NUCLEAR POWER GENERATION
CF3.ID4
ATTACHMENT 7.2

Index No. 402
Binder No.

TITLE: CALCULATION COVER SHEET

Unit(s): 1 & 2

File No.: 52.27

Responsible Group: Civil

Calculation No.: 52.27.100.733

No. of Pages 3 pages + Index (4 pages) + 1 Attachment (134 pages)

Design Calculation YES [x] NO [ ]

System No. 42C

Quality Classification Q (Safety-Related)

Structure, System or Component: Independent Spent Fuel Storage Facility

Subject: Pseudostatic Wedge Analysis of DCPP ISFSI Cutslope (SWEDGE Analysis) [GEO.DCPP.01.23, Rev. 0]

Electronic calculation YES [ ] NO [x]

Computer Model	Computer ID	Program Location	Date of Last Change

Registered Engineer Stamp: Complete A or B

A. Insert PE Stamp or Seal Below	B. Insert stamp directing to the PE stamp or seal
Expiration Date:	***REGISTERED ENGINEERS' STAMPS AND EXPIRATION DATES ARE SHOWN ON DWG 063618***

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NOTE 2: Forward electronic calculation file to CCTG for uploading to EDMS.

TITLE: CALCULATION COVER SHEET

CALC No. 52.27.100.733, R0

RECORD OF REVISIONS

Rev No.	Status	Reason for Revision	Prepared By:	LBIE Screen	LBIE	Check Method*	LBIE Approval		Checked	Supervisor	Registered Engineer
		Remarks	Initials/ LAN ID/ Date	Yes/ No/ NA	Yes/ No/ NA		PSRC Mtg. No.	PSRC Mtg. Date	Initials/ LAN ID/ Date	Initials/ LAN ID/ Date	Signature/ LAN ID/ Date
0	F	Acceptance of Geosciences Calc. No. GEO.DCPP.01.23, Rev. 0. Calc. supports current edition of 10CFR72 DCPP License Application to be reviewed by NRC prior to implementation. Prepared per CF3.ID17.	AFT2 [signature] 12/13/01	[ ] Yes [ ] No [x] NA	[ ] Yes [ ] No [x] NA	[ ] A [ ] B [x] C	N/A	N/A	N/A	[signature] LJS2 12/13/01	[signature] LJS2 12/13/01
				[ ] Yes [ ] No [ ] NA	[ ] Yes [ ] No [ ] NA	[ ] A [ ] B [ ] C					
				[ ] Yes [ ] No [ ] NA	[ ] Yes [ ] No [ ] NA	[ ] A [ ] B [ ] C					

*Check Method: A: Detailed Check, B: Alternate Method (note added pages), C: Critical Point Check

SUBJECT Pseudostatic Wedge Analysis of DCPP ISFSI Cutslope (SWEDGE Analysis)

MADE BY A. Tafoya DATE 12/13/01 CHECKED BY N/A DATE

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SUBJECT Pseudostatic Wedge Analysis of DCPP ISFSI Cutslope (SWEDGE Analysis)

MADE BY A. Tafoya DATE 12/13/01 CHECKED BY N/A DATE

1- This table cross references between Geosciences calculation numbers and DCPP (Civil Group's) calculation numbers. This section is For Information Only.

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AT 12/13/01

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PACIFIC GAS AND ELECTRIC COMPANY
GEOSCIENCES DEPARTMENT
CALCULATION DOCUMENT

Calc Number:	GEO.DCPP.01.23
Revision:	0
Date:	November 14, 2001
No. of Calc Pages:	134
Verification Method:	A
No. of Verification Pages:	2 NOT ATTACHED AT 12/13/01

TITLE Pseudostatic Wedge Analysis of DCPP ISFSI Cutslope (SWEDGE Analysis)

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PG&E
Geosciences Department
Departmental Calculation Procedure

Page: 1 of 1

Title: Record of Revision

Calc Number: GEO.DCPP.01.23

Pseudostatic Wedge Analysis of DCPP ISFSI Cutslope (SWEDGE Analysis)

Rev. No.	Reason for Revision	Revision Date
0	Initial issue	11/14/01

DCPP ISFSI

CALCULATION PACKAGE GEO.DCPP.01.23

Pseudostatic Wedge Analysis of DCPP ISFSI Cutslope (SWEDGE Analysis)

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Pseudostatic Wedge Analysis of DCPP ISFSI Cutslope (SWEDGE Analysis)

Revision 01

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DCPP ISFSI GEOTECHNICAL CALCULATION PACKAGE

Title: Pseudostatic wedge analysis of DCPP ISFSI cutslope (SWEDGE analysis)

Calc Number: GEO.DCPP.01.23

Revision: Rev. 0

Author: Jeff L. Bachhuber

Date: November 14, 2001

Verifier: Robert K. White

1.0 PURPOSE

The purpose of this Calculation Package is to evaluate the pseudostatic stability of the proposed DCPP ISFSI cutslopes. The proposed cutslopes will be excavated in sandstone and dolomite bedrock of the Obispo Formation. A pseudostatic stability analysis of the cutslope was performed to evaluate the potential for wedge sliding failures along discontinuities in the rock mass using the SWEDGE program (Rocscience, 1999). The results from these analyses will be used to help develop conceptual design support for the excavated slope (Calculation Package GEO.DCPP.01.08). Figure 23-1 shows the general configuration and plan view of the proposed cutslopes (the Eastcut, Backcut, and Westcut), and Figure 23-2 shows the proposed cutslope profile. The cutslope geometry that was analyzed was obtained from PG&E/Enercon preliminary design drawing PGE-009-SK-001, dated 9/22/01, and transmitted by A. Tafoya on 9/27/01. The preparation of this calculation package was performed under the WLA Work Plan (Rev. 2) dated November 28, 2000 using data collected under that Work Plan, and a second WLA Work Plan (Rev. 1) dated September 19, 2001.

SWEDGE is a computer program for the analyses of translational slip of surface wedges in a rock slope. Rock block wedges are defined by two intersecting discontinuity planes (joints, faults, bedding), a slope face, and an optional tension crack parallel to the slope face. The program performs analyses using two techniques: probabilistic analyses (probability of failure), and deterministic analyses (factor of safety). For probabilistic analyses, variation or uncertainty in discontinuity orientation and strength values can be accounted for, resulting in calculated safety factor distributions and predictions of failure probability. For deterministic analyses, a factor of safety is calculated for a specified wedge geometry and discontinuity shear strength condition. Both types of analyses can also factor influences of water pressure from accumulated rainfall or groundwater accumulation within the wedges, external/seismic forces, and effects of rock anchor reinforcement. The stability method used in SWEDGE is explained in Hoek and Bray (1981), and is based on limit equilibrium methodology.

Kinematic analyses using discontinuity data for the cutslope area (ISFSI SAR Section 2.6 Topical Report Appendix F) were performed for each of the proposed cutslopes bounding the southeast Backcut (South), Westcut (southwest), and Eastcut (northeast) margins of the ISFSI pad and stereonet plots of the data are presented in Calculation Package GEO.DCPP.01.22. Each potentially unstable wedge identified on the stereonet plots in the kinematic analyses was modeled with the SWEDGE program to evaluate the probability and relative risk of failure. Figures 23-3 through 23-5 are kinematic plots from GEO.DCPP.01.22 showing potential wedges in each cutslope.

2.0 INPUTS

Input parameters used for the modeling are shown in Table 23-1, and were obtained as follows:

- Dip and dip direction average-values and ranges for wedge forming discontinuities were obtained from Calculation Package GEO.DCPP.01.22.

- Discontinuity shear strength values were obtained using the Barton method from Calculation Package GEO.DCPP.01.20.
- Preliminary cutslope geometry is shown on PG&E/Enercon Drawing PGE-009-SK-001, dated 9/12/01, and transmitted by W.D. Page on 10/12/01. The design consists of two 70° cutslopes separated by a 25-foot-wide bench. The height of the cutslope risers below the bench varies from 20.5 to 23.3 feet high (Backcut, Eastcut), and the upper cut slope riser in the Backcut is a maximum of 31.8 feet high. The maximum composite height for the benched cut is in the Backcut, and is 52.3 feet high. This was determined by overlying the cutslope geometry drawing on the ISFSI site topographic map drawing (GEO.DCPP.01.21 Figure 21-4). The preliminary design includes a drainage system consisting of culvert pipes with inlet risers. The culvert is to be installed in a backfilled ditch at the back of the mid-slope bench, as per Enercon Drawings PGE-009-SK-340 and -341 (R. White memo, Nov. 9, 2001). We have assumed maximum drainage ditch width of 3 feet, and a maximum depth of 7 feet. The ditch location and geometry do not significantly change slope heights or conditions for stability analyses, and potential wedges daylighting in the ditch would be constrained by compacted backfill and rock in the opposite ditch wall. Therefore, critical wedges were modeled to daylight at the toe of the cutslope above the drainage ditch.
- The minimum required factor of safety of 1.3 for dynamic loading of wedges was used, as recommended by ASCE (1982) for design and analysis of nuclear safety-related earth structures induced by the vibratory ground motion.
- The pseudostatic horizontal acceleration coefficent of 0.5 was obtained from Calculation Package GEO.DCPP.01.05. Seismic forces were assumed to act in a horizontal inclination at an azimuth perpendicular to the slope face.

The dip and dip direction of wedge-forming discontinuities were given variation ranges of 5 and 10 degrees, respectively, to capture the possible range of natural variation in field measurements that are not at the exact locations of the cutslopes and is based on examination of field variability of discontinuity geometry. The frictional strength of each discontinuity set was based on strength criteria developed using the Barton equation as presented in Calculation Package GEO.DCPP.01.20. Different strengths were used for joints and fault planes in dolomite and sandstone, respectively, according to the respective Barton shear strength curves selected values are shown on Table 23-1. The friction angles were assigned a range in values that correspond to the upper and lower bound strength curves developed using the Barton equations. The SWEDGE program probabilistic analyses allows input of mean and minimum/maximum ranges of values for discontinuity dip and dip direction, and shear strength (cohesion and friction angle). These values are varied within the designated range by the program using user-selected statistical distribution models, and Monte Carlo simulation. For analyses of the ISFSI cutslope stability, a normal distribution was selected, and 1000 Monte Carlo iterations were performed per stability run. Only the mean values for input parameters are shown on Table 23-2.

3.0 ASSUMPTIONS

The following assumptions were included in the pseudostatic stability analyses:

1. The pseudostatic analysis method models forces in the slope related to the stability of rock wedges. The basis for this assumption is presented in Hoek and Bray (1981), and is considered to be a reasonable assumption.

2. The presence and geometry of discontinuities forming possible wedge failures have been identified by the kinematic analyses in Calculation Package GEO.DCPP.01.22. The large data set of measured discontinuities (William Lettis & Associates, Inc., 2001, Diablo Canyon ISFSI Data Report F) is sufficient to identify critical wedges, and individual data sets were developed for each cutslope face to account for local variations in geometry. Variations in discontinuity dip and dip direction are assumed to follow a normal distribution.

3. Rock mass shear strength estimated by the Barton method (Calculation Package GEO.DCPP.01.20) is appropriate for shear strength of the discontinuities bounding modeled wedges and provides conservative values for the in-situ rock friction. This is discussed in Calculation Package GEO.DCPP.01.22. Variations in shear strength values were assumed to follow a normal distribution. Cohesion was conservatively neglected in the analyses to factor the possibility of existing parting surfaces or partly disturbed and dilated rock mass conditions.

4. Groundwater and infiltrated rainwater will not collect in rock mass discontinuities greater than half the height of the wedge. This assumption is based on three factors: (1) field observations of the ISFSI site area that noted the slope to be free of wet areas, springs, and only temporal evidence of a local perched water table (William Lettis & Associates, Inc., 2001, Diablo Canyon ISFSI Data Report B); (2) observations from borings drilled in the ISFSI site area, all of which were dry to depths of over 100 feet below the proposed ISFSI site pad grade; (3) measured water levels in borings 98BA-1 and 91BA-3 that were finished with piezometer casings (William Lettis & Associates, Inc., 2001, Diablo Canyon ISFSI Data Report B); and (4) the recommended installation of drains in the ISFSI cutslopes that will prevent temporary perched water tables during winter rains. Thus, the assumption of the slopes filled with water to half the cutslope height is conservative for most of the year and reasonable during and immediately following heavy rains.

5. The maximum depth (into the rock slopes) of the modeled wedges is about 20 feet (7 meters). Field observations of joint spacing and bed thickness show that intact rock blocks at the surface in the ISFSI site have dimensions less than about 14 feet, and typically are on the order of 2 to 3 feet in maximum dimension (William Lettis & Associates, Inc., 2001, Diablo Canyon ISFSI Data Report F). Thus, the assumption of rock blocks extending up to 20 feet deep into the slope is conservative and accommodates the potential for multiple-block composite wedge slides.

6. In all cases, the failure mode of the wedge is assumed to be translational slip; rotational slip and toppling are not modeled. Kinematic analyses in Calculation Package GEO.DCPP.01.22, and field observations of the rock mass and exploratory trench sidewall stability, suggest that wedge sliding is the most likely failure mode for small-to-moderate size (generally 2 to 3 feet and up to 14 feet) failures into the ISFSI pads cutslope. Potentially larger slab or planar rock slides along clay beds in the slope are modeled separately in Calculation Package GEO.DCPP.01.24.

7. For purposes of determining the rock anchor force required to achieve wedge stability at the required factor of safety, rock anchors are assumed to be spaced in a staggered pattern at 5-foot (1.52 m) intervals (Figure 23-6), which is reasonable, and typical construction practice. Only half the wedge face area is assumed available for anchoring, which conservatively neglects the contribution to stability from anchors located at or very near the edge of the wedge that would not provide sufficient penetration of the wedge to ISFSI sliding.

8. Seismic forces are modeled in a horizontal inclination with an azimuth perpendicular to the slope face. This is a reasonably conservative assumption and typical approach for slope stability analyses.

9. Drainage ditches located at the back of the midslope bench were considered as possible tension crack locations. However, iterative analyses showed that joint intersections likely would not extend back to the drainage ditch location for most wedge configurations.

4.0 METHOD

Each potential wedge identified in kinematic analyses (Calculation Package GEO.DCPP.01.22) was modeled probabilistically with the SWEDGE program to evaluate the relative risk of failure. Figures 23-3 through 23-5 present stereographic plots showing potential wedges in each cutslope. Input parameters used for the modeling are shown in Table 23-1, and are explained under the Inputs section of this Calculation Package (see above).

The step-by-step methodology used for the pseudostatic wedge stability analyses is presented below:

1. Identification of wedge geometries of potential failure, and selection of parameters for the pseudostatic analyses;
2. Probabilistic analyses of each wedge geometry to identify the most critical unstable wedge and the probability of failure associated with that wedge; and,
3. Deterministic analyses of these hazardous wedges to determine the required anchor forces to achieve the required factor of safety of 1.3 for dynamic loading.

Step 1

The potentially unstable wedges in each ISFSI cutslope was defined in Calculation Package GEO.DCPP.01.22. No potential wedge failures were identified for the Westcut, while four potential wedges were identified for the Backcut, and three potential wedges were identified for the Eastcut. Each wedge is defined in SWEDGE using the mean orientations of the discontinuity sets identified above. Each discontinuity set is also assigned a mean friction angle and distribution to be used in the probabilistic analyses. These friction angles were determined by the Barton criteria, as presented in Calculation Package GEO.DCPP.01.20. Wedges encompassing a single cut face between benches, and wedges that extend from the base of the cut to the top of the cut and fail through the benches, are considered (Figure 23-2B).

Step 2

For each wedge geometry defined above, several probabilistic analyses are run which vary input parameters such as water conditions, seismic forces, and the presence of a tension crack. Probability of failure and mean factor of safety are calculated for each model. This step allows for the calculation of the least stable scenario for each wedge geometry.

Step 3

The scenario with the highest probability of failure for each wedge geometry in each cutslope is analyzed deterministically in SWEDGE. The geometry of each modeled wedge was evaluated to determine if it was consistent with dimensional limitations described in Assumption No. 5, and with observed field rock mass conditions. In some cases, a tension crack was modeled to limit the dimensions of the wedge as described later in Section 7.0. Wedge sizes were determined by the SWEDGE program based on the largest (least stable) wedge that could daylight in the defined cutslope. The deterministic analyses calculate a discrete factor of safety for the given wedge, which serves as confirmation of the results from the probabilistic analyses. External support forces are then added in order to assess the effects of rock anchors on the factor of safety of the wedge. Per-anchor forces can then be calculated using the face area of the wedge and an assumed rock anchor pattern.

5.0 SOFTWARE

Analysis of the potential wedge failures in the ISFSI cutslopes was performed using SWEDGE, v.3.06 (Rocscience, 1999) on a DELL Inspiron model 8000 laptop computer running the Microsoft Windows ME operating system. The software was purchased by and is licensed to William Lettis & Associates, Inc. (WLA), and all analyses were performed by WLA. The program has not been modified from the version purchased from Rocscience. Probabilistic and deterministic pseudostatic stability analyses were performed using standard SWEDGE functions.

SWEDGE examples presented in Rocscience (1999) were used to verify the SWEDGE functions, using method 1 of PG&E Geosciences Department, GEO.001, Rev. 4, Development and Independent Verification of Calculations for Nuclear Facilities, Section 4.4.2.2. Input parameters from the examples were entered into the program provided to WLA, and the output was compared with the example output. The program successfully reproduced example solutions. Verification examples and computer output are included in Attachment 2.

The following program items were also identified as part of the verification process;

a) Program name: SWEDGE
b) Program version: 3.06
c) Program revision: not applicable
d) Computer platform compatibility: Windows ME
e) Program capabilities and limitations: The program performs analyses using two techniques: probabilistic analyses (probability of failure), and deterministic analyses (factor of safety). For probabilistic analyses, variation or uncertainty in discontinuity orientation and strength values can be accounted for, resulting in calculated safety factor distributions and predictions of failure probability. For deterministic analyses, a factor of safety is calculated for a specified wedge geometry and discontinuity shear strength condition. Analyses results are valid when ranges of input values are within those described in Rocscience (1999).
f) Program test cases: described in Attachment 2. Includes tension crack, water, seismic/dynamic loads.
g) Instructions for use: input values for two intersecting discontinuity planes (joints, faults, fractures), a slope face, and an optional tension crack parallel to the slope face as described in Rocscience (1999).
h) Program owner: Rocscience, Inc.
i) Identification of individual responsible for controlling the software or executables: See PG&E Geosciences QA procedure CF2.GEI.
j) Change control: See PG&E Geosciences QA procedure CF2.GEI.
k) Verification methods used: PG&E Geosciences GEO.001, Rev. 3, 4.2.2, method 1 as shown in Attachment 2.

6.0 ANALYSIS

Separate analyses were performed for each of the two walls (Backcut and Eastcut) of the ISFSI site excavation indicated by kinematic analyses in Calculation Package GEO.DCPP.01.22 to be susceptible to wedge failure. For each potentially hazardous wedge geometry identified in the kinematic analyses, models were run that included variations in joint surface shear strength, water conditions, seismic loading, and the presence of a tension crack in the slope behind the rock face. Models were run using a 31.8 feet (9.7 meters) high cutslope between the bench and top of cut in the proposed ISFSI site excavation as shown on Figure 23-2A. In addition, analysis of the Backcut cutslope included models using a 52.3 feet (15.9 meters) high cutslope to investigate the stability of larger wedges extending through both cutslopes and the bench to the top of the excavation. As shown in Figure 23-2B, the 52.3-foot-high cutslope was modeled using an "average" slope profile without an intermediate bench, as SWEDGE is unable to model the composite slope profile with the bench. This scenario models possible composite wedge failures involving multiple single rock blocks. Each model was run probabilistically using Monte Carlo simulation with 1,000 iterations.

After determining the worst-case wedge geometries using the probabilistic analyses, deterministic analyses of these worst-case wedges were then run to determine the rock anchor support required to achieve a factor of safety of 1.3. The SWEDGE program calculates a maximum wedge weight and the wedge face area that is available for rock anchor support. Per-anchor forces can then be calculated using the assumed rock anchor design pattern given above in the Assumptions Section of this Calculation Package, and shown in Figure 23-6. The geometry (dip and dip direction) and frictional shear strength of discontinuities in the SWEDGE model in some cases are somewhat different than those shown in the kinematic analysis in Calculation Package GEO.DCPP.01.22, because in some cases, where kinematic analyses showed that the discontinuity intersection was close to, but not quite, daylighting in the slope, the dip or dip direction mean values were changed to permit a daylighting condition to accommodate possible variations in the discontinuity geometry. The friction angles for fault planes as determined in Calculation

Package GEO.DCPP.01.20 were used for discontinuities oriented parallel to the trend of ISFSI site faults, rather than the higher friction angles as determined for clean rock-rock discontinuities (about 28°) that were used for kinematic analyses.

Westcut

Kinematic analyses demonstrate that the rock mass in the area of the westcut does not exhibit persistent discontinuities that form daylighting wedge intersections in the proposed cutslope (Figure 23-3). Therefore, SWEDGE analyses were not performed for this cutslope.

Backcut

The Backcut will be excavated in sandstone, dolomite, and friable sandstone and friable dolomite bedrock of Units Tof_{b-2}, Tof_{b-2a}, Tof_{b-1}, and Tof_{b-1a} (Figure 23-1). Strength values for sandstone, which are lower than for dolomite, were used for the analyses (WEDGE modeling is not applicable for cuts in the friable rock which does not exhibit well-developed intersecting joint wedges). The kinematic analyses show that four discontinuity sets, as referenced in GEO.DCPP.01.20, form potential wedge sliding intersections for the Backcut (Figure 23-4). The discontinuity sets are: (1) NNW striking, steeply W dipping; (2) NW striking, steeply SW dipping; (3) WNW striking, near vertical; and (4) NW striking, shallowly SW dipping. The intersections between sets 2-3, 1-3, and 2-4 are those that are potentially unstable in the backcut. Each of these potential wedge intersections was modeled probabilistically and deterministically with the SWEDGE program to evaluate the probability and relative risk of failure. Two of the discontinuities are parallel to site faults, and were modeled using friction angles for fault planes. The other two discontinuities were assumed to exhibit rock-rock frictional strength (Table 23-1). Strength curves for sandstone and dolomite bedrock were used in the analyses (refer to Calculation Package GEO.DCPP.01.20).

Tension cracks were modeled at the approximate location of the mid-slope bench drainage ditches for some models (i.e. runs Backcut D9R, D10R) to emulate possible development of tension cracks or dislocation surfaces caused by the drainage ditch excavation.

Eastcut

The Eastcut will be excavated in dolomite bedrock of Unit Tof_{b-1} (Figure 23-1). The kinematic analyses show that three discontinuity sets form potential wedge sliding intersections for the Eastcut (Figure 23-5). The discontinuity sets, as reference in GEO.DCPP.01.20, are: (1) NNE striking, near vertical; (2) NW striking, steeply SW dipping; and (3) E-W striking, steeply N dipping (Joint Set No. 2 from GEO.DCPP.01.20 is not analyzed because it is at too gentle of an angle to be prone to wedge sliding). The intersections between sets 2-4 and 1-2 are potentially unstable in the Eastcut. Each of these potentially unstable wedge intersections was modeled probabilistically and deterministically with the SWEDGE program to evaluate the probability and relative risk of failure. One of the discontinuity sets is parallel to site faults, and was modeled using a fault plane frictional strength (Table 23-1). The other two discontinuities were modeled using rock-rock frictional strength. Strength curves for dolomite bedrock were used in the analyses (refer to Calculation Package GEO.DCPP.01.20).

7.0 RESULTS

The results from SWEDGE probabilistic analyses are summarized in Tables 23-2 Backcut and 23-3 Eastcut. Results from the deterministic analyses for both the Backcut and Eastcut, including evaluations of required anchor forces to achieve a dynamic Factor of Safety (FOS) of 1.3, are summarized in Table 23-4. SWEDGE program output files are included in Attachment 1.

Backcut

Probabilistic analyses were run for 19 different cases that included the four potentially hazardous wedge geometries (Table 23-2). Each run included 1000 Monte Carlo iterations that varied the input parameters for discontinuity dip and dip direction, and frictional strength, within the specified ranges (Table 23-1) and using a normal distribution. Only the mean values are reported on Table 23-2. The calculated probability of failure for the 17 cases varies between zero (no probability of failure) to 1.0 (certain failure). In most cases, the wedges are stable under dry and non-seismic conditions, but have a high probability of failure under high seismic loads and/or the accumulation of temporary groundwater. Maximum wedge weight for the maximum 31.8-foot high upper cutslope riser varies from 10.8 kips (wedge 1-3) to 11,991.8 kips (wedge 3-4). Maximum wedge weight for the 52.3-foot high composite benched cut varies from 3243.9 kips (sets 3-4 with tension crack) to 21,826.2 kips tons (sets 3-4 without tension crack), depending on how deep the wedge extends into the slope. Model runs P6-R, and P14-R included very long (on the order of 100 feet), narrow (on the order of tens of feet) wedges that are believed to be unrealistic based on the intensity of jointing in the rock mass that suggests maximum rock block depths of 20 feet and maximum block dimensions of about 14 feet (see Assumption No. 5). These wedges likely would separate along joints several feet to a maximum of 20 feet behind the slope face. We, therefore, modeled tension cracks about 20 feet behind the slope face to limit the dimension of these wedges to a realistic size consistent with our field observations and discontinuity data (DCPP ISFSI SAR Section 2.6 Topical Report Appendix F). Modeled wedges for the lower 20.5-foot high cutslope riser ranged between 9.7 and 1751.6 kips, much smaller than those for the higher upper cutslope riser.

For each modeled wedge geometry, the deterministic analyses confirmed the high probability of failure and low factor of safety for the cutslopes under seismic and/or water accumulation loading conditions (Table 23-4). The deterministic models also incorporated support forces to simulate the effects of rock anchors on the cutslope stability. The analyses indicate that stabilization with rock anchors will raise the factor of safety above the target goal of 1.3. Estimated per-anchor capacity for the Backcut cutslope range between 9.4 and 33.9 tons for a 5-foot by 5-foot staggered pattern. Estimated minimum anchor lengths of between about 4 and 23 feet are required to penetrate possible wedge basal surfaces, assuming that anchors are inclined at an angle of 15° below horizontal.

Eastcut

Probabilistic analyses were run for 7 different cases that included the two potentially hazardous wedge geometries (Table 23-3). Each run included 1000 Monte Carlo iterations with varying dip and dip direction and shear strength parameters as discussed previously for the Backcut results. The calculated probability of failure for the 7 models varies between 0.12 (low probability of failure) to 1.0 (certain failure). As in the Backcut, a high probability of failure (low factor of safety) is associated with high seismic loads and/or the temporary presence of groundwater in the slope. Maximum wedge weight varies from 23.8 kips (wedge 1-2) to 34.0 kips (wedge 2-4).

For both modeled wedge geometries, the deterministic analyses confirmed the high probability of failure and low factor of safety for seismic and combined or partly saturated and seismic conditions. With the addition of rock anchor support forces, the analyses indicate that stabilization will raise the factor of safety above the target goal of 1.3. Estimated per-anchor capacity for the Eastcut are about 8.4 to 9.0 kips for a 5- by 5-foot pattern. An estimated minimum anchor length of about 3 feet is required to penetrate possible wedge basal surfaces. This reflects the small size of the wedges on this cutslope. It should be noted that these anchor lengths do not include bonding lengths into the intact rock behind the wedges.

8.0 CONCLUSIONS

Tables 23-2 through 23-4 summarize the results of the SWEDGE modeling of potential rock wedges at the ISFSI site. The results from pseudostatic wedge stability analyses show that both the Backcut and the Eastcut have the potential for rock wedges that are stable under dry, non-seismic conditions but potentially fail under seismic loads and/or accumulation of temporary water in the slope. The analyses show that the ISFSI cutslopes will require engineered support to meet a factor of safety of at least 1.3 under earthquake loads and/or water accumulation in the slope. Possible failure wedges and rock masses are up to 25 feet thick and weigh up to tons 4474.6 kips. Individual rock anchors will need to be able to support up to 33.9 kips, based on a 5-foot by 5-foot staggered pattern, in order to achieve a factor of safety of 1.3.

9.0 REFERENCES

ASCE, 1982, Guideline for design and analysis of nuclear safety related earth structures, ASCE Standard N-725, January 1, 1988 (ANSI/ASCE 1-82, ANSI approved Nov. 5, 1986).

Hoek, E., and Bray, J.W., 1981, Rock Slope Engineering, 3rd edition, Institution of Mining and Metallurgy, London, 402 pages.

Rocscience, 1999, SWEDGE: Probabilistic analysis of the geometry and stability of surface wedges, version 3.06, Toronto, 64 pp.

William Lettis & Associates, Inc., 2001, Letter to Robert White, PG&E Geosciences from Robert C. Witter, November 5, 2001, Completion of Data Reports transmitting Data Reports A through K to PG&E Geosciences Department;

Diablo Canyon ISFSI Data Report B - Borings in ISFSI Site Area, Rev. 0, November 5, 2001, prepared by J. Bachhuber, 244 p.

Diablo Canyon ISFSI Data Report D - Trenches in the ISFSI Site Area, Rev. 0, November 5, 2001, prepared by J. Bachhuber, 66 p.

Diablo Canyon ISFSI Data Report F - Field Discontinuity Measurements, Rev. 0, November 5, 2001, prepared by C. Brankman and J. Bachhuber, 85 p.

Geosciences Calculation packages

GEO.DCPP.01.05 Determination of psuedostatic acceleration coefficient for use in DCPP ISFSI cutslope

GEO.DCPP.01.08	Determination of rock anchor design parameters for DCPP ISFSI cutslope and CTF guy lines
GEO.DCPP.01.20	Development of strength envelopes for shallow discontinuities at DCPP ISFSI using Barton equations
GEO.DCPP.01.21	Analysis of bedrock stratigraphy and geologic structure at the DCPP ISFSI site
GEO.DCPP.01.22	Stereographic-kinematic analysis of DCPP ISFSI cutslope (DIPS analysis) and laboratory data
GEO.DCPP.01.24	Determination of critical rock slides on DCPP ISFSI slope (UTEXAS3 analysis)

PG&E Memorandums and Design Drawing

Page, W.D., October 12, 2001, Transmittal of requested drawings, DCPP used fuel storage projects, for Calculation Package GEO.DCPP.01.21, Analysis of bedrock stratigraphy and geologic structure at the DCPP ISFSI site, including PG&E/Enercon Drawing PGE-009-SK-001, 9/27/01.

White, R.K., November 9, 2001, Transmittal of Enercon drawings showing drainage design for DCPP ISFSI site, including PG&E/Enercon Drawings PGE-009-SK-340 and PGE-009-SK-341.

QA Documents

PG&E Quality Assurance Procedure GEO.001, Development and Independent Verification of Calculations for Nuclear Facilities

PG&E Quality Assurance Procedure CF2.GE1, Verification and Change Control of Quality-related Software

Table 23-1. Pseudostatic SWEDGE Analyses Input Data, ISFSI Cutslopes

BACKCUT

Orientation: 70°/330° Geometry: Benched cut with 20.5 and 31.8-ft-high risers

Geology: Sandstone (Tof_{b-2}) and Dolomite (Tof_{b-1}). Zones of friable sandstone (Tof_{b-2a}) and friable Dolomite (Tof_{b-1a}) also occur but these weathered and/or altered rocks do not contain significant fractures and were not modeled.

Rock unit weight: 0.071 US tons/ft^3 (based on William Lettis & Associates, Inc., 2001, Diablo Canyon ISFSI Data Report I).

Potential wedges formed by combinations of four discontinuities[(1)]

Discontinuity	Mean Dip/Dip Direction[(2)]	Relative Range in Dip/Dip Direction	Mean Friction Angle[(3)]	Relative Range in Friction Angle
1. joint	75-77/261†	±5/±10	30.5	-12 to +15.5
2. fault/joint	69/220	±5/±10	26.5	-10.5 to +15.5
3. fault	75-88/12†	±5/±10	26.5	-10.5 to +15.5
4. joint	24/232	±5/±10	30.5	-12 to +15.5

EASTCUT

Orientation: 70°/240° Geometry: 23.3-ft-high cut with a small bench at top

Geology: Dolomite (Tof_{b-1}) (zones of friable Dolomite (Tof_{b-1a}) also occur but is weathered and/or altered soil does not contain significant fractures).

Rock unit weight: 0.071 US tons/ft^3

Potential wedges formed by combinations of three discontinuities[(1)]

Note: Discontinuity set 2 from GEO.DCPP.01.22 not modeled because it is too shallow to form potential wedge sliding intersection.

Discontinuity	Mean Dip/Dip Direction[(2)]	Relative Range in Dip/Dip Direction	Mean Friction Angle[(3)]	Relative Range in Friction Angle
1. joint	88/98	±5/±10	36.0	-17.0 to +16.0
3. joint	67/239	±5/±10	36.0	-17.0 to +16.0
4. fault	70-76/08†	±5/±10	35.0	-17.5 to +19.0

WESTCUT – no wedge intersections defined by kinematic analyses.

NOTES:

[(1)]Potential wedge intersections defined by kinematic analyses presented in Calculation Package GEO.DCPP.01.22

[(2)]Mean dip/dip direction obtained by DIPS program in Calculation Package GEO.DCPP.01.22, except where noted with a †. For the exceptions, the dip and/or dip direction were changed to permit the mean value to daylight in the slope face. The lower value of dip is the changed value in these cases. Ranges estimated based on typical variations in discontinuity orientations observed in the field at the ISFSI site (e.g., DCPP ISFSI SAR Section 2.6 Topical Report Appendix D).

[(3)]Friction angle (Phi) mean values and ranges taken from Barton equation analyses of discontinuity shear strength described in Calculation Package GEO.DCPP.01.20.

Table 23-2 Pseudostatic Probabilistic SWEDGE Analyses of ISFSI Backcut

Run	Cut[1] Height (ft)	Discontinuity[2] A	Discontinuity[2] B	Mean[3] Friction Angle	Tension[4] Crack Distance (ft)	Seismic[5] Force (g)	Water[6] Unit Weight (kips*/ft3)	Probability of Failure	Factor of Safety	Wedge Weight (kips*)	Wedge Face Area (ft2)
Backcut P1R	31.8	69/220 (2)	88/12 (3)	26.5 (A/B)	None	None	None	0.036	1.39	40.1	101.8
Backcut P2R	31.8	69/220 (2)	88/12 (3)	26.5 (A/B)	3.3	None	None	0.007	1.39	25.1	101.8
Backcut P3R	31.8	69/220 (2)	88/12 (3)	26.5 (A/B)	None	None	0.031	0.978	0.27	40.1	101.8
Backcut P4R	31.8	69/220 (2)	88/12 (3)	26.5 (A/B)	None	0.50	None	1.0	0.49	40.1	101.8
Backcut P5R	31.8	69/220 (2)	88/12 (3)	26.5 (A/B)	None	0.50	0.031	1.0	0	40.1	101.8
Backcut P6R	31.8	88/12 (3)	24/232 (4)	26.5(A)30.5(B)	None	None	None	0	2.74	11,991.8	1059.9
Backcut P7R	31.8	88/12 (3)	24/232 (4)	26.5(A)30.5(B)	11.5	None	None	0	2.74	915.9	1059.9
Backcut P8R	31.8	88/12 (3)	24/232 (4)	26.5(A)30.5(B)	23.0	None	None	0	2.74	1783.8	1059.9
Backcut P9R	31.8	88/12 (3)	24/232 (4)	26.5(A)30.5(B)	23.0	None	0.031	0	1.44	1783.8	1059.9
Backcut P10R	31.8	88/12 (3)	24/232 (4)	26.5(A)30.5(B)	23.0	0.50	None	0.90	0.92	1783.8	1059.9
Backcut P11R-R	31.8	88/12 (3)	24/232 (4)	26.5(A)30.5(B)	23.0	0.50	0.031	1.0	0.62	1783.8	1059.9
Backcut P12R	31.8	75/12 (3)	75/261 (1)	26.5(A)30.5(B)	None	None	None	1.0	0.43	10.8	77.5
Backcut P13R	31.8	75/12 (3)	75/261 (1)	26.5(A)30.5(B)	None	0.50	0.031	1.0	0	10.8	77.5
Backcut P14R	52.3	88/12 (3)	24/232 (4)	26.5(A)30.5(B)	None	None	None	0	2.74	21,836.2	2649.1
Backcut P15R	52.3	88/12 (3)	24/232 (4)	26.5(A)30.5(B)	11.5	None	None	0	2.74	3243.9	2649.1
Backcut P16R	52.3	88/12 (3)	24/232 (4)	26.5(A)30.5(B)	23.0	None	None	0	2.74	4474.6	2649.1
Backcut P17R	52.3	88/12 (3)	24/232 (4)	26.5(A)30.5(B)	23.0	0.50	0.031	1.0	0.63	4474.6	2649.1
Backcut P18R	20.5	69/220 (2)	88/12 (3)	26.5(A/B)	4.9	0.50	0.031	1.0	0.42	9.7	42.2
Backcut P19R	20.5	88/12 (3)	24/232 (4)	26.5(A)30.5(B)	4.9	0.50	0.031	1.0	0.71	1,751.6	1,059.9

* 1 kip = 1000 pounds

(1) Cut height geometry from PG&E/Enercon Drawing PGE-009-SK-001, 9/12/01, transmitted by A. Tafoya, 9/27/01.

(2) Mean dip and dip direction of intersecting joints (set number indicated in parentheses) that were identified by kinematic analyses in Calculation Package GEO.DCPP.01.22 as forming potential wedges. Geometry of discontinuity is defined by the dip/dip direction convention. Refer to Table 23-1. Numbers in brackets refer to Joint Set identification on Table 23-1 and in GEO.DCPP.01.20.

(3) Mean rock discontinuity friction angle determined by Barton Equation as developed in Calculation Package GEO.DCPP.01.20.

(4) Tension crack distance is the distance between the top of the wedge block crest and tension crack location measured along strike of discontinuity A. Wedges modeled in Runs P6-P11 and P14-P17 consisted of unrealistically long, narrow wedges when tension cracks were not included. Final runs, therefore, include a tension crack at 23 ft behind slope face.

(5) Seismic force recommended for pseudostatic wedge analyses as defined in Calculation Package GEO.DCPP.01.05.

(6) Water unit weight of 0.031 kips/ft represents approximately a condition with water collecting half-way up wedge-bounding discontinuities.

Table 23-3. Pseudostatic Probabilistic SWEDGE Analyses of ISFSI Eastcut

Run	Cut Height[1] (Ft)	Discontinuity[2] A	Discontinuity[2] B	Mean Friction (phi) Angle [3]	Tension Crack Distances[4] (ft)	Seismic Force[5] (g)	Water Unit Weight[6] (kips/ft^3)	Probability of Failure	Factor of Safety	Wedge Weights kips)	Wedge Face Area (ft)
Eastcut P1	23.3	76/08 (4)	67/239 (2)	35.0 (A) 36.0 (B)	None	None	None	0.20	1.08	33.96	446.0
Eastcut P2	23.3	76/08 (4)	67/239 (2)	35.0 (A) 36.0 (B)	1.64	None	None	0.12	1.08	33.96	446.0
Eastcut P3	23.3	76/08 (4)	67/239 (2)	35.0 (A) 36.0 (B)	None	None	0.031	0.31	1.02	33.96	446.0
Eastcut P4	23.3	76/08 (4)	67/239 (2)	35.0 (A) 36.0 (B)	None	0.50	None	1.0	0.65	33.96	446.0
Eastcut P5	23.3	76/08 (4)	67/239 (2)	35.0 (A) 36.0 (B)	None	0.50	0.031	1.0	0.54	33.96	446.0
	23.3										
Eastcut P6	23.3	88/98 (1)	67/239 (2)	36.0 (A) 36.0 (B)	None	None	None	0.97	0.31	23.81	469.8
Eastcut P7	23.3	88/98 (1)	67/239 (2)	36.0 (A) 36.0 (B)	None	0.50	0.031	0.99	0	23.81	469.8

NOTES:

(1)Cut geometrics from PG&E/Eneron drawing, PGE-009-SK-001, 9/12/01, transmitted by A. Tafoya, 9/27/01.

(2)Mean dip and dip direction of intersecting joints (set number indicated in parentheses) that were identified by kinematic analyses in Calculation Package GEO.DCPP.01.22 as forming potential wedges. Geometry of discontinuity is defined by the dip/dip convention. Refer to Table 23-1. Numbers in brackets refer to Joint Set identification on Table 23-1 and in GEO.DCPP.01.22.

(3)Mean rock discontinuity friction angle determined by Barton equation as developed in Calculation Package GEO.DCPP.01.20.

(4)Tension crack distance is the distance between the top of the wedge block crest and tension crack location measured along strike of discontinuity A.

(5)Seismic force recommended for pseudostatic wedge analyses as defined in Calculation Package GEO.DCPP.01.05.

(6)Water pressure of 0.031 kips/ft^3 approximates a condition with water collecting half-way up wedge-bounding discontinuities.

Table 23-4 Pseudostatic Deterministic SWEDGE Analyses of ISFSI Backcut and Eastcut

Run	Cut(1) Height (ft)	Discontinuity (2) A	Discontinuity(2) B	Mean(3) Friction Angle	Tension(4) Crack Distance (ft)	Seismic(5) Force (g)	Water(6) Unit Weight (kips*/ft^3)	Bolt (7) Force (kips*)	Factor of Safety	Wedge Weight (kips*)	Wedge Face Area (ft2)	Penetration(8) Anchor Length (ft)	Per Anchor (9) Force (kips*)
Backcut D1RR	31.8	69/220 (2)	88/12 (3)	26.5 (A/B)	None	0.5	0.031	None	0	40.1	101.8		
Backcut D2R	31.8	69/220 (2)	88/12 (3)	26.5 (A/B)	None	0.5	0.031	41.8	1.39	40.1	101.8	6.6	18.6
Backcut D3R	31.8	88/12 (3)	24/232 (4)	26.5(A)30.5(B)	23.0	0.5	0.031	None	0.62	1783.8	1059.9		
Backcut D4R	31.8	88/12 (3)	24/232 (4)	26.5(A)30.5(B)	23.0	0.5	0.031	796.4	1.30	1783.8	1059.9	13.1	33.9
Backcut D5R	52.3	88/12 (3)	24/232 (4)	26.5(A)30.5(B)	23.0	0.5	0.031	None	0.63	4474.6	2649.1		
Backcut D6R	52.3	88/12 (3)	24/232 (4)	26.5(A)30.5(B)	23.0	0.5	0.031	1881.0	1.30	4474.6	2649.1	23.0	32.1
Backcut D7R	20.5	69/220 (2)	88/12 (3)	26.5 (A/B)	4.92	0.5	0.031	-	0.27	10.12	41.94		
Backcut D8R	20.5	69/220 (2)	88/12 (3)	26.5 (A/B)	4.92	0.5	0.031	8.8	1.67	10.12	41.94	3.9	9.4
Backcut D9R	20.5	88/12 (3)	24/232 (4)	26.5(A)30.5(B)	20.0	0.5	0.031	-	0.76	596.2	440.1		
Backcut D10R	20.5	88/12 (3)	24/232 (4)	26.5(A)30.5(B)	20.0	0.5	0.031	189.2	1.31	596.2	440.1	16.4	19.4
Eastcut D1R	23.3	76/08 (4)	67/239 (2)	35.0(A)36.0(B)	None	None	None	None	1.08	33.96	446.0		
Eastcut D2R	23.3	76/08 (4)	67/239 (2)	35.0(A)36.0(B)	None	0.5	0.031	None	0.54	33.97	446.0		
Eastcut D3R	23.3	76/08 (4)	67/239 (2)	35.0(A)36.0(B)	None	0.5	0.031	81.6	1.34	33.98	446.0	3.3	9.0
Eastcut D4R	23.3	88/98 (1)	67/239 (2)	36.0 (A/B)	None	None	None	None	0.31	23.81	469.8		
Eastcut D5R	23.3	88/98 (1)	67/239 (2)	36.0 (A/B)	None	0.5	0.031	None	0	23.81	469.8		
Eastcut D6R	23.3	88/98 (1)	67/239 (2)	36.0 (A/B)	None	0.5	0.032	83.8	1.43	23.81	469.8	3.3	8.4

*1 kip = 1000 lbs

(1) Cut height estimated from PG&E Drawing Fig 4.2-6, Rev. A.

(2) Mean dip and dip direction of intersecting joints (set number indicated in parentheses) that were identified by kinematic analyses in Calculation Package GEO.DCPP.01.22 as forming potential wedge. Geometry of discontinuity is defined by the dip/dip direction convention. Refer to Table 23-1.Numbers in brackets refer to Joint Set identification on Table 23-1 and in GEO.DCPP.01.22.

(3) Mean rock discontinuity friction angle determined by Barton Equation as developed in Calculation Package GEO.DCPP.01.20.

(4) Tension crack distance is the distance between the top of the wedge block crest and tension crack location measured along strike of discontinuity A. Wedges modeled in runs D3-D6 were unrealistically long and narrow when tension cracks were not included. Final runs therefore include tension cracks at 23 feet behind the slope face.

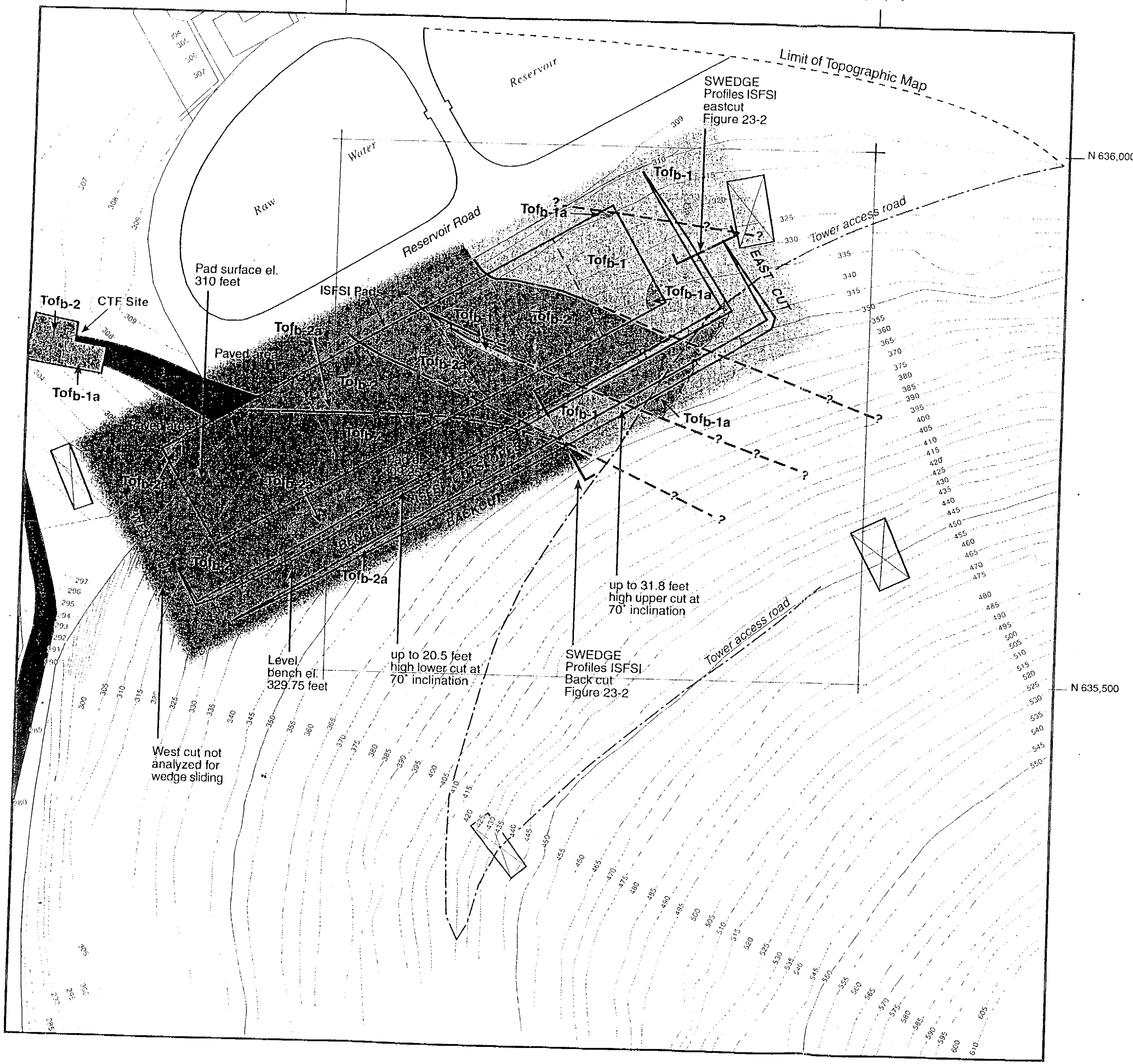
(5) Seismic force recommended for pseudostatic wedge analyses as defined in Calculation Package GEO.DCPP.01.05.

