Tennessee Valley Authority
Regulatory Submittal for Kingston Fossil Plant

Documents submitted:
Dike 2 Remediation Work Plan

Date Submitted:
08/02/2010

Submitted to whom
Leo Francendese, EPA

Concurrence

Received	Not Applicable	TVA
☐	☒	Steve McCracken
☒	☐	Dennis Yankee DHY
☒	☐	Kathryn Nash
☒	☐	Steve Cherry - via email
☒	☐	Michelle Cagley MC

Received	Not Applicable	Jacobs
☒	☐	Steve Richardson
☒	☐	Jack Howard
☒	☐	Butch Parton
☐	☐	
☐	☐	
☐	☐	

Approvals

TVA Kathryn Nash Date 8/2/10

EPA Leo Francendese Date 8/26/10

Consulted w/ TDEC

cc:

- ☒ Anda Ray, TVA
- ☒ Barbara Scott, TDEC
- ☒ Brenda Brickhouse, TVA
- ☒ John Dizer, TVA
- ☒ Craig Zeller, EPA
- ☒ Dennis Yankee, TVA
- ☒ Kathryn Nash, TVA
- ☒ Cynthia Anderson, TVA
- ☒ Steve McCracken, TVA
- ☒ EDM
- ☒ Julie Pfeffer, Jacobs
- ☒ Steve Richardson, Jacobs
- ☒ Michelle Cagley, TVA
- ☒ Greg Signer, TVA
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- ☒ Katie Kline, TVA
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- ☒ Jeff Gary, Jacobs
- ☒ Robert Pullen, Jacobs

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10 August 2010

Mr. Jack Howard
Engineering Manager
Jacobs Engineering
Kingston Dredge Cell Recovery Project
Swan Pond Road
Harriman, TN

Subject: **Response to Comments**
Technical Memorandum, Integrity Evaluation of Dike 2 for Extreme Rainfall Events
Tennessee Valley Authority (TVA), Kingston Fossil Plant

Dear Mr. Howard:

The purpose of this letter is to address the review comments made by U.S. Bureau of Reclamation (BOR) on the Technical Memorandum titled, "Integrity Evaluation of Dike 2 for Extreme Rainfall Events" prepared by Geosyntec Consultants (Geosyntec) dated 14 July 2010. The review comments were included in a memorandum dated 5 August 2010 from the U.S.BOR titled "Review of Dike 2 Remediation Work Plan dated 8/2/2010" and was transmitted to Geosyntec by Jacobs Engineering (Jacobs). Specific comments are listed in italics below, and Geosyntec's response to each comment is provided following the comment.

Comment: *The seismic stability analysis did not consider the presence of a deep layer of liquefiable material under the foundation clay. For completeness the document should discuss whether or not such a layer is present under this portion of the site. Also, even if a liquefiable layer is present under Dike 2, it is our opinion that it need not be analyzed for this temporary structure. The geotechnical integrity evaluation should address the liquefiable layer and make it clear that the analysis did not consider the presence of the layer.*

Response: At the time of conducting this evaluation, local geologic information available to Geosyntec for this site did not indicate the presence of a deep liquefiable layer. Therefore, the geotechnical integrity evaluation did not consider the presence of a deep liquefiable layer. If future field evaluations/assessments indicate the existence of a deep liquefiable layer, additional analyses should be performed.

Comment: *Also, we do not believe that a flood elevated sediment pond need be considered for the seismic case, just the normal reservoir. It is highly unlikely that a flood elevated reservoir and a severe earthquake event would occur at the same time.*

Response: Geosyntec acknowledges that it is highly unlikely that a flood elevated reservoir condition and a severe earthquake event would occur simultaneously (i.e., the scenario that was considered in the evaluation). However, a normal reservoir condition in combination with a severe earthquake event represents a less critical case than the scenario that was considered in the evaluation. Therefore, the scenario that was considered is conservative, and no further analysis is required.

Comment: *In order for the geotechnical integrity evaluation to be complete, a foundation sliding analysis needs to be provided for Dike 2 in addition to the circular analysis which was presented. When the first panel of the Dike C buttress was placed, it was evident that 6 inches to 1 foot of ash underlies Dike 2 at that interface. We believe that the ash underlies other portions of Dike 2 as well. The sliding analysis should consider a layer of ash under the rock fill dike. It would also be useful for TVA to provide detailed documentation regarding how much or how little ash underlies the dike. For the sliding analysis, a sediment pond with water at the spillway crest elevation of 746 should be evaluated.*

Response: In July 2009, as part of the original geotechnical design of Dike 2, Geosyntec prepared a calculation package titled "Slope Stability Analyses for Dike 2" (included as an Attachment to this letter). This package included a foundation sliding analysis (i.e., analysis of a block slip failure mechanism). The results of the analysis indicated that a block slip failure of the Dike has higher factor of safety values when compared with the corresponding values for a global stability analysis (i.e., circular slip failure mechanism). Therefore, it is concluded that the circular slip failure mechanism (i.e., the scenario that was considered in the evaluation) is a more critical scenario for the present evaluation. Hence, Geosyntec does not believe that a foundation stability analysis is required for the present evaluation.

It is additionally noted that based on information provided by Jacobs, the ash underlying Dike 2 was fully excavated down to a hard clay layer before shot rock placement operations began. Therefore, while some leftover ash may have mixed with the initial layer of shot rock, it is not believed that a single thin ash layer underlies Dike 2. Based on this information it can be concluded that a block slip failure mechanism through a thin ash layer with weak geotechnical strength is not considered a cause of failure.

CLOSING

Geosyntec greatly appreciates the opportunity to be of service to TVA on this important project. Please do not hesitate to contact us if you have any questions.

Sincerely,
Geosyntec Consultants, Inc.

Ganesh Krishnan

Ganesh Krishnan, P.E., CPESC
Associate, Water & Natural Resources

R. Neil Davies

R. Neil Davies, C.Eng., MICE, P.E.
Principal/Branch Manager

Attachment: *"Slope Stability Analyses for Dike 2"*, Geosyntec Consultants, 2009.

Dike 2 Remediation Work Plan

1.0 Purpose of Work

The purpose of this work is to improve the appearance and to minimize ash migration thru Dike 2. This will be accomplished by placing a combination of riprap and earth materials on the out-slope of Dike 2 and then seeding the earth portion of this slope. Crusher run material will be placed on the surface of the dike to slope the dike toward the settling areas. This re-sloping will minimize ash-laden runoff flowing off the dike into the Emory River.

2.0 Design Components

The slope will be a 2 horizontal to 1 vertical with riprap placed to elevation 742.0 The riprap will mitigate wave action from the river thus minimizing loss of material. The earth material above elevation 742.0 will be seeded and mulched.

The top of the dike will be re-graded to slope at a minimum of 1% toward the settling areas to minimize runoff toward the Emory River.

3.0 Construction Management

The construction will be accomplished with track hoes and construction haul vehicles.

4.0 Schedule

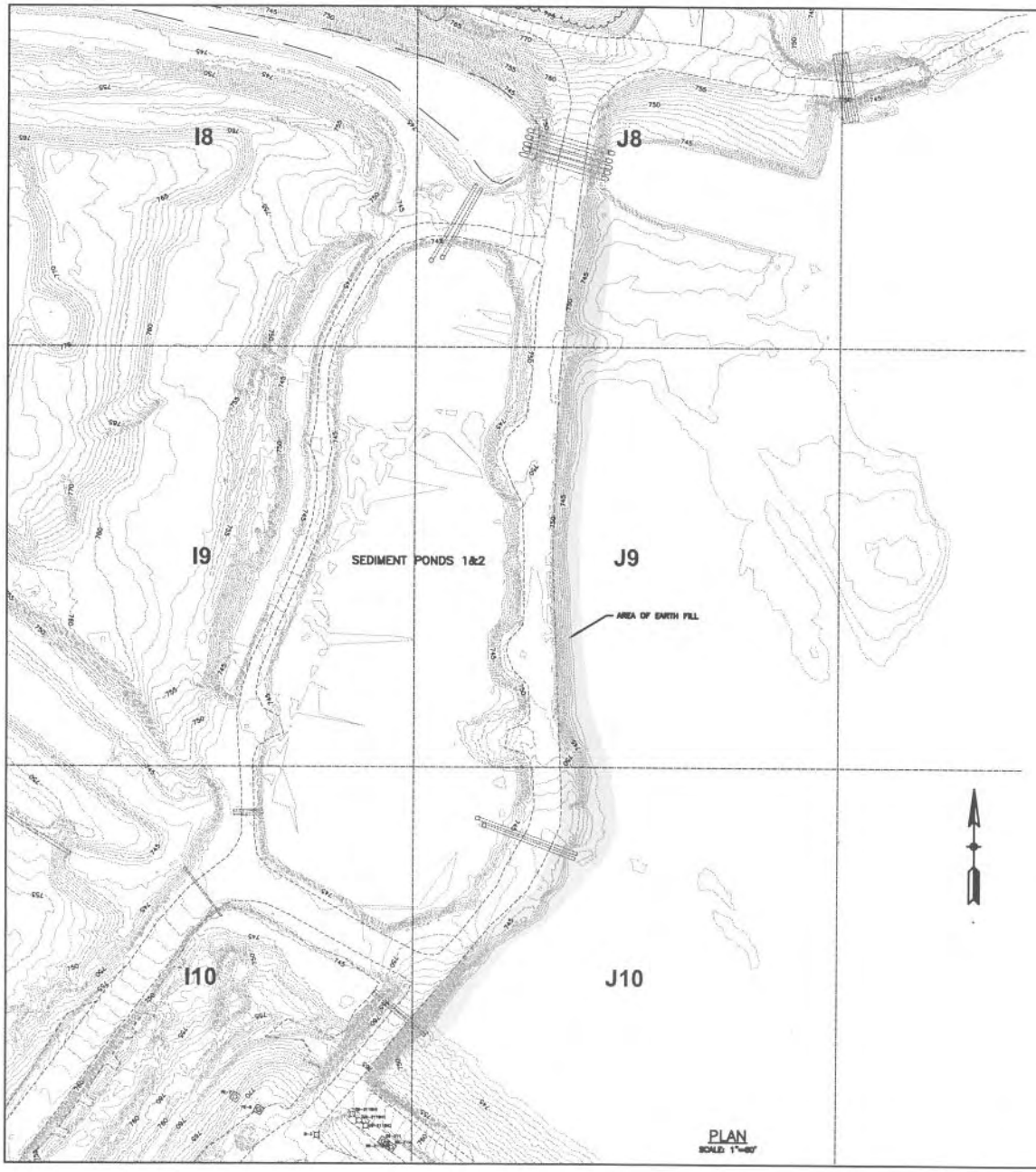
The construction will begin as soon as possible.

5.0 Waste Management

No waste will be generated by this work.

6.0 Health and Safety

All construction activities will be done in accordance with Site Wide Health and Safety Plan.



PLAN
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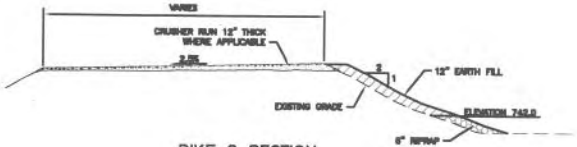
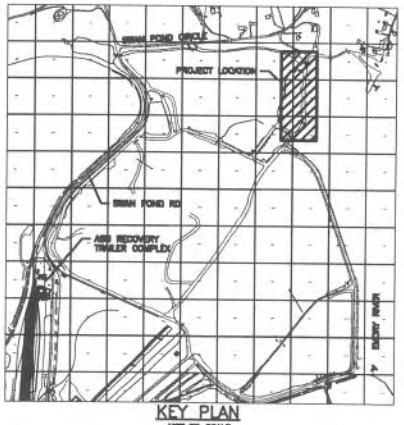


DIKE 2 SECTION
NOT TO SCALE



KEY PLAN
NOT TO SCALE

0 60' 90' 120'

A		ISSUED FOR CONSTRUCTION			

SEAL

JACOBS

KINGSTON FOSSIL PLANT
TENNESSEE VALLEY AUTHORITY

DIKE 2 SIDE SLOPE IMPROVEMENTS
OPTION 1

SCALE	DRAWING NO.	REV.
SHOWN	INF-SK-0578	A

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Draft Technical Memorandum

Date: 12 July 2010

To: Jack Howard, Engineering Manager, Jacobs Engineering

From: Jesus Sanchez, Geosyntec Consultants
Joseph Sura, Geosyntec Consultants
Ganesh Krishnan, P.E., CPESC, Geosyntec Consultants
Neil Davies, P.E., Geosyntec Consultants

Subject: Integrity Evaluation of Dike 2 for an Extreme Rainfall Event
Tennessee Valley Authority (TVA), Kingston Fossil Plant

PURPOSE & BACKGROUND

The purpose of this memorandum is to present the results of the Integrity Evaluation of Dike 2 for an Extreme Rainfall Event which was conducted by Geosyntec Consultants (Geosyntec). Dike 2 is located at Tennessee Valley Authority's (TVA) Kingston Fossil Plant. Dike 2 was constructed to detain surface water runoff from the extent of the failed dredge cell areas (ash area) west of the location of the dike. For the purposes of this evaluation, an Extreme Rainfall Event was defined as the calculated runoff conditions arising from a 100-year, 24-hour design storm event.

OVERALL APPROACH & ASSUMPTIONS

The evaluation was conducted in two steps. The first step involved a hydrologic analysis. The purpose of the hydrologic analysis was to calculate the peak impounded water level behind Dike 2 arising from a 100-year, 24-hour design storm event. The second step involved a geotechnical integrity evaluation. The purpose of the geotechnical integrity evaluation was to calculate the factor of safety against static and seismic slope stability failure of Dike 2.

