MEMORANDUM

SUBJECT: EPA Comments on "Assessment of Dam Safety of Coal Combustion Surface Impoundments: Constellation Energy, NRG Energy, GenOn, and Others – Keystone Generating Station, Shelocta, Pennsylvania"

DATE: August 20, 2013

1. In Section 1.2.3 "Recommendations Regarding the Supporting Technical Documentation," please remove the statement "(This need not be rigorous analysis.)" as this may infer the wrong impression regarding the detail of analysis warranted, although "Basic" would be an accurate description of the minimal level.
2. In Section 2.1 "Location and Project Description," the final paragraph, it may be worth noting the management of FGD when speaking about the use of FGD systems. According to section 2.2.4, FGD is "dewatered and transported through an enclosed tubular gallery conveyor to a dome covered storage pad." It may be advantageous to note FGD gypsum is not sluiced or managed in embanked impoundments.
3. In section 2.5.1 "Earth Embankments/Ponds," it may be advantageous to explicitly state the hydraulic connection between the cells of the Ash Filter Ponds. It seems to be inferred with "three contiguous cells," but it may be advantageous to establish the potential or lack thereof of a hydraulic head difference between individual cells.
4. In section 7.1.1 "Stability Analyses and Load Cases Analyzed," the report states that no slope stability analyses was provided for the Ash Filter Ponds (Max height 10.5 ft). The unit is partly incised. The report goes on to state, Section 7.3 "Assessment of Structural Stability," that formal slope stability analysis, both static and seismic, for the Ash Filter Ponds is not warranted due to informal analysis being performed using soil parameters taken from the Thermal Pond, and assumption of increased conservative soil parameters yields factors of safety in excess of 1.6. EPA agrees with this rationalization of the lack of need for slope stability analysis. However, this section needs the following statements or clarifications from Dewberry:
    a. What is the basis for the assumption that "Ash Filter Pond dike embankment soils could reasonably be expected to have similar unit weight and strength parameters (as the Thermal Pond embankment soils)?" Clarification is needed, e.g., construction documentation, staff description of soils, best practice, etc.
    b. Provide a brief clarifier regarding the use of NAVFAC DM-7.1. if it is commonly used in engineering application, it should be explained as such.
    c. Provide a description of how the informal analysis meets the criteria for both static and seismic slope stability. Currently, the section is somewhat unclear of the loading conditions that are analyzed (assumed steady-state). Reasoning should be explained as to the stability of the embankment under dynamic (seismic) conditions.
    d. A statement explaining the potential for liquefaction should be stated. Is the liquefaction potential identical to the Thermal Ponds based on soil composition? If so, it should be explicitly stated.
    e. Removal of the "by comparison" element of the Thermal Pond. Section 7.2 explains that the analysis of the Thermal Pond is limited. Because the validity of the slope stability analysis for the Thermal Pond is somewhat impugned, the stability of the Ash Filter Ponds should stand on its own merit.
    f. Dewberry should provide a memorandum as an attachment explaining their analyses with the inclusion of applicable calculations, processes used and results shown.

g. Insert a statement that EPA has considered the lack of stability analysis and, based on the low height of the embankment, partially incised portion, low hazard potential, and justification by Dewberry, deems it not necessary for utility to perform independent formal structural stability analysis of the embankment.

From: Frank, Stephen
To: Hoffman, Stephen; Englander, Jana
Subject: Comment Request on Coal Ash Site Assessment Round 12 Draft Report - Keystone Generating Station
Date: Monday, November 25, 2013 10:43:46 AM
Attachments: Final MD13353_Keystone 11.19.13.pdf
Keystone - Ash Recycle Ponds Inspection Report.pdf
Keystone text revision.pdf

Dear Mr. Hoffman and Ms. Englander,

As requested, NRG has reviewed and is providing the following comments on the Draft Report for Keystone Generating Station:

1. The station operator is GenOn Northeast Management Company (GenOn), a subsidiary of NRG Energy, Inc. (NRG).

2. Revised text reflecting the ownership is attached.

3. The surveillance program has been formalized and expanded to include the Ash Filter Ponds (Example Inspection Report attached). The surveillance program includes a complete mowing of the embankments prior to the quarterly inspections.

4. Work is scheduled to paint corroded metal parts and hardware at the discharge structures.

5. Based on the assessment conducted by Geosyntec (attached), the embankments for the Ash Filter Ponds and Thermal Pond are sufficiently stable, and it is appropriate for the EPA to report a condition of “Satisfactory,” instead of “Fair,” for continued safe and reliable operations of the impoundments at the Keystone Generating Station.

6. An investigation of the seep area (Figure 5.3.3-1) observed along the access road berm ditch was evaluated by Geosyntec (attached) and was not found to be associated with a phreatic surface/line of seepage from the impounded water through the dam embankment.

Please do not hesitate to contact me with any questions or comments.

Thank you, Steve

NRG Energy

Stephen M. Frank, PE
Senior Environmental Specialist
NRG Energy Southpointe Operations Center
121 Champion Way, Suite 300
Canonsburg, PA 15317
P 724.597.8310
M 724.249.3610

Geosyntec consultants

10220 Old Columbia Road, Suite A
Columbia, Maryland 21046
PH 410.381.4333
FAX 410.381.4499
www.geosyntec.com

19 November 2013

NRG Energy Southpointe Operations Center
121 Champion Way, Suite 300
Canonsburg, PA 15317

Attention: Mr. Stephen Frank
Senior Environmental Specialist

Subject: Geotechnical and Hydraulic Assessment Report
Keystone Generating Station – Ash Filter Ponds and Thermal Pond
Shelocta, Pennsylvania

Dear Mr. Frank:

Geosyntec Consultants (Geosyntec) is pleased to submit this letter report presenting the findings of an assessment of the coal combustion waste (CCW) impoundments at the Keystone Generating Station (Site). The assessment was performed to address the recommendations of the draft report issued by the United States Environmental Protection Agency (EPA) regarding the condition of the impoundments. This report presents the results of the following assessment activities: (i) field investigation of soil properties of the impoundment embankments; (ii) general assessment of the geotechnical stability of the pond embankments; (iii) hydrologic/hydraulic evaluation of these ponds; and (iv) results and recommendations of a seepage evaluation of the thermal pond. This letter report was prepared by Dr. Chunling Li, P.E., and Mr. Wade Tyner, P.E. and it was reviewed by Dr. Lucas de Melo, P.E., and Mr. Michael Houlihan, P.E., in accordance with Geosyntec's peer review policy.

1. BACKGROUND

The CCW system at the site includes a cluster of three contiguous Ash Filter Ponds and a separate Thermal Pond. These CCW impoundments were recently evaluated by the EPA as part of its ongoing national effort to assess the management of coal combustion waste (CCW). The draft EPA report, prepared by Dewberry & Davis, LLC (Dewberry) and dated November 2012, provides a Condition Assessment for each of the impoundments. According to EPA's guidelines, the Condition Assessment result can be "Satisfactory", "Fair", "Poor", or "Unsatisfactory" based on the availability of data, analysis, loading condition, and several other factors. The EPA draft report for the Keystone site [Dewberry, 2012] provides a Condition Assessment result of "Fair" to both the Ash Filter Ponds and the Thermal Pond. The report

states that the "rating is influenced by the lack of some formal documentation of engineering analyses and the discrepancy in slope geometry that needs to be resolved."

Section 1.2.3 of the draft EPA report also provides the following recommendations for each of the impoundments:

Ash Filter Ponds:

Recommendation 1: "Prepare and maintain on file formal documentation of slope stability analyses. (This need not be a rigorous analysis.)"

Recommendation 2: "Prepare and maintain on file formal documentation of hydrologic/hydraulic safety. (This need not be a rigorous analysis)."

Thermal Pond:

Recommendation 1: "Provide PE or RLS certified documentation of the actual downstream slope geometry. If the actual slope geometry is found to be steeper or more critical than what was assumed in slope stability analyses, re-calculate the slope stability analyses to verify that acceptable safety margins exist."

Recommendation 2: "Investigate and provide documented field evidence that the source of the seep area observed along the access road berm ditch on the downstream right side of the main dam is not seepage through the embankment due to liner failure. It is suggested that this investigation include at least two temporary observation wells, with one of these installed on the dam crest above the seep area to check for a phreatic surface or line of seepage through the dam embankment. The other observation well would preferably be installed on the railroad embankment, if feasible, or on the berm next to the seep area."

NRG retained Geosyntec to perform an assessment of these CCW impoundments. The purpose of this assessment is to:

- Evaluate the conditions that led to the assessment outcome of "Fair"; and
- Address the recommendations provided in the EPA report.

The findings of the assessment are presented in this letter report.

2. SUMMARY OF WORK

Geosyntec's work conducted in response to EPA's comments is summarized in the following table.

TABLE 1
SUMMARY OF WORK

Keystone Generating Station
Shelocta, Pennsylvania

Impoundment	EPA Recommendation	Work Conducted	Relevant Portion in this Report
Ash Filter Ponds	1	• Field investigation and laboratory tests • Slope stability analyses • Liquefaction potential evaluation	Section 3, Appendices B and C Section 4, Appendix D Section 6
	2	• Hydrologic/Hydraulic analysis	Section 7
Thermal Pond	1	• Field investigation and laboratory tests • Slope stability analyses • Liquefaction potential evaluation	Section 3, Appendices B and C Section 4, Appendix D Section 6
	2	• Two piezometers installed and monitored	Section 5

3. GEOTECHNICAL FIELD INVESTIGATION

On 17 October 2013, Geosyntec conducted a geotechnical field investigation to collect data needed to assess the characteristics and properties of the Ash Filter Pond and Thermal Pond embankments. The geotechnical field investigation consisted of drilling four test borings, identified as B–1 through B–3, and TH–1, at the locations shown in Figures 1 and 2. These borings were all drilled from the crest of the exterior slope of the embankments. Boring TH–1, drilled near where a seep was observed at the Thermal Pond, was converted to a piezometer (PZ–1) for groundwater table monitoring. One additional piezometer (i.e., PZ–2) was installed on the railroad embankment but no soil samples were taken at the time of drilling because no relevant geotechnical information for the scope of this report could be obtained from this location. Borings B–1 through B–3 were drilled to an approximate depth of 16 to 21 feet below the existing ground surface (ft-bgs). Piezometer PZ–1(TH–1) was drilled to a depth of approximately 30 ft-bgs and piezometer PZ–2 to depth of approximately 25 ft-bgs.

A track-mounted hollow-stem auger was used to advance the test borings. The drill bit has an internal diameter of 3.25 inches and outside diameter of 6 inches. Soil samples were obtained using a split-spoon sampler in accordance with ASTM D 1586 [ASTM, 2009]. At each boring location, soil samples were obtained every 2 ft. Sampling was conducted continuously in all of the four borings. The soil penetration resistance was measured at all sample locations using the Standard Penetration Test (SPT) and recording blow counts (i.e., N-values). The N-value is the number of blows required for a 140-pound (lb.) hammer dropping 30 inches (in.) to drive the sampler through a 12-in. interval. Boring logs are included in Appendix B of this report. The geotechnical boreholes were backfilled to ground surface using a cement grout.

Based on the boring logs for B–1 through B–3, the Ash Filter Ponds' embankments were constructed using silty or clayey soils, which classifies under the Unified Soils Classifications system as CL (i.e., low-plasticity clay) and ML (i.e., sandy silt). The SPT N-values varied between 10 and 45 blows/ft. The soils below the original ground surface prior to pond construction have similar appearance and comparable SPT-N value; thus, they are considered to have similar physical properties to the fill material used for embankment construction. Indication of rock formation was encountered at approximately 20 ft-bgs; i.e., at the bottom of the three boring locations (i.e., B–1 through B–3), where refusal (likely rock blocks) was encountered.

At the Thermal Pond, soils in the upper 14 ft from the top of the embankment consists of silty sand (SM) or silty gravel (GM) and the SPT-N values ranges from 2 to 31 blows/ft (boring TH–1). The soils below the original ground surface prior to pond construction consist mainly of low plasticity clay with pockets of high-plasticity clay. The SPT-N values of the foundation soils below the embankment were between 6 and 20. The boring was terminated at a depth of 30 ft-bgs and no bedrock encountered at this location.

Laboratory test results were conducted to classify the soil samples collected from boring investigation. The tests conducted include:

- Water content tests (ASTM D2216)
- Grain size distribution tests (ASTM D1140)
- Atterberg Limit tests (ASTM D4318)

The results of laboratory tests are shown in Appendix C.

Shear strength properties for the embankment and foundations soils were derived from data collected during this field investigation and previous studies conducted as a part of the dam permit application [Gilbert, 1993]. The shear strength parameters and other soil parameters are presented in Appendix D (i.e., Stability Analysis).

The groundwater table was not encountered during drilling or after completion of the four borings.

4. STABILITY EVALUATION

Geosyntec performed a stability analysis for the Filter Ash Pond and Thermal pond embankments. Two representative cross sections were selected at each of the impoundments for the analysis based on review of subsurface conditions, visual inspection, and pond geometry. The locations of the selected cross sections are shown in Figures 1 and 2. These sections were selected because the embankment heights at these locations are the highest and the slopes are the steepest or longest. The most critical subsurface condition identified during the sub-surface investigation for each of the ponds was conservatively assumed to be present at these cross sections. Thus, the selected cross sections represent the most critical conditions and the analysis results will likely represent the lowest expected factor of safety against failure of the pond embankments.

Design drawings for the Thermal Pond were prepared by Gilbert Associates, Inc. dated August 1993. The exterior slope of the Thermal Pond was constructed with a slope steeper than design. Thus, the geometry for the Thermal Pond was selected from the aerial survey drawings provided by NRG on 8 October 2013. The Thermal Pond design drawings also show the grades of Ash Filter Ponds at the time the drawings were prepared. These grades were used to obtain the geometry of the Ash Filter Pond for this slope stability analysis.

Stability was analyzed under both static and seismic loading conditions. The impoundments were considered to be full because this is the critical failure scenario. No rapid drawdown analysis was found to be necessary because, under this loading condition, the inner slope of the empty pond would represent the critical failure condition, which would not cause ash release or result in a hazard of the type that is contemplated in the EPA assessment. The major static load applied to the foundation soils is the gravity load exerted by the weight of the berm. A surcharge load of 250 psf was applied to the top of the embankment to model traffic loading on top of the embankment. This is a conservative assumption, because traffic loads are not permanent loads. Seismic loading was modeled considering the maximum horizontal acceleration in bedrock for the Keystone facility site of 0.050*g* (where *g* is the gravitational acceleration) and seismic coefficient of 0.041. Details on the derivation of these parameters are included in Appendix D (i.e., Stability Analysis).

No phreatic surface would be expected to develop in the pond embankments if the liners at both the Filter Ash Ponds and the Thermal Pond perform as designed. To model the water pressure acting on the embankment, material inside the impoundments were represented by a no-shear strength material with unit weight of 62.4 lbs/ft^3.

If the seep at the Thermal Pond resulted from the leakage of the lined Thermal Pond, the seepage through the pond would negatively affect the stability of the embankment. However, because readings collected at the two piezometers installed near the seep indicated that water encountered at the impounded water location is likely not due to seepage (see Section below), seepage through the embankment was not considered in this slope stability analyses. Should future piezometer readings identify seepage through the embankment, slope stability should be reevaluated by a geotechnical engineer.

A summary of stability analyses results are presented in Table 2. Complete analyses are included in Appendix D (i.e., Stability Analysis).

TABLE 2
RESULTING FACTOR OF SAFETY – SLOPE STABILITY ANALYSIS

Keystone Generating Station
Shelocta, Pennsylvania

Cross Sections	Loading Conditions	Failure Mode	Calculated F.S.	Target F.S.
A-A (Ash Filter Pond)	Static (undrained)	Block	6.73	1.30
		Circular	6.83	1.30
	Static (drained)	Block	1.74	1.50
		Circular	1.96	1.50
	Seismic	Block	5.79	1.20
		Circular	5.78	1.20
B-B (Thermal Pond)	Static (undrained)	Block	1.87	1.30
		Circular	1.64	1.30
	Static (drained)	Block	1.67	1.50
		Circular	1.70	1.50
	Seismic	Block	1.69	1.20
		Circular	1.53	1.20

5. THERMAL POND GROUNDWATER MONITORING

In response to EPA's recommendations in the draft report, two piezometers were installed at the Thermal Pond area to assess potential groundwater flow near where the seep was observed and identify whether observed ponded water was due to seepage through the pond's liner system. Locations of the installed piezometers are shown in Figure 2. The as-built information for these piezometers, PZ-1, and PZ-2, are summarized below:

TABLE 3
PIEZOMETERS AS-BUILT INFORMATION

Keystone Generating Station
Shelocta, Pennsylvania

Piezometer	Total Depth Below Ground Surface (ft)	Depth to Bottom of Screen (ft)	Screen Interval Length (ft)	Ground Elevation (ft-msl)	Top of Casing Elevation (ft-msl)
PZ–1	29.73	29.73	25	1020.38	1021.5
PZ–2	25.75	25.75	20	1018.82	1020.7

The piezometers were found to be dry at completion of the monitoring well installation. On 30 October 2013 (i.e., two weeks after piezometer installation), Geosyntec field personnel collected reading at these piezometers. Both readings showed that the two piezometers were dry. At time of the second reading (i.e., on 30 October 2013), moist soils were found at the location previously identified by Dewberry [2012] as a potential seep location. Based on the results of the findings at the piezometers, it appears that the seep at this location is not the result of leakage through the Thermal Pond liner. The seep observed by Dewberry [2012] are likely due to other reasons other than leak through the liner, including perching water at a localized more-permeable soil pocket created by infiltrating surface water or leak from the piping system installed in the berm.

6. LIQUEFACTION POTENTIAL

Liquefaction is a phenomenon where soil substantially loses strength and stiffness in response to cyclic loads (e.g., earthquake) or change in stress state. Generally, liquefiable soils are saturated or nearly saturated loose sand with relatively low fines content. According to the boring logs, the soils present at the site below groundwater table are cohesive. Therefore, the soils at the site are not considered liquefiable. Additionally, the site is located in an area with low seismic activity. The potential for liquefaction in this site is considered negligible.

7. HYDROLOGIC/HYDRAULIC EVALUATION

Section 1.2.2 of the draft EPA report recommends that a hydrologic/hydraulic safety analysis be prepared for formal documentation purpose.

In response to this recommendation, Geosyntec has performed an evaluation of the hydrologic/hydraulic performance of the impoundments. Neither the Filter Ash Ponds nor the Thermal Ponds are designed to receive stormwater runoff from outside their footprints. The normal freeboard is maintained at least 2 ft below the top of the embankment in both the Ash Filter Ponds and the Thermal Pond, based on the drawings by Gilbert Associates, Inc. [1993]. The design precipitation depth at the high end of the design range (100-year frequency) is 5.77 inches or 0.48 ft, which is considerably less than the available freeboard. Thus, there is ample available surcharge storage for safe containment of the design precipitation over the pond area.

8. CONDITION ASSESSMENT

Condition Assessment definitions, as accepted by EPA, are as follows:

- *Satisfactory: No existing or potential management unit safety deficiencies are recognized. Acceptable performance is expected under all applicable loading conditions (static, hydrologic, seismic) in accordance with the applicable criteria. Minor maintenance items may be required.*

- *Fair: Acceptable performance is expected under all required loading conditions (static, hydrologic, seismic) in accordance with the applicable safety regulatory criteria. Minor deficiencies may exist that require remedial action and/or secondary studies or investigations.*

- *Poor: A management unit safety deficiency is recognized for a required loading condition (static, hydrologic, seismic) in accordance with the applicable dam safety regulatory criteria. Remedial action is necessary. "Poor" also applies when further critical studies or investigations are needed to identify any potential dam safety deficiencies.*

- *Unsatisfactory: Considered unsafe. A dam safety deficiency is recognized that requires immediate or emergency remedial action for problem resolution. Reservoir restrictions may be necessary."*

Based on the assessment conducted in this analysis, the embankments at the site are sufficiently stable. The Ash Filter Pond and Thermal Pond can safely contain the rainfall resulting from a 100-year precipitation event. It is our opinion that, with the additional information that is now

made available in this report, it would be appropriate for the EPA to report a condition of "Satisfactory", instead of "Fair", for the ponds at the site.

9. CONCLUSIONS

Based on the assessment described in this letter (as summarized in Table 1), Geosyntec concludes that the appropriate Condition Assessment result is "Satisfactory". Other than routine inspection for potential seep at the Thermal Pond, no other action is recommended at this time.

Geosyntec is confident that the findings discussed in this report address each of the EPA's comments provided in the Condition Assessment draft report for the Keystone facility. If EPA has additional comments or requests, we would be happy to address those.

Geosyntec appreciates the opportunity to be of assistance to NRG on this project. Please call any of the undersigned if you have any questions.

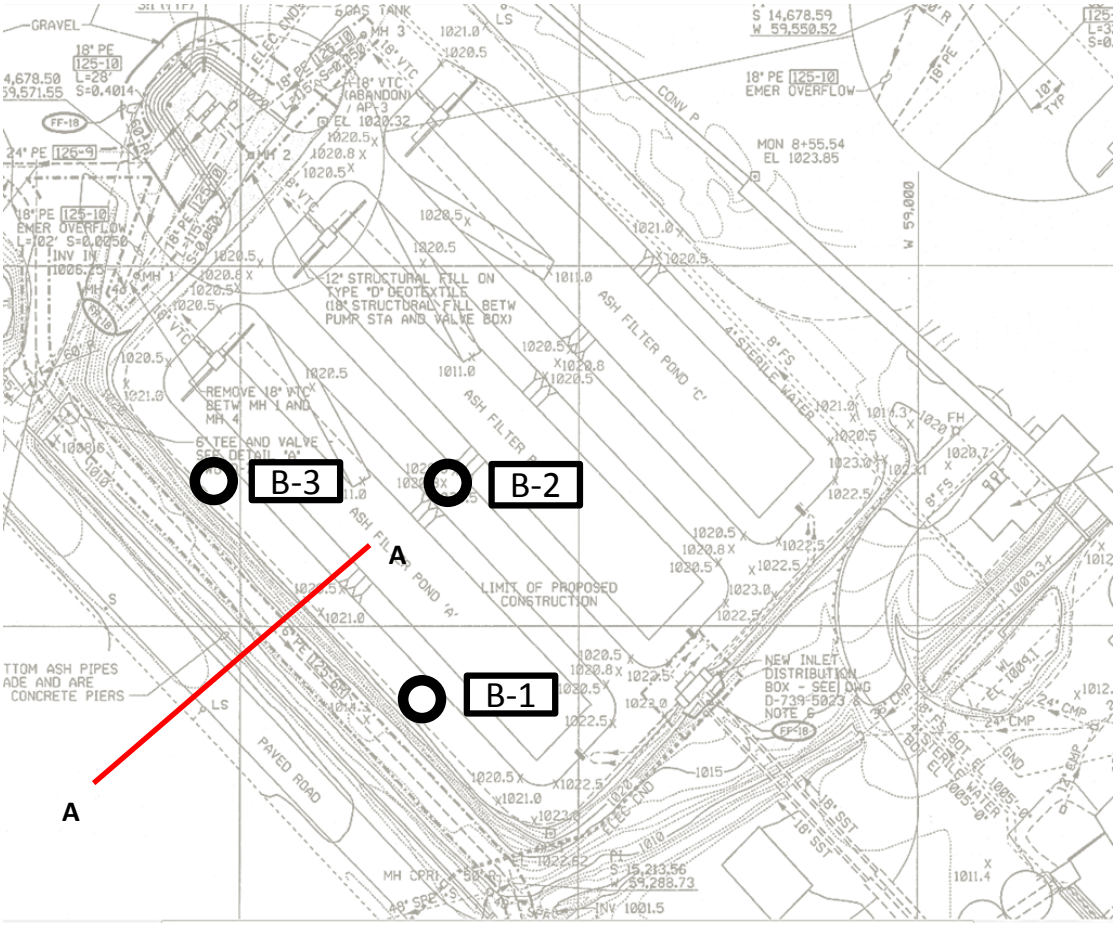
Sincerely,

Lucas de Melo, Ph.D., P.E.
Senior Engineer

Mike Houlihan, P.E.,
Principal

Attachments: Appendix A – References
Appendix B – Boring Logs
Appendix C – Laboratory Test Results
Appendix D – Stability Analysis

FIGURES



Legend

B-1 Approximate Boring Location

FIGURE 1 - SOIL BORING LOCATION

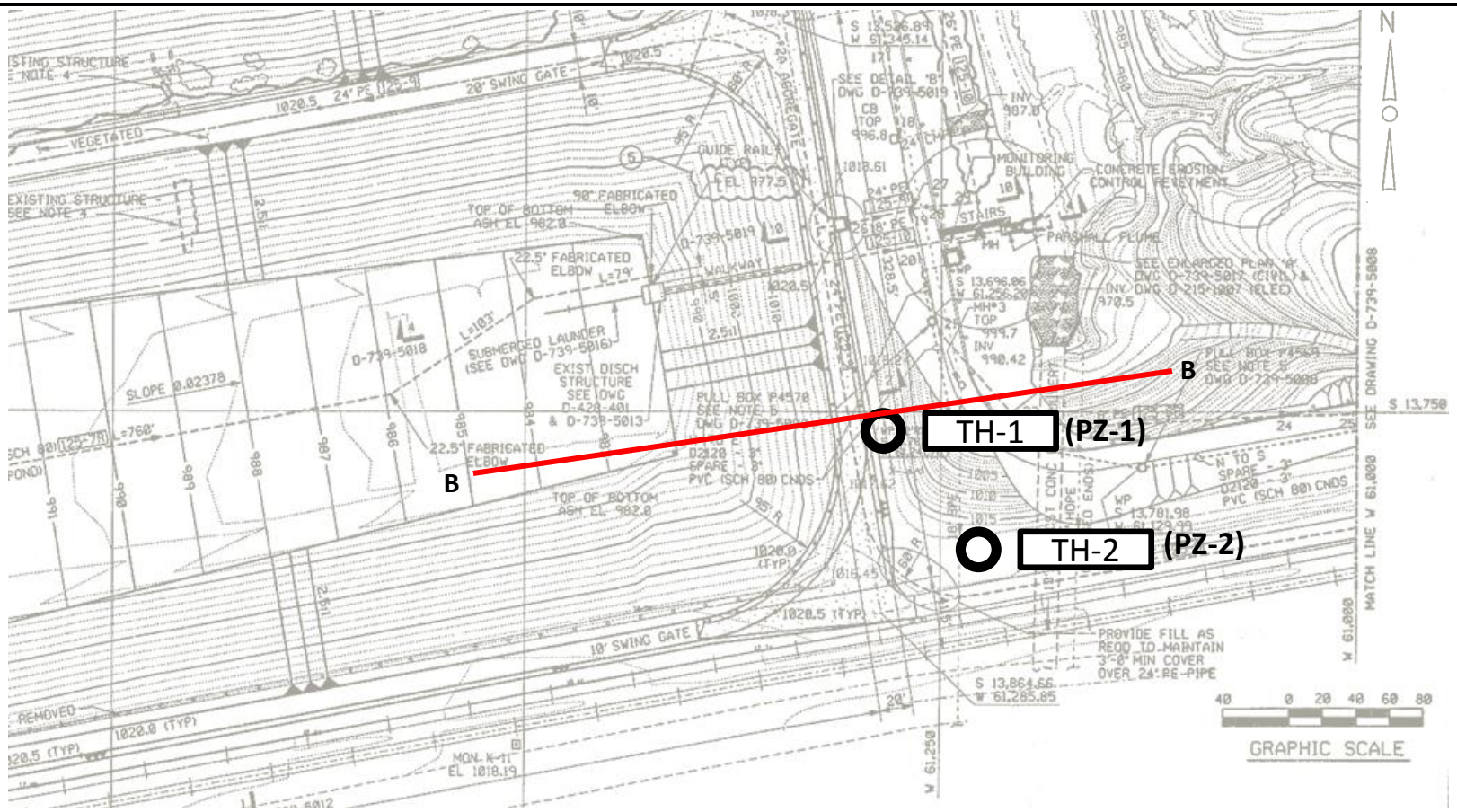
Keystone Generating Station – Ash Filter Pond

Shelocta, PA

Geosyntec consultants

COLUMBIA, MARYLAND

DATE:	Oct 2013
PROJECT NO.	ME1000
DOCUMENT NO.	
FIGURE NO:	1



Legend

B-1 Approximate Piezometer Location

FIGURE 2 - PIEZOMETER LOCATION

Keystone Generating Station – Thermal Pond

Shelocta, PA

Geosyntec consultants

COLUMBIA, MARYLAND

DATE:	Oct 2013
PROJECT NO.	ME1000
DOCUMENT NO.	
FIGURE NO:	2

APPENDIX A

REFERENCES

List of References

Dewberry & Davis, Inc. (2012)., "Coal Combustion Residue Impoundment Round 12 - Dam Assessment Report, Keystone Generating Station Ash Filter Ponds & Thermal Pond, GenOn Energy Shelocta, PA." prepared for United States Environmental Protection Agency, November, 2012 (draft).

