year, to check whether or not the elimination of sluice water in the gypsum stack reduces the seepage exit gradients sufficiently to result in acceptable factors of safety against piping. Closely monitor the seepage conditions at the critical section in the interim. If the seepage exit gradients have not sufficiently abated, develop and implement a remedial measure to lower the exit gradients and achieve acceptable factor of safety against piping failure.*

Stantec Response: The FML-Lined Gypsum Settling Channels project is currently under construction and is scheduled for completion in April 2013. Sluicing to the stack has been discontinued and has not occurred for about 3 years. Since sluicing has stopped, piezometer levels in the gypsum have lowered. Stantec has revised the seepage analysis for Section H and the current piping FS is 3.1 (see attached results) which is satisfactory. TVA will continue to collect piezometer data and ensure that an acceptable factor of safety against piping is maintained.

Dewberry Report Section 1.2.3 1) – Gypsum Disposal Area: *Perform a quantitative liquefaction analysis of embankment sections overlying very loose/ loose saturated fly ash at the Dry Fly Ash Stack and the Gypsum Disposal Area; evaluate the impact of liquefaction on the containment dikes, if liquefaction is indicated; and evaluate the consequences of liquefaction failure of the containment dikes.*

Stantec Response: Stantec performed a liquefaction potential assessment based on ground motion estimates for the 2,500-year earthquake scenarios, Standard Penetration Test borings, and corresponding laboratory test results. A description of the methodology and the results (ground response analysis and factor of safety against liquefaction versus elevation) are attached. Consistent with previously submitted seismic stability analyses, Section H was analyzed for the Gypsum Disposal Area. The saturated ash materials are anticipated to undergo liquefaction for the 2,500-year earthquake.

Dewberry Report Section 1.2.3 2) – Gypsum Disposal Area: *If it is determined that liquefaction will not occur, review/investigate any soft or very soft clays in the lower part of the dike embankments and in the alluvial foundation beneath the embankments. If significant soft/very soft clay deposits are indicated (e.g., 10 feet or more in thickness and continuous for 100 feet or more), analyze their deformation potential during the design earthquake, and assess the impact of any such deformations on the stability of the embankments.*

US EPA ARCHIVE DOCUMENT

Stantec Response: As noted in the previous response, Stantec's analysis indicates that liquefaction will occur for saturated ash materials under the 2,500-year earthquake; therefore the deformation analysis described by Dewberry in the above recommendation is not necessary.

Dewberry Report Section 1.2.3 3) – Gypsum Disposal Area: *Review the basis and reasoning for the "design" seismic coefficient used in the pseudostatic slope stability analysis, rerun the analysis if a modification appears appropriate, or perform a higher level of analysis that uses more sophisticated methods. (Note: If a deformation analysis is done, there may be no need for the pseudostatic analysis. However, a post-earthquake static slope stability analysis using reduced shear strengths would be appropriate.)*

Stantec Response: A higher level of analysis that uses more sophisticated methods was performed for Gypsum Disposal Area Section H. A description of the methodology and the results (slope stability cross sections, including table of material parameters) are attached. The results indicate that Section H has a factor of safety of 1.1 for post-earthquake stability using reduced shear strengths, which is satisfactory.

Dewberry Report Section 1.2.1 3) – Gypsum Disposal Area: *Depending on the results of additional seismic stability analyses and of liquefaction potential analyses recommended in Subsection 1.2.3, develop and implement measures to ensure adequate performance of the Dry Fly Ash Stack and the Gypsum Disposal Area containment dikes under the 2,500-year seismic event.*

Stantec Response: The results of the liquefaction and post-earthquake stability analyses indicate that the Gypsum Disposal Area will remain stable and display adequate performance due to the 2,500-year earthquake. Therefore, no seismic-related remedial measures are required.

Dewberry Report Section 1.2.4 – Maintenance Items: No significant problems were observed in the field assessment that would require special attention outside of routine maintenance. The minor issues observed, mostly small eroded areas or areas of seepage and poor drainage, should be addressed by TVA's routine maintenance activities. These include: 1) Repair minor erosion at various locations, 2) Continue to mow/ maintain vegetation along slopes, 3) Continue to monitor and document known seepage per seepage action plan, 4) Provide positive slope to promote drainage into perimeter ditch.

Stantec Response:

1) TVA repaired the erosion as part of Work Plan 11 (see attached photos).
2) TVA's Routine Handling Operations and Maintenance (RHO&M) group will continue vegetation maintenance along slopes.
3) TVA will continue to monitor areas of known seepage in accordance with the Seepage Action Plan.
4) TVA re-graded the perimeter drainage ditch as part of Work Plan 11 (see attached photos).

US EPA ARCHIVE DOCUMENT

Summary:

Based on the results of Dewberry's report, and on the responses/additional analyses provided herein, it is Stantec's opinion that the final rating for the CUF Ash Pond and Gypsum Disposal Area should be upgraded to Satisfactory.

We appreciate the opportunity to provide these responses. If you have any questions or need additional information, please call.

Sincerely,

STANTEC CONSULTING SERVICES INC.

Stephen H. Bickel, PE
Senior Principal

Randy L. Roberts, PE
Principal

/db

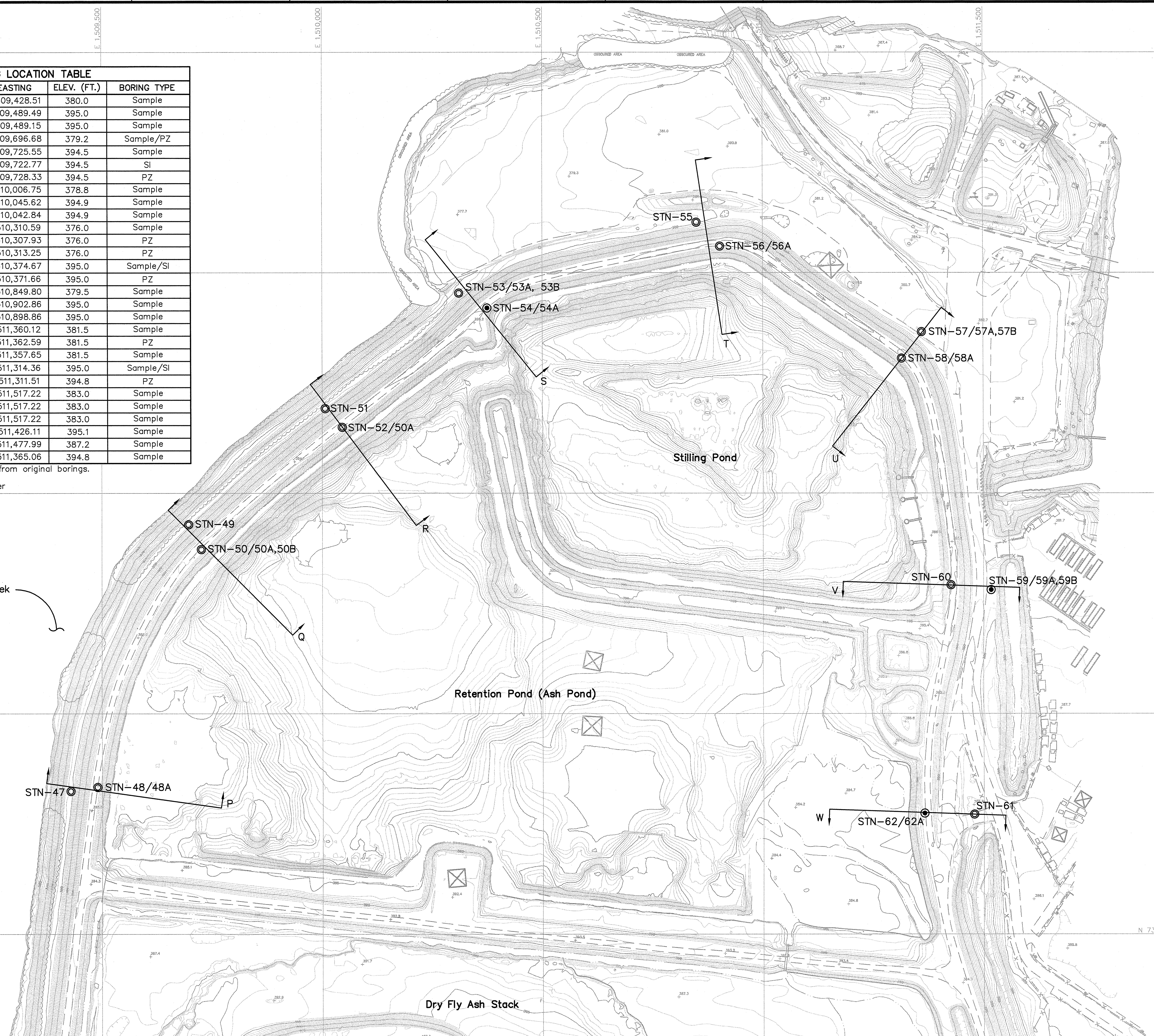
Cc: Roberto L. Sanchez, PE
Michael S. Turnbow