(6) Water pressure of 0.031 kips/ft^3 represents approximately a condition with water collecting half-way up wedge-bounding discontinuities.

(7) Total force required to stabilize block to the listed factor of safety.

(8) Length of anchor in meters required to penetrate modeled wedge sliding plane, assuming a anchor inclination of 15° below horizontal, and plunge direction perpendicular to slope face. Additional length is required to provide anchor anchorage and capacity in sound rock behind the failure wedge.

(9) Per anchor force calculated by dividing wedge face area by 50% to account for wedge margins that are not suitable for providing anchor restraint, and then dividing this value by the required anchor force, and assuming one anchor per 22.6 ft^2 which represents a anchor pattern spacing of 5.0 feet.



Explanation

Footprint of 500 kV tower

Outline of ISFSI Pads

Proposed cutslope above ISFSI Pads

DOLOMITE SUBUNIT

Tofb-1 Dolomite, clayey dolomite, dolomitic siltstone to fine-grained dolomitic sandstone, and limestone beds. The unit contains occasional discontinuous to continuous (tens to hundreds of feet) clay layers that are generally 1/32 to 1/2-inch thick, but locally are thicker. Rocks in this unit are moderately- to well-cemented, medium hard, moderately to slightly weathered, brittle and typically medium strong.

Tofb-1a Friable (poorly cemented) dolomite and dolomitic rocks of unit Tofb-1. These rocks typically have low hardness, are very weak to weak, and occur as discontinuous zones where weathering and/or alteration has been concentrated.

SANDSTONE SUBUNIT

Tofb-2 Dolomitic medium- to coarse-grained sandstone (arkose to graywacke), and altered sandstone, detrital clasts are composed primarily of dolomitized feldspars, marine fossil fragments, and volcanic rock fragments. Discontinuous clay layers that are generally less than 1/2-inch thick occur locally within the unit. The rocks are of low to medium hardness, moderately- to- well cemented and typically medium strong.

Tofb-2a Friable (poorly cemented) dolomitic sandstone and sandstone of unit Tofb-2. These rocks typically are of low hardness and are very weak to weak, and occur as discontinuous zones, in places where weathering and/or alteration has been concentrated.

Altered zones expected within 5 feet below ISFSI pads subgrade (el. 302').

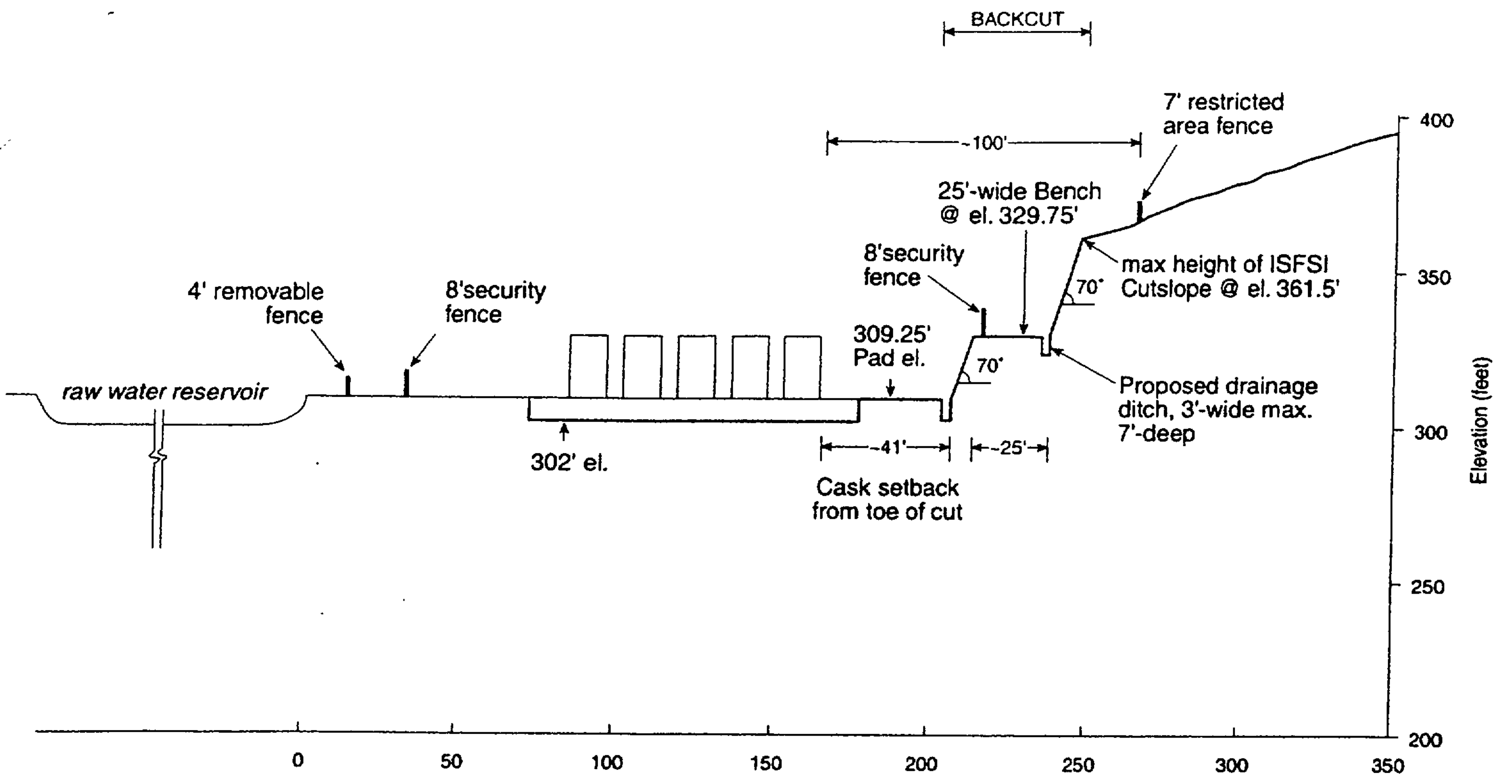
N

0 50 100 150 200

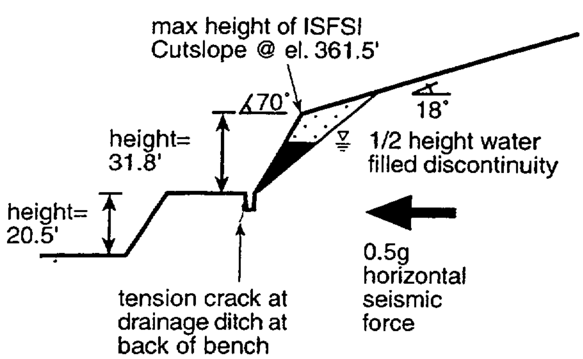
Contour interval = 5 feet

DIABLO CANYON ISFSI

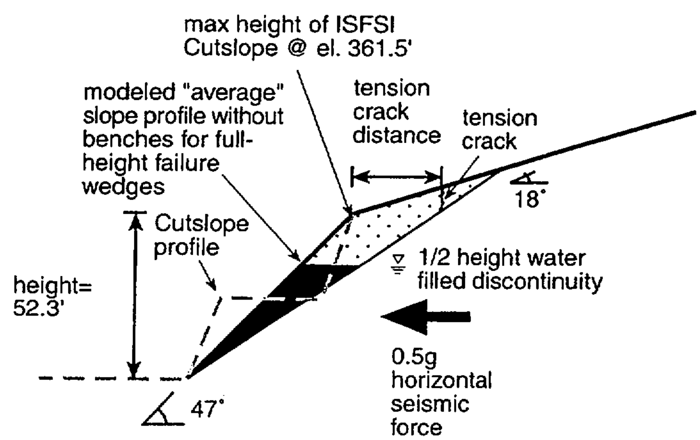
FIGURE 23-1
CONFIGURATION OF ISFSI CUTSLOPES



23-2 A CROSS SECTION THROUGH ISFSI PAD AND BACKCUT LOOKING EAST



Example of Riser-height (single bench) wedge



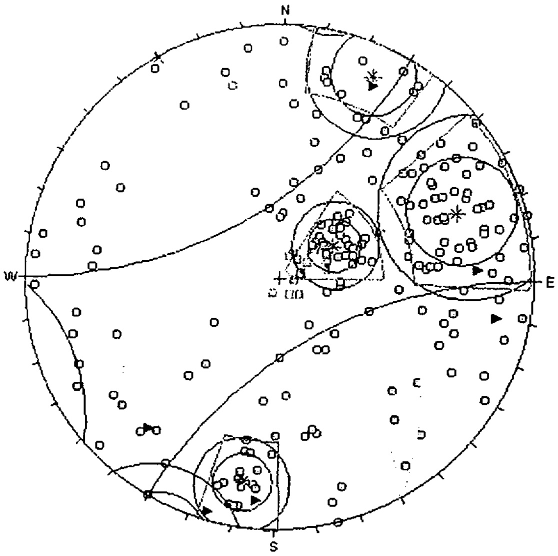
Example of total cut-height wedge as modeled by SWEDGE Program

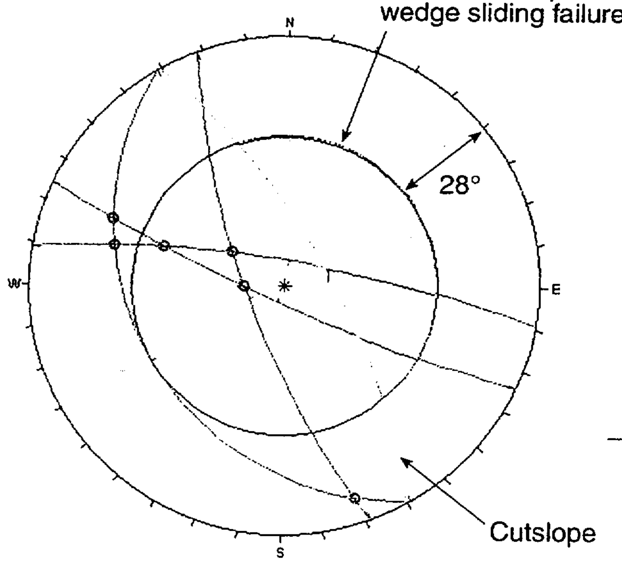
23-2 B ILLUSTRATION OF THE TWO SWEDGE ANALYSIS CUT CONFIGURATIONS

Note: cutslope geometry is based on PG&E/Enercon drawing PGE-009-SK-001,9/12/01 Transmitted by A.Tafoya 9/27/01

DIABLO CANYON ISFSI

FIGURE 23-2
CUTSLOPE CONFIGURATION USED IN SWEDGE ANALYSES





No potential for wedge failure

Note: The 28° friction angle shown on plots was used for kinematic analysis, not SWEDGE analysis as shown on Table 23-1

Notes: 1. Westcut kinematic analyses plot showing absence of wedge intersections in cutslope

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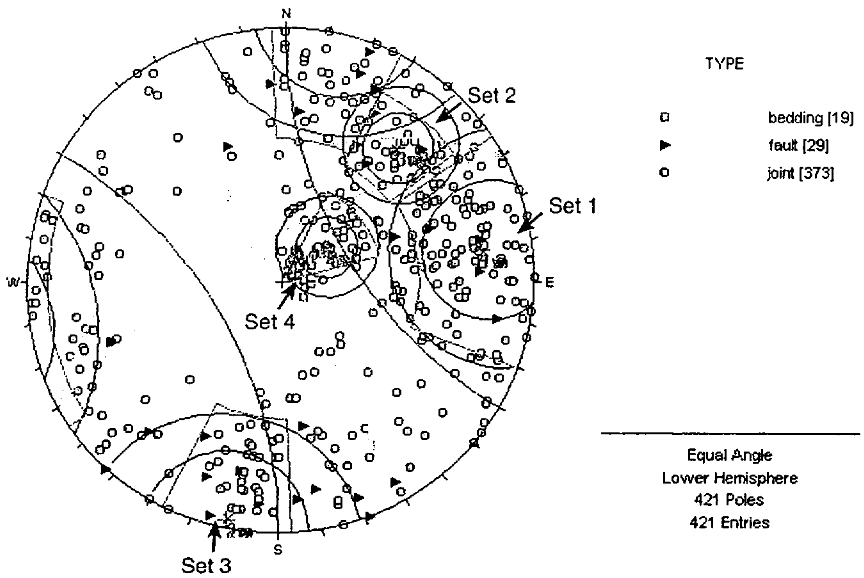
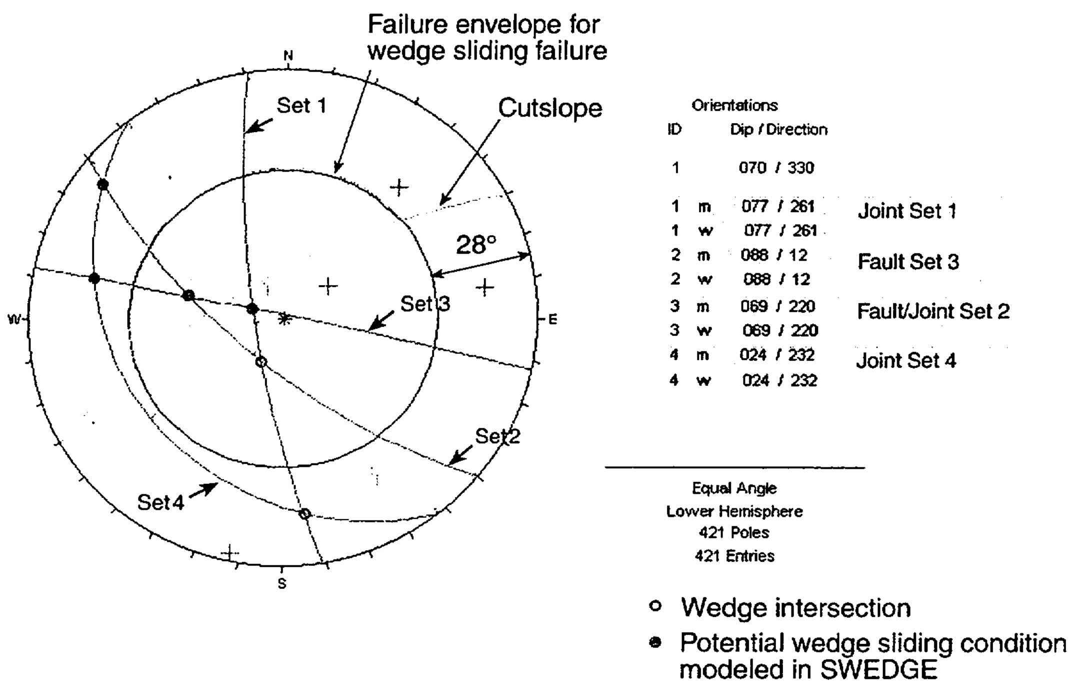
FIGURE 23-3
KINEMATIC PLOT OF WEDGE POTENTIAL IN WESTCUT

GEO.DCPP.01.23 REV 0





Note: The 28° friction angle shown on plots was used for kinematic analysis, not SWEDGE analysis as shown on Table 23-1

Notes: 1. Backcut kinematic analyses plot showing wedge intersection modeled in SWEDGE Analyses

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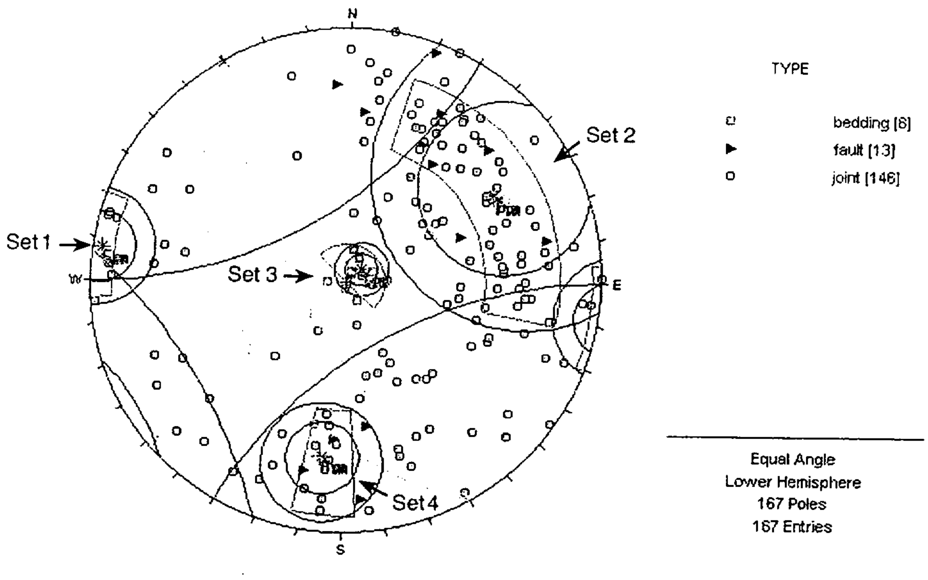
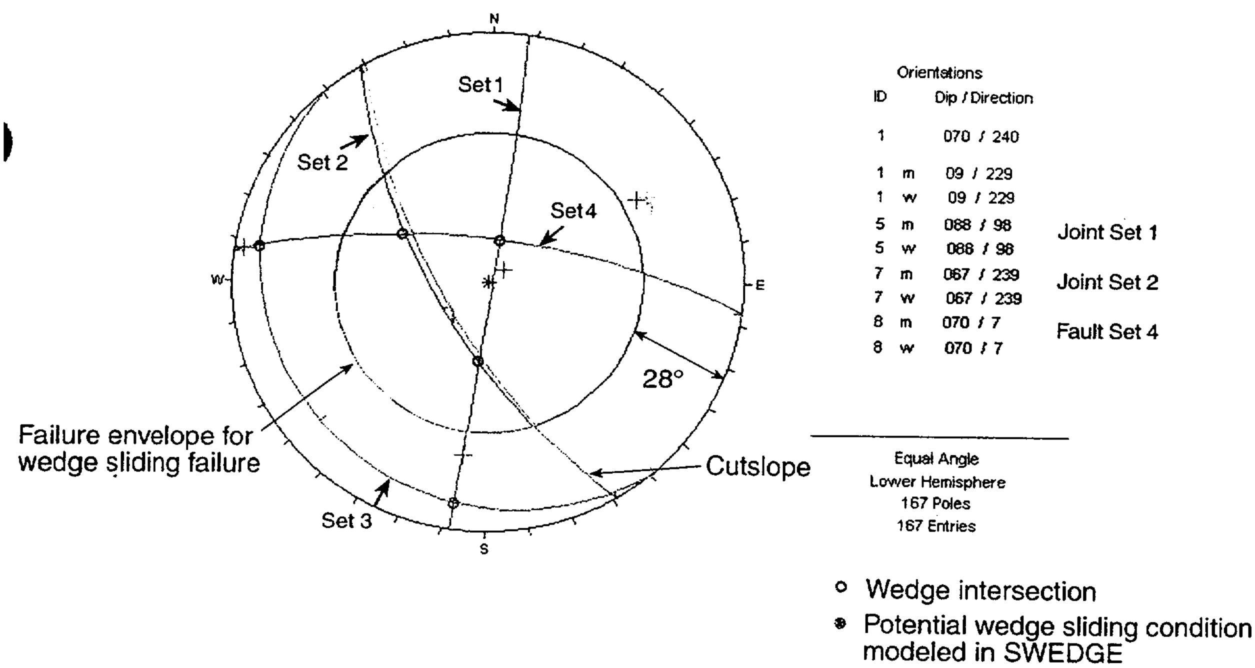
FIGURE 23-4
KINEMATIC PLOT OF WEDGE POTENTIAL IN BACKCUT (SOUTH CUTSLOPE)





Note: The 28° friction angle shown on plots was used for kinematic analysis, not SWEDGE analysis as shown on Table 23-1

otes: 1. Kinematic analyses plot showing wedge intersections modeled in SWEDGE Analyses

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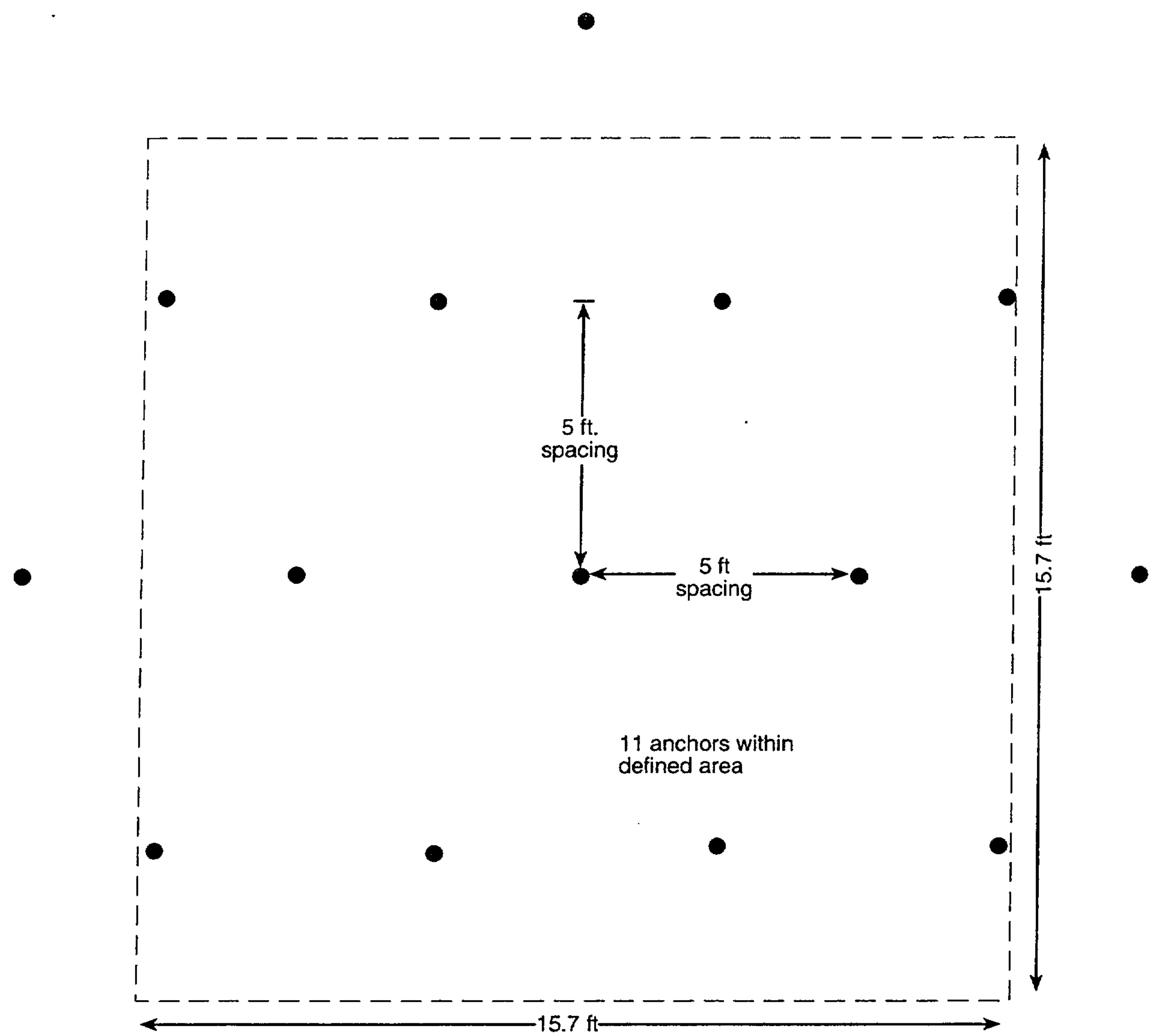
FIGURE 23-5
KINEMATIC PLOT OF WEDGE POTENTIAL IN EASTCUT



Area = $(15.7\ ft)^2 = 247.9\ ft^2$
11 anchors /$247.9\ ft^2$ = 1 anchor /$22.54\ m^2$

Explanation

● =modeled anchor location on a 5 ft. square, staggered pattern

Face-on view of regular 5 ft. spacing anchor pattern

Note: for anchor design, use assumption that only 50% of the anchors have sufficient rock block penetration to support the wedge, neglecting blocks at or near the edge of the block that would have minimal penetration width.

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FIGURE 23-6
GRAPHICAL CALCULATION OF ANCHORS PER AREA FOR 1.52 M ANCHOR PATTERN

GEO.DCPP.01.23 REV 0

ATTACHMENT 1
SWEDGE PROGRAM OUTPUT FILES

Swedge Analysis Information

Document Name:
ISFSIBackCutD1R-R

Job Title:
ISFSIBackCut-31.8

Analysis Results:
Analysis Type=DETERMINISTIC
Safety Factor=0
Wedge Volume=8.02 m3
Wedge Weight=18.2054 tonnes
Wedge Area (Joint 1)=19.6323 m2
Wedge Area (Joint 2)=14.9651 m2
Wedge Area (Slope)=9.45875 m2
Wedge Area (Upper Slope)=2.95786 m2
Normal Force (Joint 1)=-13.0369 tonnes
Normal Force (Joint 2)=-0.288031 tonnes
Failure Mode:
Contact lost on both joints
Joint Sets 1&2 line of Intersection:
plunge=48.5227 deg, trend=284.264 deg

Joint Set 1 Data:
dip=88 deg, dip direction=12 deg
cohesion=0 tonnes/m2, friction angle=26.5 deg

Joint Set 2 Data:
dip=69 deg, dip direction=220 deg
cohesion=0 tonnes/m2, friction angle=26.5 deg

Slope Data:
dip=70 deg, dip direction=330 deg
slope height=9.7 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=YES
water unit weight=0.5 tonnes/m3
Overhanging slope face=NO
Externally applied force=NO
Tension crack=NO

Upper Slope Data:
dip=18 deg, dip direction=330 deg

Seismic Data:
seismic coefficient=0.5
Direction=user defined
trend=330 deg, plunge=0 deg
magnitude=9.1027 tonnes

Swedge Analysis Information

Document Name:
ISFSIBackCutD2R.swd

Job Title:
ISFSIBackCutDet-31.8'

Analysis Results:
Analysis Type=DETERMINISTIC
Safety Factor=1.38843
Wedge Volume=8.02 m3
Wedge Weight=18.2054 tonnes
Wedge Area (Joint 1)=19.6323 m2
Wedge Area (Joint 2)=14.9651 m2
Wedge Area (Slope)=9.45875 m2
Wedge Area (Upper Slope)=2.95786 m2
Normal Force (Joint 1)=18.4174 tonnes
Normal Force (Joint 2)=21.8586 tonnes
Failure Mode:
Sliding on intersection line (joints 1&2)
Joint Sets 1&2 line of Intersection:
plunge=48.5227 deg, trend=284.264 deg

Joint Set 1 Data:
dip=88 deg, dip direction=12 deg
cohesion=0 tonnes/m2, friction angle=26.5 deg

Joint Set 2 Data:
dip=69 deg, dip direction=220 deg
cohesion=0 tonnes/m2, friction angle=26.5 deg

Slope Data:
dip=70 deg, dip direction=330 deg
slope height=9.7 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=YES
water unit weight=0.5 tonnes/m3
Overhanging slope face=NO
Externally applied force=NO
Tension crack=NO

Upper Slope Data:
dip=18 deg, dip direction=330 deg

Seismic Data:
seismic coefficient=0.5
Direction=user defined
trend=330 deg, plunge=0 deg
magnitude=9.1027 tonnes

Bolt Data:
Number of Bolts=1
Bolt #1
trend=150 deg, plunge=20 deg
length=2 meters, capacity=19 tonnes

Swedge Analysis Information

Document Name:
ISFSIBackCutD3R.swd

Job Title:
ISFSIBackCutDet-31.8'

Analysis Results:
Analysis Type=DETERMINISTIC
Safety Factor=0.619849
Wedge Volume=357.18 m3
Wedge Weight=810.799 tonnes
Wedge Area (Joint 1)=57.4702 m2
Wedge Area (Joint 2)=95.4164 m2
Wedge Area (Slope)=98.4874 m2
Wedge Area (Upper Slope)=90.1562 m2
Wedge Area (Tension Crack)=88.4611 m2
Normal Force (Joint 1)=-243.43 tonnes
Normal Force (Joint 2)=557.423 tonnes
Failure Mode:
Sliding on joint 2
Joint Sets 1&2 line of Intersection:
plunge=15.7912 deg, trend=282.566 deg

Joint Set 1 Data:
dip=88 deg, dip direction=12 deg
cohesion=0 tonnes/m2, friction angle=26.5 deg

Joint Set 2 Data:
dip=24 deg, dip direction=232 deg
cohesion=0 tonnes/m2, friction angle=30.5 deg

Slope Data:
dip=70 deg, dip direction=330 deg
slope height=9.7 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=YES
water unit weight=0.5 tonnes/m3
Overhanging slope face=NO
Externally applied force=NO
Tension crack=YES

Upper Slope Data:
dip=18 deg, dip direction=330 deg

Tension Crack Data:
dip=70 deg, dip direction=330 deg
trace length=7 meters

Seismic Data:
seismic coefficient=0.5
Direction=user defined
trend=330 deg, plunge=0 deg
magnitude=405.4 tonnes

Swedge Analysis Information

Document Name:
ISFSIBackCutD4R.swd

Job Title:
ISFSIBackCutDet-31.8'

Analysis Results:
Analysis Type=DETERMINISTIC
Safety Factor=1.30127
Wedge Volume=357.18 m3
Wedge Weight=810.799 tonnes
Wedge Area (Joint 1)=57.4702 m2
Wedge Area (Joint 2)=95.4164 m2
Wedge Area (Slope)=98.4874 m2
Wedge Area (Upper Slope)=90.1562 m2
Wedge Area (Tension Crack)=88.4611 m2
Normal Force (Joint 1)=61.7682 tonnes
Normal Force (Joint 2)=708.527 tonnes
Failure Mode:
Sliding on intersection line (joints 1&2)
Joint Sets 1&2 line of Intersection:
plunge=15.7912 deg, trend=282.566 deg

Joint Set 1 Data:
dip=88 deg, dip direction=12 deg
cohesion=0 tonnes/m2, friction angle=26.5 deg

Joint Set 2 Data:
dip=24 deg, dip direction=232 deg
cohesion=0 tonnes/m2, friction angle=30.5 deg

Slope Data:
dip=70 deg, dip direction=330 deg
slope height=9.7 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=YES
water unit weight=0.5 tonnes/m3
Overhanging slope face=NO
Externally applied force=NO
Tension crack=YES

Upper Slope Data:
dip=18 deg, dip direction=330 deg

Tension Crack Data:
dip=70 deg, dip direction=330 deg
trace length=7 meters

Seismic Data:
seismic coefficient=0.5
Direction=user defined
trend=330 deg, plunge=0 deg
magnitude=405.4 tonnes

Bolt Data:
Number of Bolts=1
Bolt #1
trend=150 deg, plunge=15 deg
length=4 meters, capacity=362 tonnes

Swedge Analysis Information

Document Name:
ISFSIBackCutD5R.swd

Job Title:
ISFSIBackCutDet-52.3'

Analysis Results:
Analysis Type=DETERMINISTIC
Safety Factor=0.633637
Wedge Volume=896.001 m3
Wedge Weight=2033.92 tonnes
Wedge Area (Joint 1)=146.115 m2
Wedge Area (Joint 2)=242.591 m2
Wedge Area (Slope)=246.225 m2
Wedge Area (Upper Slope)=107.128 m2
Wedge Area (Tension Crack)=125.994 m2
Normal Force (Joint 1)=-569.452 tonnes
Normal Force (Joint 2)=1378.53 tonnes
Failure Mode:
Sliding on joint 2
Joint Sets 1&2 line of Intersection:
plunge=15.7912 deg, trend=282.566 deg

Joint Set 1 Data:
dip=88 deg, dip direction=12 deg
cohesion=0 tonnes/m2, friction angle=26.5 deg

Joint Set 2 Data:
dip=24 deg, dip direction=232 deg
cohesion=0 tonnes/m2, friction angle=30.5 deg

Slope Data:
dip=47 deg, dip direction=330 deg
slope height=15.95 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=YES
water unit weight=0.5 tonnes/m3
Overhanging slope face=NO
Externally applied force=NO
Tension crack=YES

Upper Slope Data:
dip=18 deg, dip direction=330 deg

Tension Crack Data:
dip=70 deg, dip direction=330 deg
trace length=7 meters

Seismic Data:
seismic coefficient=0.5
Direction=user defined
trend=330 deg, plunge=0 deg
magnitude=1016.96 tonnes

Swedge Analysis Information

Document Name:
ISFSIBackCutD6R.swd

Job Title:
ISFSIBackCutDet-52.3'

Analysis Results:
Analysis Type=DETERMINISTIC
Safety Factor=1.30146
Wedge Volume=896.001 m3
Wedge Weight=2033.92 tonnes
Wedge Area (Joint 1)=146.115 m2
Wedge Area (Joint 2)=242.591 m2
Wedge Area (Slope)=246.225 m2
Wedge Area (Upper Slope)=107.128 m2
Wedge Area (Tension Crack)=125.994 m2
Normal Force (Joint 1)=151.388 tonnes
Normal Force (Joint 2)=1735.42 tonnes
Failure Mode:
Sliding on intersection line (joints 1&2)
Joint Sets 1&2 line of Intersection:
plunge=15.7912 deg, trend=282.566 deg

Joint Set 1 Data:
dip=88 deg, dip direction=12 deg
cohesion=0 tonnes/m2, friction angle=26.5 deg

Joint Set 2 Data:
dip=24 deg, dip direction=232 deg
cohesion=0 tonnes/m2, friction angle=30.5 deg

Slope Data:
dip=47 deg, dip direction=330 deg
slope height=15.95 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=YES
water unit weight=0.5 tonnes/m3
Overhanging slope face=NO
Externally applied force=NO
Tension crack=YES

Upper Slope Data:
dip=18 deg, dip direction=330 deg

Tension Crack Data:
dip=70 deg, dip direction=330 deg
trace length=7 meters

Seismic Data:
seismic coefficient=0.5
Direction=user defined
trend=330 deg, plunge=0 deg
magnitude=1016.96 tonnes

Bolt Data:
Number of Bolts=1
Bolt #1
trend=150 deg, plunge=15 deg
length=7 meters, capacity=855 tonnes

Swedge Analysis Information

Document Name:
ISFSIBackCutD7R.swd

Job Title:
ISFSIBackCut-20.5'

Analysis Results:
Analysis Type=DETERMINISTIC
Safety Factor=0.271783
Wedge Volume=2.0205 m3
Wedge Weight=4.58654 tonnes
Wedge Area (Joint 1)=7.20221 m2
Wedge Area (Joint 2)=5.49003 m2
Wedge Area (Slope)=3.9269 m2
Wedge Area (Upper Slope)=0.920788 m2
Wedge Area (Tension Crack)=0.378583 m2
Normal Force (Joint 1)=-0.528601 tonnes
Normal Force (Joint 2)=2.04834 tonnes
Failure Mode:
Sliding on joint 2
Joint Sets 1&2 line of Intersection:
plunge=48.5227 deg, trend=284.264 deg

Joint Set 1 Data:
dip=88 deg, dip direction=12 deg
cohesion=0 tonnes/m2, friction angle=26.5 deg

Joint Set 2 Data:
dip=69 deg, dip direction=220 deg
cohesion=0 tonnes/m2, friction angle=26.5 deg

Slope Data:
dip=70 deg, dip direction=330 deg
slope height=6.25 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=YES
water unit weight=0.5 tonnes/m3
Overhanging slope face=NO
Externally applied force=NO
Tension crack=YES

Upper Slope Data:
dip=18 deg, dip direction=330 deg

Tension Crack Data:
dip=90 deg, dip direction=330 deg
trace length=1.5 meters

Seismic Data:
seismic coefficient=0.5
Direction=user defined
trend=330 deg, plunge=0 deg
magnitude=2.29327 tonnes

Swedge Analysis Information

Document Name:
ISFSIBackCutD8R.swd

Job Title:
ISFSIBackCut-20.5'

Analysis Results:
Analysis Type=DETERMINISTIC
Safety Factor=1.67065
Wedge Volume=2.0205 m3
Wedge Weight=4.58654 tonnes
Wedge Area (Joint 1)=7.20221 m2
Wedge Area (Joint 2)=5.49003 m2
Wedge Area (Slope)=3.9269 m2
Wedge Area (Upper Slope)=0.920788 m2
Wedge Area (Tension Crack)=0.378583 m2
Normal Force (Joint 1)=6.09338 tonnes
Normal Force (Joint 2)=6.71079 tonnes
Failure Mode:
Sliding on intersection line (joints 1&2)
Joint Sets 1&2 line of Intersection:
plunge=48.5227 deg, trend=284.264 deg

Joint Set 1 Data:
dip=88 deg, dip direction=12 deg
cohesion=0 tonnes/m2, friction angle=26.5 deg

Joint Set 2 Data:
dip=69 deg, dip direction=220 deg
cohesion=0 tonnes/m2, friction angle=26.5 deg

Slope Data:
dip=70 deg, dip direction=330 deg
slope height=6.25 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=YES
water unit weight=0.5 tonnes/m3
Overhanging slope face=NO
Externally applied force=NO
Tension crack=YES

Upper Slope Data:
dip=18 deg, dip direction=330 deg

Tension Crack Data:
dip=90 deg, dip direction=330 deg
trace length=1.5 meters

Seismic Data:
seismic coefficient=0.5
Direction=user defined
trend=330 deg, plunge=0 deg
magnitude=2.29327 tonnes

Bolt Data:
Number of Bolts=1
Bolt #1
trend=150 deg, plunge=19.9998 deg
length=1.2 meters, capacity=4 tonnes

Swedge Analysis Information

Document Name:
ISFSIBackCutD9R.swd

Job Title:
ISFSIBackCutDet-20.5'

Analysis Results:
Analysis Type=DETERMINISTIC
Safety Factor=0.76218
Wedge Volume=119.442 m3
Wedge Weight=271.133 tonnes
Wedge Area (Joint 1)=36.1481 m2
Wedge Area (Joint 2)=60.0158 m2
Wedge Area (Slope)=40.8881 m2
Wedge Area (Upper Slope)=42.1042 m2
Wedge Area (Tension Crack)=14.9727 m2
Normal Force (Joint 1)=-50.239 tonnes
Normal Force (Joint 2)=211.947 tonnes
Failure Mode:
Sliding on joint 2
Joint Sets 1&2 line of Intersection:
plunge=15.7912 deg, trend=282.566 deg

Joint Set 1 Data:
dip=88 deg, dip direction=12 deg
cohesion=0 tonnes/m2, friction angle=26.5 deg

Joint Set 2 Data:
dip=24 deg, dip direction=232 deg
cohesion=0 tonnes/m2, friction angle=30.5 deg

Slope Data:
dip=70 deg, dip direction=330 deg
slope height=6.25 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=YES
water unit weight=0.5 tonnes/m3
Overhanging slope face=NO
Externally applied force=NO
Tension crack=YES

Upper Slope Data:
dip=0 deg, dip direction=330 deg

Tension Crack Data:
dip=90 deg, dip direction=330 deg
trace length=6.1 meters

Seismic Data:
seismic coefficient=0.5
Direction=user defined
trend=330 deg, plunge=0 deg
magnitude=135.566 tonnes

Swedge Analysis Information

Document Name:
ISFSIBackCutD10R.swd

Job Title:
ISFSIBackCutDet-20.5'

Analysis Results:
Analysis Type=DETERMINISTIC
Safety Factor=1.30886
Wedge Volume=119.442 m3
Wedge Weight=271.133 tonnes
Wedge Area (Joint 1)=36.1481 m2
Wedge Area (Joint 2)=60.0158 m2
Wedge Area (Slope)=40.8881 m2
Wedge Area (Upper Slope)=42.1042 m2
Wedge Area (Tension Crack)=14.9727 m2
Normal Force (Joint 1)=22.7405 tonnes
Normal Force (Joint 2)=254.641 tonnes
Failure Mode:
Sliding on intersection line (joints 1&2)
Joint Sets 1&2 line of Intersection:
plunge=15.7912 deg, trend=282.566 deg

Joint Set 1 Data:
dip=88 deg, dip direction=12 deg
cohesion=0 tonnes/m2, friction angle=26.5 deg

Joint Set 2 Data:
dip=24 deg, dip direction=232 deg
cohesion=0 tonnes/m2, friction angle=30.5 deg

Slope Data:
dip=70 deg, dip direction=330 deg
slope height=6.25 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=YES
water unit weight=0.5 tonnes/m3
Overhanging slope face=NO
Externally applied force=NO
Tension crack=YES

Upper Slope Data:
dip=0 deg, dip direction=330 deg

Tension Crack Data:
dip=90 deg, dip direction=330 deg
trace length=6.1 meters

Seismic Data:
seismic coefficient=0.5
Direction=user defined
trend=330 deg, plunge=0 deg
magnitude=135.566 tonnes

Bolt Data:
Number of Bolts=1
Bolt #1
trend=150 deg, plunge=20 deg
length=5 meters, capacity=86 tonnes

Swedge Analysis Information

Document Name:
ISFSIBackCutP1R.swd

Job Title:
ISFSIBackCut-31.8

Analysis Results:
Analysis Type=PROBABILISTIC
Probability of Failure=0.0361446
Number of Samples=1000
Number of Valid Wedges=996
Number of Failed Wedges=36
Number of Safe Wedges=960

Current Wedge Data (Mean Wedge):
Safety Factor=1.38685
Wedge Volume=8.02 m3
Wedge Weight=18.2054 tonnes
Wedge Area (Joint 1)=14.9651 m2
Wedge Area (Joint 2)=19.6323 m2
Wedge Area (Slope)=9.45875 m2
Wedge Area (Upper Slope)=2.95786 m2
Normal Force (Joint 1)=20.5958 tonnes
Normal Force (Joint 2)=17.3446 tonnes
Failure Mode:
Sliding on intersection line (joints 1&2)
Joint Sets 1&2 line of Intersection:
plunge=48.5227 deg, trend=284.264 deg

Joint Set 1 Data:
Dip (degrees):
dist=NORMAL,mean=69 ,sd=2
minimum=64,maximum=74
Dip Direction (degrees):
dist=NORMAL,mean=220 ,sd=2
minimum=210,maximum=230
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=26.5 ,sd=1
minimum=16,maximum=42

Joint Set 2 Data:
Dip (degrees):
dist=NORMAL,mean=88 ,sd=2
minimum=83,maximum=93
Dip Direction (degrees):
dist=NORMAL,mean=12 ,sd=2
minimum=2,maximum=22
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=26.5 ,sd=1
minimum=16,maximum=42

Slope Data:
Dip (degrees):
dist=NONE,dip=70
Dip Direction (degrees):
dist=NONE,dip direction=330
Other Data:
slope height=9.7 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=NO
Overhanging slope face=NO
Externally applied force=NO
Tension crack=NO

Upper Slope Data:
Dip (degrees):
dist=NONE,dip=18
Dip Direction (degrees):
dist=NONE,dip direction=330

Swedge Analysis Information

Document Name:
ISFSIBackCutP2R.swd

Job Title:
ISFSIBackCut-31.8'

Analysis Results:
Analysis Type=PROBABILISTIC
Probability of Failure=0.00723888
Number of Samples=1000
Number of Valid Wedges=967
Number of Failed Wedges=7
Number of Safe Wedges=960

Current Wedge Data (Mean Wedge):
Safety Factor=1.38685
Wedge Volume=5.02793 m3
Wedge Weight=11.4134 tonnes
Wedge Area (Joint 1)=7.20959 m2
Wedge Area (Joint 2)=9.45806 m2
Wedge Area (Slope)=9.45875 m2
Wedge Area (Upper Slope)=1.42498 m2
Wedge Area (Tension Crack)=4.9019 m2
Normal Force (Joint 1)=12.912 tonnes
Normal Force (Joint 2)=10.8737 tonnes
Failure Mode:
Sliding on intersection line (joints 1&2)
Joint Sets 1&2 line of Intersection:
plunge=48.5227 deg, trend=284.264 deg

Joint Set 1 Data:
Dip (degrees):
dist=NORMAL,mean=69 ,sd=2
minimum=64,maximum=74
Dip Direction (degrees):
dist=NORMAL,mean=220 ,sd=2
minimum=210,maximum=230
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=26.5 ,sd=1
minimum=16,maximum=42

Joint Set 2 Data:
Dip (degrees):
dist=NORMAL,mean=88 ,sd=2
minimum=83,maximum=93
Dip Direction (degrees):
dist=NORMAL,mean=12 ,sd=2
minimum=2,maximum=22
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):

dist=NORMAL,mean=26.5 ,sd=1
minimum=16,maximum=42

Slope Data:
Dip (degrees):
dist=NONE,dip=70
Dip Direction (degrees):
dist=NONE,dip direction=330
Other Data:
slope height=9.7 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=NO
Overhanging slope face=NO
Externally applied force=NO
Tension crack=YES

Upper Slope Data:
Dip (degrees):
dist=NONE,dip=18
Dip Direction (degrees):
dist=NONE,dip direction=330

Tension Crack Data:
Dip (degrees):
dist=NONE,dip=70
Dip Direction (degrees):
dist=NONE,dip direction=330
Trace Length:
trace length=1 meters

Swedge Analysis Information

Document Name:
ISFSIBackCutP3R.swd

Job Title:
ISFSIBackCut-31.8'

Analysis Results:
Analysis Type=PROBABILISTIC
Probability of Failure=0.971859
Number of Samples=1000
Number of Valid Wedges=995
Number of Failed Wedges=967
Number of Safe Wedges=28

Current Wedge Data (Mean Wedge):
Safety Factor=0.269839
Wedge Volume=8.02 m3
Wedge Weight=18.2054 tonnes
Wedge Area (Joint 1)=14.9651 m2
Wedge Area (Joint 2)=19.6323 m2
Wedge Area (Slope)=9.45875 m2
Wedge Area (Upper Slope)=2.95786 m2
Normal Force (Joint 1)=7.255 tonnes
Normal Force (Joint 2)=-0.156798 tonnes
Failure Mode:
Sliding on joint 1
Joint Sets 1&2 line of Intersection:
plunge=48.5227 deg, trend=284.264 deg

Joint Set 1 Data:
Dip (degrees):
dist=NORMAL,mean=69 ,sd=2
minimum=64,maximum=74
Dip Direction (degrees):
dist=NORMAL,mean=220 ,sd=2
minimum=210,maximum=230
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=26.5 ,sd=1
minimum=16,maximum=42

Joint Set 2 Data:
Dip (degrees):
dist=NORMAL,mean=88 ,sd=2
minimum=83,maximum=93
Dip Direction (degrees):
dist=NORMAL,mean=12 ,sd=2
minimum=2,maximum=22
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=26.5 ,sd=1

minimum=16,maximum=42

Slope Data:
Dip (degrees):
dist=NONE,dip=70
Dip Direction (degrees):
dist=NONE,dip direction=330
Other Data:
slope height=9.7 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=YES
water unit weight=0.5 tonnes/m3
Overhanging slope face=NO
Externally applied force=NO
Tension crack=NO

Upper Slope Data:
Dip (degrees):
dist=NONE,dip=18
Dip Direction (degrees):
dist=NONE,dip direction=330

Swedge Analysis Information

Document Name:
ISFSIBackCutP4R.swd

Job Title:
ISFSIBackCut-31.8'

Analysis Results:
Analysis Type=PROBABILISTIC
Probability of Failure=0.998998
Number of Samples=1000
Number of Valid Wedges=998
Number of Failed Wedges=997
Number of Safe Wedges=1

Current Wedge Data (Mean Wedge):
Safety Factor=0.489346
Wedge Volume=8.02 m3
Wedge Weight=18.2054 tonnes
Wedge Area (Joint 1)=14.9651 m2
Wedge Area (Joint 2)=19.6323 m2
Wedge Area (Slope)=9.45875 m2
Wedge Area (Upper Slope)=2.95786 m2
Normal Force (Joint 1)=13.0527 tonnes
Normal Force (Joint 2)=4.46446 tonnes
Failure Mode:
Sliding on intersection line (joints 1&2)
Joint Sets 1&2 line of Intersection:
plunge=48.5227 deg, trend=284.264 deg

Joint Set 1 Data:
Dip (degrees):
dist=NORMAL,mean=69 ,sd=2
minimum=64,maximum=74
Dip Direction (degrees):
dist=NORMAL,mean=220 ,sd=2
minimum=210,maximum=230
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=26.5 ,sd=1
minimum=16,maximum=42

Joint Set 2 Data:
Dip (degrees):
dist=NORMAL,mean=88 ,sd=2
minimum=83,maximum=93
Dip Direction (degrees):
dist=NORMAL,mean=12 ,sd=2
minimum=2,maximum=22
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=26.5 ,sd=1
minimum=16,maximum=42

Slope Data:
Dip (degrees):
dist=NONE,dip=70
Dip Direction (degrees):
dist=NONE,dip direction=330
Other Data:
slope height=9.7 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=NO
Overhanging slope face=NO
Externally applied force=NO
Tension crack=NO

