Appendix H-4
Slope Stability Report

Prepared for

Southern California Gas Company
555 West 5th Street
Los Angeles, California 90051

SLOPE STABILITY EVALUATION

HONOR RANCHO COMPRESSOR MODERNIZATION PROJECT

SANTA CLARITA, CALIFORNIA

Prepared by

Geosyntec consultants

engineers | scientists | innovators

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Project Number SC0766U

August 2021

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August 9, 2021

Niu Quan
Southern California Gas Company
555 W 5th St.
Los Angeles, California 90013

Subject: Slope Stability Evaluation
Honor Rancho Compressor Modernization Project
Santa Clarita, California

Dear Mrs. Niu Quan:

Geosyntec Consultants (Geosyntec) is pleased to provide Southern California Gas Company (SoCalGas) with the accompanying report presenting the results of our geotechnical slope stability evaluations and recommendations to support the front-end engineering design (FEED) for the proposed Honor Rancho Compressor Modernization (HRCM) Project at SoCalGas's Honor Rancho Facility in Santa Clarita, California.

Our services were performed in general agreement with the Standard Services Agreement with SoCalGas (Agreement No. 5660060731), dated December 8, 2020, and Amendment No. 2 to the existing Agreement, dated May 17, 2021.

Geosyntec recently completed a geotechnical investigation (Geosyntec, 2021) for the HRCM project and this report builds on the evaluations presented there and presents our slope stability evaluation for the proposed grading plan. Based on our evaluation, the site is generally suitable for the proposed development of slopes, provided the design and construction incorporate the recommendations provided in the Geosyntec (2021) report.

We appreciate the opportunity to be of service to you on this project. If you have any questions concerning this report or if we may be of further service, please contact us. We appreciate your business and look forward to our next project with you.

Sincerely,

REGISTERED PROFESSIONAL ENGINEER
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1. INTRODUCTION

This report presents results of Geosyntec Consultants' (Geosyntec's) geotechnical engineering slope stability evaluations for the proposed Honor Rancho Compressor Modernization (HRCM) Project at the Southern California Gas Company's (SoCalGas') Honor Rancho Facility (Facility) in Santa Clarita, California. This report was prepared by Messrs. Dr. Bora Baturay, P.E., G.E and Ogul Doygun, and has been reviewed by Chris Conkle, P.E., G.E. in accordance with the peer review policies of the firm. Geosyntec prepared this report for SoCalGas's use at the time of the front-end engineering design (FEED) contractor's design effort for the project.

1.1 Project Description

The Facility is located in Santa Clarita, California, and situated to the north of Newhall Ranch road (Figure 1). Geosyntec recently completed a geotechnical investigation (Geosyntec, 2021) for the planned upgrades as part of the HRCM project, which include installation of a new hybrid compression plant that will be known as Injection Compressor Plant 2 (new Compressor Building), as well as several other facilities at various locations within the facility. The site plan, illustrating the proposed construction and surrounding areas, is presented on Figure 2.

The location of the proposed Advanced Renewable Energy (ARE) Facility has been previously graded and is currently relatively flat with a paved area containing several office trailers along with associated parking space. The proposed location of the new Compressor Building, as well as the associated buildings and Fuel Cells (see Figure 2), is currently mostly vacant, with high topography relief. Site preparation for these upgrades will require a substantial amount of excavation and grading to create a building pad at the appropriate elevation. The proposed cut slopes are typically at a 1 horizontal: 1 vertical (H:V) slope inclination with 8-foot wide drainage terraces placed no more than every 30 feet vertically. The preliminary grading plan prepared by SoCalGas design team is shown on Figure 2. The preliminary grading plan was provided to Geosyntec on July 8, 2021 and was used in the evaluations herein.

The improvements are expected to be founded on either shallow or deep foundations, depending on their location and required performance. The foundation recommendations concerning the proposed upgrades are presented in our geotechnical investigation report (Geosyntec, 2021). This report provides the results of our slope stability evaluation for the proposed cut slopes around the new Compressor Building and the existing slopes near the ARE Facility.

1.2 Scope of Work

Geosyntec's scope of work for the slope stability evaluation included:

- Task 1: Prepare a design basis memorandum for use in slope stability evaluation;

- Task 2: Assist in identifying options for the planned cut slopes in the new Compressor Building area;
- Task 3: Perform slope stability evaluations; and
- Deliverable: Prepare this report in general accordance with the County of Los Angeles Department of Public Works Manual for Preparation of Geotechnical Reports (LADPW, 2013).

1.3 Previous Site Investigations

Geosyntec (2021) advanced six cone penetration tests, four mud-rotary/rock core borings, and five hollow-stem borings and performed one OYO suspension P-S logging and a P-wave seismic refraction survey to characterize the soil and rock conditions at the Site. The Geosyntec (2021) report was the basis of our slope stability evaluations in this current report.

2. SCOPE OF SLOPE STABILITY EVALUATIONS

2.1 Design Basis Memorandum (Task 1)

Geosyntec prepared a design basis memorandum for use in the slope stability evaluation of the HRCM project and reached a consensus with the SoCalGas design team. This memorandum, dated June 8, 2021, included a discussion of the analysis approach and the design criteria for slope stability analyses of the proposed cut and existing slopes. The slope stability evaluation presented herein followed the design basis memorandum in general and the contents of the design basis memorandum are repeated in this report where appropriate.

2.2 Identification of Options during Site Grading Design Process (Task 2)

Geosyntec assisted the SoCalGas design team in identifying options for sloping and retaining proposed cut slopes adjacent to the new Compressor Building Area and ARE area based on the proposed site plan provided by SoCalGas. Within this task, Geosyntec evaluated various options such as traditional cut or steepened slopes by "top-down" methods such as soil nailing. This task included conference calls with the SoCalGas design team, during which the initial site plan and desired features of the final slopes were discussed. Different approaches (traditional cut or retaining wall) were discussed to finalize the slope design approach prior to formal evaluations in the next step.

SoCalGas' proposed site plan provided 45 feet of space between the toe of the cut slopes and the new Compressor Building Area to accommodate a 30-foot wide perimeter road and a 15-foot wide space for drainage features, as shown on Figure 2. The Los Angeles County Building Code (LACBC) sets minimum setback requirements for structures placed adjacent to slopes steeper than 3H:1V. Per LACBC, the setback requirement adjacent to ascending slopes similar to the new Compressor Building area cut slopes is smaller of half of the slope height (or 15 feet). Therefore, the provided 45 feet of space at the toe complies with LACBC.

SoCalGas' preference for the cut slopes was to maintain the existing natural ridgeline. Geosyntec proposed a 1H:1V slope inclination, following Los Angeles County Department of Public Works Grading Guidelines (LADPW, 2017) drainage terrace requirements (i.e., including minimum 8-foot wide drainage terraces every 30 feet vertically). The resulting crestline maintained the existing natural ridgeline, as desired by SoCalGas. Geosyntec also provided conceptual analyses of steeper cut slopes with slope stabilization features for SoCalGas' consideration. The option, including slope stabilization, was not further evaluated by the design team because the proposed 1H:1V cut slopes maintaining the existing ridgeline met the slope stability criteria, as discussed in the remainder of this report.

The planned site layout for the ARE area provides approximately 10 feet of space between the planned structures and the crest of the existing approximately 24-foot high slope, as shown on

Figure 2. Per LACBC, the setback requirements adjacent to descending slopes similar to the existing slopes at the ARE area are one third of the slope height, a minimum of 5 feet, and a maximum of 40 feet. Therefore, the planned site layout complies with LACBC. Additionally, because the existing slopes met the slope stability criteria, as discussed in the remainder of this report, modifications to the slope configuration or site plan was not considered.

2.3 Slope Stability Evaluations (Task 3)

Based on the consensus reached in Task 2, Geosyntec evaluated the ARE area in its existing current state. The geometry of the cut slopes in the new Compressor Building area was considered as 1H:1V with minimum 8-foot wide drainage terraces placed no more than every 30 feet vertically. (see Figure 3). The shear strength parameters used in the slope stability analyses are discussed in Section 3, and the details of the slope stability evaluations performed and the analysis results are provided in Section 4.

3. SHEAR STRENGTH PARAMETERS

The existing native slopes in the ARE area and the planned cut slopes in the new Compressor Building area are underlain by the Saugus Formation. The regional and local geology associated with the HRCM project is discussed in detail in the geotechnical investigation report for the project (Geosyntec, 2021) and is not repeated here. As discussed in Geosyntec (2021), the Saugus formation is largely “massive,” and no discernable weaknesses are present within the formation along the observed bedding; therefore, it is anticipated that an isotropic shear strength characterization is appropriate. Geosyntec used the results of the unconfined compressive strength (UCS) tests performed on the Saugus formation samples as part of the geotechnical investigation and developed rock mass shear strength parameters based on the Hooke-Brown approach (Hook et al., 2002). A detailed discussion of our Hoek-Brown evaluation is provided in Appendix A.

There is fill material on the top and fill and alluvium at the toe of the existing slopes in the ARE area. The shear strength parameters for these materials were estimated based on the direct shear tests performed on these materials as part of the geotechnical investigation (Geosyntec, 2021), and these parameters are summarized in Table 1 below.

Table 1 – Summary of Material Parameters for Stability Evaluations

Material	Model	Unit Weight (pcf)	Cohesion (psf)	Friction Angle Phi (deg)
Alluvium	Mohr-Coulomb	120	-	30
Fill	Mohr-Coulomb	120	-	30
Saugus Formation	Hoek-Brown	139	See Note 1	See Note 1

1) Shear strength parameters of the Saugus formation are based on a fully defined shear strength curve as a function of normal load, as documented in the Hoek-Brown solution in Appendix A.

4. SLOPE STABILITY EVALUATION

The slope stability evaluation of the existing slopes in the ARE area and the proposed cut slopes in the new Compressor Building area are discussed in this section. Surficial stability analyses were not performed because the exposed materials on the slope will consist of massive Saugus formation with high apparent cohesion. Per LADPW (2013), cut slopes that expose rock with an apparent cohesion greater than 250 psf need not be analyzed for surficial stability.

4.1 Selected Cross Sections for Analyses

The ARE area is located on top of a small hill that was previously graded level and paved. This area is approximately 24 feet higher than the adjacent ground on the east side, and the descending slope inclination is approximately 1H:1V. Cross Sections A-A' and B-B' were selected to evaluate the northeasterly and southeasterly facing slopes, respectively. For the ARE area, a uniform surcharge load of 250 psf was considered on the top of the slope with a horizontal setback of 10 feet from the slope crest to represent the structural loading, including the building and vehicles in the parking lots in the ARE area.