In conducting the above evaluation, it was assumed that the impoundment behind Dike 2 was filled with ash to the top of the overflow risers. It was also assumed that the tail water condition

for discharge to the Emory River was at the summer pool elevation (i.e., Elevation 741 feet-MSL).

ANALYSES

Hydrologic Analysis

The purpose of the hydrologic analysis was to calculate the peak impounded water level behind Dike 2 arising from a 100-year, 24-hour design storm event. The analysis was conducted using accepted hydrologic modeling procedures, and utilized methodology prescribed in Soil Conservation Service (SCS) Technical Release 55 (SCS, 1986). The analysis was conducted by developing a computer model of the contributing watersheds using the software package HydroCAD™ (HydroCAD, 2009).

Prior to conducting the analysis, Geosyntec conducted a site visit on 30 June 2010. The hydrologic analysis considered the scenario where the surface water runoff from the ash areas (approximately 170 acres) and the surrounding watershed (approximately 2,560 acres) would exceed the capacity of surface water conveyance features upstream of Dike 2. Therefore, detailed modeling of flow through conveyance features upstream of Dike 2 was not performed in the hydrologic analysis. Instead a fictitious modeling scenario was considered, where the flooded area below the top of Dike 2 is considered to be the effective volume of water that is impounded by the dike.

Using the above approach, the water elevation behind Dike 2 for the 100-year, 24-hour design storm event was calculated. Detailed analyses are provided in Appendix A of this memorandum.

Geotechnical Integrity Evaluation

The purpose of the geotechnical integrity evaluation was to calculate the factor of safety against static and seismic slope stability failure of Dike 2. The analysis considered a single cross-section through the emergency spillway. The material properties and subsurface conditions were based on previous work and calculations performed on the Dike 2 area (Geosyntec, 2009). The static and seismic slope stability analyses were conducted using computer program SLIDE (Rocscience, 2010). The stability analyses considered four different scenarios of water levels behind Dike 2 as indicated below.

- 744.5 feet-MSL – Lower than the crest of the emergency spillway.
- 746.0 feet MSL – Crest of the emergency spillway.

DRAFT

- 748.0 feet MSL – Approximately half available flow depth in the emergency spillway.
- 750.0 feet MSL – Top of the embankment of Dike 2.

Detailed analyses are provided in Appendix B of this memorandum.

RESULTS & CONCULSIONS

Based on the hydrologic analysis, the water level behind Dike 2 was calculated as approximately 744.3 feet MSL for the 100-year, 24-hour design storm event which was lower than the four scenarios considered in the geotechnical integrity evaluation.

Based on the geotechnical integrity evaluation, the calculated minimum factor of safety value for static slope stability was 1.6 for the four water elevation scenarios, which is greater than the target factor of safety of 1.5. For the seismic slope stability analyses, the calculated permanent seismic deformation was 1.6 inches, which is less than the acceptable value of 6 to 12 inches (Seed and Bonaparte, 1992).

REFERENCES

AECOM, *"Root Cause Analysis of TVA Kingston Dredge Pond Failure from December 22, 2008"*, Volume 4, June 12, 2009.

Frankel, A.D., Petersen, M.D., Mueller, C.S., Haller, K.M., Wheeler, R.L., Leyendecker, E.V., Wesson, R.L., Harmsen, S.C., Cramer, C.H., Perkins, D.M., and Rukstales, K.S., "*Documentation for the 2002 Update of the National Seismic Hazard Maps"*, United States Geologic Survey, 2002.

Geosyntec Consultants, *Slope Stability Analyses for Dike 2*, July 2009.

HydroCAD, *"HydroCAD™ Storm water Modeling System, Version 9.1"*, HydroCAD Software Solutions LLC., Chocorua, New Hampshire, 2009.

Hynes, M. and Franklin, A., "*Rationalizing the Seismic Coefficient Method*", Department of the Army, Waterways Experiment Station, Corps of Engineers, Vicksburg, Mississippi, Miscellaneous Paper GL-84-14, July 1984.

Robinson, K. M., Rice, C. E., and Kadavy, K. C., *"Design of Rock Chutes"*, American Society of Agricultural Engineers, Volume 41, No. 3, 1998, pp. 621-626.

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Rocscience, *"SLIDE — 2-D Limit Equilibrium Slope Stability for Soil and Rock Slopes"*, User's Guide, Rocscience Software Inc., Toronto, Ontario, Canada, 2006.

Seed, R. B., and Bonaparte, R., "Seismic Analysis and Design of Lined Waste Fills: Current Practice," *Proceedings, Stability and Performance of Slopes and Embankments-II, Vol. 2*, ASCE Geotechnical Special Publication No. 31, Berkeley, California, 1992, pp. 1521-1545.

Soil Conservation Service (SCS), *Hydrology for Small Watersheds, Technical Release 55 (TR-55)*, United States Department of Agriculture, Soil Conservation Service, Washington, D.C., 1986.

Spencer, E., *"The Thrust Line Criterion in Embankment Stability Analysis"*, Géotechnique, Vol. 23, No. 1, pp. 85-100, 1973.

TVA, Tennessee Valley Authority, Kingston Fossil Plant, *Interim Drainage Plan, Drawings 10W290 and Calculations (Worley Parsons)*, 24 April, 2009.

USEPA, RCRA Subtitle D (258) *Seismic Design Guidance for Municipal Solid Waste Landfill Facilities*. Document Number EPA600-R-95-051, 1995.

* * * * *

DRAFT

APPENDIX – A

HYDROLOGIC ANALYSIS

(NOT INCLUDED IN 12 JULY 2010 DRAFT SUBMITTAL)

DRAFT

APPENDIX – B

GEOTECHNICAL INTEGRITY EVALUATION

DRAFT

GEOSYNTEC CONSULTANTS

COMPUTATION COVER SHEET

Client: TVA **Project:** Integrity Evaluation of Dike 2 **Project/Proposal #:** GK4693 **Task #:** 03

TITLE OF COMPUTATIONS **GEOTECHNICAL INTEGRITY EVALUATION**

COMPUTATIONS BY:
Signature [signature] July 12, 2010 DATE
Printed Name and Title: Joseph Sura, Senior Staff Engineer

ASSUMPTIONS AND PROCEDURES CHECKED BY:
(Peer Reviewer)
Signature [signature] 7/12/2010 DATE
Printed Name and Title: Ming Zhu, P.E., Project Engineer

COMPUTATIONS CHECKED BY:
Signature [signature] Fan Zhu 7/12/2010 DATE
Printed Name and Title: Ming Zhu, P.E. / Fan Zhu, Project Engineer / Senior Staff Engineer

COMPUTATIONS BACKCHECKED BY:
(Originator)
Signature [signature] July 12, 2010 DATE
Printed Name and Title: Joseph Sura, Senior Staff Engineer

APPROVED BY:
(PM or Designate)
Signature [signature] 12 July 2010 DATE
Printed Name and Title: Ganesh Krishnan, P.E., CPESC, Associate

APPROVAL NOTES:

REVISIONS (Number and initial all revisions)

NO.	SHEET	DATE	BY	CHECKED BY	APPROVAL

GEOTECHNICAL INTEGRITY EVALUATION

PURPOSE OF ANALYSES

The purpose of this calculation package is to calculate the slope stability for the existing Dike 2 at the Tennessee Valley Authority (TVA) Kingston site. Slope stability analyses have previously been performed by Geosyntec on Dike 2 in the package titled "Slope Stability Analyses for Dike 2" [Geosyntec, 2009] (hereafter referred to as the 2009 Stability Analyses). The analyses presented herein are intended to calculate the factor of safety (FS) for slope stability under the influence of different water elevations within the Dike 2 basin. Analyses are performed for potential slip surfaces through the embankment and/or subsurface foundation materials.

This package presents the stability analyses for four different water level elevation scenarios within the Dike 2 basin. These include the following.

- Water Elevation 744.5 Feet MSL – Water level elevation lower than the crest of the emergency spillway.
- Water Elevation 746.0 Feet MSL – Water level elevation at the crest of the emergency spillway.
- Water Elevation 748.0 Feet MSL – Water level elevation at approximately half available flow depth in the emergency spillway.
- Water Elevation 750.0 Feet MSL – Water level elevation at the top of the embankment of Dike 2.

METHODOLOGY

Static Stability

Slope stability analyses of circular slip surfaces were performed using Spencer's method [Spencer, 1973], as implemented in the computer program SLIDE, version 5.044 [Rocscience, 2010]. The program was used to generate potential slip surfaces, calculate the factor of safety (FS) for each of these surfaces, and identify the slip surface with the lowest FS. The target FS for static slope stability was considered to be 1.3 because this is a short-term, temporary condition.

Seismic Stability

Seismic slope stability analyses were performed using a procedure consistent with a guidance document prepared by the U.S. Environmental Protection Agency [USEPA, 1995]. The procedure is as follows:

1. Estimate the peak ground acceleration (PGA) at the site.

2. Perform pseudo-static slope stability analyses for the potential critical section to evaluate the yield acceleration. The yield acceleration is the horizontal acceleration at which a marginally stable condition is produced (i.e., factor of safety of 1.0) for the potential slip surface. A trial-and-error process was applied to evaluate the yield acceleration.

3. The yield acceleration (k_y) was compared to the peak horizontal acceleration (a_{max}) of the slide mass due to the design earthquake. If k_y is greater than a_{max}, the analysis is concluded, as Dike 2 will not likely undergo permanent displacement. If k_y is less than a_{max}, then Dike 2 will likely undergo permanent displacement and a displacement analysis is performed to evaluate the magnitude of the permanent displacement.

4. The seismic displacement, corresponding to the computed k_y/a_{max} ratio, is estimated using the results presented by Hynes and Franklin [1984] and the "modified mean + one standard deviation curve" developed by Geosyntec, as presented in Figure 1. The "modified mean + one standard deviation curve" considers data associated with only large earthquakes, and therefore, is more conservative to use. This procedure is consistent with those given in the recent USEPA guidance document [USEPA, 1995]. According to the USEPA guidance document [1995], and based on the recommendations of Seed and Bonaparte [1992], maximum permanent seismic deformations of 6 to 12 inches are typically considered acceptable.

Information Required

Information required for the slope stability analyses included the Dike 2 geometry, subsurface soil stratigraphy, the expected water surface elevation, and the material properties of the soils and dike.

SUBSURFACE STRATIGRAPHY & MATERIAL PROPERTIES

The current site topography in the Dike 2 area was provided by Jacobs based on LIDAR contours dated May 19, 2010 and is shown in Figure 2 [TVA, 2009]. It is noted that the LIDAR contours measure the top surface (i.e., including ponded water) and cannot determine the depth of the pond. Therefore, the elevation at the bottom of the pond and bottom of the Emory River have been assumed to be approximately 740 ft and 741 ft, respectively, based on the design drawings. The elevation of the emergency spillway (i.e., top of Dike 2) is approximately 746 ft. The side slopes of Dike 2 are assumed to be 3 horizontal to 1 vertical (3H:1V), with a top width of approximately 24 ft, based on the design details. A small channel containing the overflow risers is located inside the pond approximately 20 ft from Dike 2 and with a bottom elevation of 736 ft. The side slopes of this channel are assumed to be 2H:1V. The subsurface stratigraphy is assumed to consist of an alluvium clay and silt material, based on the Root Cause Analysis of TVA Kingston Dredge Pond Failure form December 22, 2009 Report [AECOM, 2009]. The material properties used in these analyses are based on the Root Cause Analysis [AECOM, 2009] and past experience with site materials. The material properties are summarized in Table 1 and are the same as previously presented in the 2009 Stability Analyses [Geosyntec, 2009]. It is noted that the design condition is expected to represent a short-term condition due to the storm event and therefore only the undrained case has been considered in these analyses.

A parametric study has been performed for the water table elevation inside the basin. Four different water table elevations (i.e., 744.5 ft, 746 ft, 748 ft and 750 ft) have been considered as part of the parametric study. It is noted that the pond has been assumed to be filled with ash up to the top of the lower overflow riser (i.e., elevation 743.0 ft), as shown in Figure 3. The design water table elevation in the Emory River has been assumed to be the summer high water level elevation of 741 ft.

The seismic stability analysis has been performed based on a peak ground acceleration (PGA) with a 90% or greater probability of non-exceedance in 250 years at the site location. Using the USGS Seismic Hazard Curves and Uniform Response Spectra computer program [Frankel, et. al, 2002], the PGA was calculated to be 0.25g.

ANALYZED CROSS SECTION

The selected Cross Section for analysis passes through the lowest elevation of the emergency spillway as shown on Figure 2. The section geometry and stratigraphy is shown in Figure 4.

RESULTS AND CONCLUSIONS

The calculated minimum FS values for static stability are shown in Table 2. Table 3 summarizes the calculated ground accelerations and permanent deformations under seismic loading. Associated SLIDE output files are included in Attachment 1.

Based on available information and assumptions, the calculation results indicate that Dike 2 is expected to have calculated static FS values greater than the target FS for water elevations of 750 ft and lower. The calculated permanent seismic deformations also satisfy the selected criteria. It is noted that shallow erosion or surface sloughing of the dike may be possible when water flows on the downstream side of the dike (i.e., over the emergency spillway), therefore it is recommended that the dike be inspected for evidence of erosion after large storm events.

REFERENCES

AECOM, *"Root Cause Analysis of TVA Kingston Dredge Pond Failure from December 22, 2008"*, Volume 4, June 12, 2009.

Frankel, A.D., Petersen, M.D., Mueller, C.S., Haller, K.M., Wheeler, R.L., Leyendecker, E.V., Wesson, R.L., Harmsen, S.C., Cramer, C.H., Perkins, D.M., and Rukstales, K.S., "*Documentation for the 2002 Update of the National Seismic Hazard Maps"*, United States Geologic Survey, 2002.