Upper Slope Data:
Dip (degrees):
dist=NONE,dip=18
Dip Direction (degrees):
dist=NONE,dip direction=330

Seismic Data:
seismic coefficient=0.5
Direction=user defined
trend=330 deg, plunge=0 deg
magnitude=9.1027 tonnes

Swedge Analysis Information

Document Name:
ISFSIBackCutP5R.swd

Job Title:
ISFSIBackCut-31.8'

Analysis Results:
Analysis Type=PROBABILISTIC
Probability of Failure=1
Number of Samples=1000
Number of Valid Wedges=995
Number of Failed Wedges=995
Number of Safe Wedges=0

Current Wedge Data (Mean Wedge):
Safety Factor=0
Wedge Volume=8.02 m3
Wedge Weight=18.2054 tonnes
Wedge Area (Joint 1)=14.9651 m2
Wedge Area (Joint 2)=19.6323 m2
Wedge Area (Slope)=9.45875 m2
Wedge Area (Upper Slope)=2.95786 m2
Normal Force (Joint 1)=-0.288031 tonnes
Normal Force (Joint 2)=-13.0369 tonnes
Failure Mode:
Contact lost on both joints
Joint Sets 1&2 line of Intersection:
plunge=48.5227 deg, trend=284.264 deg

Joint Set 1 Data:
Dip (degrees):
dist=NORMAL,mean=69 ,sd=2
minimum=64,maximum=74
Dip Direction (degrees):
dist=NORMAL,mean=220 ,sd=2
minimum=210,maximum=230
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=26.5 ,sd=1
minimum=16,maximum=42

Joint Set 2 Data:
Dip (degrees):
dist=NORMAL,mean=88 ,sd=2
minimum=83,maximum=93
Dip Direction (degrees):
dist=NORMAL,mean=12 ,sd=2
minimum=2,maximum=22
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=26.5 ,sd=1
minimum=16,maximum=42

Slope Data:
Dip (degrees):
dist=NONE,dip=70
Dip Direction (degrees):
dist=NONE,dip direction=330
Other Data:
slope height=9.7 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=YES
water unit weight=0.5 tonnes/m3
Overhanging slope face=NO
Externally applied force=NO
Tension crack=NO

Upper Slope Data:
Dip (degrees):
dist=NONE,dip=18
Dip Direction (degrees):
dist=NONE,dip direction=330

Seismic Data:
seismic coefficient=0.5
Direction=user defined
trend=330 deg, plunge=0 deg
magnitude=9.1027 tonnes

Swedge Analysis Information

Document Name:
ISFSIBackCutP6R.swd

Job Title:
ISFSIBackCut-31.8'

Analysis Results:
Analysis Type=PROBABILISTIC
Probability of Failure=0
Number of Samples=1000
Number of Valid Wedges=976
Number of Failed Wedges=0
Number of Safe Wedges=976

Current Wedge Data (Mean Wedge):
Safety Factor=2.74472
Wedge Volume=2401.22 m3
Wedge Weight=5450.78 tonnes
Wedge Area (Joint 1)=564.524 m2
Wedge Area (Joint 2)=937.266 m2
Wedge Area (Slope)=98.4874 m2
Wedge Area (Upper Slope)=885.596 m2
Normal Force (Joint 1)=1716.11 tonnes
Normal Force (Joint 2)=5459.2 tonnes
Failure Mode:
Sliding on intersection line (joints 1&2)
Joint Sets 1&2 line of Intersection:
plunge=15.7912 deg, trend=282.566 deg

Joint Set 1 Data:
Dip (degrees):
dist=NORMAL,mean=88 ,sd=2
minimum=83,maximum=93
Dip Direction (degrees):
dist=NORMAL,mean=12 ,sd=2
minimum=2,maximum=22
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=26.5 ,sd=1
minimum=16,maximum=42

Joint Set 2 Data:
Dip (degrees):
dist=NORMAL,mean=24 ,sd=2
minimum=19,maximum=29
Dip Direction (degrees):
dist=NORMAL,mean=232 ,sd=2
minimum=222,maximum=242
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=30.5 ,sd=1
minimum=18.5,maximum=46

Slope Data:
Dip (degrees):
dist=NONE,dip=70
Dip Direction (degrees):
dist=NONE,dip direction=330
Other Data:
slope height=9.7 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=NO
Overhanging slope face=NO
Externally applied force=NO
Tension crack=NO

Upper Slope Data:
Dip (degrees):
dist=NONE,dip=18
Dip Direction (degrees):
dist=NONE,dip direction=330

Swedge Analysis Information

Document Name:
ISFSIBackCutP7R.swd

Job Title:
ISFSIBackCut-31.8'

Analysis Results:
Analysis Type=PROBABILISTIC
Probability of Failure=0
Number of Samples=1000
Number of Valid Wedges=972
Number of Failed Wedges=0
Number of Safe Wedges=972

Current Wedge Data (Mean Wedge):
Safety Factor=2.74472
Wedge Volume=183.381 m3
Wedge Weight=416.276 tonnes
Wedge Area (Joint 1)=29.1207 m2
Wedge Area (Joint 2)=48.3483 m2
Wedge Area (Slope)=98.4874 m2
Wedge Area (Upper Slope)=45.683 m2
Wedge Area (Tension Crack)=93.407 m2
Normal Force (Joint 1)=131.059 tonnes
Normal Force (Joint 2)=416.919 tonnes
Failure Mode:
Sliding on intersection line (joints 1&2)
Joint Sets 1&2 line of Intersection:
plunge=15.7912 deg, trend=282.566 deg

Joint Set 1 Data:
Dip (degrees):
dist=NORMAL,mean=88 ,sd=2
minimum=83,maximum=93
Dip Direction (degrees):
dist=NORMAL,mean=12 ,sd=2
minimum=2,maximum=22
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=26.5 ,sd=1
minimum=16,maximum=42

Joint Set 2 Data:
Dip (degrees):
dist=NORMAL,mean=24 ,sd=2
minimum=19,maximum=29
Dip Direction (degrees):
dist=NORMAL,mean=232 ,sd=2
minimum=222,maximum=242
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=30.5 ,sd=1

minimum=18.5,maximum=46

Slope Data:
Dip (degrees):
dist=NONE,dip=70
Dip Direction (degrees):
dist=NONE,dip direction=330
Other Data:
slope height=9.7 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=NO
Overhanging slope face=NO
Externally applied force=NO
Tension crack=YES

Upper Slope Data:
Dip (degrees):
dist=NONE,dip=18
Dip Direction (degrees):
dist=NONE,dip direction=330

Tension Crack Data:
Dip (degrees):
dist=NONE,dip=70
Dip Direction (degrees):
dist=NONE,dip direction=330
Trace Length:
trace length=3.5 meters

Swedge Analysis Information

Document Name:
ISFSIBackCutP8R.swd

Job Title:
ISFSIBackCut-31.8'

Analysis Results:
Analysis Type=PROBABILISTIC
Probability of Failure=0
Number of Samples=1000
Number of Valid Wedges=976
Number of Failed Wedges=0
Number of Safe Wedges=976

Current Wedge Data (Mean Wedge):
Safety Factor=2.74472
Wedge Volume=357.18 m3
Wedge Weight=810.799 tonnes
Wedge Area (Joint 1)=57.4702 m2
Wedge Area (Joint 2)=95.4164 m2
Wedge Area (Slope)=98.4874 m2
Wedge Area (Upper Slope)=90.1562 m2
Wedge Area (Tension Crack)=88.4611 m2
Normal Force (Joint 1)=255.27 tonnes
Normal Force (Joint 2)=812.051 tonnes
Failure Mode:
Sliding on intersection line (joints 1&2)
Joint Sets 1&2 line of Intersection:
plunge=15.7912 deg, trend=282.566 deg

Joint Set 1 Data:
Dip (degrees):
dist=NORMAL,mean=88 ,sd=2
minimum=83,maximum=93
Dip Direction (degrees):
dist=NORMAL,mean=12 ,sd=2
minimum=2,maximum=22
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=26.5 ,sd=1
minimum=16,maximum=42

Joint Set 2 Data:
Dip (degrees):
dist=NORMAL,mean=24 ,sd=2
minimum=19,maximum=29
Dip Direction (degrees):
dist=NORMAL,mean=232 ,sd=2
minimum=222,maximum=242
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=30.5 ,sd=1

minimum=18.5,maximum=46

Slope Data:
Dip (degrees):
dist=NONE,dip=70
Dip Direction (degrees):
dist=NONE,dip direction=330
Other Data:
slope height=9.7 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=NO
Overhanging slope face=NO
Externally applied force=NO
Tension crack=YES

Upper Slope Data:
Dip (degrees):
dist=NONE,dip=18
Dip Direction (degrees):
dist=NONE,dip direction=330

Tension Crack Data:
Dip (degrees):
dist=NONE,dip=70
Dip Direction (degrees):
dist=NONE,dip direction=330
Trace Length:
trace length=7 meters

Swedge Analysis Information

Document Name:
ISFSIBackCutP9R.swd

Job Title:
ISFSIBackCut-31.8'

Analysis Results:
Analysis Type=PROBABILISTIC
Probability of Failure=0
Number of Samples=1000
Number of Valid Wedges=971
Number of Failed Wedges=0
Number of Safe Wedges=971

Current Wedge Data (Mean Wedge):
Safety Factor=1.43464
Wedge Volume=357.18 m3
Wedge Weight=810.799 tonnes
Wedge Area (Joint 1)=57.4702 m2
Wedge Area (Joint 2)=95.4164 m2
Wedge Area (Slope)=98.4874 m2
Wedge Area (Upper Slope)=90.1562 m2
Wedge Area (Tension Crack)=88.4611 m2
Normal Force (Joint 1)=76.2146 tonnes
Normal Force (Joint 2)=623.817 tonnes
Failure Mode:
Sliding on intersection line (joints 1&2)
Joint Sets 1&2 line of Intersection:
plunge=15.7912 deg, trend=282.566 deg

Joint Set 1 Data:
Dip (degrees):
dist=NORMAL,mean=88 ,sd=2
minimum=83,maximum=93
Dip Direction (degrees):
dist=NORMAL,mean=12 ,sd=2
minimum=2,maximum=22
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=26.5 ,sd=1
minimum=16,maximum=42

Joint Set 2 Data:
Dip (degrees):
dist=NORMAL,mean=24 ,sd=2
minimum=19,maximum=29
Dip Direction (degrees):
dist=NORMAL,mean=232 ,sd=2
minimum=222,maximum=242
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=30.5 ,sd=1

minimum=18.5,maximum=46

Slope Data:
Dip (degrees):
dist=NONE,dip=70
Dip Direction (degrees):
dist=NONE,dip direction=330
Other Data:
slope height=9.7 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=YES
water unit weight=0.5 tonnes/m3
Overhanging slope face=NO
Externally applied force=NO
Tension crack=YES

Upper Slope Data:
Dip (degrees):
dist=NONE,dip=18
Dip Direction (degrees):
dist=NONE,dip direction=330

Tension Crack Data:
Dip (degrees):
dist=NONE,dip=70
Dip Direction (degrees):
dist=NONE,dip direction=330
Trace Length:
trace length=7 meters

Swedge Analysis Information

Document Name:
ISFSIBackCutP10R.swd

Job Title:
ISFSIBackCut-31.8'

Analysis Results:
Analysis Type=PROBABILISTIC
Probability of Failure=0.90102
Number of Samples=1000
Number of Valid Wedges=980
Number of Failed Wedges=883
Number of Safe Wedges=97

Current Wedge Data (Mean Wedge):
Safety Factor=0.920924
Wedge Volume=357.18 m3
Wedge Weight=810.799 tonnes
Wedge Area (Joint 1)=57.4702 m2
Wedge Area (Joint 2)=95.4164 m2
Wedge Area (Slope)=98.4874 m2
Wedge Area (Upper Slope)=90.1562 m2
Wedge Area (Tension Crack)=88.4611 m2
Normal Force (Joint 1)=-64.3748 tonnes
Normal Force (Joint 2)=745.657 tonnes
Failure Mode:
Sliding on joint 2
Joint Sets 1&2 line of Intersection:
plunge=15.7912 deg, trend=282.566 deg

Joint Set 1 Data:
Dip (degrees):
dist=NORMAL,mean=88 ,sd=2
minimum=83,maximum=93
Dip Direction (degrees):
dist=NORMAL,mean=12 ,sd=2
minimum=2,maximum=22
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=26.5 ,sd=1
minimum=16,maximum=42

Joint Set 2 Data:
Dip (degrees):
dist=NORMAL,mean=24 ,sd=2
minimum=19,maximum=29
Dip Direction (degrees):
dist=NORMAL,mean=232 ,sd=2
minimum=222,maximum=242
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=30.5 ,sd=1

minimum=18.5,maximum=46

Slope Data:
Dip (degrees):
dist=NONE,dip=70
Dip Direction (degrees):
dist=NONE,dip direction=330
Other Data:
slope height=9.7 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=NO
Overhanging slope face=NO
Externally applied force=NO
Tension crack=YES

Upper Slope Data:
Dip (degrees):
dist=NONE,dip=18
Dip Direction (degrees):
dist=NONE,dip direction=330

Tension Crack Data:
Dip (degrees):
dist=NONE,dip=70
Dip Direction (degrees):
dist=NONE,dip direction=330
Trace Length:
trace length=7 meters

Seismic Data:
seismic coefficient=0.5
Direction=user defined
trend=330 deg, plunge=0 deg
magnitude=405.4 tonnes

Swedge Analysis Information

Document Name:
ISFSIBackCutP11R-R

Job Title:
ISFSIBackCut-31.8'

Analysis Results:
Analysis Type=PROBABILISTIC
Probability of Failure=1
Number of Samples=1000
Number of Valid Wedges=972
Number of Failed Wedges=972
Number of Safe Wedges=0

Current Wedge Data (Mean Wedge):
Safety Factor=0 .619849
Wedge Volume=357.18 m3
Wedge Weight=810.799 tonnes
Wedge Area (Joint 1)=57.4702 m2
Wedge Area (Joint 2)=95.4164 m2
Wedge Area (Slope)=98.4874 m2
Wedge Area (Upper Slope)=90.1562 m2
Wedge Area (Tension Crack)=88.4611 m2
Normal Force (Joint 1)=243.43 tonnes
Normal Force (Joint 2)=557.423 tonnes
Failure Mode:
Sliding up intersection line (joints 1&2)
Joint Sets 1&2 line of Intersection:
plunge=15.7912 deg, trend=282.566 deg

Joint Set 1 Data:
Dip (degrees):
dist=NORMAL,mean=88 ,sd=2
minimum=83,maximum=93
Dip Direction (degrees):
dist=NORMAL,mean=12 ,sd=2
minimum=2,maximum=22
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=26.5 ,sd=1
minimum=16,maximum=42

Joint Set 2 Data:
Dip (degrees):
dist=NORMAL,mean=24 ,sd=2
minimum=19,maximum=29
Dip Direction (degrees):
dist=NORMAL,mean=232 ,sd=2
minimum=222,maximum=242
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=30.5 ,sd=1

minimum=18.5,maximum=46

Slope Data:
Dip (degrees):
dist=NONE,dip=70
Dip Direction (degrees):
dist=NONE,dip direction=330
Other Data:
slope height=9.7 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=YES
water unit weight=0.5 tonnes/m3
Overhanging slope face=NO
Externally applied force=NO
Tension crack=YES

Upper Slope Data:
Dip (degrees):
dist=NONE,dip=18
Dip Direction (degrees):
dist=NONE,dip direction=330

Tension Crack Data:
Dip (degrees):
dist=NONE,dip=70
Dip Direction (degrees):
dist=NONE,dip direction=330
Trace Length:
trace length=7 meters

Seismic Data:
seismic coefficient=0.5
Direction=user defined
trend=330 deg, plunge=0 deg
magnitude=405.4 tonnes

Swedge Analysis Information

Document Name:
ISFSIBackCutP12R.swd

Job Title:
ISFSIBackCut-31.8'

Analysis Results:
Analysis Type=PROBABILISTIC
Probability of Failure=1
Number of Samples=1000
Number of Valid Wedges=978
Number of Failed Wedges=978
Number of Safe Wedges=0

Current Wedge Data (Mean Wedge):
Safety Factor=0.425058
Wedge Volume=2.17317 m3
Wedge Weight=4.93309 tonnes
Wedge Area (Joint 1)=7.24606 m2
Wedge Area (Joint 2)=5.19351 m2
Wedge Area (Slope)=7.18478 m2
Wedge Area (Upper Slope)=0.801487 m2
Normal Force (Joint 1)=1.74274 tonnes
Normal Force (Joint 2)=1.74274 tonnes
Failure Mode:
Sliding on intersection line (joints 1&2)
Joint Sets 1&2 line of Intersection:
plunge=64.6826 deg, trend=316.5 deg

Joint Set 1 Data:
Dip (degrees):
dist=NORMAL,mean=75 ,sd=2
minimum=70,maximum=80
Dip Direction (degrees):
dist=NORMAL,mean=12 ,sd=2
minimum=2,maximum=22
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=26.5 ,sd=1
minimum=16,maximum=42

Joint Set 2 Data:
Dip (degrees):
dist=NORMAL,mean=75 ,sd=2
minimum=70,maximum=80
Dip Direction (degrees):
dist=NORMAL,mean=261 ,sd=2
minimum=251,maximum=271
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=30.5 ,sd=1

minimum=18.5,maximum=46

Slope Data:
Dip (degrees):
dist=NONE,dip=70
Dip Direction (degrees):
dist=NONE,dip direction=330
Other Data:
slope height=9.7 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=NO
Overhanging slope face=NO
Externally applied force=NO
Tension crack=NO

Upper Slope Data:
Dip (degrees):
dist=NONE,dip=18
Dip Direction (degrees):
dist=NONE,dip direction=330

Swedge Analysis Information

Document Name:
ISFSIBackCutP13R.swd

Job Title:
ISFSIBackCut-31.8'

Analysis Results:
Analysis Type=PROBABILISTIC
Probability of Failure=1
Number of Samples=1000
Number of Valid Wedges=981
Number of Failed Wedges=981
Number of Safe Wedges=0

Current Wedge Data (Mean Wedge):
Safety Factor=0
Wedge Volume=2.17317 m3
Wedge Weight=4.93309 tonnes
Wedge Area (Joint 1)=7.24606 m2
Wedge Area (Joint 2)=5.19351 m2
Wedge Area (Slope)=7.18478 m2
Wedge Area (Upper Slope)=0.801487 m2
Normal Force (Joint 1)=-6.48209 tonnes
Normal Force (Joint 2)=-4.03875 tonnes
Failure Mode:
Contact lost on both joints
Joint Sets 1&2 line of Intersection:
plunge=64.6826 deg, trend=316.5 deg

Joint Set 1 Data:
Dip (degrees):
dist=NORMAL,mean=75 ,sd=2
minimum=70,maximum=80
Dip Direction (degrees):
dist=NORMAL,mean=12 ,sd=2
minimum=2,maximum=22
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=26.5 ,sd=1
minimum=16,maximum=42

Joint Set 2 Data:
Dip (degrees):
dist=NORMAL,mean=75 ,sd=2
minimum=70,maximum=80
Dip Direction (degrees):
dist=NORMAL,mean=261 ,sd=2
minimum=251,maximum=271
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=30.5 ,sd=1

minimum=18.5,maximum=46

Slope Data:
Dip (degrees):
dist=NONE,dip=70
Dip Direction (degrees):
dist=NONE,dip direction=330
Other Data:
slope height=9.7 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=YES
water unit weight=0.5 tonnes/m3
Overhanging slope face=NO
Externally applied force=NO
Tension crack=NO

Upper Slope Data:
Dip (degrees):
dist=NONE,dip=18
Dip Direction (degrees):
dist=NONE,dip direction=330

Seismic Data:
seismic coefficient=0.5
Direction=user defined
trend=330 deg, plunge=0 deg
magnitude=2.46654 tonnes

Swedge Analysis Information

Document Name:
ISFSIBackCutP14R.swd

Job Title:
ISFSIBackCut-52.3'

Analysis Results:
Analysis Type=PROBABILISTIC
Probability of Failure=0
Number of Samples=1000
Number of Valid Wedges=974
Number of Failed Wedges=0
Number of Safe Wedges=974

Current Wedge Data (Mean Wedge):
Safety Factor=2.74472
Wedge Volume=4370.47 m3
Wedge Weight=9920.96 tonnes
Wedge Area (Joint 1)=868.308 m2
Wedge Area (Joint 2)=1441.63 m2
Wedge Area (Slope)=246.225 m2
Wedge Area (Upper Slope)=1240.07 m2
Normal Force (Joint 1)=3123.49 tonnes
Normal Force (Joint 2)=9936.29 tonnes
Failure Mode:
Sliding on intersection line (joints 1&2)
Joint Sets 1&2 line of Intersection:
plunge=15.7912 deg, trend=282.566 deg

Joint Set 1 Data:
Dip (degrees):
dist=NORMAL,mean=88 ,sd=2
minimum=83,maximum=93
Dip Direction (degrees):
dist=NORMAL,mean=12 ,sd=2
minimum=2,maximum=22
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=26.5 ,sd=1
minimum=16,maximum=42

Joint Set 2 Data:
Dip (degrees):
dist=NORMAL,mean=24 ,sd=2
minimum=19,maximum=29
Dip Direction (degrees):
dist=NORMAL,mean=232 ,sd=2
minimum=222,maximum=242
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=30.5 ,sd=1
minimum=18.5,maximum=46

Slope Data:
Dip (degrees):
dist=NONE,dip=47
Dip Direction (degrees):

dist=NONE,dip direction=330
Other Data:
slope height=15.95 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=NO
Overhanging slope face=NO
Externally applied force=NO
Tension crack=NO

Upper Slope Data:
Dip (degrees):
dist=NONE,dip=18
Dip Direction (degrees):
dist=NONE,dip direction=330

Swedge Analysis Information

Document Name:
ISFSIBackCutP15R.swd

Job Title:
ISFSIBackCut-52.3'

Analysis Results:
Analysis Type=PROBABILISTIC
Probability of Failure=0
Number of Samples=1000
Number of Valid Wedges=969
Number of Failed Wedges=0
Number of Safe Wedges=969

Current Wedge Data (Mean Wedge):
Safety Factor=2.74472
Wedge Volume=649.556 m3
Wedge Weight=1474.49 tonnes
Wedge Area (Joint 1)=112.356 m2
Wedge Area (Joint 2)=186.542 m2
Wedge Area (Slope)=246.225 m2
Wedge Area (Upper Slope)=54.1687 m2
Wedge Area (Tension Crack)=131.884 m2
Normal Force (Joint 1)=464.225 tonnes
Normal Force (Joint 2)=1476.77 tonnes
Failure Mode:
Sliding on intersection line (joints 1&2)
Joint Sets 1&2 line of Intersection:
plunge=15.7912 deg, trend=282.566 deg

Joint Set 1 Data:
Dip (degrees):
dist=NORMAL,mean=88 ,sd=2
minimum=83,maximum=93
Dip Direction (degrees):
dist=NORMAL,mean=12 ,sd=2
minimum=2,maximum=22
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=26.5 ,sd=1
minimum=16,maximum=42

Joint Set 2 Data:
Dip (degrees):
dist=NORMAL,mean=24 ,sd=2
minimum=19,maximum=29
Dip Direction (degrees):
dist=NORMAL,mean=232 ,sd=2
minimum=222,maximum=242
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):

dist=NORMAL,mean=30.5 ,sd=1
minimum=18.5,maximum=46

Slope Data:
Dip (degrees):
dist=NONE,dip=47
Dip Direction (degrees):
dist=NONE,dip direction=330
Other Data:
slope height=15.95 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=NO
Overhanging slope face=NO
Externally applied force=NO
Tension crack=YES

Upper Slope Data:
Dip (degrees):
dist=NONE,dip=18
Dip Direction (degrees):
dist=NONE,dip direction=330

Tension Crack Data:
Dip (degrees):
dist=NONE,dip=70
Dip Direction (degrees):
dist=NONE,dip direction=330
Trace Length:
trace length=3.5 meters

Swedge Analysis Information

Document Name:
ISFSIBackCutP16R.swd

Job Title:
ISFSIBackCut-52.3'

Analysis Results:
Analysis Type=PROBABILISTIC
Probability of Failure=0
Number of Samples=1000
Number of Valid Wedges=972
Number of Failed Wedges=0
Number of Safe Wedges=972

Current Wedge Data (Mean Wedge):
Safety Factor=2.74472
Wedge Volume=896.001 m3
Wedge Weight=2033.92 tonnes
Wedge Area (Joint 1)=146.115 m2
Wedge Area (Joint 2)=242.591 m2
Wedge Area (Slope)=246.225 m2
Wedge Area (Upper Slope)=107.128 m2
Wedge Area (Tension Crack)=125.994 m2
Normal Force (Joint 1)=640.355 tonnes
Normal Force (Joint 2)=2037.06 tonnes
Failure Mode:
Sliding on intersection line (joints 1&2)
Joint Sets 1&2 line of Intersection:
plunge=15.7912 deg, trend=282.566 deg

Joint Set 1 Data:
Dip (degrees):
dist=NORMAL,mean=88 ,sd=2
minimum=83,maximum=93
Dip Direction (degrees):
dist=NORMAL,mean=12 ,sd=2
minimum=2,maximum=22
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=26.5 ,sd=1
minimum=16,maximum=42

Joint Set 2 Data:
Dip (degrees):
dist=NORMAL,mean=24 ,sd=2
minimum=19,maximum=29
Dip Direction (degrees):
dist=NORMAL,mean=232 ,sd=2
minimum=222,maximum=242
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):

dist=NORMAL,mean=30.5 ,sd=1
minimum=18.5,maximum=46

Slope Data:
Dip (degrees):
dist=NONE,dip=47
Dip Direction (degrees):
dist=NONE,dip direction=330
Other Data:
slope height=15.95 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=NO
Overhanging slope face=NO
Externally applied force=NO
Tension crack=YES

Upper Slope Data:
Dip (degrees):
dist=NONE,dip=18
Dip Direction (degrees):
dist=NONE,dip direction=330

Tension Crack Data:
Dip (degrees):
dist=NONE,dip=70
Dip Direction (degrees):
dist=NONE,dip direction=330
Trace Length:
trace length=7 meters

Swedge Analysis Information

Document Name:
ISFSIBackCutP17R.swd

Job Title:
ISFSIBackCut-52.3'

Analysis Results:
Analysis Type=PROBABILISTIC
Probability of Failure=1
Number of Samples=1000
Number of Valid Wedges=974
Number of Failed Wedges=974
Number of Safe Wedges=0

Current Wedge Data (Mean Wedge):
Safety Factor=0.633637
Wedge Volume=896.001 m3
Wedge Weight=2033.92 tonnes
Wedge Area (Joint 1)=146.115 m2
Wedge Area (Joint 2)=242.591 m2
Wedge Area (Slope)=246.225 m2
Wedge Area (Upper Slope)=107.128 m2
Wedge Area (Tension Crack)=125.994 m2
Normal Force (Joint 1)=-569.452 tonnes
Normal Force (Joint 2)=1378.53 tonnes
Failure Mode:
Sliding on joint 2
Joint Sets 1&2 line of Intersection:
plunge=15.7912 deg, trend=282.566 deg

Joint Set 1 Data:
Dip (degrees):
dist=NORMAL,mean=88 ,sd=2
minimum=83,maximum=93
Dip Direction (degrees):
dist=NORMAL,mean=12 ,sd=2
minimum=2,maximum=22
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=26.5 ,sd=1
minimum=16,maximum=42

Joint Set 2 Data:
Dip (degrees):
dist=NORMAL,mean=24 ,sd=2
minimum=19,maximum=29
Dip Direction (degrees):
dist=NORMAL,mean=232 ,sd=2
minimum=222,maximum=242
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):

dist=NORMAL,mean=30.5 ,sd=1
minimum=18.5,maximum=46

Slope Data:
Dip (degrees):
dist=NONE,dip=47
Dip Direction (degrees):
dist=NONE,dip direction=330
Other Data:
slope height=15.95 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=YES
water unit weight=0.5 tonnes/m3
Overhanging slope face=NO
Externally applied force=NO
Tension crack=YES

Upper Slope Data:
Dip (degrees):
dist=NONE,dip=18
Dip Direction (degrees):
dist=NONE,dip direction=330

Tension Crack Data:
Dip (degrees):
dist=NONE,dip=70
Dip Direction (degrees):
dist=NONE,dip direction=330
Trace Length:
trace length=7 meters

Seismic Data:
seismic coefficient=0.5
Direction=user defined
trend=330 deg, plunge=0 deg
magnitude=1016.96 tonnes

Swedge Analysis Information

Document Name:
ISFSIBackCutP18R.swd

Job Title:
ISFSIBackCut-20.5'

Analysis Results:
Analysis Type=PROBABILISTIC
Probability of Failure=1
Number of Samples=1000
Number of Valid Wedges=628
Number of Failed Wedges=628
Number of Safe Wedges=0

Current Wedge Data (Mean Wedge):
Safety Factor=0.419715
Wedge Volume=1.94428 m3
Wedge Weight=4.41352 tonnes
Wedge Area (Joint 1)=5.60628 m2
Wedge Area (Joint 2)=7.35472 m2
Wedge Area (Slope)=3.9269 m2
Wedge Area (Upper Slope)=0.922707 m2
Wedge Area (Tension Crack)=0.0178949 m2
Normal Force (Joint 1)=2.90324 tonnes
Normal Force (Joint 2)=0.739483 tonnes
Failure Mode:
Sliding on intersection line (joints 1&2)
Joint Sets 1&2 line of Intersection:
plunge=48.5227 deg, trend=284.264 deg

Joint Set 1 Data:
Dip (degrees):
dist=NORMAL,mean=69 ,sd=2
minimum=64,maximum=74
Dip Direction (degrees):
dist=NORMAL,mean=220 ,sd=2
minimum=210,maximum=230
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=26.5 ,sd=1
minimum=16,maximum=42

Joint Set 2 Data:
Dip (degrees):
dist=NORMAL,mean=88 ,sd=2
minimum=83,maximum=93
Dip Direction (degrees):
dist=NORMAL,mean=12 ,sd=2
minimum=2,maximum=22
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):

dist=NORMAL,mean=26.5 ,sd=1
minimum=16,maximum=42

Slope Data:
Dip (degrees):
dist=NONE,dip=70
Dip Direction (degrees):
dist=NONE,dip direction=330
Other Data:
slope height=6.25 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=YES
water unit weight=0.5 tonnes/m3
Overhanging slope face=NO
Externally applied force=NO
Tension crack=YES

Upper Slope Data:
Dip (degrees):
dist=NONE,dip=0
Dip Direction (degrees):
dist=NONE,dip direction=330

Tension Crack Data:
Dip (degrees):
dist=NONE,dip=90
Dip Direction (degrees):
dist=NONE,dip direction=330
Trace Length:
trace length=1.5 meters

Seismic Data:
seismic coefficient=0.5
Direction=user defined
trend=330 deg, plunge=0 deg
magnitude=2.20676 tonnes

Swedge Analysis Information

Document Name:
ISFSIBackCutP19R.swd

Job Title:
ISFSIBackCut-20.5'

Analysis Results:
Analysis Type=PROBABILISTIC
Probability of Failure=1
Number of Samples=1000
Number of Valid Wedges=1000
Number of Failed Wedges=1000
Number of Safe Wedges=0

Current Wedge Data (Mean Wedge):
Safety Factor=0.71425
Wedge Volume=350.751 m3
Wedge Weight=796.205 tonnes
Wedge Area (Joint 1)=66.6979 m2
Wedge Area (Joint 2)=110.737 m2
Wedge Area (Slope)=98.4874 m2
Wedge Area (Upper Slope)=69.8063 m2
Wedge Area (Tension Crack)=49.2803 m2
Normal Force (Joint 1)=-177.874 tonnes
Normal Force (Joint 2)=603.181 tonnes
Failure Mode:
Sliding on joint 2
Joint Sets 1&2 line of Intersection:
plunge=15.7912 deg, trend=282.566 deg

Joint Set 1 Data:
Dip (degrees):
dist=NORMAL,mean=88 ,sd=2
minimum=83,maximum=93
Dip Direction (degrees):
dist=NORMAL,mean=12 ,sd=2
minimum=2,maximum=22
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=26.5 ,sd=1
minimum=16,maximum=42

Joint Set 2 Data:
Dip (degrees):
dist=NORMAL,mean=24 ,sd=2
minimum=19,maximum=29
Dip Direction (degrees):
dist=NORMAL,mean=232 ,sd=2
minimum=222,maximum=242
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):

dist=NORMAL,mean=30.5 ,sd=1
minimum=18.5,maximum=46

Slope Data:
Dip (degrees):
dist=NONE,dip=70
Dip Direction (degrees):
dist=NONE,dip direction=330
Other Data:
slope height=9.7 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=YES
water unit weight=0.5 tonnes/m3
Overhanging slope face=NO
Externally applied force=NO
Tension crack=YES

Upper Slope Data:
Dip (degrees):
dist=NONE,dip=0
Dip Direction (degrees):
dist=NONE,dip direction=330

Tension Crack Data:
Dip (degrees):
dist=NONE,dip=90
Dip Direction (degrees):
dist=NONE,dip direction=330
Trace Length:
trace length=6.1 meters

Seismic Data:
seismic coefficient=0.5
Direction=user defined
trend=330 deg, plunge=0 deg
magnitude=398.102 tonnes

Swedge Analysis Information

Document Name:
ISFSIEastCutD1.swd

Job Title:
ISFSIEastCut-7.1m

Analysis Results:
Analysis Type=DETERMINISTIC
Safety Factor=1.08118
Wedge Volume=6.77124 m3
Wedge Weight=15.3707 tonnes
Wedge Area (Joint 1)=2.42994 m2
Wedge Area (Joint 2)=43.7495 m2
Wedge Area (Slope)=41.3049 m2
Wedge Area (Upper Slope)=3.73798 m2
Normal Force (Joint 1)=8.35255 tonnes
Normal Force (Joint 2)=9.91112 tonnes
Failure Mode:
Sliding on intersection line (joints 1&2)
Joint Sets 1&2 line of Intersection:
plunge=51.7423 deg, trend=296.432 deg

Joint Set 1 Data:
dip=76 deg, dip direction=8 deg
cohesion=0 tonnes/m2, friction angle=35 deg

Joint Set 2 Data:
dip=67 deg, dip direction=239 deg
cohesion=0 tonnes/m2, friction angle=36 deg

Slope Data:
dip=70 deg, dip direction=240 deg
slope height=7.1 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=NO
Overhanging slope face=NO
Externally applied force=NO
Tension crack=NO

Upper Slope Data:
dip=18 deg, dip direction=330 deg

Swedge Analysis Information

Document Name:
ISFSIEastCutD2.swd

Job Title:
ISFSIEastCut-7.1m

Analysis Results:
Analysis Type=DETERMINISTIC
Safety Factor=0.538306
Wedge Volume=6.77124 m3
Wedge Weight=15.3707 tonnes
Wedge Area (Joint 1)=2.42994 m2
Wedge Area (Joint 2)=43.7495 m2
Wedge Area (Slope)=41.3049 m2
Wedge Area (Upper Slope)=3.73798 m2
Normal Force (Joint 1)=8.52442 tonnes
Normal Force (Joint 2)=-22.881 tonnes
Failure Mode:
Sliding on joint 1
Joint Sets 1&2 line of Intersection:
plunge=51.7423 deg, trend=296.432 deg

Joint Set 1 Data:
dip=76 deg, dip direction=8 deg
cohesion=0 tonnes/m2, friction angle=35 deg

Joint Set 2 Data:
dip=67 deg, dip direction=239 deg
cohesion=0 tonnes/m2, friction angle=36 deg

Slope Data:
dip=70 deg, dip direction=240 deg
slope height=7.1 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=YES
water unit weight=0.5 tonnes/m3
Overhanging slope face=NO
Externally applied force=NO
Tension crack=NO

Upper Slope Data:
dip=18 deg, dip direction=330 deg

Seismic Data:
seismic coefficient=0.5
Direction=user defined
trend=240 deg, plunge=0 deg
magnitude=7.68536 tonnes

Swedge Analysis Information

Document Name:
ISFSIEastCutD3.swd

Job Title:
ISFSIEastCut-7.1m

Analysis Results:
Analysis Type=DETERMINISTIC
Safety Factor=1.34484
Wedge Volume=6.77124 m3
Wedge Weight=15.3707 tonnes
Wedge Area (Joint 1)=2.42994 m2
Wedge Area (Joint 2)=43.7495 m2
Wedge Area (Slope)=41.3049 m2
Wedge Area (Upper Slope)=3.73798 m2
Normal Force (Joint 1)=6.08729 tonnes
Normal Force (Joint 2)=12.6144 tonnes
Failure Mode:
Sliding on intersection line (joints 1&2)
Joint Sets 1&2 line of Intersection:
plunge=51.7423 deg, trend=296.432 deg

Joint Set 1 Data:
dip=76 deg, dip direction=8 deg
cohesion=0 tonnes/m2, friction angle=35 deg

Joint Set 2 Data:
dip=67 deg, dip direction=239 deg
cohesion=0 tonnes/m2, friction angle=36 deg

Slope Data:
dip=70 deg, dip direction=240 deg
slope height=7.1 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=YES
water unit weight=0.5 tonnes/m3
Overhanging slope face=NO
Externally applied force=NO
Tension crack=NO

Upper Slope Data:
dip=18 deg, dip direction=330 deg

Seismic Data:
seismic coefficient=0.5
Direction=user defined
trend=240 deg, plunge=0 deg
magnitude=7.68536 tonnes

Bolt Data:
Number of Bolts=1
Bolt #1
trend=59.9996 deg, plunge=14.9995 deg
length=1 meters, capacity=37 tonnes

Swedge Analysis Information

Document Name:
ISFSIEastCutD4.swd

Job Title:
ISFSIEastCut-7.1m

Analysis Results:
Analysis Type=DETERMINISTIC
Safety Factor=0.308399
Wedge Volume=4.77948 m3
Wedge Weight=10.8494 tonnes
Wedge Area (Joint 1)=2.02524 m2
Wedge Area (Joint 2)=42.65 m2
Wedge Area (Slope)=43.4701 m2
Wedge Area (Upper Slope)=1.81521 m2
Normal Force (Joint 1)=-6.59517 tonnes
Normal Force (Joint 2)=8.86436 tonnes
Failure Mode:
Sliding on joint 2
Joint Sets 1&2 line of Intersection:
plunge=54.3039 deg, trend=185.214 deg

Joint Set 1 Data:
dip=88 deg, dip direction=98 deg
cohesion=0 tonnes/m2, friction angle=36 deg

Joint Set 2 Data:
dip=67 deg, dip direction=239 deg
cohesion=0 tonnes/m2, friction angle=36 deg

Slope Data:
dip=70 deg, dip direction=240 deg
slope height=7.1 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=NO
Overhanging slope face=NO
Externally applied force=NO
Tension crack=NO

Upper Slope Data:
dip=18 deg, dip direction=330 deg

Swedge Analysis Information

Document Name:
ISFSIEastCutD5.swd

Job Title:
ISFSIEastCut-7.1m

Analysis Results:
Analysis Type=DETERMINISTIC
Safety Factor=0
Wedge Volume=4.77948 m3
Wedge Weight=10.8494 tonnes
Wedge Area (Joint 1)=2.02524 m2
Wedge Area (Joint 2)=42.65 m2
Wedge Area (Slope)=43.4701 m2
Wedge Area (Upper Slope)=1.81521 m2
Normal Force (Joint 1)=-9.28907 tonnes
Normal Force (Joint 2)=-19.8558 tonnes
Failure Mode:
Contact lost on both joints
Joint Sets 1&2 line of Intersection:
plunge=54.3039 deg, trend=185.214 deg

Joint Set 1 Data:
dip=88 deg, dip direction=98 deg
cohesion=0 tonnes/m2, friction angle=36 deg

Joint Set 2 Data:
dip=67 deg, dip direction=239 deg
cohesion=0 tonnes/m2, friction angle=36 deg

Slope Data:
dip=70 deg, dip direction=240 deg
slope height=7.1 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=YES
water unit weight=0.5 tonnes/m3
Overhanging slope face=NO
Externally applied force=NO
Tension crack=NO

Upper Slope Data:
dip=18 deg, dip direction=330 deg

Seismic Data:
seismic coefficient=0.5
Direction=user defined
trend=240 deg, plunge=0 deg
magnitude=5.42471 tonnes

Swedge Analysis Information

Document Name:
ISFSIEastCutD6.swd

Job Title:
ISFSIEastCut-7.1m

Analysis Results:
Analysis Type=DETERMINISTIC
Safety Factor=1.43106
Wedge Volume=4.77948 m3
Wedge Weight=10.8494 tonnes
Wedge Area (Joint 1)=2.02524 m2
Wedge Area (Joint 2)=42.65 m2
Wedge Area (Slope)=43.4701 m2
Wedge Area (Upper Slope)=1.81521 m2
Normal Force (Joint 1)=-5.00516 tonnes
Normal Force (Joint 2)=14.765 tonnes
Failure Mode:
Sliding on joint 2
Joint Sets 1&2 line of Intersection:
plunge=54.3039 deg, trend=185.214 deg

Joint Set 1 Data:
dip=88 deg, dip direction=98 deg
cohesion=0 tonnes/m2, friction angle=36 deg

Joint Set 2 Data:
dip=67 deg, dip direction=239 deg
cohesion=0 tonnes/m2, friction angle=36 deg

Slope Data:
dip=70 deg, dip direction=240 deg
slope height=7.1 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=YES
water unit weight=0.5 tonnes/m3
Overhanging slope face=NO
Externally applied force=NO
Tension crack=NO

Upper Slope Data:
dip=18 deg, dip direction=330 deg

Seismic Data:
seismic coefficient=0.5
Direction=user defined
trend=240 deg, plunge=0 deg
magnitude=5.42471 tonnes

Bolt Data:
Number of Bolts=1
Bolt #1
trend=60.0002 deg, plunge=15.0001 deg
length=1 meters, capacity=38 tonnes

Swedge Analysis Information

Document Name:
ISFSIEastCutP1.swd

Job Title:
ISFSIEastCut-7.1m

Analysis Results:
Analysis Type=PROBABILISTIC
Probability of Failure=0.197286
Number of Samples=1000
Number of Valid Wedges=958
Number of Failed Wedges=189
Number of Safe Wedges=769

Current Wedge Data (Mean Wedge):
Safety Factor=1.08118
Wedge Volume=6.77124 m3
Wedge Weight=15.3707 tonnes
Wedge Area (Joint 1)=2.42994 m2
Wedge Area (Joint 2)=43.7495 m2
Wedge Area (Slope)=41.3049 m2
Wedge Area (Upper Slope)=3.73798 m2
Normal Force (Joint 1)=8.35255 tonnes
Normal Force (Joint 2)=9.91112 tonnes
Failure Mode:
Sliding on intersection line (joints 1&2)
Joint Sets 1&2 line of Intersection:
plunge=51.7423 deg, trend=296.432 deg

Joint Set 1 Data:
Dip (degrees):
dist=NORMAL,mean=76 ,sd=2
minimum=71,maximum=81
Dip Direction (degrees):
dist=NORMAL,mean=8 ,sd=2
minimum=-2,maximum=18
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=35 ,sd=1
minimum=17.5,maximum=54

Joint Set 2 Data:
Dip (degrees):
dist=NORMAL,mean=67 ,sd=2
minimum=62,maximum=72
Dip Direction (degrees):
dist=NORMAL,mean=239 ,sd=1
minimum=229,maximum=249
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=36 ,sd=1
minimum=19,maximum=52

Slope Data:
Dip (degrees):
dist=NONE,dip=70
Dip Direction (degrees):
dist=NONE,dip direction=240
Other Data:
slope height=7.1 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=NO
Overhanging slope face=NO
Externally applied force=NO
Tension crack=NO

Upper Slope Data:
Dip (degrees):
dist=NONE,dip=18
Dip Direction (degrees):
dist=NONE,dip direction=330

Swedge Analysis Information

Document Name:
ISFSIEastCutP2.swd

Job Title:
ISFSIEastCut-7.1m

Analysis Results:
Analysis Type=PROBABILISTIC
Probability of Failure=0.117727
Number of Samples=1000
Number of Valid Wedges=739
Number of Failed Wedges=87
Number of Safe Wedges=652

Current Wedge Data (Mean Wedge):
Safety Factor=1.08118
Wedge Volume=6.77067 m3
Wedge Weight=15.3694 tonnes
Wedge Area (Joint 1)=2.4095 m2
Wedge Area (Joint 2)=43.7395 m2
Wedge Area (Slope)=41.3049 m2
Wedge Area (Upper Slope)=3.72423 m2
Wedge Area (Tension Crack)=0.0123592 m2
Normal Force (Joint 1)=8.35184 tonnes
Normal Force (Joint 2)=9.91029 tonnes
Failure Mode:
Sliding on intersection line (joints 1&2)
Joint Sets 1&2 line of Intersection:
plunge=51.7423 deg, trend=296.432 deg

Joint Set 1 Data:
Dip (degrees):
dist=NORMAL,mean=76 ,sd=2
minimum=71,maximum=81
Dip Direction (degrees):
dist=NORMAL,mean=8 ,sd=2
minimum=-2,maximum=18
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=35 ,sd=1
minimum=17.5,maximum=54

Joint Set 2 Data:
Dip (degrees):
dist=NORMAL,mean=67 ,sd=2
minimum=62,maximum=72
Dip Direction (degrees):
dist=NORMAL,mean=239 ,sd=1
minimum=229,maximum=249
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=36 ,sd=1

minimum=19,maximum=52

Slope Data:
Dip (degrees):
dist=NONE,dip=70
Dip Direction (degrees):
dist=NONE,dip direction=240
Other Data:
slope height=7.1 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=NO
Overhanging slope face=NO
Externally applied force=NO
Tension crack=YES

Upper Slope Data:
Dip (degrees):
dist=NONE,dip=18
Dip Direction (degrees):
dist=NONE,dip direction=330

Tension Crack Data:
Dip (degrees):
dist=NONE,dip=70
Dip Direction (degrees):
dist=NONE,dip direction=165
Trace Length:
trace length=0.5 meters

Swedge Analysis Information

Document Name:
ISFSIEastCutP3.swd

Job Title:
ISFSIEastCut-7.1m

Analysis Results:
Analysis Type=PROBABILISTIC
Probability of Failure=0.314607
Number of Samples=1000
Number of Valid Wedges=712
Number of Failed Wedges=224
Number of Safe Wedges=488

Current Wedge Data (Mean Wedge):
Safety Factor=1.02083
Wedge Volume=6.77067 m3
Wedge Weight=15.3694 tonnes
Wedge Area (Joint 1)=2.4095 m2
Wedge Area (Joint 2)=43.7395 m2
Wedge Area (Slope)=41.3049 m2
Wedge Area (Upper Slope)=3.72423 m2
Wedge Area (Tension Crack)=0.0123592 m2
Normal Force (Joint 1)=8.29958 tonnes
Normal Force (Joint 2)=8.95799 tonnes
Failure Mode:
Sliding on intersection line (joints 1&2)
Joint Sets 1&2 line of Intersection:
plunge=51.7423 deg, trend=296.432 deg

Joint Set 1 Data:
Dip (degrees):
dist=NORMAL,mean=76 ,sd=2
minimum=71,maximum=81
Dip Direction (degrees):
dist=NORMAL,mean=8 ,sd=2
minimum=-2,maximum=18
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=35 ,sd=1
minimum=17.5,maximum=54

Joint Set 2 Data:
Dip (degrees):
dist=NORMAL,mean=67 ,sd=2
minimum=62,maximum=72
Dip Direction (degrees):
dist=NORMAL,mean=239 ,sd=1
minimum=229,maximum=249
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=36 ,sd=1

minimum=19,maximum=52

Slope Data:
Dip (degrees):
dist=NONE,dip=70
Dip Direction (degrees):
dist=NONE,dip direction=240
Other Data:
slope height=7.1 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=YES
water unit weight=0.5 tonnes/m3
Overhanging slope face=NO
Externally applied force=NO
Tension crack=YES

Upper Slope Data:
Dip (degrees):
dist=NONE,dip=18
Dip Direction (degrees):
dist=NONE,dip direction=330

Tension Crack Data:
Dip (degrees):
dist=NONE,dip=70
Dip Direction (degrees):
dist=NONE,dip direction=165
Trace Length:
trace length=0.5 meters

Swedge Analysis Information

Document Name:
ISFSIEastCutP4.swd

Job Title:
ISFSIEastCut-7.1m

Analysis Results:
Analysis Type=PROBABILISTIC
Probability of Failure=1
Number of Samples=1000
Number of Valid Wedges=965
Number of Failed Wedges=965
Number of Safe Wedges=0