The planned cut slopes in new Compressor Building area will daylight near the existing ridgeline at two locations on the east side and at one location on the south side. Sections C-C' and D-D' were selected to evaluate the highest and steepest slope configuration in the east cut slope, and Section E-E' was selected for the south cut slope. The locations of the cross sections are shown on Figure 2, and the cross sections are shown on Figure 3.

4.2 Method of Analysis

For the stability analysis described herein, Geosyntec used the conventional two-dimensional limit equilibrium analysis method and calculated a factor of safety (FS) against sliding for static and seismic conditions. In particular, Geosyntec employed the Morgenstern and Price (1965) method, as implemented in SLOPE/W (GeoStudio, 2018). The results of the static analyses are presented in the form of critical (static) failure surfaces and the corresponding lowest calculated FS.

For the seismic stability evaluation, a pseudostatic stability analysis was performed by applying a horizontal seismic coefficient, k_h, as an additional driving force and calculating the FS. Two separate pseudostatic analyses were performed for each cross section. The first analysis was performed by applying a k_h of 0.15 and checking for a minimum FS of 1.1, as per the LADPW (2013). The second analysis was performed following the method presented in Bray and Travasarou (2007) and provides an estimate of the anticipated permanent seismic deformations following the design seismic event. The input parameters to Bray and Travasarou (2007) method for each cross section are the k_h value providing an FS of 1.0 (i.e., yield acceleration), the natural period of the potential slip surface, and the design response spectral acceleration corresponding to 1.5 times the natural period of the potential slip surface. the design response spectrum was developed based on the ground motion parameters provide in Geosyntec (2021). The results of the slope stability analyses are provided in Appendix B.

4.3 Acceptance Criteria

The slope stability acceptance criteria were developed primarily based on LADPW (2013). The maximum seismic deformation criterion was set as 36 inches for the cut slopes (Sections C-C, D-D’, and E-E’). The maximum seismic deformation criterion was set as 2 inches for the existing slopes (Sections A-A’ and B-B’) where potential slip surfaces intercept foundations or pavements. The static and seismic FS and permanent seismic deformation criteria used in our evaluation are summarized below:

Table 2 – Acceptance Criteria

Analysis Case	Criteria	Notes
Slope Stability Criteria		
Long-term static	FS ≥ 1.5	Per LADPW (2013)
Seismic	FS ≥ 1.1 with a k_h = 0.15	Per LADPW (2013)
Seismic Deformation Criteria		
Permanent Seismic Deformation (Sections A-A’ and B-B’)	≤ 2 inches	Method: Bray and Travasarou (2007)
Permanent Seismic Deformation (Sections C-C’, D-D’, and E-E’)	≤ 3 feet	Method: Bray and Travasarou (2007)

4.4 Analysis Results

The calculated FS for the static and seismic conditions are summarized in Table 3, and the permanent seismic deformations are summarized in Table 4. The graphical outputs of the Slope/W computer program are included in Appendix B. The FS for static and seismic cases and the maximum permanent seismic deformation criteria were met for all five sections analyzed.

Table 3 – Summary of Slope Stability Analysis Results

Appendix B Figure Number	Analysis Case	FS (Calculated)	FS (Criteria)
A.1	Long-term Static	2.44	1.5
A.2	Seismic (with k_h=0.15)	1.91	1.1
B.1	Long-term Static	2.35	1.5
B.2	Seismic (with k_h=0.15)	1.85	1.1
C.1	Long-term Static	1.52	1.5
C.2	Seismic (with k_h=0.15)	1.19	1.1
D.1	Long-term Static	1.54	1.5
D.2	Seismic (with k_h=0.15)	1.21	1.1
E.1	Long-term Static	1.77	1.5
E.2	Seismic (with k_h=0.15)	1.39	1.1

Table 4 – Summary of Permanent Seismic Deformation Analysis Results

Appendix B Figure Number	Analysis Case	Calculated Seismic Deformation (in)	Seismic Deformation Criteria (in)
A.3 and A.4	Permanent Seismic Deformation	1.5	2
B.3 and B.4	Permanent Seismic Deformation	1.5	2
C.3 and C.4	Permanent Seismic Deformation	12	36
D.3 and D.4	Permanent Seismic Deformation	12	36
E.3 and E.4	Permanent Seismic Deformation	12	36

5. CONSTRUCTION OBSERVATION

The project plans and specifications prepared by the FEED and Engineering Procurement and Construction (EPC) contractors should be reviewed by Geosyntec for conformance with the recommendations of this report.

The interpretations of the subsurface conditions described in this report are based on extrapolation of the limited observed conditions from the borings conducted into areas where excavations are planned. As actual conditions in the field may vary from those assumed in our analyses, during grading observations and testing should be conducted by Geosyntec to evaluate whether the anticipated geologic conditions were encountered. Geosyntec recommends that cut slopes be observed by our engineering geologist and that an “in grade” geologic map of these slopes be prepared.

Geosyntec’s field observations will also server to assess whether the construction related recommendations presented herein are implemented.

6. CONFORMANCE WITH SECTION 111 OF THE LOS ANGELES COUNTY BUILDING CODE

The proposed grading plan for the proposed Honor Rancho Compressor Modernization project has been designed in accordance with generally accepted standards of engineering practice. The design will be safe from the hazards of land sliding, settlement, or slippage for the proposed maintenance shop work area. The design conforms to the requirements of Section 111 of the Los Angeles County Building Code.

7. CONCLUSIONS AND RECOMMENDATIONS

The evaluations documented in this report shall be used for SoCalGas preliminary planning purposes in evaluating slope stability and seismic slope deformations within the footprint of future upgrades in the Honor Rancho Compressor Facility in the areas of the ARE and new compressor building. The results of our analyses show that the grading plans developed by SoCalGas, based on stability analyses conducted by Geosyntec, show acceptable safety factors and seismic deformation performance.

8. LIMITATIONS

The geotechnical slope stability and seismic deformation evaluation for this project observed only a small portion of the Site. The recommendations made herein are based on the assumption that soil conditions do not deviate appreciably from those found during Geosyntec (2021) field investigation. This geotechnical slope stability evaluation report has been prepared in accordance with current practices and the standard of care exercised by scientists and engineers performing similar tasks in this area. The conclusions contained in this report are based solely on the analysis of the conditions observed by Geosyntec personnel. We cannot make any assurances concerning the completeness of the data presented to us.

No warranty, expressed or implied, is made regarding the professional opinions expressed in this report. If actual conditions are found to differ from those described in the report, or if new information regarding the site conditions is obtained, Geosyntec should be notified and additional recommendations, if required, will be provided. Geosyntec is not liable for any use of the information contained in this report by persons other than SoCalGas, or their subconsultants, or the use of information in this report for any purposes other than referenced in this report without the expressed, written consent of Geosyntec.

9. REFERENCES

Bray, J.D. and Travasarou, T. (2007) "Simplified Procedure for Estimating Earthquake-Induced Deviatoric Slope Displacements," J. of Geotech. & Geoenv. Engrg., ASCE, Vol. 133(4), 381-392.

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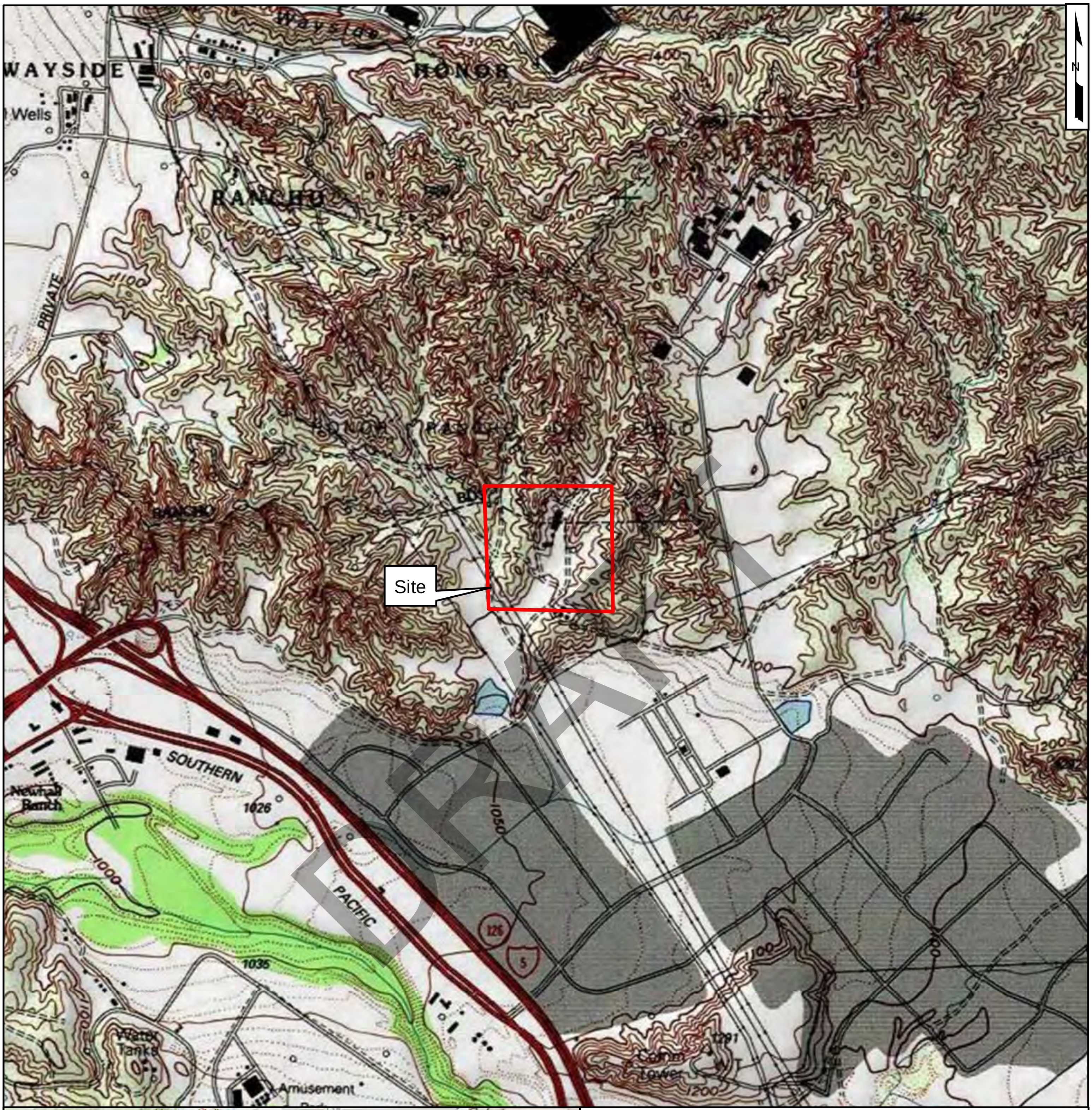
Hoek, E., Carranza-Torres, C., Corkum, B. (2002). Hoek-Brown Criterion-2002 Edition, Proc. NARMS-TAC Conference, Toronto, 2002, 1, 267-273.