Gilbert/Commonwealth, Inc. (1993), "Dam Permit Application, Industrial Waste Treatment Modifications: Thermal Discharge Abatement Project Cooling Ponds", Pennsylvania Electric Company Keystone Station, April, 1993.

Rocscience. (2012). "Slide (Version 6.0): A 2D Slope Stability Analysis for Soil and Rock Slopes", Toronto, Canada.

USGS (2008). "2008 United States National Seismic Hazard Maps", United States Geological Survey, http://earthquake.usgs.gov/research/hazmaps/products_data/2008/

APPENDIX B

BORING LOGS

BORING LOG

Geosyntec consultants
engineers | scientists | innovators

Boring ID	B-1		
Logged By	L. Chai	Elevation	90 feet from water
Date	10/16/2013	Northing	monitoring well
Project No.	ME1000	Easting	
Project Name	Keystone Power Plant		
		Drilling Method	HSA
Drilling Co.	Eichelbergers, Inc.	Bore Hole Diameter	6 inches
Driller(s)	Tom Growden	Cave Depth	N/A
Rig Type	Track Mounted HSA	Depth to Water	Not Encountered

Elevation	Depth (ft)	Blow Counts				N- Value	Material Description	USCS	Sample No.	Recovery
	0-2	6	10	12	10	22	Top 3": black topsoil, middle 1': gravel with sand, bottom 0.7': gray clay	GP CL	1	100%
	2-4	8	9	12	12	21	Multicolored yellowish orange, gray and black sility clay	CL	2	95%
	4-6	7	8	7	7	15	Light brown sility clay	CL	3	90%
	6-8	6	7	7	8	14	Light brown sility clay	CL	4	85%
	8-10	8	10	10	11	20	Light brown sility clay, with gray clay from 8.5' to 9.5'	CL	5	100%
	10-12	4	5	7	7	12	Yellowish orange silty clay, with trace black soil	CL	6	95%
	12-14	10	10	13	12	23	Yellowish orange silty clay, with trace black soil	CL	7	85%
	14-16	8	24	21	18	45	Top 1': Yellowish orange silty clay, with trace black silt (possibly ash), Bottom 1': coarse gravel with sandy silt	CL GM	8	100%
	16-18	REFUSE					No recovery, sampler refused at 16.3', N>50	N/A	9	0%
							BORING COMPELETE AT 16.3 FEET SAMPLE TUBE REFUSED BACKFILLED WITH CEMENT GROUT			

BORING LOG

Geosyntec consultants
engineers | scientists | innovators

Boring ID	B-2		
Logged By	L. Chai	Elevation	N/A
Date	10/16/2013	Northing	N/A
Project No.	ME1000	Easting	N/A
Project Name	Keystone Power Plant		
		Drilling Method	HSA
Drilling Co.	Eichelbergers, Inc.	Bore Hole Diameter	6 inches
Driller(s)	Tom Growden	Cave Depth	N/A
Rig Type	Track Mounted HSA	Depth to Water	Not Encountered

Elevation	Depth (ft)	Blow Counts				N- Value	Material Description	USCS	Sample No.	Recovery
	0-2	7	9	7	9	16	top 2": Black top soil, middle 8": coarse gravel with sand, bottom 1': clayey silt	GM ML	1	90%
	2-4	8	10	11	10	21	Light brown silty clay with trace sand	CL	2	95%
	4-6	3	5	8	10	13	Light brown silty clay with few gray clay	CL	3	80%
	6-8	8	7	9	10	16	Light brown silty clay with few gray clay	CL	4	90%
	8-10	8	9	9	11	18	Light brown silty clay with little gray clay	CL	5	75%
	10-12	6	7	10	13	17	Top 0.5': silty sand with trace black soil Bottom 1.5': Light brown silty clay with little gray clay	SM CL	6	100%
	12-14	10	10	12	11	22	Light brown silty clay with few gray clay	CL	7	90%
	14-16	4	5	6	7	11	Light brown silty clay with few gray clay, 1" thick layer of sand at around 15.3'	CL	8	100%
	16-18	5	9	9	9	18	Top 1': Yellowish silty clay Bottom 1': Sandy silt with coarse gravel	CL SM	9	90%
	18-20	6	10	15	22	25	Yellowish orange clay with fine gravel, wet clay at from 18.0' to 18.2' Bottom 2": gravel	CL	10	90%
	20-22	REFUSE					Sandy silt with little coarse gravel, sample tube refused at 21.2'	GM	11	60%
							BORING COMPLETE AT 21.2 FEET SAMPLE TUBE REFUSED BACKFILLED WITH CEMENT GROUT			

BORING LOG

Geosyntec consultants
engineers | scientists | innovators

Boring ID	B-3		
Logged By	L. Chai	Elevation	125 feet from water
Date	10/16/2013	Northing	monitoring well
Project No.	ME1000	Easting	
Project Name	Keystone Power Plant		
		Drilling Method	HSA
Drilling Co.	Eichelbergers, Inc.	Bore Hole Diameter	6 inches
Driller(s)	Tom Growden	Cave Depth	N/A
Rig Type	Track Mounted HSA	Depth to Water	Not Encountered

Elevation	Depth (ft)	Blow Counts				N- Value	Material Description	USCS	Sample No.	Recovery
	0-2	5	7	9	13	16	Top 3": black top soil. Below: clayey silt with few coarse gravel	ML	1	90%
	2-4	9	9	10	10	19	Light brown clayey silt. Bottom 1': greenish sility clay	ML CL	2	100%
	4-6	4	5	8	7	13	Light brown silty clay with few sand	CL	3	70%
	6-8	5	7	9	10	16	Light brown silty clay with gray clay	CL	4	80%
	8-10	10	8	8	9	16	Gray clay with light brown clayey silt, and with trace coal	CL	5	95%
	10-12	3	4	6	9	10	Gray clay with light brown clayey silt, with trace gravel	CL	6	85%
	12-14	4	7	10	10	17	Light brown silty clay, with gray clay	CL	7	80%
	14-16	7	8	10	12	18	Light brown silty clay, with gray clay bottom 1': yellowish orange silty clay	CL CL	8	100%
	16-18	8	12	13	18	25	Yellowish orange sility clay with trace sand	CL	9	90%
	18-20	REFUSE					Yellowish orange sility clay with trace sand, 1" thick of wet clay at 19' Bottom 0.5': gravel sheet, Refused at 18.9'	CL GP	10	45%
							BORING COMPLETE AT 18.9 FEET SAMPLE TUBE REFUSED BACKFILLED WITH CEMENT GROUT			

BORING LOG

Geosyntec consultants
engineers | scientists | innovators

Boring ID	TH-1 (Piezometer 1)		
Logged By	L. Chai	Elevation	N/A
Date	10/17/2013	Northing	N/A
Project No.	ME1000	Easting	N/A
Project Name	Keystone Power Plant		
		Drilling Method	HSA
Drilling Co.	Eichelbergers, Inc.	Bore Hole Diameter	6 inches
Driller(s)	Tom Growden	Cave Depth	N/A
Rig Type	Track Mounted HSA	Depth to Water	Not Encountered

Elevation	Depth (ft)	Blow Counts				N- Value	Material Description	USCS	Sample No.	Recovery
	0-2	3	4	4	8	8	Top 1": black top soil. Below: fine to coarse gravel with silty sand	GM	1	80%
	2-4	5	4	2	1	6	Clayey silt with some gravel	SM	2	20%
	4-6	3	1	1	1	2	Coarse gravel with clayey silt	GM	3	20%
	6-8	1	1	1	6	2	Yellowish orange clayey silt with some fine to coarse gravel, well graded, bottom 4": wet silt	SC	4	50%
	8-10	6	9	11	26	20	Gravel with sandy silt with clay, bottom 6": gravel sheets with sand	GM	5	90%
	10-12	3	6	8	11	14	Sandy silt with little gravel	SM	6	80%
	12-14	9	14	17	17	31	Sandy silt with some gravel, well graded	SM	7	100%
	14-16	5	7	5	3	12	Mottled gray and yellowish sandy clay with few gravel Bottom 8": wet clay	CL	8	100%
	16-18	5	6	8	8	14	High plastic mottled gray and yellowish clay	CH	9	85%
	18-20	7	6	8	9	14	High plastic mottled gray and yellowish clay Bottom 1': very moist	CH	10	100%
	20-22	6	8	6	7	14	Yellowish silty clay with some gravel Bottom 6": Dark gray silty clay with some gravel	CL	11	95%
	22-24	8	11	9	7	20	Dark gray silty clay with some gravel	CL	12	100%
	24-26	6	4	3	4	7	Dark gray silty clay with little gravel	CL	13	75%
	26-28	4	3	3	4	6	Dark gray silty clay with some gravel	CL	14	75%
	28-30	4	6	4	7	10	Dark gray silty clay with some gravel BORING COMPLETE @ 30 FEET, PIEZOMETER INSTALLED	CL	15	20%

APPENDIX C

LABORATORY TEST RESULTS

TRI/ENVIRONMENTAL, INC.
A Texas Research International Company

Client: Geosyntec Consultant
Project: NRG (Keystone): ME 1000

TRI Log No.: E2377-48-01
Test Methods: As-Noted

Jeffrey A. Kuhn, Ph.D., P.E., 10/25/13
Quality Review/Date

Tested by: Tierra Jackson and Kahlil Hart

	ASTM Standard							
	D2216			D1140	D4318			
Sample ID	w (%)	γ_{total} (pcf)	γ_{dry} (pcf)	Percent Fines	Liquid Limit	Plastic Limit	Plastic Index	USCS**
B-1 (10-12) (12-14)	18.8	-	-	71.6	33	21	12	CL
B-2 (4-6) (20-21.2)	10.0	-	-	63.7	30	19	11	CL
B-3 (10-12)*	18.0	-	-	-	31	19	12	-
TH-1 (4-6, 16-18, 26-28)	18.2	-	-	30.7	27	19	8	SC

*As per clients instructions, grain size analsis was not performed due to limited sample quantity.

**For full USCS classification/description, please refer to D422-D2216-D4318 reports.

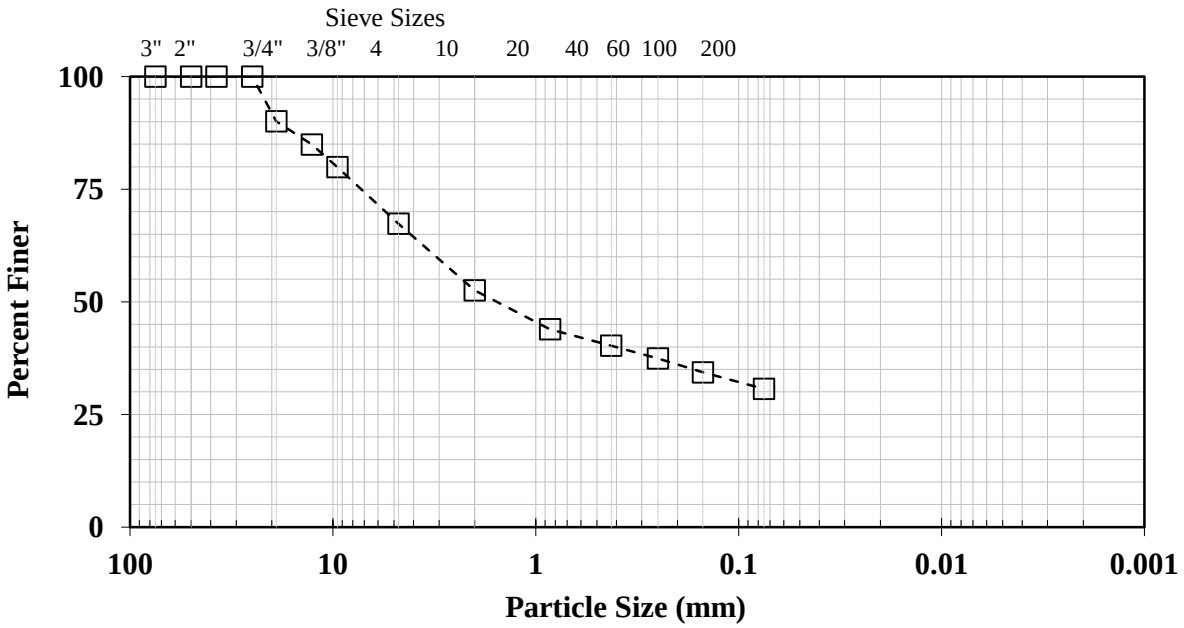
9063 Bee Caves Road □ Austin, TX 78733-6201 □ (512) 263-2101 □ (512) 263-2558 □ 1-800-880-TEST

TRI/ENVIRONMENTAL, INC.
A Texas Research International Company

Particle Size Analysis for Soils

Client: Geosyntec Consultant
Project: NRG (Keystone)
Sample: TH-1 (4-6, 16-18, 26-28)

TRI Log#: E2377-48-01
Test Method: D422
Test Date: 10/22/13



Sieve Analysis	
Sieve Size	Percent Passing
3 in.	100.0
2 in.	100.0
1.5 in.	100.0
1 in.	100.0
3/4 in.	90.1
1/2 in.	84.9
3/8 in.	79.9
No. 4 (4.75 mm)	67.3
No. 10 (2.00 mm)	52.5
No. 20 (850 µm)	43.9
No. 40 (425 µm)	40.3
No. 60 (250 µm)	37.4
No. 100 (150 µm)	34.3
No. 200 (75 µm)	30.7
Hydrometer Analysis	
Particle Size	Percent Passing
0.074 mm	- -
0.005 mm	- -
0.001 mm	- -

USCS Classification (ASTM D2487)	Clayey Sand (SC)	
As-Received Moisture Content (%)	(ASTM D2216)	18.2
Atterberg Limits (ASTM D 4318, Method A : Multipoint)	Liquid Limit (3 pt)	27
	Plastic Limit	19
	Plastic Index	8
Notes: Specimen was air dried, 3 point Liquid Limit procedure was used. (NL = No Liquid Limit, NP = No Plastic Limit)		
Specific Gravity	(ASTM D854)	- -
Organic Content (%)	(ASTM D2974)	- -
Carbonate Content (%)	(ASTM 4373)	- -

Jeffrey A. Kuhn, Ph.D., P.E., 10/25/2013
Quality Review/Date
Tested by: Kahlil Hart & Tierra Jackson

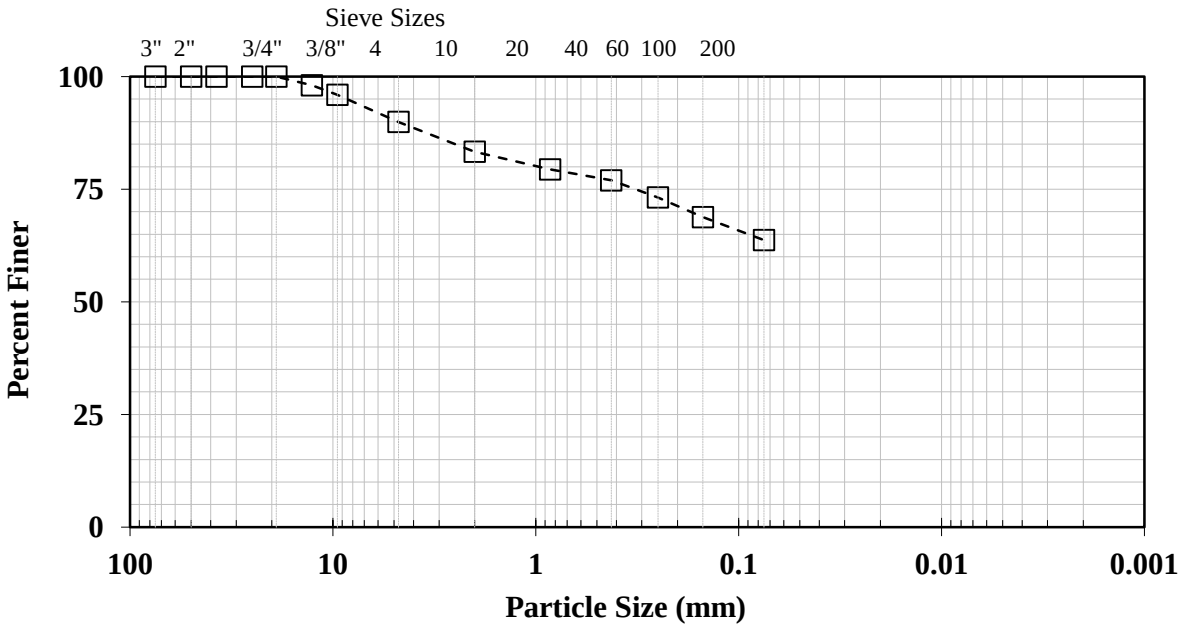
9063 Bee Caves Road □ Austin, TX 78733-6201 □ (512) 263-2101 □ (512) 263-2558 □ 1-800-880-TEST

TRI/ENVIRONMENTAL, INC.
A Texas Research International Company

Particle Size Analysis for Soils

Client: Geosyntec Consultant
Project: NRG (Keystone): ME 1000
Sample: B-2 (4-6, 20-21.2)

TRI Log#: E2377-48-01
Test Method: D422
Test Date: 10/22/13



Sieve Analysis	
Sieve Size	Percent Passing
3 in.	100.0
2 in.	100.0
1.5 in.	100.0
1 in.	100.0
3/4 in.	100.0
1/2 in.	98.1
3/8 in.	96.0
No. 4 (4.75 mm)	89.9
No. 10 (2.00 mm)	83.3
No. 20 (850 µm)	79.4
No. 40 (425 µm)	77.0
No. 60 (250 µm)	73.2
No. 100 (150 µm)	68.8
No. 200 (75 µm)	63.7
Hydrometer Analysis	
Particle Size	Percent Passing
0.074 mm	- -
0.005 mm	- -
0.001 mm	- -

USCS Classification (ASTM D2487)	Sandy Lean Clay	
As-Received Moisture Content (%)	(ASTM D2216)	10.0
Atterberg Limits (ASTM D 4318, Method A : Multipoint)	Liquid Limit (3 pt)	30
	Plastic Limit	19
	Plastic Index	11
Notes: Specimen was air dried, 3 point Liquid Limit procedure was used. (NL = No Liquid Limit, NP = No Plastic Limit)		
Specific Gravity	(ASTM D854)	- -
Organic Content (%)	(ASTM D2974)	- -
Carbonate Content (%)	(ASTM 4373)	- -

Jeffrey A. Kuhn, Ph.D., P.E., 10/25/2013
Quality Review/Date
Tested by: Kahlil Hart & Tierra Jackson

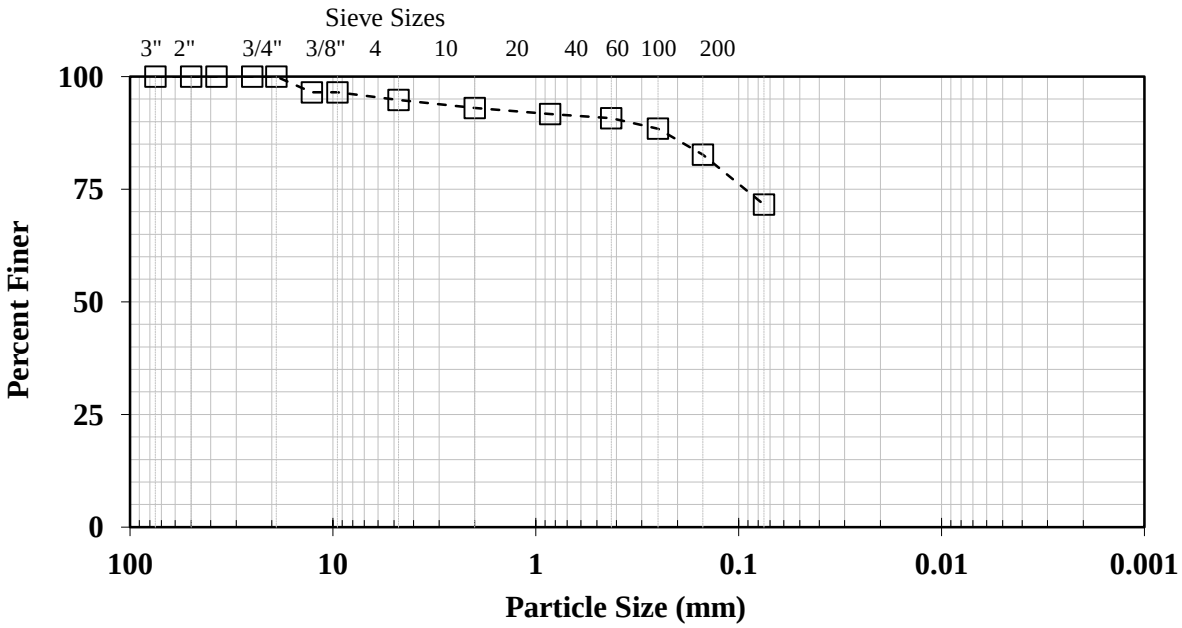
9063 Bee Caves Road □ Austin, TX 78733-6201 □ (512) 263-2101 □ (512) 263-2558 □ 1-800-880-TEST

TRI/ENVIRONMENTAL, INC.
A Texas Research International Company

Particle Size Analysis for Soils

Client: Geosyntec Consultant
Project: NRG (Keystone): ME 1000
Sample: B-1 (10-12, 12-14)

TRI Log#: E2377-48-01
Test Method: D422
Test Date: 10/22/13



Sieve Analysis	
Sieve Size	Percent Passing
3 in.	100.0
2 in.	100.0
1.5 in.	100.0
1 in.	100.0
3/4 in.	100.0
1/2 in.	96.5
3/8 in.	96.5
No. 4 (4.75 mm)	94.8
No. 10 (2.00 mm)	93.0
No. 20 (850 µm)	91.7
No. 40 (425 µm)	90.8
No. 60 (250 µm)	88.5
No. 100 (150 µm)	82.7
No. 200 (75 µm)	71.6
Hydrometer Analysis	
Particle Size	Percent Passing
0.074 mm	- -
0.005 mm	- -
0.001 mm	- -

USCS Classification (ASTM D2487)	Lean Clay with Sand (CL)	
As-Received Moisture Content (%)	(ASTM D2216)	18.8
Atterberg Limits (ASTM D 4318, Method A : Multipoint)	Liquid Limit (3 pt)	33
	Plastic Limit	21
	Plastic Index	12
Notes: Specimen was air dried, 3 point Liquid Limit procedure was used. (NL = No Liquid Limit, NP = No Plastic Limit)		
Specific Gravity	(ASTM D854)	- -
Organic Content (%)	(ASTM D2974)	- -
Carbonate Content (%)	(ASTM 4373)	- -

Jeffrey A. Kuhn, Ph.D., P.E., 10/25/2013
Quality Review/Date
Tested by: Kahlil Hart & Tierra Jackson

9063 Bee Caves Road □ Austin, TX 78733-6201 □ (512) 263-2101 □ (512) 263-2558 □ 1-800-880-TEST

Geosyntec consultants

COMPUTATION COVER SHEET

Client: NRG **Project:** Keystone Impoundment Evaluation **Project/Proposal #:** ME1000 **Task #:**

TITLE OF COMPUTATIONS Stability Analysis for CCW Impoundments at Keystone Generating Station

COMPUTATIONS BY:
Signature
Printed Name and Title: Chunling Li, Project Engineer
11/1/2013 DATE

ASSUMPTIONS AND PROCEDURES CHECKED BY: (Peer Reviewer)
Signature
Printed Name and Title: Lucas de Melo, Senior Engineer
11/1/2013 DATE

COMPUTATIONS CHECKED BY:
Signature
Printed Name and Title: Lin Chai, Staff Engineer
11/1/2013 DATE

COMPUTATIONS BACKCHECKED BY: (Originator)
Signature
Printed Name and Title: Chunling Li, Project Engineer
11/1/2013 DATE

APPROVED BY: (PM or Designate)
Signature
Printed Name and Title: Michael Houlihan, Principal
11/1/2013 DATE

APPROVAL NOTES:

REVISIONS (Number and initial all revisions)

NO.	SHEET	DATE	BY	CHECKED BY	APPROVAL

STABILITY ANALYSIS FOR CCW IMPOUNDMENTS AT KEYSTONE GENERATING STATION

1. PURPOSE

As an ongoing national effort by the United States Environmental Protection Agency (EPA) to assess the management of coal combustion waste (CCW), the stability of CCW impoundment at the Keystone Generation Station in Shelocta, Pennsylvania was recently reviewed by EPA. The review was documented in a draft report by Dewberry & Davis, LLC dated November 2012. In response to the comments and recommendation in the report, Geosyntec was engaged by NRG Energy, Inc. (NRG) to review the stability condition of the CCW impounds at the Keystone Generation Station (the site). This calculation package presents the details of the slope stability analysis.

2. BACKGROUND

The CCW system at the site includes a cluster of three contiguous Ash Filter Ponds and a separate Thermal Pond.

Each individual cell of the Ash Filter Ponds is nominally 82 ft wide by 386 ft long with a high water surface elevation at 1017 ft above mean sea level (ft-msl). The Thermal Pond has a surface area of 310,000 square feet with maximum water elevation of 1017 ft-msl.

As a part of this impoundment stability assessment project, Geosyntec drilled four borings at the site, at locations shown in Figures 1 and 2. Design drawings for both the Ash Filter Pond and Thermal Pond were prepared by Gilbert Associates, Inc. dated August 1993. The exterior slope of the Thermal Pond was constructed with a slope steeper than design. Thus, the geometry for the Thermal Pond was selected from an aerial survey provided by NRG on 8 October 2013. The geometry for Ash Filter Ponds was obtained from original design drawings.

3. CROSS SECTIONS ANALYSED

Two critical cross sections, one at Ash Filter Pond (denoted as Section A-A) and one at the Thermal Pond (denoted as Section B-B), were selected for the analysis based on review of subsurface condition and impoundment geometry. The locations of the selected cross sections are also shown in Figure 1.

These cross-sections were selected because the embankment heights at these locations are the highest. A s a conservative approach, the weakest foundation soil layer as identified from the subsurface investigation and review of construction data, was assumed to be present at these locations.

4. STABILITY CRITERIA

According to the US Corps of Engineers [2003], the minimum recommended factor of safety (FS) against global slope stability failure for permanent conditions under static loading is 1.5 (EM 110-2-1902). For seismic condition, the minimum acceptable FS is selected to be 1.2, based on recommendation of presented by the Mine Safety and Health Administration document entitled Engineering and Design Manual: Coal Refuse Disposal Facilities [2009].

5. LOADING CONDITIONS

5.1 Static Loads

The major static load applied to the foundation soils is the gravity load exerted by the weight of the berm. A surcharge load of 250 pound per square feet (psf) is applied to the top of the embankment to represent traffic loading on top of the embankment.

5.2 Seismic Loads

The maximum horizontal acceleration in bedrock for the Keystone facility site is estimated to be 0.0501g (g is the gravitational acceleration), based on a seismic hazard map with contours of peak acceleration with 2% probability of exceedance in 50 years as indicated in Figure 3 [USGS, 2008]. This represents the peak ground acceleration in bedrock.

The peak ground acceleration at a soil site should be adjusted to account for the stiffness of soil material overlying the bedrock, which is represented by a site classification in the International Building Code. Using the International Building Code (IBC) 2006 soil classification table, the lithology at the Keystone facility site classifies as a site classification D (stiff soil profile). This classification is selected based on the average standard penetration resistance (N-value) within the upper 100 foot soil profile. An IBC 2006 site classification of D pertains to a soil profile with an average N-value between 15 and 50. This site classification table is attached as Figure 4. The bedrock at the site is located at approximately 20 to 30 ft below ground surface. Considering that the bedrock has high SPT blow counts, the average blow counts for the upper 100 ft shall be greater than 15. Using the site coefficient chart for site Class D the value of 1.6

is obtained as shown in Figure 5. Based on the site coefficient and the PGA in rock, the PGA in soil site is estimated to be 0.080g.

In slope stability analysis, the horizontal seismic loading is typically considered as the weight of the soil mass multiplied by seismic coefficient, *k*. Because the peak ground acceleration will only occur for a short duration, the seismic coefficient *k* used in the design analysis will be smaller than the PGA. A seismic design guidance provided by USEPA [Richardson et. al.,1995] recommends to use approximately half of PGA as seismic coefficient. For a design PGA of 0.080g, a seismic coefficient of 0.04 was used in this analysis.

6. STRATIGRAPHY

Ash Filter Pond

The borings conducted at the Ash Filter Pond (B-1 through B-3) shows that the embankment soils are sandy silt or lean clays. The lower bound of the SPT blow counts is 10 blows/ft. The indication of bedrock was encountered near the bottom of the boring where refusal (likely rock blocks) was encountered during this boring investigation. The depth to bedrock is assumed to be 20 ft.