Current Wedge Data (Mean Wedge):
Safety Factor=0.654308
Wedge Volume=6.77124 m3
Wedge Weight=15.3707 tonnes
Wedge Area (Joint 1)=2.42994 m2
Wedge Area (Joint 2)=43.7495 m2
Wedge Area (Slope)=41.3049 m2
Wedge Area (Upper Slope)=3.73798 m2
Normal Force (Joint 1)=9.99556 tonnes
Normal Force (Joint 2)=3.606 tonnes
Failure Mode:
Sliding on intersection line (joints 1&2)
Joint Sets 1&2 line of Intersection:
plunge=51.7423 deg, trend=296.432 deg

Joint Set 1 Data:
Dip (degrees):
dist=NORMAL,mean=76 ,sd=2
minimum=71,maximum=81
Dip Direction (degrees):
dist=NORMAL,mean=8 ,sd=2
minimum=-2,maximum=18
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=35 ,sd=1
minimum=17.5,maximum=54

Joint Set 2 Data:
Dip (degrees):
dist=NORMAL,mean=67 ,sd=2
minimum=62,maximum=72
Dip Direction (degrees):
dist=NORMAL,mean=239 ,sd=1
minimum=229,maximum=249
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=36 ,sd=1
minimum=19,maximum=52

Slope Data:
Dip (degrees):
dist=NONE,dip=70
Dip Direction (degrees):
dist=NONE,dip direction=240
Other Data:
slope height=7.1 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=NO
Overhanging slope face=NO
Externally applied force=NO
Tension crack=NO

Upper Slope Data:
Dip (degrees):
dist=NONE,dip=18
Dip Direction (degrees):
dist=NONE,dip direction=330

Seismic Data:
seismic coefficient=0.5
Direction=user defined
trend=240 deg, plunge=0 deg
magnitude=7.68536 tonnes

Swedge Analysis Information

Document Name:
ISFSIEastCutP5.swd

Job Title:
ISFSIEastCut-7.1m

Analysis Results:
Analysis Type=PROBABILISTIC
Probability of Failure=1
Number of Samples=1000
Number of Valid Wedges=955
Number of Failed Wedges=955
Number of Safe Wedges=0

Current Wedge Data (Mean Wedge):
Safety Factor=0.538306
Wedge Volume=6.77124 m3
Wedge Weight=15.3707 tonnes
Wedge Area (Joint 1)=2.42994 m2
Wedge Area (Joint 2)=43.7495 m2
Wedge Area (Slope)=41.3049 m2
Wedge Area (Upper Slope)=3.73798 m2
Normal Force (Joint 1)=8.52442 tonnes
Normal Force (Joint 2)=-22.881 tonnes
Failure Mode:
Sliding on joint 1
Joint Sets 1&2 line of Intersection:
plunge=51.7423 deg, trend=296.432 deg

Joint Set 1 Data:
Dip (degrees):
dist=NORMAL,mean=76 ,sd=2
minimum=71,maximum=81
Dip Direction (degrees):
dist=NORMAL,mean=8 ,sd=2
minimum=-2,maximum=18
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=35 ,sd=1
minimum=17.5,maximum=54

Joint Set 2 Data:
Dip (degrees):
dist=NORMAL,mean=67 ,sd=2
minimum=62,maximum=72
Dip Direction (degrees):
dist=NORMAL,mean=239 ,sd=1
minimum=229,maximum=249
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=36 ,sd=1
minimum=19,maximum=52

Slope Data:
Dip (degrees):
dist=NONE,dip=70
Dip Direction (degrees):
dist=NONE,dip direction=240
Other Data:
slope height=7.1 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=YES
water unit weight=0.5 tonnes/m3
Overhanging slope face=NO
Externally applied force=NO
Tension crack=NO

Upper Slope Data:
Dip (degrees):
dist=NONE,dip=18
Dip Direction (degrees):
dist=NONE,dip direction=330

Seismic Data:
seismic coefficient=0.5
Direction=user defined
trend=240 deg, plunge=0 deg
magnitude=7.68536 tonnes

Swedge Analysis Information

Document Name:
ISFSIEastCutP6.swd

Job Title:
ISFSIEastCut-7.1m

Analysis Results:
Analysis Type=PROBABILISTIC
Probability of Failure=0.972036
Number of Samples=1000
Number of Valid Wedges=894
Number of Failed Wedges=869
Number of Safe Wedges=25

Current Wedge Data (Mean Wedge):
Safety Factor=0.308399
Wedge Volume=4.77948 m3
Wedge Weight=10.8494 tonnes
Wedge Area (Joint 1)=2.02524 m2
Wedge Area (Joint 2)=42.65 m2
Wedge Area (Slope)=43.4701 m2
Wedge Area (Upper Slope)=1.81521 m2
Normal Force (Joint 1)=-6.59517 tonnes
Normal Force (Joint 2)=8.86436 tonnes
Failure Mode:
Sliding on joint 2
Joint Sets 1&2 line of Intersection:
plunge=54.3039 deg, trend=185.214 deg

Joint Set 1 Data:
Dip (degrees):
dist=NORMAL,mean=88 ,sd=2
minimum=83,maximum=93
Dip Direction (degrees):
dist=NORMAL,mean=98 ,sd=2
minimum=88,maximum=108
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=36 ,sd=1
minimum=19,maximum=52

Joint Set 2 Data:
Dip (degrees):
dist=NORMAL,mean=67 ,sd=2
minimum=62,maximum=72
Dip Direction (degrees):
dist=NORMAL,mean=239 ,sd=1
minimum=229,maximum=249
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=36 ,sd=1
minimum=19,maximum=52

Slope Data:
Dip (degrees):
dist=NONE,dip=70
Dip Direction (degrees):
dist=NONE,dip direction=240
Other Data:
slope height=7.1 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=NO
Overhanging slope face=NO
Externally applied force=NO
Tension crack=NO

Upper Slope Data:
Dip (degrees):
dist=NONE,dip=18
Dip Direction (degrees):
dist=NONE,dip direction=330

Swedge Analysis Information

Document Name:
ISFSIEastCutP7.swd

Job Title:
ISFSIEastCut-7.1m

Analysis Results:
Analysis Type=PROBABILISTIC
Probability of Failure=0.993318
Number of Samples=1000
Number of Valid Wedges=898
Number of Failed Wedges=892
Number of Safe Wedges=6

Current Wedge Data (Mean Wedge):
Safety Factor=0
Wedge Volume=4.77948 m3
Wedge Weight=10.8494 tonnes
Wedge Area (Joint 1)=2.02524 m2
Wedge Area (Joint 2)=42.65 m2
Wedge Area (Slope)=43.4701 m2
Wedge Area (Upper Slope)=1.81521 m2
Normal Force (Joint 1)=-9.28907 tonnes
Normal Force (Joint 2)=-19.8558 tonnes
Failure Mode:
Contact lost on both joints
Joint Sets 1&2 line of Intersection:
plunge=54.3039 deg, trend=185.214 deg

Joint Set 1 Data:
Dip (degrees):
dist=NORMAL,mean=88 ,sd=2
minimum=83,maximum=93
Dip Direction (degrees):
dist=NORMAL,mean=98 ,sd=2
minimum=88,maximum=108
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=36 ,sd=1
minimum=19,maximum=52

Joint Set 2 Data:
Dip (degrees):
dist=NORMAL,mean=67 ,sd=2
minimum=62,maximum=72
Dip Direction (degrees):
dist=NORMAL,mean=239 ,sd=1
minimum=229,maximum=249
Cohesion (tonnes/m2):
dist=NONE,cohesion=0
Friction Angle (degrees):
dist=NORMAL,mean=36 ,sd=1
minimum=19,maximum=52

Slope Data:
Dip (degrees):
dist=NONE,dip=70
Dip Direction (degrees):
dist=NONE,dip direction=240
Other Data:
slope height=7.1 meters
rock unit weight=2.27 tonnes/m3
Water pressures in the slope=YES
water unit weight=0.5 tonnes/m3
Overhanging slope face=NO
Externally applied force=NO
Tension crack=NO

Upper Slope Data:
Dip (degrees):
dist=NONE,dip=18
Dip Direction (degrees):
dist=NONE,dip direction=330

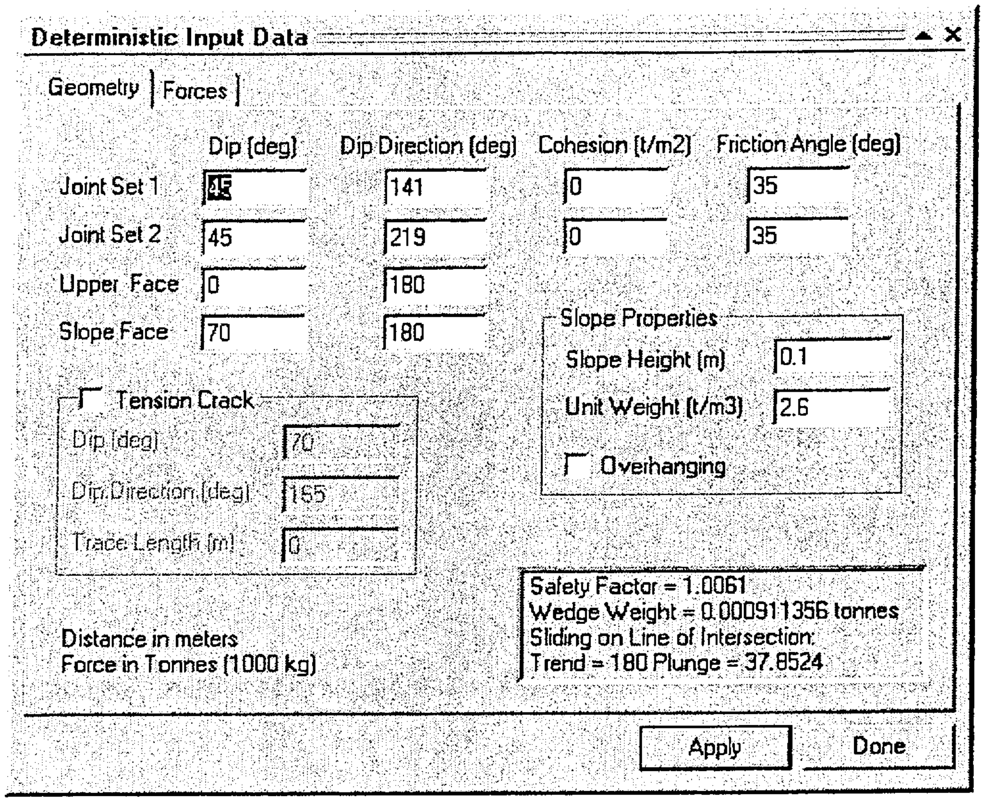
Seismic Data:
seismic coefficient=0.5
Direction=user defined
trend=240 deg, plunge=0 deg
magnitude=5.42471 tonnes

ATTACHMENT 2

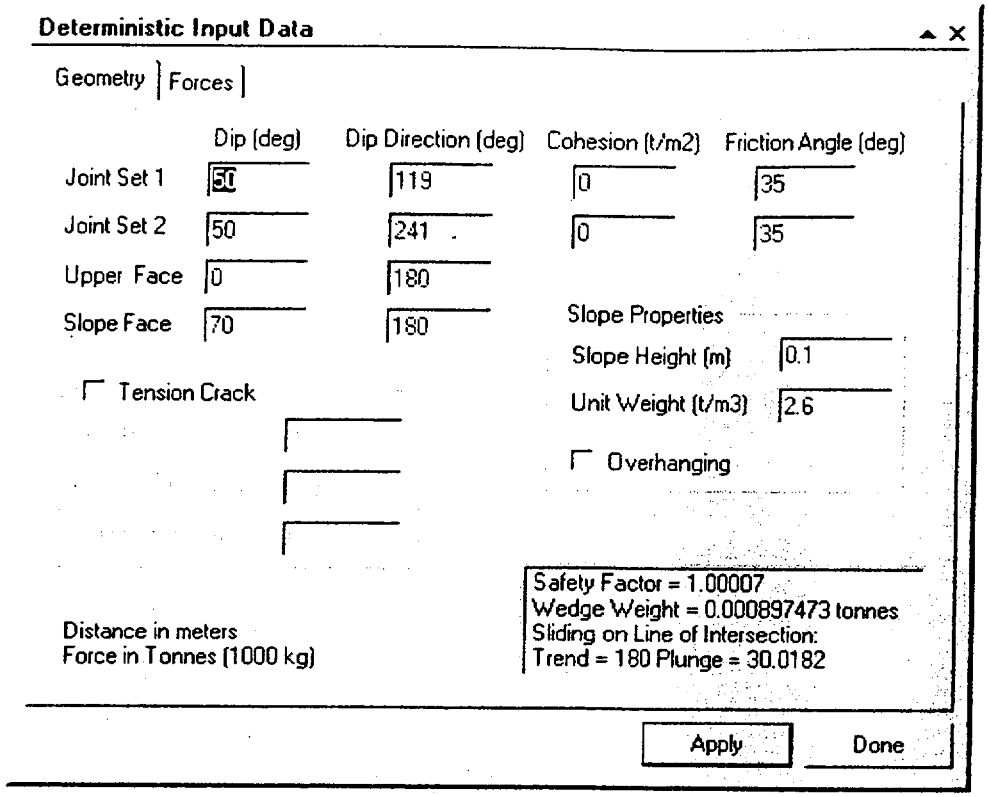
SWEDGE PROGRAM VERIFICATION RUNS

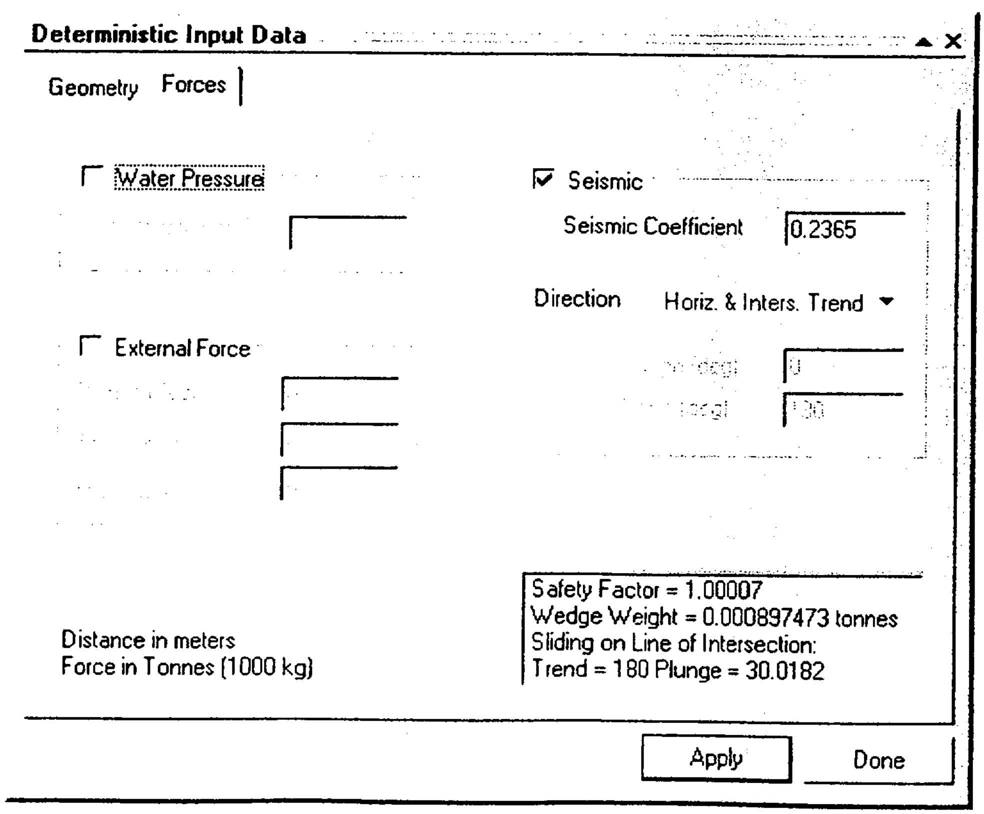
The following five pages show screen output obtained when working through the example problems for SWEDGE, v. 3.06, to verify the accuracy and calibration of the program. The screen output match those found in the program verification manual provided by Rocscience, Inc., the maker of SWEDGE.

SWEDGE program verification problem 1:

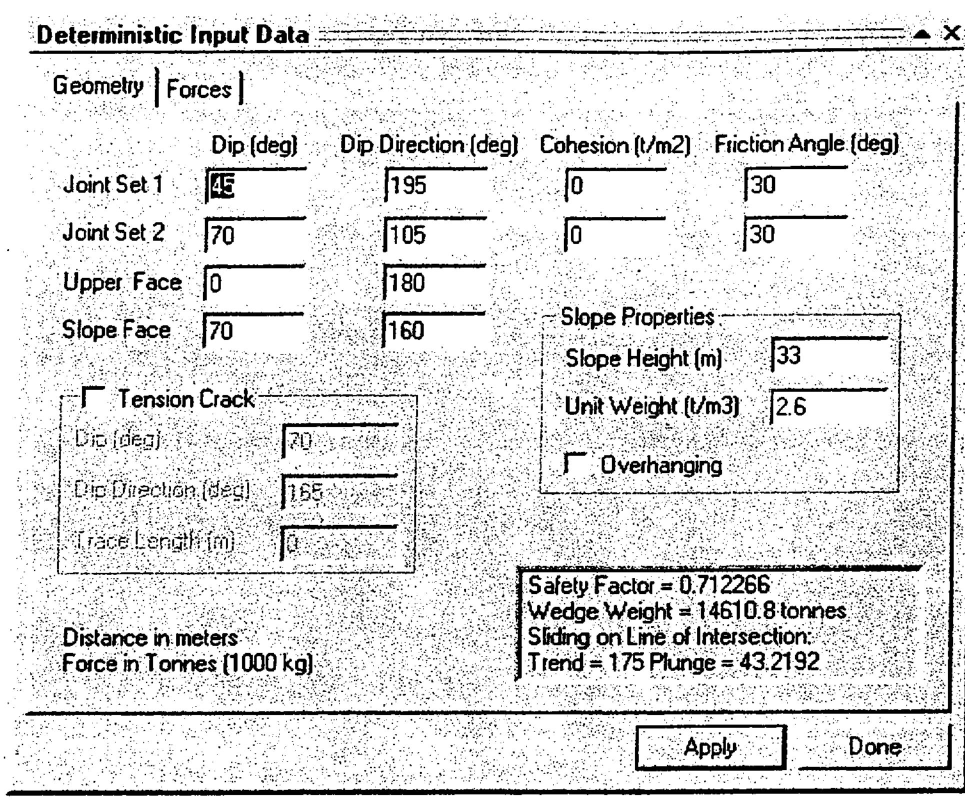


SWEDGE program verification problem 2:

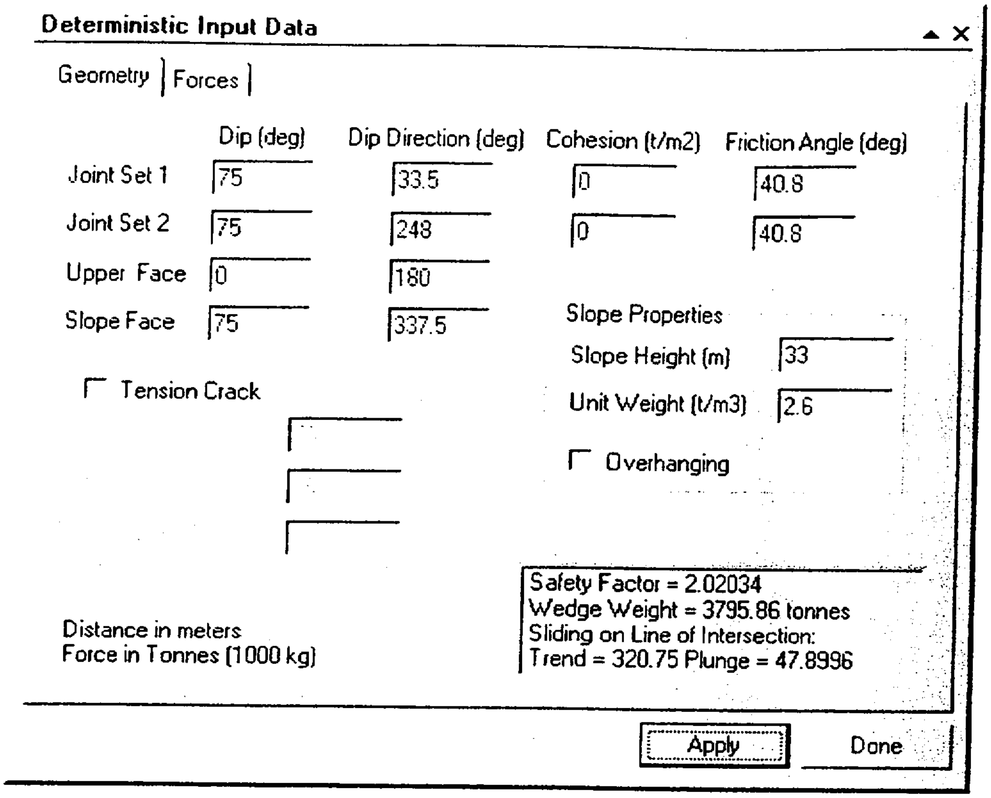


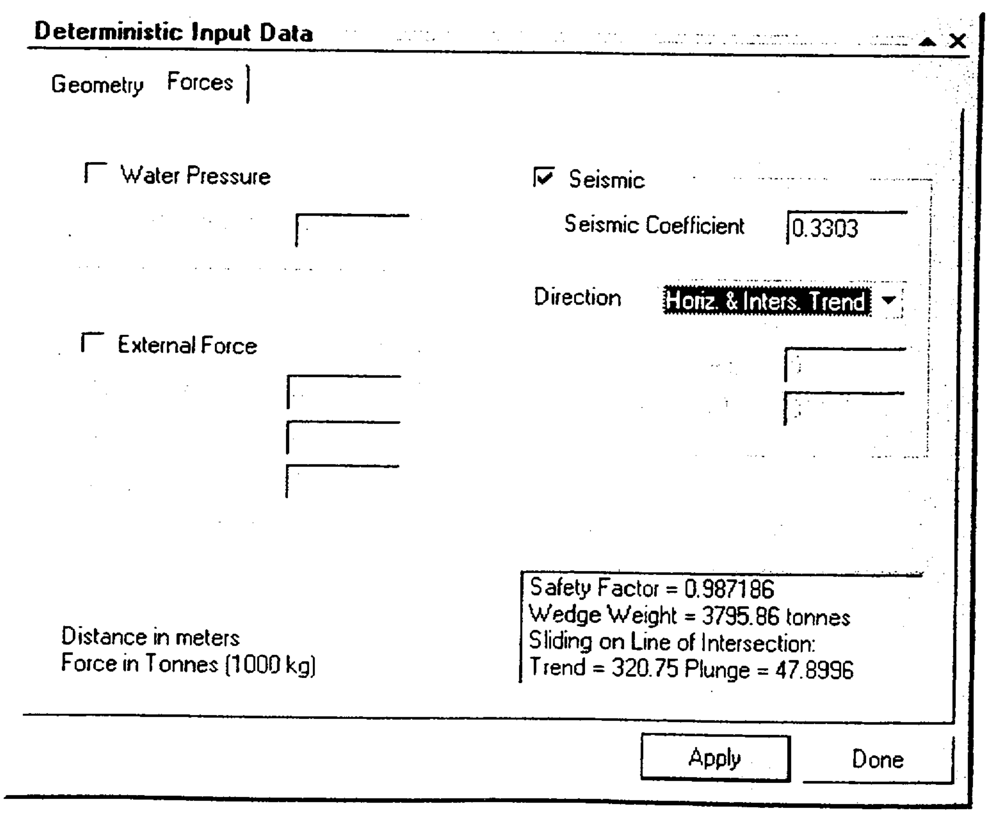


SWEDGE program verification problem 3:

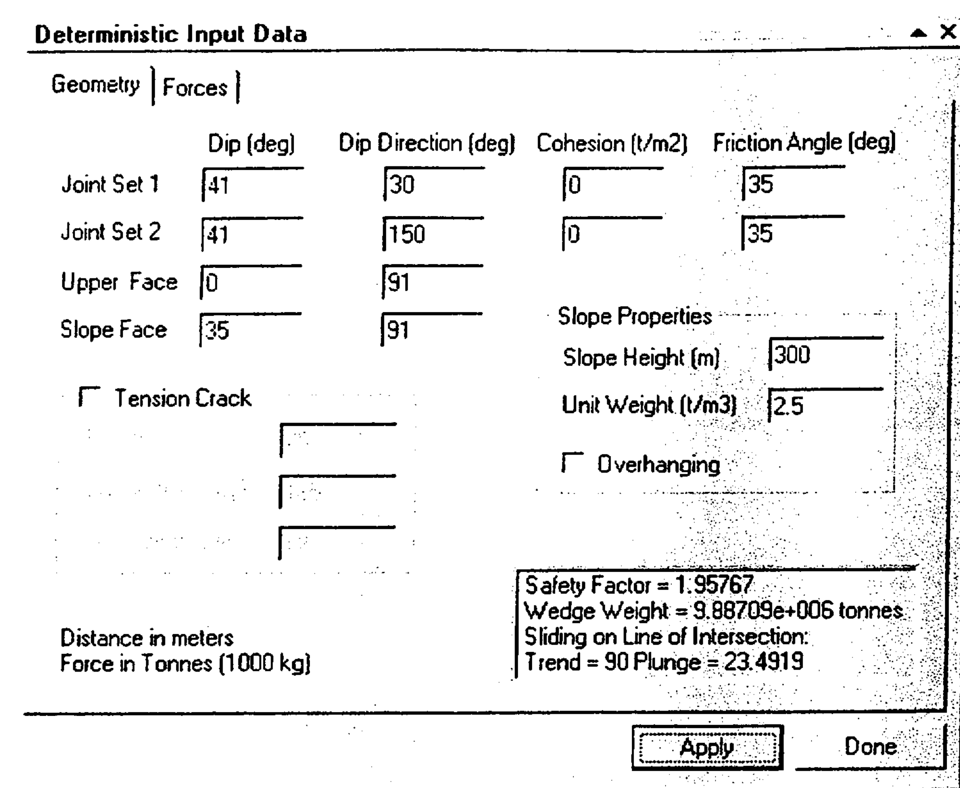


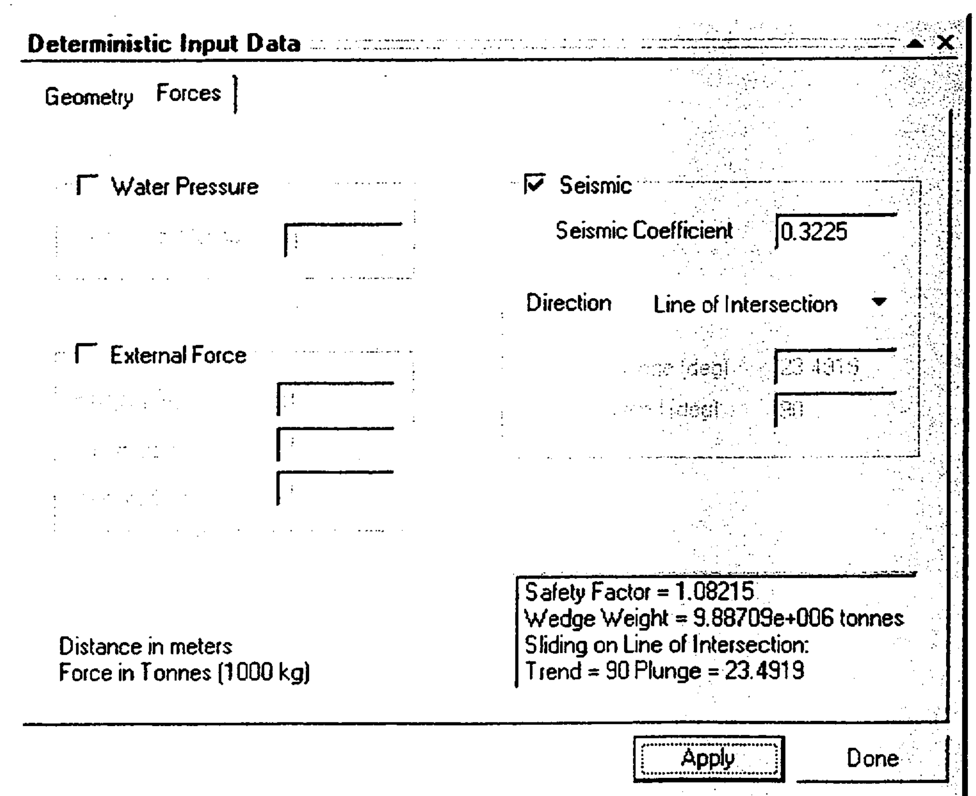
SWEDGE program verification problem 4:





SWEDGE program verification problem 5:





The program verification manual provided by Rocscience Inc., the maker of SWEDGE, in attached in the next several pages.

INTRODUCTION

This document presents several examples, which have been used as verification problems for the program SWEDGE. SWEDGE is an engineering analysis program, produced by Rocscience Inc. of Toronto, Canada, for assessing the stability of wedges formed in rock slopes.

The examples presented here, are based on a number of examples and case studies presented in ref. [1]. In ref. [1], lab tests were performed on wedge models. The results of these lab tests were used to confirm the validity of a limit equilibrium analysis method presented in ref. [2].

The results produced by SWEDGE, as documented in this paper, agree very well with the examples discussed in ref. [1], and confirm the reliability of results produced by SWEDGE.

SWEDGE VERIFICATION PROBLEM # 1

Introduction

Here we begin a static stability assessment (SSA) to verify that the Swedge program written by Rocscience Inc. computes values using the correct equations. The equations we will use to verify the results produced by SWEDGE, were originally presented by Kovari and Fritz (1975) [2]. These equations were later shown to be valid, by laboratory tests of wedge models discussed in ref. [1]. In the following example problem, a wedge with joints having the same dip allows a maximum wedging effect. A tension crack is not present.

Equations

The following equations were all verified against lab samples [1].

$$\mathrm{SF} = \lambda \frac{\cos i_a \tan \phi}{\sin i_a} \qquad (1)$$

$$\lambda = \frac{\cos \omega_1 + \cos \omega_2}{\sin(\omega_1 + \omega_2)} \qquad (2)$$

$$\omega_1 + \omega_2 = 2\omega \qquad (3)$$

θ is the apparent frictional angle due to the geometric configuration of the wedge. ϕ is the friction angle. λ is the wedge factor by Kovári and Fritz (1975) [2]. ω is the half wedge angle. ω_1 and ω_2 are the angles between the surfaces of each joint with the vertical respectively. Notice that $\omega_1 = \omega_2 = \omega$. i_a is the inclination angle (or intersection angle).

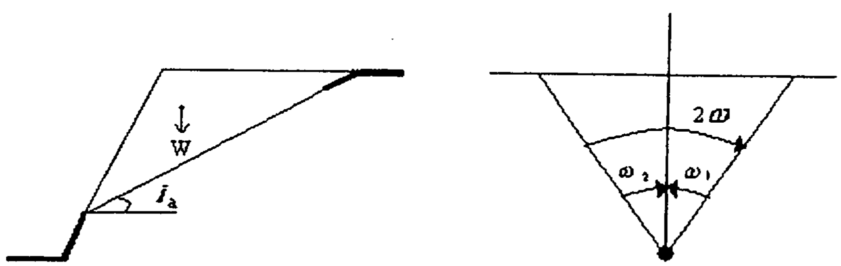


Figure 1. Front and side cross-sectional views of a wedge without a tension crack

Example Verification

Here we show the calculation process for a specific wedge (using the proven equations above), and then we use a graphed plot to get the inclination angle (i_a). If the Swedge program will compute the same inclination angle, we then will know that it is functioning correctly. The plot is shown below and is based on a safety factor, SF = 1.

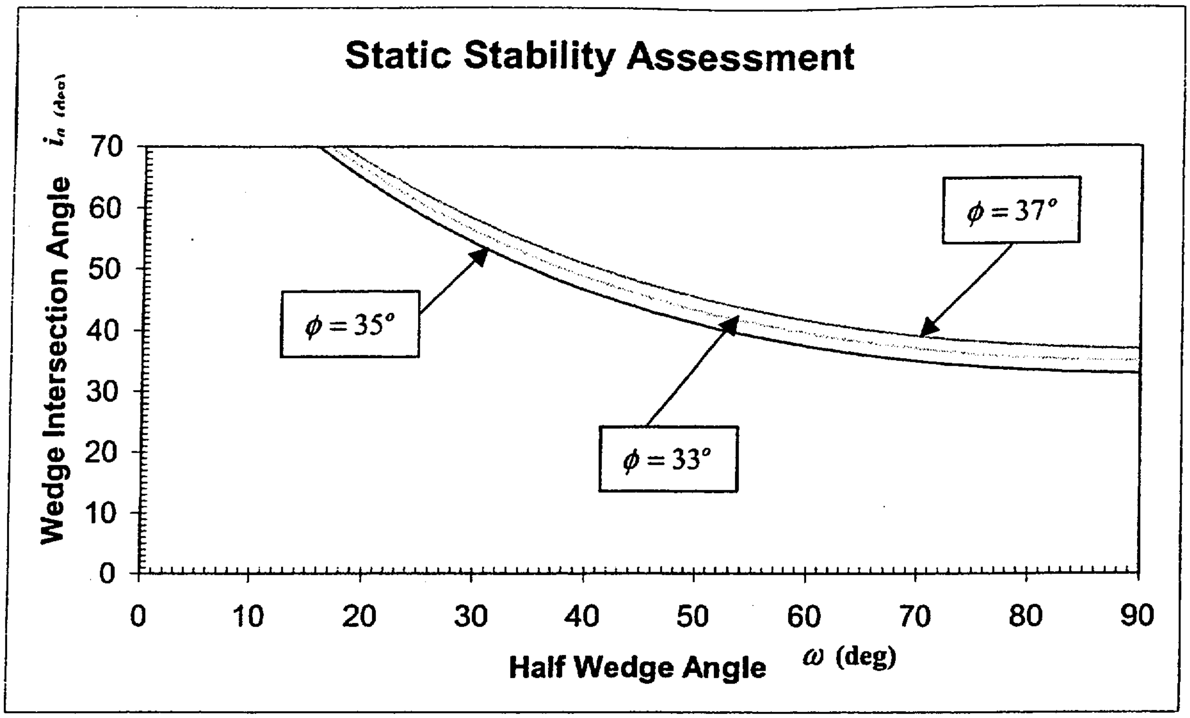


Figure 2. The graph lines are based on $\phi = 33^0, 35^0, 37^0$. SF = 1. Note: λ is simplified to $\lambda = \dfrac{1}{\sin\omega}$

When ω is calculated, and ϕ is chosen, a corresponding intersection angle can be found using the plot above - all which is based on equation (1).

Normal vectors to the joint planes have components

l = sin(dip) x cos(dip direction)
m = sin(dip) x sin(dip direction)
n = cos(dip)

Joint #	Dip (^{0})	Dip Direction (^{0})	l	m	n
1	45	141	-0.777	0.629	0.707
2	45	219	-0.777	-0.629	0.707

Table 1: Sample set of values where $\omega_1 = \omega_2 = \omega$.

By inputting the above values for dip and dip direction for the joints in the 'input data' screen of the Swedge program, it shows us that we have a SF ≅ 1. Referring back to figure 1, the normal vectors to the planes of joints 1 and 2 intersect. 2 ω is equal to their obtuse angle of intersection.

Angle between vectors → $\cos\alpha = \dfrac{a \bullet b}{\|a\| \times \|b\|}$ = $(0.777)^2$ - $(0.629)^2$ + $(0.707)^2$

$$\therefore \quad \omega = \frac{180 - \alpha}{2} = 67.53^0$$

Now that the half wedge angle ($\omega = 67.53^0$) is known, an intersection angle can be traced out using the graph of Figure 2. Let us choose the line plotted for ϕ = 35^0. The intersection angle (if *approximately* traced using a pencil) is about $i_a = 37^0$. The equations used have been validated by experimental results [1]. The plotted graph that is based on equation (1) is also correct. All that is needed now is to verify that Swedge creates the same intersection angle.

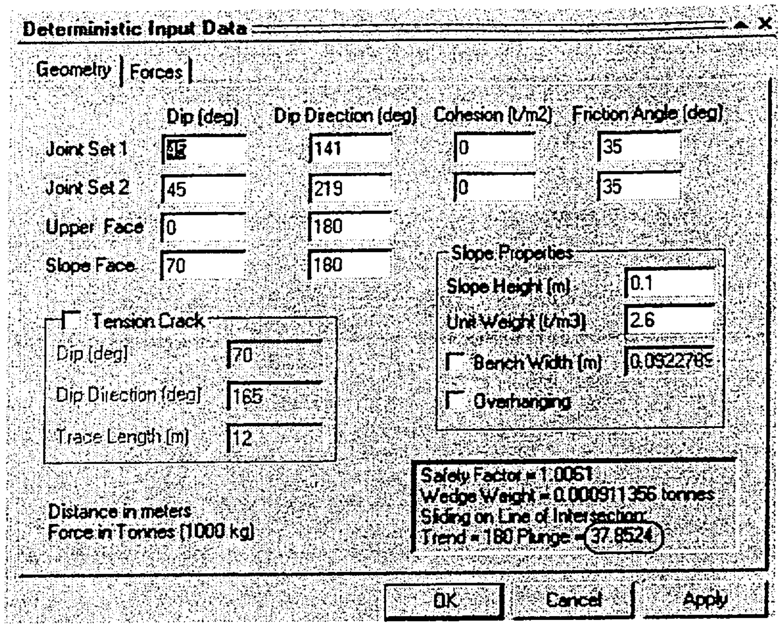


Figure 3. Analysis input within the Swedge program (refer to the Swedge manual).

By inserting the settings from Table 1 into the input data dialog window within the Swedge program and clicking the 'Apply' button, the Plunge (or i_a) = 37.85 ^{0}. This is the same value as that which we traced out by hand before. Notice that the plunge is not affected by changing the slope height, unit weight, or values for the upper face and slope face. Such values are not included within the equations we used and therefore should not affect the plunge.

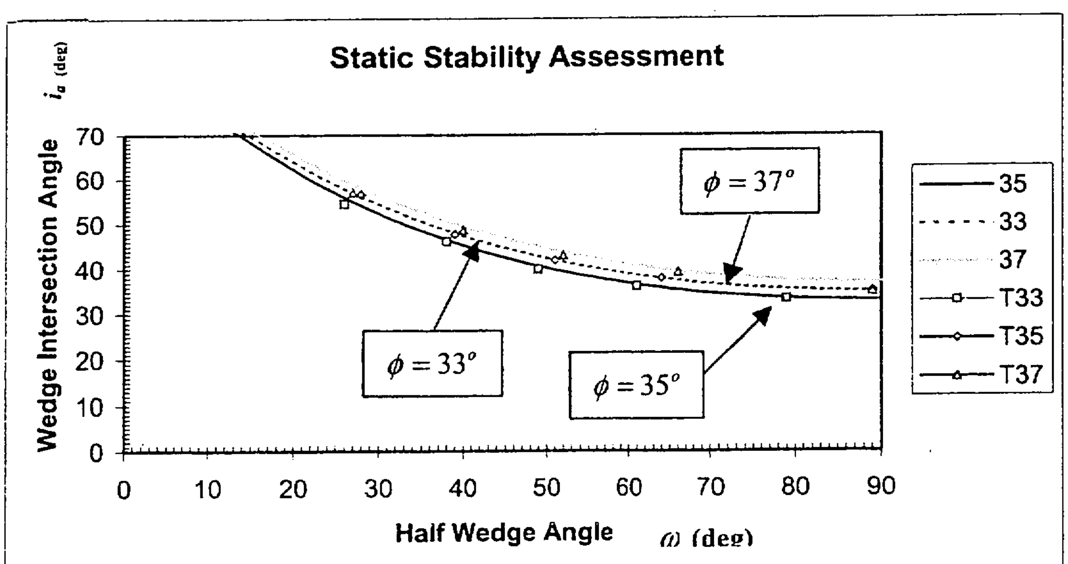


Figure 4. Tests performed with different ω angle values all with a SF = 1. Separate tests were done for specific ϕ values in the same way. For example, T33 measures a specific test for a friction angle of 33^0.

The Swedge program is now verified to work for this specific example. Many more tests were made as shown in Figure 4. Each test was done with the same method as this example problem. For example, T33 stands for a test done with a friction angle of 33^0. Many values were derived and lie on the line on which their friction angle is based in the graph of Figure 4. It should be noted that the wedge created in this exercise as well as the others tested were symmetrical not only due to the dip but also in dip direction. When viewing the 'front' view in the Swedge program, the wedge has symmetry. To make this symmetry, we maintained the dip directions with a sum of 360^0. Symmetry was maintained in order to reproduce the conditions for the model wedges that were described in [1].

SWEDGE VERIFICATION PROBLEM # 2

Introduction

In the previous verification example, we tested Swedge for static stability. The Swedge program will now be used for a dynamic stability assessment (DSA). In this experiment, we will set the intersection angle at certain values yielding SF > 1. The dips will once again be identical for both joints and the dip directions will sum up to 360^0 for symmetry. If a seismic co-efficient will be included in the analysis within Swedge, a safety factor SF = 1 can be generated. Wedge acceleration will be calculated from this seismic coefficient and then compared to a graph. The equations we use to verify those used within the program Swedge have been validated by experimental results [1]. There is no tension crack.

Equations / Derivations

The following equations were all verified from lab samples [1].

$$SF = \frac{\lambda(\cos i_a - \eta \sin(i_a + \beta))\tan\phi}{\sin i_a + \eta\cos(i_a + \beta)} \quad (1)$$

$\beta = 0$ (seismic forces have a horizontal trend – refer to figure 1) (2)

$\omega_1 + \omega_2 = 2\omega$ (3)

$$\lambda = \frac{\cos\omega_1 + \cos\omega_2}{\sin(\omega_1 + \omega_2)} = \frac{1}{\sin\omega} \quad (4)$$

$$\therefore \quad SF = \frac{\lambda(\cos i_a - \eta\sin i_a)\tan\phi}{(\sin i_a + \eta\cos i_a)} = 1 \quad (5)$$

$$\eta = \frac{\lambda\cos i_a \tan\phi - \sin i_a}{\cos(i_a + \beta) + \lambda\sin(i_a + \beta)\tan\phi} \quad (6)$$

$$\therefore \eta = \frac{\cos i_a \tan\phi - \sin i_a \sin\omega}{\cos i_a \sin\omega + \sin i_a \tan\phi} \quad (7)$$

$$\eta = \frac{a}{g} \quad (8)$$

λ is the wedge factor by Kovári and Fritz (1975) [2]. ω is the half wedge angle. ω_1 and ω_2 are the angles between the surfaces of each joint with the vertical respectively. Notice that $\omega_1 = \omega_2 = \omega$. i_a is the inclination angle (or intersection angle). η is the seismicity coefficient. ϕ is the friction angle. β is the inclination of the dynamic force (labeled 'E' in figure 1). a , g are accelerations. $g = 981 \frac{cm}{s^2}$.

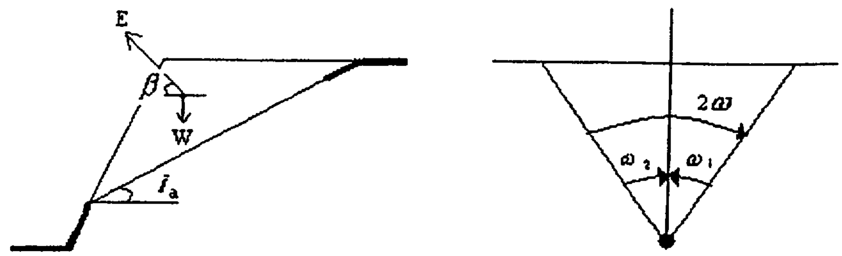


Figure 1. Front and side cross-sectional views of a wedge without a tension crack. There is a dynamic force 'E' pointed at an inclination of β.

Example Verification

We will now introduce the calculation process for a specific wedge (using the proven equations). It is now assumed (due to the previous verification exercise) that the inclination angle function in Swedge is working correctly. A plot is shown below that is based on a safety factor, SF = 1.

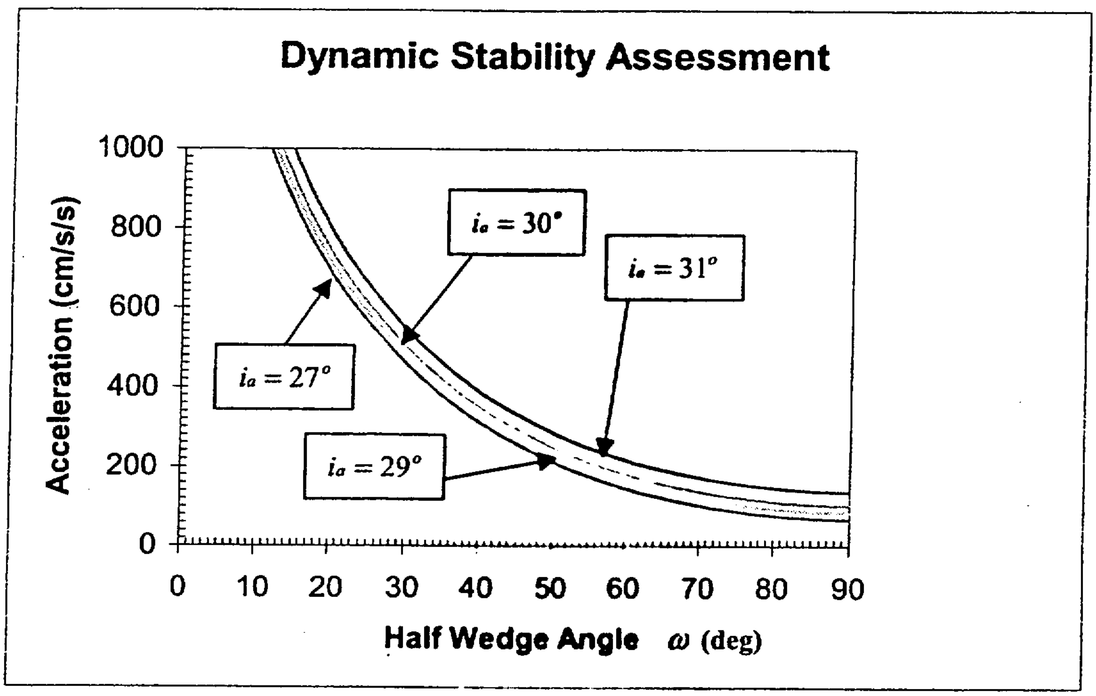


Figure 2. The graph lines are based on i_a = 27°, 29°, 30° or 31°. SF = 1. The friction angle is assumed to be $\phi = 35^0$.

We use the same procedure as in the SSA example problem to derive ω.

Normal vectors to the joint planes have components:

l = sin(dip) x cos(dip direction)
m = sin(dip) x sin(dip direction)
n = cos(dip)

Joint #	Dip (^{0})	Dip Direction (^{0})	l	m	n
1	50	119	-0.37139	0.669998	0.642788
2	50	241	-0.37139	-0.669998	0.642788

Table 1: Sample set of values

When we insert the above values for dip and dip direction for the joints in the 'input data' dialog of the Swedge program, SF = 1.6325 is computed which suggests that the wedge is statically stable. This is expected because the values in Table 1 were chosen specifically to get $i_a = 30.0182 \cong 30$. Remember that the plots in Figure 2 are based on 4 different inclination angles. Now, suppose there is a seismic force on the wedge. We seek a seismic coefficient which will lower the safety factor to SF = 1. To do so we use equation (7). We know the inclination angle (i_a), the friction angle ($\phi = 35^0$), and now we will solve for the wedge angle all in order to solve for the seismic coefficient (η).