Morgenstern, N.R. & Price, V.E. (1965). The analysis of the stability of general slip surface. Geotechnique 15(1), 79-93.

FIGURES



2,000 1,000 0 2,000 Feet

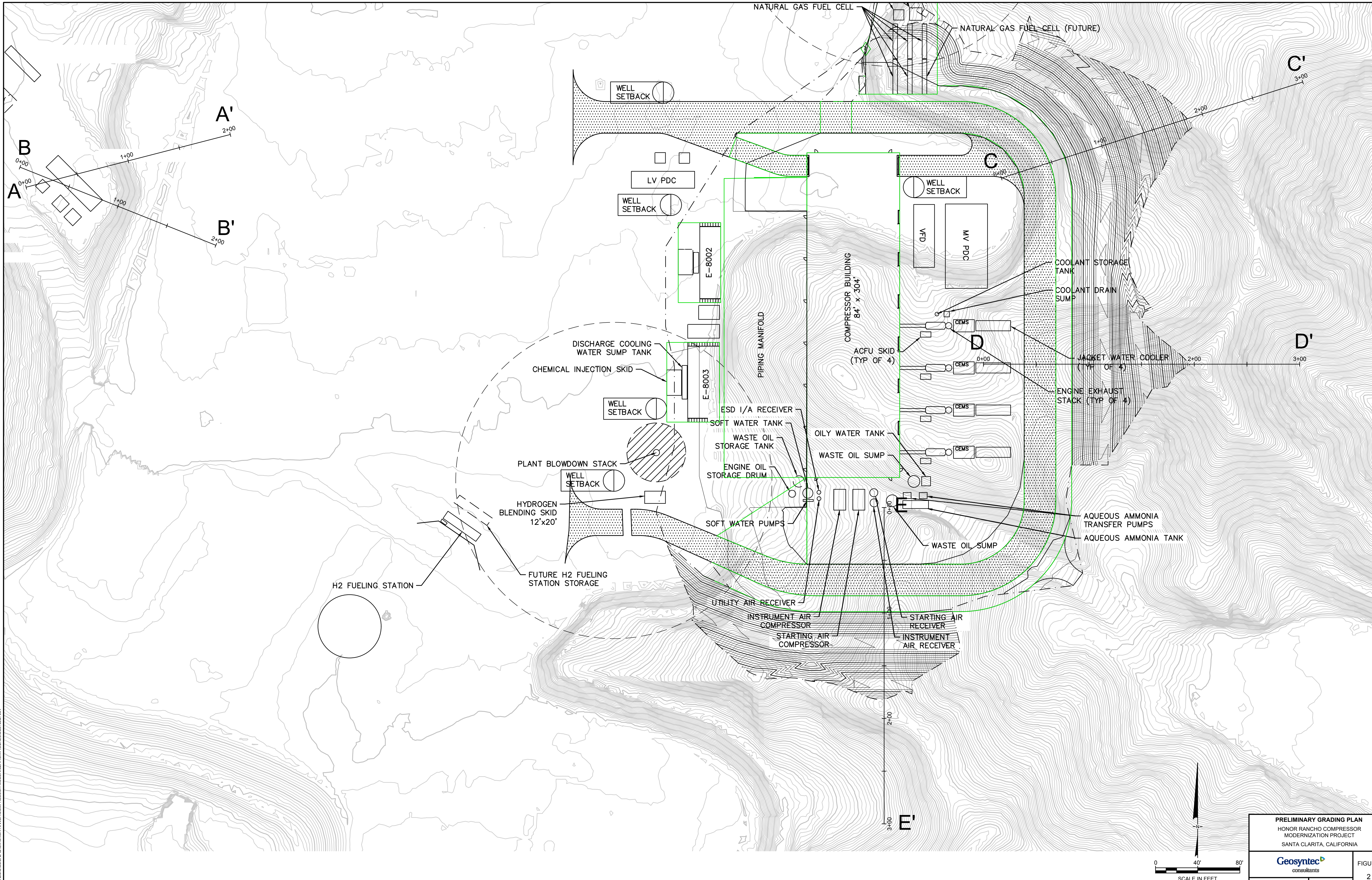
SITE LOCATION MAP

HONOR RANCHO COMPRESSOR MODERNIZATION PROJECT

SANTA CLARITA, CALIFORNIA

Geosyntec consultants

SC0766U	AUG 2021	FIGURE 1



PRELIMINARY GRADING PLAN

HONOR RANCHO COMPRESSOR MODERNIZATION PROJECT

SANTA CLARITA, CALIFORNIA

Geosyntec consultants

FIGURE 2

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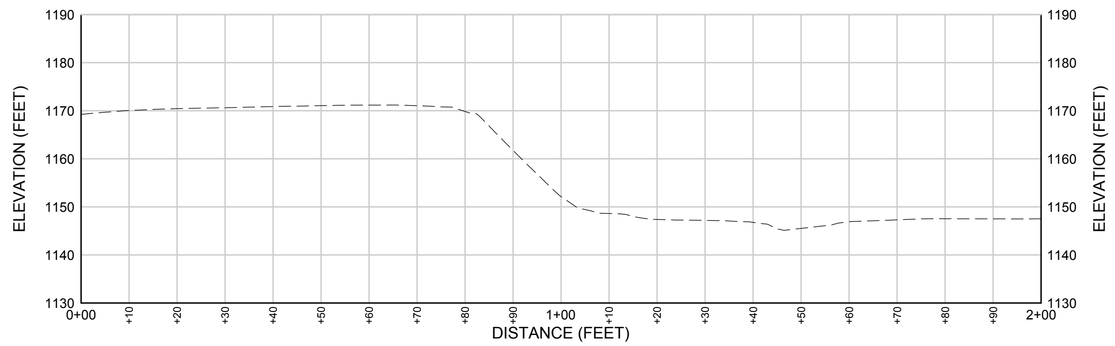
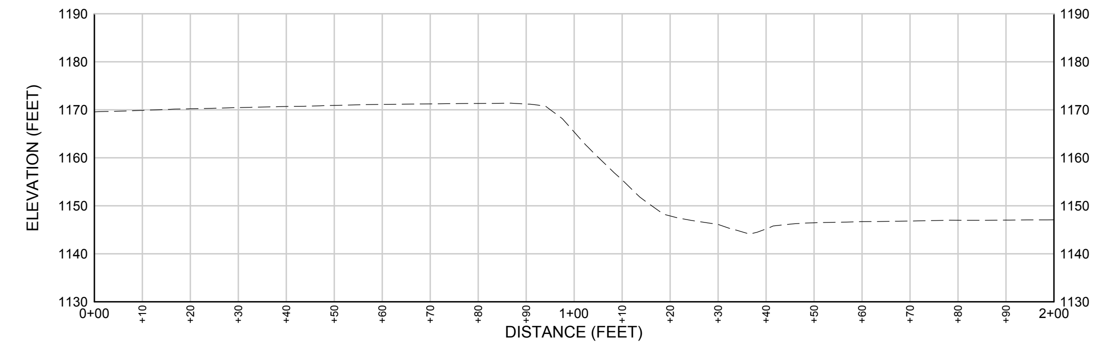


SECTION A-A' PROFILE
HORIZONTAL: 1" =20'
VERTICAL: 1" =20'



SECTION B-B' PROFILE
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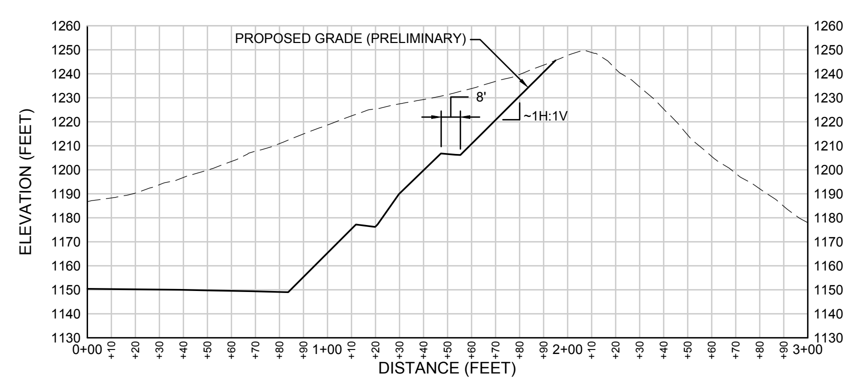
VERTICAL: 1" =20'

SECTION C-C' PROFILE
HORIZONTAL: 1" =40'
VERTICAL: 1" =40'



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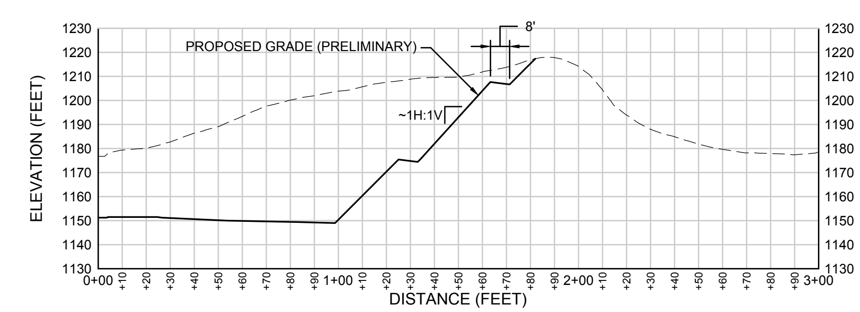
HORIZONTAL: 1" =40'
VERTICAL: 1" =40'



SECTION E-E' PROFILE
HORIZONTAL: 1" =40'
VERTICAL: 1" =40'

CROSS SECTIONS
HONOR RANCHO COMPRESSOR MODERNIZATION PROJECT
SANTA CLARITA, CALIFORNIA

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FIGURE 3

PROJECT NO: SC0776U | AUG 2021

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APPENDIX A

Evaluation of Hoek-Brown Strength Parameters for Saugus Formation

Geosyntec consultants

COMPUTATION COVER SHEET

Client: **SoCalGas** Project: **Honor Rancho Compressor Modernization** Project/ Proposal No.: **SC0766U**
Phase/ Task No. **06**

Title of Computations **Equivalent Mohr Coulomb Parameters for Saugus Formation**

Computations by:	Signature		06/16/2021
	Printed Name	Ogul Doygun, Ph.D.	Date
	Title	Senior Staff Professional	
Assumptions and Procedures Checked by: (peer reviewer)	Signature		06/16/2021
	Printed Name	Dennis Kilian, P.G., C.E.G.	Date
	Title	Project Geologist	
Computations Checked by:	Signature		06/16/2021
	Printed Name	Bora Baturay, Ph.D., P.E., G.E.	Date
	Title	Principal Geotechnical Engineer	
Computations backchecked by: (originator)	Signature		06/16/2021
	Printed Name	Ogul Doygun, Ph.D.	Date
	Title	Senior Staff Professional	
Approved by: (pm or designate)	Signature		06/17/2021
	Printed Name	Alexander Greene, P.G., C.E.G.	Date
	Title	Senior Principal Engineering Geologist	

Approval notes:

Revisions (number and initial all revisions)

No.	Sheet	Date	By	Checked by	Approval

Written by:	O. Doygun	Date:	06/16/2021	Reviewed by:	Dennis Kilian	Date:	06/16/2021
Client:	SoCal Gas	Project:	Honor Rancho Compressor	Project No.	SC0766U	Task No.:	6

EVALUATION OF MOHR COULOMB PARAMETERS FOR SAUGUS FORMATION

1. PURPOSE AND SCOPE

The purpose of this calculation package is to develop equivalent Mohr-Coulomb shear strength parameters (i.e., friction angle and cohesion) for the Saugus Formation at the Site. Hoek-Brown failure criterion (1980, 2002) was used along with the unconfined compression strength test results obtained from intact rock samples at the Site, observation of the continuous rock cores, and the site visit observations of exposed cut slopes.