Thermal Pond

Based on the Boring logs for TH-1, the upper 14 feet of the Thermal Pond embankment are mainly composed of silty sand that classifies as SM or GM with lower bound SPT-N of 2 blows/ft. Below this layer there is a clay layer with SPT-N between 6 and 20 blows/ft. Boring TH-1 did not reach the bedrock. The bedrock is assumed to be located at elevation of 968 ft-msl based on the stratigraphy studied by Gilbert/Commonwealth Inc. [1993], included in the original permit application for the site.

7. MATERIAL PARAMETERS

The selection for material parameters used for the slope stability analysis is described below:

Embankment Fill (Ash Filter Pond)

The embankment at the Filter Ash Pond was constructed using fill material. Based on the boring logs, the material used for the embankment construction is primarily silt and clay.

For temporary undrained condition analysis, the undrained shear strength is selected based on the empirical correlation of the Standard Penetration Test blow counts (SPT-N) by Kulhawy and Mayne [1990]:

$$S_u/P_a = 0.06\ N \quad (1)$$

where: S_u = undrained shear strength;
P_a = atmospheric pressure (= 2,116 psf)
N = SPT-N value (blows/ft)

The lower bound of the SPT-N is 10 blows/ft at the Ash Filter Pond. Using the empirical correlations in equation (1), the undrained shear strength of the embankment material at the Filter Ash Pond is assumed to be 1,250 psf.

The drained shear strength of the embankment soil at the Filter Ash Pond is assumed based on the empirical correlations between friction angle and plasticity index (PI) for normally consolidated clay (see Figure 5). Laboratory test results shows that the upper bound of PI for soil samples collected within this area is 12%. Independent verification tests conducted by Geosyntec personnel shows that some soil pockets may have PI as high as 17%. A friction angle of 32 degrees was conservatively assumed based on a PI of 17%.

Foundation Soil (Ash Filter Pond)

The foundation soil at the Ash Filter Pond is silt and clay with similar SPT-N values at embankment soil. Thus, the undrained and drained shear strength was assumed to be the same as the embankment soil (i.e., undrained shear strength of 1,200 psf and drained friction angle of 32 degrees).

Embankment Soil (Thermal Pond)

The material parameters for the embankment soil are selected to be the same as previous slope stability analysis by Gilbert/Commonwealth, Inc. [1993], which used a friction angle of 28 degrees and a cohesion of 240 psf. Based on the empirical correlations between SPT-N and friction angle (see Figure 7), the friction angle of 28 degrees used by Gilbert/Commonwealth, Inc. is considered reasonable.

Foundation Soil (Thermal Pond)

The material parameters for the foundation soil are also selected to be consistent with previous analysis by Gilbert/Commonwealth, Inc. [1993], which used an undrained shear strength of 1,250 psf. This undrained shear strength coincides well with the undrained shear strength predicted using Equation (1) for an average SPT-N of approximately 10 blows/ft. No drained shear strength was used in the analysis by Gilbert [1993]. Based on empirical correlations between Plasticity Index and friction angle (see Figure 6), a friction angle of 32 degrees was estimated using the upper bound of Plasticity Index obtained from the laboratory tests.

Bedrock

Consistent with previous analysis by Gilbert [1993], the weathered bedrock was conservatively assumed to have a shear strength of 8,000 psf.

Table 1 summaries the material properties used in the slope stability analysis.

Table 1. Material Properties Used in Slope Stability Analyses

Material	Moist Unit Weight (lb/ft^3)	Saturated Unit Weight (lb/ft^3)	Drained Shear Strength		Undrained Shear Strength (psf)
			Cohesion (psf)	Friction Angle (deg)	
Embankment Soil (Ash Filter Pond)	120	-	0	32	1250
Foundation Soil (Ash Filter Pond)	135	135	0	32	1250
Embankment Soil (Thermal Pond)	120	-	240	28	-
Foundation Soil (Thermal Pond)	135	135	0	32	1250
Weathered rock	145	145	8000	0	-

8. GROUNDWATER CONDITION

Consistent with previous analysis by Gilbert [1993], the groundwater table is assumed to be shallow at approximately the bottom of the thermal ponds and conservatively assumed to be at ground surface outside the exterior slope.

For this analysis, the water level in the CCW impoundment is assumed based on the high water table shown in the design drawings [Gilbert, 1993], which is 1017 ft-msl in both the

Ash Filter Pond and Thermal Pond areas. The material in the lined ponds is modeled as material with no shear strength in the analysis.

In the EPA assessment report by Dewberry & Davis Inc [2012], a seep was observed at the exterior slope of the thermal pond. If the seep resulted from the leakage of the lined Thermal Pond it would negatively affect the stability of the embankment. Two piezometers were installed to monitor the groundwater condition near where the seep was observed. Two readings taken immediately after installation and two weeks after installation indicated that the two piezometers were dry. Thus, no seepage through the embankment was considered in this slope stability evaluation. Should future piezometer readings identify seepage through the embankment, the slope stability analysis should be reevaluated by a geotechnical engineer.

9. METHOD OF SLOPE STABILITY ANALYSIS

The stability of the selected cross sections was evaluated using the limit equilibrium method. The analyses were conducted using SLIDE [Rocscience, 2002], a two-dimensional (2D) slope stability computer program. The factors of safety for both circular and non-circular potential slip surface were evaluated. The Spencer's Method [Spencer, 1967], was used in the analysis. The interslice force assumption made in the Spencer's Method satisfies force equilibrium in horizontal and vertical directions as well as moment equilibrium. Therefore, Spencer's method is considered as a rigorous methods, which generally provide more precise results for factor of safety than non-rigorous method. The factors of safety reported herein are from Spencer's method.

Thousands of potential failure surfaces were analyzed to find the critical failure surface resulting in the minimum factor of safety for the slope. For the circular slip surface search, a search grid with 25 horizontal increments and 25 vertical increments was used. For the block failure analysis, two search windows were used for searching the most critical failure surface. SLIDE provides results graphically and as output text files. SLIDE graphical provides both the minimum factor of safety and contours of the calculated factors of safety. For each case analyzed, a figure and text are generated and presented in Attachment I of this calculation package.

10. RESULTS OF SLOPE STABILITY

The results of the SLIDE analyses using the material properties listed in Table 1 are summarized in Table 2.

Table 2. Summary of Slope Stability Results

Cross Sections	Loading Conditions	Failure Mode	Calculated F.S.	Target F.S.
A-A (Ash Filter Pond)	Static (undrained)	Block	6.73	1.30
		Circular	6.83	1.30
	Static (drained)	Block	1.74	1.50
		Circular	1.96	1.50
	Seismic	Block	5.79	1.20
		Circular	5.78	1.20
B-B (Thermal Pond)	Static (undrained)	Block	1.87	1.30
		Circular	1.64	1.30
	Static (drained)	Block	1.67	1.50
		Circular	1.70	1.50
	Seismic	Block	1.69	1.20
		Circular	1.53	1.20

11. SUMMARY

The stability of the both the Ash Filter Ponds and Thermal Pond of the Keystone facility was evaluated for several scenarios. The results of these analyses show factors of safety exceeding the minimum recommended factors of safety. Thus, the CCW impoundments at the Keystone facility are considered to be stable.

12. REFERENCES

Bishop, A.W. (1955), "The use of the slip circle in the stability analysis of slopes", Géotechnique, Volume 5, Issue 1, pages 7 –17.

Dewberry & Davis, Inc. (2012)., "Coal Combustion Residue Impoundment Round 12 - Dam Assessment Report, Keystone Generating Station Ash Filter Ponds & Thermal Pond, GenOn Energy Shelocta, PA." prepared for United States Environmental Protection Agency, November, 2012 (draft).

Gilbert/Commonwealth, Inc. (1993), "Dam Permit Application, Industrial Waste Treatment Modifications: Thermal Discharge Abatement Project Cooling Ponds", Pennsylvania Electric Company Keystone Station, April, 1993.

Janbu, N. (1954) "Application of composite slip surface for slope stability analysis". Proceedings of European conference on stability of earth slopes, Stockholm 3, 43-49.

Kulhawy F.H., and Mayne, P.W., *Manual on Estimating Soil Properties for Foundation Design*, EPRI Document EL-6800, Electric Power Research Institute, Palo Alto, California.

MHSA (2009), *Engineering and Design Manual, Coal Refuse Disposal Facility*, 2nd Edition, prepared by D'Appolonia Engineering, Mine Safety and Health Administration, United States Department of Labor, Arlington, Virginia.

Rocscience. (2002). "Slide (Version 5.0): A 2D Slope Stability Analysis for Soil and Rock Slopes", Toronto, Canada.

Spencer (1967). "A Method of Analysis of the Stability of Embankments Assuming Parallel Interslice Forces," Geotechnique, London, England, 17(1), pp. 11-26.

U.S. Department of Labor Mine Safety and Health Administration - MSHA (2009) "Engineering And Design Manual Coal Refuse Disposal Facilities". Second Edition.

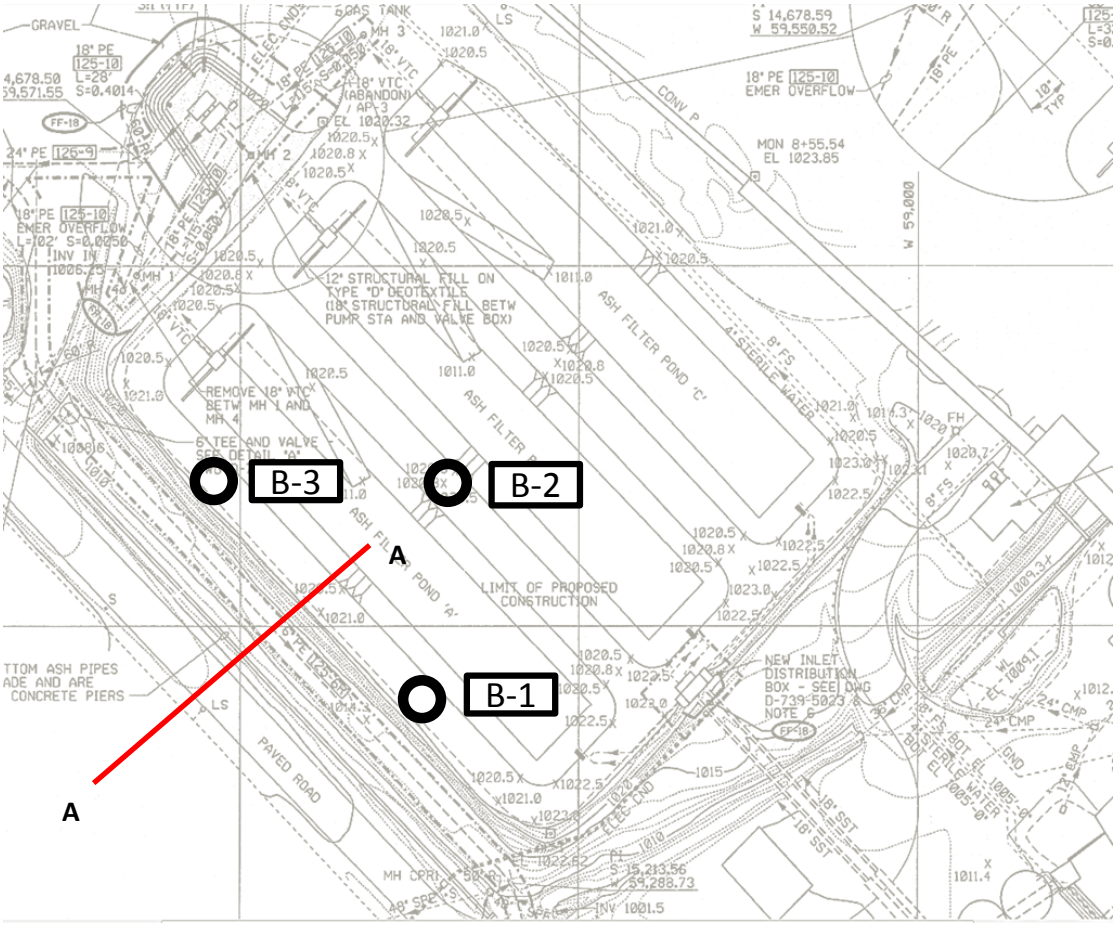
US Army Corps of Engineers (2003) "Engineer Manual EM 1110-2-1902 Slope Stability"

U.S. Navy, (1971). "Soil Mechanics, Foundations, and Earth Structures," NAVFAC Design Manual DM-7, Washington, D.C.

USGS (2008). "2008 United States National Seismic Hazard Maps", United States Geological Survey, http://earthquake.usgs.gov/research/hazmaps/products_data/2008/

APPENDIX D

STABILITY ANALYSIS



Legend

B-1 Approximate Boring Location

FIGURE 1 - SOIL BORING LOCATION

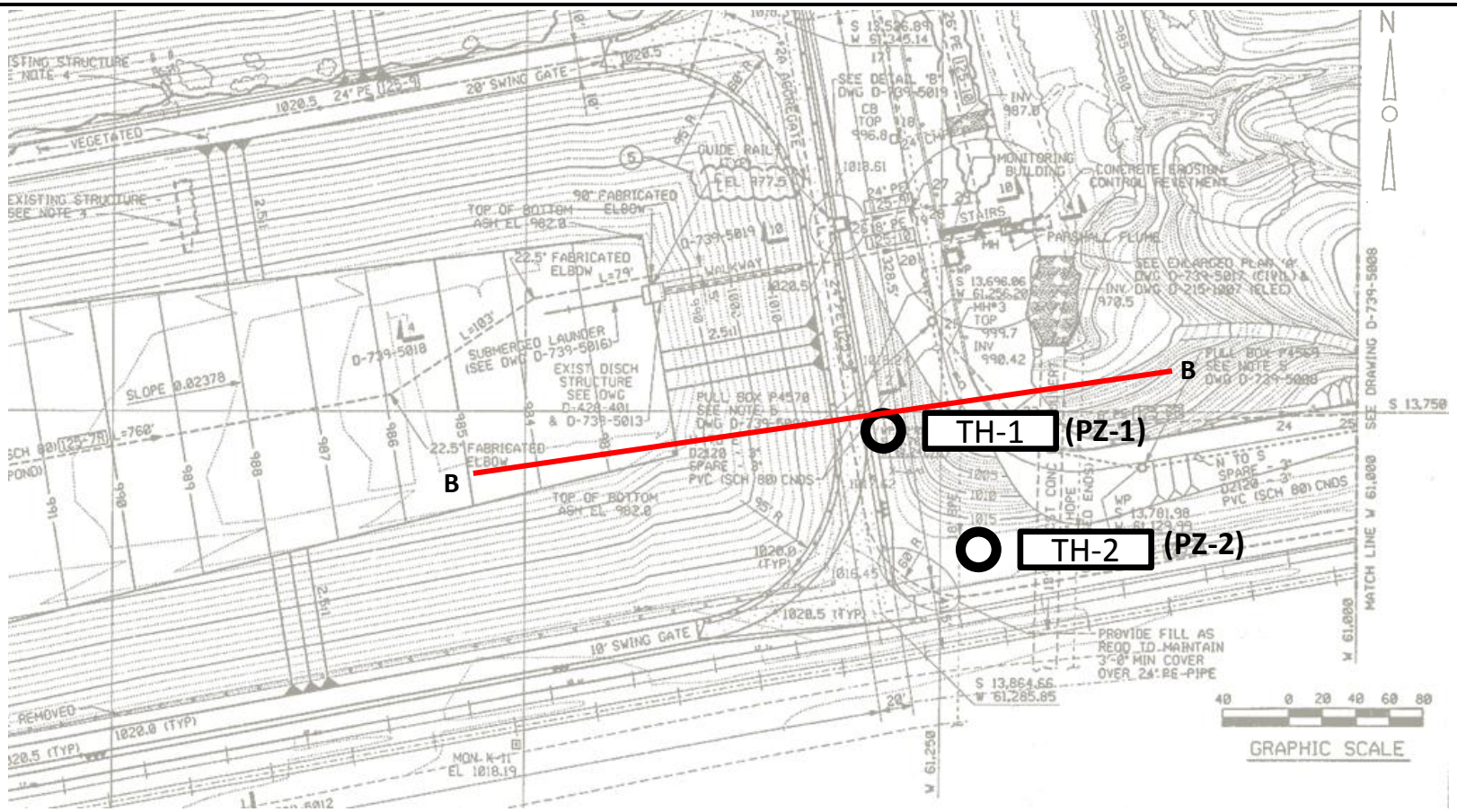
Keystone Generating Station – Ash Filter Pond

Shelocta, PA

Geosyntec consultants

COLUMBIA, MARYLAND

DATE:	Oct 2013
PROJECT NO.	ME1000
DOCUMENT NO.	
FIGURE NO:	1



Legend

B-1 Approximate Piezometer Location

FIGURE 2 - PIEZOMETER LOCATION

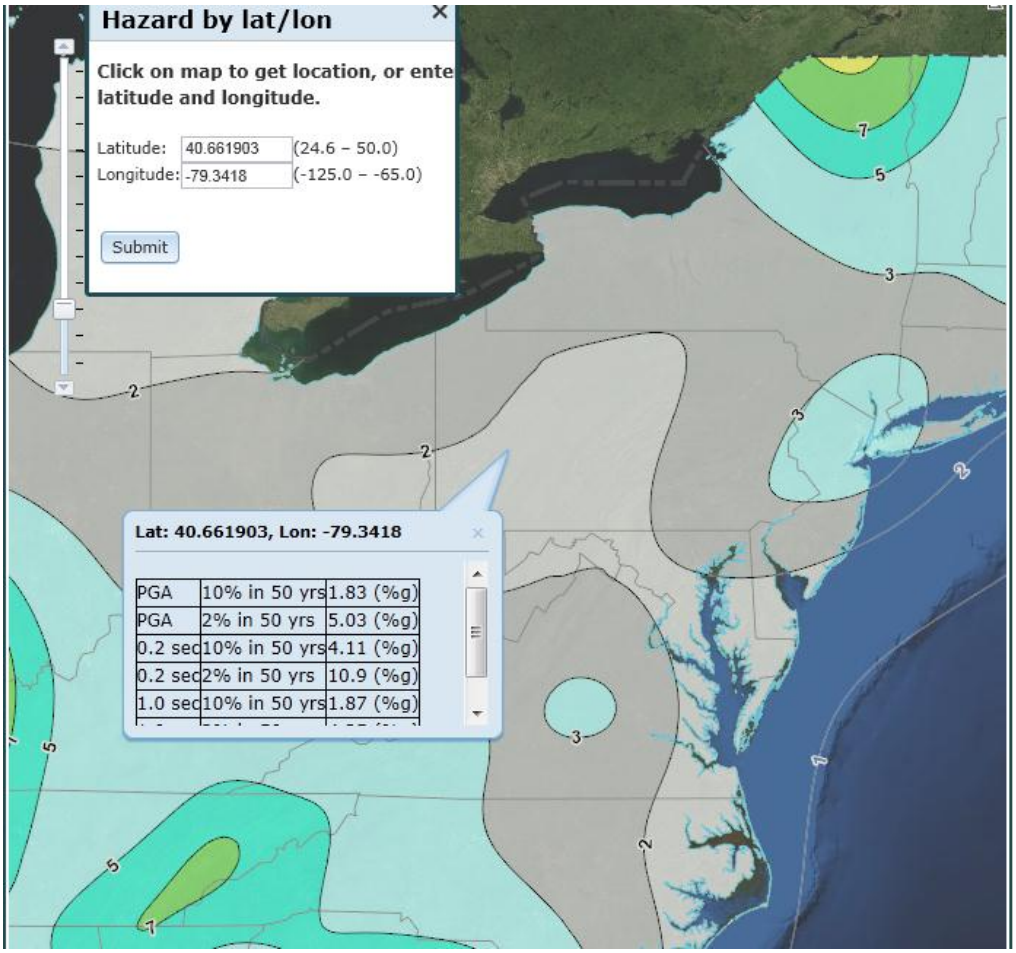
Keystone Generating Station – Thermal Pond

Shelocta, PA

Geosyntec consultants

COLUMBIA, MARYLAND

DATE:	Oct 2013
PROJECT NO.	ME1000
DOCUMENT NO.	
FIGURE NO:	2



Source: USGS [2008]

Figure 3. USGS Seismic Hazard Map

TABLE 1613.5.2
SITE CLASS DEFINITIONS

SITE CLASS	SOIL PROFILE NAME	AVERAGE PROPERTIES IN TOP 100 feet, SEE SECTION 1613.5.5		
		Soil shear wave velocity, $\bar{v}_s$, (ft/s)	Standard penetration resistance, $\bar{N}$	Soil undrained shear strength, $\bar{s}_u$, (psf)
A	Hard rock	$\bar{v}_s > 5{,}000$	N/A	N/A
B	Rock	$2{,}500 < \bar{v}_s \leq 5{,}000$	N/A	N/A
C	Very dense soil and soft rock	$1{,}200 < \bar{v}_s \leq 2{,}500$	$\bar{N} > 50$	$\bar{s}_u \geq 2{,}000$
D	Stiff soil profile	$600 \leq \bar{v}_s \leq 1{,}200$	$15 \leq \bar{N} \leq 50$	$1{,}000 \leq \bar{s}_u \leq 2{,}000$
E	Soft soil profile	$\bar{v}_s < 600$	$\bar{N} < 15$	$\bar{s}_u < 1{,}000$
E	—	Any profile with more than 10 feet of soil having the following characteristics: 1. Plasticity index $PI > 20$, 2. Moisture content $w \geq 40\%$, and 3. Undrained shear strength $\bar{s}_u < 500$ psf		
F	—	Any profile containing soils having one or more of the following characteristics: 1. Soils vulnerable to potential failure or collapse under seismic loading such as liquefiable soils, quick and highly sensitive clays, collapsible weakly cemented soils. 2. Peats and/or highly organic clays (H > 10 feet of peat and/or highly organic clay where H = thickness of soil) 3. Very high plasticity clays (H >25 feet with plasticity index PI >75) 4. Very thick soft/medium stiff clays (H >120 feet)		

For SI: 1 foot = 304.8 mm, 1 square foot = 0.0929 m², 1 pound per square foot = 0.0479 kPa. N/A = Not applicable

Source: International Building Code 2006

Figure 4. Site Classification

TABLE 1613.5.3(1)
VALUES OF SITE COEFFICIENT F_a [a]

SITE CLASS	MAPPED SPECTRAL RESPONSE ACCELERATION AT SHORT PERIOD				
	$S_s \leq 0.25$	$S_s = 0.50$	$S_s = 0.75$	$S_s = 1.00$	$S_s \geq 1.25$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	Note b	Note b	Note b	Note b	Note b

a. Use straight-line interpolation for intermediate values of mapped spectral response acceleration at short period, S_s.
b. Values shall be determined in accordance with Section 11.4.7 of ASCE 7.

Source: International Building Code 2006

Figure 5. Site Coefficient

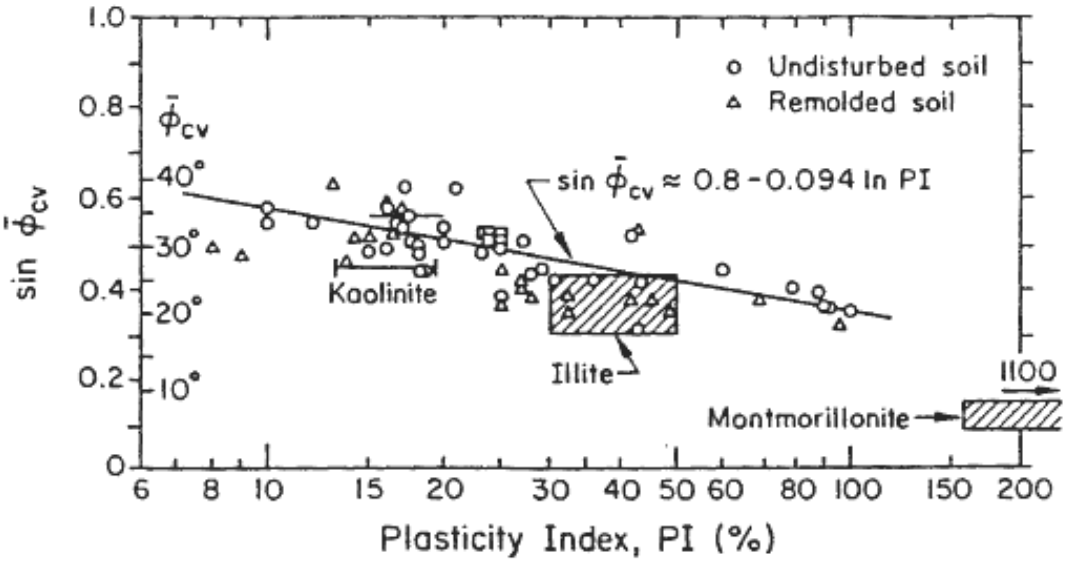


Figure 4-20. $\bar{\phi}_{cv}$ for NC Clays versus PI

Source: Mitchell (22), p. 284.

Reproduced from Kulhawy and Mayne [1990]

Figure 6. Empirical Correlations between Critical Void Ratio Friction Angle and Plasticity Index

Table 4-3

N VERSUS $\bar{\phi}_{tc}$ RELATIONSHIPS

N Value (blows/ft or 305 mm)	Relative Density	Approximate $\bar{\phi}_{tc}$ (degrees) (a)	(b)
0 to 4	very loose	< 28	< 30
4 to 10	loose	28 to 30	30 to 35
10 to 30	medium	30 to 36	35 to 40
30 to 50	dense	36 to 41	40 to 45
> 50	very dense	> 41	> 45

a - Source: Peck, Hanson, and Thornburn (12), p. 310.
b - Source: Meyerhof (13), p. 17.

Embankment (Thermal Pond) →

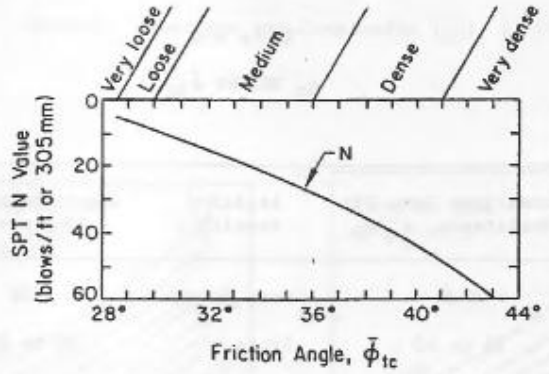


Figure 4-12. N versus $\bar{\phi}_{tc}$

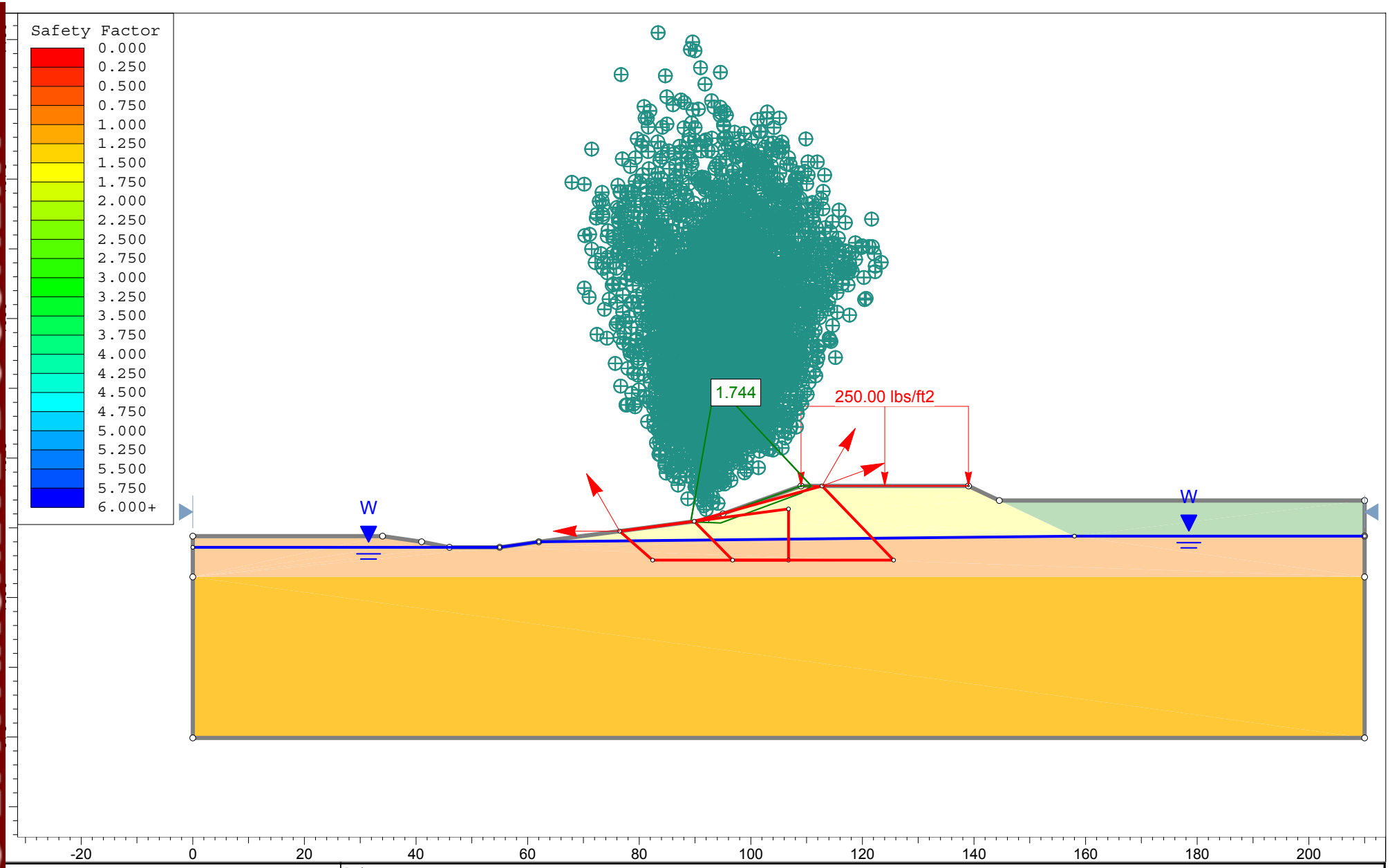
Source: Peck, Hanson, and Thornburn (12), p. 310.