Attachments

US EPA ARCHIVE DOCUMENT

BORING LOCATION TABLE				
BORING	NORTHING	EASTING	ELEV. (FT.)	BORING TYPE
STN-47	732,324.14	1,509,428.51	380.0	Sample
STN-48	732,333.24	1,509,489.49	395.0	Sample
*STN-48A	732,329.25	1,509,489.15	395.0	Sample
STN-49	732,928.84	1,509,696.68	379.2	Sample/PZ
STN-50	732,872.44	1,509,725.55	394.5	Sample
*STN-50A	732,869.56	1,509,722.77	394.5	SI
*STN-50B	732,875.32	1,509,728.33	394.5	PZ
STN-51	733,191.78	1,510,006.75	378.8	Sample
STN-52	733,149.40	1,510,045.62	394.9	Sample
*STN-52A	733,146.52	1,510,042.84	394.9	Sample
STN-53	733,453.67	1,510,310.59	376.0	Sample
*STN-53A	733,456.66	1,510,307.93	376.0	PZ
*STN-53B	733,450.68	1,510,313.25	376.0	PZ
STN-54	733,419.93	1,510,374.67	395.0	Sample/SI
*STN-54A	733,417.30	1,510,371.66	395.0	PZ
STN-55	733,614.54	1,510,849.80	379.5	Sample
STN-56	733,560.12	1,510,902.86	395.0	Sample
*STN-56A	733,560.12	1,510,898.86	395.0	Sample
STN-57	733,365.74	1,511,360.12	381.5	Sample
*STN-57A	733,368.89	1,511,362.59	381.5	PZ
*STN-57B	733,362.59	1,511,357.65	381.5	Sample
STN-58	733,305.89	1,511,314.36	395.0	Sample/SI
*STN-58A	733,308.70	1,511,311.51	394.8	PZ
STN-59	732,780.76	1,511,517.22	383.0	Sample
*STN-59A	732,784.76	1,511,517.22	383.0	Sample
STN-60	732,776.76	1,511,517.22	383.0	Sample
STN-61	732,791.74	1,511,426.11	395.1	Sample
STN-62	732,271.84	1,511,477.99	387.2	Sample
*STN-62A	732,274.04	1,511,365.06	394.8	Sample

*Estimated based on offsets from original borings.
"PZ" denotes Piezometer
"SI" denotes Slope Inclinometer



BORING LAYOUT
SCALE: 1"=100'

50 0 100 200 FEET
GRAPHIC SCALE: 1" = 100'
CONTOUR INTERVAL = 1'

LEGEND

- Soil Boring with Undisturbed (Shelby) Tube Samples and/or Standard Penetration Tests
- Soil Boring with Undisturbed (Shelby) Tube Samples and/or Standard Penetration Tests and Rock Core

NOTE:

The topographic mapping provided is based on horizontal datum NAD27 and vertical datum NGV29 using State Plane Tennessee coordinate system. The site photography was performed on 4/17/2009.

FOR INFORMATION ONLY
This Record Drawing which has been previously submitted to TVA is provided for Information Only.

RECORD DRAWING

For Supporting Design Calculations see FPGCUFFESCDX00000020100002

REV. NO.	DATE	DSGN	DRWN	CHKD	SUPV	RVWD	APPD	ISSD	PROJECT ID	AS CONST	REV CD
R –	–	–	–	–	–	–	–	–	–	–	–
R 0	03/29/10	DBR	CW	DBR	SAH	SAH	SAH	TJ	–	–	–

RECORD DRAWING

DISCIPLINE INTERFACE 1 2 3 4

SCALE: 1"=100' EXCEPT AS NOTED

YARD
RETENTION AND STILLING PONDS

GEOTECHNICAL EXPLORATION
BORING LAYOUT

STAN A. HARRIS REGISTERED ENGINEER AGRICULTURE COMMERCE No. 00113308 STATE OF TENNESSEE
3/25/10

DESIGNED BY:	DRAWN BY:	CHECKED BY:	SUPERVISED BY:	REVIEWED BY:	APPROVED BY:	ISSUED BY:
D. ROGERS	C. WITHERS	D. ROGERS	S. HARRIS	S. HARRIS	S. HARRIS	T. JOHNSON

Stantec
Stantec Consulting Services Inc.
11687 Lebanon Rd.
Cincinnati, Ohio
45241-2012
Tel. 513.842.8200
Fax 513.842.8250
www.stantec.com

CUMBERLAND FOSSIL PLANT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

AUTOCAD R 2000	DATE 03/29/10	46	C	10W544-01	R 0

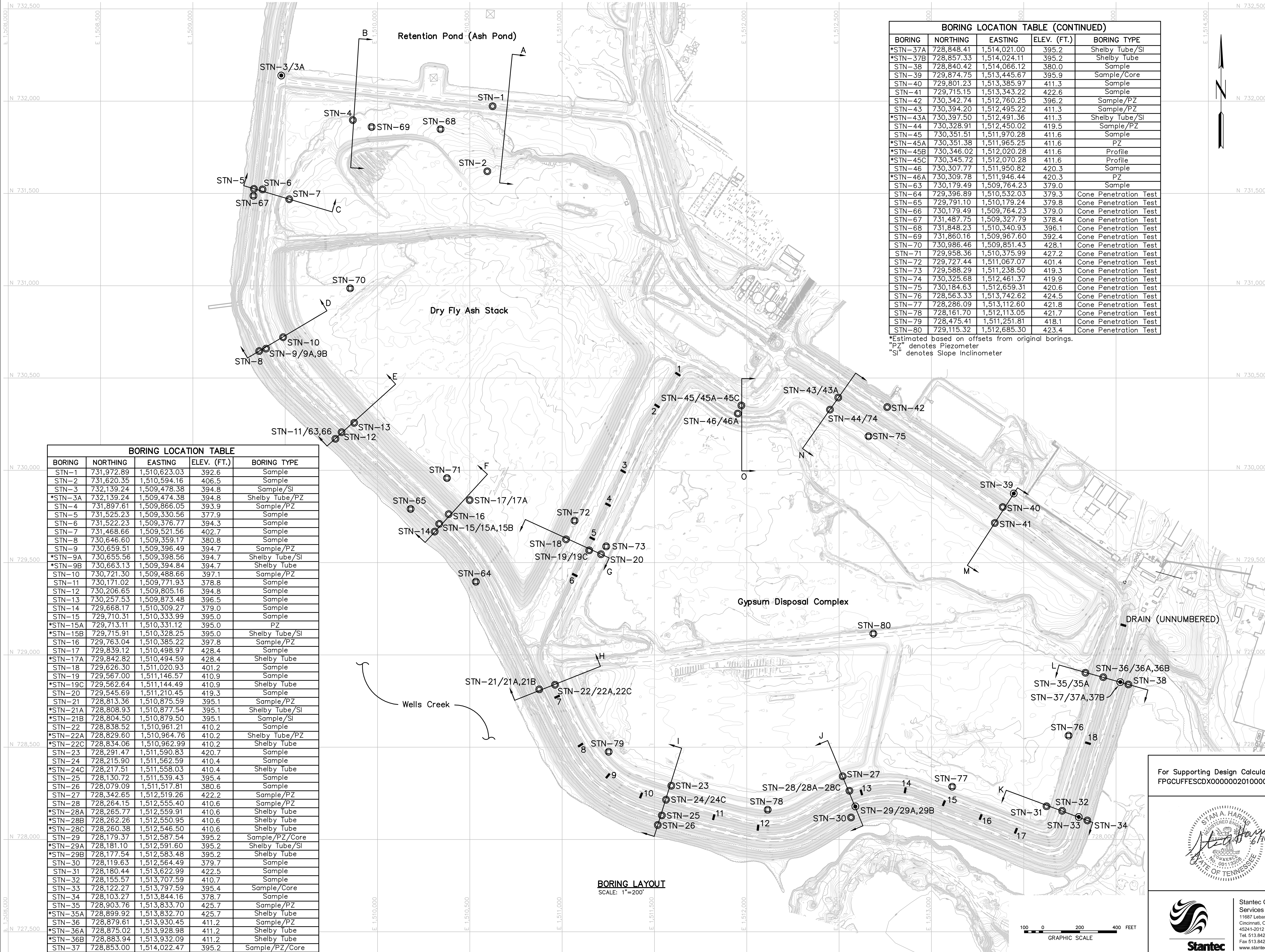
STANTEC	0
TASK COMPLETED BY:	REV NO.