2. BACKGROUND

The original Hoek-Brown failure criterion was developed in 1980 in the form of a dimensionless equation that could be scaled in relation to geological information and geological observations. In 2002, the entire Hoek-Brown criterion was re-examined and the relationships between the Mohr-Coulomb and the Hoek-Brown criteria were examined for slopes and a set of equations linking the two were presented (Hoek et al. 2002). The final relationships were derived by comparing hundreds of tunnel and slope stability analyses in which both the Hoek-Brown and the Mohr Coulomb criteria were used, and the best match was found by iteration. In the following, first the implemented equations and assumptions are introduced, which is followed by the presentation of the resulting equivalent Mohr Coulomb parameters (friction angle and cohesion)..

3. INPUT PARAMETERS

3.1 Rock Type

Based on the explorations, including continuous rock coring in multiple locations, as well as geologic mapping, Plio-Pleistocene age Saugus Formation underlies the slope area. The Saugus Formation encountered during the explorations generally consists predominantly of silty and clayey sandstones with gravels and cobbles with interbedded red and light brown sandy claystone. The approximate range observed in the unit was estimated at 60% sandstone to 40% claystone. The Saugus Formation was observed to be moderately to highly weathered and occasionally friable in the absence of fines. Topsoils, residual soils, and slopewash encountered overlying the Saugus formation are generally unconsolidated and remediated through grading and therefore, not considered for use in this analysis. Based on geologic mapping the Saugus Formation indicated a general dip of 50 to 70 degrees to the southwest, correlating with the southern leg of an anticline with the axis located approximately parallel to the San Gabriel Fault, 1.5 miles north of the site.

Written by:	O. Doygun	Date:	06/16/2021	Reviewed by:	Dennis Kilian	Date:	06/16/2021
Client:	SoCal Gas	Project:	Honor Rancho Compressor	Project No.	SC0766U	Task No.:	6

The unit observed was generally intact and massive with thick to very thick bedding. Well-developed jointing and fracturing of in-situ rock was minimal. Based on the results of the seismic refraction survey (Geosyntec, 2021), the Saugus Formation within the footprint of the proposed Compressor Facility is interpreted to be rippable with Primary compression wave (P-wave) velocities in the range of 2,500 to 4,500 ft/s within the depth of the investigation of about 40 ft. The maximum P-wave velocities in the Saugus Formation underlying the alluvium in the valley area were approximately 5,500 to 6,000 ft/s.

3.2 Intact uniaxial compressive strength

The unconfined compression test results for the rock samples from the Saugus formation are summarized in Table 1. Based on the evaluation of the results in Table 1 and averaging the results between the estimated sandstone and claystone ratio (60:40), an intact uniaxial strength of 21 ksf (1 MPa) was deemed representative for the Saugus formation. The chosen uniaxial compressive strength indicates that the Saugus formation on Site corresponds to a very weak formation based on Table 2, which is also in good agreement with our geological surveys on Site. Based on our review, the results from samples 3 and 6 were omitted because the samples may have been compromised and are not believed to be representative of the intact rock within the overall rock mass.

Table 1. Uniaxial Compressive Strength Test Results (Geosyntec, 2021)

Sample Information				Description	Uniaxial Compressive Strength Test Results (ASTM D7012)
Sample Number	Sample ID	Sample Type [a]	Depth (ft bgs)		
1	B-1@40-43	Rock Core	40.5-41	Clayey Sandstone	UCS = 14.08 ksf
2	B-1@43-46	Rock Core	44.1-44.5	Clayey Sandstone	UCS = 31.83 ksf
3	B-2@7.5-10	Rock Core	9-9.5	Silty Sandstone	UCS = 2.32 ksf
4	B-2@15-17.5	Rock Core	15.5-16	Silty Claystone	UCS = 7.04 ksf

5	B-2@22.5-25	Rock Core	24-24.5	Claystone	UCS = 6.14 ksf
6	B-2@27-30	Rock Core	27.5-28	Silty Sandstone	UCS = 0.89 ksf
7	B-3@6-11	Rock Core	7.5-8	Sandy Claystone	UCS = 5.33 ksf
8	B-4@1.5-6	Rock Core	5-5.5	Silty Sandstone	UCS = 47.60 ksf

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Client:	SoCal Gas	Project:	Honor Rancho Compressor	Project No.	SC0766U	Task No.:	6

Table 2. Field estimates of unconfined compressive strength (Hoek, 2001)

Grade*	Term	Uniaxial Comp. Strength (MPa)	Point Load Index (MPa)	Field estimate of strength	Examples
R6	Extremely Strong	> 250	>10	Specimen can only be chipped with a geological hammer	Fresh basalt, chert, diabase, gneiss, granite, quartzite
R5	Very strong	100 - 250	4 - 10	Specimen requires many blows of a geological hammer to fracture it	Amphibolite, sandstone, basalt, gabbro, gneiss, granodiorite, peridotite , rhyolite, tuff
R4	Strong	50 - 100	2 - 4	Specimen requires more than one blow of a geological hammer to fracture it	Limestone, marble, sandstone, schist
R3	Medium strong	25 - 50	1 - 2	Cannot be scraped or peeled with a pocket knife, specimen can be fractured with a single blow from a geological hammer	Concete, phyllite, schist, siltstone
R2	Weak	5 - 25	**	Can be peeled with a pocket knife with difficulty, shallow indentation made by firm blow with point of a geological hammer	Chalk, claystone, potash, marl, siltstone, shale, rocksalt,
R1	Very weak	1 - 5	**	Crumbles under firm blows with point of a geological hammer, can be peeled by a pocket knife	Highly weathered or altered rock, shale
R0	Extremely weak	0.25 - 1	**	Indented by thumbnail	Stiff fault gouge

* Grade according to Brown (1981).
** Point load tests on rocks with a uniaxial compressive strength below 25 MPa are likely to yield highly ambiguous results.

3.3 Geological strength index (GSI)

The strength of a jointed rock mass depends on the properties of the intact rock pieces and also upon the freedom of these pieces to slide and rotate under different stress conditions. This freedom is controlled by the geometrical shape of the intact rock pieces as well as the condition of the surfaces separating the pieces. Angular rock pieces with clean, rough discontinuity surfaces will result in a much stronger rock mass than one which contains rounded particles surrounded by weathered and altered material. The Geological Strength Index (GSI), introduced by Hoek (1994) and Hoek, Kaiser and Bawden (1995) provides a system for estimating the reduction in rock mass strength for different geological conditions. This system is presented in Table 3, for blocky rock masses, and Table 4 for schistose metamorphic rocks.

Table 3. Characterization of a blocky rock masses based on particle interlocking and discontinuity condition (Hoek, 2001)

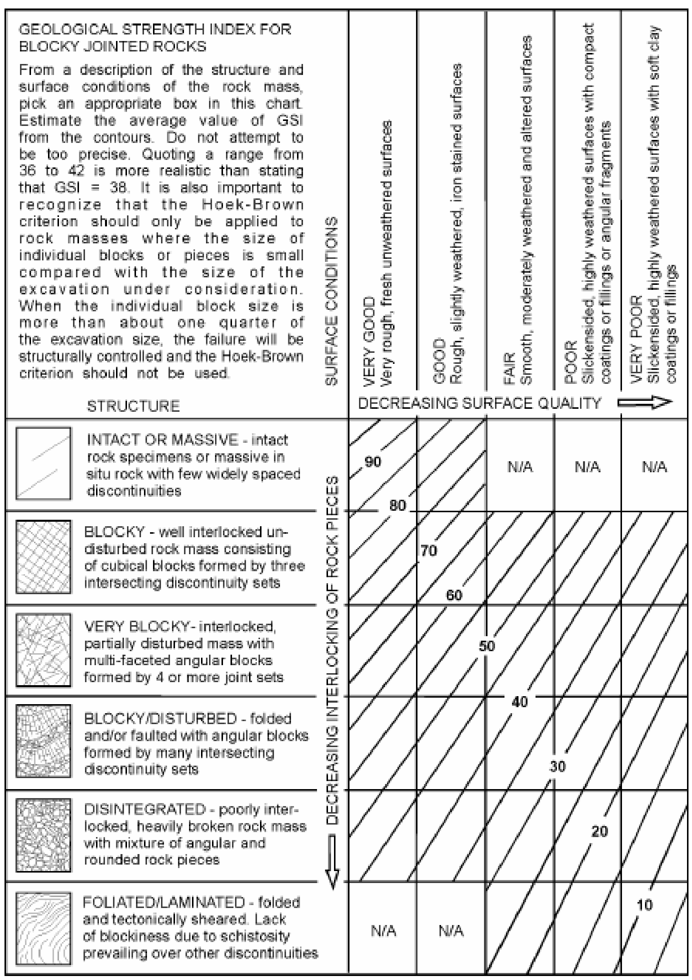
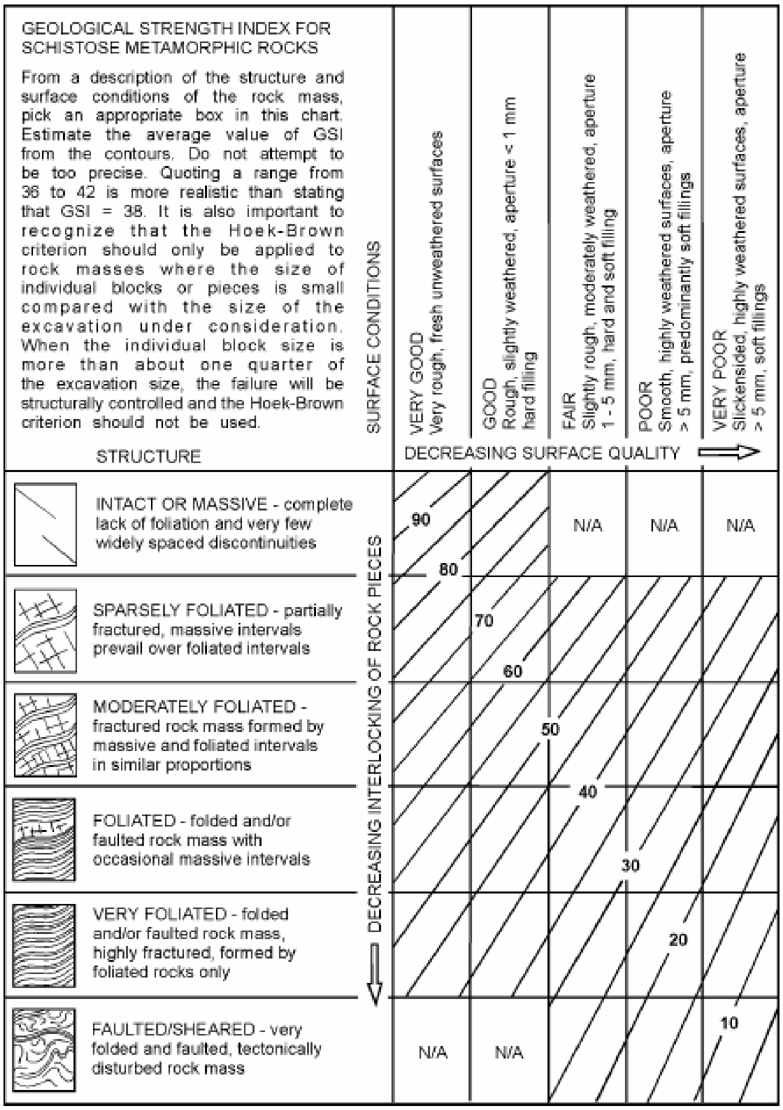