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Rocscience., *"SLIDE — 2-D Limit Equilibrium Slope Stability for Soil and Rock Slopes"*, User's Guide, Rocscience Software Inc., Toronto, Ontario, Canada, 2010.

Seed, R. B., and Bonaparte, R., "Seismic Analysis and Design of Lined Waste Fills: Current Practice," *Proceedings, Stability and Performance of Slopes and Embankments-II, Vol. 2*, ASCE Geotechnical Special Publication No. 31, Berkeley, California, 1992, pp. 1521-1545.

Spencer, E., *"The Thrust Line Criterion in Embankment Stability Analysis"*, Géotechnique, Vol. 23, No. 1, pp. 85-100, 1973.

Tennessee Valley Authority, *"Drawing Set 10W290: Kingston Fossil Plant"*, 2009.

USEPA. RCRA Subtitle D (258) *Seismic Design Guidance for Municipal Solid Waste Landfill Facilities*. Document Number EPA600-R-95-051, 1995.

Tables

Table 1: Material Properties

Material	Unit Weight (pcf)	Shear Strength Properties
Rock Dike	150	c'=0 psf, φ'=45°
Ash	107	c'=100 psf, φ'=0°
Clay and Silt (Foundation Soils)	110	c'=1200 psf, φ'=0°

Note:

These properties are based on data and assumptions previously presented in the 2009 Stability Analyses [Geosyntec, 2009].

Table 2: Summary of Results

Water Elevation (ft)	Description	Static Analysis			Seismic Analysis			
		FS	Target FS	Acceptable?	Yield Acceleration, k_y (g)	k_y/a_{max}	Calculated Deformation (in)	Acceptable?
744.5	Water elevation below emergency spillway	1.61	1.5	Yes	0.15	0.60	1.6	Yes
746	Water elevation at the crest of emergency spillway	1.61	1.5	Yes	0.15	0.60	1.6	Yes
748	Water elevation at approximately half available flow depth in the emergency spillway	1.61	1.5	Yes	0.15	0.60	1.6	Yes
750	Water elevation at the top of the embankment.	1.61	1.5	Yes	0.15	0.60	1.6	Yes

Notes:

1) Water elevation refers to the height of water on the upstream side of Dike 2. The height of water on the downstream side of Dike 2 (i.e., the Emory River) is assumed to be 741 ft.
2) According to the USEPA guidance document [1995], and based on the recommendations of Seed and Bonaparte [1992], maximum permanent seismic deformations of 6 to 12 inches are typically considered acceptable.
3) The associated SLIDE output files are included in Attachment 1.

Figures

Written by:	Joseph Sura	Date:	7/8/2010	Reviewed by:	Ming Zhu	Date:	7/9/2010

Client:	TVA	Project:	Integrity Evaluation of Dike 2	Project/ Proposal No.:	GK4693	Task No.:	03

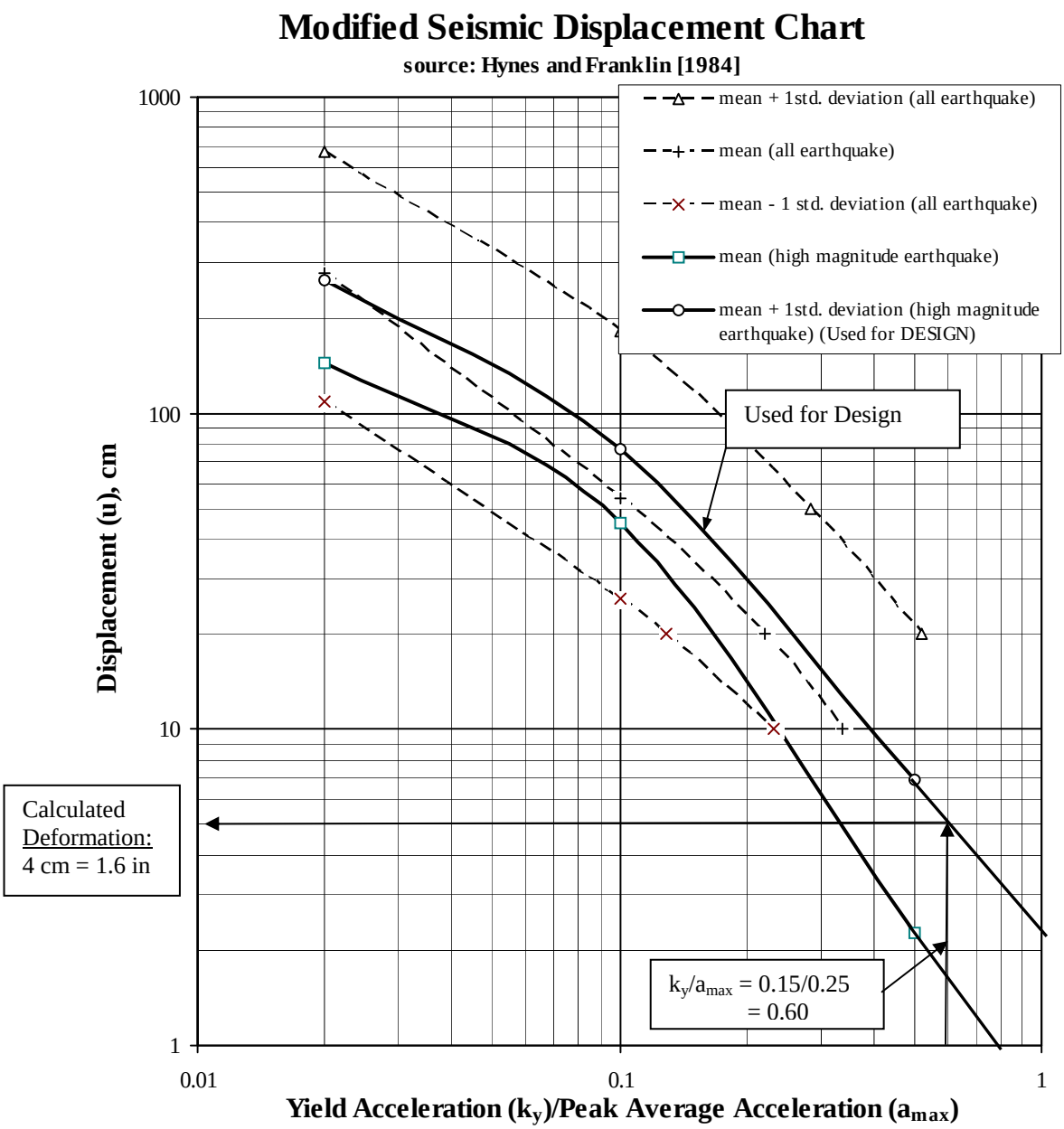


Figure 1. Seismic Deformation Chart [Hynes and Franklin, 1984]

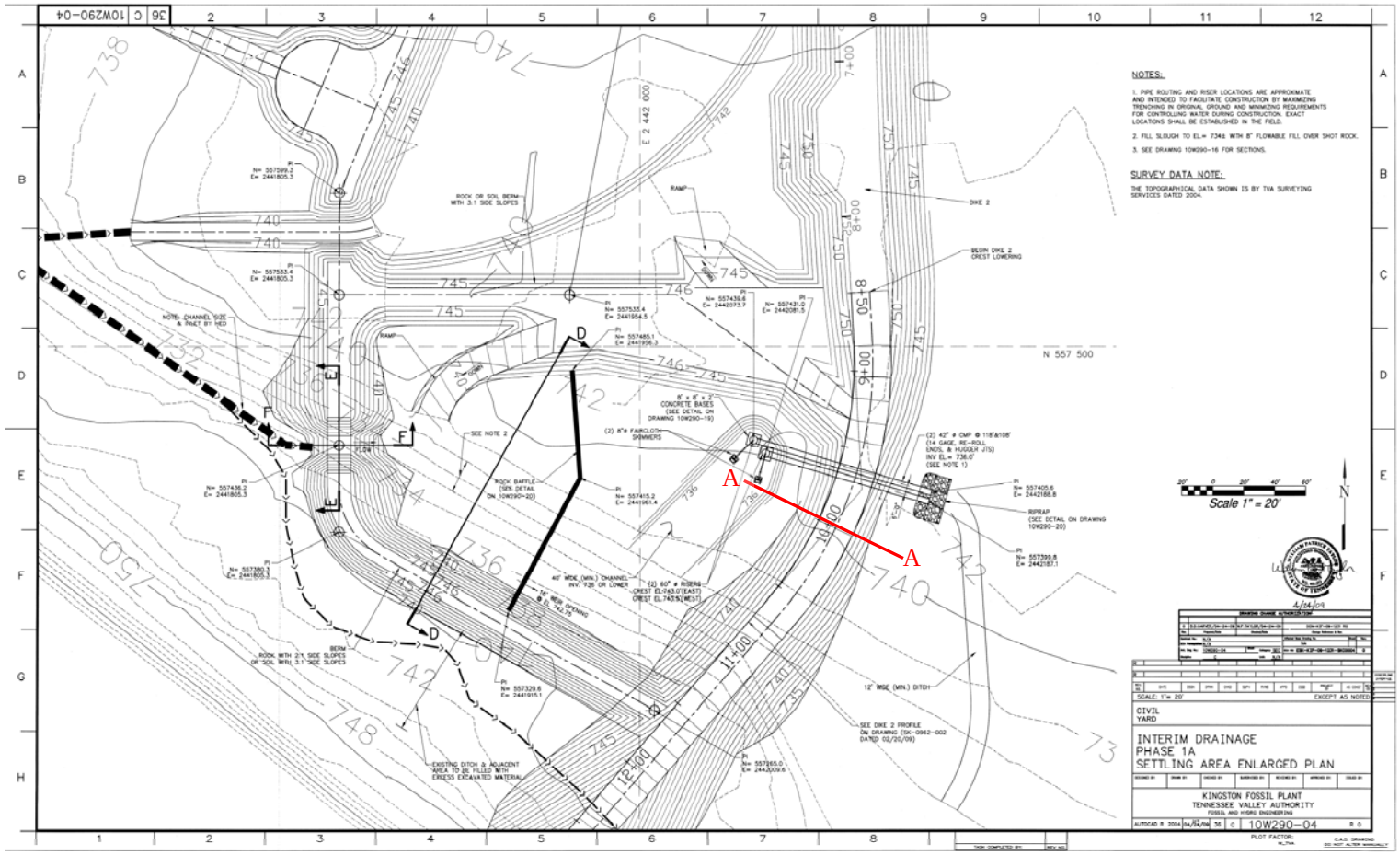


Figure 2. Site Plan near Dike 2 [TVA, 2009]

Note: Cross Section A-A was selected for analysis, as discussed in the package.

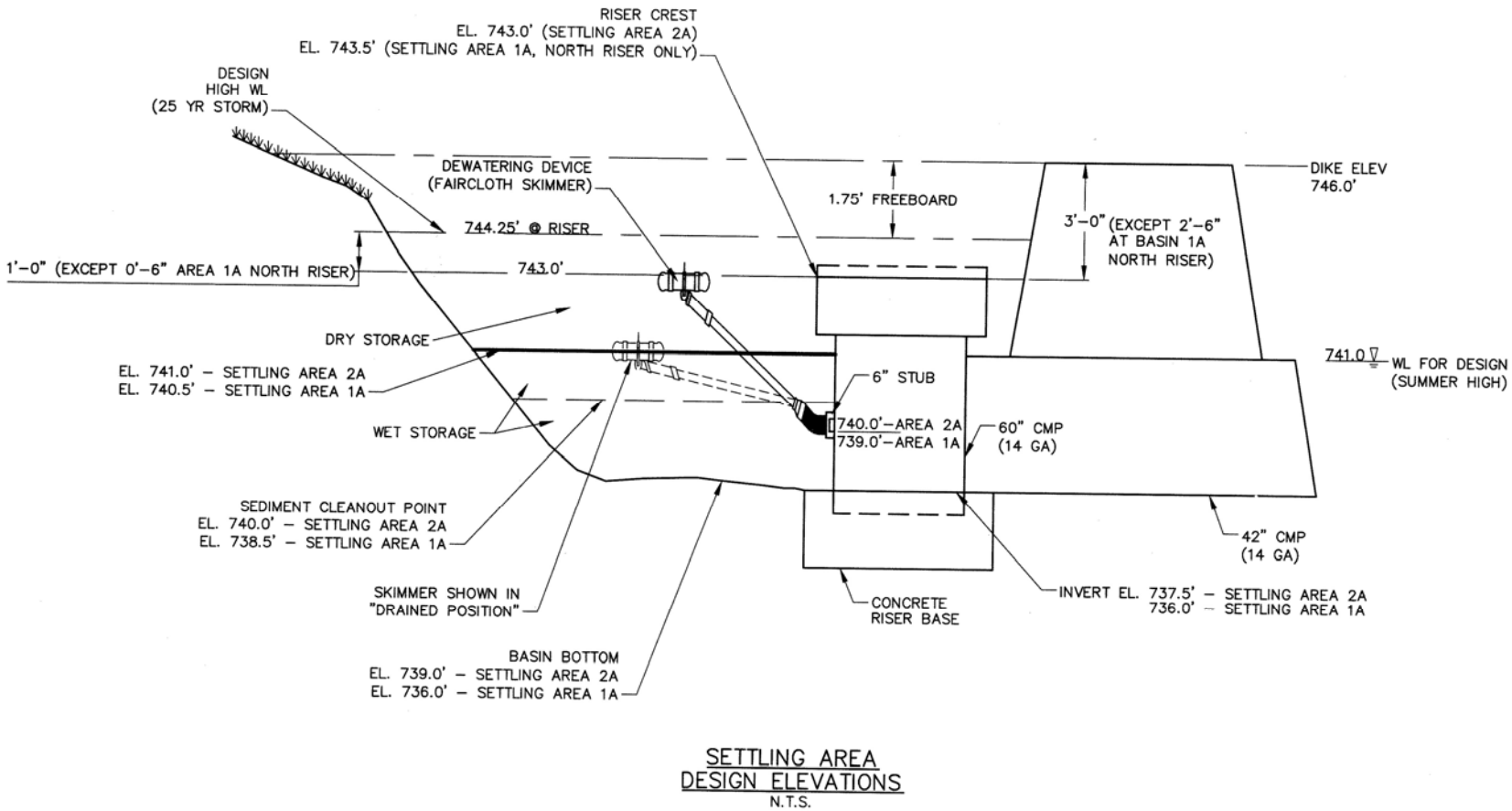


Figure 3. Detail of Overflow Riser [TVA, 2009]