Angle between vectors → $\cos\alpha = \dfrac{a \bullet b}{\|a\| \times \|b\|} = (0.37139)^2 - (0.669998)^2 + (0.642788)^2$

$$\therefore \quad \omega = \frac{180-\alpha}{2} = 47.93^0$$

Equation (7) is used to get a seismic coefficient which changes the safety factor to SF = 1.

$$\therefore \eta = \frac{\cos i_a \tan\phi - \sin i_a \sin\omega}{\cos i_a \sin\omega + \sin i_a \tan\phi} = \frac{\cos(30.0182)\tan(35) - \sin(30.0182)\sin(47.93)}{\cos(30.0182)\sin(47.93) + \sin(30.0182)\tan(35)} = 0.2365$$

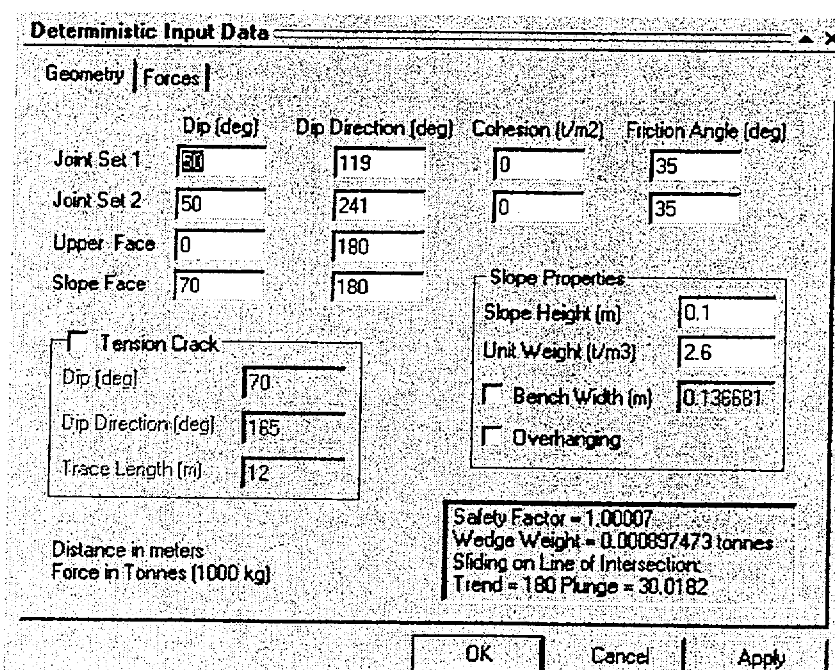


Figure 3. Analysis input within the Swedge program (refer to the Swedge manual).

Notice that the plunge (or i_a) in Figure 3 is not affected by changing the slope height, unit weight, or values for upper face and slope face. Such values are not factors in the equations we used and they do not affect the plunge.

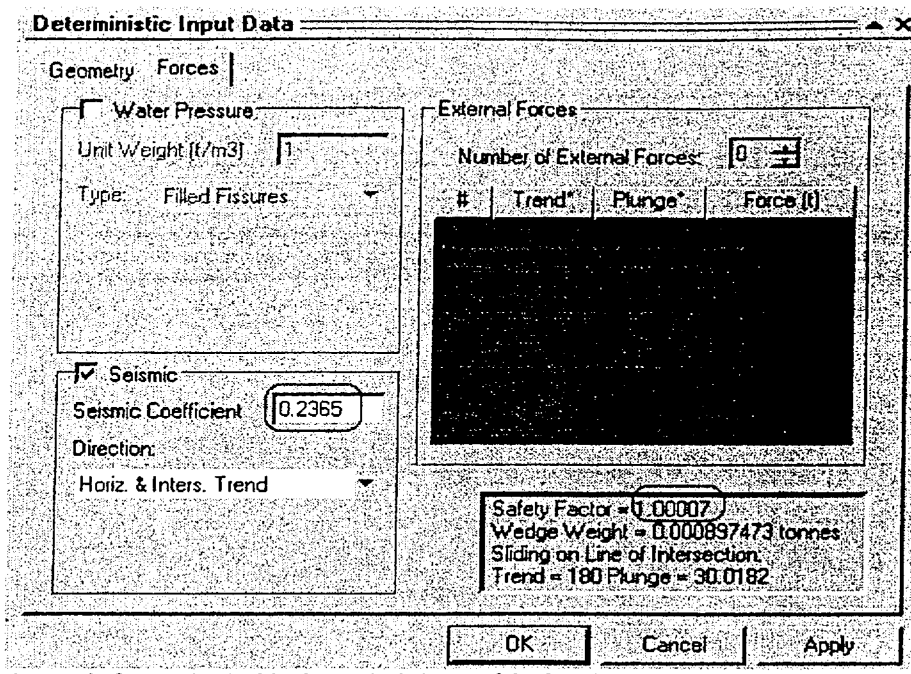


Figure 4. Dynamic forces checked in the analysis input of the Swedge program.

Since the safety factor has changed to SF = 1, we know that the analysis functions for Swedge in DSA are functioning correctly. To make sure that this is so, we can go a little further and see if the acceleration (derived from equation (8)) using the seismic coefficient in Swedge is equal to the acceleration range of the graph in Figure 2. The acceleration (if approximately traced using a pencil) is about 235 $\frac{cm}{s^2}$. By using equation (8), the acceleration from the seismic coefficient (shown in Figure 4) is 232 $\frac{cm}{s^2}$. Such an accurate result justifies the reliability of the Swedge program.

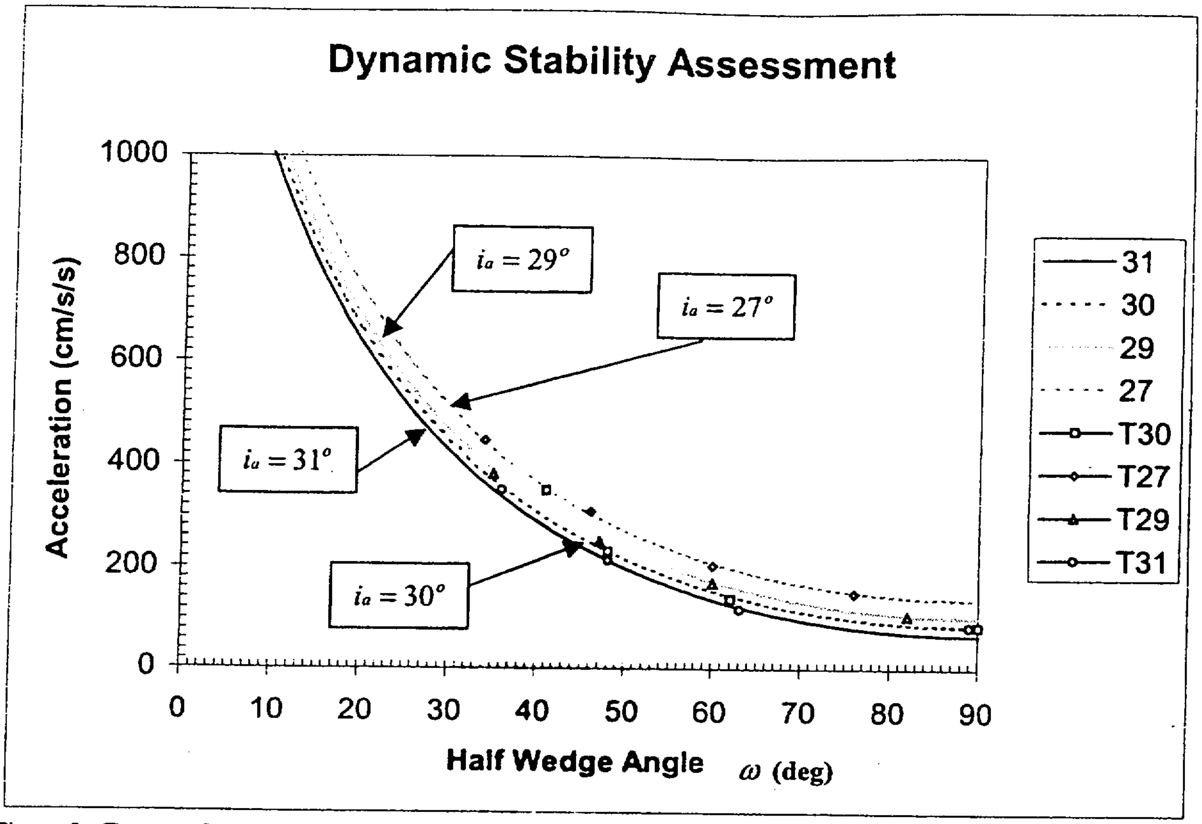


Figure 5. Tests performed with different ω angle values all with a SF = 1. Separate tests were done for specific i_a values. All tests were done in the same way for DSA.

The Swedge program is now verified to work for this specific example. Many more tests were made as shown above in figure 5. Each test was done with the same method as this example problem. For example, T30 stands for a test done with an inclination angle of 30°. Many values were derived and lie on the line on which their inclination angle is based in the graph of Figure 5.

SWEDGE VERIFICATION PROBLEM # 3

Introduction

This example verification is based on the case study presented as "case 3" on page 43 of reference [1]. A rock mass near Ankara Castle in Bent Deresi region of Ankara City had a wedge failure. The authors of [1] studied this wedge and found that the wedge block was unstable. During their analysis, they found that the friction angle was $\phi = 30^0$. There was a stability assessment with dry-static conditions. The experiment yielded a safety factor of SF = 0.73. In the following, we will verify that Swedge will give the same safety factor.

Given information

	Dip (deg)	Dip Direction (deg)
Joint #1	45	195
Joint #2	70	105
Slope	70	160

Table 1. Stereonet on p.46, Fig. 13 (c), [1]

Parameter	Value
ω_1 (degree)	77
ω_2 (degree)	28
i_a (degree)	42

Table 2. Geometrical characteristics of the wedge on p.46, Fig. 13 (c), [1]

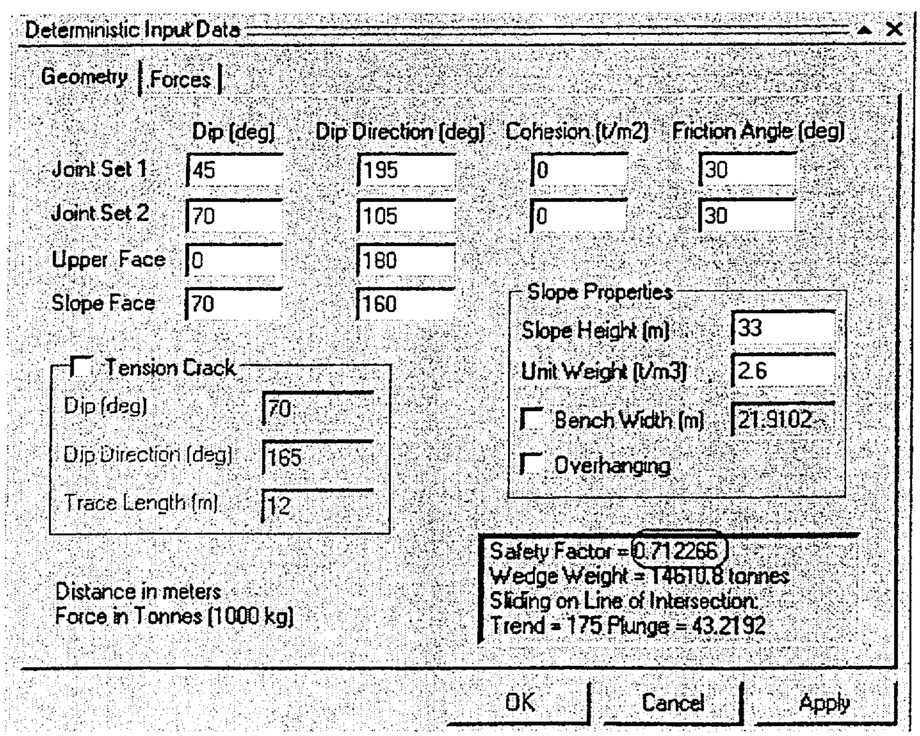


Figure 2. Analysis input within the Swedge program (refer to the manual).

Conclusion

From Figure 2, the safety factor is SF = 0.71. Such a result was expected when compared to the result of the experiment for which this exercise is based on. The Swedge program has verified the experimental result taken from p.45 [1].

SWEDGE VERIFICATION PROBLEM # 4

Introduction

This example is based on the case study presented as "case 4" on page 45 of reference [1]. In this case study, we turn to the town of Dinar in western Turkey. This area has many earthquakes and therefore in this analysis verification we will make both static and dynamic assessments. The author of reference [1] made a wedge analysis and the wedge friction angle was determined to be $\phi = 40.8^0$. The first analysis (before an earthquake occurred) yielded a safety factor of SF = 2.02. A second test was made during dynamic conditions and a safety factor of SF = 0.99 was found. In the following analysis using Swedge, we will verify that Swedge gives the same results as the experiment. For more information, refer to p.45, [1].

Given information

	Dip (deg)	Dip Direction (deg)
Joint #1	75	33.5
Joint #2	75	248
Slope	75	337.5

Table 1. Stereonet on p.47, Fig. 14 (b), [1]

Parameter name	Value
ω_1 (degree)	17
ω_2 (degree)	25
i_a (degree)	50
Friction angle (degree)	40.8
β (degree)	0
a_{max} in NS direction (cm/s^2)	282
a_{max} in EW direction (cm/s^2)	324

Table 2. The information above can be used to calculate the same results as shown in Swedge.

By inserting the values from Table 1 into the input data of the Swedge program, the result for the safety factor will be SF = 2.02 as shown below in figure 1.

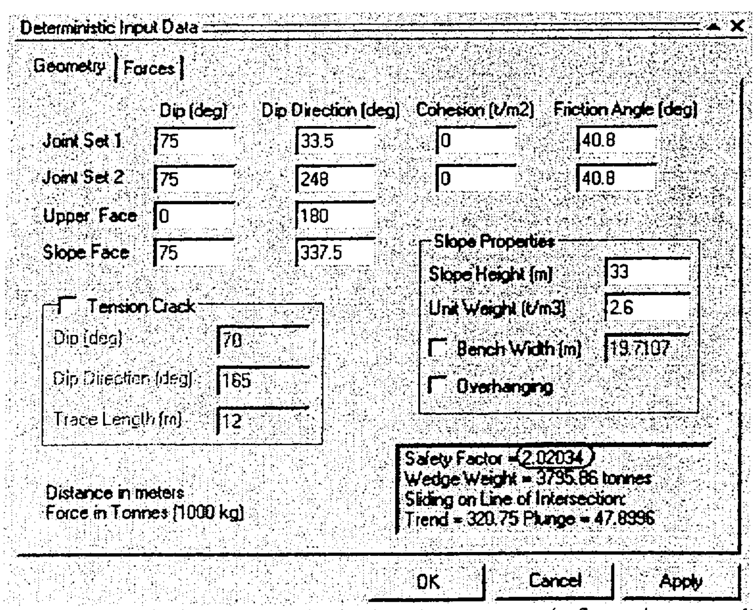


Figure 1. Analysis input within the Swedge program (refer to the manual).

The above verifies the experiment for static conditions with the Swedge program.

From Table 2, the maximum acceleration is in the east – west direction. Suppose that this acceleration is in the same direction as the intersection angle of the wedge to be considered. We can then say that this is dynamically the worst condition for stability. Therefore, we choose a = 324 cm/s^2.

The seismic co-efficient is

$$\eta = \frac{a}{g} \quad (\text{ where } g = 981 \text{ cm/s}^2)$$

$$\therefore \eta = \frac{324}{981} = 0.3303$$

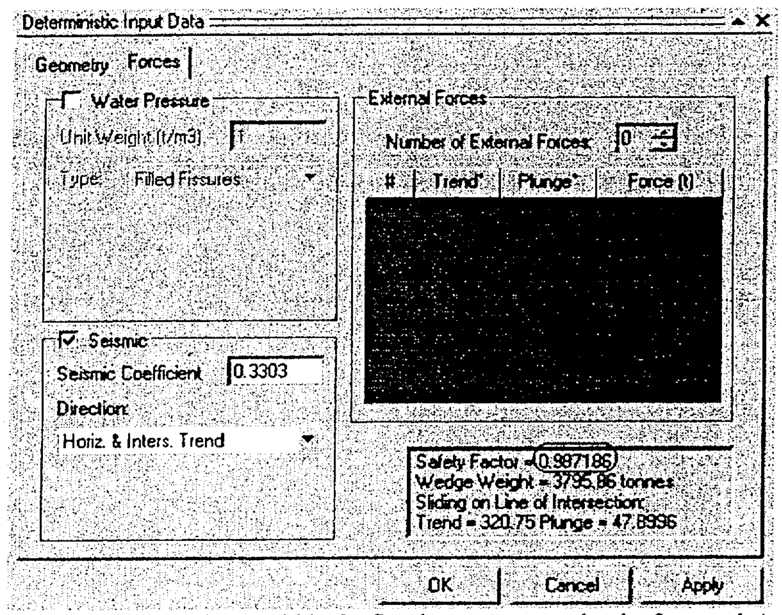


Figure 2. Analysis input within the Swedge program under the forces tab (refer to the manual)

When inserting the calculated seismic coefficient, we get a safety factor of SF = 0.99 as shown above in Figure 2.

The safety factors determined by Swedge are equal to those that were found experimentally as written in [1]. Therefore Swedge has been confirmed for dynamic stability assessment with respect to the safety factor, for this example.

SWEDGE VERIFICATION PROBLEM # 5

Introduction

This example is based on the "case 5" study on p.46 of reference [1]. In this case study, we study a wedge failure at Mt. Mayuyama (Japan), which occurred in 1792. This failure occurred after an earthquake. The authors of reference [1] made a few tests to determine the possible mechanisms of the wedge failure. Four conditions were considered in this analysis. We will use Swedge to verify the results of their experiments. The details of this experiment are written starting on p. 46, [1]. We utilized the following equations and information for each condition on p. 49, [1] to plot the graph shown in Figure 2. In this verification problem, we will use joints 1 and 2 for verification.

Given Information

Parameter	Value
ω_1 (degree)	54
ω_2 (degree)	54
i_a (degree)	23

Equations

The following equations were all verified from lab samples in [1].

$$SF = \frac{[\lambda[W(\cos i_a - \eta\sin(i_a+\beta)) + U_s\sin i_a + U_t\cos i_a] - \alpha U_b]\tan\phi + c(A_1+A_2)}{W(\sin i_a + \eta\cos(i_a+\beta)) - U_s\cos i_a + U_t\sin i_a} \quad (1)$$

$$\lambda = \frac{\cos\omega_1 + \cos\omega_2}{\sin(\omega_1+\omega_2)} \quad (2)$$

$$U_b = U_{bs} + U_{be} = (\gamma_s + \gamma_e)W \quad (3)$$

$$U_b = U_{b1}\sin\omega_1 + U_{b2}\sin\omega_2 \quad (4)$$

λ is called the wedge factor by Kovári and Fritz (1975) [2] i_a is the inclination angle. β is the inclination angle of a dynamic force. ω_1 and ω_2 are the half wedge angles Since both are equal to 54^0, $\omega_1 = \omega_2 = \omega$, the half wedge angle. U_s and U_t are the water forces acting on the face and the upper part of the slope (if such forces are there). A_1 and A_2 are the joint surface areas. U_b is a force caused by fluid pressure that has components normal to each joint. U_b itself is the force, which points vertically, hence the trigonometric system shown in equation (4). All these are shown below in figure 1. We will refer to figure 1 often to assure our calculations. γ_s and γ_e are the static and excess fluid pressure coefficients respectfully.

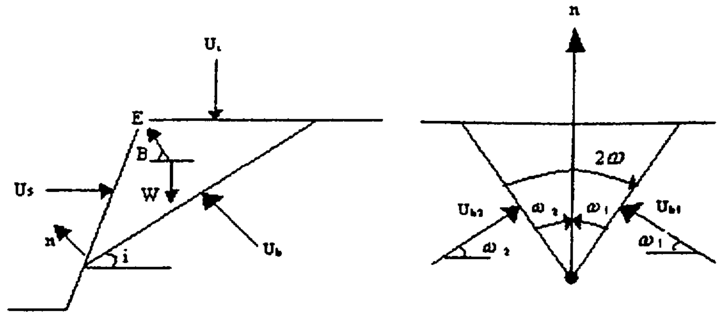


Figure 1. Front and side cross-sectional views of a wedge without a tension crack.

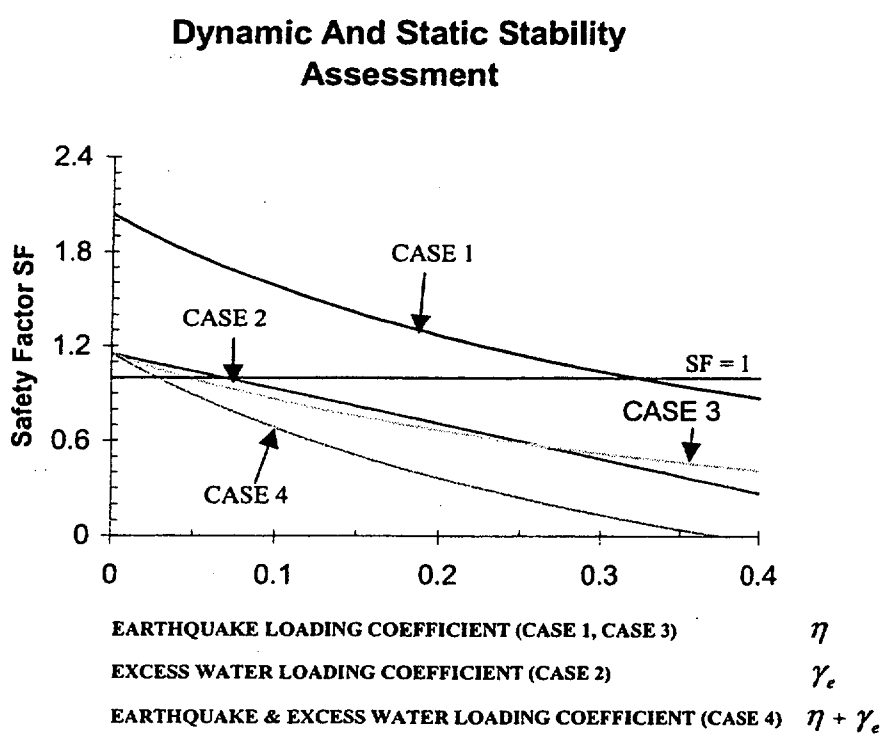


Figure 2. The comparison of case results for the wedge failure at Mt. Mayuyama as described on p.49, [1]. Note that to derive the equations for this graph we took a friction angle $\phi = 35^o$.

CASE 1:

Here we have a mass of dry rock and there is an earthquake present. The seismic coefficient (η) is constantly increasing from 0.0 to 0.5 as described in Figure 2. On p.49, [1] the following is given:

$$c = 0;\ \ U_s = 0;\ \ U_t = 0;\ \ U_b = 0;\ \ \alpha = 1;\ \ \beta = 0$$

$$\therefore SF = \frac{\lambda(\cos i_a - \eta \sin i_a)\tan\phi}{\sin i_a + \eta \cos i_a}$$

$$\lambda = \frac{2\cos 54^0}{\sin(2 \bullet 54^0)} = \frac{1}{\sin 54^0}$$

$i_a = 23^0$

$$\therefore SF = \frac{(\tan 35^0)}{(\sin 54^0)} \frac{(\cos 23^0 - \eta \sin 23^0)}{(\sin 23^0 + \eta \sin 23^0)} \tag{5}$$

Equation (5) is used to plot the line in Figure 2 for CASE 1. Notice (from Figure 2) that when the seismic coefficient is $\eta \cong 0.32$, we reach a point on the line where the safety factor is SF = 1. By inserting this into an Swedge analysis, we should find that SF =1 there as well. The settings for dip and dip directions are found in figure 3 and are the same for all the cases.

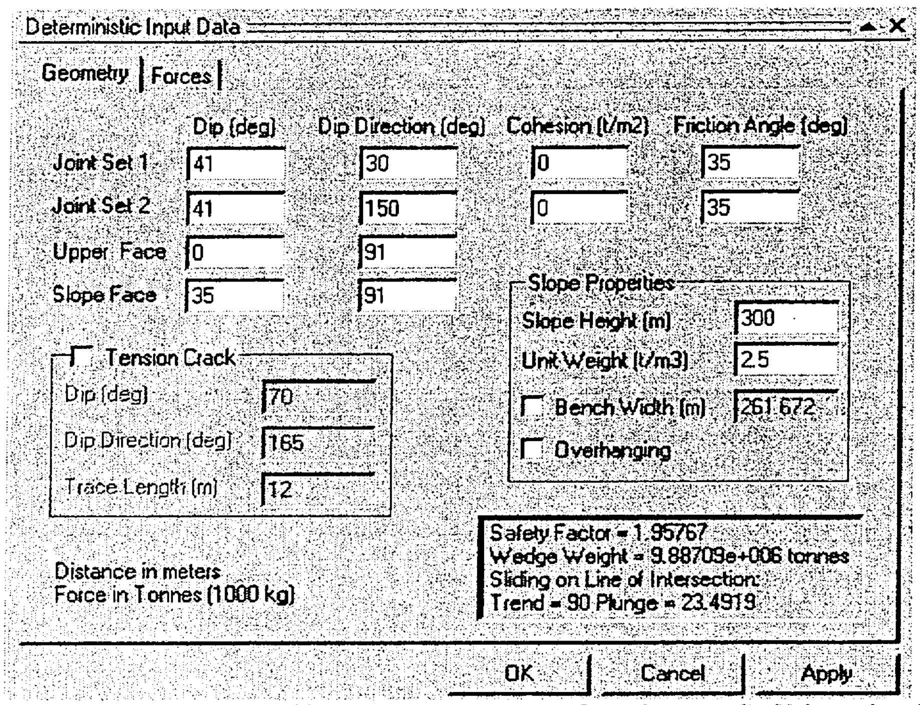


Figure 3. Analysis input within the Swedge program (refer to the manual). Values taken from the stereonet located on p.48 ,[1].

If we insert the seismic coefficient just discussed into the analysis, the safety factor will change to the value of SF ≅ 1. This once again will verify Swedge with the equations used in reference [1]. The result is shown in Figure 4 below.

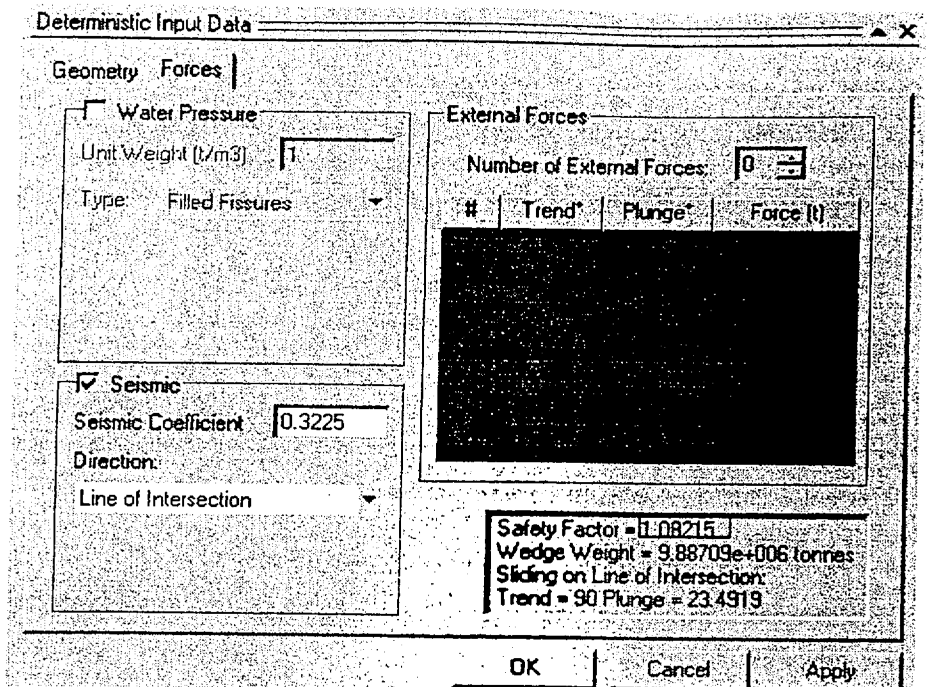


Figure 4. Analysis input within the Swedge program under the tab 'Forces' (refer to the manual).

CASE 2:

In this case we know that the excess fluid pressure (γ_e) is changing as the domain in Figure 2 from 0.0 to 0.5. The static fluid pressure is constant at γ_s = 0.4. On p.49, [1] the following is given:

$$c = 0;\ \ U_s = 0;\ \ U_t = 0;\ \ U_h = 0;\ \ \alpha = 1;\ \ \beta = 0;\ \ \eta = 0$$

Static fluid pressure: $U_{bs} = \gamma_s W$

Excess fluid pressure: $U_{be} = \gamma_e W$

$$\therefore U_b = (0.4 + \gamma_e)W$$

$$\therefore SF = \frac{(\lambda \cos i_a - 0.4 - \gamma_e)\tan\phi}{\sin i_a}$$

$$\lambda = \frac{2\cos 54^0}{\sin(2 \bullet 54^0)} = \frac{1}{\sin 54^0}$$

$i_a = 23^0$

$$SF = \frac{(\tan 35^0)}{(\sin 23^0)} \frac{(\cos 23^0 - 0.4 - \gamma_e)}{(\sin 54^0)} \qquad (6)$$

Equation (6) is used to plot the line in Figure 2 for CASE 2. Notice (from Figure 2) that when the excess fluid pressure coefficient is γ_e=0.06, we reach a point on the line where the safety factor is SF = 1. By inserting this into an Swedge analysis, we should find that SF =1 there as well. The settings for dip and dip directions are found in figure 3 and are the same for all the cases.

We will now utilize the Swedge program for water forces analysis of the wedge. The following is a derivation of how much pressure is put on the surface of each joint. A few assumptions were made.

$U_b = U_{b1} \sin\omega_1 + U_{b2} \sin\omega_2$

$U_b = P_1A_1 \sin\omega_1 + P_2A_2 \sin\omega_2$ (P is pressure (t/m^2) and A is surface area of each joint)

Click on the info viewer within the Swedge program and make sure that the analysis input is set up to that shown in figure 3. When inside the infoviewer, you will be given the wedge weight and the two joint areas.

Wedge weight=9.88709e+006 tonnes Wedge area (joint1)=68404.6 m^2 Wedge area (joint2)=69797.4 m^2

Assume: $P_1 \cong P_2 \cong P$
$A_1 \cong A_2 \cong A$
$\omega_1 \cong \omega_2 \cong \omega$

$$\therefore P = \frac{U_b}{2A\sin\omega}$$

A = average = 69101 m^2
W = 9.88709e+006 tonnes
At γ_e= 0.06,

$$\therefore U_b = (0.4 + 0.06)(9.88709e+006)$$
$$= (4.548e+006) \text{ tonnes}$$

$$\therefore P = \frac{(4.548e+006)}{2(69101)\sin 54^0} = 40.6 \frac{tonnes}{m^2}$$

In this case, we increase the friction angle from $\phi = 35^0$ to $\phi = 36^0$. Notice that this will not change the settings for weight or surface area of the joints. Based on the stereonet, the friction angle is simply within the range of 35 and 40 degrees. By changing it to a friction angle of $\phi = 36^0$, we achieve a better accuracy. Below, the safety factor turns to SF $\cong$ 1.

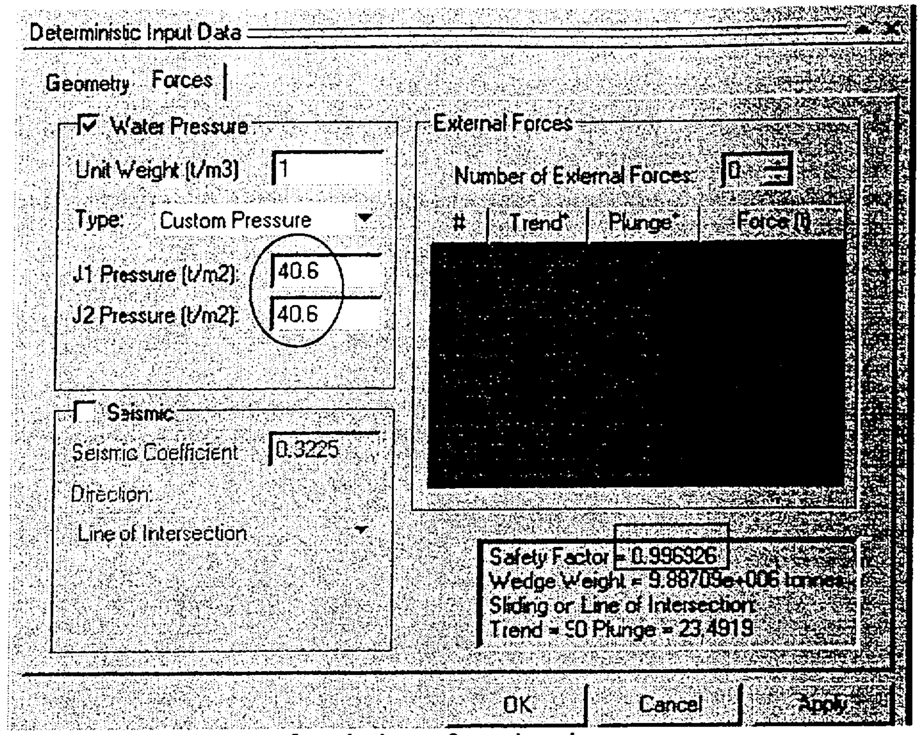


Figure 5. Custom pressure force is chosen for each wedge.

Our assumptions were valid due to the areas being almost the same and the Swedge program yielding a safety factor of SF = 1.

CASE 3:

Now we have a mass of rock where there is an earthquake present with increasing seismicity. The seismic coefficient (η) is constantly increasing from 0.0 to 0.5 as described in F igure 2. On p.49, [1] the following is given:

$$c = 0; \quad U_s = 0; \quad U_t = 0; \quad \alpha = 1;$$

The fluid pressure was kept constant during the earthquake.

$$\therefore SF = \frac{\lambda[W(\cos i_a - \eta \sin i_a) - U_b]\tan\phi}{W(\sin i_a + \eta \cos i_a)}$$

$$U_b = (0.4 + \gamma_e)W$$

$$\gamma_e = 0$$

$$\therefore U_b = 0.4W$$

$$\therefore SF = \frac{(\cos 23^0 - \eta \sin 23^0 - 0.4)(\tan 35^0)}{(\sin 23^0 + \eta \cos 23^0)(\sin 54^0)} \tag{7}$$

Equation (7) is used to plot the line in Figure 2 for CASE 3. Notice (from Figure 2) that when the seismic coefficient is $\eta = 0.05$ we reach a point on the line where the safety factor is SF = 1. Remember that the equation used for this plot is based on a constant fluid pressure. By inserting values for the seismic coefficient and also the fluid pressure into an Swedge analysis, we should find that SF =1 there as well.

We will now utilize the Swedge program for an analysis of the constant water and seismic forces. The following is a derivation of how much pressure is put on the surface of each joint.

$$U_b = 0.4W$$
$$W = 9.887e + 006$$

$$\therefore U_b = 3.955e + 006 \text{ tonnes}$$

$$P = {U_b}/{2A\sin\omega}$$

$$\therefore P = {(3.955\mathrm{e}+006)}/{2(69101)\sin 54^0} = 35.35 \frac{tonnes}{m^2}$$

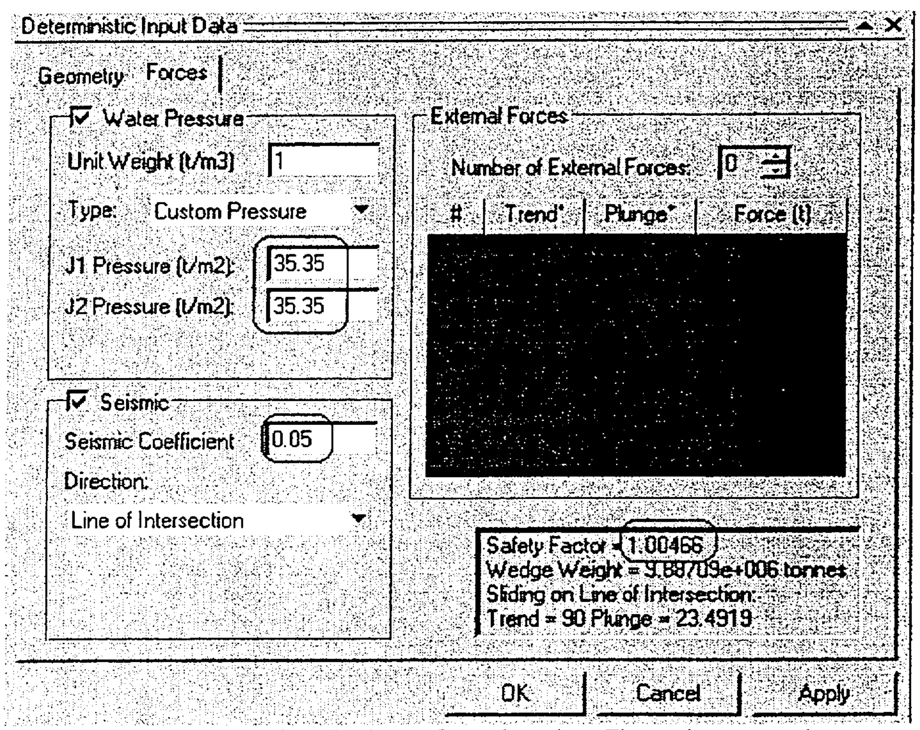


Figure 6. Custom seismic force is chosen for each wedge. The static pressure is constant and there is no excess fluid pressure.

The Swedge program is now verified with the 3rd case of this verification exercise. Our assumptions were valid due to the areas being almost the same and the Swedge program yielding a safety factor of SF = 1.

CASE 4:

Here we have a mass of rock and there is an earthquake present. Both the seismic coefficient (η) and the excess fluid pressure (γ_e) are constantly increasing (at the same time) from 0.0 to 0.5 as described in Figure 2. On p.49, [1] the following is given:

$$c = 0; \quad U_s = 0; \quad U_t = 0; \quad \alpha = 1;$$

$$\therefore SF = \frac{\lambda[W(\cos i_a - \eta \sin i_a) - U_b]\tan\phi}{W(\sin i_a + \eta \cos i_a)}$$

$$U_b = (0.4 + \gamma_e)W$$

$$\therefore SF = \frac{(\cos 23^0 - \eta \sin 23^0 - 0.4 - \gamma_e)\tan 35^0}{(\sin 54^0)(\sin 23^0 + \eta \cos 23^0)} \quad (8)$$

Equation (8) is used to plot the line in Figure 2 for CASE 3. Notice (from Figure 2) that when $\eta = \gamma_e = 0.02$, the safety factor is SF = 1. We will now verify this with Swedge.

$$U_b = U_{bs} + U_{be} = (0.4 + 0.02)W$$
$$W = 9.887e + 006$$
$$\therefore U_b = 4.153e + 006 \; tonnes$$

$$P = {U_b}/{2A \sin\omega}$$

$$\therefore P = (4.153e+006)/{2(69101)\sin 54^0} = 37.14 \frac{tonnes}{m^2}$$

We will now insert the values for seismicity and pressure into the program as shown in Figure 7 below.

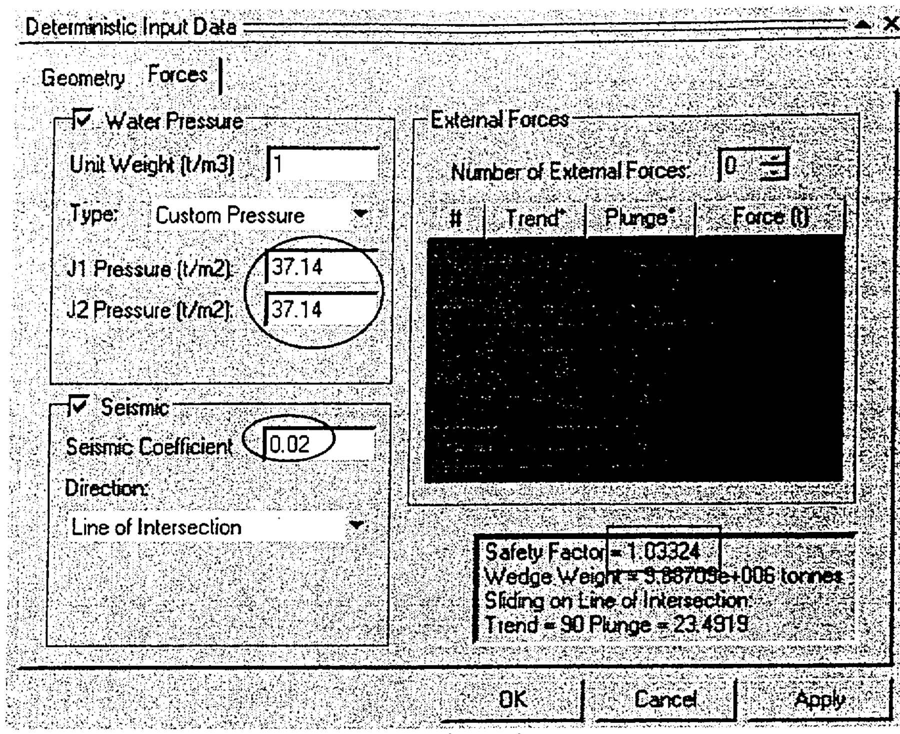


Figure 7. Pressure and seismicity are changing at the same rate.

When both values are inserted above, equation (8) is satisfied by showing that the safety factor SF = 1. The Swedge program is now verified with the 4th case of this verification exercise. Our assumptions were valid due to the areas being almost the same and the Swedge program yielding a safety factor of SF = 1.

NUCLEAR POWER GENERATION
CF3.ID4
ATTACHMENT 7.2

Index No. 402______
Binder No. ________

TITLE: CALCULATION COVER SHEET

Unit(s): 1 & 2

File No.: 52.27

Responsible Group: Civil

Calculation No.: 52.27.100.734

No. of Pages 3 pages + Index (4 pages) + 1 Attachment (65 pages)

Design Calculation YES [x] NO [ ]

System No. 42C

Quality Classification Q (Safety-Related)

Structure, System or Component: Independent Spent Fuel Storage Facility

Subject: Stability and Yield Analysis of Cross Section I-I' (GEO.DCPP.01.24, Rev. 1)

Electronic calculation YES [ ] NO [x]

Computer Model	Computer ID	Program Location	Date of Last Change

Registered Engineer Stamp: Complete A or B

A. Insert PE Stamp or Seal Below	B. Insert stamp directing to the PE stamp or seal
Expiration Date:	***REGISTERED ENGINEERS' STAMPS AND EXPIRATION DATES ARE SHOWN ON DWG 063618***

NOTE 1: Update DCI promptly after approval.
NOTE 2: Forward electronic calculation file to CCTG for uploading to EDMS.

TITLE: CALCULATION COVER SHEET

CALC No. 52.27.100.734, R0

RECORD OF REVISIONS

Rev No.	Status	Reason for Revision	Prepared By:	LBIE Screen	LBIE	Check Method*	LBIE Approval		Checked	Supervisor	Registered Engineer
		Remarks	Initials/ LAN ID/ Date	Yes/ No/ NA	Yes/ No/ NA		PSRC Mtg. No.	PSRC Mtg. Date	Initials/ LAN ID/ Date	Initials/ LAN ID/ Date	Signature/ LAN ID/ Date
0	F	Acceptance of Geosciences Calc. No. GEO.DCPP.01.24, Rev. 1. Calc. supports current edition of 10CFR72 DCPP License Application to be reviewed by NRC prior to implementation. Prepared per CF3.ID17.	AFT2 AT 12/15/01	[ ] Yes [ ] No [x] NA	[ ] Yes [ ] No [x] NA	[ ] A [ ] B [x] C	N/A	N/A	N/A	[signature] LJS2 12/17/01	[signature] LJS2 12/17/01
				[ ] Yes [ ] No [ ] NA	[ ] Yes [ ] No [ ] NA	[ ] A [ ] B [ ] C					
				[ ] Yes [ ] No [ ] NA	[ ] Yes [ ] No [ ] NA	[ ] A [ ] B [ ] C					

*Check Method: A: Detailed Check, B: Alternate Method (note added pages), C: Critical Point Check

SUBJECT Stability and Yield Acceleration Analysis of Cross Section I-I'

MADE BY A. Tafoya DATE 12/15/01 CHECKED BY N/A DATE

Table of Contents:

SUBJECT Stability and Yield Acceleration Analysis of Cross Section I-I'

MADE BY A. Tafoya KI DATE 12/15/01 CHECKED BY N/A DATE

1- This table cross references between Geosciences calculation numbers and DCPP (Civil Group's) calculation numbers. This section is For Information Only.

Cross-Index
(For Information Only)

Item No.	Geosciences Calc. No.	Title	PG&E Calc. No.	Comments
1	GEO.DCPP.01.01	Development of Young's Modulus and Poisson's Ratios for DCPP ISFSI Based on Field Data	52.27.100.711	
2	GEO.DCPP.01.02	Determination of Probabilistically Reduced Peak Bedrock Accelerations for DCPP ISFSI Transporter Analyses	52.27.100.712	
3	GEO.DCPP.01.03	Development of Allowable Bearing Capacity for DCPP ISFSI Pad and CTF Stability Analyses	52.27.100.713	
4	GEO.DCPP.01.04	Methodology for Determining Sliding Resistance Along Base of DCPP ISFSI Pads	52.27.100.714	
5	GEO.DCPP.01.05	Determination of Pseudostatic Acceleration Coefficient for Use in DCPP ISFSI Cutslope Stability Analyses	52.27.100.715	
6	GEO.DCPP.01.06	Development of Lateral Bearing Capacity for DCPP CTF Stability Analyses	52.27.100.716	
7	GEO.DCPP.01.07	Development of Coefficient of Subgrade Reaction for DCPP ISFSI Pad Stability Checks	52.27.100.717	
8	GEO.DCPP.01.08	Determination of Rock Anchor Design Parameters for DCPP ISFSI Cutslope	52.27.100.718	
9	GEO.DCPP.01.09	Determination of Applicability of Rock Elastic	52.27.100.719	Calculation to be replaced by letter

Cross-Index
(For Information Only)

Item No.	Geosciences Calc. No.	Title	PG&E Calc. No.	Comments
		Applicability of Rock Elastic Stress-Strain Values to Calculated Strains Under DCPP ISFSI Pad		replaced by letter
10	GEO.DCPP.01.10	Determination of SSER 34 Long Period Spectral Values	52.27.100.720	
11	GEO.DCPP.01.11	Development of ISFSI Spectra	52.27.100.721	
12	GEO.DCPP.01.12	Development of Fling Model for Diablo Canyon ISFSI	52.27.100.722	
13	GEO.DCPP.01.13	Development of Spectrum Compatible Time Histories	52.27.100.723	
14	GEO.DCPP.01.14	Development of Time Histories with Fling	52.27.100.724	
15	GEO.DCPP.01.15	Development of Young's Modulus and Poisson's Ratio Values for DCPP ISFSI Based on Laboratory Data	52.27.100.725	
16	GEO.DCPP.01.16	Development of Strength Envelopes for Non-jointed Rock at DCPP ISFSI Based on Laboratory Data	52.27.100.726	
17	GEO.DCPP.01.17	Determination of Mean and Standard Deviation of Unconfined Compression Strengths for Hard Rock at DCPP ISFSI Based on Laboratory Tests	52.27.100.727	
18	GEO.DCPP.01.18	Determination of Basic Friction Angle Along Rock Discontinuities at DCPP ISFSI Based on Laboratory	52.27.100.728	

Pacific Gas and Electric Company
Engineering - Calculation Sheet
Project: Diablo Canyon Unit ( )1 ( ) 2 (x) 1&2

69-392(10/92)
Engineering
CALC. NO. 52.27.100.734
REV. NO. 0
SHEET NO. 1-3 of 4

SUBJECT Stability and Yield Acceleration Analysis of Cross Section I-I'
MADE BY A. Tafoya DATE 12/15/01 CHECKED BY N/A DATE

Cross-Index
(For Information Only)

Item No.	Geosciences Calc. No.	Title	PG&E Calc. No.	Comments
		Hoek-Brown Equations		
20	GEO.DCPP.01.20	Development of Strength Envelopes for Shallow Discontinuities at DCPP ISFSI Using Barton Equations	52.27.100.730	
21	GEO.DCPP.01.21	Analysis of Bedrock Stratigraphy and Geologic Structure at the DCPP ISFSI Site	52.27.100.731	
22	GEO.DCPP.01.22	Kinematic Stability Analysis for Cutslopes at DCPP ISFSI Site	52.27.100.732	
23	GEO.DCPP.01.23	Pseudostatic Wedge Analyses of DCPP ISFSI Cutslopes (SWEDGE Analysis)	52.27.100.733	
24	GEO.DCPP.01.24	Stability and Yield Acceleration Analysis of Cross-Section I-I'	52.27.100.734	
25	GEO.DCPP.01.25	Determination of Seismic Coefficient Time Histories for Potential Siding Masses Along Cut Slope Behind ISFSI Pad	52.27.100.735	
26	GEO.DCPP.01.26	Determination of Earthquake-Induced Displacements of Potential Sliding Masses on ISFSI Slope	52.27.100.736	
27	GEO.DCPP.01.27	Cold Machine Shop Retaining Wall Stability	52.27.100.737	
28	GEO.DCPP.01.28	Stability and Yield Acceleration Analysis of Potential Sliding Masses Along DCPP ISFSI Transport Route	52.27.100.738	

Cross-Index
(For Information Only)

Item No.	Geosciences Calc. No.	Title	PG&E Calc. No.	Comments
		Retaining Wall Stability		
28	GEO.DCPP.01.28	Stability and Yield Acceleration Analysis of Potential Sliding Masses Along DCPP ISFSI Transport Route	52.27.100.738	
29	GEO.DCPP.01.29	Determination of Seismic Coefficient Time Histories for Potential Sliding Masses on DCPP ISFSI Transport Route	52.27.100.739	
30	GEO.DCPP.01.30	Determination of Potential Earthquake-Induced Displacements of Potential Sliding Masses Along DCPP ISFSI Transport Route	52.27.100.740	
31	GEO.DCPP.01.31	Development of Strength Envelopes for Clay Beds at DCPP ISFSI	52.27.100.741	
32	GEO.DCPP.01.32	Verification of Computer Program SPCTLR.EXE	52.27.100.742	
33	GEO.DCPP.01.33	Verification of Program UTEXAS3	52.27.100.743	
34	GEO.DCPP.01.34	Verification of Computer Code - QUAD4M	52.27.100.744	
35	GEO.DCPP.01.35	Verification of Computer Program DEFORMP	52.27.100.745	
36	GEO.DCPP.01.36	Reserved	52.27.100.746	
37	GEO.DCPP.01.37	Development of Freefield Ground Motion Storage Cask Spectra and Time Histories for the Used Fuel Storage Project	52.27.100.747	

DEC. 15. 2001 4:01PM P 4
FROM : Cluff - San Francisco PHONE NO. : 415 564 6697
NO.089 P.3/5

PACIFIC GAS AND ELECTRIC COMPANY
GEOSCIENCES DEPARTMENT
CALCULATION DOCUMENT

Calc Number	GEO.DCPP.01.24
Revision	1
Date	12/13/01
Calc Pages:	62
Verification Method:	A
Verification Pages:	1

TITLE: Stability and Yield Acceleration Analysis of Cross Section I-I'

PREPARED BY: [signature] DATE 12/13/01
Karthik Narayanan
Printed Name
Geomatrix
Organization

VERIFIED BY: [signature] DATE 12/14/01
Faiz I. Makdisi
Printed Name
Geomatrix
Organization

APPROVED BY: [signature] DATE 12/15/01
Lloyd Cluff
Printed Name
Geosciences
Organization

REGISTERED GEOLOGIST
LLOYD S. CLUFF
No. EG667
CERTIFIED ENGINEERING GEOLOGIST
STATE OF CALIFORNIA

Exp. 12/31/02

PACIFIC GAS AND ELECTRIC COMPANY
GEOSCIENCES DEPARTMENT
CALCULATION DOCUMENT

Calc Number	GEO.DCPP.01.24
Revision	1
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TITLE: Stability and Yield Acceleration Analysis of Cross Section I-I'

PREPARED BY: [signature] DATE 12/13/01

KARTHIK NARAYANAN — Printed Name
GEOMATRIX — Organization

VERIFIED BY: [signature] DATE 12/14/01

Faiz I. Makdisi — Printed Name
Geomatrix — Organization

APPROVED BY: ______________ DATE ______________

Printed Name — Organization

REGISTERED GEOLOGIST
LLOYD S. CLUFF
No. EG567
CERTIFIED ENGINEERING GEOLOGIST
STATE OF CALIFORNIA

Exp. 12/31/02

Stability and Yield Acceleration Analysis of Cross Section I-I′
Calc. Number GEO.DCPP.01.24

Record of Revisions

Rev. No.	Reason for Revision	Revision Date
00	Initial Issue	11/07/01
01	Revised test to incorporate PG&E NQS, UFSP, and Geosciences comments including: 1) reference used for back calculation; 2) inclusion of record of revision sheet, and 3) minor editorial changes.	12/13/01

Calculation Title: Stability and Yield Acceleration Analysis of Cross Section I-I'
Calculation No.: GEO.DCPP.01.24
Revision No.: 1
Calculation Author: Karthik Narayanan and Chris Krivanec (Geomatrix Consultants)
Calculation Date: December 13, 2001

PURPOSE

The purpose of this calculation is to evaluate the stability and yield acceleration of potential sliding masses postulated for the slope behind the proposed DCPP ISFSI site. An approximate back analysis of the slope in its pre-excavated (pre-1971) configuration is also conducted to assess the degree of conservatism in the assumed lateral continuity and shear strength of the clay beds. The analyses described in this calculation package are conducted in accordance with the Geomatrix Consultants, Inc. Work Plan "Laboratory Testing of Soil and Rock Samples, Slope Stability Analysis, and Excavation design for Diablo Canyon Power Plant Independent Spent Fuel Storage Installation Site."