PLOT FACTOR:XX
W_TVA

C.A.D. DRAWING
DO NOT ALTER MANUALLY

PLOT DATE: 03/24/2010

46 C 10W544-01



BORING LOCATION TABLE

BORING	NORTHING	EASTING	ELEV. (FT.)	BORING TYPE
STN-1	731,972.89	1,510,623.03	392.6	Sample
STN-2	731,620.35	1,510,594.16	406.5	Sample
STN-3	732,139.24	1,509,478.38	394.8	Sample/SI
*STN-3A	732,139.24	1,509,474.38	394.8	Shelby Tube/PZ
STN-4	731,897.61	1,509,866.05	393.9	Sample/PZ
STN-5	731,525.23	1,509,330.56	377.9	Sample
STN-6	731,522.23	1,509,376.77	394.3	Sample
STN-7	731,468.66	1,509,521.56	402.7	Sample
STN-8	730,646.60	1,509,359.17	380.8	Sample
STN-9	730,659.51	1,509,396.49	394.7	Sample/PZ
*STN-9A	730,655.56	1,509,398.56	394.7	Shelby Tube/SI
*STN-9B	730,663.13	1,509,394.84	394.7	Shelby Tube
STN-10	730,721.30	1,509,488.66	397.1	Sample/PZ
STN-11	730,171.02	1,509,771.93	378.8	Sample
STN-12	730,206.65	1,509,805.16	394.8	Sample
STN-13	730,257.53	1,509,873.48	396.5	Sample
STN-14	729,668.17	1,510,309.27	379.0	Sample
STN-15	729,710.31	1,510,333.99	395.0	Sample
*STN-15A	729,713.11	1,510,331.12	395.0	PZ
*STN-15B	729,715.91	1,510,328.25	395.0	Shelby Tube/SI
STN-16	729,763.04	1,510,385.22	397.8	Sample/PZ
STN-17	729,839.12	1,510,498.97	428.4	Sample
*STN-17A	729,842.82	1,510,494.59	428.4	Shelby Tube
STN-18	729,626.30	1,511,020.93	401.2	Sample
STN-19	729,567.00	1,511,146.57	410.9	Sample
*STN-19C	729,562.64	1,511,144.49	410.9	Shelby Tube
STN-20	729,545.69	1,511,210.45	419.3	Sample
STN-21	728,813.36	1,510,875.59	395.1	Sample/PZ
*STN-21A	728,808.93	1,510,877.54	395.1	Shelby Tube/SI
*STN-21B	728,804.50	1,510,879.50	395.1	Sample/SI
STN-22	728,838.52	1,510,961.21	410.2	Sample
*STN-22A	728,829.60	1,510,964.76	410.2	Shelby Tube/PZ
*STN-22C	728,834.06	1,510,962.99	410.2	Shelby Tube
STN-23	728,291.47	1,511,590.83	420.7	Sample
STN-24	728,215.90	1,511,562.59	410.4	Sample
*STN-24C	728,217.51	1,511,558.03	410.4	Shelby Tube
STN-25	728,130.72	1,511,539.43	395.4	Sample
STN-26	728,079.09	1,511,517.81	380.6	Sample
STN-27	728,342.65	1,512,519.26	422.2	Sample/PZ
STN-28	728,264.15	1,512,555.40	410.6	Sample/PZ
*STN-28A	728,265.77	1,512,559.91	410.6	Shelby Tube
*STN-28B	728,262.26	1,512,550.95	410.6	Shelby Tube
*STN-28C	728,260.38	1,512,546.50	410.6	Shelby Tube
STN-29	728,179.37	1,512,587.54	395.2	Sample/PZ/Core
*STN-29A	728,181.10	1,512,591.60	395.2	Shelby Tube/SI
*STN-29B	728,177.54	1,512,583.48	395.2	Shelby Tube
STN-30	728,119.63	1,512,564.49	379.7	Sample
STN-31	728,180.44	1,513,622.99	422.5	Sample
STN-32	728,155.57	1,513,707.59	410.7	Sample
STN-33	728,122.27	1,513,797.59	395.4	Sample/Core
STN-34	728,103.27	1,513,844.16	378.7	Sample
STN-35	728,903.76	1,513,833.70	425.7	Sample/PZ
*STN-35A	728,899.92	1,513,832.70	425.7	Shelby Tube
STN-36	728,879.61	1,513,930.45	411.2	Sample/PZ
*STN-36A	728,875.02	1,513,928.98	411.2	Shelby Tube
*STN-36B	728,883.94	1,513,932.09	411.2	Shelby Tube
STN-37	728,853.00	1,514,022.47	395.2	Sample/PZ/Core

BORING LOCATION TABLE (CONTINUED)

BORING	NORTHING	EASTING	ELEV. (FT.)	BORING TYPE
*STN-37A	728,848.41	1,514,021.00	395.2	Shelby Tube/SI
*STN-37B	728,857.33	1,514,024.11	395.2	Shelby Tube
STN-38	728,840.42	1,514,066.12	380.0	Sample
STN-39	729,874.75	1,513,445.67	395.9	Sample/Core
STN-40	729,801.23	1,513,385.97	411.3	Sample
STN-41	729,715.15	1,513,343.22	422.6	Sample
STN-42	730,342.74	1,512,760.25	396.2	Sample/PZ
STN-43	730,394.20	1,512,495.22	411.3	Sample/PZ
*STN-43A	730,397.50	1,512,491.36	411.3	Shelby Tube/SI
STN-44	730,328.91	1,512,450.02	419.5	Sample/PZ
STN-45	730,351.51	1,511,970.28	411.6	Sample
*STN-45A	730,351.38	1,511,965.25	411.6	PZ
*STN-45B	730,346.02	1,512,020.28	411.6	Profile
*STN-45C	730,345.72	1,512,070.28	411.6	Profile
STN-46	730,307.77	1,511,950.82	420.3	Sample
*STN-46A	730,309.78	1,511,946.44	420.3	PZ
STN-63	730,179.49	1,509,764.23	379.0	Sample
STN-64	729,396.89	1,510,532.03	379.3	Cone Penetration Test
STN-65	729,791.10	1,510,179.24	379.8	Cone Penetration Test
STN-66	730,179.49	1,509,764.23	379.0	Cone Penetration Test
STN-67	731,487.75	1,509,327.79	378.4	Cone Penetration Test
STN-68	731,848.23	1,510,340.93	396.1	Cone Penetration Test
STN-69	731,860.16	1,509,967.60	392.4	Cone Penetration Test
STN-70	730,986.46	1,509,851.43	428.1	Cone Penetration Test
STN-71	729,958.36	1,510,375.99	427.2	Cone Penetration Test
STN-72	729,727.44	1,511,067.07	401.4	Cone Penetration Test
STN-73	729,588.29	1,511,238.50	419.3	Cone Penetration Test
STN-74	730,325.68	1,512,461.37	419.9	Cone Penetration Test
STN-75	730,184.63	1,512,659.31	420.6	Cone Penetration Test
STN-76	728,563.33	1,513,742.62	424.5	Cone Penetration Test
STN-77	728,286.09	1,513,112.60	421.8	Cone Penetration Test
STN-78	728,161.70	1,512,113.05	421.7	Cone Penetration Test
STN-79	728,475.41	1,511,251.81	418.1	Cone Penetration Test
STN-80	729,115.32	1,512,685.30	423.4	Cone Penetration Test

*Estimated based on offsets from original borings.
"PZ" denotes Piezometer
"SI" denotes Slope Inclinometer

FOR INFORMATION ONLY
This Record Drawing which has been previously submitted to TVA is provided for Information Only.