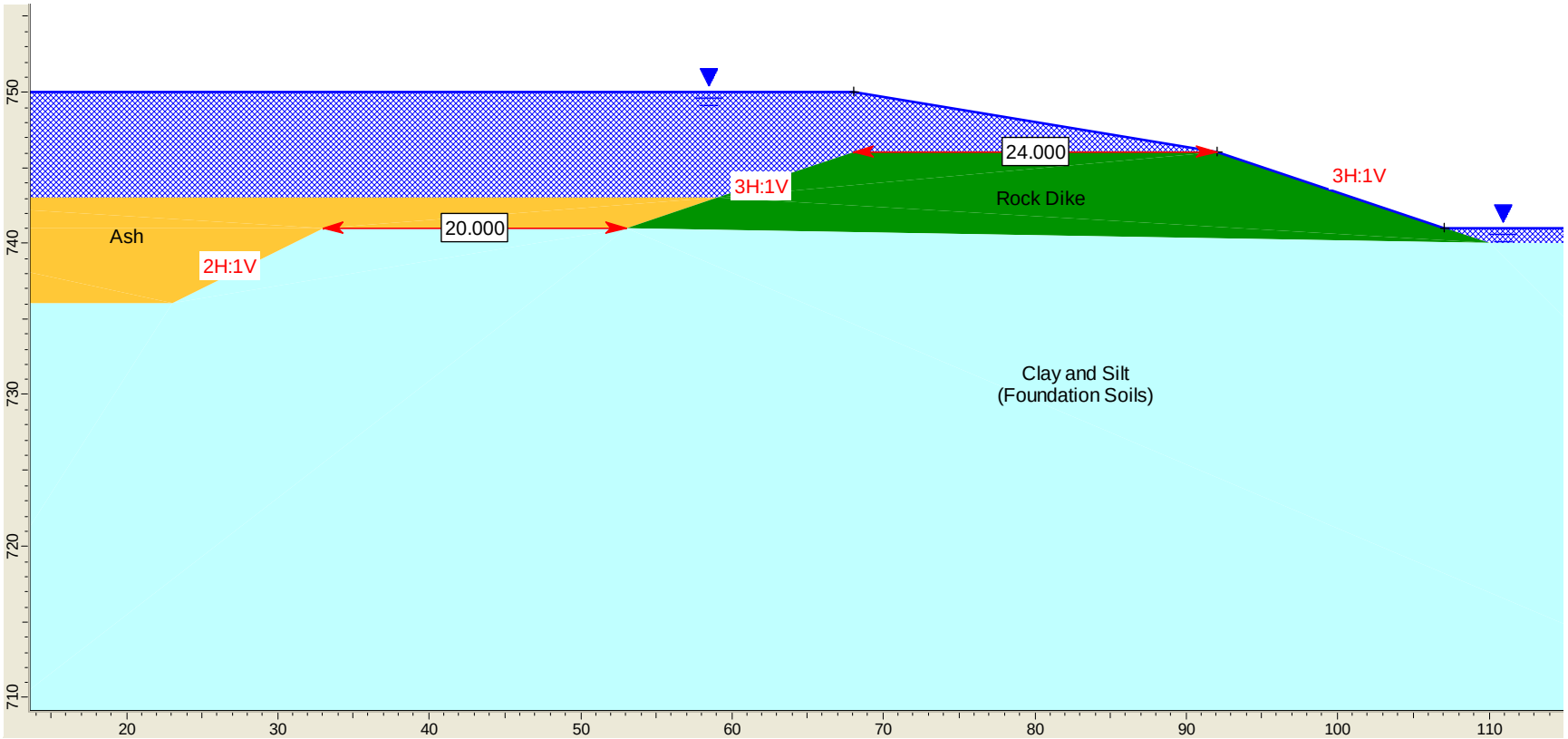


Figure 4. Geometry of Selected Cross Section
Note: This Cross Section is shown as A-A on Figure 2.

Attachment 1:

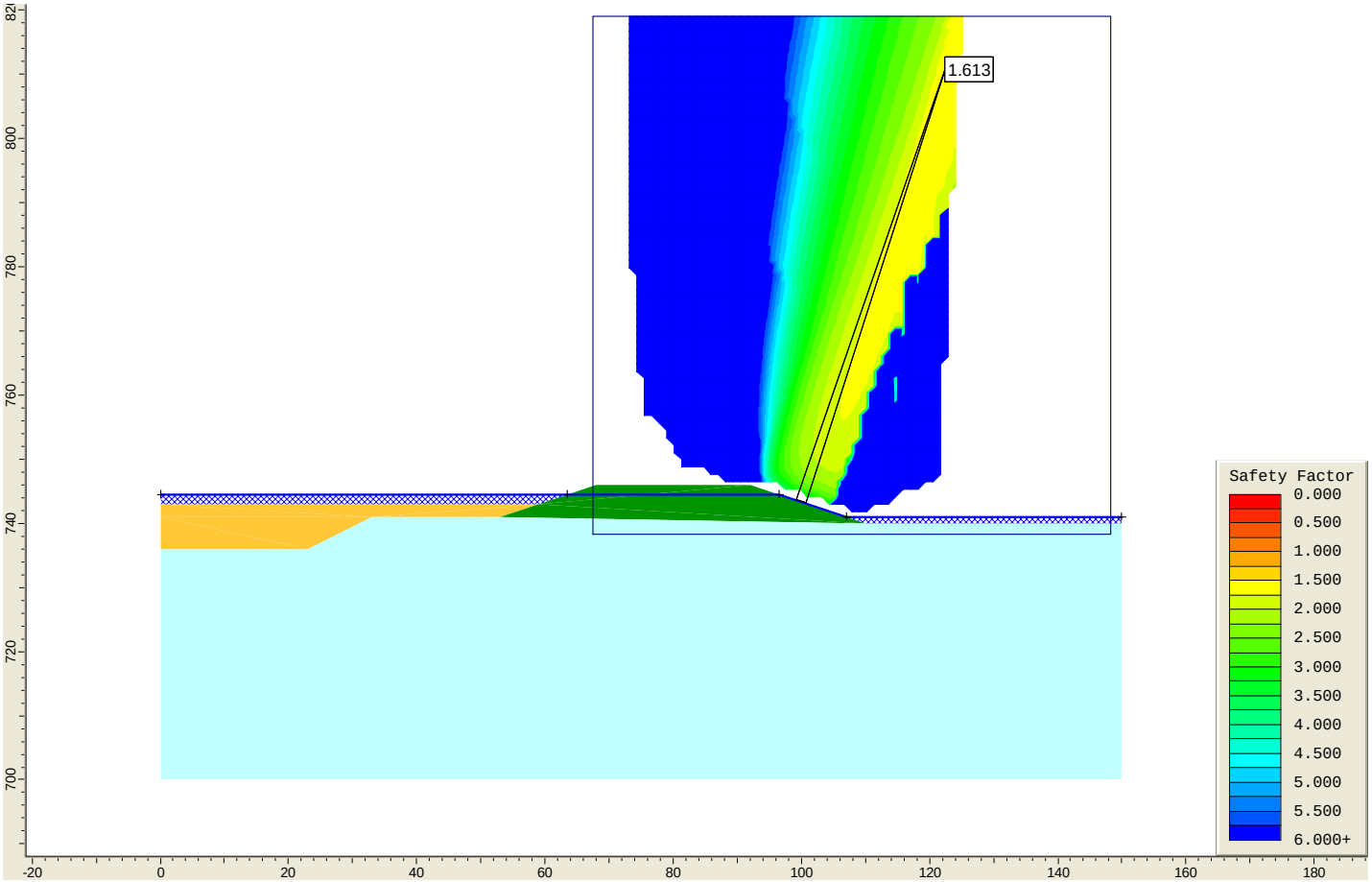
SLIDE Output Files

Notes:

1. The error messages in the output files are a result of invalid slip surfaces generated by the SLIDE program during the automatic search for the most critical slip surface. The invalid slip surfaces do not affect the valid slip surfaces from which the critical slip surface is identified.

Written by: **Joseph Sura** Date: **7/8/2010** Reviewed by: **Ming Zhu** Date: **7/9/2010**

Client: **TVA** Project: **Integrity Evaluation of Dike 2** Project/ Proposal No.: **GK4693** Task No.: **03**



Static Slope Stability with Water Elevation of 744.5 ft

Slide Analysis Information

Document Name

File Name: Section A_744

Project Settings

Project Title: SLIDE - An Interactive Slope Stability Program
Failure Direction: Left to Right
Units of Measurement: Imperial Units
Pore Fluid Unit Weight: 62.4 lb/ft3
Groundwater Method: Water Surfaces
Data Output: Standard
Calculate Excess Pore Pressure: Off
Allow Ru with Water Surfaces or Grids: Off
Random Numbers: Pseudo-random Seed
Random Number Seed: 10116
Random Number Generation Method: Park and Miller v.3

Analysis Methods

Analysis Methods used:
Spencer

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50

Surface Options

Surface Type: Circular
Search Method: Grid Search
Radius increment: 10
Composite Surfaces: Disabled
Reverse Curvature: Invalid Surfaces
Minimum Elevation: Not Defined
Minimum Depth: Not Defined

Material Properties

Material: Rock Dike
Strength Type: Mohr-Coulomb
Unit Weight: 150 lb/ft3
Cohesion: 0 psf
Friction Angle: 45 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Ash (UD)
Strength Type: Undrained
Unit Weight: 107 lb/ft3
Cohesion Type: Constant
Cohesion: 100 psf
Water Surface: None

Material: Clay and Silt (UD)
Strength Type: Undrained
Unit Weight: 110 lb/ft3
Cohesion Type: Constant
Cohesion: 1200 psf
Water Surface: None

Global Minimums

Method: spencer
FS: 1.613400
Center: 122.843, 812.144
Radius: 72.507
Left Slip Surface Endpoint: 99.138, 743.621
Right Slip Surface Endpoint: 100.693, 743.102
Resisting Moment=27.9871 lb-ft
Driving Moment=17.3466 lb-ft
Resisting Horizontal Force=0.366185 lb
Driving Horizontal Force=0.226964 lb

Valid / Invalid Surfaces

Method: spencer
Number of Valid Surfaces: 25472
Number of Invalid Surfaces: 29979
Error Codes:
Error Code -102 reported for 118 surfaces
Error Code -103 reported for 294 surfaces
Error Code -106 reported for 641 surfaces
Error Code -107 reported for 6322 surfaces
Error Code -108 reported for 11511 surfaces
Error Code -111 reported for 475 surfaces
Error Code -112 reported for 521 surfaces

Error Code -114 reported for 3068 surfaces
Error Code -1000 reported for 7029 surfaces

Error Codes

The following errors were encountered during the computation:

-102 = Two surface / slope intersections, but resulting arc is actually outside soil region.

-103 = Two surface / slope intersections, but one or more surface / nonslope external polygon intersections lie between them. This usually occurs when the slip surface extends past the bottom of the soil region, but may also occur on a benched slope model with two sets of Slope Limits.

-106 = Average slice width is less than 0.0001 * (maximum horizontal extent of soil region). This limitation is imposed to avoid numerical errors which may result from too many slices, or too small a slip region.

-107 = Total driving moment or total driving force is negative. This will occur if the wrong failure direction is specified, or if high external or anchor loads are applied against the failure direction.

-108 = Total driving moment or total driving force < 0.1. This is to limit the calculation of extremely high safety factors if the driving force is very small (0.1 is an arbitrary number).

-111 = safety factor equation did not converge

-112 = The coefficient M-Alpha = cos(alpha)(1+tan(alpha)tan(phi)/F) < 0.2 for the final iteration of the safety factor calculation. This screens out some slip surfaces which may not be valid in the context of the analysis, in particular, deep seated slip surfaces with many high negative base angle slices in the passive zone.

-114 = Surface with Reverse Curvature.

-1000 = No valid slip surfaces are generated at a grid center. Unable to draw a surface.