Table 4. Characterization of schistose metamorphic rock masses based on foliation and discontinuity condition (Hoek, 2001)



Based on the observed surface and structure conditions of the thick to very thick beds (generally greater than ten inches and as much as five feet thick) observed during Geosyntec field soil investigation visit on Site, a good to fair surface condition with a GSI value of 65 was deemed to be representative for the observed surface conditions and rock structure (Rough, slightly to moderately weathered surfaces, altered surfaces, and blocky).

3.4 Material Constants

The generalized Hoek-Brown failure criterion for rock masses is defined by the equation below:

$$\sigma_1' = \sigma_3' + \sigma_{ci} * (m_b * \frac{\sigma_3'}{\sigma_{ci}} + s)^a \quad (1)$$

where σ_1' and σ_3' are the major and minor effective principal stresses at failure;

m_b is a reduced value of the material constant m_i and is given by $m_b = m_i * \exp\left(\frac{GSI-100}{28-14D}\right)$

D is disturbance factor (defined in Section 3.4)

σ_{ci} is the uniaxial compressive strength of the intact rock material;

m_i is the material constant for intact rock;

s and *a* are constants for the rock mass given by the following relationships:

$$s = \exp\left(\frac{GSI-100}{9-3D}\right) \quad (2)$$

$$a = \frac{1}{2} + \frac{1}{6} * (e^{-\frac{GSI}{15}} - e^{-\frac{20}{3}}) \quad (3)$$

The material constant, m_i can be estimated for the Saugus formation considering the 60 to 40 sandstone to claystone ratio as 10 based on Table 5.

3.5 Disturbance Factor (*D*)

Disturbance factor (*D*) depends on the degree of disturbance to which the rock mass has been subjected by blast damage, mechanical excavation and/or stress relaxation. It varies from 0 for undisturbed in-situ rock masses to 1 for very disturbed rock masses. Guidelines for the selection of *D* are presented in Table 6. Considering the fact that rock masses at Site are observed to be weathered yet primarily intact on the surface, the Saugus formation can be assumed to possess a *D* factor of 0.7 based on Geosyntec's observations on site and observed intact rock samples from the site.

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3.6 Rock mass deformation modulus (E_{rm}), Modulus Ratio (MR), Intact modulus (E_i)

Hoek and Diederichs (2006) re-examined existing empirical methods for estimating rock mass deformation modulus. In their analysis, they incorporated modulus ratio (MR), which is the ratio of rock mass deformation modulus to intact modulus (E_{rm}/E_i). Using the modulus ratio (MR), the intact modulus (E_i) can be estimated as:

$$E_i = MR * \sigma_{ci} \quad (4)$$

The modulus ratio (MR) in equation (4) can be assumed as MR=250 based on Table 7 for the encountered Saugus formation at Site, which results in an intact modulus value of E_i = 250 MPa based on the uniaxial compressive strength of the rock material (σ_{ci} = 1 MPa).

Based on the detailed analysis of Hoek and Diederichs (2006), rock deformation modulus (E_{rm}) can be estimated as:

$$E_{rm} = E_i * \left(0.02 + \frac{1-\frac{D}{2}}{1+e^{\left(\frac{60+15D-GSI}{11}\right)}}\right) \quad (5)$$

By considering a GSI value of 65 and D value of 0.7, the rock deformation modulus can be calculated as E_{rm}= 66.4 MPa.

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Table 5. Values of the constant m_i for intact rock, by rock group. Note that values in parenthesis are estimates. (Hoek, 2001)

Rock type	Class	Group	Texture: Coarse	Texture: Medium	Texture: Fine	Texture: Very fine
SEDIMENTARY	Clastic		Conglomerates (21 ± 3) Breccias (19 ± 5)	Sandstones 17 ± 4	Siltstones 7 ± 2 Greywackes (18 ± 3)	Claystones 4 ± 2 Shales (6 ± 2) Marls (7 ± 2)
SEDIMENTARY	Non-Clastic	Carbonates	Crystalline Limestone (12 ± 3)	Sparitic Limestones (10 ± 2)	Micritic Limestones (9 ± 2)	Dolomites (9 ± 3)
SEDIMENTARY	Non-Clastic	Evaporites		Gypsum 8 ± 2	Anhydrite 12 ± 2	
SEDIMENTARY	Non-Clastic	Organic				Chalk 7 ± 2
METAMORPHIC	Non Foliated		Marble 9 ± 3	Hornfels (19 ± 4) Metasandstone (19 ± 3)	Quartzites 20 ± 3	
METAMORPHIC	Slightly foliated		Migmatite (29 ± 3)	Amphibolites 26 ± 6		
METAMORPHIC	Foliated*		Gneiss 28 ± 5	Schists 12 ± 3	Phyllites (7 ± 3)	Slates 7 ± 4
IGNEOUS	Plutonic	Light	Granite 32 ± 3 Granodiorite (29 ± 3)	Diorite 25 ± 5		
IGNEOUS	Plutonic	Dark	Gabbro 27 ± 3 Norite 20 ± 5	Dolerite (16 ± 5)		
IGNEOUS	Hypabyssal		Porphyries (20 ± 5)		Diabase (15 ± 5)	Peridotite (25 ± 5)
IGNEOUS	Volcanic	Lava		Rhyolite (25 ± 5) Andesite 25 ± 5	Dacite (25 ± 3) Basalt (25 ± 5)	Obsidian (19 ± 3)
IGNEOUS	Volcanic	Pyroclastic	Agglomerate (19 ± 3)	Breccia (19 ± 5)	Tuff (13 ± 5)	

* These values are for intact rock specimens tested normal to bedding or foliation. The value of m_i will be significantly different if failure occurs along a weakness plane.

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Table 6. Guidelines for estimating disturbance factor *D*. (Hoek et al, 2002)

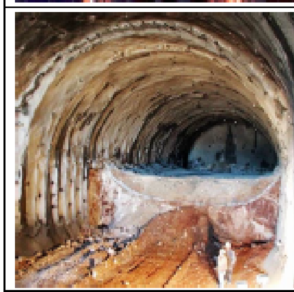
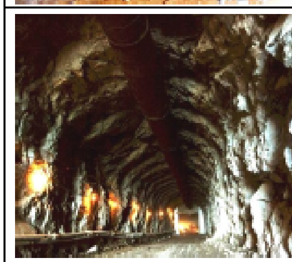
Appearance of rock mass	Description of rock mass	Suggested value of *D*
	Excellent quality controlled blasting or excavation by Tunnel Boring Machine results in minimal disturbance to the confined rock mass surrounding a tunnel.	$D = 0$
	Mechanical or hand excavation in poor quality rock masses (no blasting) results in minimal disturbance to the surrounding rock mass. Where squeezing problems result in significant floor heave, disturbance can be severe unless a temporary invert, as shown in the photograph, is placed.	$D = 0$ $D = 0.5$ No invert
	Very poor quality blasting in a hard rock tunnel results in severe local damage, extending 2 or 3 m, in the surrounding rock mass.	$D = 0.8$
	Small scale blasting in civil engineering slopes results in modest rock mass damage, particularly if controlled blasting is used as shown on the left hand side of the photograph. However, stress relief results in some disturbance.	$D = 0.7$ Good blasting $D = 1.0$ Poor blasting
	Very large open pit mine slopes suffer significant disturbance due to heavy production blasting and also due to stress relief from overburden removal. In some softer rocks excavation can be carried out by ripping and dozing and the degree of damage to the slopes is less.	$D = 1.0$ Production blasting $D = 0.7$ Mechanical excavation

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Table 7. Guidelines for the selection of modulus ratio (MR) values in Equation (4) (Hoek, and Diederichs, 2006)

Rock type	Class	Group	Texture: Coarse	Texture: Medium	Texture: Fine	Texture: Very fine
Sedimentary	Clastic		Conglomerates 300–400 Breccias 230–350	Sandstones 200–350	Siltstones 350–400 Greywackes 350	Claystones 200–300 Shales 150–250[a] Marls 150–200
Sedimentary	Non-clastic	Carbonates	Crystalline limestones 400–600	Sparitic limestones 600–800	Micritic Limestones 800–1000	Dolomites 350–500
Sedimentary	Non-clastic	Evaporites		Gypsum (350)[b]	Anhydrite (350)[b]	
Sedimentary	Non-clastic	Organic				Chalk 1000+
Metamorphic	Non-foliated		Marble 700–1000	Hornfels 400–700 Metasandstone 200–300	Quartzites 300–450	
Metamorphic	Slightly foliated		Migmatite 350–400	Amphibolites 400–500	Gneiss 300–750[a]	
Metamorphic	Foliated[a]			Schists 250–1100[a]	Phyllites/Mica Schist 300–800[a]	Slates 400–600[a]
Igneous	Plutonic	Light	Granite[c] 300–550 Granodiorite[c] 400–450	Diorite[c] 300–350		
Igneous	Plutonic	Dark	Gabbro 400–500 Norite 350–400	Dolerite 300–400		
Igneous	Hypabyssal		Porphyries (400)[b]		Diabase 300–350	Peridotite 250–300
Igneous	Volcanic	Lava		Rhyolite 300–500 Andesite 300–500	Dacite 350–450 Basalt 250–450	
Igneous	Volcanic	Pyroclastic	Agglomerate 400–600	Volcanic breccia (500)[b]	Tuff 200–400	

[a]Highly anisotropic rocks: the value of MR will be significantly different if normal strain and/or loading occurs parallel (high MR) or perpendicular (low MR) to a weakness plane. Uniaxial test loading direction should be equivalent to field application.
[b]No data available, estimated on the basis of geological logic.
[c]Felsic Granitoids: coarse grained or altered (high MR), fined grained (low MR).