NOTE:

The topographic mapping provided is based on horizontal datum NAD27 and vertical datum NGV29 using State Plane Tennessee coordinate system. The site photography was performed on 4/17/2009.

LEGEND

- Soil Boring with Undisturbed (Shelby) Tube Samples and/or Standard Penetration Tests
- Soil Boring with Undisturbed (Shelby) Tube Samples and/or Standard Penetration Tests and Rock Core
- Cone Penetration Test
- Drain, Number

RECORD DRAWING

For Supporting Design Calculations see FPGCUFFESCDX00000020100001

STAN A. HARRIS REGISTERED ENGINEER AGRICULTURE COMMERCE No. 00113308 STATE OF TENNESSEE 6/11/10

REV. NO.	DATE	DSGN	DRWN	CHKD	SUPV	RVWD	APPD	ISSD	PROJECT ID	AS CONST	REV CD
R 0	06/11/10	DBR	CW	DBR	SAH	SAH	SAH	TJ	-	-	-

RECORD DRAWING

SCALE: 1"=200' EXCEPT AS NOTED

YARD
DRY FLY ASH STACK AND GYPSUM DISPOSAL COMPLEX
GEOTECHNICAL EXPLORATION
BORING LAYOUT

DESIGNED BY:	DRAWN BY:	CHECKED BY:	SUPERVISED BY:	REVIEWED BY:	APPROVED BY:	ISSUED BY:
D. ROGERS	C. WITHERS	D. ROGERS	S. HARRIS	S. HARRIS	S. HARRIS	T. JOHNSON

Stantec Consulting Services Inc.
11687 Lebanon Rd.
Cincinnati, Ohio
45241-2012
Tel. 513.842.8200
Fax 513.842.8250
www.stantec.com

CUMBERLAND FOSSIL PLANT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

AUTOCAD R 2000 | DATE 06/11/10 | 46 | C | 10W543-01 | R 0

STANTEC | 0
TASK COMPLETED BY: | REV NO.

PLOT FACTOR:XX
W_TVA

C.A.D. DRAWING
DO NOT ALTER MANUALLY

46 C 10W543-01

SLOPE STABILITY ANALYSIS
Cumberland Fossil Plant - Fly Ash Stack
Tennessee Valley Authority (TVA)