List of All Coordinates

Search Grid

67.466	738.359
148.224	738.359
148.224	819.061
67.466	819.061

Material Boundary

53.000	741.000
110.000	740.000

Material Boundary

0.000	741.000
33.000	741.000
53.000	741.000

Material Boundary

0.000	736.000
23.000	736.000
33.000	741.000

Material Boundary

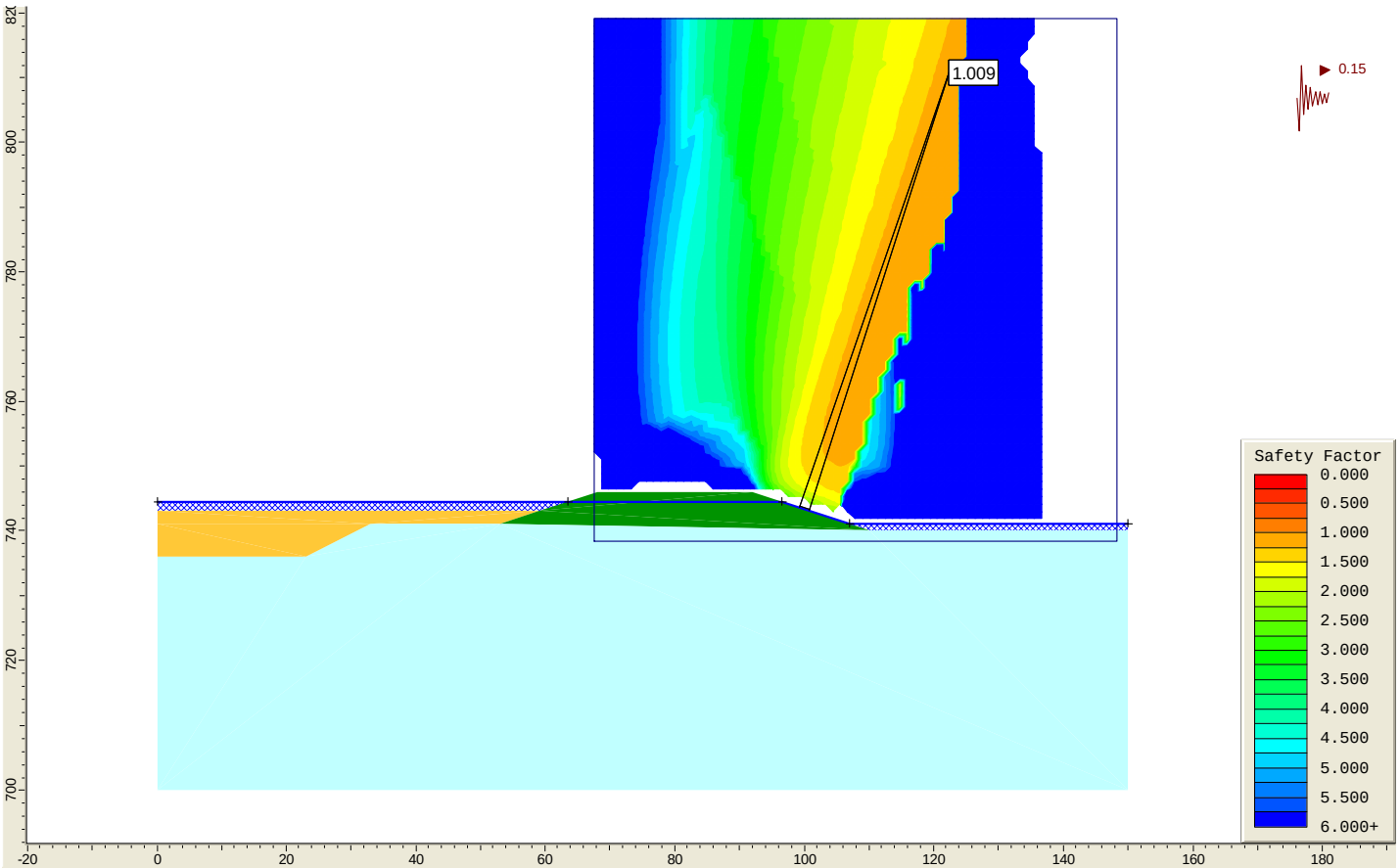
53.000	741.000
59.000	743.000

Water Table

0.000	744.500
63.500	744.500
96.500	744.500
107.000	741.000
150.000	741.000

Written by: **Joseph Sura** Date: **7/8/2010** Reviewed by: **Ming Zhu** Date: **7/9/2010**

Client: **TVA** Project: **Integrity Evaluation of Dike 2** Project/ Proposal No.: **GK4693** Task No.: **03**



Seismic Slope Stability with Water Elevation of 744.5 ft

Slide Analysis Information

Document Name

File Name: Section A_744_Seismic_FS1

Project Settings

Project Title: SLIDE - An Interactive Slope Stability Program
Failure Direction: Left to Right
Units of Measurement: Imperial Units
Pore Fluid Unit Weight: 62.4 lb/ft3
Groundwater Method: Water Surfaces
Data Output: Standard
Calculate Excess Pore Pressure: Off
Allow Ru with Water Surfaces or Grids: Off
Random Numbers: Pseudo-random Seed
Random Number Seed: 10116
Random Number Generation Method: Park and Miller v.3

Analysis Methods

Analysis Methods used:
Spencer

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50

Surface Options

Surface Type: Circular
Search Method: Grid Search
Radius increment: 10
Composite Surfaces: Disabled
Reverse Curvature: Invalid Surfaces
Minimum Elevation: Not Defined
Minimum Depth: Not Defined

Loading

Seismic Load Coefficient (Horizontal): 0.15

Material Properties

Material: Rock Dike
Strength Type: Mohr-Coulomb
Unit Weight: 150 lb/ft3
Cohesion: 0 psf
Friction Angle: 45 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Ash (UD)
Strength Type: Undrained
Unit Weight: 107 lb/ft3
Cohesion Type: Constant
Cohesion: 100 psf
Water Surface: None

Material: Clay and Silt (UD)
Strength Type: Undrained
Unit Weight: 110 lb/ft3
Cohesion Type: Constant
Cohesion: 1200 psf
Water Surface: None

Global Minimums

Method: spencer
FS: 1.009230
Center: 122.843, 812.144
Radius: 72.507
Left Slip Surface Endpoint: 99.138, 743.621
Right Slip Surface Endpoint: 100.693, 743.102
Resisting Moment=25.3847 lb-ft
Driving Moment=25.1525 lb-ft
Resisting Horizontal Force=0.33214 lb
Driving Horizontal Force=0.329101 lb

Valid / Invalid Surfaces

Method: spencer
Number of Valid Surfaces: 41085
Number of Invalid Surfaces: 14366
Error Codes:
Error Code -102 reported for 118 surfaces
Error Code -103 reported for 294 surfaces
Error Code -106 reported for 641 surfaces
Error Code -107 reported for 12 surfaces

Error Code -108 reported for 1552 surfaces
Error Code -111 reported for 837 surfaces
Error Code -112 reported for 815 surfaces
Error Code -114 reported for 3068 surfaces
Error Code -1000 reported for 7029 surfaces

Error Codes

The following errors were encountered during the computation:

-102 = Two surface / slope intersections, but resulting arc is actually outside soil region.

-103 = Two surface / slope intersections, but one or more surface / nonslope external polygon intersections lie between them. This usually occurs when the slip surface extends past the bottom of the soil region, but may also occur on a benched slope model with two sets of Slope Limits.

-106 = Average slice width is less than 0.0001 * (maximum horizontal extent of soil region). This limitation is imposed to avoid numerical errors which may result from too many slices, or too small a slip region.

-107 = Total driving moment or total driving force is negative. This will occur if the wrong failure direction is specified, or if high external or anchor loads are applied against the failure direction.

-108 = Total driving moment or total driving force < 0.1. This is to limit the calculation of extremely high safety factors if the driving force is very small (0.1 is an arbitrary number).

-111 = safety factor equation did not converge

-112 = The coefficient M-Alpha = cos(alpha)(1+tan(alpha)tan(phi)/F) < 0.2 for the final iteration of the safety factor calculation. This screens out some slip surfaces which may not be valid in the context of the analysis, in particular, deep seated slip surfaces with many high negative base angle slices in the passive zone.

-114 = Surface with Reverse Curvature.

-1000 = No valid slip surfaces are generated at a grid center. Unable to draw a surface.

List of All Coordinates

Search Grid

67.466	738.359
148.224	738.359
148.224	819.061
67.466	819.061

Material Boundary

53.000	741.000
110.000	740.000

Material Boundary

0.000	741.000
33.000	741.000
53.000	741.000

Material Boundary

0.000	736.000
23.000	736.000
33.000	741.000

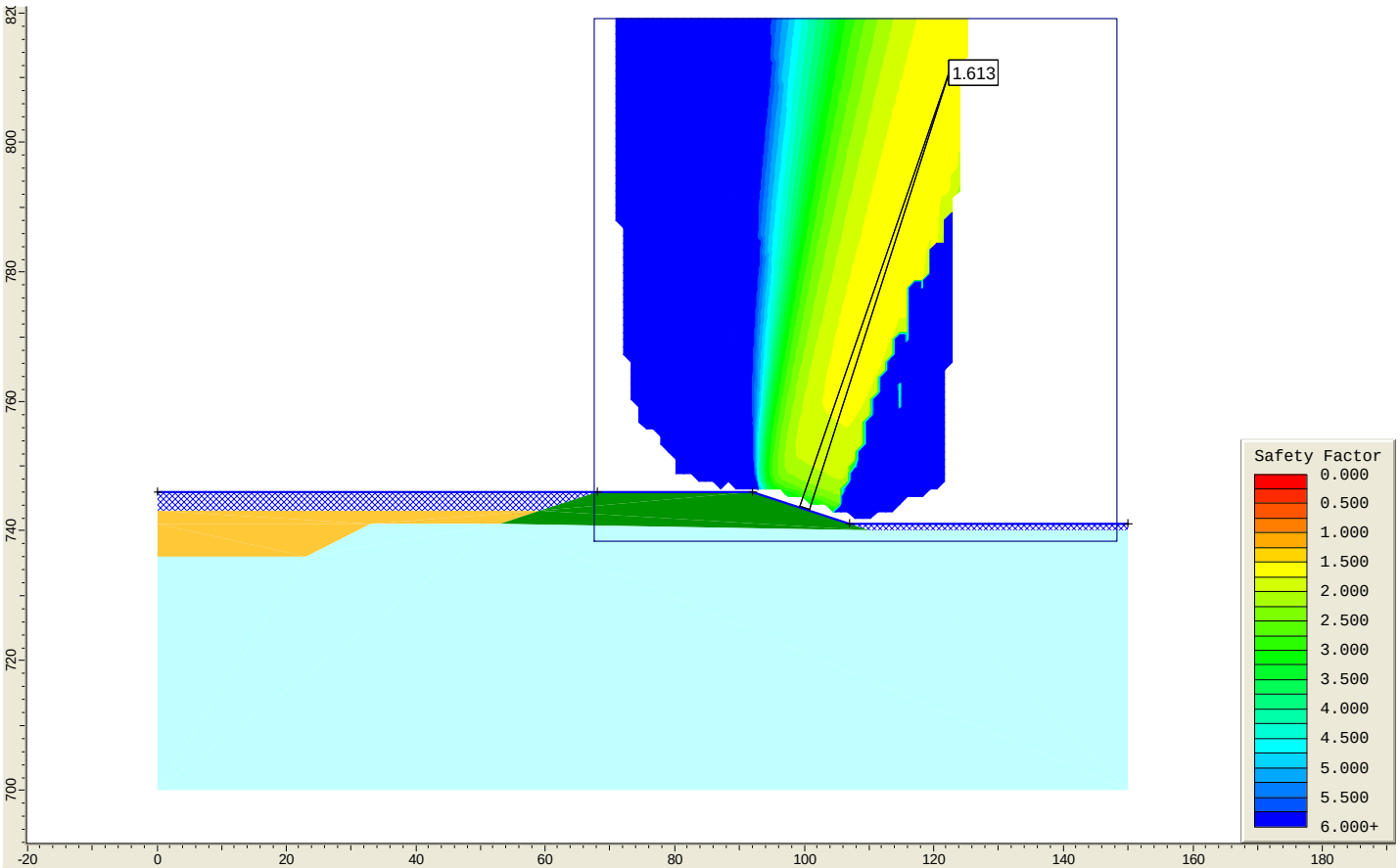
Material Boundary

53.000	741.000
59.000	743.000

Water Table

0.000	744.500
63.500	744.500
96.500	744.500
107.000	741.000
150.000	741.000

Written by:	**Joseph Sura**	Date:	**7/8/2010**	Reviewed by:	**Ming Zhu**	Date:	**7/9/2010**
Client:	**TVA**	Project:	**Integrity Evaluation of Dike 2**	Project/ Proposal No.:	**GK4693**	Task No.:	**03**



Static Slope Stability with Water Elevation of 746 ft

Slide Analysis Information

Document Name

File Name: Section A_746

Project Settings

Project Title: SLIDE - An Interactive Slope Stability Program
Failure Direction: Left to Right
Units of Measurement: Imperial Units
Pore Fluid Unit Weight: 62.4 lb/ft3
Groundwater Method: Water Surfaces
Data Output: Standard
Calculate Excess Pore Pressure: Off
Allow Ru with Water Surfaces or Grids: Off
Random Numbers: Pseudo-random Seed
Random Number Seed: 10116
Random Number Generation Method: Park and Miller v.3

Analysis Methods

Analysis Methods used:
Spencer

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50

Surface Options

Surface Type: Circular
Search Method: Grid Search
Radius increment: 10
Composite Surfaces: Disabled
Reverse Curvature: Invalid Surfaces
Minimum Elevation: Not Defined
Minimum Depth: Not Defined

Material Properties

Material: Rock Dike
Strength Type: Mohr-Coulomb
Unit Weight: 150 lb/ft3
Cohesion: 0 psf
Friction Angle: 45 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Ash (UD)
Strength Type: Undrained
Unit Weight: 107 lb/ft3
Cohesion Type: Constant
Cohesion: 100 psf
Water Surface: None

Material: Clay and Silt (UD)
Strength Type: Undrained
Unit Weight: 110 lb/ft3
Cohesion Type: Constant
Cohesion: 1200 psf
Water Surface: None

Global Minimums

Method: spencer
FS: 1.613400
Center: 122.843, 812.144
Radius: 72.507
Left Slip Surface Endpoint: 99.138, 743.621
Right Slip Surface Endpoint: 100.693, 743.102
Resisting Moment=27.9871 lb-ft
Driving Moment=17.3466 lb-ft
Resisting Horizontal Force=0.366185 lb
Driving Horizontal Force=0.226964 lb

Valid / Invalid Surfaces

Method: spencer
Number of Valid Surfaces: 26342
Number of Invalid Surfaces: 29109
Error Codes:
Error Code -102 reported for 118 surfaces
Error Code -103 reported for 294 surfaces
Error Code -106 reported for 641 surfaces
Error Code -107 reported for 5349 surfaces
Error Code -108 reported for 11566 surfaces
Error Code -111 reported for 486 surfaces
Error Code -112 reported for 558 surfaces
Error Code -114 reported for 3068 surfaces

Error Code -1000 reported for 7029 surfaces

Error Codes

The following errors were encountered during the computation:

-102 = Two surface / slope intersections, but resulting arc is actually outside soil region.