Reproduced from Kulhawy and Mayne [1990]

Figure 7. Empirical Correlation between SPT-N and Friction Angle

Attachment I

SLIDE Output



rocscience	Project: SLIDE - An Interactive Slope Stability Program		
	Analysis Description:		
	Drawn By:	Scale: 1:285	Company:
	Date: 10/16/2013, 3:13:47 PM		File Name: A-A_ Keystone_drained block.slim

DEINTERPRET 6.019

Slide Analysis Information

SLIDE - An Interactive Slope Stability Program

Project Summary

File Name: A-A_ Keystone_drained block
Slide Modeler Version: 6.019
Project Title: SLIDE - An Interactive Slope Stability Program
Date Created: 10/16/2013, 3:13:47 PM

General Settings

Units of Measurement: Imperial Units
Time Units: days
Permeability Units: feet/second
Failure Direction: Right to Left
Data Output: Standard
Maximum Material Properties: 20
Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

Spencer

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50
Check malpha < 0.2: Yes
Initial trial value of FS: 1
Steffensen Iteration: Yes

Groundwater Analysis

Groundwater Method: Water Surfaces
Pore Fluid Unit Weight: 62.4 lbs/ft3
Advanced Groundwater Method: None

Random Numbers

Pseudo-random Seed: 10116
Random Number Generation Method: Park and Miller v.3

Surface Options

Surface Type: Non-Circular Block Search
Number of Surfaces: 5000
Pseudo-Random Surfaces: Enabled
Convex Surfaces Only: Disabled
Left Projection Angle (Start Angle): 120
Left Projection Angle (End Angle): 180
Right Projection Angle (Start Angle): 20
Right Projection Angle (End Angle): 60
Minimum Elevation: Not Defined
Minimum Depth: Not Defined

Loading

1 Distributed Load present

Distributed Load 1

Distribution: Constant
Magnitude [psf]: 250
Orientation: Normal to boundary

Material Properties

Property	embankment soil	water	Foundation soil	bedrock
Color				
Strength Type	Mohr-Coulomb	No strength	Mohr-Coulomb	Undrained
Unsaturated Unit Weight [lbs/ft3]			135	145
Saturated Unit Weight [lbs/ft3]			135	145
Cohesion [psf]	0		0	
Friction Angle [deg]	32		32	
Cohesion Type				8000
Water Surface	Water Table	None	Water Table	None
Hu Value	1		0	
Ru Value		0		0

Global Minimums

Method: spencer

FS: 1.744260
Axis Location: 93.612, 1038.400
Left Slip Surface Endpoint: 89.232, 1013.573
Right Slip Surface Endpoint: 110.846, 1020.000
Resisting Moment=49356.5 lb-ft

Driving Moment=28296.6 lb-ft
Resisting Horizontal Force=1889.64 lb
Driving Horizontal Force=1083.35 lb
Total Slice Area=24.5947 ft2

Global Minimum Coordinates

Method: spencer

X	Y
89.2324	1013.57
94.5861	1013.36
108.998	1018.69
110.846	1020

Valid / Invalid Surfaces

Method: spencer

Number of Valid Surfaces: 4239
Number of Invalid Surfaces: 761

Error Codes:

Error Code -105 reported for 27 surfaces
Error Code -107 reported for 7 surfaces
Error Code -108 reported for 430 surfaces
Error Code -111 reported for 177 surfaces
Error Code -112 reported for 120 surfaces

Error Codes

The following errors were encountered during the computation:

-105 = More than two surface / slope intersections with no valid slip surface.
-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.

Slice Data

Global Minimum Query (spencer) - Safety Factor: 1.74426

Slice	Width	Weight	Base	Base	Base Friction	Shear	Shear	Base Normal	Pore	Effective Normal

Number	[ft]	[lbs]	Material	[psf]	Angle [degrees]	[psf]	[psf]	Stress [psf]	[psf]	Stress [psf]
1	0.892285	8.16164	embankment soil	0	32	3.86616	6.74359	10.792	0	10.792
2	0.892285	24.4849	embankment soil	0	32	11.5985	20.2308	32.376	0	32.376
3	0.892285	40.8082	embankment soil	0	32	19.3308	33.7179	53.96	0	53.96
4	0.892285	65.1313	embankment soil	0	32	30.8526	53.815	86.122	0	86.122
5	0.892285	102.832	embankment soil	0	32	48.7115	84.9655	135.973	0	135.973
6	0.892285	140.742	embankment soil	0	32	66.6695	116.289	186.1	0	186.1
7	0.84777	151.191	embankment soil	0	32	56.2103	98.0454	156.905	0	156.905
8	0.84777	150.114	embankment soil	0	32	55.8099	97.3469	155.788	0	155.788
9	0.84777	149.037	embankment soil	0	32	55.4094	96.6484	154.669	0	154.669
10	0.84777	147.96	embankment soil	0	32	55.0089	95.9499	153.552	0	153.552
11	0.84777	146.883	embankment soil	0	32	54.6085	95.2514	152.435	0	152.435
12	0.84777	145.806	embankment soil	0	32	54.208	94.5529	151.316	0	151.316
13	0.84777	144.728	embankment soil	0	32	53.8076	93.8544	150.198	0	150.198
14	0.84777	143.651	embankment soil	0	32	53.4071	93.1559	149.081	0	149.081
15	0.84777	142.574	embankment soil	0	32	53.0067	92.4574	147.962	0	147.962
16	0.84777	141.497	embankment soil	0	32	52.6062	91.7589	146.845	0	146.845
17	0.84777	140.42	embankment soil	0	32	52.2057	91.0604	145.728	0	145.728
18	0.84777	139.343	embankment soil	0	32	51.8053	90.3619	144.609	0	144.609
19	0.84777	138.266	embankment soil	0	32	51.4048	89.6634	143.491	0	143.491
20	0.84777	137.189	embankment soil	0	32	51.0044	88.9649	142.374	0	142.374
21	0.84777	136.111	embankment soil	0	32	50.6039	88.2664	141.255	0	141.255
22	0.84777	135.034	embankment soil	0	32	50.2035	87.5679	140.138	0	140.138
23	0.84777	133.957	embankment soil	0	32	49.803	86.8694	139.021	0	139.021
24	0.923746	109.087	embankment soil	0	32	95.558	166.678	266.74	0	266.74
			embankment							

soil

Interslice Data

Global Minimum Query (spencer) - Safety Factor: 1.74426

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	89.2324	1013.57	0	0	0
2	90.1246	1013.54	3.83695	1.35126	19.4008
3	91.0169	1013.5	15.3478	5.40503	19.4007
4	91.9092	1013.47	34.5326	12.1613	19.4007
5	92.8015	1013.43	65.1521	22.9446	19.4007
6	93.6938	1013.4	113.496	39.9697	19.4007
7	94.5861	1013.36	179.661	63.2712	19.4007
8	95.4338	1013.67	178.221	62.7641	19.4007
9	96.2816	1013.99	176.792	62.2607	19.4007
10	97.1294	1014.3	175.372	61.7609	19.4008
11	97.9771	1014.61	173.963	61.2646	19.4007
12	98.8249	1014.93	172.565	60.772	19.4007
13	99.6727	1015.24	171.176	60.283	19.4007
14	100.52	1015.55	169.798	59.7977	19.4007
15	101.368	1015.87	168.43	59.3159	19.4007
16	102.216	1016.18	167.072	58.8377	19.4007
17	103.064	1016.49	165.725	58.3632	19.4007
18	103.912	1016.81	164.387	57.8923	19.4008
19	104.759	1017.12	163.06	57.4249	19.4008
20	105.607	1017.43	161.744	56.9612	19.4007
21	106.455	1017.75	160.437	56.5011	19.4007
22	107.303	1018.06	159.141	56.0447	19.4007
23	108.15	1018.37	157.855	55.5918	19.4007
24	108.998	1018.69	156.579	55.1425	19.4008
25	109.922	1019.34	69.991	24.6487	19.4007
26	110.846	1020	0	0	0

List Of Coordinates

Water Table

X	Y
0	1009
55	1009
62	1010
158	1011
210	1011

Line Load

X	Y
139	1020
109	1020

Block Search Window

X	Y
76.4952	1011.9
82.401	1006.7
106.769	1006.7
106.769	1015.87

Block Search Window

X	Y
89.8588	1013.66
96.7216	1006.7
125.594	1006.7
112.774	1020

External Boundary

X	Y
144.542	1017.38
139	1020
109	1020
95	1015
92.0333	1013.94
62	1010
55	1009
46	1009
41	1010
34	1011
0	1011
0	1003.69
0	974.831
210	974.831
210	1003.69
210	1011
210	1017.38

Material Boundary

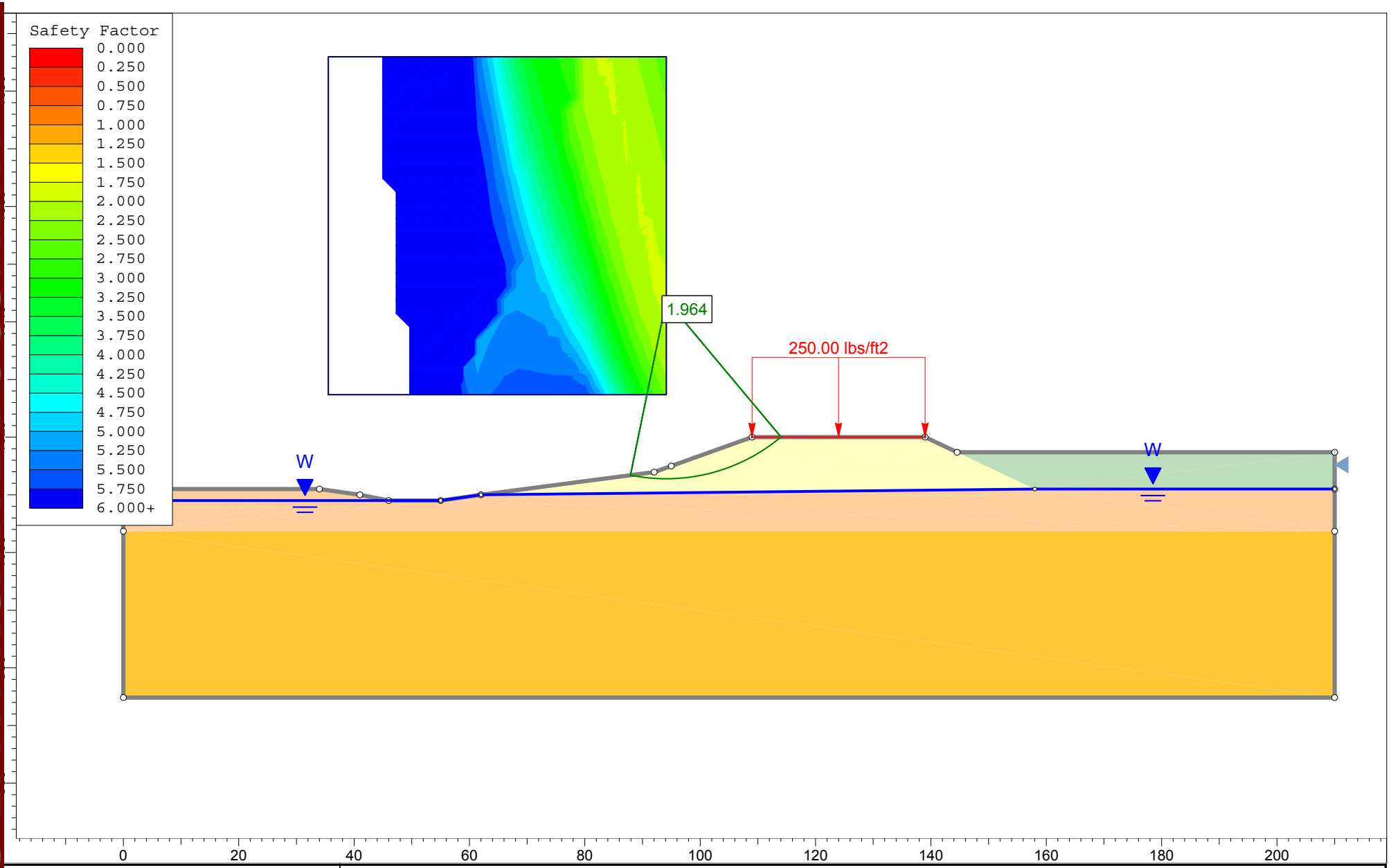
X	Y
62	1010
158	1011

Material Boundary

X	Y
0	1003.69
210	1003.69

Material Boundary

X	Y
144.542	1017.38
158	1011
210	1011



rocscience	Project: SLIDE - An Interactive Slope Stability Program		
	Analysis Description:		
	Drawn By:	Scale: 1:277	Company:
	Date: 10/16/2013, 3:13:47 PM		File Name: A-A_ Keystone_drained Circular.slim

DEINTERPRET 6.019

Slide Analysis Information

SLIDE - An Interactive Slope Stability Program

Project Summary

File Name: A-A_ Keystone_drained Circular
Slide Modeler Version: 6.019
Project Title: SLIDE - An Interactive Slope Stability Program
Date Created: 10/16/2013, 3:13:47 PM

General Settings

Units of Measurement: Imperial Units
Time Units: days
Permeability Units: feet/second
Failure Direction: Right to Left
Data Output: Standard
Maximum Material Properties: 20
Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

Spencer

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50
Check malpha < 0.2: Yes
Initial trial value of FS: 1
Steffensen Iteration: Yes

Groundwater Analysis

Groundwater Method: Water Surfaces
Pore Fluid Unit Weight: 62.4 lbs/ft3
Advanced Groundwater Method: None

Random Numbers

Pseudo-random Seed: 10116
Random Number Generation Method: Park and Miller v.3

Surface Options

Surface Type: Circular
Search Method: Grid Search
Radius Increment: 10
Composite Surfaces: Disabled
Reverse Curvature: Create Tension Crack
Minimum Elevation: Not Defined
Minimum Depth: 2

Loading

1 Distributed Load present

Distributed Load 1

Distribution: Constant
Magnitude [psf]: 250
Orientation: Normal to boundary

Material Properties

Property	embankment soil	water	Foundation soil	bedrock
Color				
Strength Type	Mohr-Coulomb	No strength	Mohr-Coulomb	Undrained
Unsaturated Unit Weight [lbs/ft3]			135	145
Saturated Unit Weight [lbs/ft3]			135	145
Cohesion [psf]	0		0	
Friction Angle [deg]	32		32	
Cohesion Type				8000
Water Surface	Water Table	None	Water Table	None
Hu Value	1		0	
Ru Value		0		0

Global Minimums

Method: spencer

FS: 1.964350
Center: 94.127, 1043.775
Radius: 31.006
Left Slip Surface Endpoint: 87.907, 1013.399
Right Slip Surface Endpoint: 114.030, 1020.000
Resisting Moment=170070 lb-ft
Driving Moment=86578.2 lb-ft
Resisting Horizontal Force=5104.71 lb

Driving Horizontal Force=2598.68 lb
Total Slice Area=64.491 ft2

Valid / Invalid Surfaces

Method: spencer

Number of Valid Surfaces: 4608
Number of Invalid Surfaces: 2828

Error Codes:

Error Code -103 reported for 817 surfaces
Error Code -107 reported for 1290 surfaces
Error Code -108 reported for 256 surfaces
Error Code -115 reported for 465 surfaces

Error Codes

The following errors were encountered during the computation:

-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).
-115 = Surface too shallow, below the minimum depth.

Slice Data

Global Minimum Query (spencer) - Safety Factor: 1.96435

Slice Number	Width [ft]	Weight [lbs]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]
1	1.04493	20.844	embankment soil	0	32	8.03915	15.7917	25.272	0	25.272
2	1.04493	60.2278	embankment soil	0	32	22.6192	44.432	71.1061	0	71.1061
3	1.04493	95.0388	embankment soil	0	32	34.7896	68.3389	109.365	0	109.365
4	1.04493	125.378	embankment soil	0	32	44.7708	87.9456	140.742	0	140.742
5	1.04493	167.478	embankment soil	0	32	58.3806	114.68	183.527	0	183.527
6	1.04493	218.484	embankment soil	0	32	74.392	146.132	233.859	0	233.859
7	1.04493	265.068	embankment soil	0	32	88.2022	173.26	277.275	0	277.275

8	1.04493	307.232	embankment soil	0	32	99.9506	196.338	314.206	0	314.206
9	1.04493	344.959	embankment soil	0	32	109.755	215.597	345.028	0	345.028
10	1.04493	378.218	embankment soil	0	32	117.719	231.241	370.064	0	370.064
11	1.04493	406.961	embankment soil	0	32	123.931	243.444	389.592	0	389.592
12	1.04493	431.125	embankment soil	0	32	128.467	252.355	403.853	0	403.853
13	1.04493	450.627	embankment soil	0	32	131.396	258.107	413.057	0	413.057
14	1.04493	465.366	embankment soil	0	32	132.772	260.81	417.383	0	417.383
15	1.04493	475.218	embankment soil	0	32	132.645	260.562	416.987	0	416.987
16	1.04493	480.036	embankment soil	0	32	131.059	257.446	411.999	0	411.999
17	1.04493	479.645	embankment soil	0	32	128.047	251.53	402.531	0	402.531
18	1.04493	473.84	embankment soil	0	32	123.64	242.873	388.678	0	388.678
19	1.04493	462.376	embankment soil	0	32	117.863	231.524	370.515	0	370.515
20	1.04493	444.969	embankment soil	0	32	110.734	217.521	348.106	0	348.106
21	1.04493	405.795	embankment soil	0	32	150.1	294.848	471.855	0	471.855
22	1.04493	329.439	embankment soil	0	32	139.745	274.509	439.306	0	439.306
23	1.04493	245.102	embankment soil	0	32	116.61	229.063	366.577	0	366.577
24	1.04493	153.018	embankment soil	0	32	92.7375	182.169	291.532	0	291.532
25	1.04493	52.4801	embankment soil	0	32	68.5855	134.726	215.606	0	215.606

Interslice Data

Global Minimum Query (spencer) - Safety Factor: 1.96435

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	87.9066	1013.4	0	0	0
2	88.9515	1013.2	13.3422	4.07449	16.9818
3	89.9964	1013.05	48.2688	14.7405	16.9818
4	91.0414	1012.92	98.0305	29.937	16.9819
5	92.0863	1012.84	157.037	47.9566	16.9818
6	93.1312	1012.78	227.473	69.4669	16.9819

7	94.1761	1012.77	308.977	94.3569	16.9819
8	95.2211	1012.79	395.845	120.885	16.9819
9	96.266	1012.84	483.195	147.56	16.9818
10	97.3109	1012.93	566.872	173.114	16.9819
11	98.3558	1013.06	643.376	196.477	16.9819
12	99.4008	1013.22	709.802	216.762	16.9818
13	100.446	1013.42	763.792	233.25	16.9818
14	101.491	1013.66	803.506	245.378	16.9818
15	102.536	1013.93	827.594	252.734	16.9818
16	103.58	1014.25	835.185	255.052	16.9818
17	104.625	1014.6	825.882	252.212	16.9819
18	105.67	1015	799.768	244.237	16.9819
19	106.715	1015.44	757.422	231.305	16.9819
20	107.76	1015.93	699.948	213.753	16.9818
21	108.805	1016.46	629.018	192.092	16.9818
22	109.85	1017.05	508.537	155.299	16.9818
23	110.895	1017.69	372.179	113.658	16.9819
24	111.94	1018.4	236.678	72.2777	16.9818
25	112.985	1019.16	110.167	33.6432	16.9818
26	114.03	1020	0	0	0

List Of Coordinates

Water Table

X	Y
0	1009
55	1009
62	1010
158	1011
210	1011

Line Load

X	Y
139	1020
109	1020

External Boundary

X	Y
144.542	1017.38
139	1020
109	1020
95	1015
92.0333	1013.94

62	1010
55	1009
46	1009
41	1010
34	1011
0	1011
0	1003.69
0	974.831
210	974.831
210	1003.69
210	1011
210	1017.38

Material Boundary

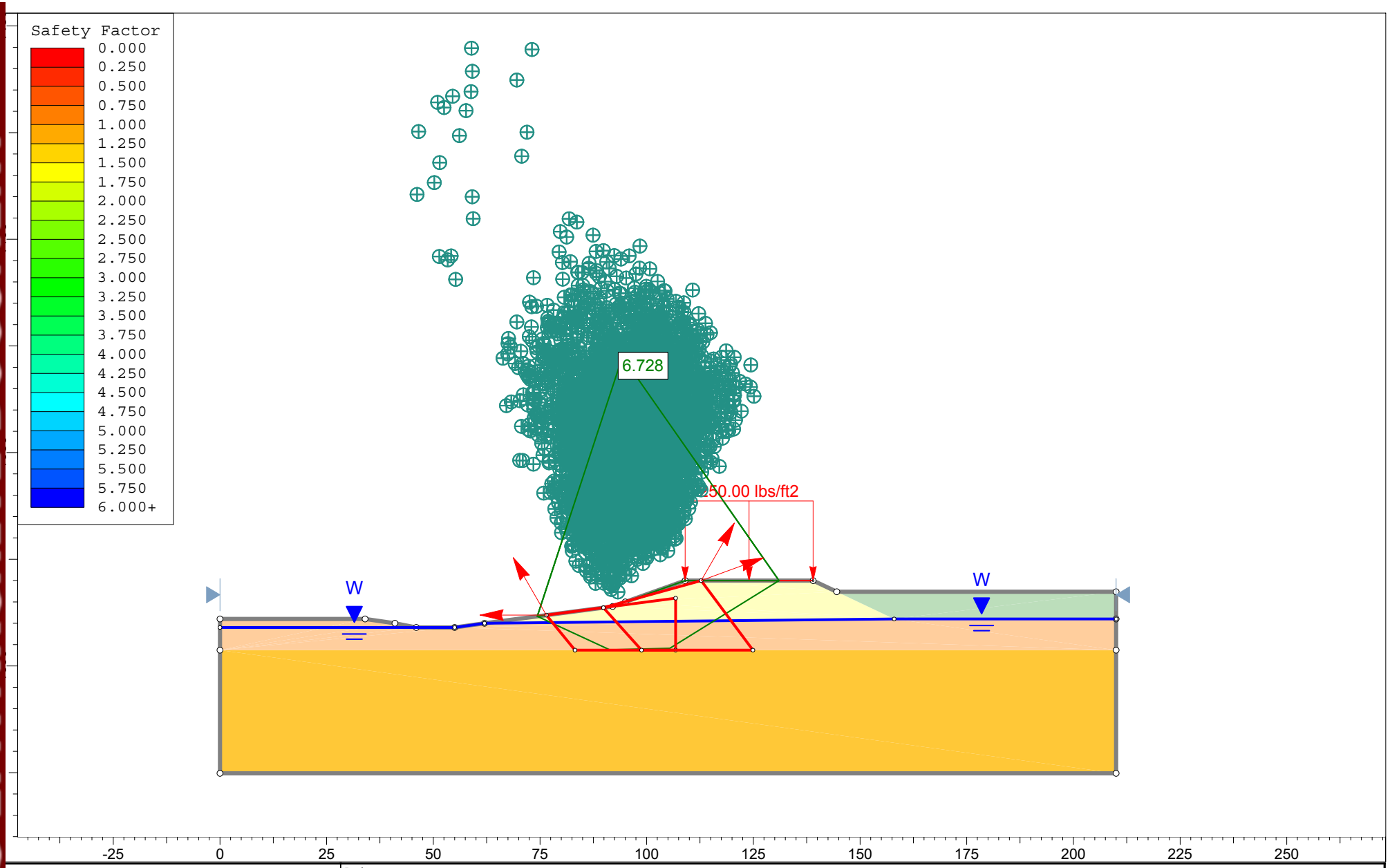
X	Y
62	1010
158	1011

Material Boundary

X	Y
0	1003.69
210	1003.69

Material Boundary

X	Y
144.542	1017.38
158	1011
210	1011



rocscience	Project: SLIDE - An Interactive Slope Stability Program		
	Analysis Description:		
	Drawn By:	Scale: 1:373	Company:
	Date: 10/16/2013, 3:13:47 PM		File Name: A-A_ Keystone_undrained block.slim

DEINTERPRET 6.019

Slide Analysis Information

SLIDE - An Interactive Slope Stability Program

Project Summary

File Name: A-A_ Keystone_undrained block
Slide Modeler Version: 6.019
Project Title: SLIDE - An Interactive Slope Stability Program
Date Created: 10/16/2013, 3:13:47 PM

General Settings

Units of Measurement: Imperial Units
Time Units: days
Permeability Units: feet/second
Failure Direction: Right to Left
Data Output: Standard
Maximum Material Properties: 20
Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

Spencer

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50
Check malpha < 0.2: Yes
Initial trial value of FS: 1
Steffensen Iteration: Yes

Groundwater Analysis

Groundwater Method: Water Surfaces
Pore Fluid Unit Weight: 62.4 lbs/ft3
Advanced Groundwater Method: None

Random Numbers

Pseudo-random Seed: 10116
Random Number Generation Method: Park and Miller v.3

Surface Options

Surface Type: Non-Circular Block Search
Number of Surfaces: 5000
Pseudo-Random Surfaces: Enabled
Convex Surfaces Only: Disabled
Left Projection Angle (Start Angle): 120
Left Projection Angle (End Angle): 180
Right Projection Angle (Start Angle): 20
Right Projection Angle (End Angle): 60
Minimum Elevation: Not Defined
Minimum Depth: Not Defined

Loading

1 Distributed Load present

Distributed Load 1

Distribution: Constant
Magnitude [psf]: 250
Orientation: Normal to boundary

Material Properties

Property	embankment soil	water	Foundation soil	bedrock
Color				
Strength Type	Undrained	No strength	Undrained	Undrained
Unsaturated Unit Weight [lbs/ft3]			135	145
Saturated Unit Weight [lbs/ft3]			135	145
Cohesion Type	1250		1250	8000
Water Surface	None	None	None	None
Ru Value	0	0	0	0

Global Minimums

Method: spencer

FS: 6.728310
Axis Location: 94.313, 1072.462
Left Slip Surface Endpoint: 74.365, 1011.622
Right Slip Surface Endpoint: 131.016, 1020.000
Resisting Moment=5.10355e+006 lb-ft
Driving Moment=758518 lb-ft
Resisting Horizontal Force=70814.2 lb
Driving Horizontal Force=10524.8 lb
Total Slice Area=459.352 ft2

Global Minimum Coordinates

Method: spencer

X	Y
74.3649	1011.62
91.3283	1003.76
105.443	1004.13
131.016	1020

Valid / Invalid Surfaces

Method: spencer

Number of Valid Surfaces: 4077
Number of Invalid Surfaces: 923

Error Codes:

Error Code -105 reported for 10 surfaces
Error Code -107 reported for 16 surfaces
Error Code -108 reported for 667 surfaces
Error Code -111 reported for 171 surfaces
Error Code -112 reported for 59 surfaces

Error Codes

The following errors were encountered during the computation:

-105 = More than two surface / slope intersections with no valid slip surface.
-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.