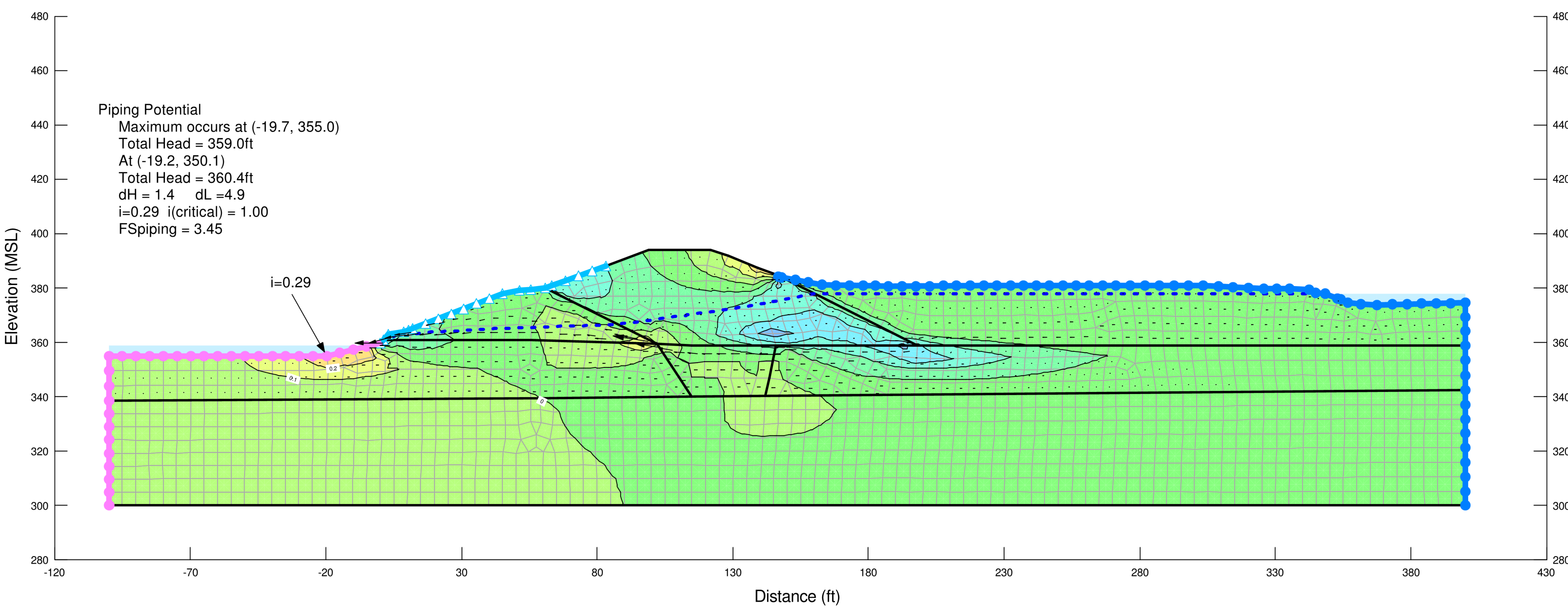
File Name: Section P.gsz

Analysis Name: Steady-State Seepage

Date Saved: 10/12/2012

Last Solved on 10/12/2012 at 1:03:58 PM

Y-Gradient

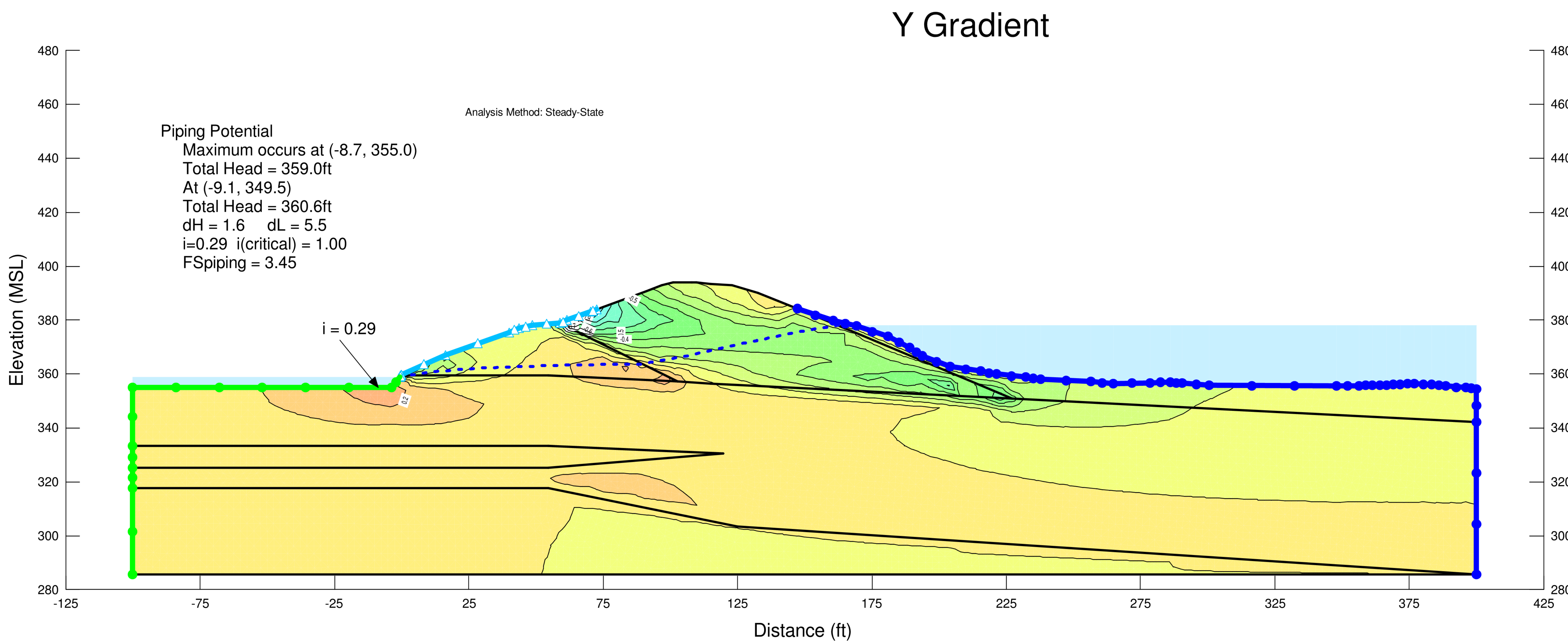


SLOPE STABILITY ANALYSIS
Cumberland Fossil Plant - Fly Ash Stack
Tennessee Valley Authority (TVA)

File Name: Section Q.gsz

Analysis Name: Steady-State Seepage
Last Solved on 9/20/2012 at 9:33:02 AM
Date Saved: 9/20/2012

Stantec



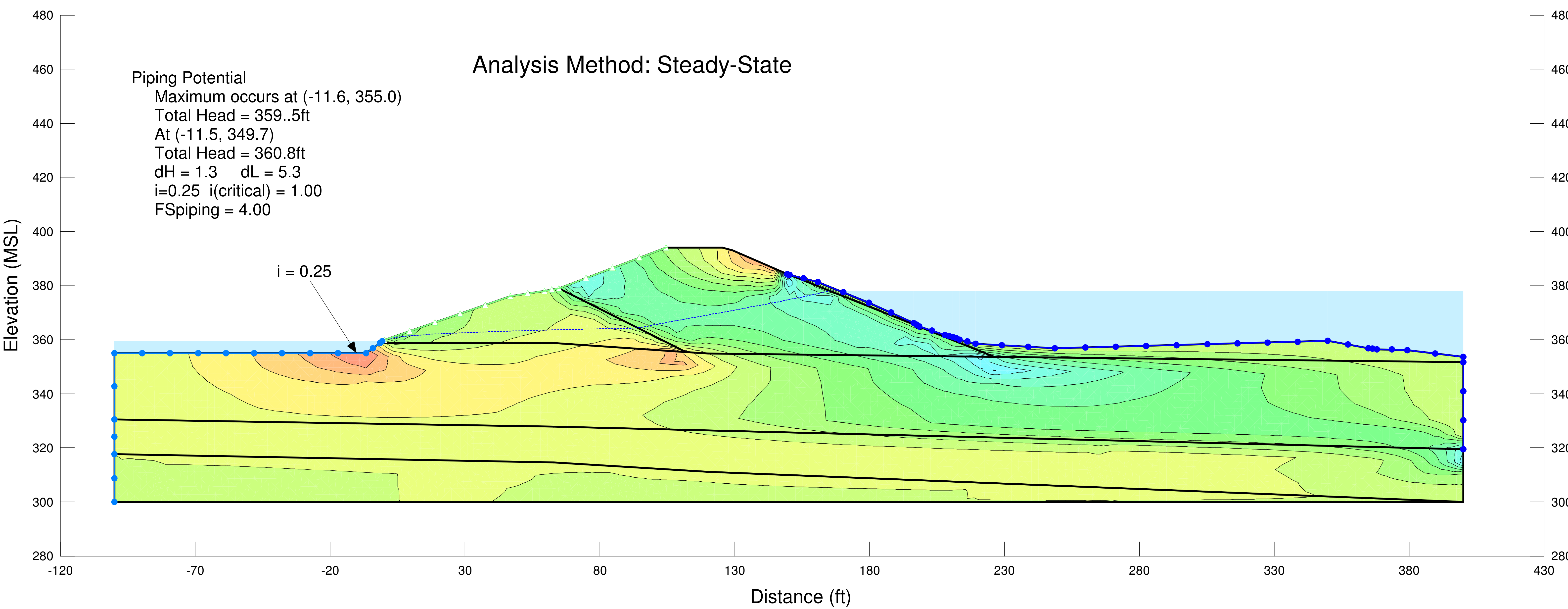
SLOPE STABILITY ANALYSIS
Cumberland Fossil Plant - Fly Ash Stack
Tennessee Valley Authority (TVA)

File Name: Section R.gsz

Analysis Name: Steady-State Seepage
Last Solved on 9/20/2012 at 9:49:06 AM
Date Saved: 9/20/2012

Stantec

Y-Gradient

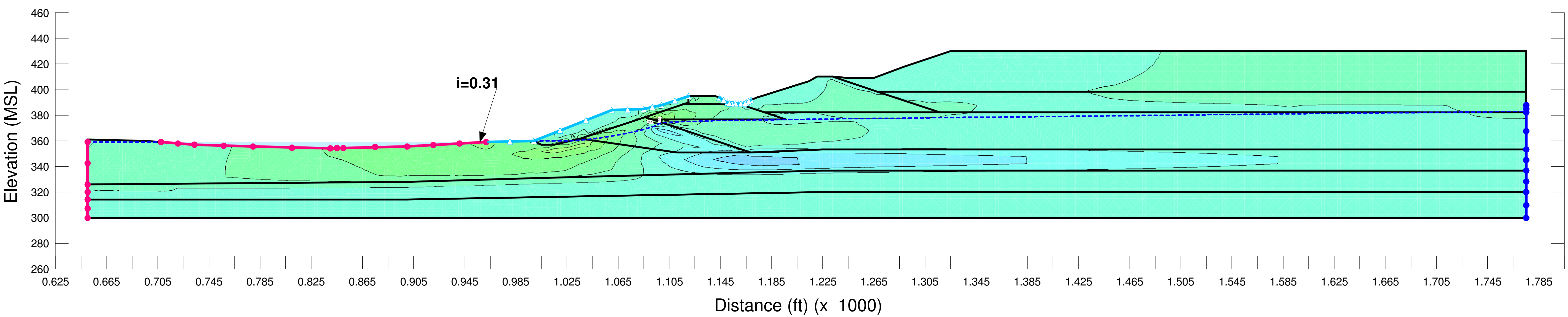


US EPA ARCHIVE DOCUMENT

SLOPE STABILITY ANALYSIS
Cumberland Fossil Plant - Gypsum Stack Complex
Tennessee Valley Authority (TVA)

File Name: Section H (StabRepDgn)revised.gsz
Analysis Name: Steady-State Seepage
Date Saved: 10/12/2012
Last Solved on 10/12/2012 at 11:06:02 AM
Analysis Method: Steady-State

Piping Potential
Maximum occurs at (956.7, 358.7)
Total Head = 359.0ft
At (956.6, 353.9)
Total Head = 360.5ft
dH = 1.50 dL = 4.80
i=0.31 i(critical) = 0.97
FSpiping = 3.13



GENERAL METHODOLOGY
SEISMIC STABILITY ANALYSIS
TVA FOSSIL PLANTS

1. Seismic Hazards

1.1. Regional Seismic Sources

Seismicity in the TVA service area is attributed to the New Madrid fault and smaller, less concentrated crustal faults. Located in the western region, along the borders of Tennessee, Kentucky, Missouri, and Arkansas, the New Madrid source zone is capable of producing large magnitude earthquakes (M > 7). Events of this size would produce relatively long durations of strong ground shaking across the entire Tennessee River Valley. Fortunately, large magnitude New Madrid events are infrequent. Other source zones that may represent significant seismic risks for TVA facilities include those in eastern Tennessee, along the Wabash River Valley, and less significant sources throughout the region. While the maximum earthquake magnitudes associated with these other sources are smaller, compared to the New Madrid events, larger site accelerations can result from the closer proximity of TVA facilities.