-103 = Two surface / slope intersections, but one or more surface / nonslope external polygon intersections lie between them. This usually occurs when the slip surface extends past the bottom of the soil region, but may also occur on a benched slope model with two sets of Slope Limits.

-106 = Average slice width is less than 0.0001 * (maximum horizontal extent of soil region). This limitation is imposed to avoid numerical errors which may result from too many slices, or too small a slip region.

-107 = Total driving moment or total driving force is negative. This will occur if the wrong failure direction is specified, or if high external or anchor loads are applied against the failure direction.

-108 = Total driving moment or total driving force < 0.1. This is to limit the calculation of extremely high safety factors if the driving force is very small (0.1 is an arbitrary number).

-111 = safety factor equation did not converge

-112 = The coefficient M-Alpha = cos(alpha)(1+tan(alpha)tan(phi)/F) < 0.2 for the final iteration of the safety factor calculation. This screens out some slip surfaces which may not be valid in the context of the analysis, in particular, deep seated slip surfaces with many high negative base angle slices in the passive zone.

-114 = Surface with Reverse Curvature.

-1000 = No valid slip surfaces are generated at a grid center. Unable to draw a surface.

List of All Coordinates

Search Grid

67.466	738.359
148.224	738.359
148.224	819.061
67.466	819.061

Material Boundary

53.000	741.000
110.000	740.000

Material Boundary

0.000	741.000
33.000	741.000
53.000	741.000

Material Boundary

0.000	736.000
23.000	736.000
33.000	741.000

Material Boundary

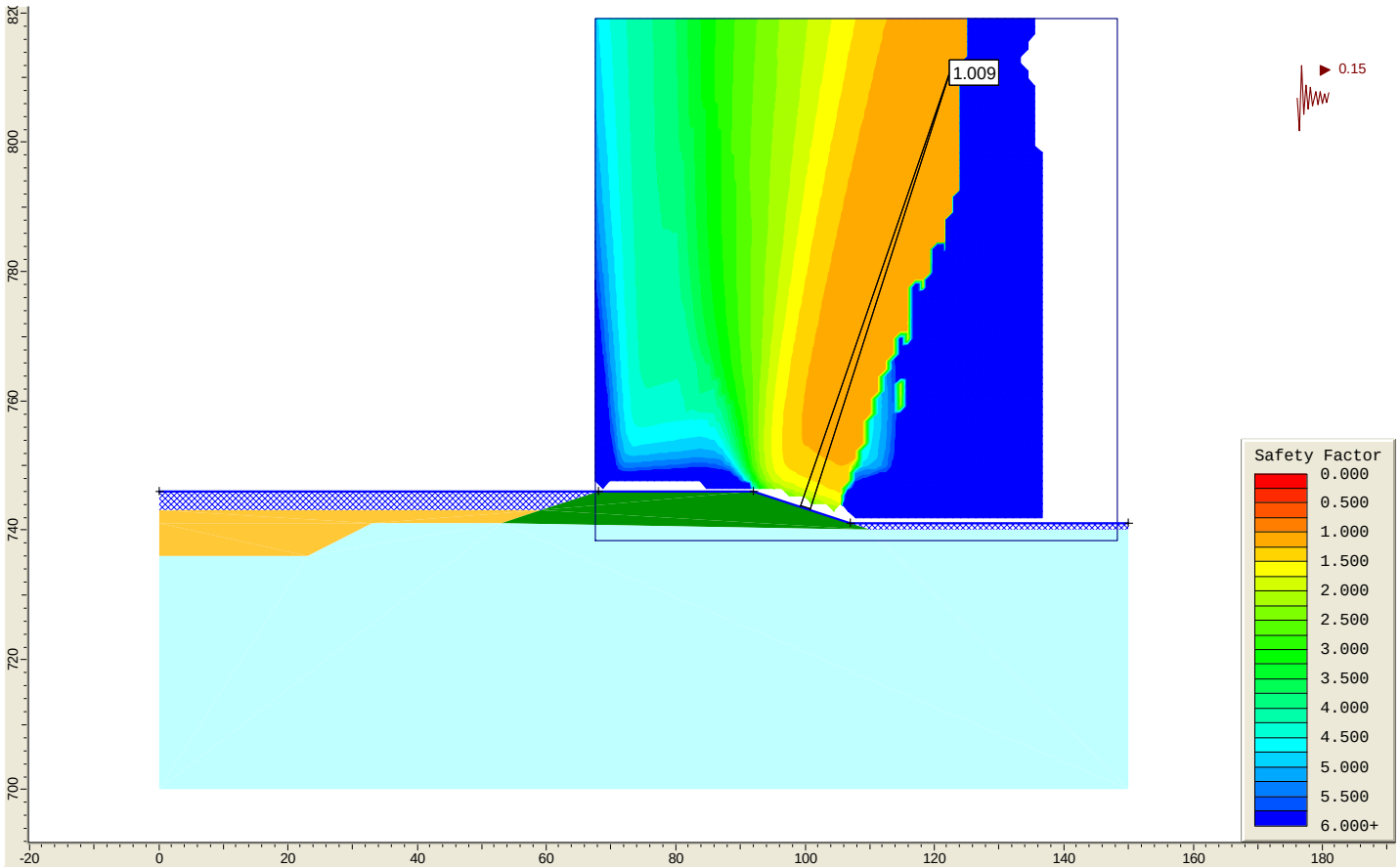
53.000	741.000
59.000	743.000

Water Table

0.000	746.000
68.000	746.000
92.000	746.000
107.000	741.000
150.000	741.000

Written by: **Joseph Sura** Date: **7/8/2010** Reviewed by: **Ming Zhu** Date: **7/9/2010**

Client: **TVA** Project: **Integrity Evaluation of Dike 2** Project/ Proposal No.: **GK4693** Task No.: **03**



Seismic Slope Stability with Water Elevation of 746 ft

Slide Analysis Information

Document Name

File Name: Section A_746_Seismic_FS1

Project Settings

Project Title: SLIDE - An Interactive Slope Stability Program
Failure Direction: Left to Right
Units of Measurement: Imperial Units
Pore Fluid Unit Weight: 62.4 lb/ft3
Groundwater Method: Water Surfaces
Data Output: Standard
Calculate Excess Pore Pressure: Off
Allow Ru with Water Surfaces or Grids: Off
Random Numbers: Pseudo-random Seed
Random Number Seed: 10116
Random Number Generation Method: Park and Miller v.3

Analysis Methods

Analysis Methods used:
Spencer

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50

Surface Options

Surface Type: Circular
Search Method: Grid Search
Radius increment: 10
Composite Surfaces: Disabled
Reverse Curvature: Invalid Surfaces
Minimum Elevation: Not Defined
Minimum Depth: Not Defined

Loading

Seismic Load Coefficient (Horizontal): 0.15

Material Properties

Material: Rock Dike
Strength Type: Mohr-Coulomb
Unit Weight: 150 lb/ft3
Cohesion: 0 psf
Friction Angle: 45 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Ash (UD)
Strength Type: Undrained
Unit Weight: 107 lb/ft3
Cohesion Type: Constant
Cohesion: 100 psf
Water Surface: None

Material: Clay and Silt (UD)
Strength Type: Undrained
Unit Weight: 110 lb/ft3
Cohesion Type: Constant
Cohesion: 1200 psf
Water Surface: None

Global Minimums

Method: spencer
FS: 1.009230
Center: 122.843, 812.144
Radius: 72.507
Left Slip Surface Endpoint: 99.138, 743.621
Right Slip Surface Endpoint: 100.693, 743.102
Resisting Moment=25.3847 lb-ft
Driving Moment=25.1525 lb-ft
Resisting Horizontal Force=0.33214 lb
Driving Horizontal Force=0.329101 lb

Valid / Invalid Surfaces

Method: spencer
Number of Valid Surfaces: 41392
Number of Invalid Surfaces: 14059
Error Codes:
Error Code -102 reported for 118 surfaces
Error Code -103 reported for 294 surfaces
Error Code -106 reported for 641 surfaces

Error Code -108 reported for 1516 surfaces
Error Code -111 reported for 508 surfaces
Error Code -112 reported for 885 surfaces
Error Code -114 reported for 3068 surfaces
Error Code -1000 reported for 7029 surfaces

Error Codes

The following errors were encountered during the computation:

-102 = Two surface / slope intersections, but resulting arc is actually outside soil region.

-103 = Two surface / slope intersections, but one or more surface / nonslope external polygon intersections lie between them. This usually occurs when the slip surface extends past the bottom of the soil region, but may also occur on a benched slope model with two sets of Slope Limits.

-106 = Average slice width is less than 0.0001 * (maximum horizontal extent of soil region). This limitation is imposed to avoid numerical errors which may result from too many slices, or too small a slip region.

-108 = Total driving moment or total driving force < 0.1. This is to limit the calculation of extremely high safety factors if the driving force is very small (0.1 is an arbitrary number).

-111 = safety factor equation did not converge

-112 = The coefficient M-Alpha = cos(alpha)(1+tan(alpha)tan(phi)/F) < 0.2 for the final iteration of the safety factor calculation. This screens out some slip surfaces which may not be valid in the context of the analysis, in particular, deep seated slip surfaces with many high negative base angle slices in the passive zone.

-114 = Surface with Reverse Curvature.

-1000 = No valid slip surfaces are generated at a grid center. Unable to draw a surface.

List of All Coordinates

Search Grid

67.466	738.359
148.224	738.359
148.224	819.061
67.466	819.061

Material Boundary

53.000	741.000
110.000	740.000

Material Boundary

0.000	741.000
33.000	741.000
53.000	741.000

Material Boundary

0.000	736.000
23.000	736.000
33.000	741.000

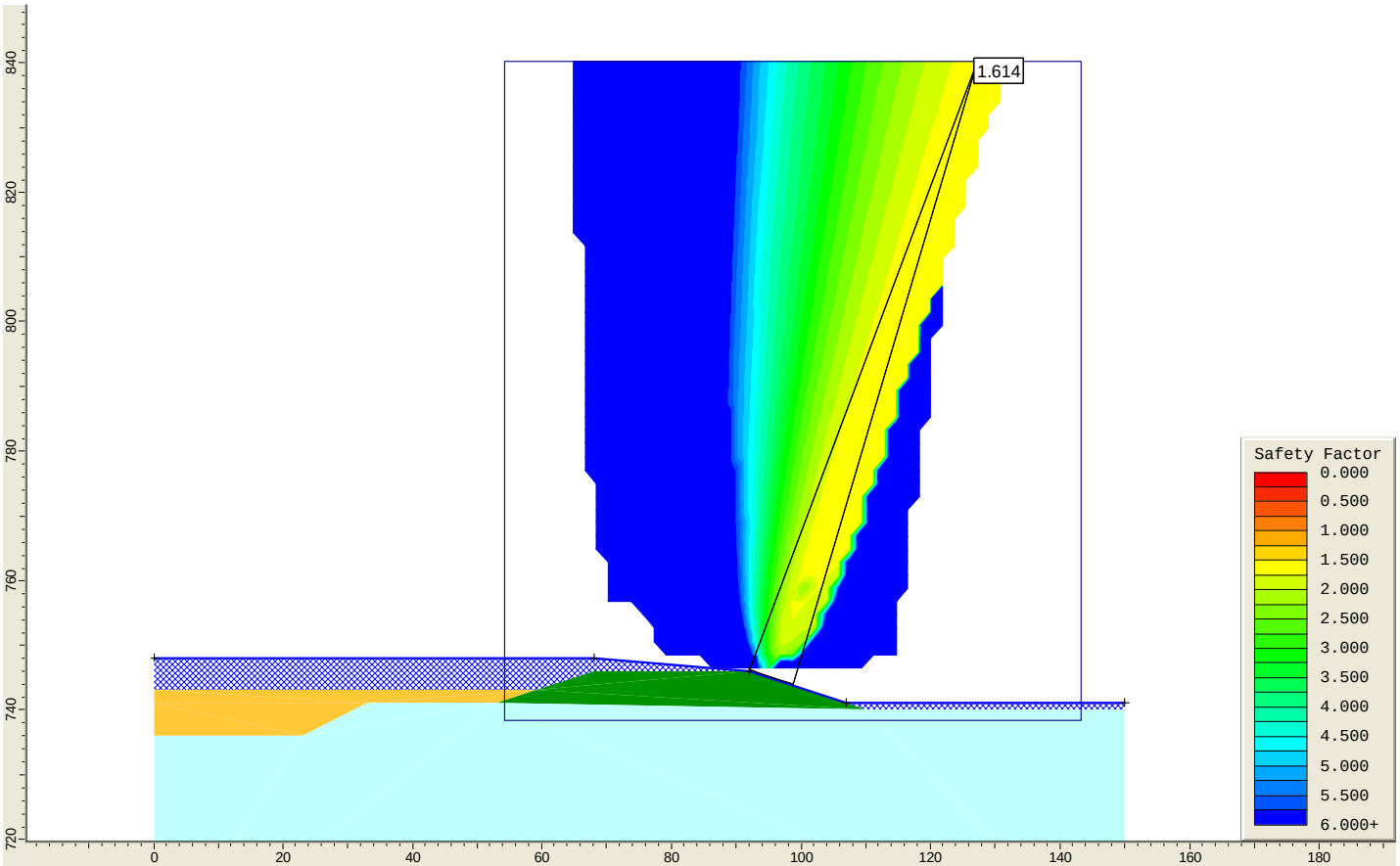
Material Boundary

53.000	741.000
59.000	743.000

Water Table

0.000	746.000
68.000	746.000
92.000	746.000
107.000	741.000
150.000	741.000

Written by:	**Joseph Sura**	Date:	**7/8/2010**	Reviewed by:	**Ming Zhu**	Date:	**7/9/2010**
Client:	**TVA**	Project:	**Integrity Evaluation of Dike 2**	Project/ Proposal No.:	**GK4693**	Task No.:	**03**