Slice Data

Global Minimum Query (spencer) - Safety Factor: 6.72831

Slice Number	Width [ft]	Weight [lbs]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]
1	3.15207	354.464	embankment soil	1250	0	185.782	1250	227.817	0	227.817
2	2.3019	725.585	Foundation soil	1250	0	185.782	1250	440.457	0	440.457

3	2.3019	1141.32	Foundation soil	1250	0	185.782	1250	629.867	0	629.867
4	2.3019	1557.06	Foundation soil	1250	0	185.782	1250	819.276	0	819.276
5	2.3019	1972.8	Foundation soil	1250	0	185.782	1250	1008.69	0	1008.69
6	2.3019	2388.54	Foundation soil	1250	0	185.782	1250	1198.1	0	1198.1
7	2.3019	2804.27	Foundation soil	1250	0	185.782	1250	1387.5	0	1387.5
8	2.35239	3149.23	Foundation soil	1250	0	185.782	1250	1348.98	0	1348.98
9	2.35239	3360.98	Foundation soil	1250	0	185.782	1250	1438.76	0	1438.76
10	2.35239	3579.47	Foundation soil	1250	0	185.782	1250	1531.4	0	1531.4
11	2.35239	3797.95	Foundation soil	1250	0	185.782	1250	1624.03	0	1624.03
12	2.35239	4016.44	Foundation soil	1250	0	185.782	1250	1716.67	0	1716.67
13	2.35239	4234.92	Foundation soil	1250	0	185.782	1250	1809.3	0	1809.3
14	2.07235	3739.48	Foundation soil	1250	0	185.782	1250	1607.78	0	1607.78
15	2.07235	3557.04	Foundation soil	1250	0	185.782	1250	1591.61	0	1591.61
16	2.07235	3245.2	Foundation soil	1250	0	185.782	1250	1618.59	0	1618.59
17	2.07235	2886.09	Foundation soil	1250	0	185.782	1250	1455.44	0	1455.44
18	2.07235	2526.99	Foundation soil	1250	0	185.782	1250	1292.29	0	1292.29
19	2.17311	2285.75	embankment soil	1250	0	185.782	1250	1134.54	0	1134.54
20	2.17311	1934.1	embankment soil	1250	0	185.782	1250	982.18	0	982.18
21	2.17311	1582.44	embankment soil	1250	0	185.782	1250	829.821	0	829.821
22	2.17311	1230.79	embankment soil	1250	0	185.782	1250	677.466	0	677.466
23	2.17311	879.136	embankment soil	1250	0	185.782	1250	525.107	0	525.107
24	2.17311	527.481	embankment soil	1250	0	185.782	1250	372.749	0	372.749
25	2.17311	175.827	embankment soil	1250	0	185.782	1250	220.649	0	220.649

Interslice Data

Global Minimum Query (spencer) - Safety Factor: 6.72831

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	74.3649	1011.62	0	0	0
2	77.5169	1010.16	918.22	92.2816	5.73899
3	79.8188	1009.09	1815.6	182.469	5.73899
4	82.1207	1008.03	2915.03	292.962	5.73898
5	84.4226	1006.96	4216.5	423.76	5.73898
6	86.7245	1005.89	5720.01	574.864	5.73899
7	89.0264	1004.83	7425.56	746.273	5.73899
8	91.3283	1003.76	9333.16	937.987	5.73898
9	93.6807	1003.82	9687.09	973.557	5.73898
10	96.0331	1003.88	10035.5	1008.57	5.73897

11	98.3855	1003.95	10378.2	1043.01	5.73896
12	100.738	1004.01	10715.2	1076.88	5.73897
13	103.09	1004.07	11046.5	1110.18	5.73899
14	105.443	1004.13	11372.1	1142.9	5.73898
15	107.515	1005.42	9689.45	973.795	5.73899
16	109.587	1006.7	8027.59	806.777	5.73899
17	111.66	1007.99	6331.03	636.271	5.73898
18	113.732	1009.27	4844.27	486.851	5.73898
19	115.804	1010.56	3567.32	358.517	5.73898
20	117.978	1011.91	2441.01	245.323	5.73899
21	120.151	1013.26	1520.16	152.777	5.73899
22	122.324	1014.61	804.768	80.8795	5.73898
23	124.497	1015.95	294.828	29.6304	5.73899
24	126.67	1017.3	-9.65531	-0.970364	5.73899
25	128.843	1018.65	-108.683	-10.9227	5.73899
26	131.016	1020	0	0	0

List Of Coordinates

Water Table

X	Y
0	1009
55	1009
62	1010
158	1011
210	1011

Line Load

X	Y
139	1020
109	1020

Block Search Window

X	Y
76.4952	1011.9
83.2094	1003.69
106.769	1003.69
106.769	1015.87

Block Search Window

X	Y
89.8588	1013.66

98.8	1003.69
124.901	1003.69
112.774	1020

External Boundary

X	Y
144.542	1017.38
139	1020
109	1020
95	1015
92.0333	1013.94
62	1010
55	1009
46	1009
41	1010
34	1011
0	1011
0	1003.69
0	974.831
210	974.831
210	1003.69
210	1011
210	1017.38

Material Boundary

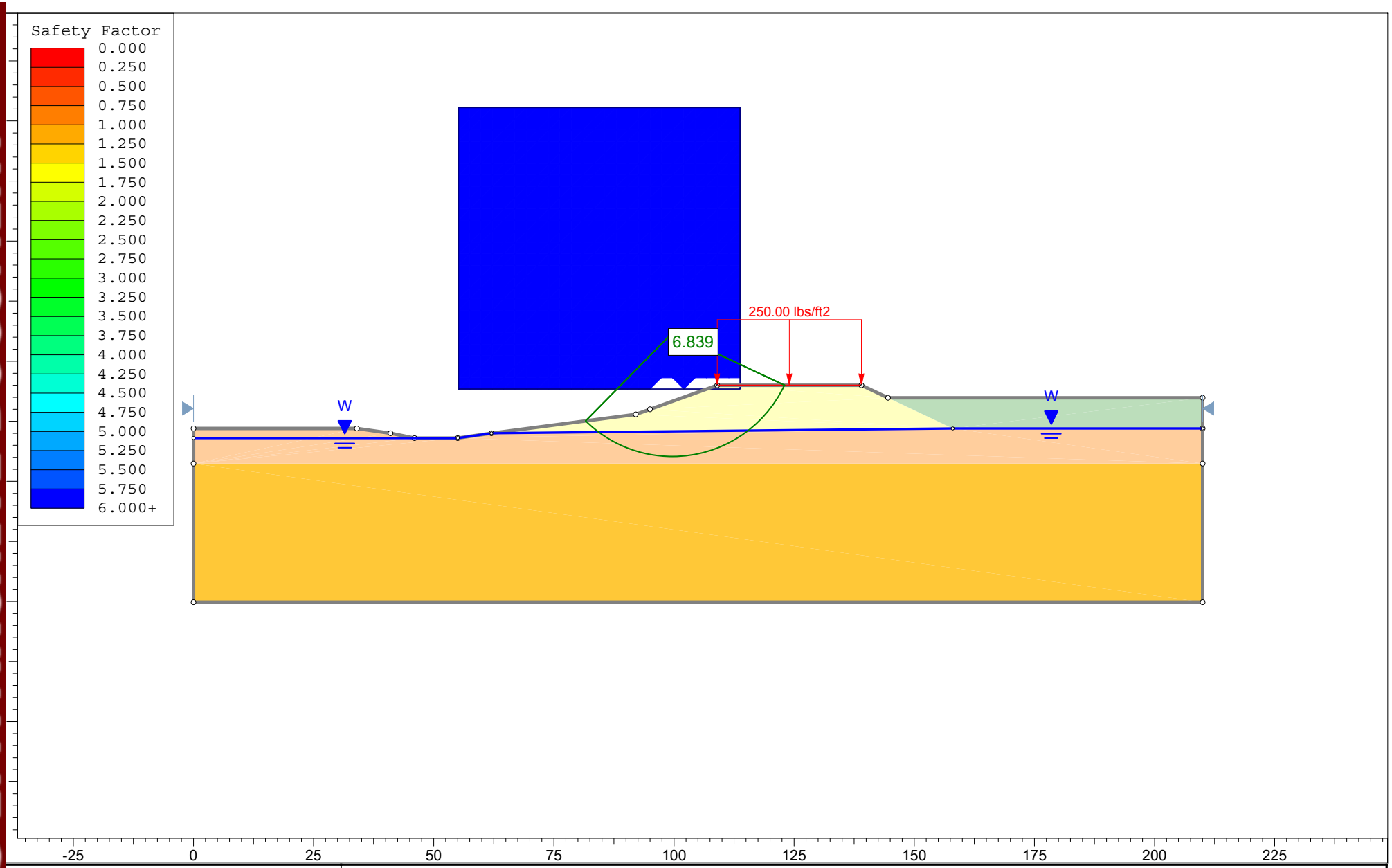
X	Y
62	1010
158	1011

Material Boundary

X	Y
0	1003.69
210	1003.69

Material Boundary

X	Y
144.542	1017.38
158	1011
210	1011



rocscience	Project: SLIDE - An Interactive Slope Stability Program		
	Analysis Description:		
	Drawn By:	Scale: 1:332	Company:
	Date: 10/16/2013, 3:13:47 PM		File Name: A-A_ Keystone_undrained Circular.slim

DEINTERPRET 6.019

Slide Analysis Information

SLIDE - An Interactive Slope Stability Program

Project Summary

File Name: A-A_ Keystone_undrained Circular
Slide Modeler Version: 6.019
Project Title: SLIDE - An Interactive Slope Stability Program
Date Created: 10/16/2013, 3:13:47 PM

General Settings

Units of Measurement: Imperial Units
Time Units: days
Permeability Units: feet/second
Failure Direction: Right to Left
Data Output: Standard
Maximum Material Properties: 20
Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

Spencer

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50
Check malpha < 0.2: Yes
Initial trial value of FS: 1
Steffensen Iteration: Yes

Groundwater Analysis

Groundwater Method: Water Surfaces
Pore Fluid Unit Weight: 62.4 lbs/ft3
Advanced Groundwater Method: None

Random Numbers

Pseudo-random Seed: 10116
Random Number Generation Method: Park and Miller v.3

Surface Options

Surface Type: Circular
Search Method: Grid Search
Radius Increment: 10
Composite Surfaces: Disabled
Reverse Curvature: Create Tension Crack
Minimum Elevation: Not Defined
Minimum Depth: 2

Loading

1 Distributed Load present

Distributed Load 1

Distribution: Constant
Magnitude [psf]: 250
Orientation: Normal to boundary

Material Properties

Property	embankment soil	water	Foundation soil	bedrock
Color				
Strength Type	Undrained	No strength	Undrained	Undrained
Unsaturated Unit Weight [lbs/ft3]			135	145
Saturated Unit Weight [lbs/ft3]			135	145
Cohesion Type	1250		1250	8000
Water Surface	None	None	None	None
Ru Value	0	0	0	0

Global Minimums

Method: spencer

FS: 6.838840
Center: 99.689, 1030.913
Radius: 25.764
Left Slip Surface Endpoint: 81.596, 1012.571
Right Slip Surface Endpoint: 123.027, 1020.000
Resisting Moment=1.58614e+006 lb-ft
Driving Moment=231932 lb-ft
Resisting Horizontal Force=51788.9 lb
Driving Horizontal Force=7572.76 lb
Total Slice Area=353.118 ft2

Valid / Invalid Surfaces

Method: spencer

Number of Valid Surfaces: 5021
Number of Invalid Surfaces: 2415

Error Codes:

Error Code -103 reported for 2082 surfaces
Error Code -108 reported for 44 surfaces
Error Code -112 reported for 150 surfaces
Error Code -115 reported for 139 surfaces

Error Codes

The following errors were encountered during the computation:

-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).
-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.
-115 = Surface too shallow, below the minimum depth.

Slice Data

Global Minimum Query (spencer) - Safety Factor: 6.83884

Slice Number	Width [ft]	Weight [lbs]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]
1	1.36372	117.065	embankment soil	1250	0	182.78	1250	300.342	0	300.342
2	1.36372	337.691	embankment soil	1250	0	182.78	1250	448.332	0	448.332
3	1.6399	676.294	Foundation soil	1250	0	182.78	1250	597.968	0	597.968
4	1.6399	948.51	Foundation soil	1250	0	182.78	1250	747.106	0	747.106
5	1.6399	1184.75	Foundation soil	1250	0	182.78	1250	873.473	0	873.473
6	1.6399	1389.01	Foundation soil	1250	0	182.78	1250	979.711	0	979.711
7	1.6399	1567.4	Foundation soil	1250	0	182.78	1250	1069.78	0	1069.78
8	1.6399	1770.52	Foundation soil	1250	0	182.78	1250	1175.39	0	1175.39
9	1.6399	1966.09	Foundation soil	1250	0	182.78	1250	1275.84	0	1275.84
10	1.6399	2137.28	Foundation soil	1250	0	182.78	1250	1360.61	0	1360.61
11	1.6399	2284.79	Foundation soil	1250	0	182.78	1250	1430.21	0	1430.21
12	1.6399	2409.03	Foundation soil	1250	0	182.78	1250	1484.94	0	1484.94
13	1.6399	2510.1	Foundation soil	1250	0	182.78	1250	1524.89	0	1524.89
14	1.6399	2587.81	Foundation soil	1250	0	182.78	1250	1549.99	0	1549.99
15	1.6399	2641.7	Foundation soil	1250	0	182.78	1250	1559.95	0	1559.95
16	1.6399	2670.95	Foundation soil	1250	0	182.78	1250	1554.26	0	1554.26
17	1.6399	2674.38	Foundation soil	1250	0	182.78	1250	1532.18	0	1532.18
18	1.6399	2598.04	Foundation soil	1250	0	182.78	1250	1690.31	0	1690.31
19	1.6399	2429.08	Foundation soil	1250	0	182.78	1250	1574.8	0	1574.8
20	1.6399	2227.08	Foundation soil	1250	0	182.78	1250	1427.91	0	1427.91
21	1.6399	1987.82	Foundation soil	1250	0	182.78	1250	1258.47	0	1258.47
22	1.8864	1954.78	embankment soil	1250	0	182.78	1250	1056.41	0	1056.41
23	1.8864	1548	embankment soil	1250	0	182.78	1250	811.11	0	811.11
24	1.8864	1041.78	embankment soil	1250	0	182.78	1250	510.779	0	510.779
25	1.8864	379.775	embankment soil	1250	0	182.78	1250	121.594	0	121.594

Interslice Data

Global Minimum Query (spencer) - Safety Factor: 6.83884

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	81.596	1012.57	0	0	0
2	82.9598	1011.32	625.075	63.9209	5.83884
3	84.3235	1010.23	1361.41	139.219	5.83882
4	85.9634	1009.11	2332.44	238.518	5.83884
5	87.6033	1008.16	3341.73	341.729	5.83883
6	89.2432	1007.36	4338.28	443.638	5.83884
7	90.8831	1006.7	5285.4	540.491	5.83883
8	92.523	1006.17	6157.26	629.649	5.83884
9	94.1629	1005.75	6946.96	710.405	5.83884
10	95.8028	1005.44	7635.44	780.809	5.83884
11	97.4427	1005.25	8202.58	838.806	5.83884
12	99.0826	1005.16	8632.24	882.743	5.83884
13	100.722	1005.17	8911.59	911.31	5.83884
14	102.362	1005.29	9030.68	923.488	5.83884
15	104.002	1005.51	8982.18	918.528	5.83884
16	105.642	1005.85	8761.31	895.942	5.83884
17	107.282	1006.29	8365.94	855.511	5.83884
18	108.922	1006.86	7796.86	797.316	5.83884
19	110.562	1007.56	6920.85	707.734	5.83884
20	112.202	1008.39	5903.99	603.749	5.83884
21	113.842	1009.38	4786.01	489.423	5.83884
22	115.482	1010.56	3610.06	369.169	5.83884
23	117.368	1012.17	2248.54	229.939	5.83885

24	119.254	1014.15	987.976	101.032	5.83886
25	121.141	1016.64	58.9126	6.02447	5.83884
26	123.027	1020	0	0	0

List Of Coordinates

Water Table

X	Y
0	1009
55	1009
62	1010
158	1011
210	1011

Line Load

X	Y
139	1020
109	1020

External Boundary

X	Y
144.542	1017.38
139	1020
109	1020
95	1015
92.0333	1013.94
62	1010
55	1009
46	1009
41	1010
34	1011
0	1011
0	1003.69
0	974.831
210	974.831
210	1003.69
210	1011
210	1017.38

Material Boundary

X	Y
62	1010

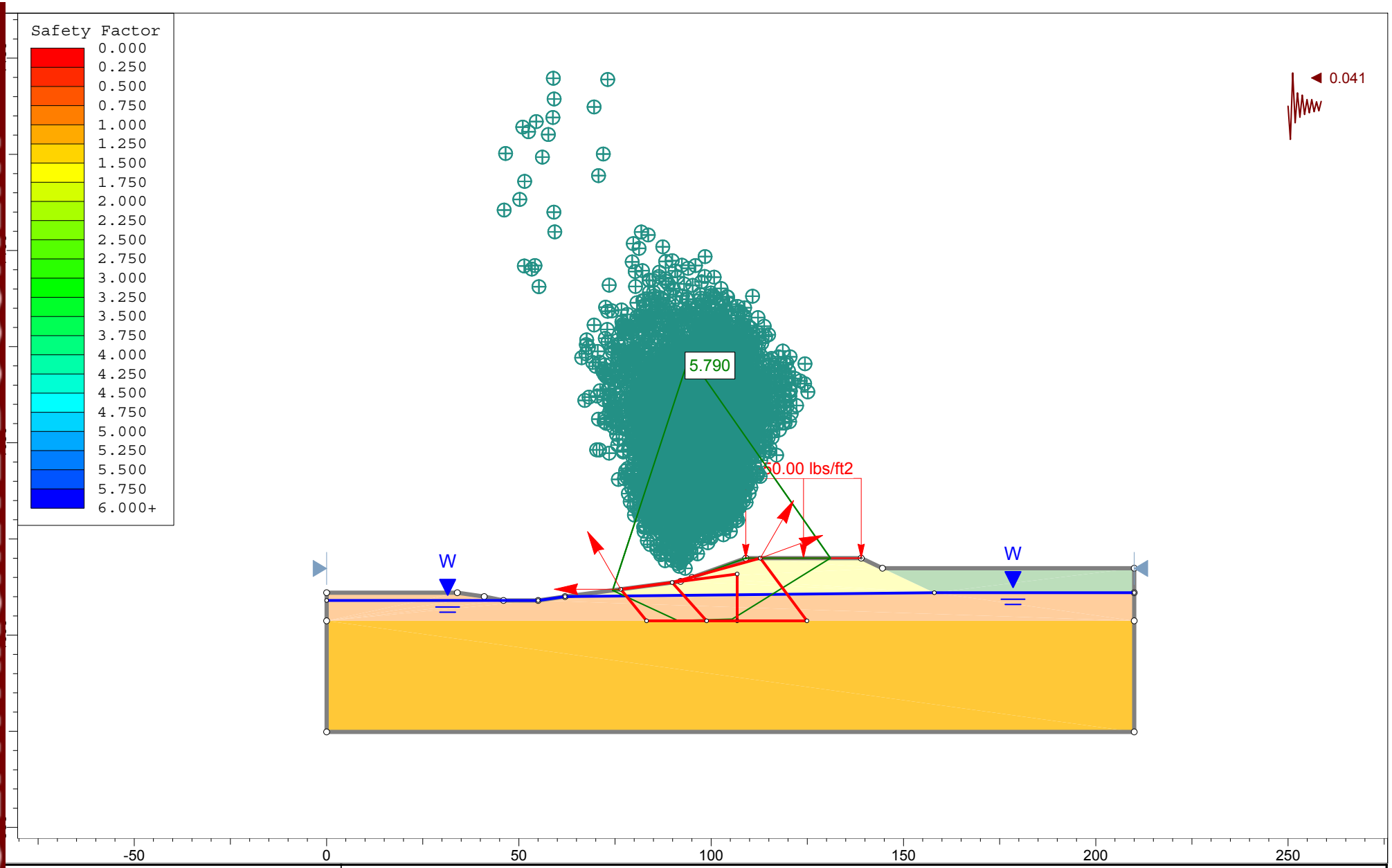
158	1011

Material Boundary

X	Y
0	1003.69
210	1003.69

Material Boundary

X	Y
144.542	1017.38
158	1011
210	1011



	Project: SLIDE - An Interactive Slope Stability Program		
	Analysis Description:		
	Drawn By:	Scale: 1:415	Company:
	Date: 10/16/2013, 3:13:47 PM		File Name: A-A_ Keystone_undrained block_seismic.slim

DEINTERPRET 6.019

Slide Analysis Information

SLIDE - An Interactive Slope Stability Program

Project Summary

File Name: A-A_ Keystone_undrained block_seismic
Slide Modeler Version: 6.019
Project Title: SLIDE - An Interactive Slope Stability Program
Date Created: 10/16/2013, 3:13:47 PM

General Settings

Units of Measurement: Imperial Units
Time Units: days
Permeability Units: feet/second
Failure Direction: Right to Left
Data Output: Standard
Maximum Material Properties: 20
Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

Spencer

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50
Check malpha < 0.2: Yes
Initial trial value of FS: 1
Steffensen Iteration: Yes

Groundwater Analysis

Groundwater Method: Water Surfaces
Pore Fluid Unit Weight: 62.4 lbs/ft3
Advanced Groundwater Method: None

Random Numbers

Pseudo-random Seed: 10116
Random Number Generation Method: Park and Miller v.3

Surface Options

Surface Type: Non-Circular Block Search
Number of Surfaces: 5000
Pseudo-Random Surfaces: Enabled
Convex Surfaces Only: Disabled
Left Projection Angle (Start Angle): 120
Left Projection Angle (End Angle): 180
Right Projection Angle (Start Angle): 20
Right Projection Angle (End Angle): 60
Minimum Elevation: Not Defined
Minimum Depth: Not Defined

Loading

Seismic Load Coefficient (Horizontal): 0.041
1 Distributed Load present

Distributed Load 1

Distribution: Constant
Magnitude [psf]: 250
Orientation: Normal to boundary

Material Properties

Property	embankment soil	water	Foundation soil	bedrock
Color				
Strength Type	Undrained	No strength	Undrained	Undrained
Unsaturated Unit Weight [lbs/ft3]			135	145
Saturated Unit Weight [lbs/ft3]			135	145
Cohesion Type	1250		1250	8000
Water Surface	None	None	None	None
Ru Value	0	0	0	0

Global Minimums

Method: spencer

FS: 5.790160
Axis Location: 94.313, 1072.462
Left Slip Surface Endpoint: 74.365, 1011.622
Right Slip Surface Endpoint: 131.016, 1020.000
Resisting Moment=5.1012e+006 lb-ft
Driving Moment=881013 lb-ft
Resisting Horizontal Force=70814.2 lb
Driving Horizontal Force=12230.1 lb

Total Slice Area=459.352 ft2

Global Minimum Coordinates

Method: spencer

X	Y
74.3649	1011.62
91.3283	1003.76
105.443	1004.13
131.016	1020

Valid / Invalid Surfaces

Method: spencer

Number of Valid Surfaces: 4119
Number of Invalid Surfaces: 881

Error Codes:

Error Code -105 reported for 10 surfaces
Error Code -107 reported for 4 surfaces
Error Code -108 reported for 615 surfaces
Error Code -111 reported for 194 surfaces
Error Code -112 reported for 58 surfaces

Error Codes

The following errors were encountered during the computation:

-105 = More than two surface / slope intersections with no valid slip surface.
-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.

Slice Data

Global Minimum Query (spencer) - Safety Factor: 5.79016

Slice Number	Width [ft]	Weight [lbs]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]
			embankment soil							

2	2.3019	725.585	Foundation soil	1250	0	215.883	1250	466.602	0	466.602
3	2.3019	1141.32	Foundation soil	1250	0	215.883	1250	657.091	0	657.091
4	2.3019	1557.06	Foundation soil	1250	0	215.883	1250	847.581	0	847.581
5	2.3019	1972.8	Foundation soil	1250	0	215.883	1250	1038.07	0	1038.07
6	2.3019	2388.54	Foundation soil	1250	0	215.883	1250	1228.56	0	1228.56
7	2.3019	2804.27	Foundation soil	1250	0	215.883	1250	1419.05	0	1419.05
8	2.35239	3149.23	Foundation soil	1250	0	215.883	1250	1348.48	0	1348.48
9	2.35239	3360.98	Foundation soil	1250	0	215.883	1250	1437.75	0	1437.75
10	2.35239	3579.47	Foundation soil	1250	0	215.883	1250	1529.87	0	1529.87
11	2.35239	3797.95	Foundation soil	1250	0	215.883	1250	1621.98	0	1621.98
12	2.35239	4016.44	Foundation soil	1250	0	215.883	1250	1714.1	0	1714.1
13	2.35239	4234.92	Foundation soil	1250	0	215.883	1250	1806.22	0	1806.22
14	2.07235	3739.48	Foundation soil	1250	0	215.883	1250	1568.9	0	1568.9
15	2.07235	3557.04	Foundation soil	1250	0	215.883	1250	1553.34	0	1553.34
16	2.07235	3245.2	Foundation soil	1250	0	215.883	1250	1580.69	0	1580.69
17	2.07235	2886.09	Foundation soil	1250	0	215.883	1250	1420.39	0	1420.39
18	2.07235	2526.99	Foundation soil	1250	0	215.883	1250	1260.09	0	1260.09
19	2.17311	2285.75	embankment soil	1250	0	215.883	1250	1105.09	0	1105.09
20	2.17311	1934.1	embankment soil	1250	0	215.883	1250	955.396	0	955.396
21	2.17311	1582.44	embankment soil	1250	0	215.883	1250	805.7	0	805.7
22	2.17311	1230.79	embankment soil	1250	0	215.883	1250	656.008	0	656.008
23	2.17311	879.136	embankment soil	1250	0	215.883	1250	506.312	0	506.312
24	2.17311	527.481	embankment soil	1250	0	215.883	1250	356.616	0	356.616
25	2.17311	175.827	embankment soil	1250	0	215.883	1250	207.324	0	207.324

Interslice Data

Global Minimum Query (spencer) - Safety Factor: 5.79016

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	74.3649	1011.62	0	0	0
2	77.5169	1010.16	1035	126.884	6.9892
3	79.8188	1009.09	1999.83	245.164	6.98915
4	82.1207	1008.03	3150.8	386.265	6.98917
5	84.4226	1006.96	4487.93	550.186	6.98915
6	86.7245	1005.89	6011.21	736.929	6.98916
7	89.0264	1004.83	7720.63	946.492	6.98916
8	91.3283	1003.76	9616.21	1178.88	6.98919

9	93.6807	1003.82	9911.88	1215.12	6.98915
10	96.0331	1003.88	10193.4	1249.63	6.98913
11	98.3855	1003.95	10460.2	1282.35	6.9892
12	100.738	1004.01	10712.5	1313.27	6.98915
13	103.09	1004.07	10950.1	1342.4	6.98916
14	105.443	1004.13	11173.1	1369.73	6.98912
15	107.515	1005.42	9449.48	1158.44	6.98919
16	109.587	1006.7	7753.38	950.506	6.98916
17	111.66	1007.99	6034.9	739.834	6.98916
18	113.732	1009.27	4537.29	556.238	6.98916
19	115.804	1010.56	3260.54	399.718	6.98916
20	117.978	1011.91	2145.65	263.041	6.98917
21	120.151	1013.26	1247.05	152.879	6.98916
22	122.324	1014.61	564.726	69.2312	6.98916
23	124.497	1015.95	98.6875	12.0983	6.98913
24	126.67	1017.3	-151.069	-18.5199	6.98915
25	128.843	1018.65	-184.542	-22.6235	6.98917
26	131.016	1020	0	0	0

List Of Coordinates

Water Table

X	Y
0	1009
55	1009
62	1010
158	1011
210	1011

Line Load

X	Y
139	1020
109	1020

Block Search Window

X	Y
76.4952	1011.9
83.2094	1003.69
106.769	1003.69
106.769	1015.87

Block Search Window

X	Y
89.8588	1013.66
98.8	1003.69
124.901	1003.69
112.774	1020

External Boundary

X	Y
144.542	1017.38
139	1020
109	1020
95	1015
92.0333	1013.94
62	1010
55	1009
46	1009
41	1010
34	1011
0	1011
0	1003.69
0	974.831
210	974.831
210	1003.69
210	1011
210	1017.38