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3.7 Uniaxial compressive strength, tensile strength and rock mass (global) strength

The uniaxial compressive strength of in-situ rock mass is obtained by setting $\boldsymbol{\sigma'_3}$=0 in equation (1), giving:

$$\sigma_c = \sigma_{ci} * s^a \tag{6}$$

and, the tensile strength is:

$$\sigma_t = -\frac{s*\sigma_{ci}}{m_b} \tag{7}$$

The uniaxial compressive strength of the rock mass σ_c is given by equation (6). This strength is representative for failures that initiate at the boundary of an excavation when σ_c is exceeded by the stress induced on that boundary. The failure propagates from this initiation point into a biaxial stress field and it eventually stabilizes when the local strength, defined by equation (1), is higher than the induced stresses σ'_1 and σ'_3 .

Based on Hoek et al. (2002), it is useful to consider the overall behavior of a rock mass rather than the detailed failure propagation process described above. This leads to the concept of a global rock mass strength σ'_{cm}, which can be estimated from the Mohr Coulomb relationship:

$$\sigma'_{cm} = \frac{2*c*cos\varphi}{1-sin\varphi} \tag{8}$$

with cohesion (c) and friction angle (φ) determined for the stress range $\sigma_t < \sigma_3 < \sigma_{ci}/4$, resulting in the rock mass (global) strength as:

$$\sigma'_{cm} = \sigma_{ci} * \frac{(m_b+4s-a(m_b-8s))*(\frac{m_b}{4}+s)^{(a-1)}}{2*(1+a)*(2+a)} \tag{9}$$

For the project boundary conditions, the resulting in-situ uniaxial compressive strength, tensile strength, and the rock mass (global) strength values are calculated as: σ_c = 0.08 MPa, σ_t = -0.004 MPa, σ'_{cm} = 0.17 MPa.

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3.8 Maximum confining Stress (σ_{3max}) and Mohr-Coulomb Criterion

The equivalent Mohr-Coulomb parameters (friction angle and cohesion) for a rock mass will be determined case-specifically for the relevant stress range. This is done by fitting an average linear relationship to the curve generated by solving equation (1) for a range of minor principal stress values defined by $\boldsymbol{\sigma_t < \sigma_3 < \sigma_{3max}}$, as illustrated in Figure 1.

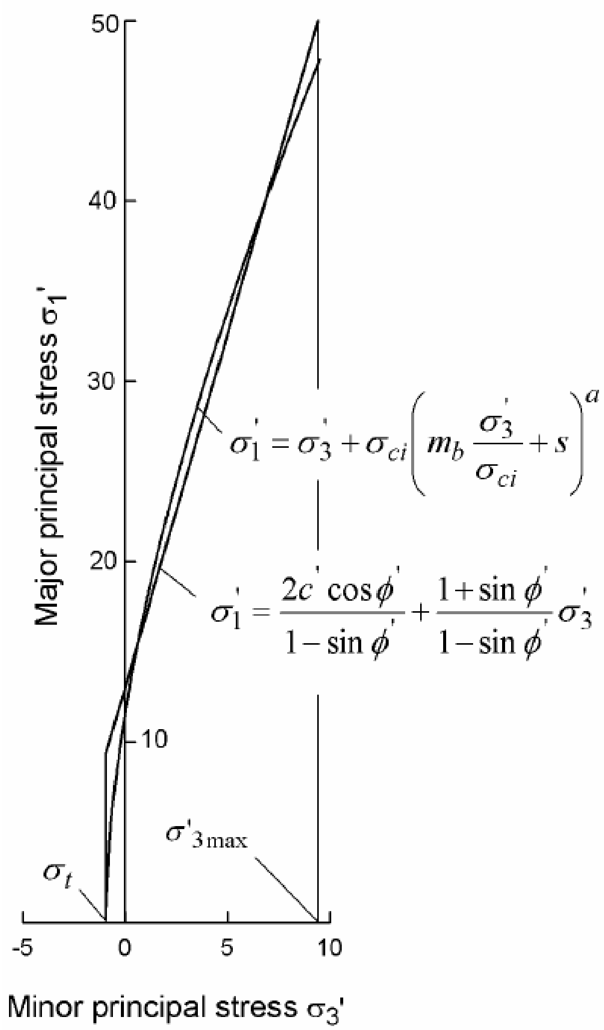

Figure 1. Relationships between major and minor principal stresses for Hoek-Brown and equivalent Mohr-Coulomb criteria (Hoek et al, 2002)

The fitting process involves balancing the areas above and below the Mohr-Coulomb plot. This results in the following equations for the equivalent angle of friction and cohesive strength of the in-situ rock mass:

$$\varphi = sin^{-1}\left[\frac{6am_b(s+m_b\sigma_{3n})^{(a-1)}}{2(1+a)(2+a)+6am_b(s+m_b\sigma_{3n})^{(a-1)}}\right] \quad (10)$$

$$c = \frac{\sigma_{ci}[(1+2a)s+(1-a)m_b\sigma_{3n}](s+m_b\sigma_{3n})^{(a-1)}}{(1+a)(2+a)\sqrt{1+\frac{(6am_b(s+m_b\sigma_{3n})^{(a-1)}}{(1+a)(2+a)}}} \quad (11)$$

where $\sigma_{3n} = \frac{\sigma_{3max}}{\sigma_{ci}}$

The maximum confining stress (σ_{3max}), is the upper limit of confining stress over which the relationship between the Hoek-Brown and Mohr-Coulomb criteria is considered and this has to be determined for each individual case. Based on Hoek et al. (2002), extensive studies for slopes, using Bishop's circular failure analysis for a wide range of slope geometries and rock mass properties, gave:

$$\frac{\sigma_{3max}}{\sigma'_{cm}} = 0.72 * (\frac{\sigma'_{cm}}{\gamma H})^{-0.91} \quad (12)$$

where H is the height of the slope.

4. RESULTS

Based on the previously described calculations (Equation 1 through 12), the equivalent Mohr-Coulomb strength parameters for the Saugus formation at Site are summarized in Table 8 for various slope heights considered in our slope stability evaluations. The graphical illustration of the equivalent Mohr-Coulomb soil strength model along with the Hoek-Brown rock model for the considered rock parameters is shown in Figure 2. Shear strength parameters used in slope stability analyses may either be based on equivalent Mohr-Coulomb parameters for corresponding equivalent slope height or the fully defined shear strength curve as a function of normal load as shown in the Hoek-Brown model solution in Figure 2 for the Saugus formation at the Site.

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Table 8. Equivalent Mohr Coulomb Parameters based on Hoek-Brown Model

Cross Section	Slope Height, H (ft)	phi (deg)	c (psf)
A, B	20	38	569
E	70	28	1107
C, D	100	26	1350