These two earthquake scenarios generate significantly different seismic hazards at each locality and were considered independently in the analysis. To appropriately capture the influence of each, the assessments were completed independently for:

1. New Madrid events, and

2. events from “All Other Sources”.

1.2. Site-Specific Hazards

Site-specific seismic hazards were characterized for the seismic stability assessments. AMEC Geomatrix, Inc. (Oakland, California) used the 2004 TVA “Valley-wide” seismic hazard model (Geomatrix 2004) to generate seismic inputs for each of TVA’s fossil plants. Geomatrix documented their efforts in a report (AMEC Geomatrix Inc. 2011); excerpts are included herein.

The key data sets generated by Geomatrix and utilized by Stantec are:

1. Peak ground accelerations at top of hard rock (PGA_{rock}) for two different seismic sources (New Madrid Source and All Other Sources), for the 2,500-year return period, for each fossil plant location.

2. Seismic hazard deaggregation for PGA_{rock} for the 2,500-year return period. The hazards were deaggregated into appropriately sized bins of magnitude and epicentral distance.

1.3. PGA at Ground Surface

The peak horizontal accelerations obtained from the seismic hazard study represent accelerations at the top of hard bedrock (PGA_{rock}). For the assessment of liquefaction potential, the cyclic loads on natural soils and ash deposits were estimated using the simplified method described in Youd et al. (2001). This method requires estimates of the peak horizontal

US EPA ARCHIVE DOCUMENT

acceleration at the ground surface (PGA_{soil}).

Depending on the site and ground motion characteristics, peak accelerations may be amplified or attenuated (deamplified) as the energy propagates upward through the soil profile. Numerical ground response analyses can be used to model the propagation of ground motions and compute the cyclic stresses at various locations in the soil profile. One-dimensional, equivalent-linear elastic codes like ProShake can be used for this purpose if ground motion time histories are available.

To support sophisticated analyses at sites subject to higher seismic loads (i.e., large magnitudes and large accelerations), AMEC Geomatrix developed ground motion time histories for four TVA plants: Allen (ALF), Cumberland (CUF), Gallatin (GAF), and Shawnee (SHF). Relevant excerpts of the AMEC Geomatrix deliverable are provided herein. For these sites, Geocomp and Prof. Steve Kramer (University of Washington) performed ground response analyses using ProShake. These results, including profiles of acceleration and shear stress versus depth, were used for these four facilities. Compared to the more simplified method outlined below, the ProShake results allow for a more detailed representation of the ground response, particularly for facilities with extremely deep soils such as ALF and SHF.

Given the large portfolio of facilities that were considered, a simpler approach was used for the remaining facilities in this assessment. Developed for TVA by Dr. Gonzalo Castro and GEI Consultants, and implemented by Stantec in a spreadsheet, the method approximates what would be performed via one-dimensional, equivalent-linear elastic methods. For a representative soil profile, unit weights and groundwater conditions are applied to calculate total and effective stresses in the soil column. Soil stiffness (small-strain shear modulus or shear wave velocity), modulus reduction, and damping parameters are assigned based on estimated properties and published correlations. An iterative process is then used to estimate the PGA_{soil} at the top of ground, resulting from the PGA_{rock} for a given earthquake. The GEI method does not require a ground motion time history, but yields a result that appropriately considers the thickness and properties of the site-specific foundation soils. Instead of using acceleration time histories, this method utilizes response spectra for various levels of damping, which were generated by AMEC Geomatrix for use in these analyses. Relevant excerpts of the AMEC Geomatrix deliverable are provided herein. This method is more site-specific than using generic published correlations, and is judged to give reasonable results when compared to ProShake output.

2. Liquefaction Potential Assessment

2.1. Soil Loading from Earthquake Motions

The magnitude of the cyclic shear stresses induced by an earthquake is represented by the cyclic stress ratio (CSR). The simplified method proposed by Seed and Idriss (1971) and adopted by Youd et al. (2001) was used to estimate CSR. The cyclic stresses imparted to the soil were estimated from the earthquake parameters described above, representing earthquakes on the New Madrid fault and local crustal events.

2.2. Soil Resistance from Correlations with Penetration Resistance

The resistance to soil liquefaction, expressed in terms of the cyclic resistance ratio (CRR), was assessed using the empirical NCEER methodology (Youd et al. 2001). Updates to the procedure from recently published research were used where warranted. The analyses were

US EPA ARCHIVE DOCUMENT

based on the blowcount value (N) measured in the Standard Penetration Test (SPT) or the tip resistance (q_c) measured in the Cone Penetration Test (CPT).

The NCEER procedure involves a number of correction factors. Based on the site-specific conditions and soil characteristics, engineering judgment was used to select appropriate correction factors consistent with the consensus recommendations of the NCEER panel (Youd et al. 2001). To avoid inappropriately inflating the CRR, the NCEER fines content adjustment was not applied where zero blowcounts are recorded. The magnitude scaling factor (MSF) is used in the procedure to normalize the representative earthquake magnitude to a baseline 7.5M earthquake. The earthquake magnitude (M) most representative of the liquefaction risk was determined by applying the MSF to the de-aggregation data for the 2,500-year earthquakes (New Madrid and All Other Sources).

2.3. Factor of Safety Against Liquefaction

The factor of safety against liquefaction (FS_{liq}) is defined as the ratio of the liquefaction resistance (CRR) over the earthquake load (CSR). Following TVA design guidance and the precedent set by Seed and Harder (1990), FS_{liq} is interpreted as follows:

- Soil will liquefy where $FS_{liq} \leq 1.1$.
- Expect substantial soil softening where $1.1 < FS_{liq} \leq 1.4$.
- Soil does not liquefy where $FS_{liq} > 1.4$.

Using these criteria for guidance, values of FS_{liq} computed throughout a soil deposit or cross section (at specific CPT-q_c and SPT-N locations) were reviewed in aggregate. Occasional pockets of liquefied material in isolated locations are unlikely to induce a larger failure, and are typically considered tolerable. Instead, problems associated with soil liquefaction are indicated where continuous zones of significant lateral extent exhibit low values of FS_{liq}. Engineering judgment, including consideration for the likely performance in critical areas, was used in the overall assessment for each facility.

3. Post-Earthquake Slope Stability

3.1. Characterize Post-Earthquake Soil Strengths

The post-earthquake shearing resistance of each soil and coal combustion product (CCP) was estimated with consideration for the specific characteristics of that material. Specifically:

- Full static, undrained strength parameters were assigned to unsaturated soils, where significant excess pore pressures are not anticipated to develop under seismic loading.
- In saturated clays and soils with $FS_{liq} > 1.4$, 80% of the static undrained strength was assumed. These reduced strengths account for the softening effects of pore pressure buildup during an earthquake.
- In saturated, low-plasticity, granular soils with $1.1 < FS_{liq} \leq 1.4$, a reduced strength was assigned, based on the excess pore pressure ratio, r_u (Seed and Harder 1990). Typical relationships between FS_{liq} and r_u have been published by Marcuson and Hynes (1989).
- In saturated, low-plasticity, granular soils with $FS_{liq} \leq 1.1$, a residual (steady state) strength (S_r) was estimated for the liquefied soil.