ASSUMPTIONS

The assumptions made to the stability and yield acceleration analysis are:

1. The clay beds are saturated. This assumption is reasonable because rainfall would infiltrate the slope through the fractured rock and temporarily perch on the clay beds during the short rainy season, and would saturate at least the upper part of the clay.

2. There is little water in the slope. This assumption is reasonable because the ground water table is about 200 feet below the ISFSI site and because the rock is fractured and well drained. No springs from perched water tables occur near the ISFSI slope.

3. The lateral margins of the potential sliding masses have no strength. This is conservative because the margins of a potential failure wedge would follow, in part, discontinuous joints, small faults, and, in part, break through rock, which would provide some resistance to sliding.

4. The upper 20 feet of the rock mass forming the head of a potential sliding mass is modeled as a tension crack, i.e., the zone is given no strength. This assumption is based on the geologic interpretation presented in the explanations on the figures provided in Attachment B, as confirmed in Attachment J.

INPUTS

The information required for the slope stability and yield acceleration analyses are the surface topography, geometry of potential sliding masses, and soil and rock strengths and unit weights. The analyses described in this calculation package were conducted for cross section I-I' (Attachment A, as confirmed in Attachments H and J) transmitted to Geomatrix on September 27, 2001. Surface topography and the location of potential sliding masses were taken from the cross sections transmitted to Geomatrix on October 10, 2001 (Attachment B, as confirmed in Attachment J). Two additional potential sliding masses were also analyzed at the request of the ITR. The potential sliding masses analyzed in this calculation package are shown in Attachment B.

Drained rock strengths were taken from Attachment C (as confirmed in Attachment J). Drained and undrained clay bed strength parameters are shown as Figure D-1 and D-2, respectively, in Attachment D. A bi-linear undrained strength envelope, described in GEO.DCPP.01.31, was used for the clay beds.

A summary of properties used for the stability and yield acceleration analyses is shown on page 9. The unit weight for rock was taken as 140 pounds per cubic foot (pcf) per the recommendations transmitted to Geomatrix on June 28, 2001 (Attachment E, as confirmed in Attachment I). The unit weight of the clay bed material was evaluated from laboratory tests (presented in their entirety in Witter, 11/5/01 [Data Report G]) performed on samples collected in test pits in the vicinity of the ISFSI site. A summary of the unit weights measured in the laboratory is shown in Attachment F. The average moist unit weight of the clay samples is 120 pcf. A value of 115 pcf was used for the stability analysis. It is noted that the unit weight of the clay beds has no practical effect on the results.

For the back-calculation of the pre-excavated slope, a yield acceleration of 0.65g was used. This yield acceleration was taken from the relationship between yield acceleration and deformation shown in Figure 14 for a displacement of 4-inches (from Attachment G). The method used to calculate the yield acceleration is discussed in the "Methods" section of this calculation summary.

METHODS

Methods used for slope stability and yield acceleration analyses are described in this section. The methodology for the back-`calculation of clay bed strengths is also described.

Slope Stability Analysis

Slope stability analyses were performed using the computer program UTEXAS3 (Wright, 1990). Analyses were conducted to evaluate the stability of potential sliding masses identified in Attachment B. Spencer's method, a method of slices that satisfies force and moment equilibrium, was used for the analyses. Drained strengths were used for the clay and rock for the evaluation of long-term static stability.

Yield Acceleration Analysis

Computations were made using UTEXAS3 to identify sliding masses with the lowest yield acceleration. The yield accelerations will be used in GEO.DCPP.01.26 for evaluation of earthquake-induced displacements. For the calculation of yield accelerations, a two-stage approach was used. The two-stage approach consists of first calculating the normal stresses on the failure plane under pre-earthquake (i.e., long-term static) loading conditions using drained strength properties. For each slice, the normal effective stress on the failure plane was then used to calculate the undrained strength on the failure plane. In the second stage of the analysis, horizontal seismic coefficients were applied to the potential sliding mass and the stability analysis was repeated using the undrained strengths calculated at the end of the first stage. The yield acceleration was calculated by incrementally increasing the horizontal seismic coefficient until the factor of safety equaled unity.

Drained rock strengths were used for both stages of the yield acceleration analysis. Drained clay strengths were used for the first stage, and a bi-linear undrained strength envelope was used for the clay beds in the second stage of the analysis.

Potential sliding masses found in this calculation to have low yield accelerations are analyzed further in calculation package GEO.DCPP.01.26 to evaluate their potential for earthquake-induced deformations.

Back-Calculation of Clay Bed Strengths

Calculations were conducted for the pre-excavated slope configuration (shown as the dashed line on Attachment A) to assess the degree of conservatism in the assumed lateral extent and undrained strength of the clay beds. The premise of the back-calculation is that historical earthquakes on the Hosgri fault have not caused slope movements large enough (less than 4-inches per event, as described in Attachment G) to be detected from geologic evidence. The method followed for the back-calculation is summarized below.

The back-calculation was conducted in the program UTEXAS3 using the same multi-stage approach as described for the yield acceleration analysis. First, the surfaces of potential sliding masses 1a and 1b (Attachment B) were extended to the pre-excavated ground surface. Then an undrained strength was specified for the clay beds, and a yield acceleration was calculated. The clay bed strengths were varied until a target value of the yield acceleration was calculated that would produce the 4-inch per-event displacement for the ground motion used.

As in the yield acceleration analysis for the existing slope configuration (described previously), a relationship between displacement and yield acceleration was derived for the back-calculation. This relationship was developed using the procedure described in GEO.DCPP.01.26. Ground motion sets 1 and 5 were multiplied by 1.6 (per Attachment G) to approximate the seismic coefficient time histories. These input motions were double-integrated to estimate earthquake-induced displacements. The resulting relationship between displacement and yield acceleration for ground motion sets 1 and 5 are shown on Figures 13 and 14. The plots of displacement versus yield acceleration indicate that yield accelerations of 0.75 and 0.65 for ground motion sets 1 and 5, respectively, are needed to produce the 4-inch displacement. The lower of the two yield accelerations, 0.65 (corresponding to ground motion set 5), was used for the back-calculation because it would result in lower, more conservative undrained clay bed strengths.

The potential sliding masses analyzed in the back-calculation are shown on Figures 11 and 12. The sliding mass on Figure 11 was developed by extending sliding mass 1a (Attachment B) horizontally to the pre-1971 slope. The clay bed along the bottom of slide mass 1a was extended to the surface of the pre-1971 slope. The slide mass on Figure 12 was developed by extending slide mass 1b (Attachment B) horizontally to the pre-1971 ground surface. Since the clay bed along the slide plane did not daylight in the current configuration of the slope, it was not extended to the pre-1971 ground surface (the slide plane cuts through rock from the terminus of the clay bed to the pre-1971 ground surface).

SOFTWARE

The calculations of slope stability and yield acceleration and the back-calculation of clay bed strength were conducted using the program UTEXAS3. The program verification appears in GEO.DCPP.01.33.

ANALYSIS

The slope stability and yield acceleration calculations and the back-calculation of clay bed strength were conducted in UTEXAS3. The input and output files for the calculation of long-term stability and yield acceleration and the back-calculation are contained in the enclosed compact disc.

RESULTS

The results of the stability and yield acceleration analyses are summarized on Table 2 and in Figures 1 through 10. The lowest factor of safety for the long-term static stability analysis is 1.62, which was calculated for surface 1b shown on Figure 3. Based on standard engineering practice, this factor of safety is considered adequate for long-term stability. The lowest calculated yield acceleration was 0.19, corresponding to surface 2c shown on Figure 5. The earthquake-induced displacement corresponding to this yield acceleration is discussed in GEO.DCPP.01.26.

The clay bed strengths from back-calculation of the pre-excavated ground surface are summarized on page 11. Several combinations of the undrained strength parameters c and ϕ were considered in the back-calculation. As shown in the results on page 11, the undrained clay bed strengths from the back-calculation of the pre-excavated slope configuration are substantially greater than the undrained strength parameters developed from the laboratory test data. The undrained clay bed strengths from the back-calculation are also considerably higher than would be expected for soils similar to the clay bed material. These observations substantiate one or both of the following.

- The undrained clay bed strength parameters developed from laboratory test data for use in the stability and yield acceleration analyses are conservative.
- The lateral continuity of the clay beds is not as great as indicated in the geologic model.

These observations indicate that analysis procedures used for evaluation of long-term stability and yield acceleration are conservative.

REFERENCES

1. Geomatrix Consultants, Inc. – Work Plan, Laboratory Testing of Soil and Rock Samples, Slope Stability Analyses, and Excavation Design for Diablo Canyon Power Plant Independent Spent Fuel Storage Installation Site, Revision 4, dated December 8, 2000.
2. GEO.DCPP.01.26 – Determination of potential earthquake-induced displacements of potential sliding masses on DCPP ISFSI slope, Revision 1.
3. GEO.DCPP.01.31 – Development of strength envelopes for clay beds, Revision 1.
4. GEO.DCPP.01.33 – Verification of program UTEXAS3, Revision 1.
5. Witter – Letter from Rob Witter to Rob White (November 5, 2001), entitled, "Completion of Data Report," with enclosed Data Report G, Laboratory Test of Soil Data.

6. Wright, S.G. (1990) – UTEXAS3, A computer program for slope stability calculations, May 1990, Shinoak Software, Austin, Texas.

TABLE OF CONTENTS

ATTACHMENTS

Attachment A: Letter to Faiz Makdisi from Jeff Bachhuber, dated September 27, 2001. Subject: Transmittal of Revised Geologic Section I-I', DCPP ISFSI Site. Letter and Draft Figure 21-19, Cross Section I-I' attached as pages 27 through 29.

Attachment B: Letter to Faiz Makdisi from Jeff Bachhuber, dated October 10, 2001. Subject: Transmittal of Revised Rock Mass Failure Models – DCPP ISFSI Project. Letter and Draft Figures 21-45, 21-46, and 21-47 attached as pages 31 through 34.

Attachment C: Letter to Faiz Makdisi from Rob White, dated June 24, 2001. Subject: Recommended rock strength design parameters for DCPP ISFSI site slope stability analyses, attached as pages 36 and 37.

Attachment D: Figures D-1 and D-2 from Calculation GEO.DCPP.01.31, and determination of values to enter into analysis from figures, attached as pages 39 and 40.

Attachment E: Email to Karthik Narayanan from Rob White, dated June 28, 2001. Subject: Unit weights for stability analysis, attached as page 42.

Attachment F: Table of clay bed bed unit weights derived from Data Report entitled "Soil Laboratory Data". Table F-1 attached as page 44.

Attachment G: Letter from Rob White to Faiz Makdisi dated December 13, 2001. Subject: Confirmation of ground motion parameters for back calculations, attached as pages 46 and 47.

Attachment H : Letter to Faiz Makdisi from Rob White dated September 28, 2001. Subject: Confirmation of transmittal of inputs for DCPP ISFSI slope stability analyses, attached as pages 49 and 50.

Attachment I: Letter to Faiz Makdisi from Rob White dated October 25, 2001. Subject: Input parameters for calculations, attached as pages 52 through 56.

Attachment J: Letter to Faiz Makdisi from Rob White dated October 31, 2001. Subject: Confirmation of preliminary inputs to calculations for DCPP ISFSI site, attached as pages 58 through 62.

ENCLOSURES

Compact disc labeled, "PG&E DCPP ISFSI, GEO.DCPP.01.24, Rev. 1; GEO.DCPP.01.25, Rev. 1; and GEO.DCPP.01.26., Rev. 1, December 13, 2001," and containing the input and output files for the back-calculation and calculation of long-term stability and yield acceleration.

TABLE 1
MATERIAL PROPERTIES USED IN SLOPE STABILITY AND YIELD ACCELERATION ANALYSES

Material	Unit Weight (pcf)	Drained Strength	Undrained Strength
Clay Bed	115	$c' = 0$, $\phi' = 22^\circ$	Lower of: $c = 800$ psf, $\phi = 15^\circ$ or $\phi = 29^\circ$[1]
Rock Units Tofb-1 and Tofb-2	140	$c' = 0$, $\phi' = 50^\circ$	---

[1] Undrained strength of clay bed material is described in more detail in GEO.DCPP.01.31. Plots of drained and undrained strength envelopes are also shown in this calculation package in Attachment D.

TABLE 2

FACTORS OF SAFETY AND YIELD ACCELERATIONS COMPUTED FOR POTENTIAL SLIDING MASSES

Wedge	FS (Long-Term)	k_y (g)	Input/Output files for UTEXAS3
1a	2.55	0.28	Beda1a.dat/Beda1a.out
1b	1.62	0.20	Beda1b.dat/Beda1b.out
2a	2.55	0.31	Beda2a.dat/Beda2a.out
2b	2.16	0.24	Beda2b.dat/Beda2b.out
2c	2.18	0.19	Beda2c.dat/Beda2c.out
3a	2.86	0.44	Beda3a.dat/Beda3a.out
3b	2.70	0.39	Beda3b.dat/Beda3b.out
3c	2.26	0.25	Bede3cm2.dat/Bede3cm2.out
3c-1	2.38	0.28	Beda3c.dat/Beda3c.out
3c-2	2.28	0.23	Beda3cm.dat/Beda3cm.out

Subject SUMMARY OF BACKCALC'D CLAY STRENGTHS

GEO.DCPP.01.24
REVISION 1

By KRN Checked By FIM

Date 10/23/01 Date 10/25/01

SUMMARY OF RESULTS

- BACK CALC OF POTENTIAL SLIDE MASS [1b] w/ $k_y = 0.65$

$c = 2500$ psf, $\phi = 23°$

$c = 800$ psf, $\phi = 26°$

$c = 0$ psf, $\phi = 37°$

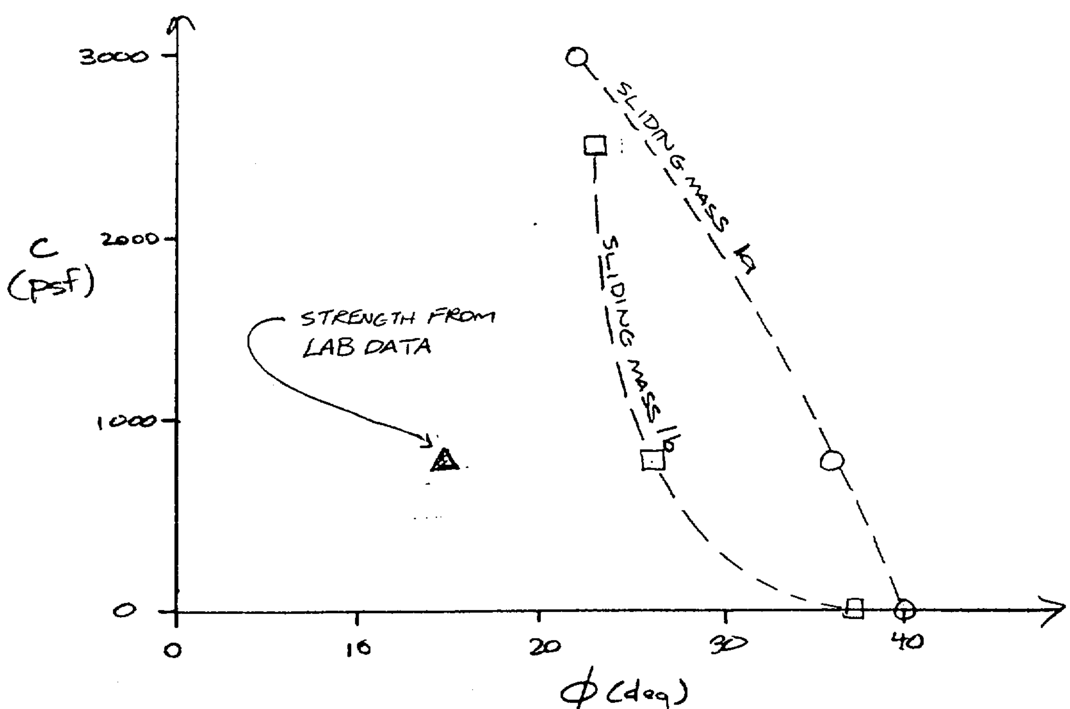
- BACK CALC OF POTENTIAL SLIDE MASS (1a) w/ $k_y = 0.65$

AND CLAY BED EXTENDED TO THE PRE-1971 GROUND SURFACE

$c = 3000$ psf, $\phi = 22°$

$c = 800$ psf, $\phi = 36°$

$c = 0$ psf, $\phi = 40°$



GEO.DCPP.01.24
REVISION Ø

GEOMATRIX CONSULTANTS

UTEXAS3 2-Stage Stability Analysis
Corss Section I-I', Diablo Canyon Power Plant ISFSI
Potential Sliding Mass **3b**
Long Term Factor of Safety = 2.70
Yield Acceleration = 0.39
Filename: Beda3b.dat

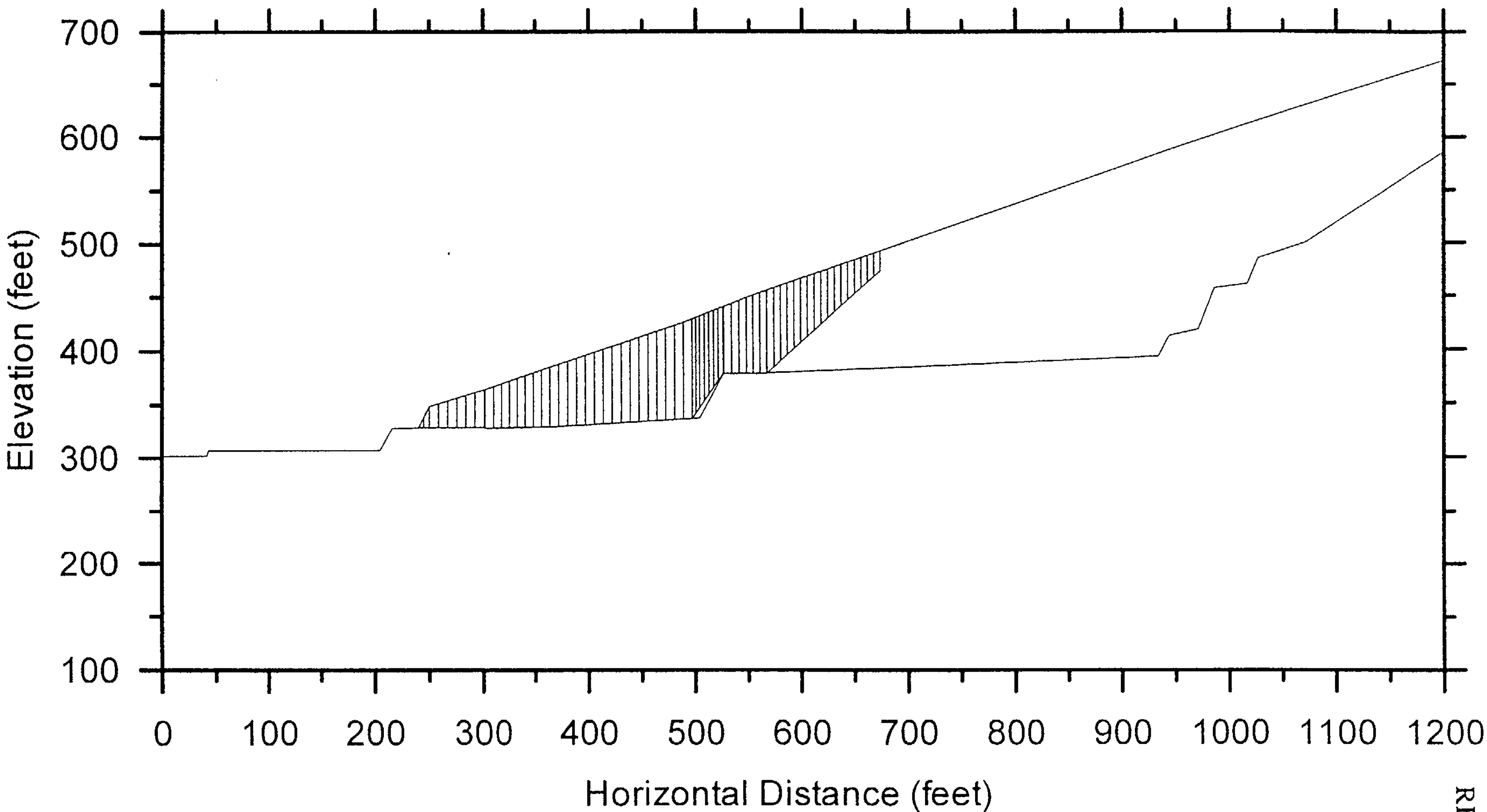


FIGURE 1

UTEXAS3 2-Stage Stability Analysis
Cross Section I-I', Diablo Canyon Power Plant ISFSI
Potential Sliding Mass **1a**
Long Term Factor of Safety = 2.55
Yield Acceleration = 0.28
Filename: Beda1a.dat

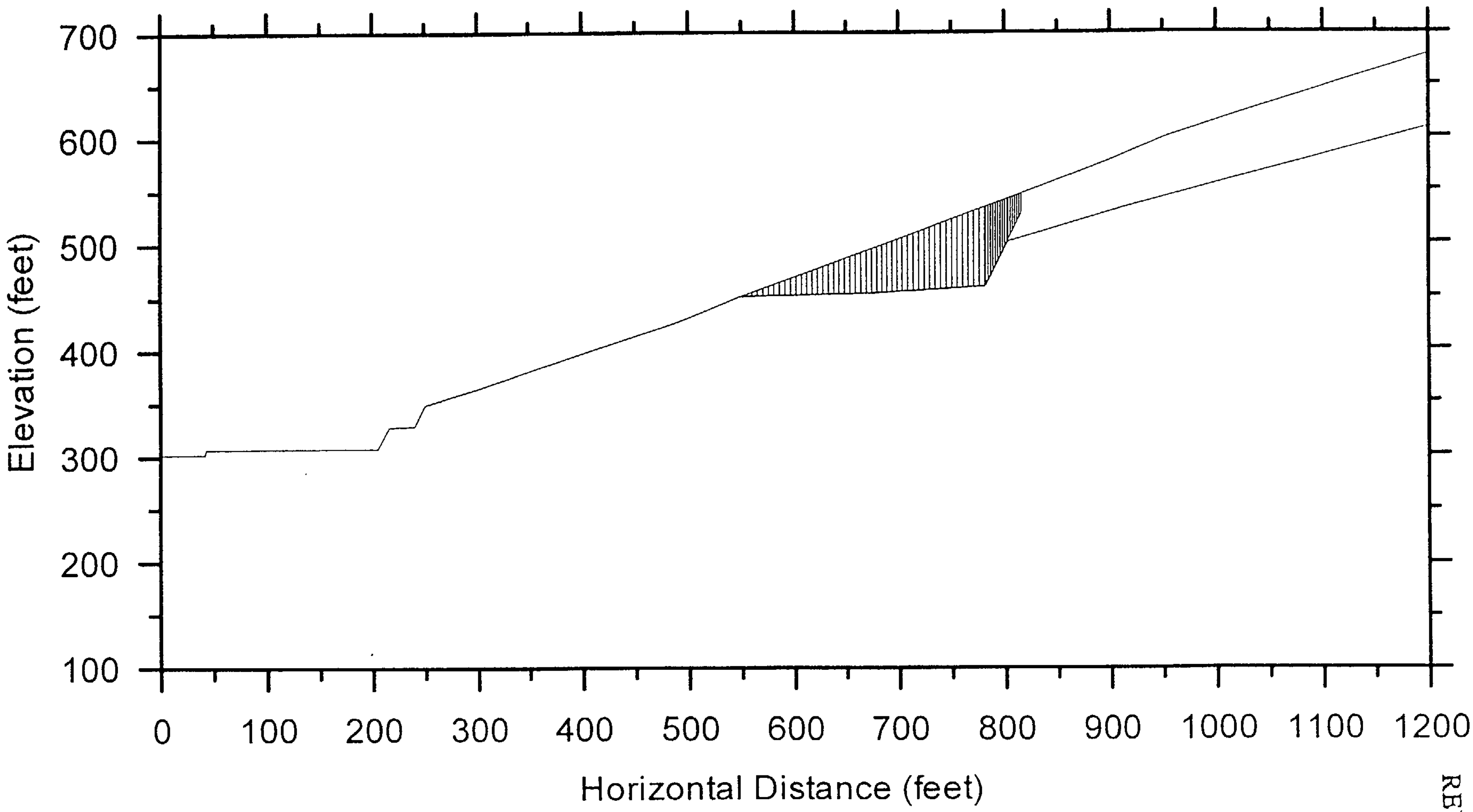


FIGURE 2

UTEXAS3 2-Stage Stability Analysis
Cross Section I-I', Diablo Canyon Power Plant ISFSI
Potential Sliding Mass **1b**
Long Term Factor of Safety = 1.62
Yield Acceleration = 0.20
Filename: Beda1b.dat

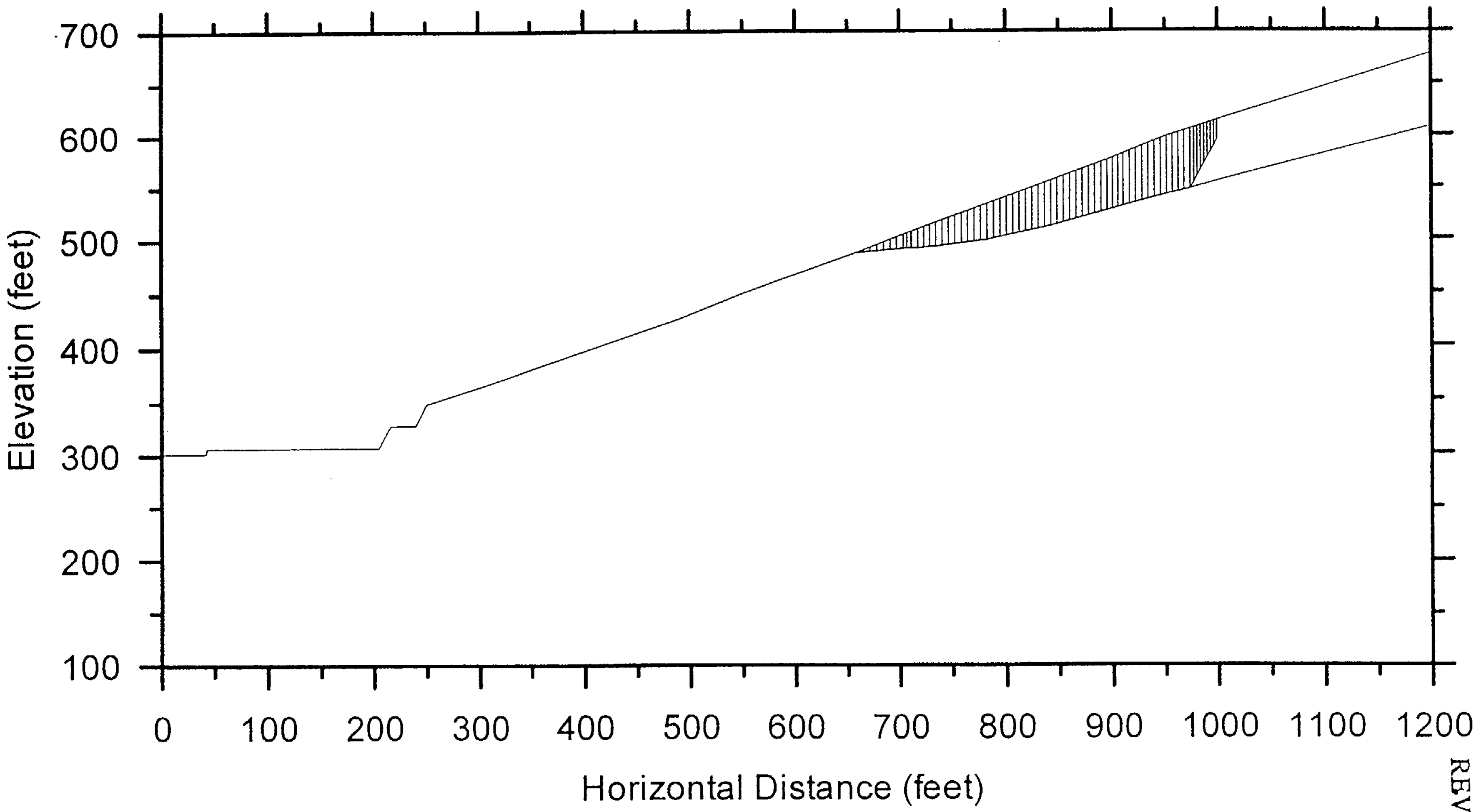


FIGURE 3

UTEXAS3 2-Stage Stability Analysis
Cross Section I-I', Diablo Canyon Power Plant ISFSI
Potential Sliding Mass **2a**
Long Term Factor of Safety = 2.55
Yield Acceleration = 0.31
Filename: Beda2a.dat

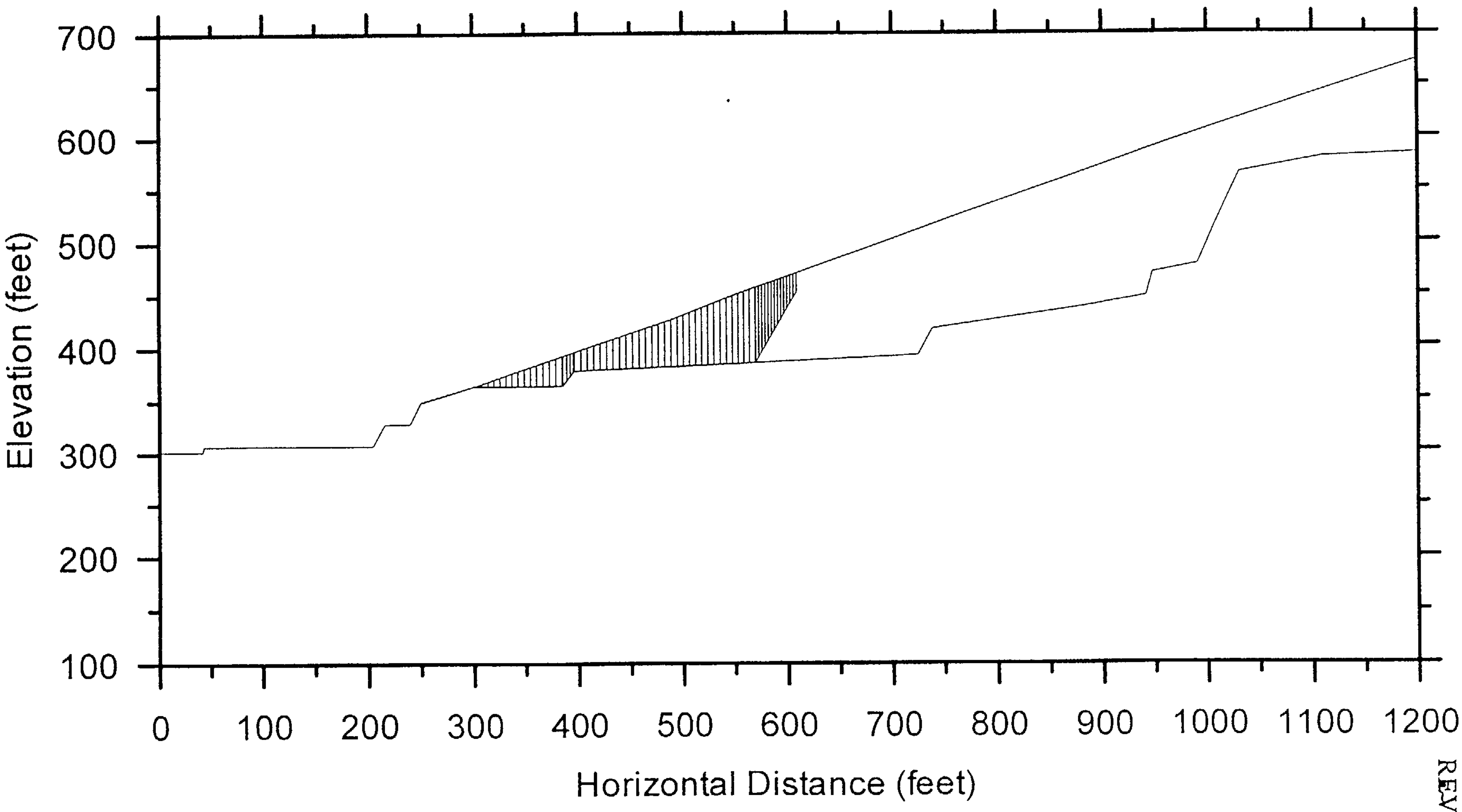


FIGURE 4

UTEXAS3 2-Stage Stability Analysis
Corss Section I-I', Diablo Canyon Power Plant ISFSI
Potential Sliding Mass **2b**
Long Term Factor of Safety = 2.16
Yield Acceleration = 0.24
Filename: Beda2b.dat

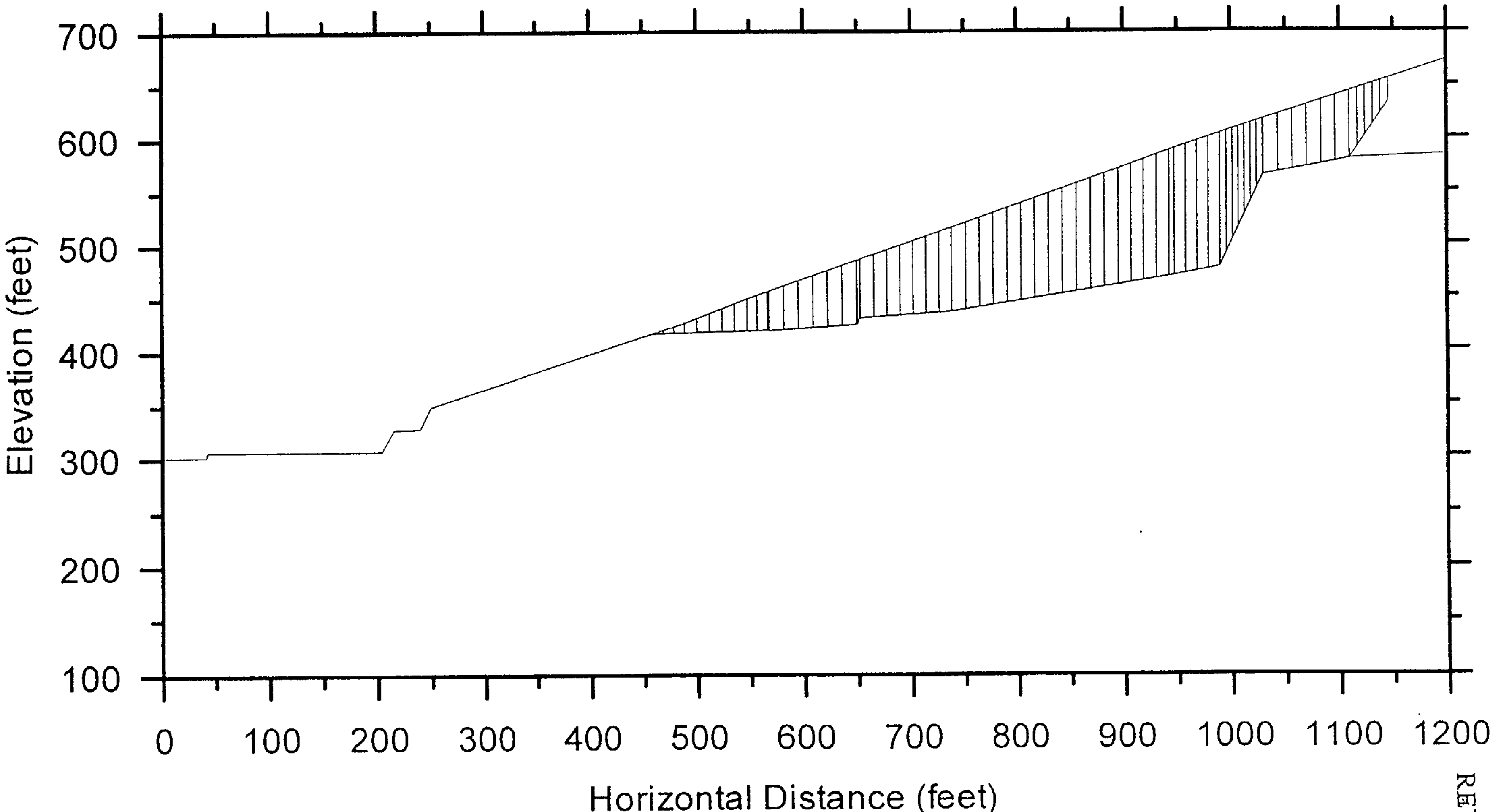


FIGURE 5

UTEXAS3 2-Stage Stability Analysis
Corss Section I-I', Diablo Canyon Power Plant ISFSI
Potential Sliding Mass **2c**
Long Term Factor of Safety = 2.18
Yield Acceleration = 0.19
Filename: Beda2c.dat

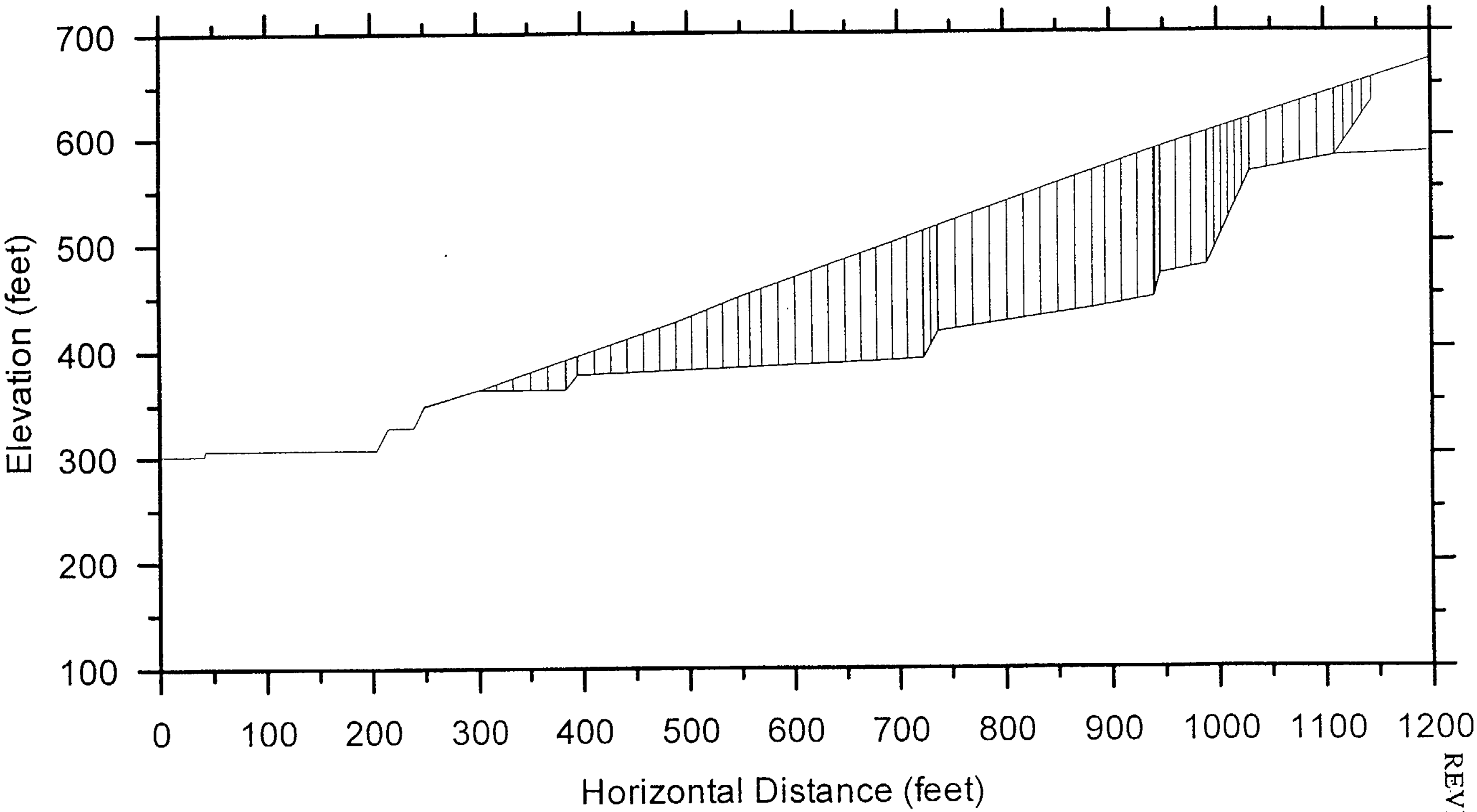


FIGURE 6

UTEXAS3 2-Stage Stability Analysis
Corss Section I-I', Diablo Canyon Power Plant ISFSI
Potential Sliding Mass **3a**
Long Term Factor of Safety = 2.86
Yield Acceleration = 0.44
Filename: Beda3a.dat

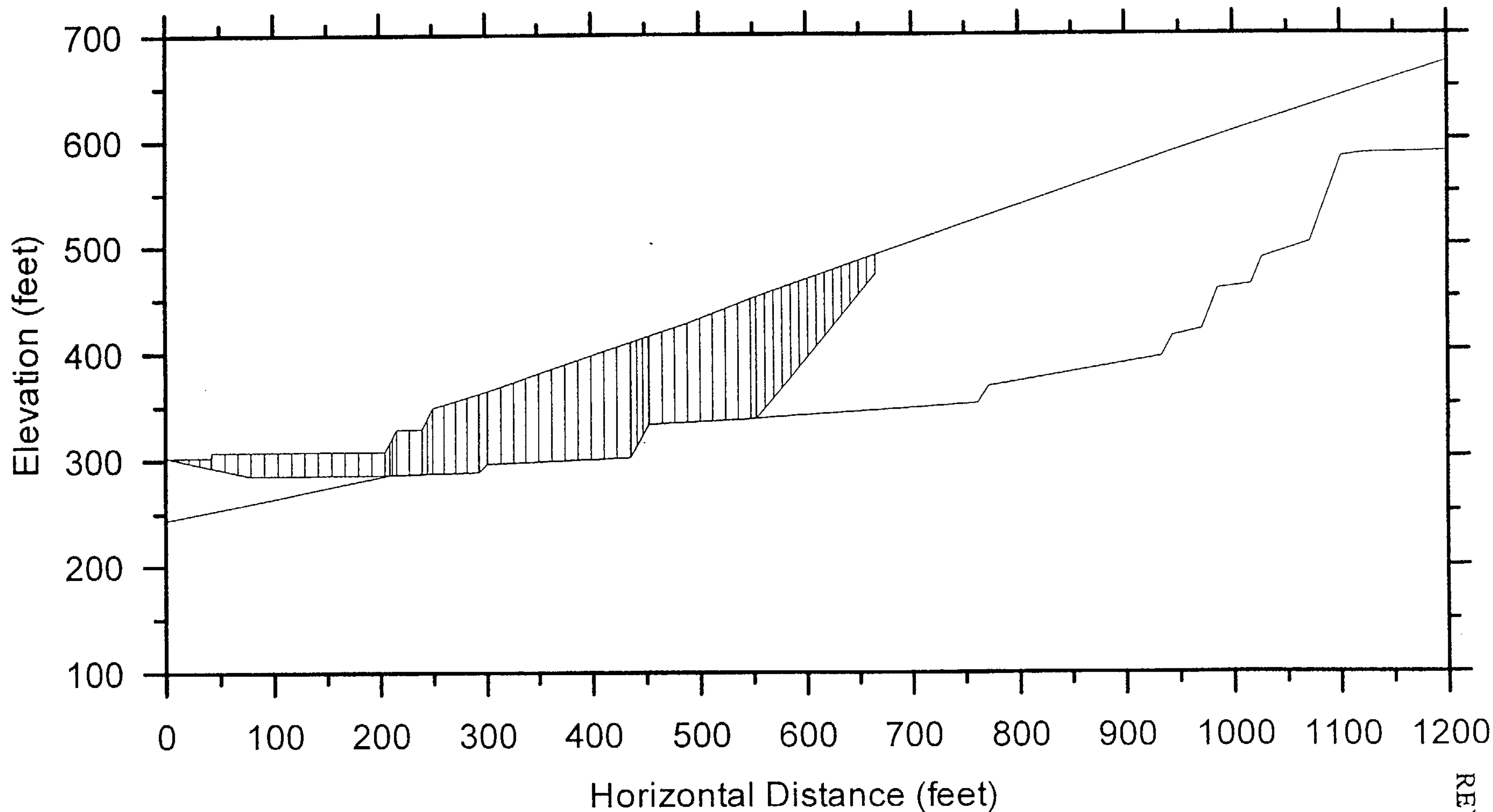


FIGURE 7

UTEXAS3 2-Stage Stability Analysis
Corss Section I-I', Diablo Canyon Power Plant ISFSI
Potential Sliding Mass 3c
Long Term Factor of Safety = 2.26
Yield Acceleration = 0.25
Filename: Bede3cm2.dat