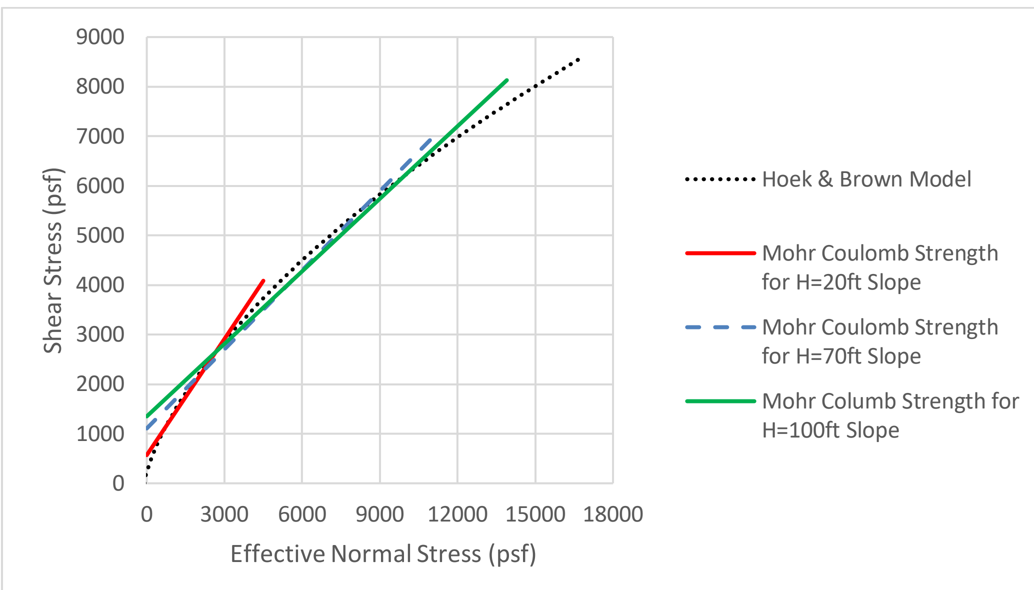

Figure 2. Equivalent Mohr Coulomb Strength based on Hoek-Brown Model

5. REFERENCES

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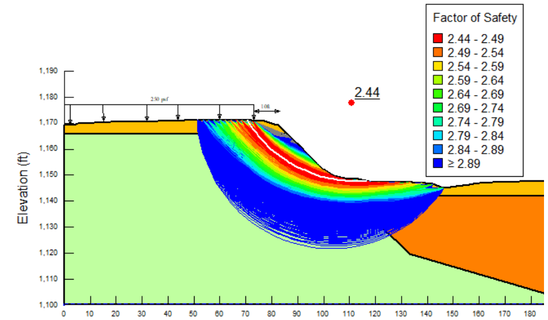
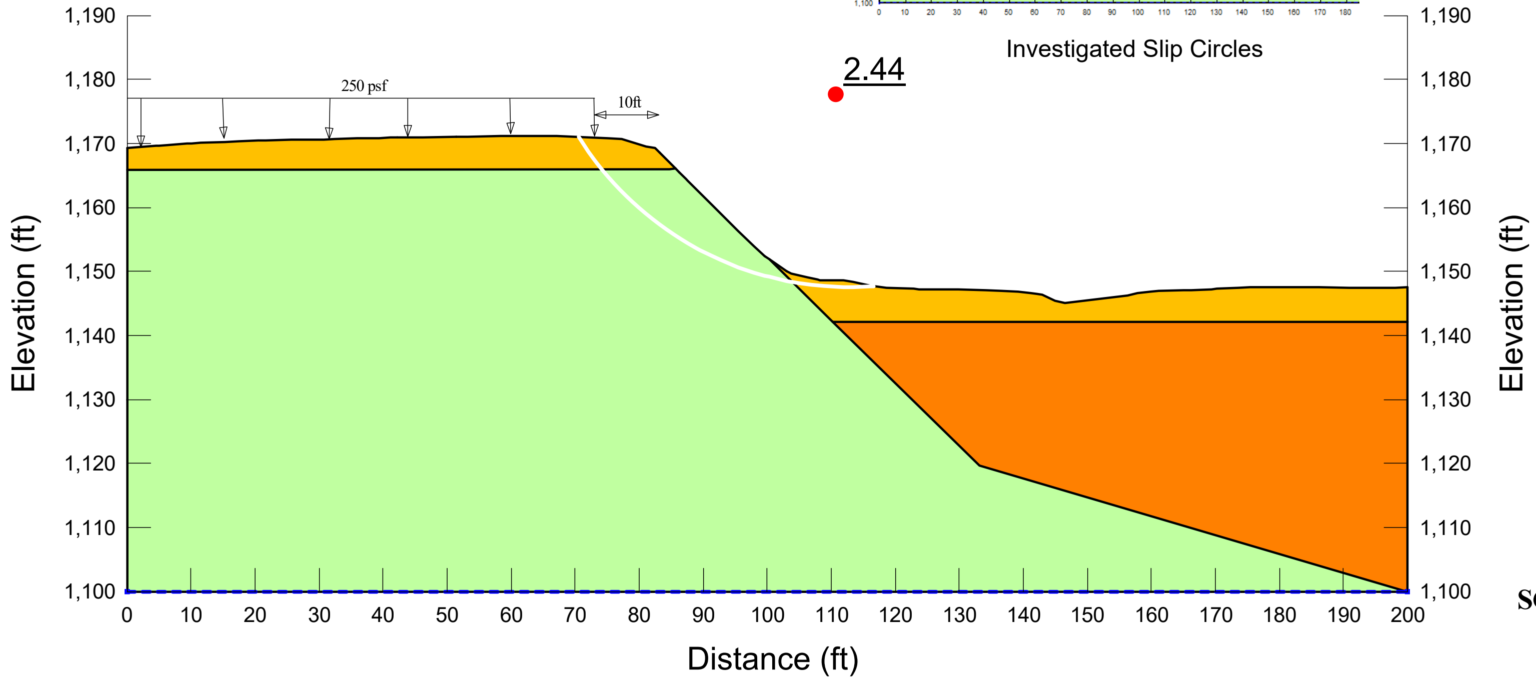
APPENDIX B

Slope Stability Calculations (Slope/W)



Investigated Slip Circles



SCALE 1:360

Color	Name	Model	Unit Weight (pcf)	Strength Function	Cohesion' (psf)	Phi' (°)
	Alluvium	Mohr-Coulomb	120		0	30
	Fill	Mohr-Coulomb	120		0	30
	Saugus Formation	Shear/Normal Fn.	139	Hoek-Brown		

CROSS SECTION A-A' - STATIC

SLOPE STABILITY ANALYSES

HONOR RANCHO COMPRESSOR MODERNIZATION

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Figure A.1

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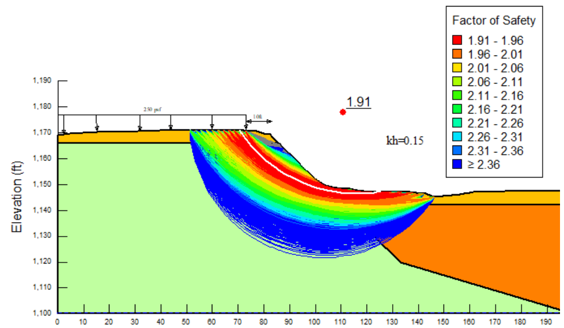
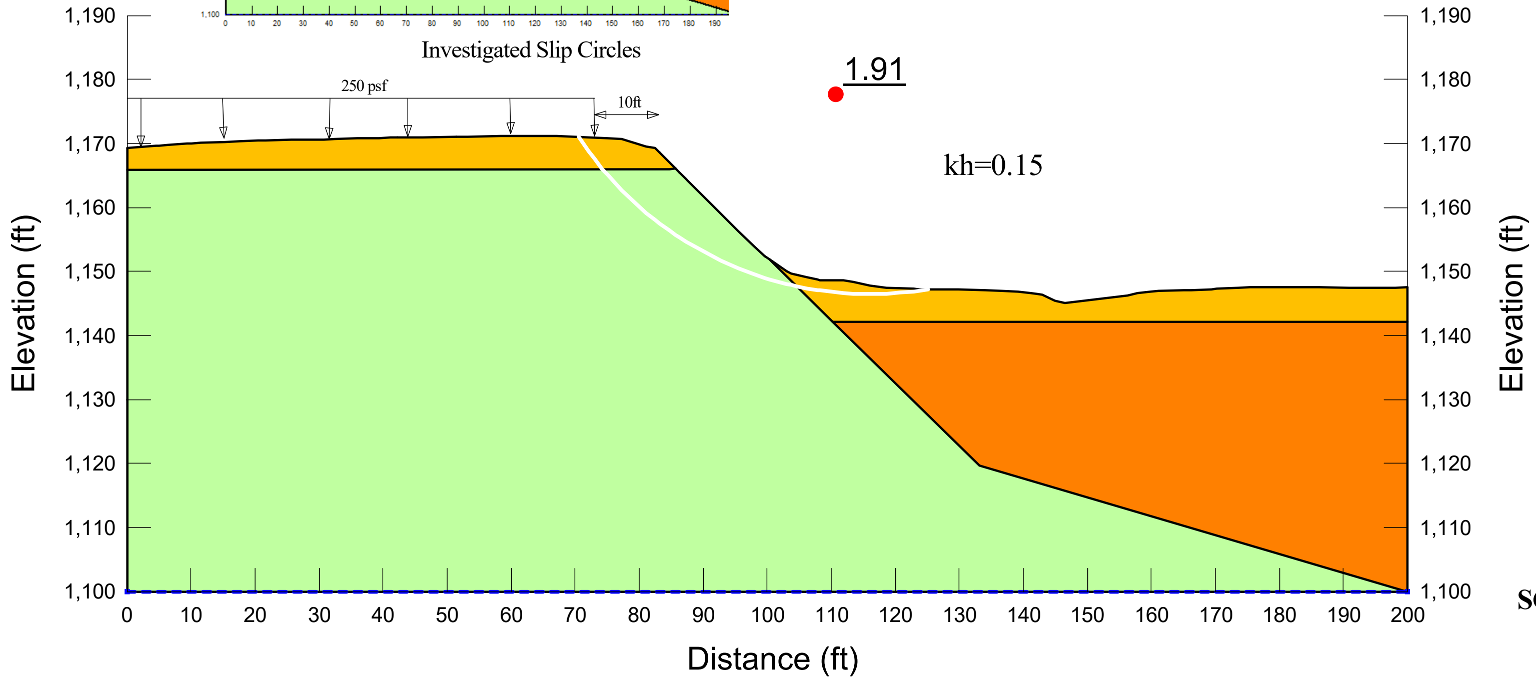


Investigated Slip Circles



SCALE 1:360

Color	Name	Model	Unit Weight (pcf)	Strength Function	Cohesion' (psf)	Phi' (°)
	Alluvium	Mohr-Coulomb	120		0	30
	Fill	Mohr-Coulomb	120		0	30
	Saugus Formation	Shear/Normal Fn.	139	Hoek-Brown		

CROSS SECTION A-A' -PSEUDOSTATIC (kh=0.15)

SLOPE STABILITY ANALYSES

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Figure A.2

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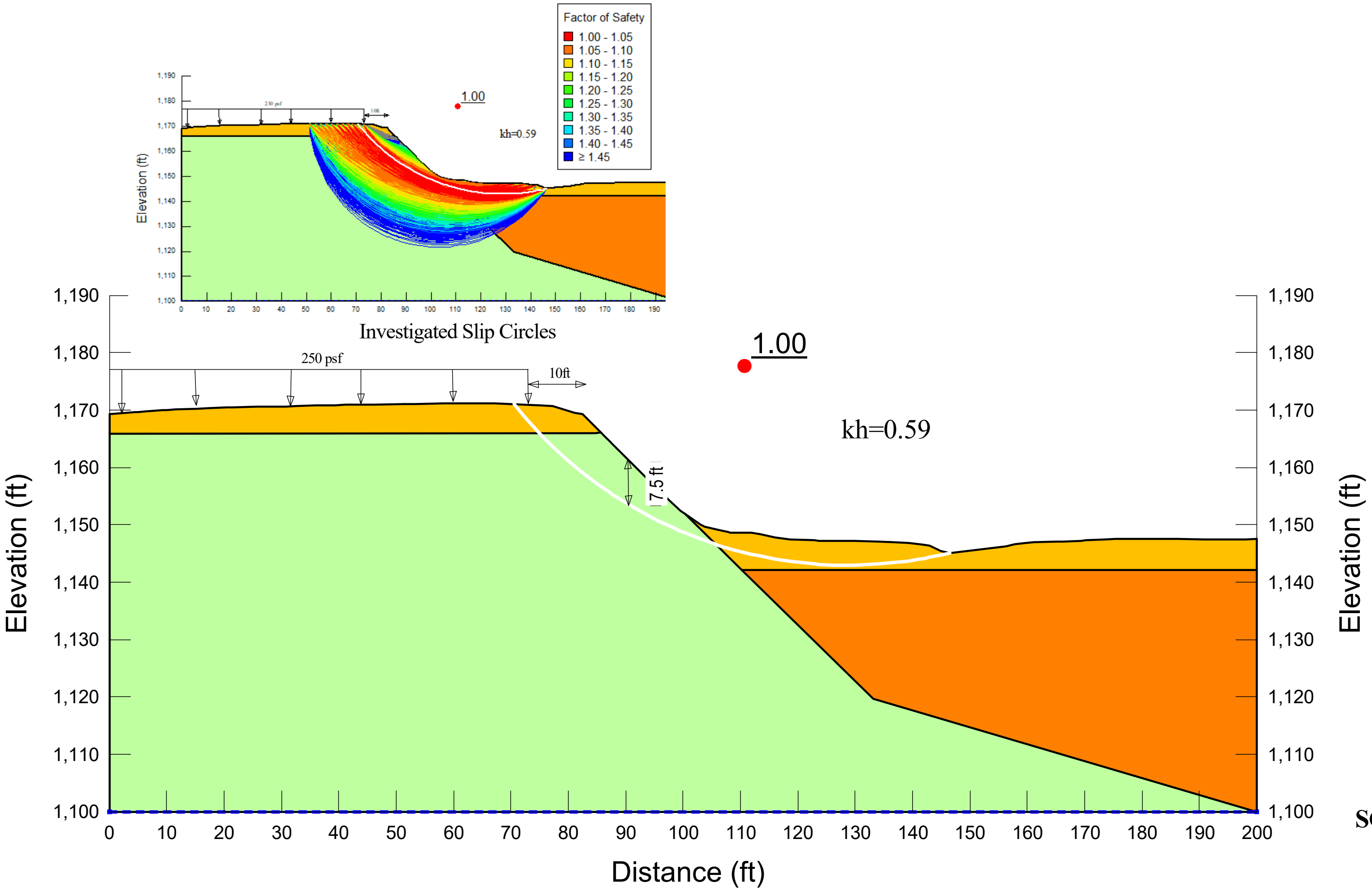