US EPA ARCHIVE DOCUMENT

Estimates of S_r can be obtained from empirical correlations published by various researchers. Typically, residual strength (or the ratio of residual strength over vertical effective stress) is correlated to corrected SPT blowcounts or corrected CPT tip resistance, based on back analysis of liquefaction case histories. For this evaluation, a new "hybrid" model developed by Kramer and Wang (in press) was used. Their hybrid model expresses mean residual strength as a function of both corrected SPT blowcounts and vertical effective stress:

$$\overline{\ln(S_r)} = -8.444 + 0.109(N_1)_{60} + 5.379(\sigma'_{vo})^{0.1}$$

Where S_r = residual strength in atmospheres, $(N_1)_{60}$ = normalized and corrected SPT N-value, and σ_{vo}' = initial vertical effective stress in atmospheres. A representative value of $(N_1)_{60}$ was selected for each liquefiable soil layer from a detailed review of the boring logs. SPT blowcounts judged to be erroneous or nonrepresentative of the in situ conditions were discarded. For example, excessively high blowcounts resulting from the SPT sampler hitting a cobble or boulder and excessively low blowcounts associated with borehole heave were discarded. The remaining blowcounts (in terms of $(N_1)_{60}$) were then averaged to arrive at the representative value.

3.2. Analyze Slope Stability

The next step in the evaluation considered slope stability for post-earthquake conditions, including liquefied strengths where appropriate. Slope stability was evaluated using two-dimensional, limit equilibrium, slope stability methods and reduced soil strengths (from above), representing the loss of shearing resistance due to cyclic pore pressure generation during the earthquake. The analyses were accomplished using Spencer's method of analysis, as implemented in the SLOPE/W software, considering both circular and translational slip mechanisms. The analyses represent current operating conditions (geometry and phreatic levels).

If extensive liquefaction is indicated, stability was evaluated for the static conditions immediately following the cessation of the earthquake motions. Residual or steady state strengths were assigned in zones of liquefied soil, with reduced strengths that account for cyclic softening and pore pressure build up assumed in unliquefied soil. Failure (large, unacceptable displacements) is indicated if the safety factor (FS_{slope}) computed in this step is less than one. Slopes exhibiting $FS_{slope} \geq 1$ with liquefaction are assumed stable with tolerable deformations.

Within SLOPE/W, the residual strength model described previously was implemented with a cohesion (equal to S_r) that varies spatially. Based on the representative $(N_1)_{60}$ value and the initial vertical effective stress, S_r was calculated and assigned at key locations within the liquefied soil layer. The strength at any other point in the deposit was interpolated in SLOPE/W, thereby recognizing the increasing strength at higher vertical effective stress.

US EPA ARCHIVE DOCUMENT

DRAFT

amec

TABLE 1

MEAN 2,500-YEAR UHRS (AT 5% DAMPING) FOR THE THREE FOSSIL PLANT SITES
(CUMBERLAND, ALLEN, SHAWNEE)

	Spectral Acceleration (g)		
	Mean 2,500-year UHRS		
Frequency (Hz)	Cumberland	Allen	Shawnee
0.1[1]	0.0100	0.0140	0.0174
0.133[1]	0.0158	0.0227	0.0286
0.167[1]	0.0223	0.0327	0.0413
0.2[1]	0.0293	0.0434	0.0552
0.25	0.0407	0.0610	0.0780
0.5	0.0832	0.1297	0.1709
1	0.1249	0.2087	0.2712
2.5	0.2673	0.4415	0.5908
5	0.3507	0.6022	0.8275
10	0.4132	0.7544	1.0565
25	0.5178	0.9491	1.3816
50	0.4544	0.8765	1.3047
100	0.2165	0.3891	0.5601

1 Extended frequencies based on ground motion spectral shapes at long periods for CEUS from NUREG/CR-6728

DRAFT

TABLE 4

GROUND MOTION PARAMETERS FOR SPECTRALLY MATCHED TIME HISTORIES

CUMBERLAND FOSSIL PLANT SITE

Tennessee Valley Authority

Comp.	Spectrally -Matched from	PGA (g)	PGV (cm/sec)	PGD (cm)	PGV/PGA (cm/sec/g)	$PGA*PGD/PGV^2$	Duration (sec)**
H	SER000	0.220	11.09	6.51	50.41	11.42	29.51
H	GRN180	0.221	13.89	8.59	62.85	9.65	24.55
H	SUL320	0.224	14.42	9.66	64.38	10.21	24.23
H	KSH-T1	0.222	13.24	8.68	59.64	10.78	15.25
H	TAP067-W	0.216	12.44	8.69	57.59	11.90	38.80
H	TAP075-W	0.219	11.01	7.92	50.27	14.04	23.74
H	TAP078-N	0.220	15.41	7.96	70.05	7.23	25.74