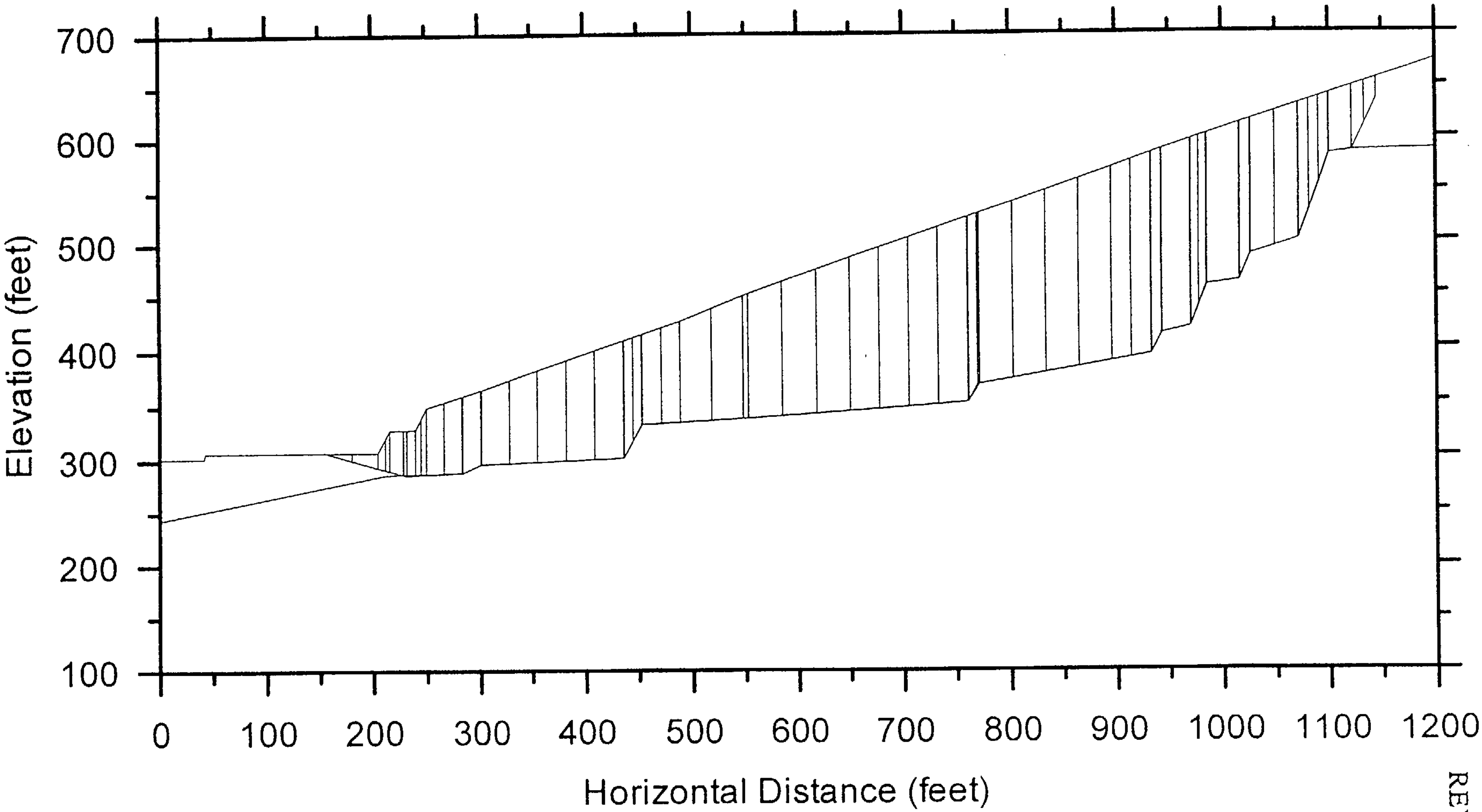


FIGURE 8

UTEXAS3 2-Stage Stability Analysis
Corss Section I-I', Diablo Canyon Power Plant ISFSI
Potential Sliding Mass **3c-1**
Long Term Factor of Safety = 2.38
Yield Acceleration = 0.28
Filename: Beda3c.dat

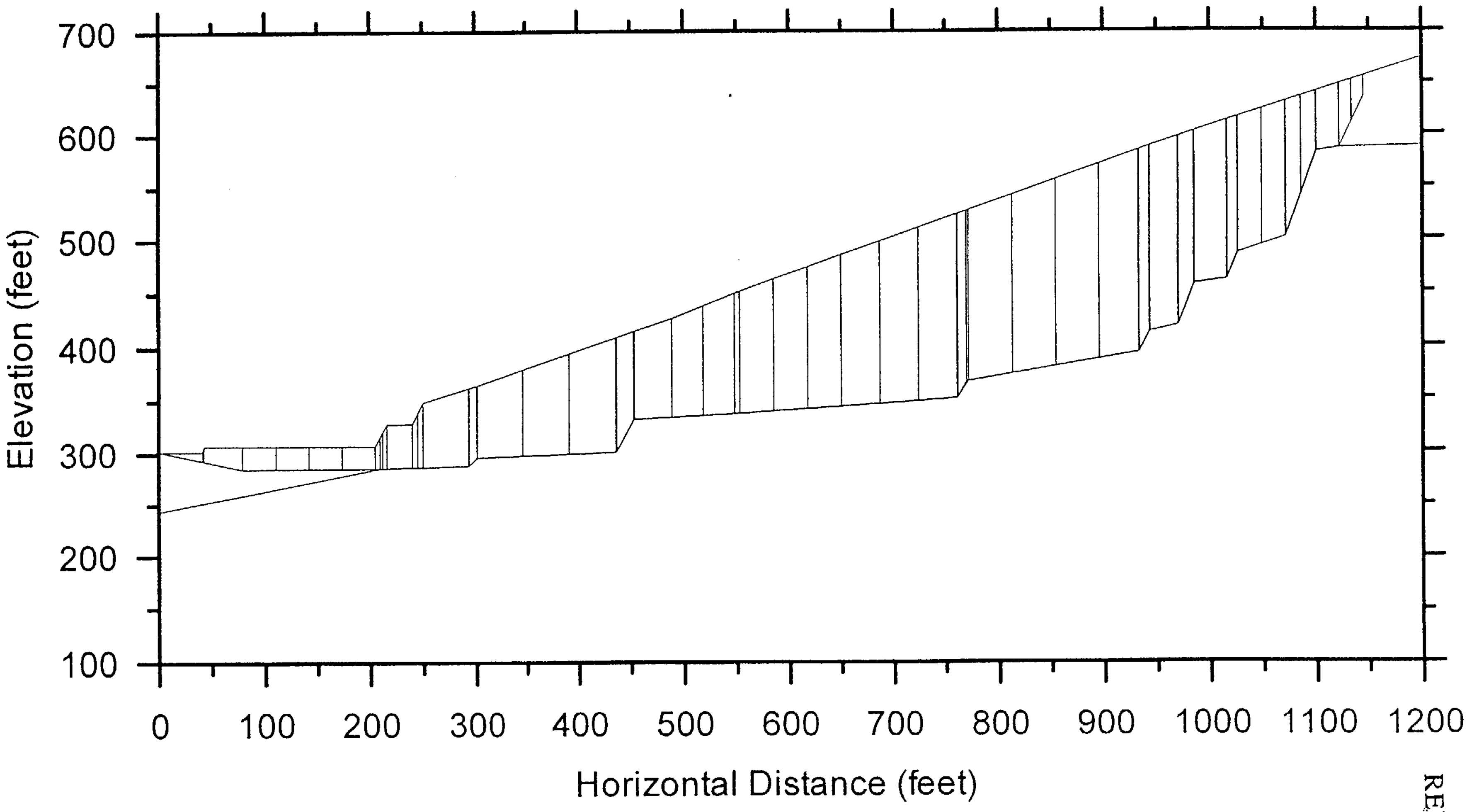


FIGURE 9

UTEXAS3 2-Stage Stability Analysis
Corss Section I-I', Diablo Canyon Power Plant ISFSI
Potential Sliding Mass **3c-2**
Long Term Factor of Safety = 2.28
Yield Acceleration = 0.23
Filename: Beda3cm.dat

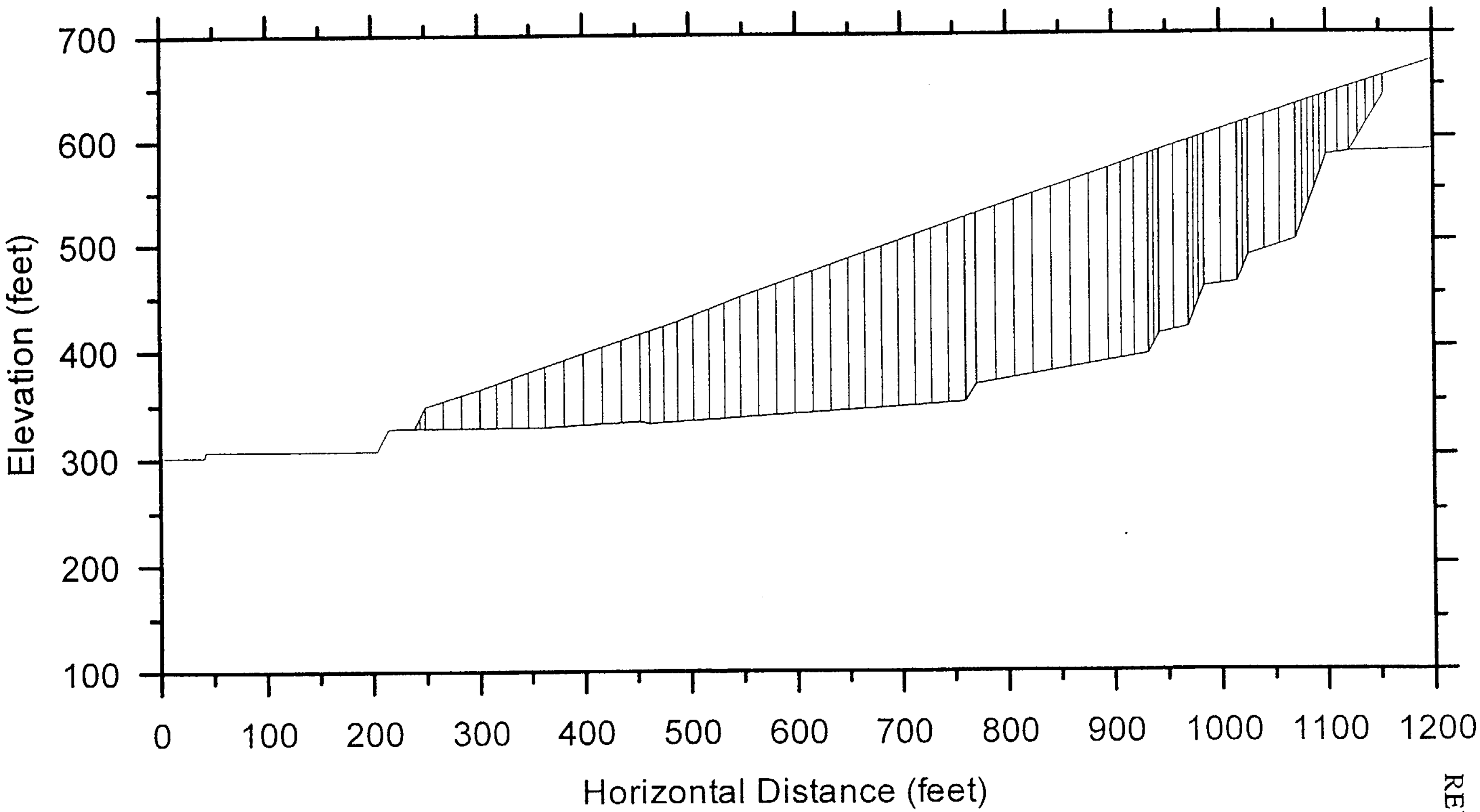


FIGURE 10

UTEXAS3 2-Stage Stability Analysis
Corss Section I-I', Diablo Canyon Power Plant ISFSI
Back Analysis of Potential Sliding Mass **1a**
Yield Acceleration = 0.65
Filename: Bed1a_a.dat

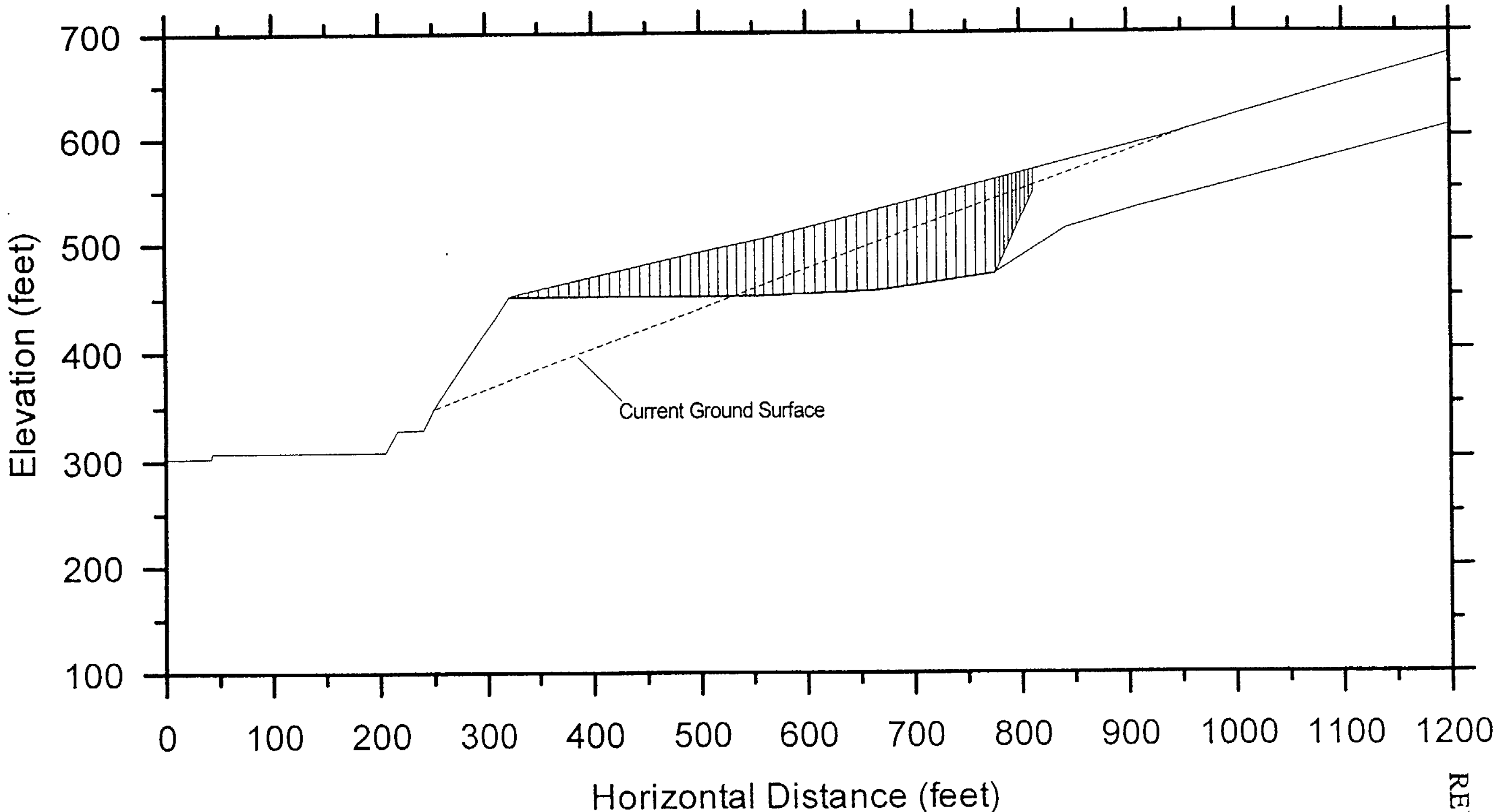


FIGURE 11

UTEXAS3 2-Stage Stability Analysis
Corss Section I-I', Diablo Canyon Power Plant ISFSI
Back-analysis of Potential Sliding Mass **1b**
Yield Acceleration = 0.65
Filename: Bed1a_b2.dat

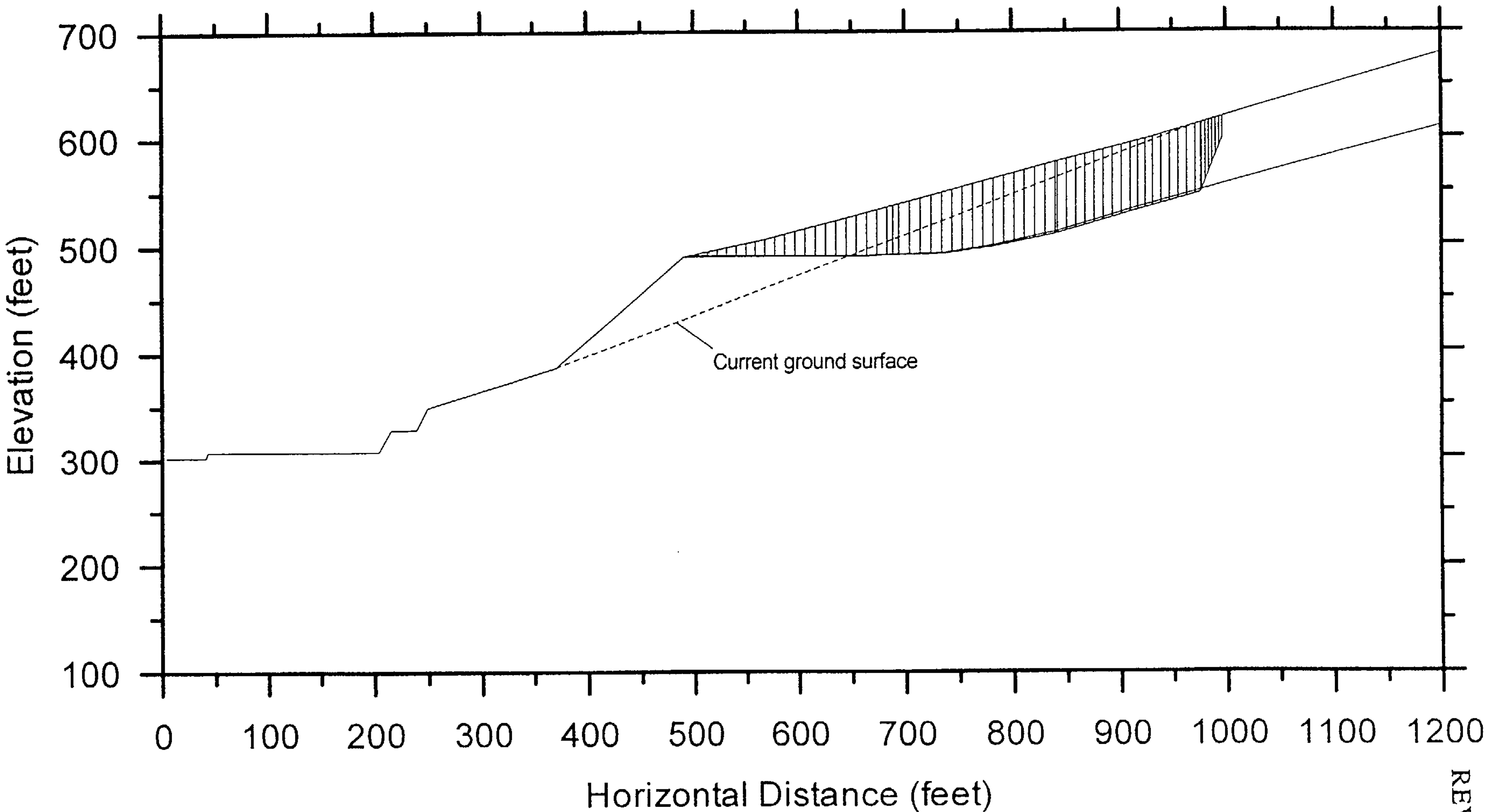


FIGURE 12

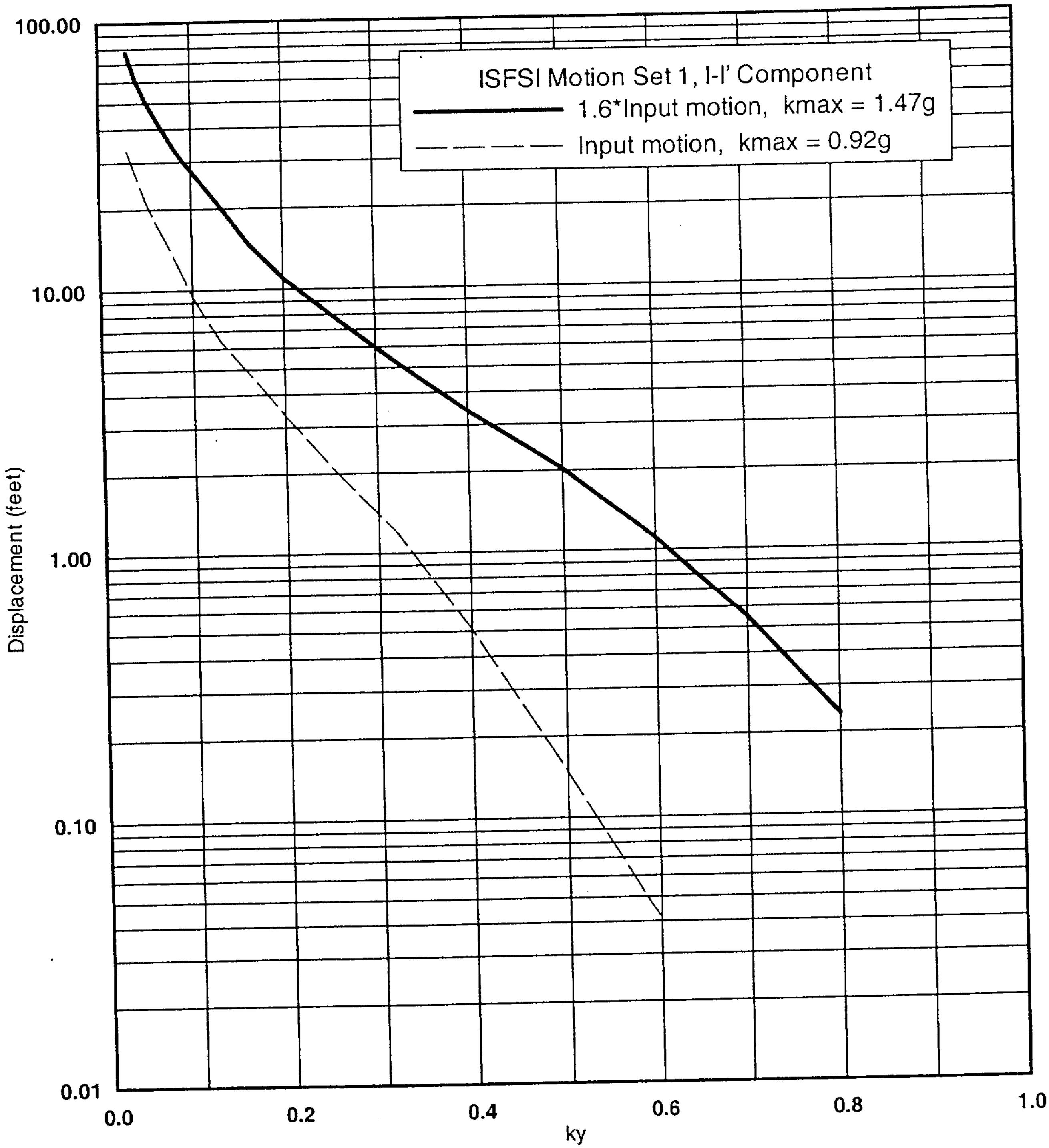


Figure 13. Permanent displacement versus yield acceleration from input acceleration time histories- I-I component of set 1.

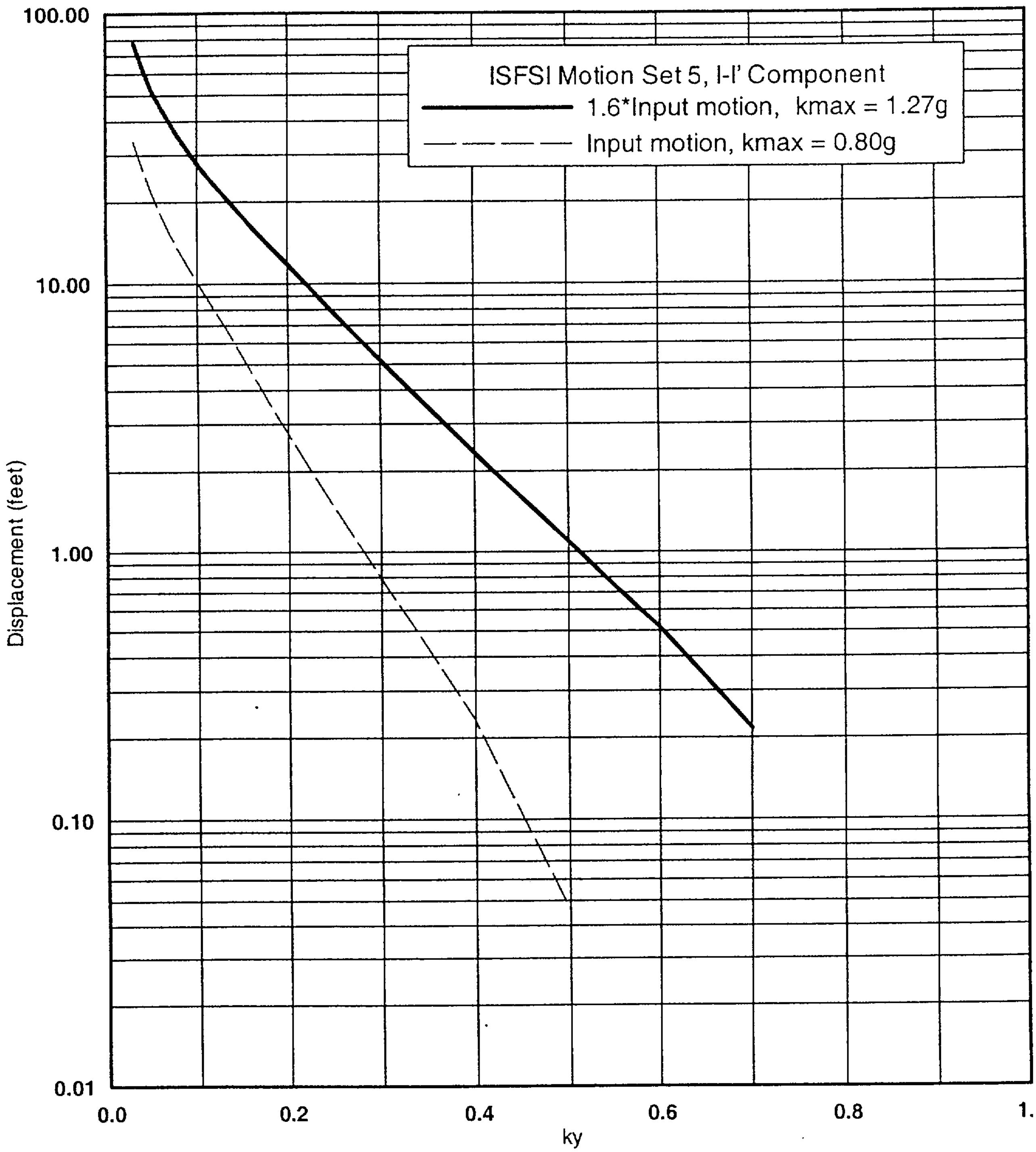


Figure 14. Permanent displacement versus yield acceleration from input acceleration time histories- I-I component of set 5.

ATTACHMENT A

WLA

William Lettis & Associates, Inc.

1777 Botelho Drive, Suite 262, Walnut Creek, California 94596
Voice: (925) 256-6070 FAX: (925) 256-6076

Dr. Faiz Makdisi
Geomatrix Consultants, Inc.
2101 Webster Street, 12th floor
Oakland, CA 94612
510-663-4141

September 27, 2001

Subject: Transmittal of Revised Geologic Section I-I', DCPP ISFSI Site

Dear Faiz:

This letter documents transmittal of a revised version of geologic section I-I' that will be included in DCPP ISFSI Calculation Package GEO.01.21 rev. 0. This revised section includes a surveyed profile that extends farther uphill than previous versions of the section. We have sent an electronic copy of the section in a pdf format to your email address, and a full-size (1-inch equals 50-feet) hardcopy to your office via Fedex.

Please contact me if you have any questions regarding the geologic section, or need additional information.

Sincerely,

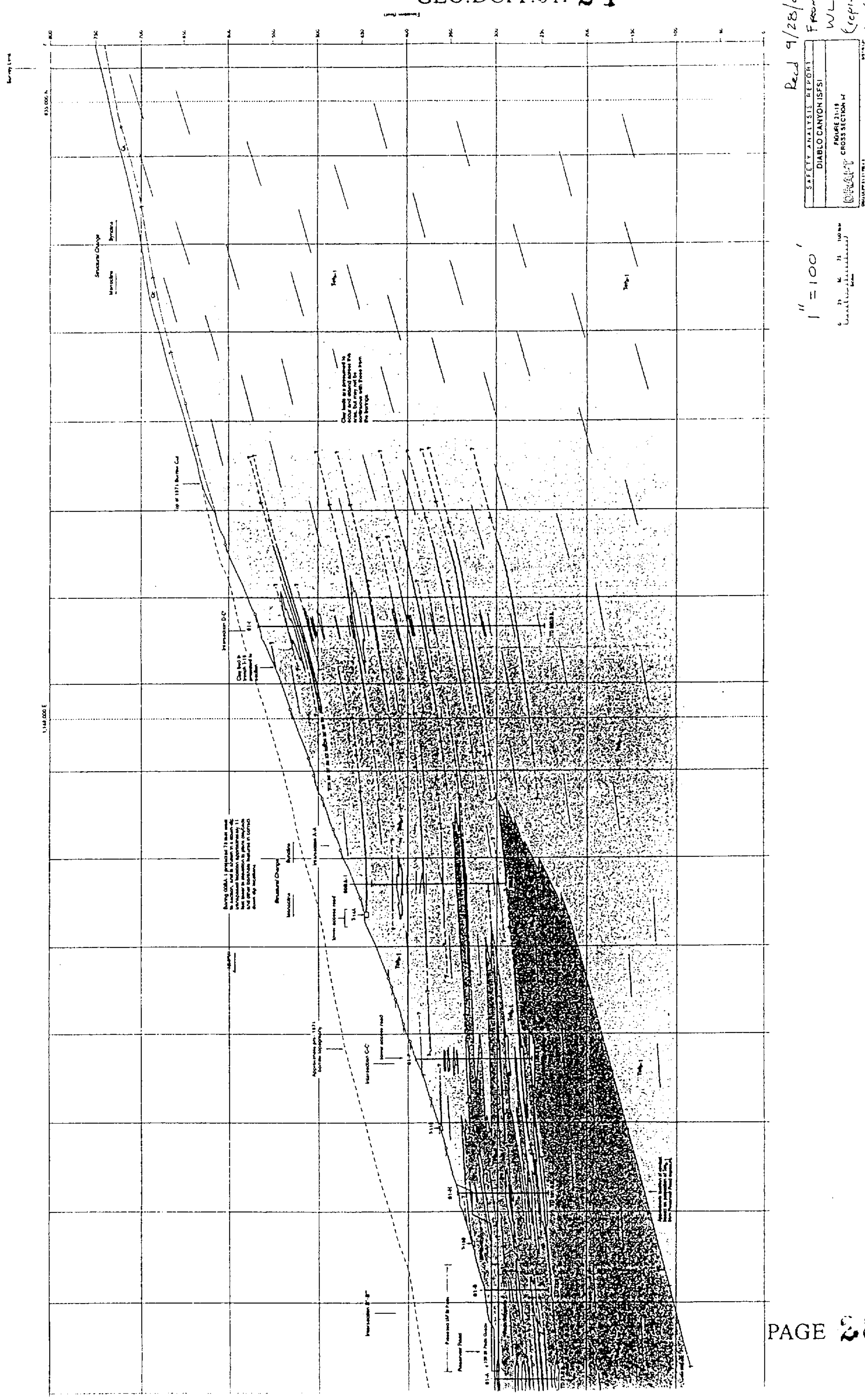
WILLIAM LETTIS & ASSOCIATES, INC.

Jeff Bachhuber
Principal Engineering Geologist

Cc: W.D. Page, R. White, PG&E Geosciences, transmitted via facsimile

WLA/ISFSIsectionI-I'rev0

Recd 9/28/01 From WLA (original by GMK)



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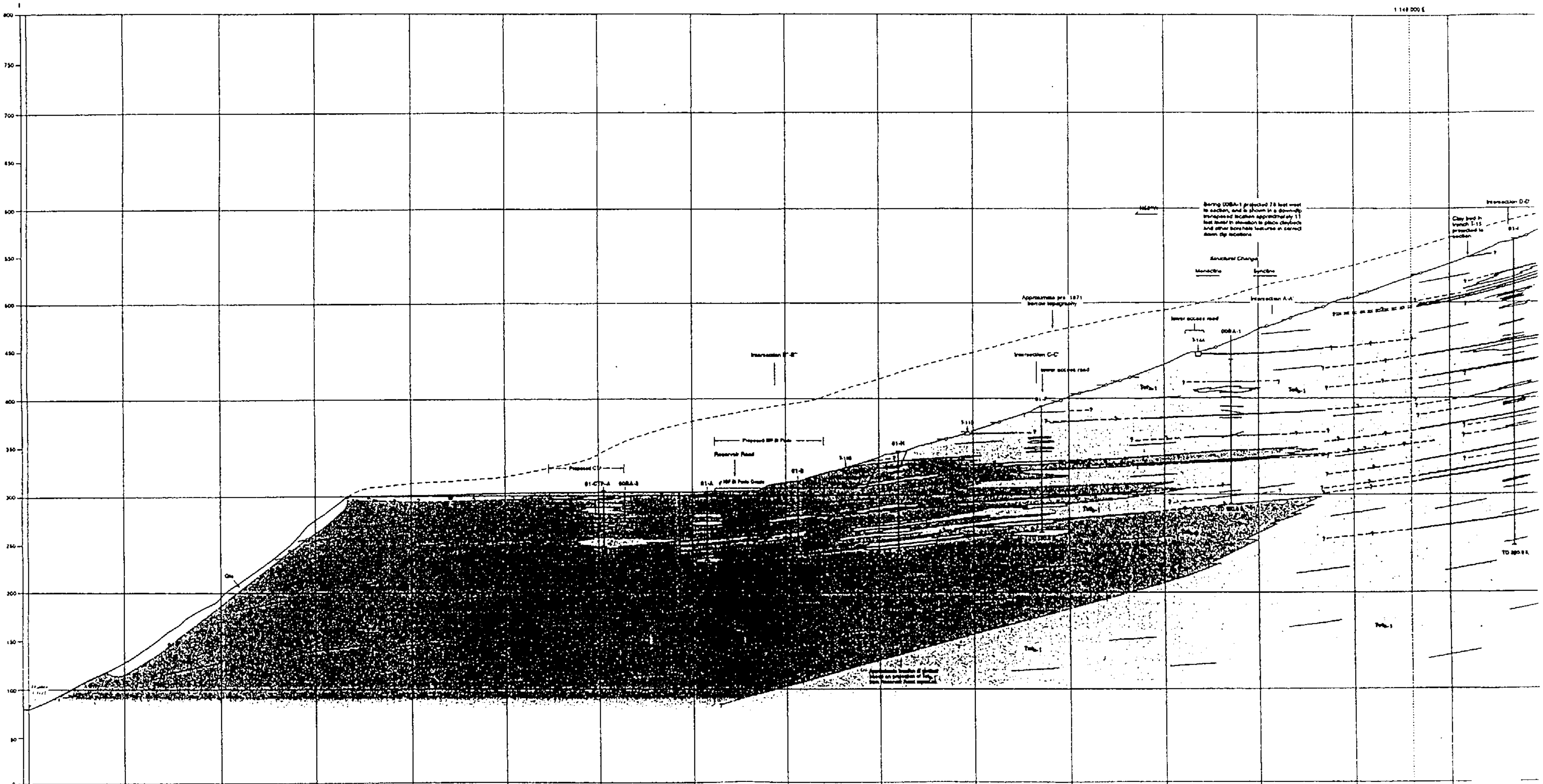


Calculation 52.27.100.734, Rev. 0, Attachment A, Page 32 of 65

GEO.DCPP.01.24
REVISION 1

PAGE 29 OF 62

ATTACHMENT B

WLA
William Lettis & Associates, Inc.
1777 Botelho Drive, Suite 262, Walnut Creek, California 94596
Voice: (925) 256-6070 FAX: (925) 256-6076

October 10, 2001

Dr. Faiz Makdisi
Geomatrix Consultants, Inc.
2101 Webster Street, 12th floor
Oakland, CA 94612
510-663-4141
email:zlwang@geomatrix.com

Subject: Transmittal of Revised Rock Mass Failure Models - DCPP ISFSI Project

Dear Faiz:

This letter documents transmittal of revised rock mass failure models for the DCPP ISFSI Project geologic section I-I'. These revised models supercede the preliminary models sent to you on October 4, 2001, and incorporate review comments by PG&E Geosciences Department, internal WLA review, and issues brought up during our telephone conversations. We sent pdf formatted versions of these models to you via email previously. The attached hardcopies are the same as the emailed revised models.

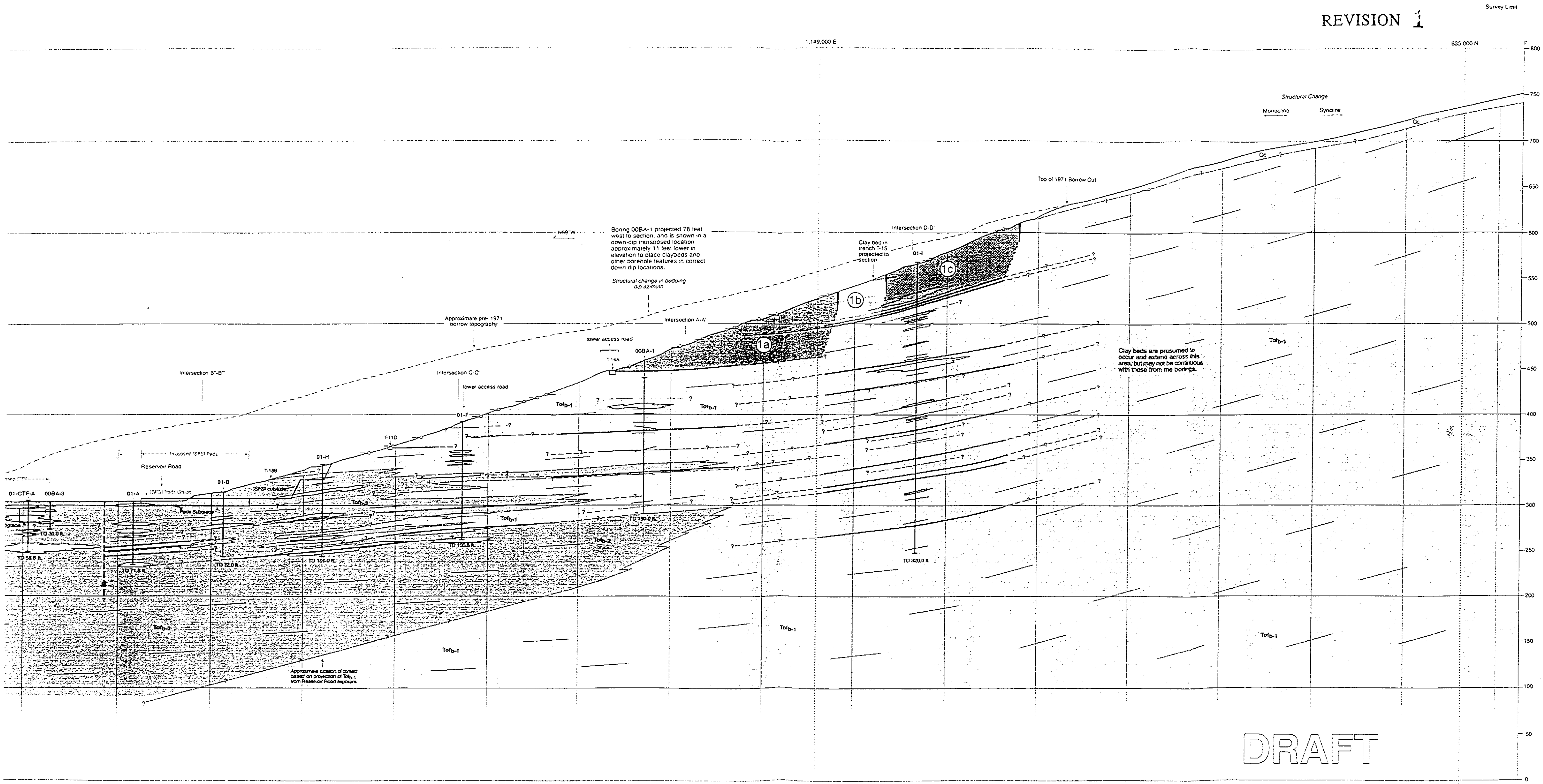
Please contact me if you have any questions regarding the rock failure models, or need additional information.

Sincerely,

WILLIAM LETTIS & ASSOCIATES, INC.

Jeff Bachhuber
Principal Engineering Geologist

Cc: W.D. Page, R. White, PG&E Geosciences, transmitted via facsimile



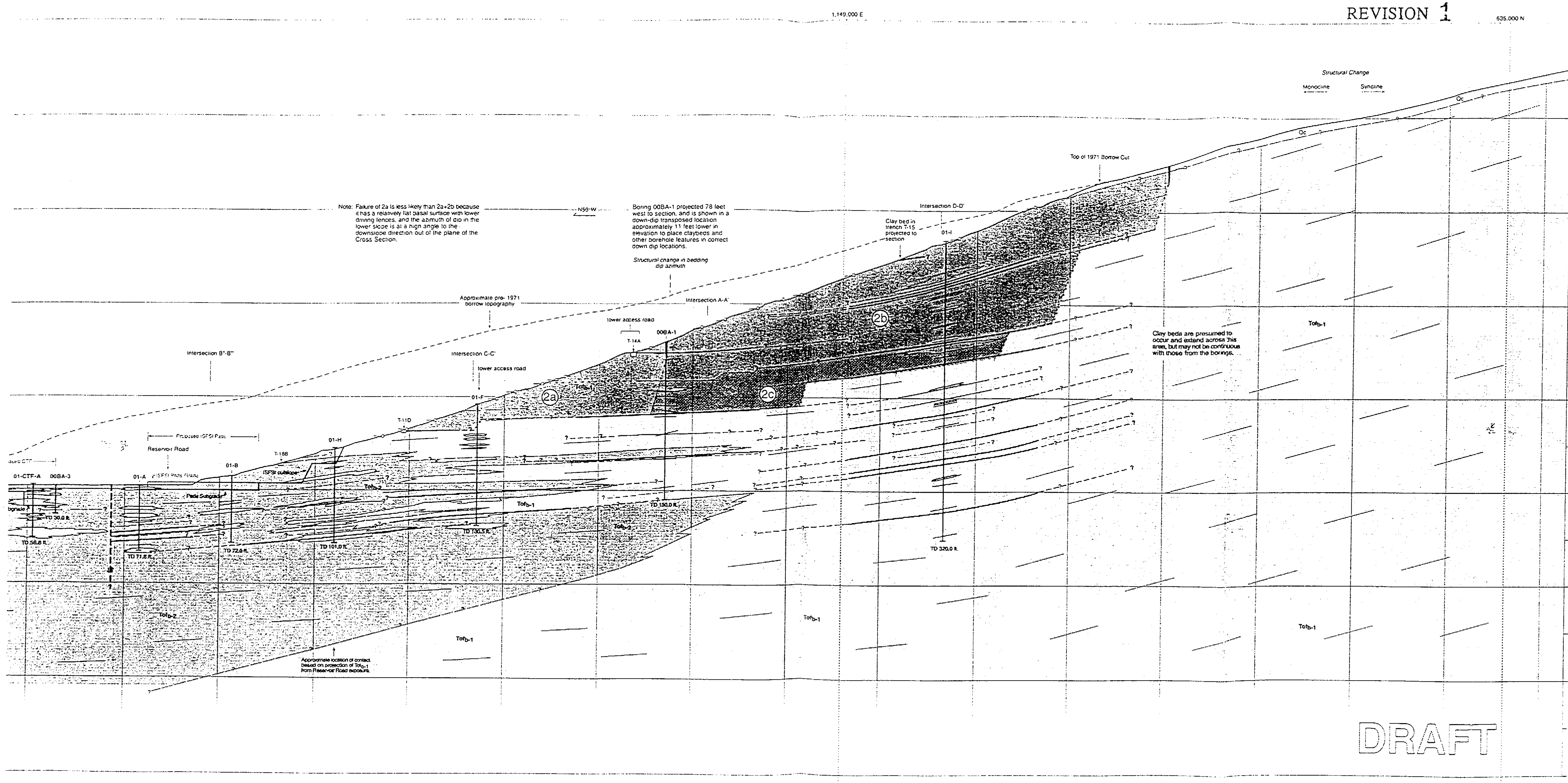
Alternative Slide Mass Models

Explanation

- Failure plane through clay bed
- Failure plane through rock
- Failure plane through rock and possibly partly through clay bed
- Modeled 20'-high tension crack at top of slide mass

0 25 50 75 100 feet
Scale

SAFETY ANALYSIS REPORT
DIABLO CANYON ISFSI
FIGURE 21-45
SLIDE MASS MODEL 1
DRAFT
GEO.DCPP.01.21 REV 0
October 2, 2001



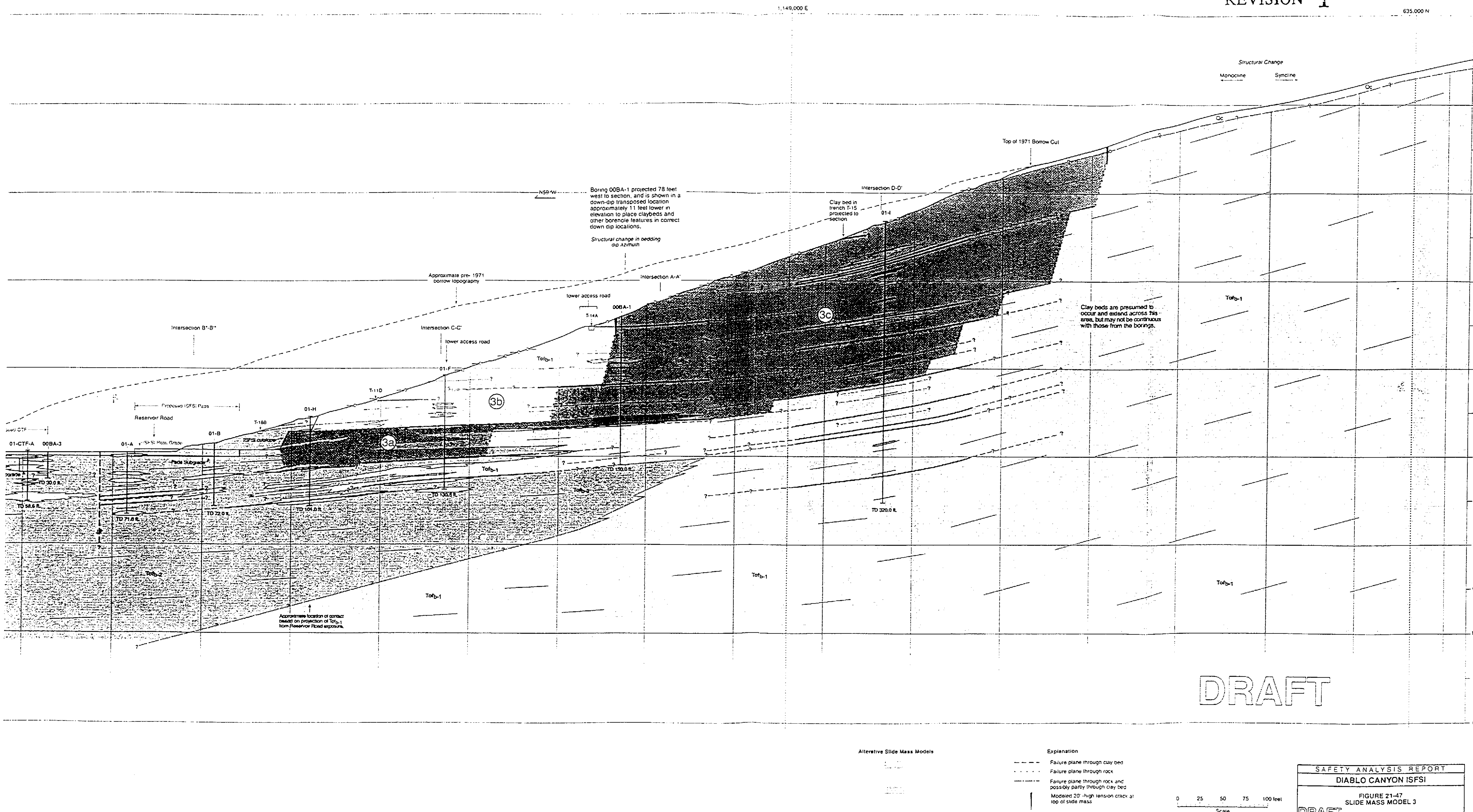
Alternative Slide Mass Models

Explanation

- Failure plane through clay bed
- Failure plane through rock
- Failure plane through rock and possibly partly through clay bed
- Modeled 20'-high tension crack at top of slide mass

Scale: 0 25 50 75 100 feet

SAFETY ANALYSIS REPORT
DIABLO CANYON ISFSI
FIGURE 21-46
SLIDE MASS MODEL 2
DRAFT
GEO.DCPP.01.21 REV 0
October 3, 2001



SAFETY ANALYSIS REPORT
DIABLO CANYON ISFSI

FIGURE 21-47
SLIDE MASS MODEL 3

DRAFT

GEO.DCPP.01.21 REV 0

October 3, 2001

ATTACHMENT C

Pacific Gas and Electric Company

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GEO.DCPP.01.24

REVISION 1

Faiz Makdisi
Geomatrix Consultants
2101 Webster Street
12th floor
Oakland, CA 94612

June 24, 2001

Re: Recommended rock strength design parameters for DCPP ISFSI site slope stability analyses

Dear Faiz:

This letter documents recommended rock strength design parameters for the DCPP ISFSI site slope stability analyses you will be performing. As you know, rock types range from harder, jointed sandstone and dolomite to softer, non-jointed, altered sandstone.