Material Boundary

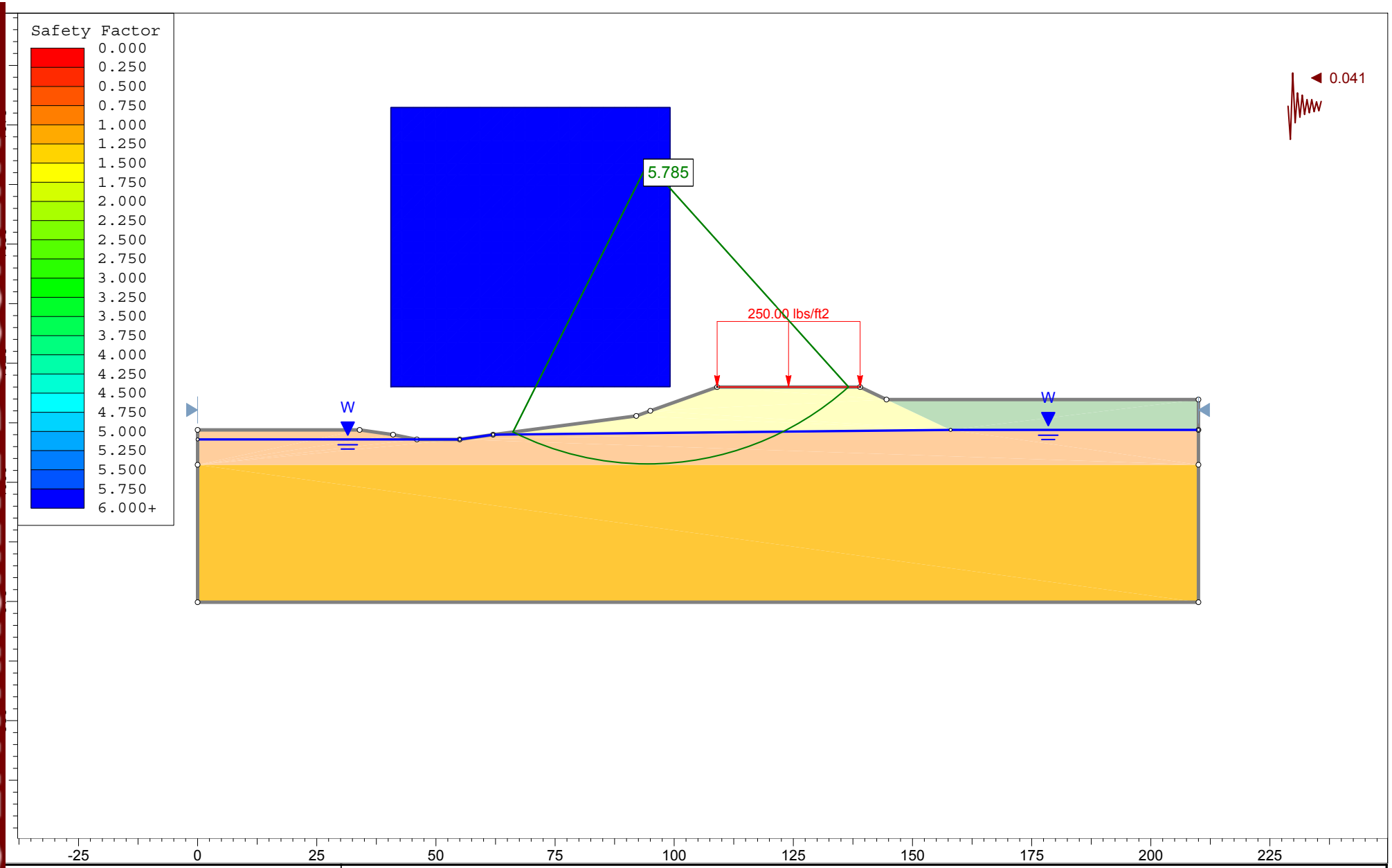
X	Y
62	1010
158	1011

Material Boundary

X	Y
0	1003.69
210	1003.69

Material Boundary

X	Y
144.542	1017.38
158	1011
210	1011



rocscience	Project: SLIDE - An Interactive Slope Stability Program		
	Analysis Description:		
	Drawn By:	Scale: 1:335	Company:
	Date: 10/16/2013, 3:13:47 PM		File Name: A-A_ Keystone_undrained Circular_seismic.slim

DEINTERPRET 6.019

Slide Analysis Information

SLIDE - An Interactive Slope Stability Program

Project Summary

File Name: A-A_ Keystone_undrained Circular_seismic
Slide Modeler Version: 6.019
Project Title: SLIDE - An Interactive Slope Stability Program
Date Created: 10/16/2013, 3:13:47 PM

General Settings

Units of Measurement: Imperial Units
Time Units: days
Permeability Units: feet/second
Failure Direction: Right to Left
Data Output: Standard
Maximum Material Properties: 20
Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

Spencer

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50
Check malpha < 0.2: Yes
Initial trial value of FS: 1
Steffensen Iteration: Yes

Groundwater Analysis

Groundwater Method: Water Surfaces
Pore Fluid Unit Weight: 62.4 lbs/ft3
Advanced Groundwater Method: None

Random Numbers

Pseudo-random Seed: 10116
Random Number Generation Method: Park and Miller v.3

Surface Options

Surface Type: Circular
Search Method: Grid Search
Radius Increment: 10
Composite Surfaces: Disabled
Reverse Curvature: Create Tension Crack
Minimum Elevation: Not Defined
Minimum Depth: 2

Loading

Seismic Load Coefficient (Horizontal): 0.041
1 Distributed Load present

Distributed Load 1

Distribution: Constant
Magnitude [psf]: 250
Orientation: Normal to boundary

Material Properties

Property	embankment soil	water	Foundation soil	bedrock
Color				
Strength Type	Undrained	No strength	Undrained	Undrained
Unsaturated Unit Weight [lbs/ft3]			135	145
Saturated Unit Weight [lbs/ft3]			135	145
Cohesion Type	1250		1250	8000
Water Surface	None	None	None	None
Ru Value	0	0	0	0

Global Minimums

Method: spencer

FS: 5.784620
Center: 94.445, 1066.925
Radius: 63.075
Left Slip Surface Endpoint: 66.162, 1010.546
Right Slip Surface Endpoint: 136.594, 1020.000
Resisting Moment=5.94799e+006 lb-ft
Driving Moment=1.02824e+006 lb-ft
Resisting Horizontal Force=88040.3 lb
Driving Horizontal Force=15219.7 lb
Total Slice Area=608.899 ft2

Valid / Invalid Surfaces

Method: spencer

Number of Valid Surfaces: 5324
Number of Invalid Surfaces: 2112

Error Codes:

Error Code -103 reported for 1304 surfaces
Error Code -107 reported for 253 surfaces
Error Code -108 reported for 137 surfaces
Error Code -111 reported for 2 surfaces
Error Code -112 reported for 93 surfaces
Error Code -115 reported for 323 surfaces

Error Codes

The following errors were encountered during the computation:

-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.
-115 = Surface too shallow, below the minimum depth.

Slice Data

Global Minimum Query (spencer) - Safety Factor: 5.78462

Slice Number	Width [ft]	Weight [lbs]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]
1	1.00325	37.5527	embankment soil	1250	0	216.09	1250	179.578	0	179.578
2	2.93359	548.682	Foundation soil	1250	0	216.09	1250	326.355	0	326.355
3	2.93359	1172.36	Foundation soil	1250	0	216.09	1250	532.375	0	532.375
4	2.93359	1729.09	Foundation soil	1250	0	216.09	1250	712.776	0	712.776
5	2.93359	2222.38	Foundation soil	1250	0	216.09	1250	869.314	0	869.314
6	2.93359	2655.03	Foundation soil	1250	0	216.09	1250	1003.39	0	1003.39
7	2.93359	3029.24	Foundation soil	1250	0	216.09	1250	1116.13	0	1116.13
8	2.93359	3346.69	Foundation soil	1250	0	216.09	1250	1208.41	0	1208.41
9	2.93359	3608.62	Foundation soil	1250	0	216.09	1250	1280.92	0	1280.92
10	2.93359	3847.76	Foundation soil	1250	0	216.09	1250	1345.04	0	1345.04

11	2.93359	4207.55	Foundation soil	1250	0	216.09	1250	1449.42	0	1449.42
12	2.93359	4539.79	Foundation soil	1250	0	216.09	1250	1543.34	0	1543.34
13	2.93359	4817.66	Foundation soil	1250	0	216.09	1250	1617.85	0	1617.85
14	2.93359	5040.56	Foundation soil	1250	0	216.09	1250	1672.95	0	1672.95
15	2.93359	5207.49	Foundation soil	1250	0	216.09	1250	1708.48	0	1708.48
16	2.93359	5216.25	Foundation soil	1250	0	216.09	1250	1870.4	0	1870.4
17	2.93359	4910.24	Foundation soil	1250	0	216.09	1250	1811.11	0	1811.11
18	2.93359	4530.02	Foundation soil	1250	0	216.09	1250	1664.9	0	1664.9
19	2.93359	4085.04	Foundation soil	1250	0	216.09	1250	1498.46	0	1498.46
20	2.93359	3571.46	Foundation soil	1250	0	216.09	1250	1310.83	0	1310.83
21	2.73815	2835.8	embankment soil	1250	0	216.09	1250	1118.73	0	1118.73
22	2.73815	2322.96	embankment soil	1250	0	216.09	1250	923.278	0	923.278
23	2.73815	1747.66	embankment soil	1250	0	216.09	1250	707.863	0	707.863
24	2.73815	1103.34	embankment soil	1250	0	216.09	1250	470.739	0	470.739
25	2.73815	381.501	embankment soil	1250	0	216.09	1250	209.735	0	209.735

Interslice Data

Global Minimum Query (spencer) - Safety Factor: 5.78462

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	66.1616	1010.55	0	0	0
2	67.1649	1010.05	303.623	36.2929	6.81638
3	70.0985	1008.74	1344.56	160.718	6.81634
4	73.0321	1007.6	2538.47	303.43	6.81637
5	75.9657	1006.62	3798.64	454.062	6.81638
6	78.8993	1005.8	5055.9	604.345	6.81637
7	81.8328	1005.12	6255.11	747.691	6.81639
8	84.7664	1004.6	7352.73	878.892	6.81638
9	87.7	1004.21	8314.96	993.91	6.81638
10	90.6336	1003.96	9116.48	1089.72	6.81639
11	93.5672	1003.86	9739.37	1164.17	6.81636
12	96.5008	1003.88	10161	1214.57	6.81637
13	99.4344	1004.05	10355.4	1237.8	6.81633
14	102.368	1004.35	10303.2	1231.56	6.81633
15	105.302	1004.79	9991.28	1194.28	6.81635
16	108.235	1005.38	9412.84	1125.14	6.81636
17	111.169	1006.11	8464.53	1011.79	6.81639
18	114.102	1006.99	7296.27	872.143	6.81638
19	117.036	1008.03	6007.8	718.129	6.81638
20	119.97	1009.24	4659.72	556.989	6.81638

21	122.903	1010.63	3325.71	397.531	6.81638
22	125.641	1012.1	2156.42	257.762	6.81636
23	128.379	1013.76	1128.04	134.838	6.81639
24	131.118	1015.61	338.248	40.4317	6.81638
25	133.856	1017.68	-90.5347	-10.8219	6.8164
26	136.594	1020	0	0	0

List Of Coordinates

Water Table

X	Y
0	1009
55	1009
62	1010
158	1011
210	1011

Line Load

X	Y
139	1020
109	1020

External Boundary

X	Y
144.542	1017.38
139	1020
109	1020
95	1015
92.0333	1013.94
62	1010
55	1009
46	1009
41	1010
34	1011
0	1011
0	1003.69
0	974.831
210	974.831
210	1003.69
210	1011
210	1017.38

Material Boundary

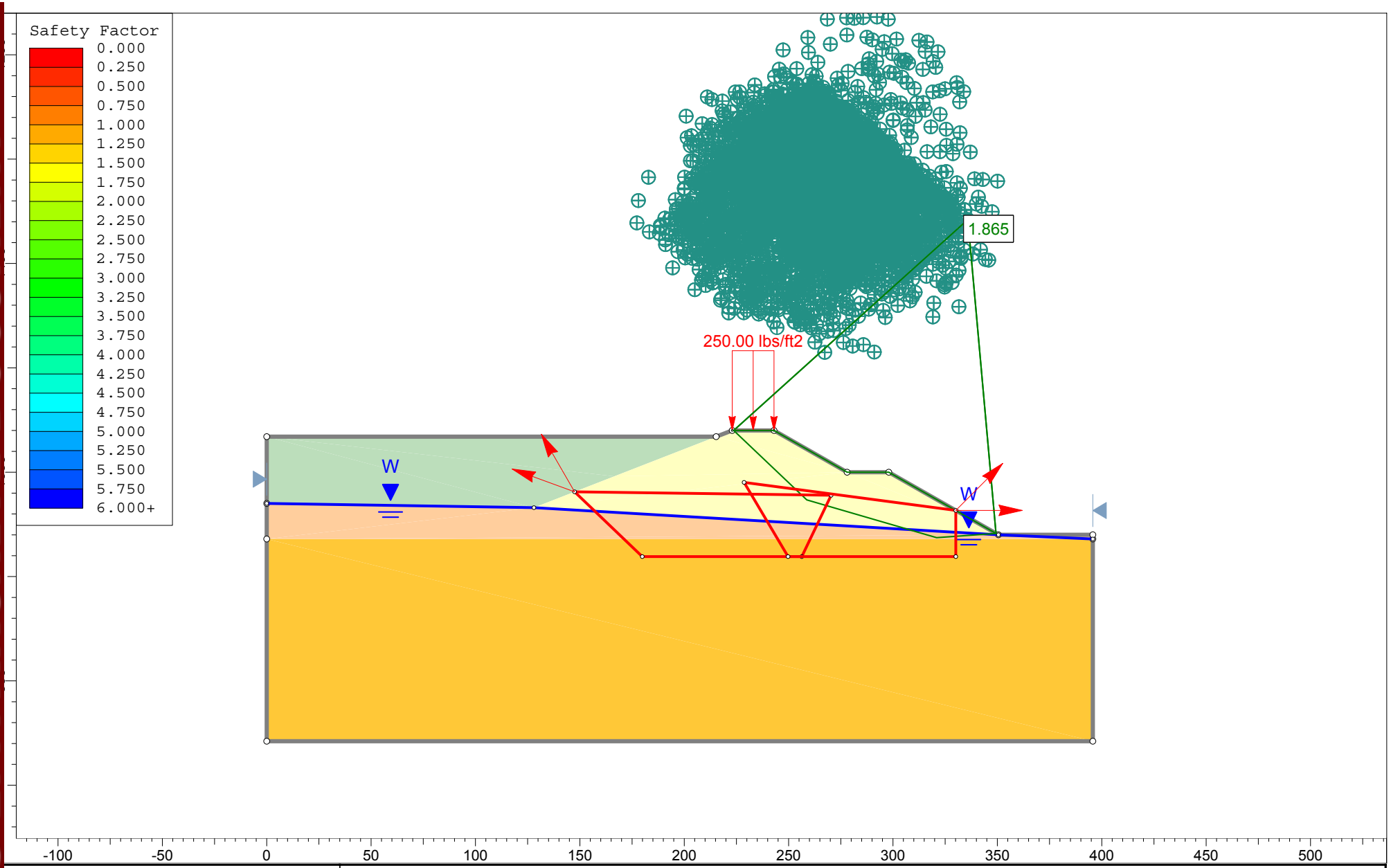
X	Y
62	1010
158	1011

Material Boundary

X	Y
0	1003.69
210	1003.69

Material Boundary

X	Y
144.542	1017.38
158	1011
210	1011



Project	SLIDE - An Interactive Slope Stability Program		
Analysis Description			
Drawn By		Scale 1:764	Company
Date	10/16/2013, 3:13:47 PM		File Name B-B_ Keystone_drained_Block.slim

DEINTERPRET 6.019

Slide Analysis Information

SLIDE - An Interactive Slope Stability Program

Project Summary

File Name: B-B_ Keystone_drained_Block
Slide Modeler Version: 6.019
Project Title: SLIDE - An Interactive Slope Stability Program
Date Created: 10/16/2013, 3:13:47 PM

General Settings

Units of Measurement: Imperial Units
Time Units: days
Permeability Units: feet/second
Failure Direction: Left to Right
Data Output: Standard
Maximum Material Properties: 20
Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

Spencer

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50
Check malpha < 0.2: Yes
Initial trial value of FS: 1
Steffensen Iteration: Yes

Groundwater Analysis

Groundwater Method: Water Surfaces
Pore Fluid Unit Weight: 62.4 lbs/ft3
Advanced Groundwater Method: None

Random Numbers

Pseudo-random Seed: 10116
Random Number Generation Method: Park and Miller v.3

Surface Options

Surface Type: Non-Circular Block Search
Number of Surfaces: 5000
Pseudo-Random Surfaces: Enabled
Convex Surfaces Only: Disabled
Left Projection Angle (Start Angle): 120
Left Projection Angle (End Angle): 160
Right Projection Angle (Start Angle): 0
Right Projection Angle (End Angle): 45
Minimum Elevation: Not Defined
Minimum Depth: Not Defined

Loading

1 Distributed Load present

Distributed Load 1

Distribution: Constant
Magnitude [psf]: 250
Orientation: Normal to boundary

Material Properties

Property	soil 1	water	Soil 2	bedrock
Color				
Strength Type	Mohr-Coulomb	No strength	Mohr-Coulomb	Undrained
Unsaturated Unit Weight [lbs/ft3]			135	145
Saturated Unit Weight [lbs/ft3]			135	145
Cohesion [psf]	240		0	
Friction Angle [deg]	28		32	
Cohesion Type				8000
Water Surface	None	None	Water Table	None
Hu Value			0	
Ru Value	0	0		0

Global Minimums

Method: spencer

FS: 1.865460
Axis Location: 335.838, 1121.020
Left Slip Surface Endpoint: 223.654, 1020.000
Right Slip Surface Endpoint: 349.344, 970.661
Resisting Moment=2.49857e+007 lb-ft

Driving Moment=1.33939e+007 lb-ft
Resisting Horizontal Force=150053 lb
Driving Horizontal Force=80437.8 lb
Total Slice Area=2116.9 ft2

Global Minimum Coordinates

Method: spencer

X	Y
223.654	1020
258.696	986.739
320.891	968.637
349.344	970.661

Valid / Invalid Surfaces

Method: spencer

Number of Valid Surfaces: 4238
Number of Invalid Surfaces: 762

Error Codes:

Error Code -107 reported for 149 surfaces
Error Code -108 reported for 531 surfaces
Error Code -111 reported for 54 surfaces
Error Code -112 reported for 28 surfaces

Error Codes

The following errors were encountered during the computation:

-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.

Slice Data

Global Minimum Query (spencer) - Safety Factor: 1.86546

Slice Number	Width [ft]	Weight [lbs]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]
1	5.00609	1427.21	soil 1	240	28	215.098	401.257	303.28	0	303.28
2	5.00609	4281.64	soil 1	240	28	321.556	599.849	676.777	0	676.777
3	5.00609	7136.07	soil 1	240	28	428.012	798.44	1050.27	0	1050.27
4	5.00609	9974.73	soil 1	240	28	527.559	984.14	1399.53	0	1399.53
5	5.00609	11752.9	soil 1	240	28	553.524	1032.58	1490.63	0	1490.63
6	5.00609	12888.9	soil 1	240	28	595.89	1111.61	1639.26	0	1639.26
7	5.00609	14024.8	soil 1	240	28	638.256	1190.64	1787.9	0	1787.9
8	5.43335	15341.7	soil 1	240	28	873.42	1629.33	2612.94	0	2612.94
9	5.43335	14348.4	soil 1	240	28	825.405	1539.76	2444.48	0	2444.48
10	5.43335	13355.1	soil 1	240	28	777.385	1450.18	2276.01	0	2276.01
11	5.43335	12564.2	soil 1	240	28	739.153	1378.86	2141.89	0	2141.89
12	5.43335	13286	soil 1	240	28	774.045	1443.95	2264.3	0	2264.3
13	5.43335	14317	soil 1	240	28	823.888	1536.93	2439.18	0	2439.18
14	5.43335	15348.1	soil 1	240	28	873.731	1629.91	2614.04	0	2614.04
15	5.43335	15784.9	soil 1	240	28	894.846	1669.3	2688.12	0	2688.12
16	5.43335	14846.9	soil 1	240	28	849.501	1584.71	2529.04	0	2529.04
17	4.43151	11408.1	Soil 2	0	32	798.023	1488.68	2382.38	0	2382.38
18	4.43151	10815.9	Soil 2	0	32	756.596	1411.4	2258.71	0	2258.71
19	4.43151	10223.7	Soil 2	0	32	715.169	1334.12	2135.03	0	2135.03
20	4.77462	9795.18	Soil 2	0	32	837.273	1561.9	2499.56	0	2499.56
21	4.77462	7993.12	Soil 2	0	32	683.236	1274.55	2039.71	0	2039.71
22	4.77462	6191.06	Soil 2	0	32	529.2	987.202	1579.85	0	1579.85
23	4.77462	4389	Soil 2	0	32	375.164	699.853	1120	0	1120
24	4.77462	2586.94	Soil 2	0	32	221.127	412.503	660.143	0	660.143
25	4.57945	808.501	soil 1	240	28	207.167	386.462	275.455	0	275.455

Interslice Data

Global Minimum Query (spencer) - Safety Factor: 1.86546

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	223.654	1020	0	0	0
2	228.66	1015.25	362.58	138.886	20.9593
3	233.666	1010.5	1966.09	753.111	20.9593
4	238.672	1005.75	4810.54	1842.68	20.9594
5	243.678	1000.99	8815.37	3376.72	20.9593
6	248.684	996.242	13122.9	5026.71	20.9593
7	253.69	991.49	17924.2	6865.86	20.9593
8	258.696	986.739	23219.4	8894.17	20.9593
9	264.13	985.158	22598.4	8656.29	20.9593
10	269.563	983.576	21972.2	8416.45	20.9593
11	274.996	981.995	21341	8174.66	20.9593
12	280.43	980.413	20705.7	7931.32	20.9593
13	285.863	978.832	20074.2	7689.39	20.9593
14	291.296	977.251	19447.9	7449.5	20.9593
15	296.73	975.669	18826.9	7211.63	20.9593

16	302.163	974.088	18208.1	6974.61	20.9593
17	307.597	972.507	17584.6	6735.76	20.9593
18	312.028	971.217	17115.3	6556.01	20.9593
19	316.46	969.927	16670.4	6385.6	20.9593
20	320.891	968.637	16249.9	6224.52	20.9593
21	325.666	968.977	11397.3	4365.73	20.9593
22	330.44	969.316	7437.44	2848.91	20.9593
23	335.215	969.656	4370.34	1674.06	20.9594
24	339.99	969.996	2195.99	841.173	20.9593
25	344.764	970.335	914.398	350.26	20.9593
26	349.344	970.661	0	0	0

List Of Coordinates

Water Table

X	Y
0	985
128	983
350.5	970
395.703	968

Line Load

X	Y
243	1020
223	1020

Block Search Window

X	Y
147.491	990.591
179.921	959.521
256.328	959.521
270.38	988.942

Block Search Window

X	Y
228.663	995.09
249.741	959.521
330.1	959.521
330.1	981.657

External Boundary

X	Y
243	1020
223	1020
215.297	1017
0	1017
0	985
0	968
0	871.073
395.703	871.073
395.703	968
395.703	970
350.5	970
298	1000
278	1000

Material Boundary

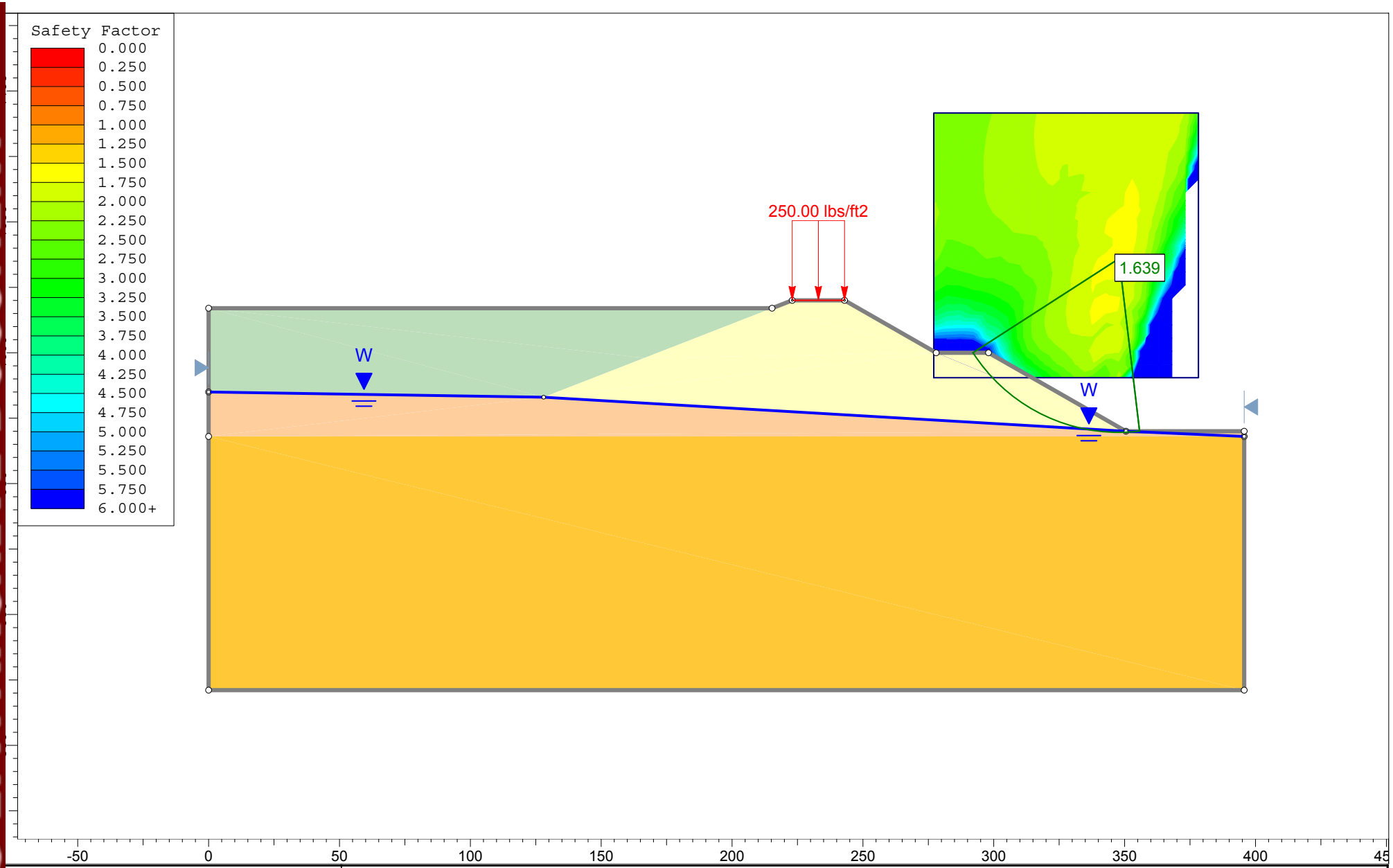
X	Y
0	985
128	983
166.514	998
215.297	1017

Material Boundary

X	Y
128	983
350.5	970

Material Boundary

X	Y
0	968
395.703	968



rocscience	Project: SLIDE - An Interactive Slope Stability Program		
	Analysis Description:		
	Drawn By:	Scale: 1:610	Company:
	Date: 10/16/2013, 3:13:47 PM		File Name: B-B_ Keystone_drained_circular.slim

DEINTERPRET 6.019

Slide Analysis Information

SLIDE - An Interactive Slope Stability Program

Project Summary

File Name: B-B_ Keystone_drained_circular
Slide Modeler Version: 6.019
Project Title: SLIDE - An Interactive Slope Stability Program
Date Created: 10/16/2013, 3:13:47 PM

General Settings

Units of Measurement: Imperial Units
Time Units: days
Permeability Units: feet/second
Failure Direction: Left to Right
Data Output: Standard
Maximum Material Properties: 20
Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

Spencer

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50
Check malpha < 0.2: Yes
Initial trial value of FS: 1
Steffensen Iteration: Yes

Groundwater Analysis

Groundwater Method: Water Surfaces
Pore Fluid Unit Weight: 62.4 lbs/ft3
Advanced Groundwater Method: None

Random Numbers

Pseudo-random Seed: 10116
Random Number Generation Method: Park and Miller v.3

Surface Options

Surface Type: Circular
Search Method: Grid Search
Radius Increment: 10
Composite Surfaces: Disabled
Reverse Curvature: Create Tension Crack
Minimum Elevation: Not Defined
Minimum Depth: Not Defined

Loading

1 Distributed Load present

Distributed Load 1

Distribution: Constant
Magnitude [psf]: 250
Orientation: Normal to boundary

Material Properties

Property	soil 1	water	Soil 2	bedrock
Color				
Strength Type	Mohr-Coulomb	No strength	Mohr-Coulomb	Undrained
Unsaturated Unit Weight [lbs/ft3]			135	145
Saturated Unit Weight [lbs/ft3]			135	145
Cohesion [psf]	240		0	
Friction Angle [deg]	28		32	
Cohesion Type				8000
Water Surface	None	None	Water Table	None
Hu Value			0	
Ru Value	0	0		0

Global Minimums

Method: spencer

FS: 1.638630
Center: 347.861, 1035.958
Radius: 66.423
Left Slip Surface Endpoint: 292.012, 1000.000
Right Slip Surface Endpoint: 355.706, 970.000
Resisting Moment=2.80637e+006 lb-ft
Driving Moment=1.71263e+006 lb-ft
Resisting Horizontal Force=36446.3 lb

Driving Horizontal Force=22242 lb
Total Slice Area=492.389 ft2

Valid / Invalid Surfaces

Method: spencer

Number of Valid Surfaces: 4219
Number of Invalid Surfaces: 632

Error Codes:

Error Code -107 reported for 17 surfaces
Error Code -108 reported for 386 surfaces
Error Code -111 reported for 78 surfaces
Error Code -112 reported for 151 surfaces

Error Codes

The following errors were encountered during the computation:

-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.