Static Slope Stability with Water Elevation of 748 ft

Slide Analysis Information

Document Name

File Name: Section A_748

Project Settings

Project Title: SLIDE - An Interactive Slope Stability Program
Failure Direction: Left to Right
Units of Measurement: Imperial Units
Pore Fluid Unit Weight: 62.4 lb/ft3
Groundwater Method: Water Surfaces
Data Output: Standard
Calculate Excess Pore Pressure: Off
Allow Ru with Water Surfaces or Grids: Off
Random Numbers: Pseudo-random Seed
Random Number Seed: 10116
Random Number Generation Method: Park and Miller v.3

Analysis Methods

Analysis Methods used:
Spencer

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50

Surface Options

Surface Type: Circular
Search Method: Grid Search
Radius increment: 10
Composite Surfaces: Disabled
Reverse Curvature: Invalid Surfaces
Minimum Elevation: Not Defined
Minimum Depth: Not Defined

Material Properties

Material: Rock Dike
Strength Type: Mohr-Coulomb
Unit Weight: 150 lb/ft3
Cohesion: 0 psf
Friction Angle: 45 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Ash (UD)
Strength Type: Undrained
Unit Weight: 107 lb/ft3
Cohesion Type: Constant
Cohesion: 100 psf
Water Surface: None

Material: Clay and Silt (UD)
Strength Type: Undrained
Unit Weight: 110 lb/ft3
Cohesion Type: Constant
Cohesion: 1200 psf
Water Surface: None

Global Minimums

Method: spencer
FS: 1.614190
Center: 127.148, 840.153
Radius: 100.500
Left Slip Surface Endpoint: 92.000, 746.000
Right Slip Surface Endpoint: 98.775, 743.742
Resisting Moment=2320.7 lb-ft
Driving Moment=1437.69 lb-ft
Resisting Horizontal Force=21.9076 lb
Driving Horizontal Force=13.5718 lb

Valid / Invalid Surfaces

Method: spencer
Number of Valid Surfaces: 14661
Number of Invalid Surfaces: 13950
Error Codes:
Error Code -101 reported for 12 surfaces
Error Code -103 reported for 288 surfaces
Error Code -107 reported for 2328 surfaces
Error Code -108 reported for 472 surfaces
Error Code -111 reported for 246 surfaces
Error Code -112 reported for 278 surfaces
Error Code -114 reported for 943 surfaces
Error Code -1000 reported for 9383 surfaces

Error Codes

The following errors were encountered during the computation:

-101 = Only one (or zero) surface / slope intersections.

-103 = Two surface / slope intersections, but one or more surface / nonslope external polygon intersections lie between them. This usually occurs when the slip surface extends past the bottom of the soil region, but may also occur on a benched slope model with two sets of Slope Limits.

-107 = Total driving moment or total driving force is negative. This will occur if the wrong failure direction is specified, or if high external or anchor loads are applied against the failure direction.

-108 = Total driving moment or total driving force < 0.1. This is to limit the calculation of extremely high safety factors if the driving force is very small (0.1 is an arbitrary number).

-111 = safety factor equation did not converge

-112 = The coefficient M-Alpha = cos(alpha)(1+tan(alpha)tan(phi)/F) < 0.2 for the final iteration of the safety factor calculation. This screens out some slip surfaces which may not be valid in the context of the analysis, in particular, deep seated slip surfaces with many high negative base angle slices in the passive zone.

-114 = Surface with Reverse Curvature.

-1000 = No valid slip surfaces are generated at a grid center. Unable to draw a surface.

List of All Coordinates

Search Grid

54.198	738.360
143.162	738.360
143.162	840.153
54.198	840.153

Material Boundary

53.000	741.000
110.000	740.000

Material Boundary

0.000	741.000
33.000	741.000
53.000	741.000

Material Boundary

0.000	736.000
23.000	736.000
33.000	741.000

Material Boundary

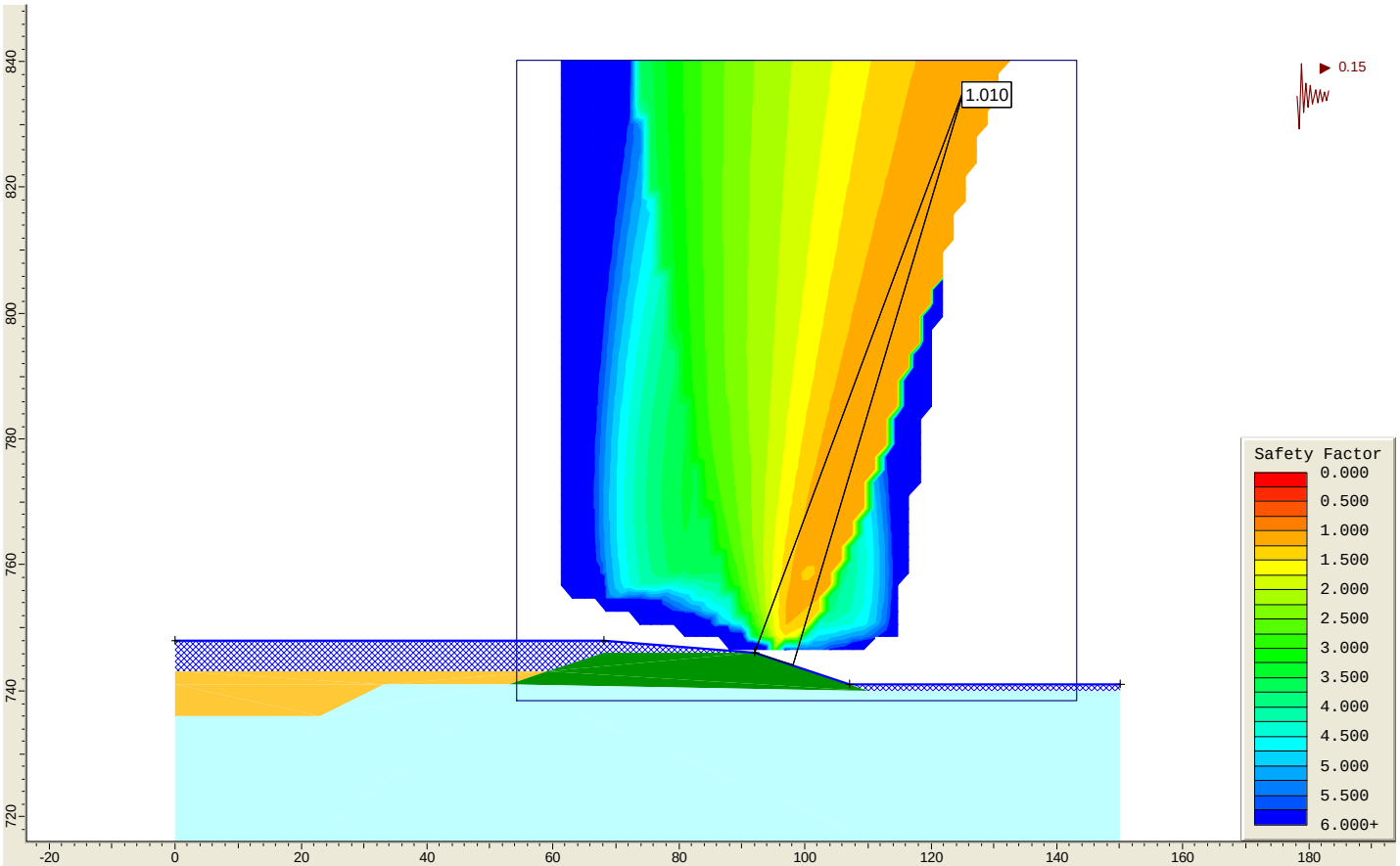
53.000	741.000
59.000	743.000

Water Table

0.000	748.000
68.000	748.000
92.000	746.000
107.000	741.000
150.000	741.000

Written by: **Joseph Sura** Date: **7/8/2010** Reviewed by: **Ming Zhu** Date: **7/9/2010**

Client: **TVA** Project: **Integrity Evaluation of Dike 2** Project/ Proposal No.: **GK4693** Task No.: **03**



Seismic Slope Stability with Water Elevation of 748 ft

Slide Analysis Information

Document Name

File Name: Section A_748_Seismic_FS1

Project Settings

Project Title: SLIDE - An Interactive Slope Stability Program
Failure Direction: Left to Right
Units of Measurement: Imperial Units
Pore Fluid Unit Weight: 62.4 lb/ft3
Groundwater Method: Water Surfaces
Data Output: Standard
Calculate Excess Pore Pressure: Off
Allow Ru with Water Surfaces or Grids: Off
Random Numbers: Pseudo-random Seed
Random Number Seed: 10116
Random Number Generation Method: Park and Miller v.3

Analysis Methods

Analysis Methods used:
Spencer

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50

Surface Options

Surface Type: Circular
Search Method: Grid Search
Radius increment: 10
Composite Surfaces: Disabled
Reverse Curvature: Invalid Surfaces
Minimum Elevation: Not Defined
Minimum Depth: Not Defined

Loading

Seismic Load Coefficient (Horizontal): 0.15

Material Properties

Material: Rock Dike
Strength Type: Mohr-Coulomb
Unit Weight: 150 lb/ft3
Cohesion: 0 psf
Friction Angle: 45 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Ash (UD)
Strength Type: Undrained
Unit Weight: 107 lb/ft3
Cohesion Type: Constant
Cohesion: 100 psf
Water Surface: None

Material: Clay and Silt (UD)
Strength Type: Undrained
Unit Weight: 110 lb/ft3
Cohesion Type: Constant
Cohesion: 1200 psf
Water Surface: None

Global Minimums

Method: spencer
FS: 1.009800
Center: 125.369, 836.081
Radius: 96.067
Left Slip Surface Endpoint: 91.988, 746.000
Right Slip Surface Endpoint: 98.136, 743.955
Left Slope Intercept: 91.988 746.001
Right Slope Intercept: 98.136 743.955
Resisting Moment=1655.85 lb-ft
Driving Moment=1639.79 lb-ft
Resisting Horizontal Force=16.3541 lb
Driving Horizontal Force=16.1954 lb

Valid / Invalid Surfaces

Method: spencer
Number of Valid Surfaces: 16904
Number of Invalid Surfaces: 11707
Error Codes:
Error Code -101 reported for 12 surfaces
Error Code -103 reported for 288 surfaces

Error Code -108 reported for 217 surfaces
Error Code -111 reported for 176 surfaces
Error Code -112 reported for 688 surfaces
Error Code -114 reported for 943 surfaces
Error Code -1000 reported for 9383 surfaces

Error Codes

The following errors were encountered during the computation:

-101 = Only one (or zero) surface / slope intersections.

-103 = Two surface / slope intersections, but one or more surface / nonslope external polygon intersections lie between them. This usually occurs when the slip surface extends past the bottom of the soil region, but may also occur on a benched slope model with two sets of Slope Limits.

-108 = Total driving moment or total driving force < 0.1. This is to limit the calculation of extremely high safety factors if the driving force is very small (0.1 is an arbitrary number).

-111 = safety factor equation did not converge

-112 = The coefficient M-Alpha = cos(alpha)(1+tan(alpha)tan(phi)/F) < 0.2 for the final iteration of the safety factor calculation. This screens out some slip surfaces which may not be valid in the context of the analysis, in particular, deep seated slip surfaces with many high negative base angle slices in the passive zone.

-114 = Surface with Reverse Curvature.

-1000 = No valid slip surfaces are generated at a grid center. Unable to draw a surface.