** Duration is defined as the time for cumulative energy to grow from 5% to 75% of its total value.

DRAFT

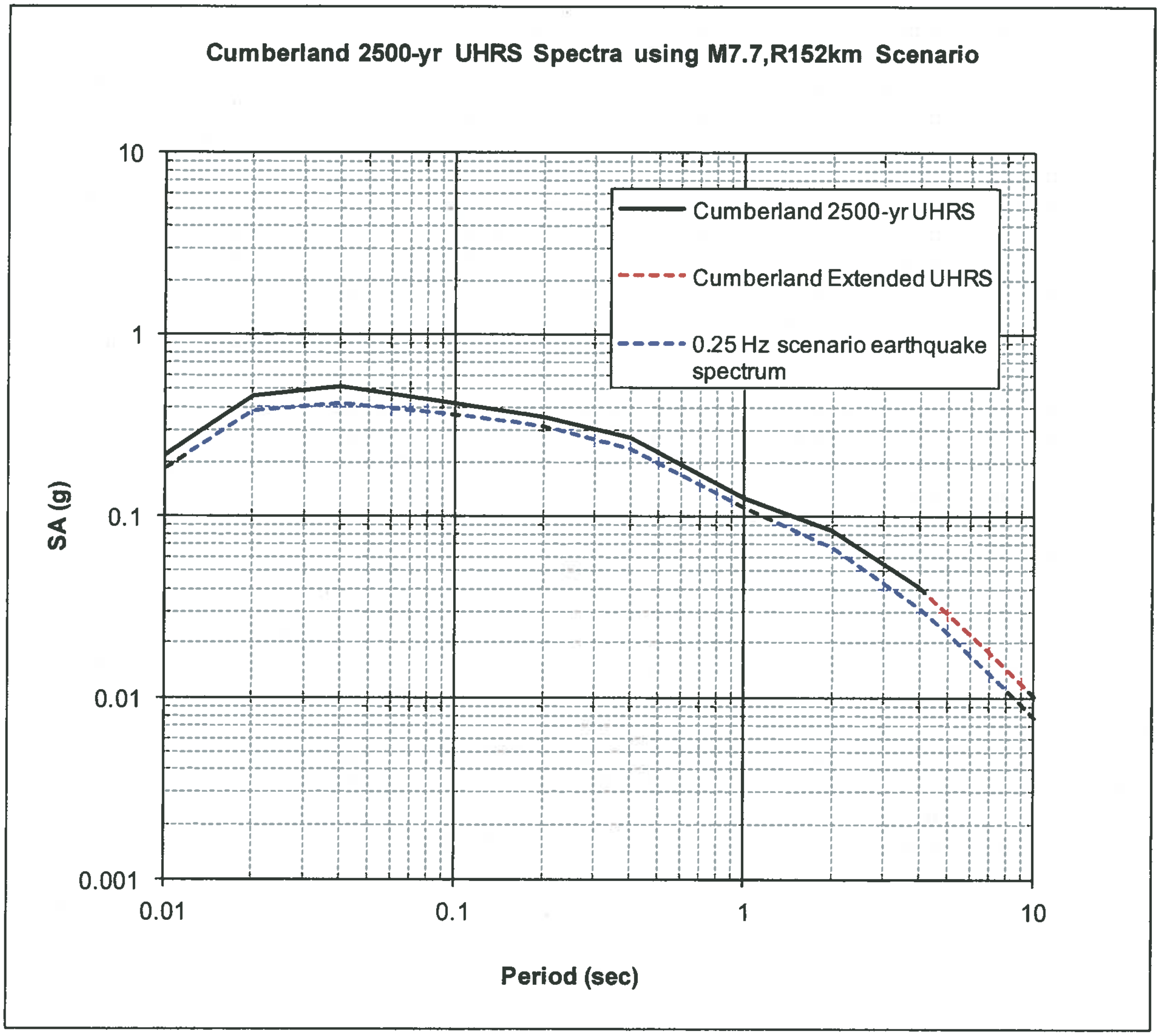
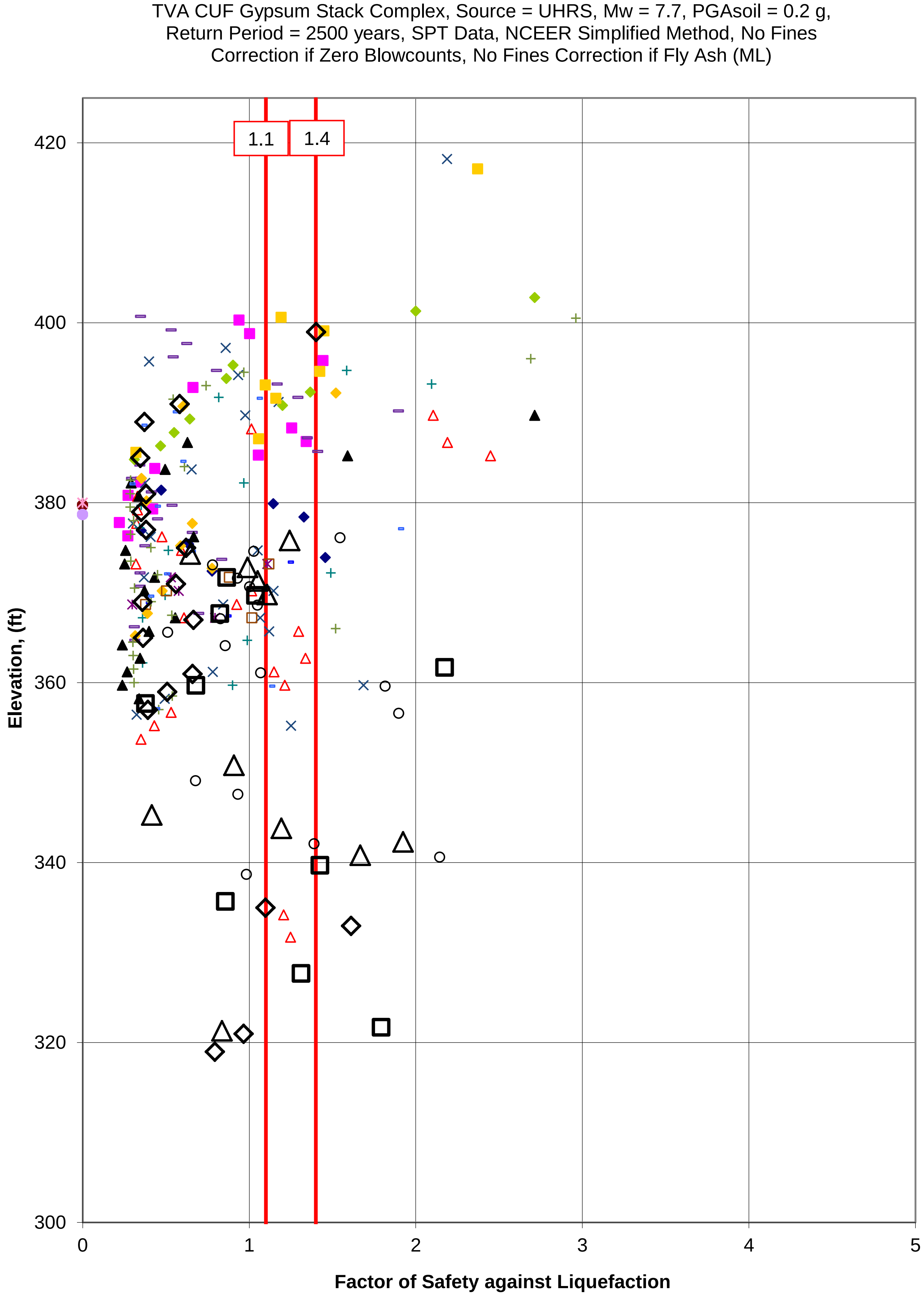


Figure 2: Horizontal Target 2500-yr UHRS (5% Damping) for the Cumberland Fossil Plant site

Acceleration versus depth profile at Boring CUF-H-2B (CUF Gypsum Stack, Section H). Results are derived from one-dimensional ground response analysis.

US EPA ARCHIVE DOCUMENT



US EPA ARCHIVE DOCUMENT

US EPA ARCHIVE DOCUMENT

Section H - Gypsum Stack
Cumberland Fossil Plant
Cumberland City, Tennessee

Stantec

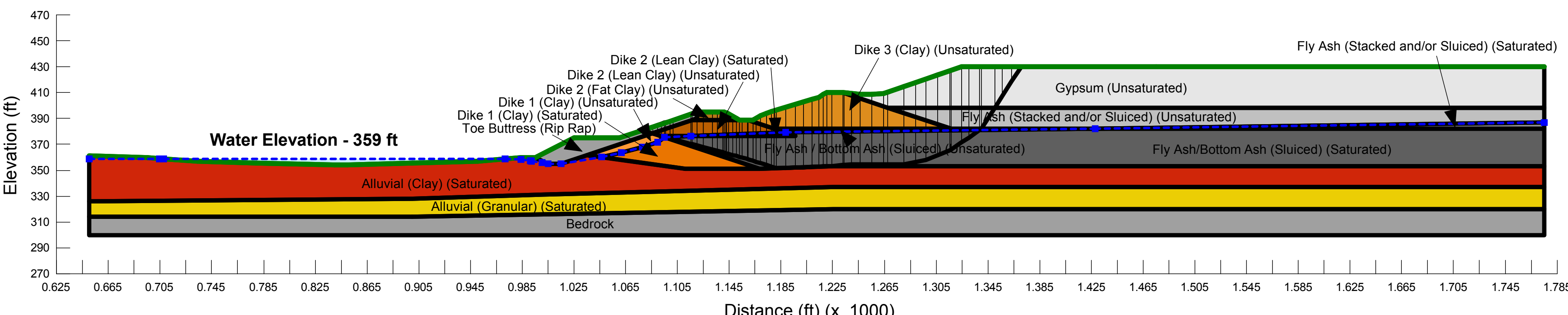
Existing Conditions - Post Earthquake

Liquefied Materials: Fly Ash/Bottom Ash (Sluiced)

ote:
he results of analysis shown here are based on available subsurface information,
boratory test results and approximate soil properties. No warranties can be made
garding the continuity of subsurface conditions between the borings.

Material Type	Unit Weight	Cohesion	Friction Angle
Alluvial (Clay) (Saturated)	121 pcf	360 psf	16.2 °
Alluvial (Granular) (Saturated)	130 pcf	80 psf	16.2 °
Dike 3 (Clay) (Unsaturated)	126 pcf	1000 psf	25 °
Dike 2 (Fat Clay) (Unsaturated)	127 pcf	200 psf	18 °
Dike 2 (Lean Clay) (Unsaturated)	128 pcf	500 psf	21 °
Dike 2 (Lean Clay) (Saturated)	128 pcf	400 psf	17.1 °
Dike 1 (Clay) (Unsaturated)	124 pcf	800 psf	20 °
Dike 1 (Clay) (Saturated)	124 pcf	640 psf	16.2 °
Fly Ash / Bottom Ash (Sluiced) (Unsaturated)	100 pcf	140 psf	11 °
Fly Ash/Bottom Ash (Sluiced) (Saturated)	100 pcf	Sr=exp(-8.444+0.109N1(60)+5.379σ'^0.1), N1(60)=12	0 °
Fly Ash (Stacked and/or Sluiced) (Unsaturated)	100 pcf	0 psf	32 °
Fly Ash (Stacked and/or Sluiced) (Saturated)	100 pcf	0 psf	26.6 °
Gypsum (Unsaturated)	105 pcf	0 psf	33 °
Toe Buttress (Rip Rap)	140 pcf	0 psf	38 °

Factor of Safety: 1.1



FORMATTED_CUF_Section H.gsz

Project No. 175551015

US EPA ARCHIVE DOCUMENT

Erosion Repair and Perimeter Ditch Improvements from CUF Work Plan 11

Perimeter Ditch Improvements from CUF Work Plan 11