Slice Data

Global Minimum Query (spencer) - Safety Factor: 1.63863

Slice Number	Width [ft]	Weight [lbs]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]
1	2.48265	534.898	soil 1	240	28	155.981	255.595	29.3307	0	29.3307
2	2.48265	1538.55	soil 1	240	28	235.578	386.025	274.632	0	274.632
3	2.48265	2350.53	soil 1	240	28	307.808	504.384	497.234	0	497.234
4	2.48265	2753.18	soil 1	240	28	352.303	577.295	634.36	0	634.36
5	2.48265	3039.96	soil 1	240	28	389.293	637.907	748.354	0	748.354
6	2.48265	3257.96	soil 1	240	28	421.728	691.056	848.312	0	848.312
7	2.48265	3415.56	soil 1	240	28	449.726	736.934	934.597	0	934.597
8	2.48265	3519.21	soil 1	240	28	473.359	775.66	1007.43	0	1007.43
9	2.48265	3573.99	soil 1	240	28	492.665	807.295	1066.92	0	1066.92
10	2.48265	3583.96	soil 1	240	28	507.648	831.847	1113.1	0	1113.1
11	2.48265	3552.42	soil 1	240	28	518.288	849.282	1145.89	0	1145.89
12	2.48265	3482.07	soil 1	240	28	524.533	859.515	1165.14	0	1165.14
13	2.48265	3375.16	soil 1	240	28	526.307	862.422	1170.61	0	1170.61
14	2.48265	3233.55	soil 1	240	28	523.506	857.832	1161.97	0	1161.97
15	2.48265	3058.79	soil 1	240	28	515.996	845.527	1138.83	0	1138.83
16	2.48265	2852.18	soil 1	240	28	503.613	825.236	1100.67	0	1100.67
17	2.48265	2614.78	soil 1	240	28	486.158	796.633	1046.87	0	1046.87
18	2.68609	2533.69	Soil 2	0	32	363.66	595.905	953.647	0	953.647
19	2.68609	2195.67	Soil 2	0	32	326.324	534.725	855.738	0	855.738
20	2.68609	1816.94	Soil 2	0	32	279.736	458.383	733.565	0	733.565
21	2.68609	1398.13	Soil 2	0	32	223.119	365.61	585.098	0	585.098
22	2.68609	939.65	Soil 2	0	32	155.553	254.894	407.917	0	407.917
23	2.68609	441.705	Soil 2	0	32	75.9262	124.415	199.106	0	199.106
24	2.68609	124.82	Soil 2	0	32	22.3057	36.5508	58.4933	0	58.4933
25	2.68609	47.9148	Soil 2	0	32	8.59785	14.0887	22.5467	0	22.5467

Interslice Data

Global Minimum Query (spencer) - Safety Factor: 1.63863

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	292.012	1000	0	0	0
2	294.495	996.409	-281.926	-120.97	23.2234
3	296.978	993.262	-2.56074	-1.09878	23.2235
4	299.46	990.467	623.039	267.337	23.2235
5	301.943	987.962	1337.28	573.809	23.2235
6	304.426	985.705	2060.47	884.116	23.2234
7	306.908	983.662	2746.52	1178.49	23.2234
8	309.391	981.809	3361.23	1442.25	23.2234
9	311.874	980.129	3879.31	1664.56	23.2235
10	314.356	978.604	4282.48	1837.55	23.2235
11	316.839	977.224	4558.19	1955.85	23.2234
12	319.321	975.979	4698.78	2016.18	23.2235
13	321.804	974.859	4700.86	2017.07	23.2235
14	324.287	973.859	4564.98	1958.77	23.2235
15	326.769	972.973	4295.38	1843.09	23.2235
16	329.252	972.195	3899.9	1673.39	23.2235
17	331.735	971.522	3389.97	1454.59	23.2235
18	334.217	970.951	2780.72	1193.17	23.2235
19	336.903	970.445	2286.7	981.192	23.2235
20	339.59	970.052	1746.48	749.388	23.2234
21	342.276	969.77	1201.77	515.661	23.2234
22	344.962	969.598	703.042	301.665	23.2235
23	347.648	969.535	310.89	133.398	23.2234
24	350.334	969.581	97.841	41.9822	23.2235
25	353.02	969.736	28.8819	12.3928	23.2235
26	355.706	970	0	0	0

List Of Coordinates

Water Table

X	Y
0	985
128	983
350.5	970
395.703	968

Line Load

X	Y
243	1020
223	1020

External Boundary

X	Y
243	1020
223	1020
215.297	1017
0	1017
0	985
0	968
0	871.073
395.703	871.073
395.703	968
395.703	970
350.5	970
298	1000
278	1000

Material Boundary

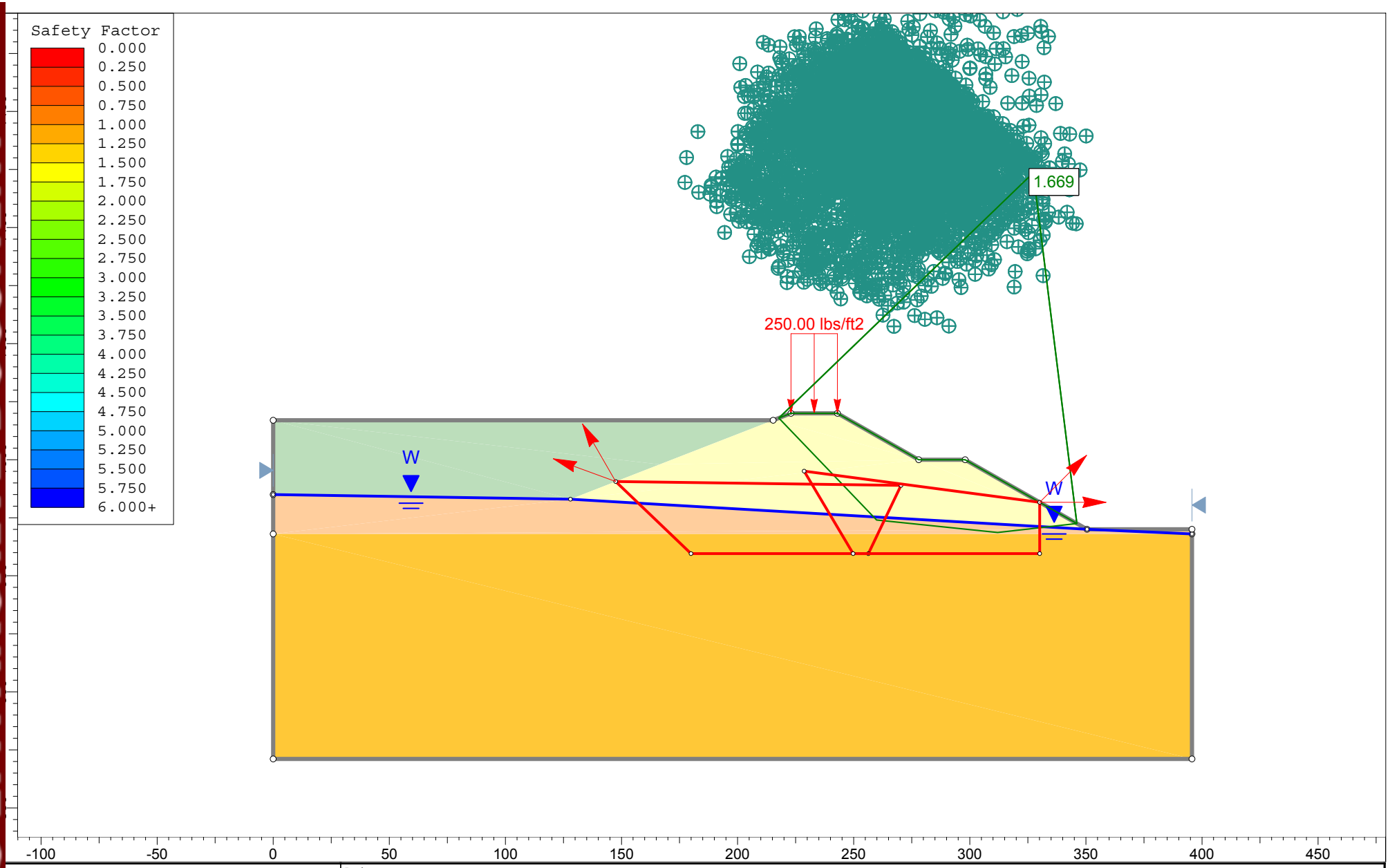
X	Y
0	985
128	983
166.514	998
215.297	1017

Material Boundary

X	Y
128	983
350.5	970

Material Boundary

X	Y
0	968
395.703	968



rocscience	Project: SLIDE - An Interactive Slope Stability Program		
	Analysis Description:		
	Drawn By:	Scale: 1:686	Company:
	Date: 10/16/2013, 3:13:47 PM		File Name: B-B_ Keystone_Undrained_Block.slim

DEINTERPRET 6.019

Slide Analysis Information

SLIDE - An Interactive Slope Stability Program

Project Summary

File Name: B-B_ Keystone_Undrained_Block
Slide Modeler Version: 6.019
Project Title: SLIDE - An Interactive Slope Stability Program
Date Created: 10/16/2013, 3:13:47 PM

General Settings

Units of Measurement: Imperial Units
Time Units: days
Permeability Units: feet/second
Failure Direction: Left to Right
Data Output: Standard
Maximum Material Properties: 20
Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

Spencer

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50
Check malpha < 0.2: Yes
Initial trial value of FS: 1
Steffensen Iteration: Yes

Groundwater Analysis

Groundwater Method: Water Surfaces
Pore Fluid Unit Weight: 62.4 lbs/ft3
Advanced Groundwater Method: None

Random Numbers

Pseudo-random Seed: 10116
Random Number Generation Method: Park and Miller v.3

Surface Options

Surface Type: Non-Circular Block Search
Number of Surfaces: 5000
Pseudo-Random Surfaces: Enabled
Convex Surfaces Only: Disabled
Left Projection Angle (Start Angle): 120
Left Projection Angle (End Angle): 160
Right Projection Angle (Start Angle): 0
Right Projection Angle (End Angle): 45
Minimum Elevation: Not Defined
Minimum Depth: Not Defined

Loading

1 Distributed Load present

Distributed Load 1

Distribution: Constant
Magnitude [psf]: 250
Orientation: Normal to boundary

Material Properties

Property	soil 1	water	Soil 2	Material 4
Color				
Strength Type	Mohr-Coulomb	No strength	Undrained	Undrained
Unsaturated Unit Weight [lbs/ft3]			135	145
Saturated Unit Weight [lbs/ft3]			135	145
Cohesion [psf]	240			
Friction Angle [deg]	28			
Cohesion Type			1250	8000
Water Surface	None	None	None	None
Ru Value	0	0	0	0

Global Minimums

Method: spencer

FS: 1.668750
Axis Location: 327.356, 1123.592
Left Slip Surface Endpoint: 217.740, 1017.952
Right Slip Surface Endpoint: 346.099, 972.515
Resisting Moment=2.59994e+007 lb-ft
Driving Moment=1.55802e+007 lb-ft
Resisting Horizontal Force=147497 lb

Driving Horizontal Force=88387.8 lb
Total Slice Area=2856.41 ft2

Global Minimum Coordinates

Method: spencer

X	Y
217.74	1017.95
259.855	974.028
312.01	968.625
346.099	972.515

Valid / Invalid Surfaces

Method: spencer

Number of Valid Surfaces: 4248
Number of Invalid Surfaces: 752

Error Codes:

Error Code -107 reported for 149 surfaces
Error Code -108 reported for 521 surfaces
Error Code -111 reported for 51 surfaces
Error Code -112 reported for 31 surfaces

Error Codes

The following errors were encountered during the computation:

-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.

Slice Data

Global Minimum Query (spencer) - Safety Factor: 1.66875

Slice Number	Width [ft]	Weight [lbs]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]
1	5.10329	2238.34	soil 1	240	28	212.133	353.997	214.397	0	214.397
2	5.10329	6143.13	soil 1	240	28	420.574	701.833	868.581	0	868.581
3	5.10329	9403.18	soil 1	240	28	554.323	925.026	1288.35	0	1288.35

4	5.10329	12662.7	soil 1	240	28	686.464	1145.54	1703.07	0	1703.07
5	5.10329	15919.9	soil 1	240	28	815.91	1361.55	2109.34	0	2109.34
6	5.10329	18198.8	soil 1	240	28	859.182	1433.76	2245.13	0	2245.13
7	5.10329	19672.5	soil 1	240	28	918.921	1533.45	2432.63	0	2432.63
8	5.10329	21146.1	soil 1	240	28	978.667	1633.15	2620.13	0	2620.13
9	1.2882	5583.01	Soil 2	1250	0	749.064	1250	2887.76	0	2887.76
10	5.21547	22089	Soil 2	1250	0	749.064	1250	4246.67	0	4246.67
11	5.21547	20580.4	Soil 2	1250	0	749.064	1250	3965.74	0	3965.74
12	5.21547	19071.7	Soil 2	1250	0	749.064	1250	3684.82	0	3684.82
13	5.21547	17816.2	Soil 2	1250	0	749.064	1250	3451.02	0	3451.02
14	5.21547	17958.7	Soil 2	1250	0	749.064	1250	3477.55	0	3477.55
15	5.21547	18315.3	Soil 2	1250	0	749.064	1250	3543.95	0	3543.95
16	5.21547	18671.9	Soil 2	1250	0	749.064	1250	3610.36	0	3610.36
17	5.21547	18589.4	Soil 2	1250	0	749.064	1250	3594.99	0	3594.99
18	5.21547	17172.6	Soil 2	1250	0	749.064	1250	3331.17	0	3331.17
19	5.21547	15663.9	Soil 2	1250	0	749.064	1250	3050.25	0	3050.25
20	5.25086	13841	Soil 2	1250	0	749.064	1250	3035.63	0	3035.63
21	5.25086	11501.5	Soil 2	1250	0	749.064	1250	2575.02	0	2575.02
22	5.25086	9161.9	Soil 2	1250	0	749.064	1250	2114.41	0	2114.41
23	5.25086	6822.34	Soil 2	1250	0	749.064	1250	1653.8	0	1653.8
24	6.54281	5282.52	soil 1	240	28	472.052	787.736	1030.14	0	1030.14
25	6.54281	1760.84	soil 1	240	28	266.033	443.942	383.558	0	383.558

Interslice Data

Global Minimum Query (spencer) - Safety Factor: 1.66875

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	217.74	1017.95	0	0	0
2	222.844	1012.63	57.7064	16.5241	15.9789
3	227.947	1007.31	2532.75	725.247	15.9789
4	233.05	1001.98	6558.9	1878.13	15.979
5	238.154	996.661	12117.5	3469.83	15.979
6	243.257	991.339	19177.4	5491.4	15.9789
7	248.36	986.016	26739	7656.67	15.979
8	253.463	980.694	34993.5	10020.3	15.9789
9	258.567	975.371	43940.9	12582.4	15.979
10	259.855	974.028	46855	13416.8	15.9789
11	265.07	973.488	45239.7	12954.3	15.979
12	270.286	972.947	43472.7	12448.3	15.9789
13	275.501	972.407	41553.8	11898.9	15.979
14	280.717	971.867	39508.7	11313.2	15.9789
15	285.932	971.326	37477.8	10731.7	15.979
16	291.148	970.786	35482.9	10160.4	15.9789
17	296.363	970.246	33523.8	9599.46	15.9789

18	301.579	969.705	31556.4	9036.11	15.979
19	306.794	969.165	29446.5	8431.94	15.9789
20	312.01	968.625	27184.8	7784.3	15.9789
21	317.26	969.224	21429.4	6136.26	15.9789
22	322.511	969.823	15950	4567.26	15.979
23	327.762	970.422	10746.7	3077.29	15.9789
24	333.013	971.022	5819.36	1666.36	15.9789
25	339.556	971.768	1959.2	561.013	15.979
26	346.099	972.515	0	0	0

List Of Coordinates

Water Table

X	Y
0	985
128	983
350.5	970
395.703	968

Line Load

X	Y
243	1020
223	1020

Block Search Window

X	Y
147.491	990.591
179.921	959.521
256.328	959.521
270.38	988.942

Block Search Window

X	Y
228.663	995.09
249.741	959.521
330.1	959.521
330.1	981.657

External Boundary

X	Y
243	1020

223	1020
215.297	1017
0	1017
0	985
0	968
0	871.073
395.703	871.073
395.703	968
395.703	970
350.5	970
298	1000
278	1000

Material Boundary

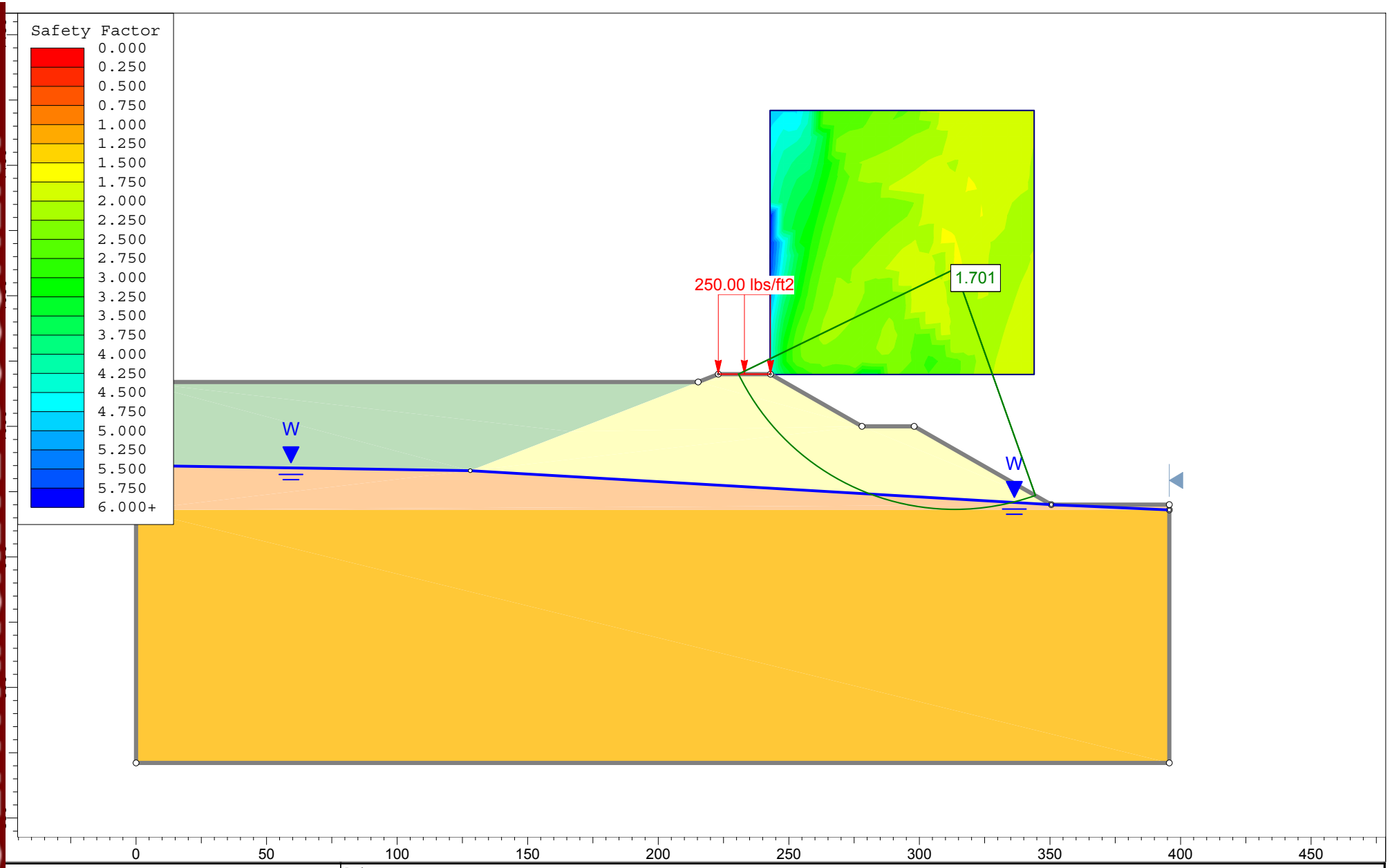
X	Y
0	985
128	983
166.514	998
215.297	1017

Material Boundary

X	Y
128	983
350.5	970

Material Boundary

X	Y
0	968
395.703	968



Project	SLIDE - An Interactive Slope Stability Program		
Analysis Description			
Drawn By		Scale 1:610	Company
Date	10/16/2013, 3:13:47 PM		File Name B-B_ Keystone_Undrained_Circular.slim

DEINTERPRET 6.019

Slide Analysis Information

SLIDE - An Interactive Slope Stability Program

Project Summary

File Name: B-B_ Keystone_Undrained_Circular
Slide Modeler Version: 6.019
Project Title: SLIDE - An Interactive Slope Stability Program
Date Created: 10/16/2013, 3:13:47 PM

General Settings

Units of Measurement: Imperial Units
Time Units: days
Permeability Units: feet/second
Failure Direction: Left to Right
Data Output: Standard
Maximum Material Properties: 20
Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

Spencer

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50
Check malpha < 0.2: Yes
Initial trial value of FS: 1
Steffensen Iteration: Yes

Groundwater Analysis

Groundwater Method: Water Surfaces
Pore Fluid Unit Weight: 62.4 lbs/ft3
Advanced Groundwater Method: None

Random Numbers

Pseudo-random Seed: 10116
Random Number Generation Method: Park and Miller v.3

Surface Options

Surface Type: Circular
Search Method: Grid Search
Radius Increment: 10
Composite Surfaces: Disabled
Reverse Curvature: Create Tension Crack
Minimum Elevation: Not Defined
Minimum Depth: Not Defined

Loading

1 Distributed Load present

Distributed Load 1

Distribution: Constant
Magnitude [psf]: 250
Orientation: Normal to boundary

Material Properties

Property	soil 1	water	Soil 2	Material 4
Color				
Strength Type	Mohr-Coulomb	No strength	Undrained	Undrained
Unsaturated Unit Weight [lbs/ft3]			135	145
Saturated Unit Weight [lbs/ft3]			135	145
Cohesion [psf]	240			
Friction Angle [deg]	28			
Cohesion Type			1250	8000
Water Surface	None	None	None	None
Ru Value	0	0	0	0

Global Minimums

Method: spencer

FS: 1.701460
Center: 313.610, 1060.322
Radius: 92.182
Left Slip Surface Endpoint: 230.715, 1020.000
Right Slip Surface Endpoint: 344.455, 973.454
Resisting Moment=1.40721e+007 lb-ft
Driving Moment=8.27059e+006 lb-ft
Resisting Horizontal Force=134120 lb
Driving Horizontal Force=78826.4 lb
Total Slice Area=2324.93 ft2

Valid / Invalid Surfaces

Method: spencer

Number of Valid Surfaces: 4814
Number of Invalid Surfaces: 37

Error Codes:

Error Code -103 reported for 2 surfaces
Error Code -108 reported for 18 surfaces
Error Code -111 reported for 17 surfaces

Error Codes

The following errors were encountered during the computation:

-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

Slice Data

Global Minimum Query (spencer) - Safety Factor: 1.70146

Slice Number	Width [ft]	Weight [lbs]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]
1	4.58282	2283.81	soil 1	240	28	223.697	380.612	264.453	0	264.453
2	4.58282	6410.63	soil 1	240	28	397.549	676.413	820.773	0	820.773
3	4.58282	9728.45	soil 1	240	28	545.747	928.567	1295.01	0	1295.01
4	4.58282	11499.5	soil 1	240	28	621.155	1056.87	1536.31	0	1536.31
5	4.58282	12544.4	soil 1	240	28	700.979	1192.69	1791.74	0	1791.74
6	4.58282	13271.9	soil 1	240	28	768.082	1306.86	2006.46	0	2006.46
7	4.58282	13732.5	soil 1	240	28	823.217	1400.67	2182.91	0	2182.91
8	4.58282	13961.8	soil 1	240	28	866.92	1475.03	2322.74	0	2322.74
9	4.58282	13986	soil 1	240	28	899.527	1530.51	2427.1	0	2427.1
10	4.58282	13824.7	soil 1	240	28	921.256	1567.48	2496.62	0	2496.62
11	4.58282	13828.3	soil 1	240	28	951.877	1619.58	2594.61	0	2594.61
12	4.5584	14670.5	Soil 2	1250	0	734.663	1250	2876.23	0	2876.23
13	4.5584	15545.4	Soil 2	1250	0	734.663	1250	3138.75	0	3138.75
14	4.5584	16263.3	Soil 2	1250	0	734.663	1250	3374.22	0	3374.22
15	4.5584	16767.2	Soil 2	1250	0	734.663	1250	3569.99	0	3569.99
16	4.5584	16114.5	Soil 2	1250	0	734.663	1250	3526.27	0	3526.27
17	4.5584	14968.4	Soil 2	1250	0	734.663	1250	3373.95	0	3373.95
18	4.5584	13682	Soil 2	1250	0	734.663	1250	3185.14	0	3185.14

19	4.5584	12256.5	Soil 2	1250	0	734.663	1250	2958.98	0	2958.98
20	4.5584	10692	Soil 2	1250	0	734.663	1250	2694.25	0	2694.25
21	4.5584	8987.56	Soil 2	1250	0	734.663	1250	2389.31	0	2389.31
22	4.5584	7141.27	Soil 2	1250	0	734.663	1250	2041.98	0	2041.98
23	4.5584	5149.99	Soil 2	1250	0	734.663	1250	1649.57	0	1649.57
24	4.31454	2952.81	soil 1	240	28	470.205	800.035	1053.27	0	1053.27
25	4.31454	1004.13	soil 1	240	28	285.49	485.75	462.19	0	462.19

Interslice Data

Global Minimum Query (spencer) - Safety Factor: 1.70146

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	230.715	1020	0	0	0
2	235.297	1011.69	1174.26	382.75	18.0534
3	239.88	1004.99	4858.92	1583.76	18.0533
4	244.463	999.361	9656.65	3147.58	18.0534
5	249.046	994.527	14245.2	4643.21	18.0533
6	253.629	990.324	18573.1	6053.9	18.0534
7	258.212	986.643	22447.6	7316.78	18.0533
8	262.794	983.411	25741.8	8390.52	18.0533
9	267.377	980.572	28374.5	9248.66	18.0534
10	271.96	978.086	30298.7	9875.82	18.0533
11	276.543	975.921	31493.7	10265.4	18.0534
12	281.126	974.053	31989.7	10427	18.0533
13	285.684	972.472	33199.4	10821.3	18.0533
14	290.242	971.151	34005.9	11084.2	18.0533
15	294.801	970.079	34282.5	11174.4	18.0534
16	299.359	969.248	33910.4	11053.1	18.0534
17	303.918	968.651	32677.2	10651.1	18.0533
18	308.476	968.283	30579.2	9967.27	18.0533
19	313.034	968.142	27690	9025.52	18.0533
20	317.593	968.226	24101.3	7855.81	18.0534
21	322.151	968.537	19925.6	6494.73	18.0533
22	326.71	969.076	15298.6	4986.57	18.0533
23	331.268	969.847	10383.9	3384.62	18.0533
24	335.826	970.857	5378.36	1753.07	18.0533
25	340.141	972.041	2109.18	687.486	18.0533
26	344.455	973.454	0	0	0

List Of Coordinates

Water Table

X	Y
0	985
128	983
350.5	970
395.703	968

Line Load

X	Y
243	1020
223	1020

External Boundary

X	Y
243	1020
223	1020
215.297	1017
0	1017
0	985
0	968
0	871.073
395.703	871.073
395.703	968
395.703	970
350.5	970
298	1000
278	1000