For the altered sandstone, review of the laboratory multi-stage triaxial test data indicates that a peak strength envelope defined by $\phi = 50$ degrees and $c = 0$ psi is appropriate for both static and dynamic stability analyses. Please refer to the attached calculation package (GEO.DCPP.01.16) for derivation of this envelope.

For the harder sandstone and dolomite, the rock mass strength at the large scale defined by your stability analyses is controlled by both the intact rock and the discontinuities. The Hoek-Brown criteria utilizes both these mechanisms as input to derive a series of strength envelopes for the rock mass. While the calculation package for these envelopes has not been completed yet, my review of draft envelopes from Jeff Bachhuber at WLA indicates that an envelope defined by $\phi = 50$ degrees and $c = 0$ psi is appropriate for both sandstone and dolomite. In a few cases, lower-bound (very low probability) Hoek-Brown envelopes cross below this envelope, thus making it unconservative, but only at overburden depths greater than the most likely slip surfaces I expect you will be analyzing (over 200 feet in the dolomite and 70 feet in the sandstone).

(For smaller scale shallow stability analyses being performed by WLA, such as rock blocks in the proposed cutslope, rock mass strength is controlled almost entirely by discontinuities and the Barton criteria for discontinuity strength is more applicable.)

Therefore, I recommend you use ϕ = 50 degrees as the preliminary rock strength envelope in all your slope stability analyses. Once the Hoek-Brown calculation is finalized and approved (sometime in the following week), I will confirm that this value is still applicable. In the meantime, I recommend you proceed with slope stability analyses so as to keep making progress on this task.

Let me know if you have any questions regarding these preliminary numbers.

Sincerely,

Rob White

Rob White

cc (w/o attachments): Joseph Sun
Jeff Bachhuber

ATTACHMENT D

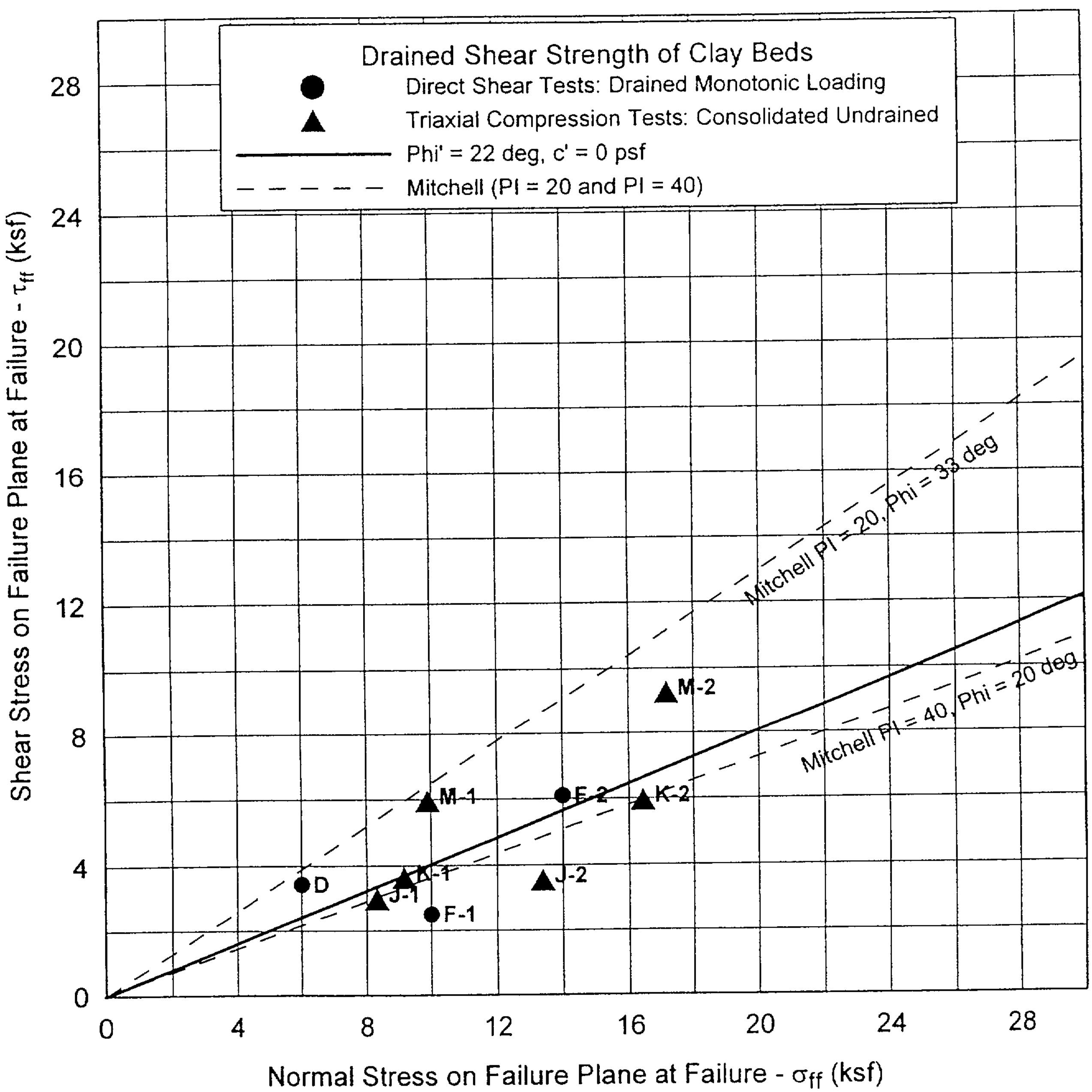

FIGURE D-1 - Drained Shear Strength of Clay Beds (from GEO.DCPP.01.31)

I:\Project\6000s\6427.006\geo.dcpp.01.24\Drained.grf
I:\Project\6000s\6427.006\Lab Data\Strength.xls

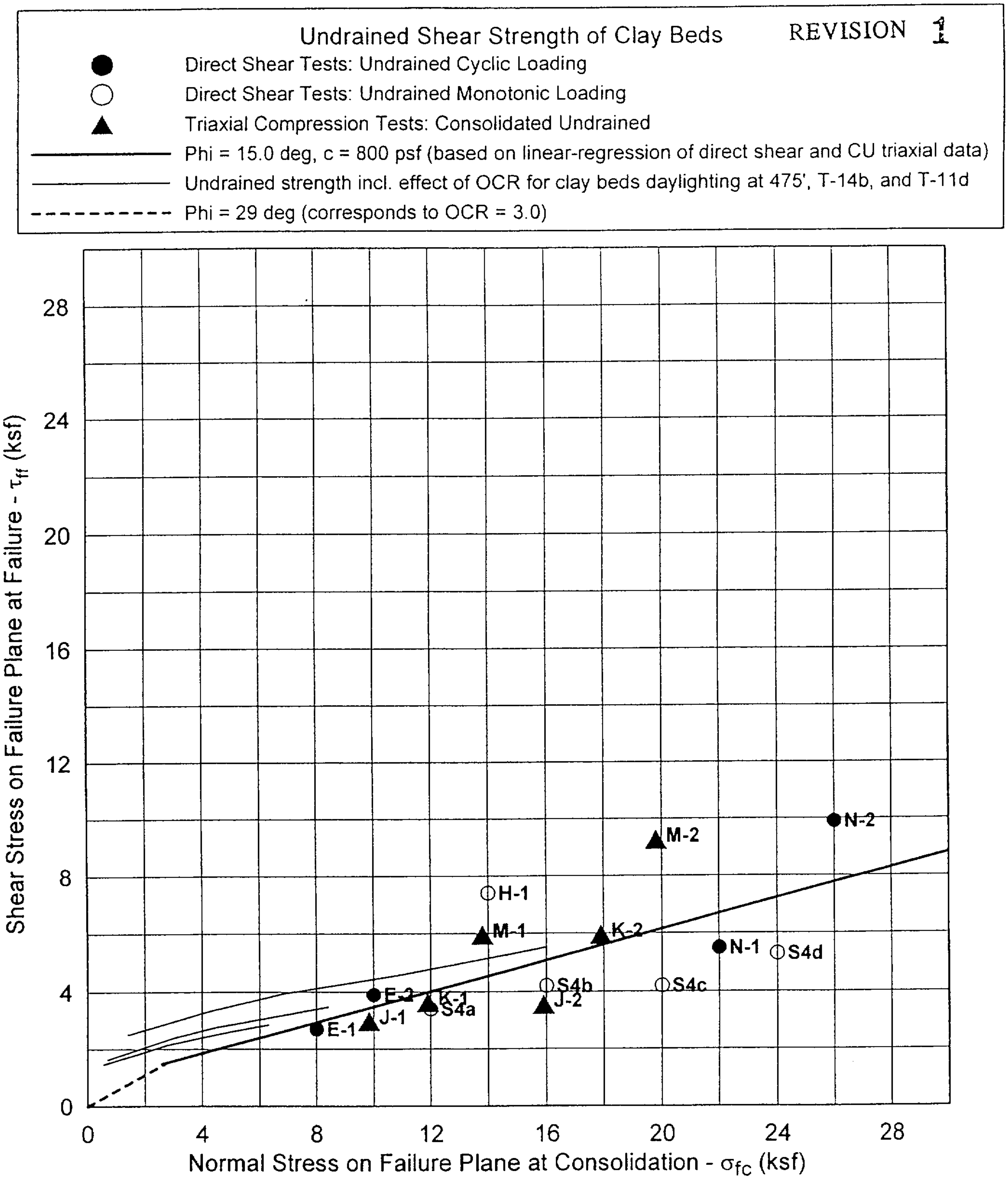

FIGURE D-2 - Undrained Shear Strength of Clay (from GEO.DCPP.01.31)

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I:\Project\6000s\6427.006\Lab Data\Strength.xls

ATTACHMENT E

Karthik Narayanan

From:	White, Robert (Geosciences) [RKW5@pge.com]
Sent:	Thursday, June 28, 2001 12:10 PM
To:	'Karthik Narayanan'; 'Jeff Bachhuber'
Cc:	Faiz Makdisi; Sun, Joseph
Subject:	RE: Unit Weights for Stability Analysis

unit_wt_SD.xls

Karthik:

Joseph just finished compiling all the bulk density data from the rock tests and determined that a good defendable average for all rock types is about 140 pcf, the number we've been using in the past. There is virtually no statistical difference between dolomite and sandstone, as Joseph's attached table indicates.

Thanks for running the numbers, Joseph!

-- Rob White

-----Original Message-----
From: Karthik Narayanan [mailto:KNarayanan@geomatrix.com]
Sent: Wednesday, June 27, 2001 10:47 AM
To: 'Jeff Bachhuber'
Cc: White, Robert (Geosciences); Faiz Makdisi
Subject: Unit Weights for Stability Analysis

Jeff,

We are in the process of running stability analysis with the rock strengths recommended in the calc packages provided to us by Rob White. Could you also provide recommendations for the unit weights of Tofb-1 and Tofb-2? Thank you for the information.

Karthik R. Narayanan, P.E.
Geomatrix Consultants, Inc.
2101 Webster Street, 12th Floor
Oakland, California 94612
Direct: (510) 663-4144
Fax: (510) 663-4141

ATTACHMENT F

TABLE F-1
Summary of Unit Weights for Clay Bed Samples from Trenches and Borings in ISFSI Site Area

Boring/ Trench	Sample Number	USCS	Moisture Content (%)	Dry Unit Weight (pcf)	Total Unit Weight (pcf)
T-14 B	B		19	99	117.8
	D	CH	15	101	116.2
	E	CL	22	102	124.4
	E		21	106	128.3
	F	CH	18	103	121.5
	F		20	102	122.4
	H	CL	21	101	122.2
	H		19	105	125.0
	J	CH	22	99	120.8
	K	CH	23	100	123.0
	M	CL	19	100	119.0
	N	GC	21	102	123.4
	N		21	103	124.6
T-14 B	S4-1	CH	23	88	108.2
	S4-2		22	89	108.6
	S4-3		26	90	113.4
	S4-4		29	89	114.8
T-14 B	Block 1	CL	17	106	124.0
T-14 B	Block 2		19	104	123.8

Mean	**120.1**
Median	**122.2**
Standard Deviation	**5.6**

Data taken from Witter (Nov. 5, 2001) Data Report G

ATTACHMENT G

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GEO.DCPP.01.24

REVISION 1

DR. FAIZ MAKDISI
GEOMATRIX CONSULTANTS
2101 WEBSTER STREET
OAKLAND, CA 94612

December 13, 2001

Re: Confirmation of DCPP ISFSI ground motion parameters for back calculation analysis

DR. MAKDISI:

As part of your analysis of the stability of the slope behind the DCPP ISFSI, you are performing a back-calculation analysis of the slope in its pre-excavated (pre-1971) configuration to evaluate the level of conservatism in the assumed lateral extent and the undrained strength of the clay beds underlying the slope. Key parameters required for this analysis, including amount of slope displacement and associated ground motions, are provided below.

Calculation GEO.DCPP.01.21, Rev. 1, pages 59 through 61, indicates that the range of potential slope displacements for past large earthquakes is 3 to 6 inches per event (page 60, attached). For purposes of the back-calculation analysis, a value within this range of 4 inches is recommended.

For purposes of defining the large earthquake causing this value of displacement, it is recommended that you multiply the ground motions provided to you on 8/17/01 (and confirmed in my letter to you dated 10/31/01) by a factor of 1.6, to represent ground motions that are at the 98th percentile (that is, one standard deviation above the 84th percentile ground motions provided).

If you have any questions regarding this information, please call.

Rob White

ROBERT K. WHITE

Attachment

site area (Figure 21-41) (Diablo Canyon ISFSI Data Report A). Similarly the many trenches excavated into the slope, the tower access road cuts, the extensive outcrops exposed by the 1971 borrow cut, and the many borings exposed no tension cracks or fissure fills on the hillslope (Diablo Canyon ISFSI Data Reports A, B and D). Open cracks or soil-filled fissures greater than 1 to 2 feet in width should be easily recognized across the slope given the extensive rock exposure provided by the borrow cut. Therefore, we conservatively assume that any cumulative displacement in the slope greater than 3 feet would have produced features that would be evident in rock slope. The absence of this evidence places a maximum threshold of 3 feet on the amount of cumulative slope displacement that may have occurred in the geologic past.

The hillslope at the ISFSI site is older than at least 300,000 years because remnants of the Q-5 (320,000 yrs) marine terrace are cut into the slope west of the ISFSI site (Figure 21-3). Preservation of the terrace documents that the slope has had minimal erosion since that time. Moreover, gradual reduction of the ridge by erosion at the ISFSI site would not destroy deep tension cracks or deep disruption of the rock mass; these features would be preserved as filled fractures and fissures even as the slope is lowered.

The topographic ridge upon which the ISFSI site is located has experienced strong ground shaking from numerous earthquakes on the Hosgri fault zone during the past 300,000 years. PG&E (1988, p. 3-39) provides a recurrence interval of 11,350 years for an M_W 7.2 earthquake on the Hosgri fault. Therefore, approximately 25 to 30 large earthquakes have occurred during the past 300,000 years without causing ground motions large enough to produce significant (i.e., greater than 3 feet) cumulative slope displacement. Based on the number of earthquakes, the hillslope likely experienced the design earthquake ground motion as described in the ISFSI SAR (PG&E, 2001). Based on the absence of cumulative slope displacement within a limit of resolution of 3 feet, the amount of possible slope displacement during the Hosgri design earthquake is a maximum of 3 feet (if only one such slope displacement has occurred) and more likely about 3 to 6 inches per event (if multiple earthquakes have caused slope displacement with cumulative displacement of up to 3 feet). Slope displacement of 3 to 6 inches,

ATTACHMENT H

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GEO.DCPP.01.__

REVISION 1

PG&E

Dr. Faiz Makdisi
Geomatrix Consultants
2101 Webster Street
Oakland, CA 94612

September 28, 2001

Re: Confirmation of transmittal of inputs for DCPP ISFSI slope stability analyses

DR. MAKDISI:

This is to confirm transmittal of inputs related to slope stability analyses you are scheduled to perform for the Diablo Canyon Power Plant (DCPP) Independent Spent Fuel Storage Installation (ISFSI) under the Geomatrix Work Plan entitled "Laboratory Testing of Soil and Rock Samples, Slope Stability Analyses, and Excavation Design for the Diablo Canyon Power Plant Independent Spent Fuel Storage Installation Site."

Inputs transmitted include:

Drawing entitled "Figure 21-19, Cross Section I-I'," dated 9/27/01, labeled "Draft," and transmitted to you via overnight mail under cover letter from Jeff Bachhuber of WLA and dated 9/27/01.

Time histories in Excel file entitled "time_histories_3comp_rev1.xls," dated 8/17/2001, file size 3,624 KB, which I transmitted to you via email on 8/17/2001.

Please confirm receipt of these items and forward confirmation to me in writing.

Please note that both these inputs are preliminary until the calculations they are part of have been fully approved. At that time, I will inform you in writing of their status. These confirmation and transmittal letters are the vehicles for referencing input sources in your calculations.

Although the Work Plan does not so state, as you are aware all calculations are required to be performed as per Geosciences Calculation Procedure GEO.001, entitled "Development and Independent Verification of Calculations for Nuclear Facilities," revision 3. All of your staff assigned to this project have been previously trained under this procedure.

I am also attaching a copy of the Work Plan. Please make additional copies for members of your staff assigned to this project, review the Work Plan with them, and have them sign Attachment 1. Please then make copies of the signed attachment and forward to me.

If you have any questions, feel free to call.

Thanks.

Rob White

ROBERT K. WHITE

Attachment

cc: Chris Hartz

ATTACHMENT I

Pacific Gas and Electric Company

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GEO.DCPP.01.24

REVISION 1

PG&E

DR. FAIZ MAKDISI
GEOMATRIX CONSULTANTS
2101 WEBSTER STREET
OAKLAND, CA 94612

October 25, 2001

Re: Input parameters for calculations

DR. MAKDISI:

As required by Geosciences Calculation Procedure GEO.001, entitled "Development and Independent Verification of Calculations for Nuclear Facilities," rev. 4, I am providing you with the following input items for your use in preparing calculations.

1. The shear wave velocity profiles obtained in borings BA98-1 and BA98-3 in 1998 are presented in Figure 21-42, attached, of Calculation GEO.DCPP.01.21, entitled "Analysis of Bedrock Stratigraphy and Geologic Structure at the DCPP ISFSI Site," rev. 0, and can be so referenced. These profiles were previously presented in Figure 10 of the WLA report entitled "Geologic and Geophysical Investigation, Dry Cask Storage Facility, Borrow and Water Tank Sites," dated January 5, 1999.

2. The average unit weight of rock obtained from the hillside has been determined to be 140 pounds per cubic foot, as documented in a data report entitled "Rock Engineering Laboratory Testing - GeoTest Unlimited."

3. Regarding the time histories provided to you on 8/17/01, since the tectonic deformation will be to the southeast, the positive direction of the fault parallel time history is defined as to the southeast, as described in Geosciences Calculation GEO.DCPP.01.14, entitled "Development of Time Histories with Fling," rev. 1, page 4.

4. The source of the shear modulus and damping curves are Figures Q19-22 and Q19-23, attached, from PG&E, 1989, Response to NRC Question 19 dated December 13, 1988, and can be so referenced.

Regarding format of calculations, please observe the following:

Contents of CD-ROMs attached to calculations should be listed in the calcul[ation] including title, size, and date saved associated with each file on the CD-ROM. If the number of files is considerable, a simple screen dump of the CD-ROM contents is sufficient.

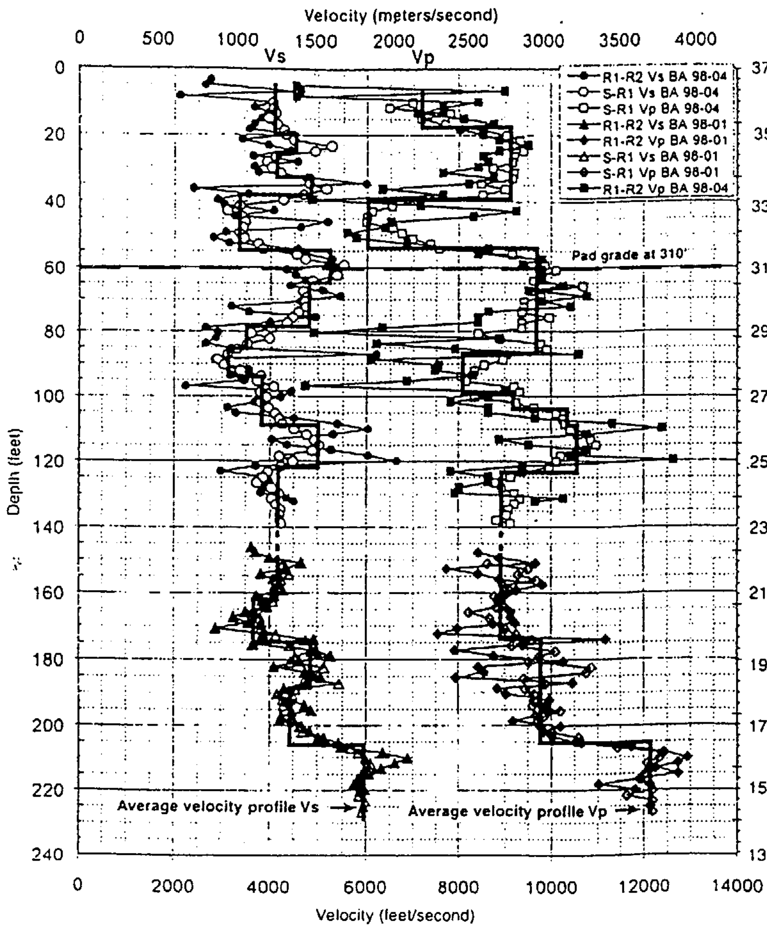
If you have any questions regarding the above, please call me.

Robert K White

ROBERT K. WHITE

Attachments

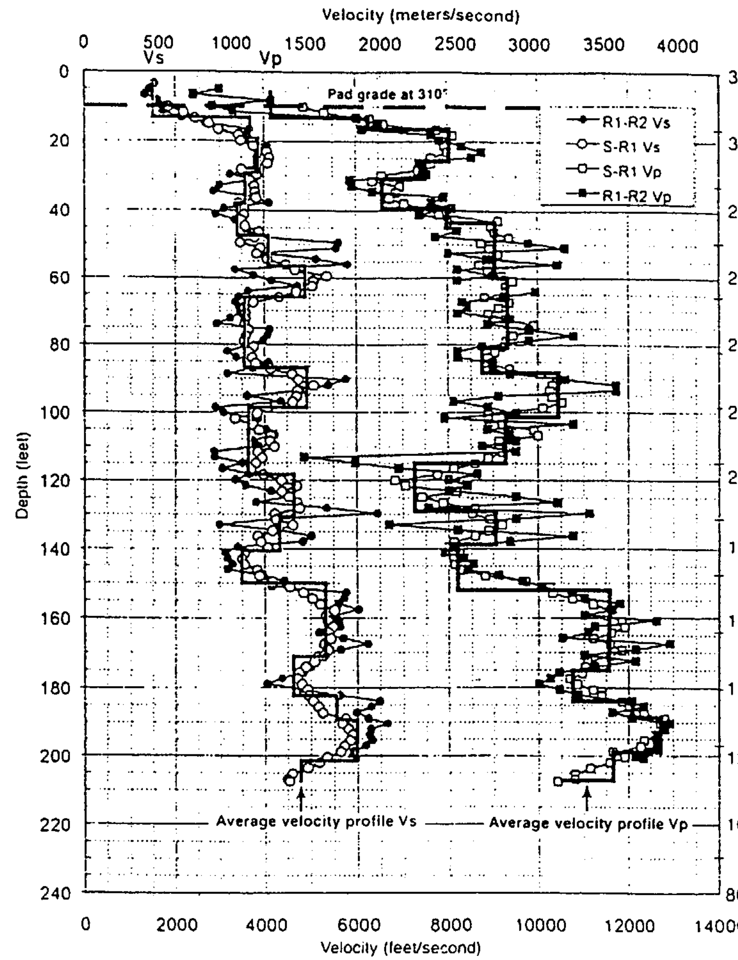
Borings 98BA-1 and 98BA-4



Note: Average velocity profiles interpreted from data.

R1 - R2 = Receiver-to-receiver velocity (3.3-foot spacing)
S-R1 = Source-to-receiver velocity (10.3-foot spacing)

Boring 98BA-3



Modified from GeoVision (1998), DCPP ISFSI SAR Section 2.6 Topical Report Appendix C

DIABLO CANYON ISFSI

FIGURE 21-42
ISFSI SITE SUSPENSION LOGS AND INTERPRETED AVERAGE SEISMIC VELOCITIES

GEO.DCPP.01.21 REV 0

October 15, 20

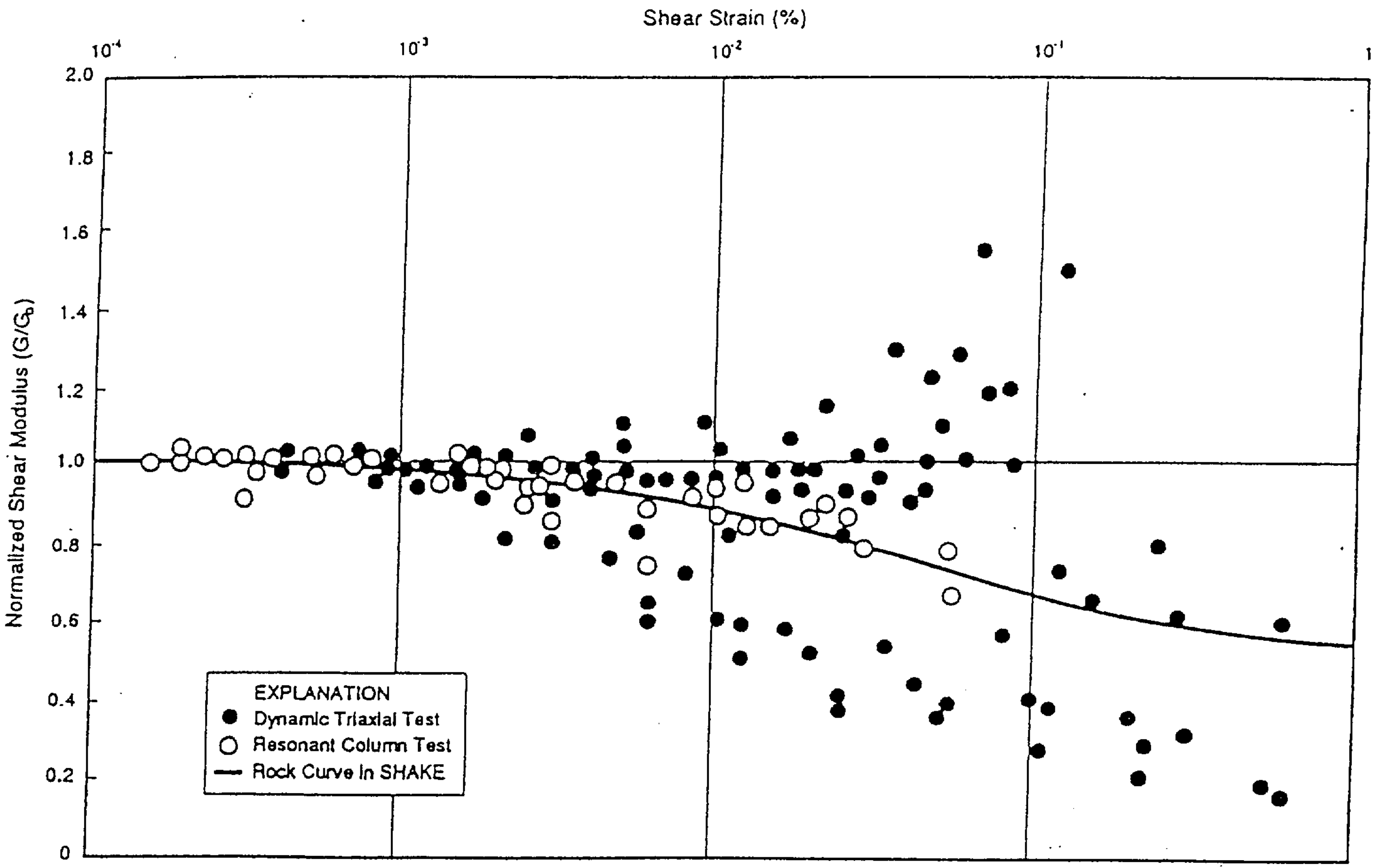


Figure Q19-22

Variation of shear modulus with shear strain for the site rock based on 1978 laboratory test data.

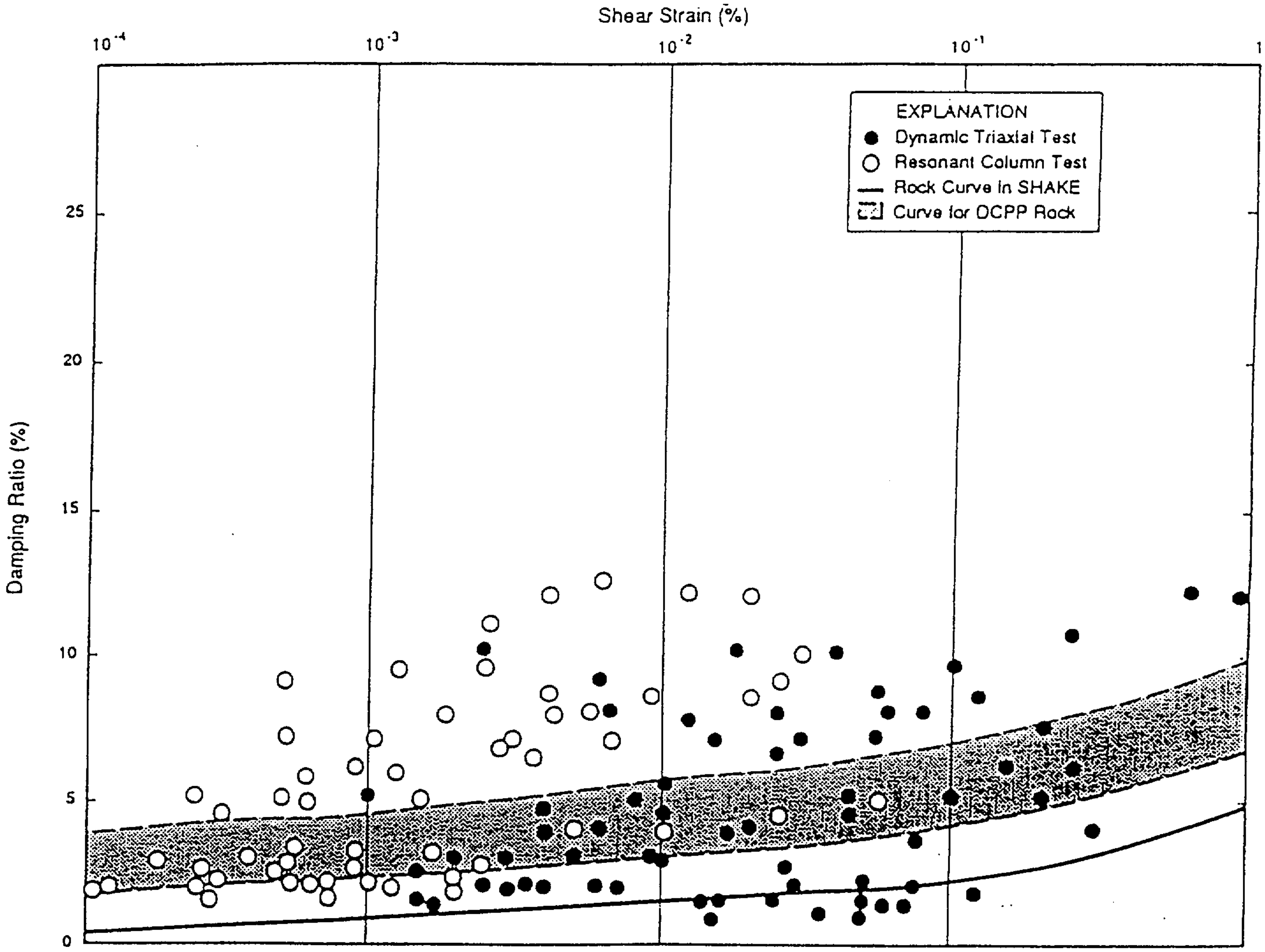


Figure Q19-23

Variation of damping ratio with shear strain for the site rock based on 1977 laboratory test data.

ATTACHMENT J

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GEO.DCPP.01.24

REVISION 1

DR. FAIZ MAKDISI
GEOMATRIX CONSULTANTS
2101 WEBSTER STREET
OAKLAND, CA 94612

October 31, 2001

Re: Confirmation of preliminary inputs to calculations for DCPP ISFSI site

DR. MAKDISI:

A number of inputs to calculations for the DCPP ISFSI slope stability analyses have been provided to you in a preliminary fashion. This letter provides confirmation of those inputs in a formal transmittal. A description of the preliminary inputs and their formal confirmation follow.

Letter to Faiz Makdisi from Rob White dated June 24, 2001. Subject: Recommended rock strength design parameters for DCPP ISFSI site slope stability analyses.

This letter recommended using $\phi = 50$ degrees for the preliminary rock strength envelope in your stability analyses, and indicated that this value would be confirmed once calculations had been finalized and approved. Calculations GEO.DCPP.01.16, rev. 0, and GEO.DCPP.01.19, rev. 0, are approved and this recommended value is confirmed.

Letter to Faiz Makdisi from Rob White dated September 28, 2001. Subject: Confirmation of transmittal of inputs for DCPP ISFSI slope stability analyses.

This letter provided confirmation of transmittal of cross section I-I' and time histories, and indicated that these preliminary inputs would be confirmed once calculations had been approved. Calculation GEO.DCPP.01.21, rev. 0, is approved and section I-I' as described in the September 28 letter is confirmed. A copy of the figure from the approved calculation is attached. Calculations GEO.DCPP.01.13, rev. 1, and GEO.DCPP.01.14, rev. 1, are both approved and time histories as described in the September 28 letter are confirmed. A CD of the time histories from the approved calculations is attached.

Email to Faiz Makdisi from Joseph Sun dated October 24, 2001. Subject: Ground motion parameters for back calculations.

This email provided input for a back calculation to assess conservatism in clay bed properties in the slope. Inputs included maximum displacement per event of 4 inches and a factor of 1.6 with which to multiply ground motions for use in the back calculation analysis. This letter confirms those input values, with the following limitation: these values have not been developed under an approved calculation, therefore should not be used to directly determine clay bed properties for use in forward analyses, but may be used for comparative purposes only, to assess the level of conservatism in those clay bed properties determined in approved calculations

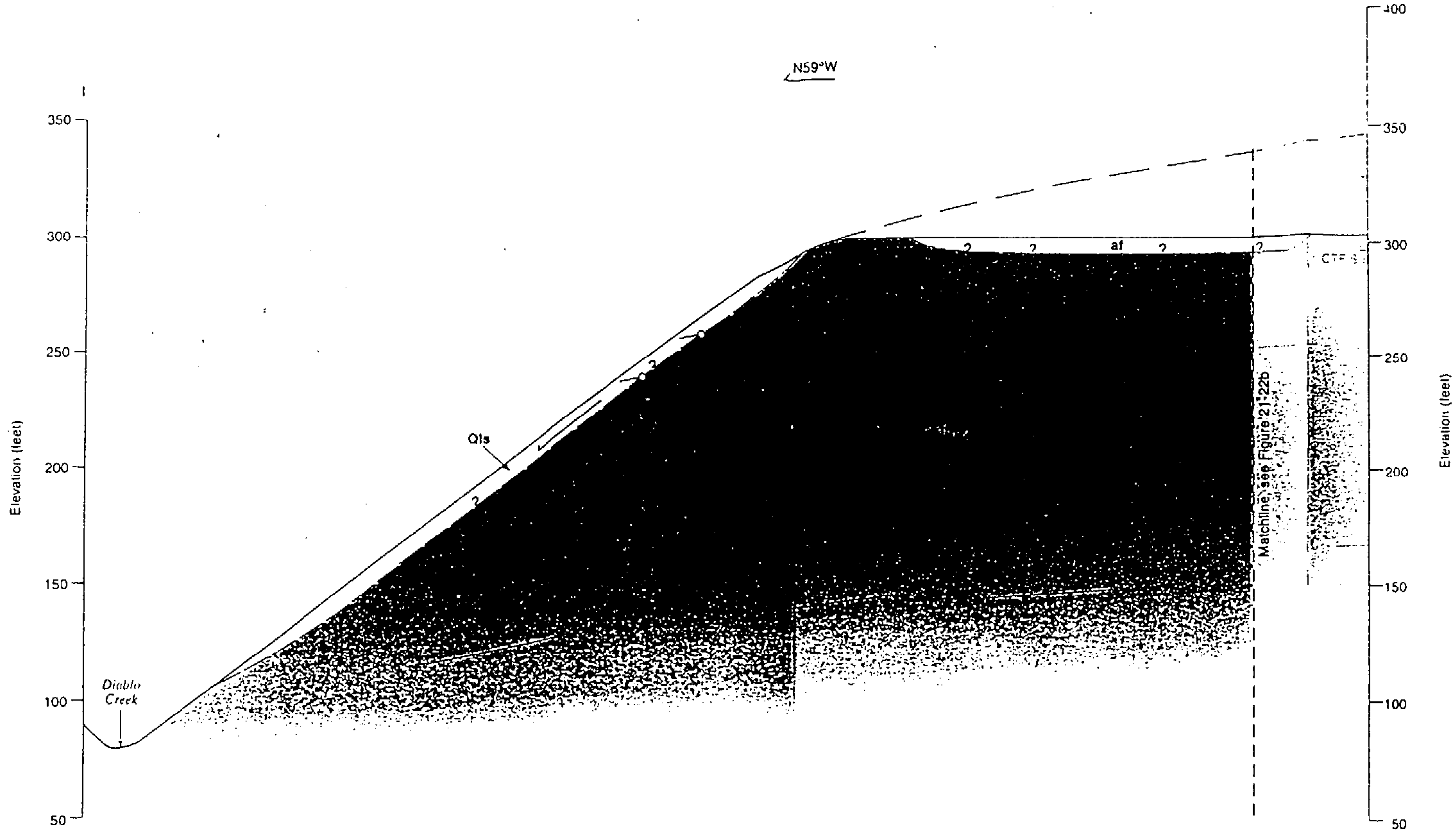
Letter to Faiz Makdisi from Jeff Bachhuber dated October 10, 2001. Subject: Transmittal of Revised Rock Mass Failure Models – DCPP ISFSI Project.

This letter provided you with figures indicating potential rock mass failure models as superimposed on section I-I'. This letter confirms PG&E approval to use these models in your analyses. These figures are labeled drafts and are currently being finalized in a revision to Calculation GEO.DCPP.01.21. Once this revision and the included figures have been approved, I will inform you in writing of their status.

Rob White

ROBERT K. WHITE

Attachments

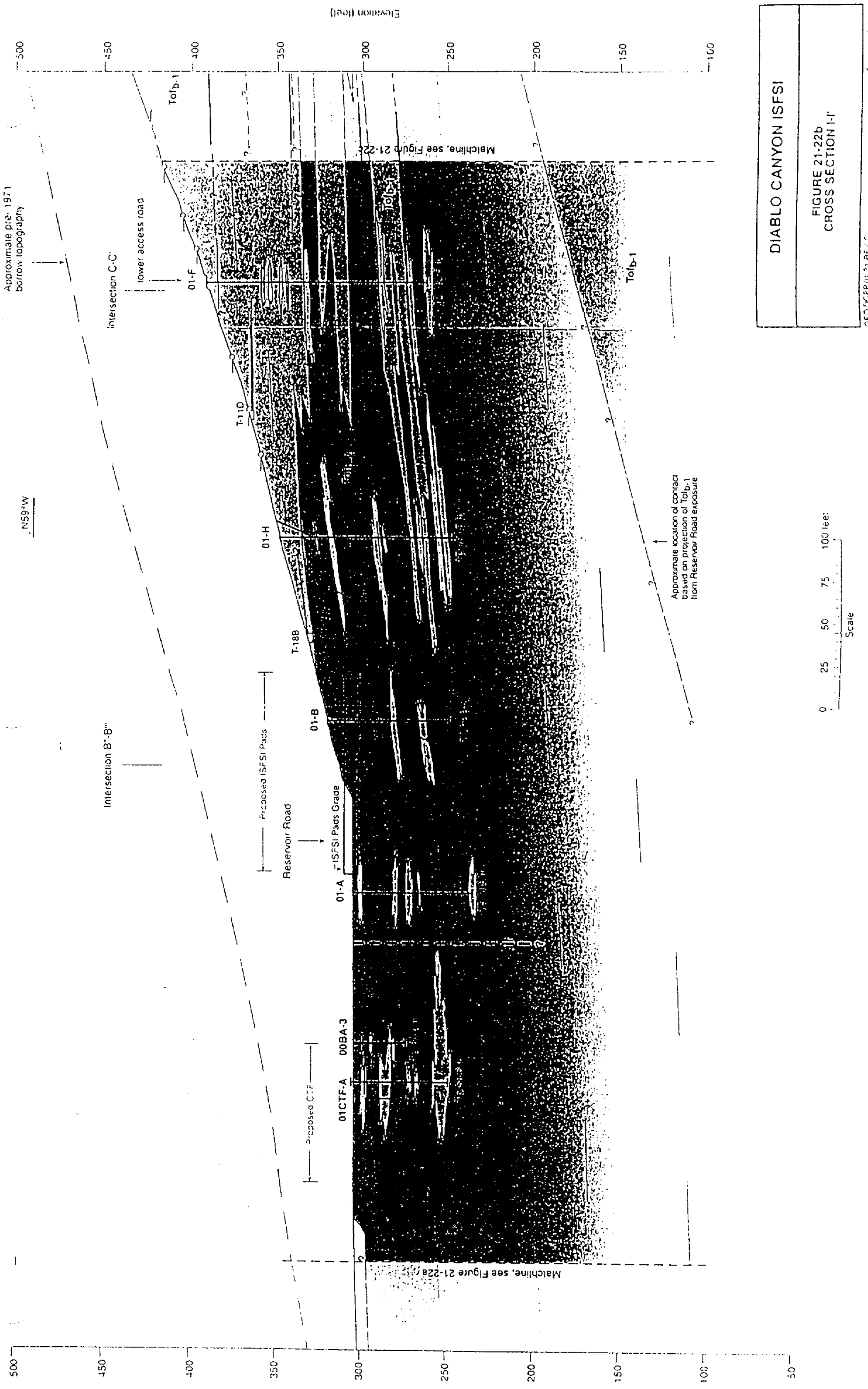


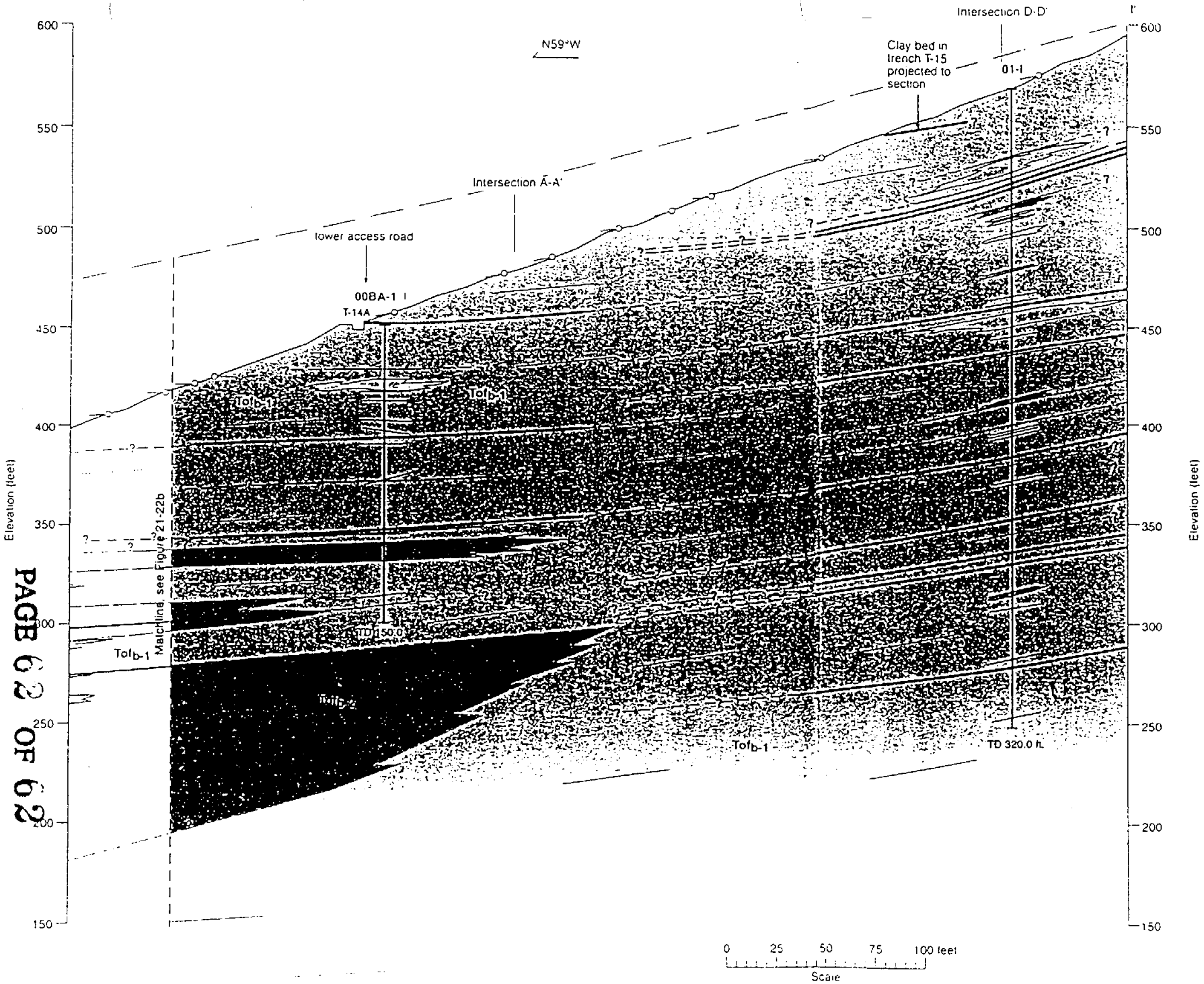
DIABLO CANYON ISFSI

FIGURE 21-22a
CROSS SECTION I-I'

GEO DCPP01 21 REV 0 October 15, 2001

GEO.DCPP.01. 24
REVISION 1





DIABLO CANYON ISFSI

FIGURE 21-22c
CROSS SECTION I-I'

GEO.DCPP.01.21 REV 0

October 15, 2001

Page 145c of 162

Calculation 52.27.100.734, Rev. 0, Attachment A, Page 62 of 65

PAGE 62 OF 62

GEO.DCPP.01.24
REVISION 1