List of All Coordinates

Search Grid

54.198	738.360
143.162	738.360
143.162	840.153
54.198	840.153

Material Boundary

53.000	741.000
110.000	740.000

Material Boundary

0.000	741.000
33.000	741.000
53.000	741.000

Material Boundary

0.000	736.000
23.000	736.000
33.000	741.000

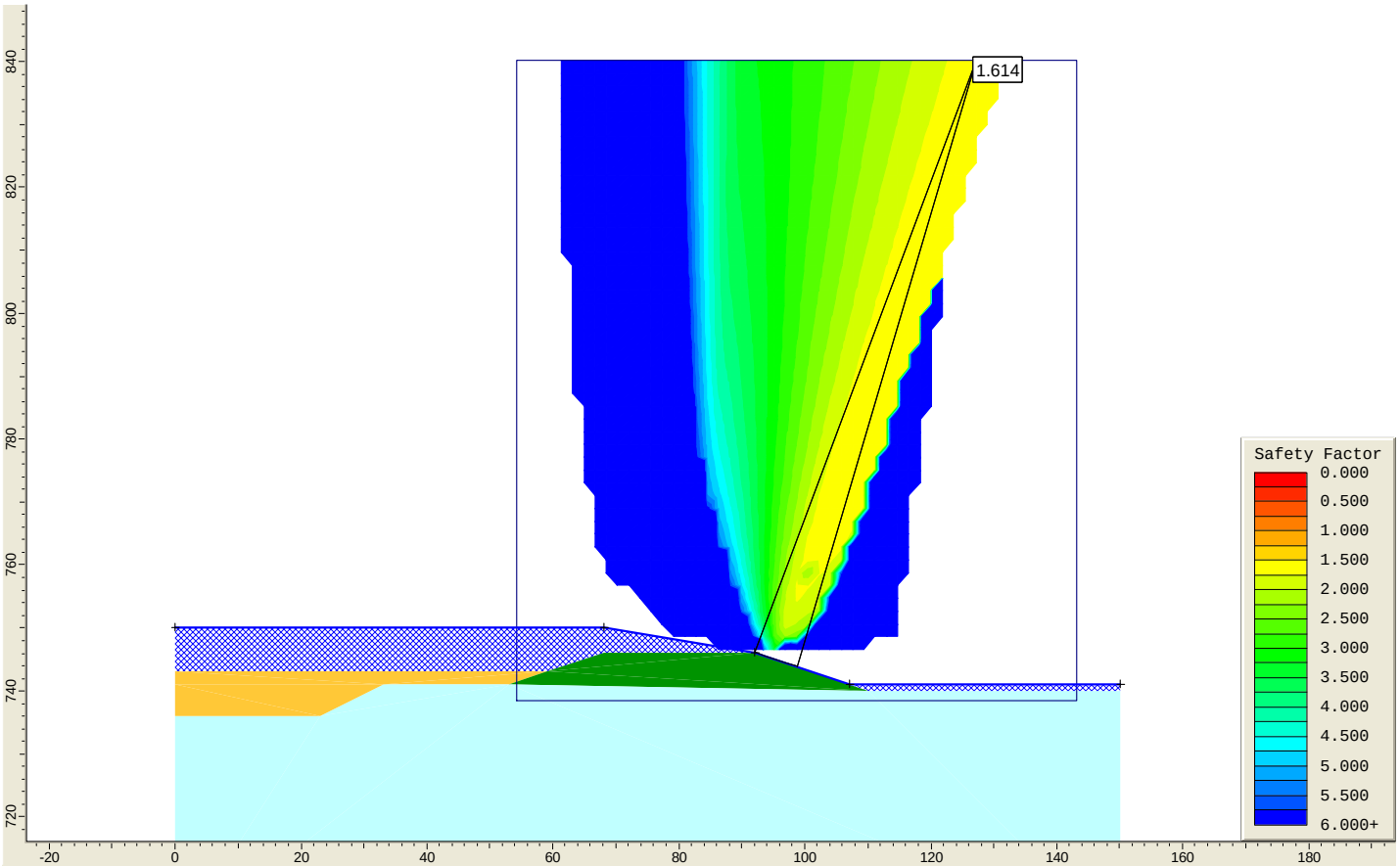
Material Boundary

53.000	741.000
59.000	743.000

Water Table

0.000	748.000
68.000	748.000
92.000	746.000
107.000	741.000
150.000	741.000

Written by:	**Joseph Sura**	Date:	**7/8/2010**	Reviewed by:	**Ming Zhu**	Date:	**7/9/2010**
Client:	**TVA**	Project:	**Integrity Evaluation of Dike 2**	Project/ Proposal No.:	**GK4693**	Task No.:	**03**



Static Slope Stability with Water Elevation of 750 ft

Slide Analysis Information

Document Name

File Name: Section A_750

Project Settings

Project Title: SLIDE - An Interactive Slope Stability Program
Failure Direction: Left to Right
Units of Measurement: Imperial Units
Pore Fluid Unit Weight: 62.4 lb/ft3
Groundwater Method: Water Surfaces
Data Output: Standard
Calculate Excess Pore Pressure: Off
Allow Ru with Water Surfaces or Grids: Off
Random Numbers: Pseudo-random Seed
Random Number Seed: 10116
Random Number Generation Method: Park and Miller v.3

Analysis Methods

Analysis Methods used:
Spencer

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50

Surface Options

Surface Type: Circular
Search Method: Grid Search
Radius increment: 10
Composite Surfaces: Disabled
Reverse Curvature: Invalid Surfaces
Minimum Elevation: Not Defined
Minimum Depth: Not Defined

Material Properties

Material: Rock Dike
Strength Type: Mohr-Coulomb
Unit Weight: 150 lb/ft3
Cohesion: 0 psf
Friction Angle: 45 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Ash (UD)
Strength Type: Undrained
Unit Weight: 107 lb/ft3
Cohesion Type: Constant
Cohesion: 100 psf
Water Surface: None

Material: Clay and Silt (UD)
Strength Type: Undrained
Unit Weight: 110 lb/ft3
Cohesion Type: Constant
Cohesion: 1200 psf
Water Surface: None

Global Minimums

Method: spencer
FS: 1.614200
Center: 127.148, 840.153
Radius: 100.500
Left Slip Surface Endpoint: 92.000, 746.000
Right Slip Surface Endpoint: 98.775, 743.742
Resisting Moment=2320.71 lb-ft
Driving Moment=1437.69 lb-ft
Resisting Horizontal Force=21.9076 lb
Driving Horizontal Force=13.5718 lb

Valid / Invalid Surfaces

Method: spencer
Number of Valid Surfaces: 15959
Number of Invalid Surfaces: 12652
Error Codes:
Error Code -101 reported for 12 surfaces
Error Code -103 reported for 288 surfaces
Error Code -107 reported for 788 surfaces
Error Code -108 reported for 635 surfaces
Error Code -111 reported for 264 surfaces
Error Code -112 reported for 339 surfaces
Error Code -114 reported for 943 surfaces
Error Code -1000 reported for 9383 surfaces

Error Codes

The following errors were encountered during the computation:

-101 = Only one (or zero) surface / slope intersections.

-103 = Two surface / slope intersections, but one or more surface / nonslope external polygon intersections lie between them. This usually occurs when the slip surface extends past the bottom of the soil region, but may also occur on a benched slope model with two sets of Slope Limits.

-107 = Total driving moment or total driving force is negative. This will occur if the wrong failure direction is specified, or if high external or anchor loads are applied against the failure direction.

-108 = Total driving moment or total driving force < 0.1. This is to limit the calculation of extremely high safety factors if the driving force is very small (0.1 is an arbitrary number).

-111 = safety factor equation did not converge

-112 = The coefficient M-Alpha = cos(alpha)(1+tan(alpha)tan(phi)/F) < 0.2 for the final iteration of the safety factor calculation. This screens out some slip surfaces which may not be valid in the context of the analysis, in particular, deep seated slip surfaces with many high negative base angle slices in the passive zone.

-114 = Surface with Reverse Curvature.

-1000 = No valid slip surfaces are generated at a grid center. Unable to draw a surface.

List of All Coordinates

Search Grid

54.198	738.360
143.162	738.360
143.162	840.153
54.198	840.153

Material Boundary

53.000	741.000
110.000	740.000

Material Boundary

0.000	741.000
33.000	741.000
53.000	741.000

Material Boundary

0.000	736.000
23.000	736.000
33.000	741.000

Material Boundary

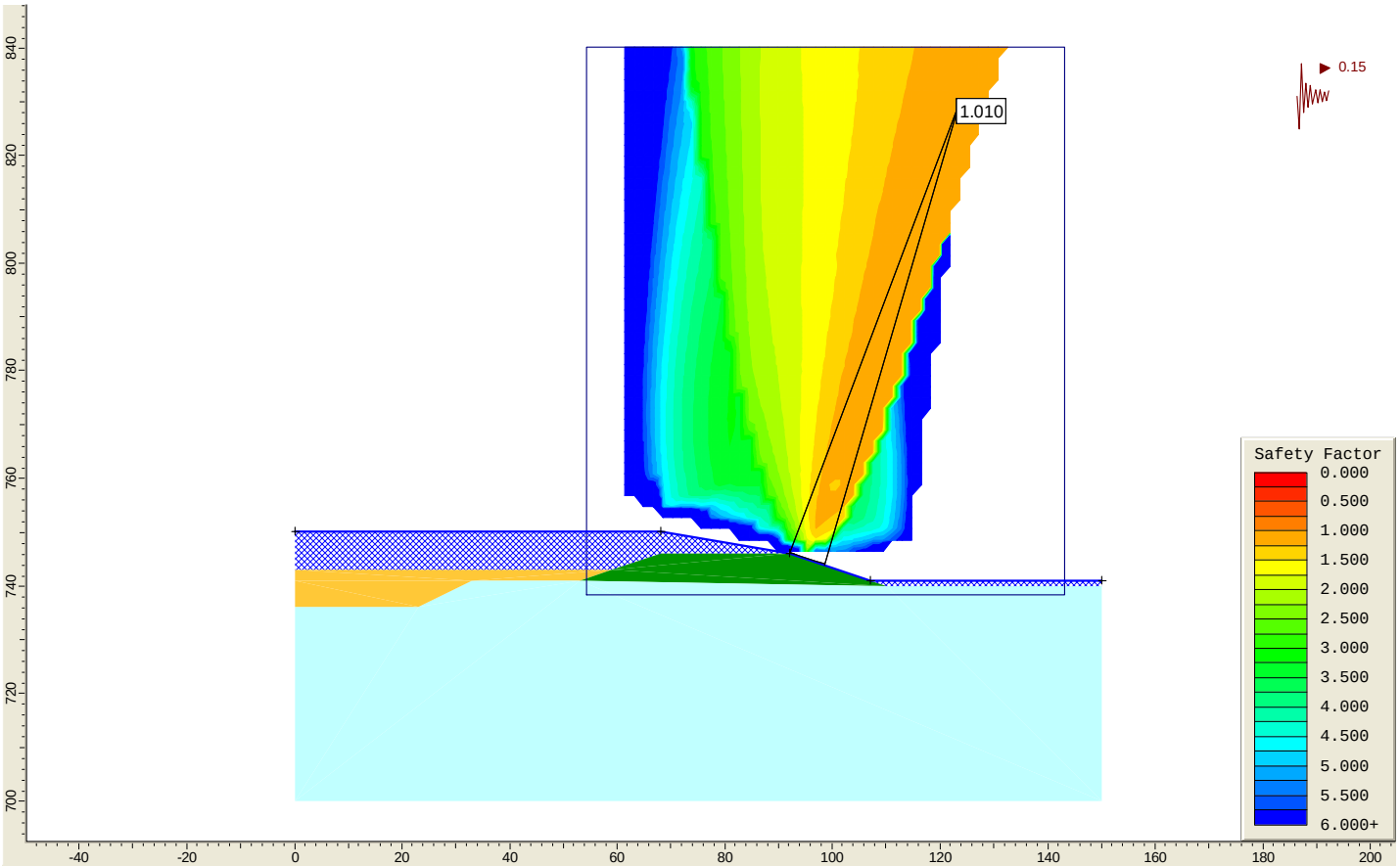
53.000	741.000
59.000	743.000

Water Table

0.000	750.000
68.000	750.000
92.000	746.000
107.000	741.000
150.000	741.000

Written by: **Joseph Sura** Date: **7/8/2010** Reviewed by: **Ming Zhu** Date: **7/9/2010**

Client: **TVA** Project: **Integrity Evaluation of Dike 2** Project/ Proposal No.: **GK4693** Task No.: **03**



Seismic Slope Stability with Water Elevation of 750 ft

Slide Analysis Information

Document Name

File Name: Section A_750_Seismic_FS1

Project Settings

Project Title: SLIDE - An Interactive Slope Stability Program
Failure Direction: Left to Right
Units of Measurement: Imperial Units
Pore Fluid Unit Weight: 62.4 lb/ft3
Groundwater Method: Water Surfaces
Data Output: Standard
Calculate Excess Pore Pressure: Off
Allow Ru with Water Surfaces or Grids: Off
Random Numbers: Pseudo-random Seed
Random Number Seed: 10116
Random Number Generation Method: Park and Miller v.3

Analysis Methods

Analysis Methods used:
Spencer

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50

Surface Options

Surface Type: Circular
Search Method: Grid Search
Radius increment: 10
Composite Surfaces: Disabled
Reverse Curvature: Invalid Surfaces
Minimum Elevation: Not Defined
Minimum Depth: Not Defined

Loading

Seismic Load Coefficient (Horizontal): 0.15

Material Properties

Material: Rock Dike
Strength Type: Mohr-Coulomb
Unit Weight: 150 lb/ft3
Cohesion: 0 psf
Friction Angle: 45 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Ash (UD)
Strength Type: Undrained
Unit Weight: 107 lb/ft3
Cohesion Type: Constant
Cohesion: 100 psf
Water Surface: None

Material: Clay and Silt (UD)
Strength Type: Undrained
Unit Weight: 110 lb/ft3
Cohesion Type: Constant
Cohesion: 1200 psf
Water Surface: None

Global Minimums

Method: spencer
FS: 1.009810
Center: 123.590, 829.974
Radius: 89.719
Left Slip Surface Endpoint: 92.000, 746.000
Right Slip Surface Endpoint: 98.478, 743.841
Resisting Moment=1839.5 lb-ft
Driving Moment=1821.63 lb-ft
Resisting Horizontal Force=19.4547 lb
Driving Horizontal Force=19.2657 lb

Valid / Invalid Surfaces

Method: spencer
Number of Valid Surfaces: 16861
Number of Invalid Surfaces: 11750
Error Codes:
Error Code -101 reported for 12 surfaces
Error Code -103 reported for 288 surfaces
Error Code -108 reported for 217 surfaces
Error Code -111 reported for 171 surfaces

Error Code -112 reported for 736 surfaces
Error Code -114 reported for 943 surfaces
Error Code -1000 reported for 9383 surfaces

Error Codes

The following errors were encountered during the computation:

-101 = Only one (or zero) surface / slope intersections.

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143.162	738.360
143.162	840.153
54.198	840.153

Material Boundary

53.000	741.000
110.000	740.000

Material Boundary

0.000	741.000
33.000	741.000
53.000	741.000

Material Boundary

0.000	736.000
23.000	736.000
33.000	741.000

Material Boundary

53.000	741.000
59.000	743.000

Water Table

0.000	750.000
68.000	750.000
92.000	746.000
107.000	741.000
150.000	741.000