Material Boundary

X	Y
0	985
128	983
166.514	998
215.297	1017

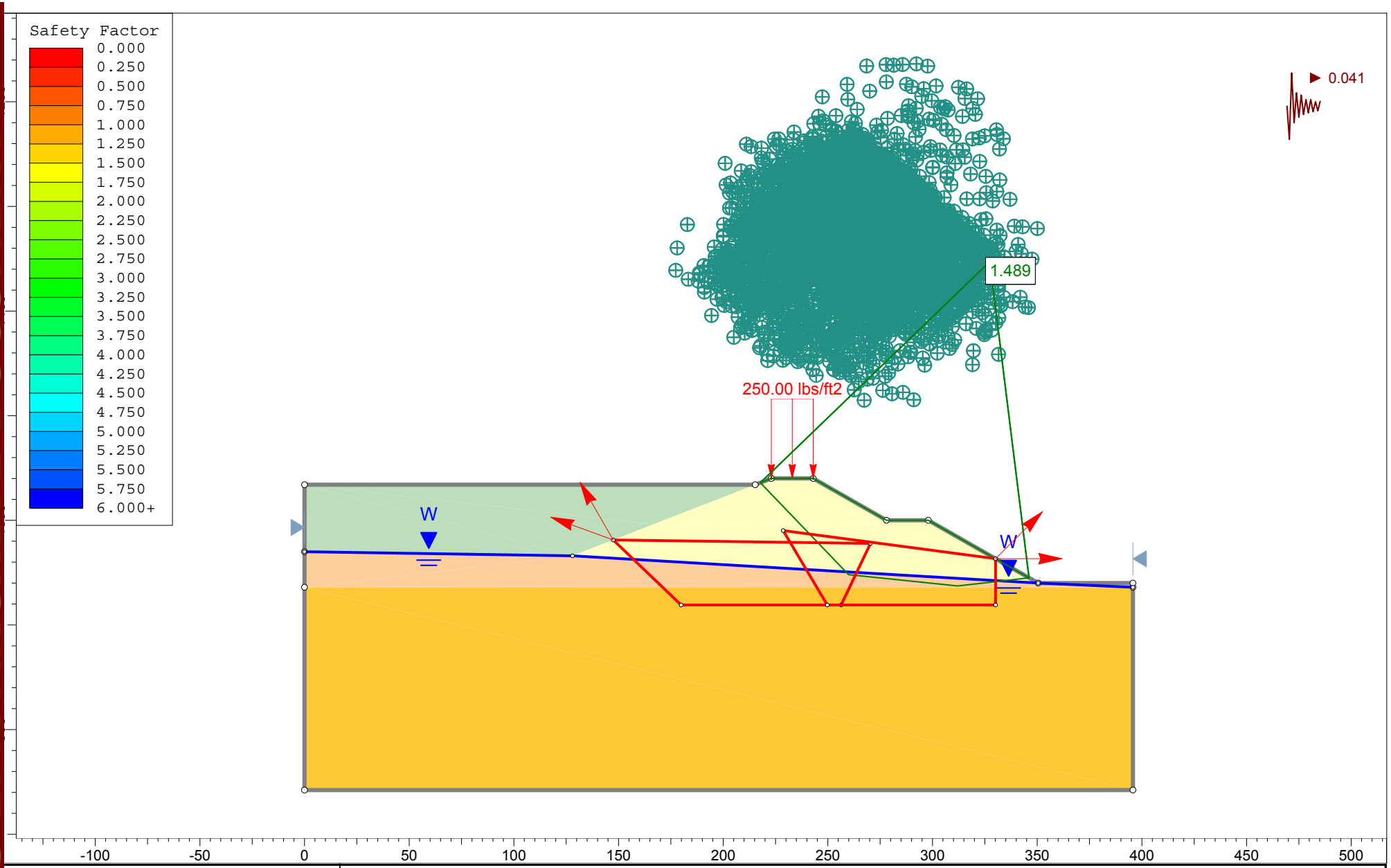
Material Boundary

X	Y
128	983
350.5	970

Material Boundary

X	Y

0	968
395.703	968



rocscience	Project: SLIDE - An Interactive Slope Stability Program		
	Analysis Description:		
	Drawn By:	Scale: 1:762	Company:
	Date: 10/16/2013, 3:13:47 PM		File Name: B-B_ Keystone_Undrained_Block_Seismic.slim

DEINTERPRET 6.019

Slide Analysis Information

SLIDE - An Interactive Slope Stability Program

Project Summary

File Name: B-B_ Keystone_Undrained_Block_Seismic
Slide Modeler Version: 6.019
Project Title: SLIDE - An Interactive Slope Stability Program
Date Created: 10/16/2013, 3:13:47 PM

General Settings

Units of Measurement: Imperial Units
Time Units: days
Permeability Units: feet/second
Failure Direction: Left to Right
Data Output: Standard
Maximum Material Properties: 20
Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

Spencer

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50
Check malpha < 0.2: Yes
Initial trial value of FS: 1
Steffensen Iteration: Yes

Groundwater Analysis

Groundwater Method: Water Surfaces
Pore Fluid Unit Weight: 62.4 lbs/ft3
Advanced Groundwater Method: None

Random Numbers

Pseudo-random Seed: 10116
Random Number Generation Method: Park and Miller v.3

Surface Options

Surface Type: Non-Circular Block Search
Number of Surfaces: 5000
Pseudo-Random Surfaces: Enabled
Convex Surfaces Only: Disabled
Left Projection Angle (Start Angle): 120
Left Projection Angle (End Angle): 160
Right Projection Angle (Start Angle): 0
Right Projection Angle (End Angle): 45
Minimum Elevation: Not Defined
Minimum Depth: Not Defined

Loading

Seismic Load Coefficient (Horizontal): 0.041
1 Distributed Load present

Distributed Load 1

Distribution: Constant
Magnitude [psf]: 250
Orientation: Normal to boundary

Material Properties

Property	soil 1	water	Soil 2	Bedrock
Color				
Strength Type	Mohr-Coulomb	No strength	Undrained	Undrained
Unsaturated Unit Weight [lbs/ft3]			135	145
Saturated Unit Weight [lbs/ft3]			135	145
Cohesion [psf]	240			
Friction Angle [deg]	28			
Cohesion Type			1250	8000
Water Surface	None	None	None	None
Ru Value	0	0	0	0

Global Minimums

Method: spencer

FS: 1.489270
Axis Location: 327.356, 1123.592
Left Slip Surface Endpoint: 217.740, 1017.952
Right Slip Surface Endpoint: 346.099, 972.515
Resisting Moment=2.5618e+007 lb-ft
Driving Moment=1.72017e+007 lb-ft

Resisting Horizontal Force=145718 lb
Driving Horizontal Force=97845 lb
Total Slice Area=2856.41 ft2

Global Minimum Coordinates

Method: spencer

X	Y
217.74	1017.95
259.855	974.028
312.01	968.625
346.099	972.515

Valid / Invalid Surfaces

Method: spencer

Number of Valid Surfaces: 4397
Number of Invalid Surfaces: 603

Error Codes:

Error Code -107 reported for 51 surfaces
Error Code -108 reported for 416 surfaces
Error Code -111 reported for 102 surfaces
Error Code -112 reported for 34 surfaces

Error Codes

The following errors were encountered during the computation:

-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.

Slice Data

Global Minimum Query (spencer) - Safety Factor: 1.48927

Slice Number	Width [ft]	Weight [lbs]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]
1	5.10329	2238.34	soil 1	240	28	232.246	345.877	199.126	0	199.126
2	5.10329	6143.13	soil 1	240	28	453.381	675.206	818.505	0	818.505

3	5.10329	9403.18	soil 1	240	28	594.81	885.832	1214.63	0	1214.63
4	5.10329	12662.7	soil 1	240	28	734.514	1093.89	1605.93	0	1605.93
5	5.10329	15919.9	soil 1	240	28	871.333	1297.65	1989.14	0	1989.14
6	5.10329	18198.8	soil 1	240	28	916.328	1364.66	2115.18	0	2115.18
7	5.10329	19672.5	soil 1	240	28	979.493	1458.73	2292.09	0	2292.09
8	5.10329	21146.1	soil 1	240	28	1042.65	1552.79	2469	0	2469
9	1.2882	5583.01	Soil 2	1250	0	839.337	1250	2685.9	0	2685.9
10	5.21547	22089	Soil 2	1250	0	839.337	1250	4227.54	0	4227.54
11	5.21547	20580.4	Soil 2	1250	0	839.337	1250	3952.18	0	3952.18
12	5.21547	19071.7	Soil 2	1250	0	839.337	1250	3676.83	0	3676.83
13	5.21547	17816.2	Soil 2	1250	0	839.337	1250	3447.64	0	3447.64
14	5.21547	17958.7	Soil 2	1250	0	839.337	1250	3473.66	0	3473.66
15	5.21547	18315.3	Soil 2	1250	0	839.337	1250	3538.75	0	3538.75
16	5.21547	18671.9	Soil 2	1250	0	839.337	1250	3603.84	0	3603.84
17	5.21547	18589.4	Soil 2	1250	0	839.337	1250	3588.77	0	3588.77
18	5.21547	17172.6	Soil 2	1250	0	839.337	1250	3330.18	0	3330.18
19	5.21547	15663.9	Soil 2	1250	0	839.337	1250	3054.82	0	3054.82
20	5.25086	13841	Soil 2	1250	0	839.337	1250	3106.36	0	3106.36
21	5.25086	11501.5	Soil 2	1250	0	839.337	1250	2649.13	0	2649.13
22	5.25086	9161.9	Soil 2	1250	0	839.337	1250	2191.89	0	2191.89
23	5.25086	6822.34	Soil 2	1250	0	839.337	1250	1734.67	0	1734.67
24	6.54281	5282.52	soil 1	240	28	550.703	820.145	1091.09	0	1091.09
25	6.54281	1760.84	soil 1	240	28	310.409	462.283	418.055	0	418.055

Interslice Data

Global Minimum Query (spencer) - Safety Factor: 1.48927

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	217.74	1017.95	0	0	0
2	222.844	1012.63	-35.275	-12.1423	18.9944
3	227.947	1007.31	2256.09	776.589	18.9944
4	233.05	1001.98	6066.75	2088.29	18.9944
5	238.154	996.661	11379.8	3917.14	18.9944
6	243.257	991.339	18166.8	6253.36	18.9944
7	248.36	986.016	25488.2	8773.51	18.9944
8	253.463	980.694	33488.7	11527.5	18.9945
9	258.567	975.371	42168.6	14515.2	18.9944
10	259.855	974.028	44923.3	15463.5	18.9945
11	265.07	973.488	43729.4	15052.5	18.9944
12	270.286	972.947	42324.9	14569	18.9944
13	275.501	972.407	40709.7	14013	18.9944
14	280.717	971.867	38919.2	13396.7	18.9944
15	285.932	971.326	37148.6	12787.3	18.9945
16	291.148	970.786	35427.9	12194.9	18.9944

17	296.363	970.246	33756.9	11619.8	18.9945
18	301.579	969.705	32074.3	11040.6	18.9945
19	306.794	969.165	30194	10393.4	18.9945
20	312.01	968.625	28103	9673.6	18.9945
21	317.26	969.224	22395.6	7709	18.9945
22	322.511	969.823	16866.2	5805.68	18.9945
23	327.762	970.422	11515	3963.66	18.9943
24	333.013	971.022	6341.72	2182.94	18.9944
25	339.556	971.768	2135.37	735.035	18.9944
26	346.099	972.515	0	0	0

List Of Coordinates

Water Table

X	Y
0	985
128	983
350.5	970
395.703	968

Line Load

X	Y
243	1020
223	1020

Block Search Window

X	Y
147.491	990.591
179.921	959.521
256.328	959.521
270.38	988.942

Block Search Window

X	Y
228.663	995.09
249.741	959.521
330.1	959.521
330.1	981.657

External Boundary

X	Y
243	1020
223	1020
215.297	1017
0	1017
0	985
0	968
0	871.073
395.703	871.073
395.703	968
395.703	970
350.5	970
298	1000
278	1000

Material Boundary

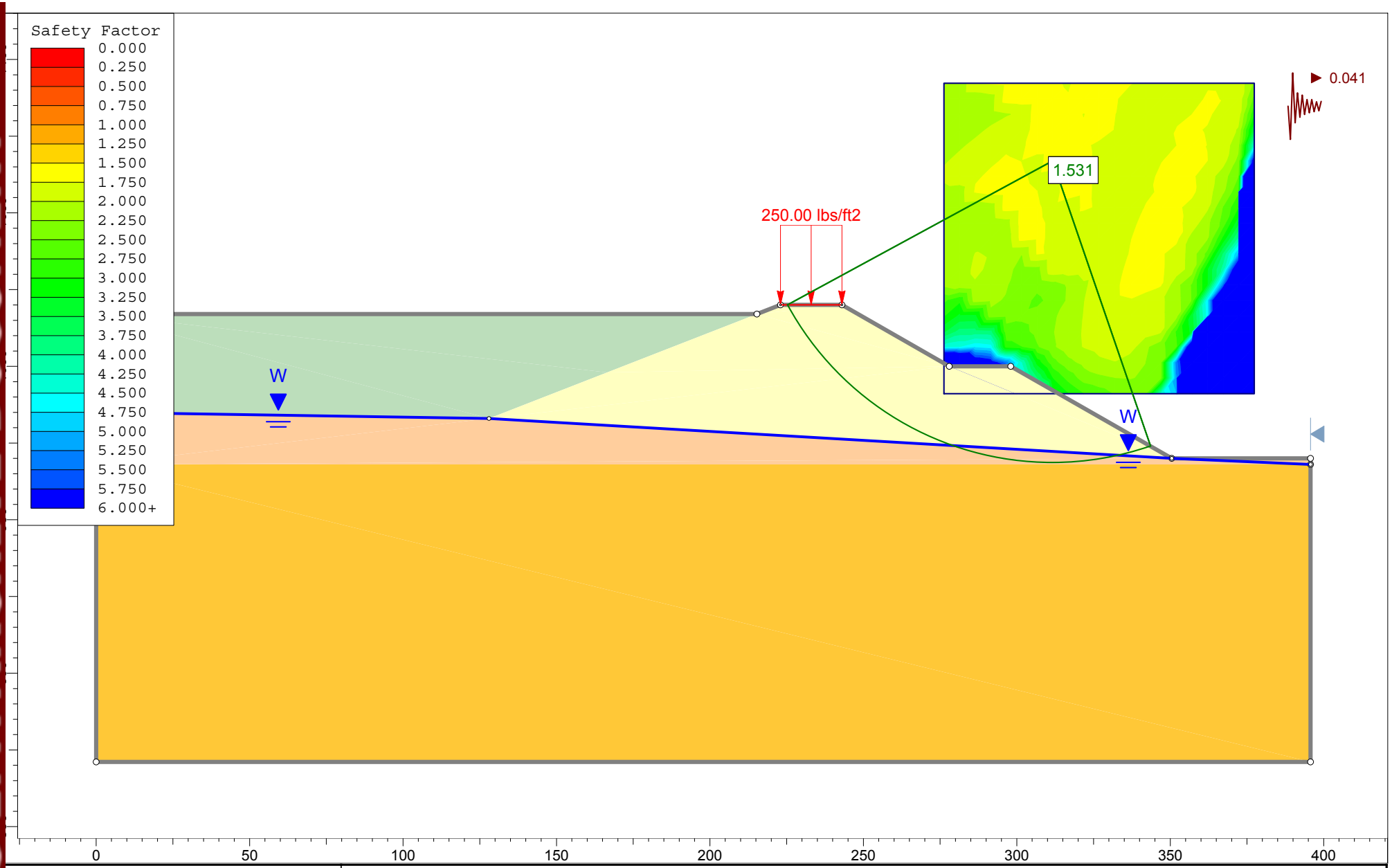
X	Y
0	985
128	983
166.514	998
215.297	1017

Material Boundary

X	Y
128	983
350.5	970

Material Boundary

X	Y
0	968
395.703	968



rocscience	Project: SLIDE - An Interactive Slope Stability Program		
	Analysis Description:		
	Drawn By:	Scale: 1:520	Company:
	Date: 10/16/2013, 3:13:47 PM		File Name: B-B_ Keystone_Undrained_Circular_seismic.slim

Slide Analysis Information

SLIDE - An Interactive Slope Stability Program

Project Summary

File Name: B-B_ Keystone_Undrained_Circular_seismic
Slide Modeler Version: 6.019
Project Title: SLIDE - An Interactive Slope Stability Program
Date Created: 10/16/2013, 3:13:47 PM

General Settings

Units of Measurement: Imperial Units
Time Units: days
Permeability Units: feet/second
Failure Direction: Left to Right
Data Output: Standard
Maximum Material Properties: 20
Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

Spencer

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50
Check malpha < 0.2: Yes
Initial trial value of FS: 1
Steffensen Iteration: Yes

Groundwater Analysis

Groundwater Method: Water Surfaces
Pore Fluid Unit Weight: 62.4 lbs/ft3
Advanced Groundwater Method: None

Random Numbers

Pseudo-random Seed: 10116
Random Number Generation Method: Park and Miller v.3

Surface Options

Surface Type: Circular
Search Method: Grid Search
Radius Increment: 10
Composite Surfaces: Disabled
Reverse Curvature: Create Tension Crack
Minimum Elevation: Not Defined
Minimum Depth: Not Defined

Loading

Seismic Load Coefficient (Horizontal): 0.041
1 Distributed Load present

Distributed Load 1

Distribution: Constant
Magnitude [psf]: 250
Orientation: Normal to boundary

Material Properties

Property	soil 1	water	Soil 2	Bedrock
Color				
Strength Type	Mohr-Coulomb	No strength	Undrained	Undrained
Unsaturated Unit Weight [lbs/ft3]			135	145
Saturated Unit Weight [lbs/ft3]			135	145
Cohesion [psf]	240			
Friction Angle [deg]	28			
Cohesion Type			1250	8000
Water Surface	None	None	None	None
Ru Value	0	0	0	0

Global Minimums

Method: spencer

FS: 1.531230
Center: 311.639, 1066.922
Radius: 98.299
Left Slip Surface Endpoint: 225.262, 1020.000
Right Slip Surface Endpoint: 343.576, 973.957
Resisting Moment=1.57758e+007 lb-ft
Driving Moment=1.03027e+007 lb-ft
Resisting Horizontal Force=141950 lb
Driving Horizontal Force=92702.7 lb

Total Slice Area=2483.76 ft2

Valid / Invalid Surfaces

Method: spencer

Number of Valid Surfaces: 4485
Number of Invalid Surfaces: 366

Error Codes:

Error Code -108 reported for 129 surfaces
Error Code -111 reported for 103 surfaces
Error Code -112 reported for 134 surfaces

Error Codes

The following errors were encountered during the computation:

-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.

Slice Data

Global Minimum Query (spencer) - Safety Factor: 1.53123

Slice Number	Width [ft]	Weight [lbs]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]
1	4.8924	2365.67	soil 1	240	28	246.082	376.808	257.298	0	257.298
2	4.8924	6678.4	soil 1	240	28	430.064	658.527	787.136	0	787.136
3	4.8924	10278.2	soil 1	240	28	608.293	931.436	1300.4	0	1300.4
4	4.8924	13243.2	soil 1	240	28	755.075	1156.19	1723.11	0	1723.11
5	4.8924	14595.7	soil 1	240	28	822.117	1258.85	1916.17	0	1916.17
6	4.8924	15291.6	soil 1	240	28	895.875	1371.79	2128.59	0	2128.59
7	4.8924	15701.6	soil 1	240	28	956.773	1465.04	2303.95	0	2303.95
8	4.8924	15861.3	soil 1	240	28	1005.16	1539.13	2443.31	0	2443.31
9	4.8924	15797.3	soil 1	240	28	1041.21	1594.33	2547.13	0	2547.13
10	4.8924	15529.6	soil 1	240	28	1064.96	1630.7	2615.51	0	2615.51
11	4.8924	15113.8	soil 1	240	28	1078.73	1651.78	2655.18	0	2655.18
12	4.50813	14407.7	Soil 2	1250	0	816.337	1250	2841.56	0	2841.56
13	4.50813	15207.8	Soil 2	1250	0	816.337	1250	3088.9	0	3088.9
14	4.50813	15867.6	Soil 2	1250	0	816.337	1250	3313.14	0	3313.14
15	4.50813	16392	Soil 2	1250	0	816.337	1250	3514.52	0	3514.52
16	4.50813	16335.5	Soil 2	1250	0	816.337	1250	3599.33	0	3599.33
17	4.50813	15232.5	Soil 2	1250	0	816.337	1250	3463.39	0	3463.39

18	4.50813	13975.4	Soil 2	1250	0	816.337	1250	3288.49	0	3288.49
19	4.50813	12592	Soil 2	1250	0	816.337	1250	3079.36	0	3079.36
20	4.50813	11082.6	Soil 2	1250	0	816.337	1250	2834.75	0	2834.75
21	4.50813	9446.57	Soil 2	1250	0	816.337	1250	2553.07	0	2553.07
22	4.50813	7682.43	Soil 2	1250	0	816.337	1250	2232.32	0	2232.32
23	4.50813	5787.88	Soil 2	1250	0	816.337	1250	1870.03	0	1870.03
24	5.19984	4207.2	soil 1	240	28	601.723	921.377	1281.48	0	1281.48
25	5.19984	1434.53	soil 1	240	28	355.534	544.404	572.501	0	572.501

Interslice Data

Global Minimum Query (spencer) - Safety Factor: 1.53123

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	225.262	1020	0	0	0
2	230.155	1011.94	967.119	360.043	20.4195
3	235.047	1005.31	4358.76	1622.7	20.4195
4	239.94	999.678	9126.88	3397.79	20.4195
5	244.832	994.815	14356.2	5344.59	20.4195
6	249.724	990.573	19062.6	7096.72	20.4195
7	254.617	986.853	23226.9	8647	20.4195
8	259.509	983.585	26721	9947.81	20.4195
9	264.402	980.718	29461.6	10968.1	20.4195
10	269.294	978.212	31399.5	11689.5	20.4194
11	274.186	976.038	32513.7	12104.3	20.4194
12	279.079	974.173	32810.7	12214.9	20.4195
13	283.587	972.711	33875.7	12611.4	20.4195
14	288.095	971.485	34609.1	12884.4	20.4195
15	292.603	970.484	34895.5	12991	20.4194
16	297.111	969.703	34634.9	12894	20.4195
17	301.62	969.136	33668.5	12534.3	20.4196
18	306.128	968.778	31852.1	11858	20.4195
19	310.636	968.629	29238	10884.9	20.4196
20	315.144	968.686	25899	9641.77	20.4195
21	319.652	968.951	21924.5	8162.14	20.4195
22	324.16	969.424	17424.1	6486.7	20.4195
23	328.668	970.11	12529.9	4664.7	20.4196
24	333.176	971.012	7401.55	2755.48	20.4195
25	338.376	972.33	2757.88	1026.71	20.4194
26	343.576	973.957	0	0	0

List Of Coordinates

Water Table

X	Y
0	985
128	983
350.5	970
395.703	968

Line Load

X	Y
243	1020
223	1020

External Boundary

X	Y
243	1020
223	1020
215.297	1017
0	1017
0	985
0	968
0	871.073
395.703	871.073
395.703	968
395.703	970
350.5	970
298	1000
278	1000

Material Boundary

X	Y
0	985
128	983
166.514	998
215.297	1017

Material Boundary

X	Y
128	983
350.5	970

Material Boundary

X	Y
0	968
395.703	968

a subsidiary of NRG,

DRAFT

2.0 DESCRIPTION OF THE COAL COMBUSTION RESIDUE MANAGEMENT UNIT(S)

2.1 LOCATION AND PROJECT DESCRIPTION

NRG REMA LLC,

The Keystone Generating Station is located in the southeast section of Armstrong County at 313 Keystone Drive, Shelocta, PA on 1,459-acres. The town of Shelocta is located approximately 2.5 miles east of the Keystone facility. Crooked Creek borders the facility to the south. See Figure 2.1-1 for the location of the Keystone Generating Station on a USGS topographic map. Keystone is a coal-fired electric generating station featuring two pulverized coal, supercritical boilers (1,700 MW) and four diesel units (12 MW) with total generating capacity of 1,712 megawatts.

16.67

GenOn

Keystone Generating Station is jointly owned by a group of seven co-owners. ~~GenOn~~ has a ~~16~~ percent interest in Keystone, and operates the facility for the owners group. The two units were originally commissioned in the summers of 1967 and 1968.

NRG also has a 3.7 percent interest in Keystone

The generating facility maintains a relatively small complex of Ash Filter Ponds that consist of three contiguous clay-lined cells (Ponds A, B and C) that receive water produced from dewatering of bottom ash. See Figure 2.1-2 for an aerial view of the Ash Filter Ponds. The water originates at the Bottom Ash Dewatering Bins located southeast of the Ash Filter Ponds; it consists of decant water from dewatering of the bottom ash and dewatering bin overflow of the water used to sluice bottom ash from the Ash Hoppers to the Dewatering Bins. The water is piped from the Dewatering Bins to a distribution box that controls flow to the individual cells. The water contains some fine suspended ash particles, which are removed by sedimentation in the Ash Filter Ponds. The multiple cells allow two cells to remain in operation while a third cell is dewatered and cleaned out, when needed, by excavation and removal of settled ash to an on-site landfill. The individual cells receive the water at the southeast end of the cells. Each individual cell is nominally 82 ft wide by 386 ft long at the normal water surface elevation of 1018.5 ft. The clarified water exits each cell on the northwest end via saw tooth weirs on each side of metal weir troughs that discharge into a concrete riser structure that has bottom discharge to a pump station via an 18-inch diameter vitrified clay pipe (VTC). The pump station pumps the water collected from the cells via a 24-inch diameter polyethylene pipe (PE) to the Thermal Pond located 2,000 ft northwest of the Ash Filter Ponds.

The pumped water is received at a distribution box located at the west end of the Thermal Pond. The distribution box evenly divides the flow among a series of small pipes, which are spaced at intervals of approximately twenty feet and discharge into

the geomembrane-lined Thermal Pond. The Thermal Pond has a storage volume of approximately 5.6 million cubic feet at normal operating level. See Figure 2.1-3 for an aerial view of the Thermal Pond. The available surface area for cooling is approximately 310,000 square feet. Cooled water leaves the pond through a concrete overflow structure at the east end, which has bottom discharge through an 18-inch diameter HDPE pipe that passes though the embankment dam and ultimately discharges into a stream channel at the toe of the dam. The original discharge pipe was a 21-inch diameter corrugated metal pipe (CMP), but it had been retrofitted with the HDPE pipe sleeved through it. Water discharged into the stream channel follows the channel to a 13 ft by 7 ft precast concrete culvert that passes through a high embankment that supports railroad tracks and a road; the water continues to a long lagoon on the other (south) side of the railroad embankment and ultimately discharges through a permitted outfall at Crooked Creek farther south. Upgradient (north) of the discharge location in the stream channel below the Thermal Pond dam, a small dam across the channel diverts natural stream flow into an 18-inch diameter spiral polyethylene (SPE) pipe that carries the natural stream flow all the way to Crooked Creek, separating it from the flow of water discharging from the Thermal Pond.

A number of emission control systems have either been upgraded or installed since the plant was first commissioned. The flue gas desulfurization (FGD) system, upgraded in ~~2007~~ 2009, uses state-of-the-art technology designed to remove 98 percent of the sulfur dioxide (SO2) emitted at Keystone, lowering SO2 emissions by 173,000 tons per year, in addition to approximately 80 percent of the mercury and other emissions. Other upgrades include modifications to the electrostatic precipitators, the addition of a flue-gas conditioning system to improve precipitator performance, a low-nitrogen oxide burner system to reduce NOx emissions and installation of a selective catalytic reduction system to further reduce NOx emissions.

QUARTERLY ASH RECYCLE PONDS INSPECTION CHECKLIST
NRG ENERGY - OPERATIONS TECHNICAL SUPPORT
KEYSTONE STATION

NAME OF IMPOUNDMENT: Ash Recycle Ponds

LOCATION: Plumcreek Township, Armstrong County

PERSONS PRESENT AT INSPECTION:

NAME	TITLE/POSITION	REPRESENTING
		NRG Energy

DATE OF INSPECTION: **TIME:**
WEATHER:
TEMPERATURE:

This is to certify that the above ponds have been inspected and the following are the results of this inspection.

EMBANKMENT				
CREST AND INTERIOR SLOPES		CHECK ( ) ACTION NEEDED		
CONDITION/ITEMS	OBSERVATIONS	Monitor	Investigate	Repair
SURFACE CRACKING				
LOW AREA(S)				
HORIZONTAL ALIGNMENT				
RUTS AND/OR PUDDLES				
VEGETATION GROWTH				
ADDITIONAL COMMENTS:				

EMBANKMENT				
EXTERIOR SLOPES		CHECK ( ) ACTION NEEDED		
CONDITION/ITEMS	OBSERVATIONS	Monitor	Investigate	Repair
WET AREA(S)				
SEEPAGE				
SLIDE, SLOUGH, SCARP				
SINKHOLE, ANIMAL BURROW				
EROSION				
UNUSUAL MOVEMENT				
VEGETATION CONDITION				
ADDITIONAL COMMENTS:				