SCALE 1:360

Color	Name	Model	Unit Weight (pcf)	Strength Function	Cohesion' (psf)	Phi' (°)
	Alluvium	Mohr-Coulomb	120		0	30
	Fill	Mohr-Coulomb	120		0	30
	Saugus Formation	Shear/Normal Fn.	139	Hoek-Brown		

CROSS SECTION A-A' -PSEUDOSTATIC (kh=0.59)

SLOPE STABILITY ANALYSES

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Figure A.3

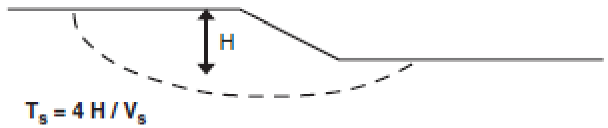
Project No. SC0766U

JULY 2021

\\hbeach-01\data\PRJ4\CAWP\SC0766U - Honor Rancho Compressor Modernization\Amendment 2 - Stability\Slope_W_Calculations\A\A-A.gsz

A-A’, ky=0.59

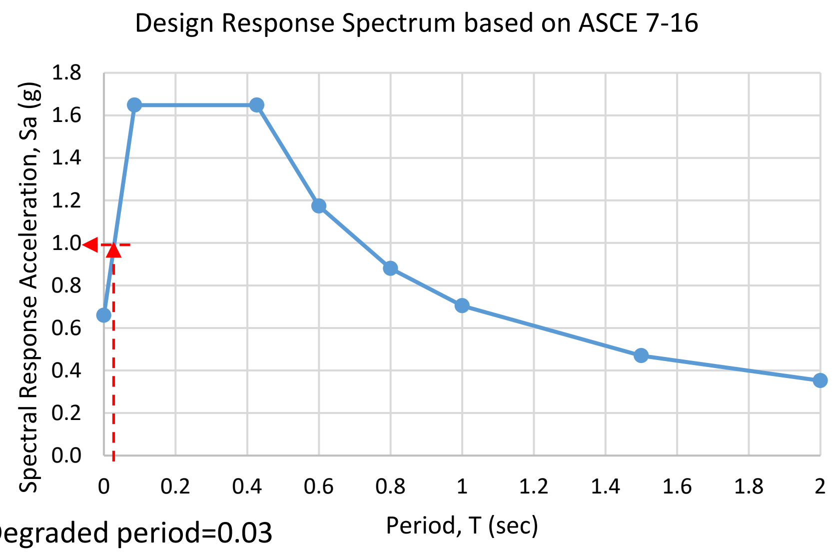
Ts=4*7.5/2000=0.02
Degraded period=0.03



M_W=7.0
Vs=610m/s=2000ft/s
S_{DS} = 1.65

Simplified Procedure for Estimating Earthquake Induced Deviatoric Slope Displacements
by Jonathan D. Bray and Thaleia Travasarou
Journal of Geotechnical and Geonvironmental Engineering, ASCE, V. 133(4), pp. 381-392, April 2007

SEE NOTES BELOW FOR GUIDANCE IN THE USE OF SPREADSHEET



Degraded period=0.03

Input Parameters			
Yield Acceleration (k_y)	0.59		Based on pseudostatic analysis
Initial Fundamental Period (Ts)	0.02	seconds	1D: Ts=4H/Vs 2D: Ts=2.6H/Vs
Degraded Period (1.5Ts)	0.03	seconds	
Moment Magnitude (Mw)	7.00		
Spectral Acceleration (Sa(1.5Ts))	1	g	
Additional Input Parameters			
Probability of Exceedance #1 (P1)	84	%	
Probability of Exceedance #2 (P2)	50	%	
Probability of Exceedance #3 (P3)	16	%	
Displacement Threshold (d_threshold)	15	cm	
Intermediate Calculated Parameters			
Non-Zero Seismic Displacement Est (D)	3.36	cm	eq. (5) or (6)
Standard Deviation of Non-Zero Seismic D	0.66		
Results			
Probability of Negligible Displ. (P(D=0))	0.52		eq. (3)
D1	<1	cm	calc. using eq. (7)
D2	<1	cm	calc. using eq. (7)
D3	4.4	cm	calc. using eq. (7)
P(D>d_threshold)	0.01		eq. (7)

Estimated range of Slope Displacement: 1 to 5cm ~ 0.5 to 2”
Estimated Slope Displacement: 3.5cm ~ 1.5”

CROSS SECTION A-A’
SEISMIC SLOPE DEFORMATION ANALYSIS
HONOR RANCHO COMPRESSOR MODERNIZATION
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Figure **A.4**

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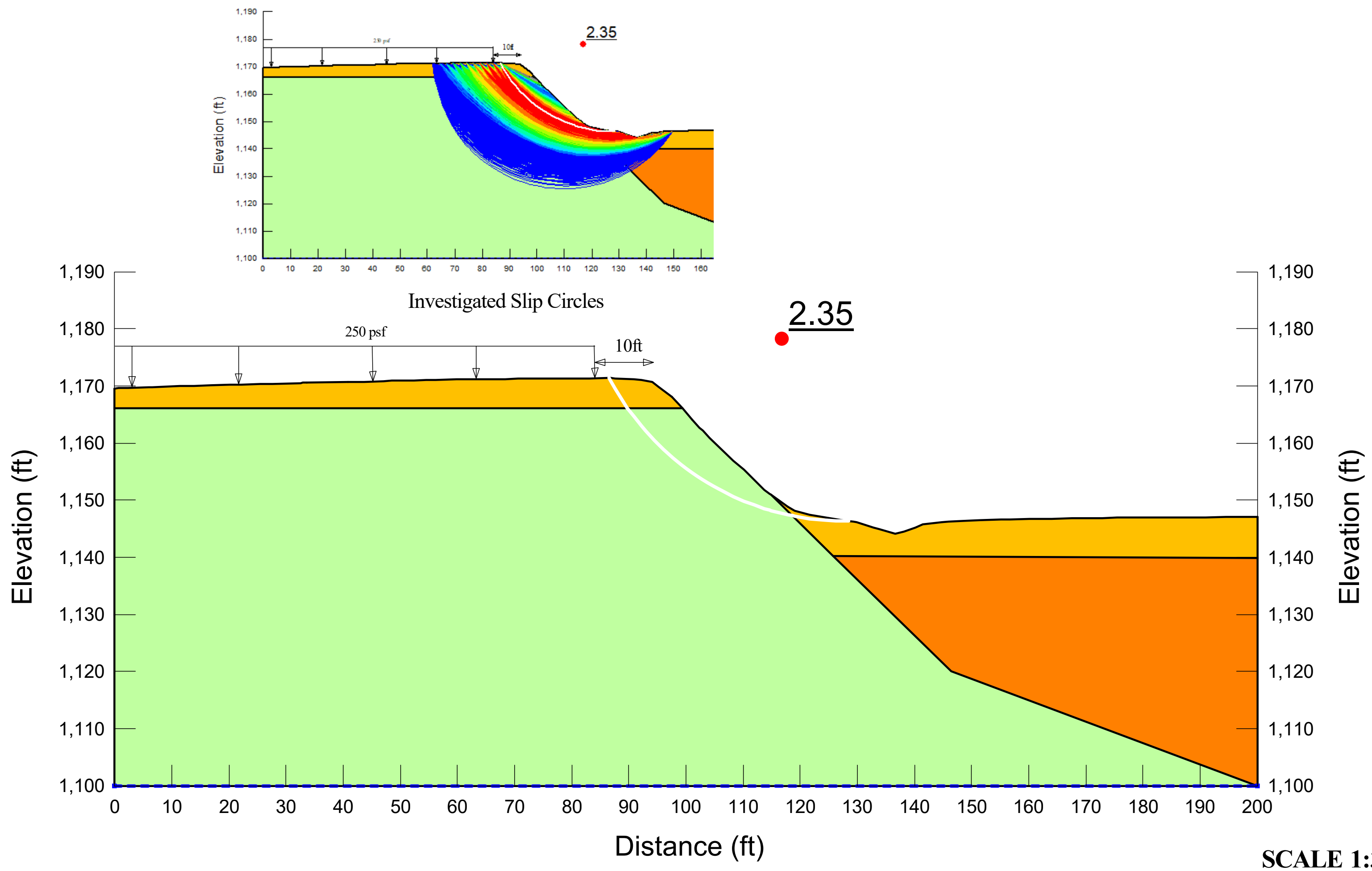

SCALE 1:360

Color	Name	Model	Unit Weight (pcf)	Strength Function	Cohesion' (psf)	Phi' (°)
	Alluvium	Mohr-Coulomb	120		0	30
	Fill	Mohr-Coulomb	120		0	30
	Saugus Formation	Shear/Normal Fn.	139	Hoek-Brown		

CROSS SECTION B-B' - STATIC

SLOPE STABILITY ANALYSES

HONOR RANCHO COMPRESSOR MODERNIZATION

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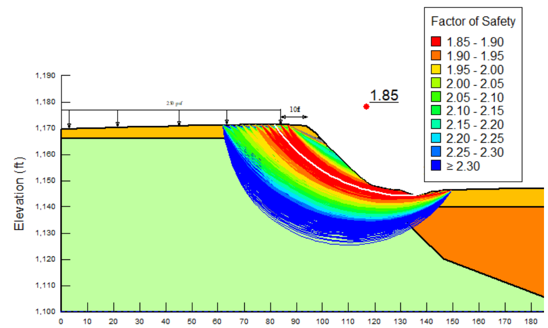
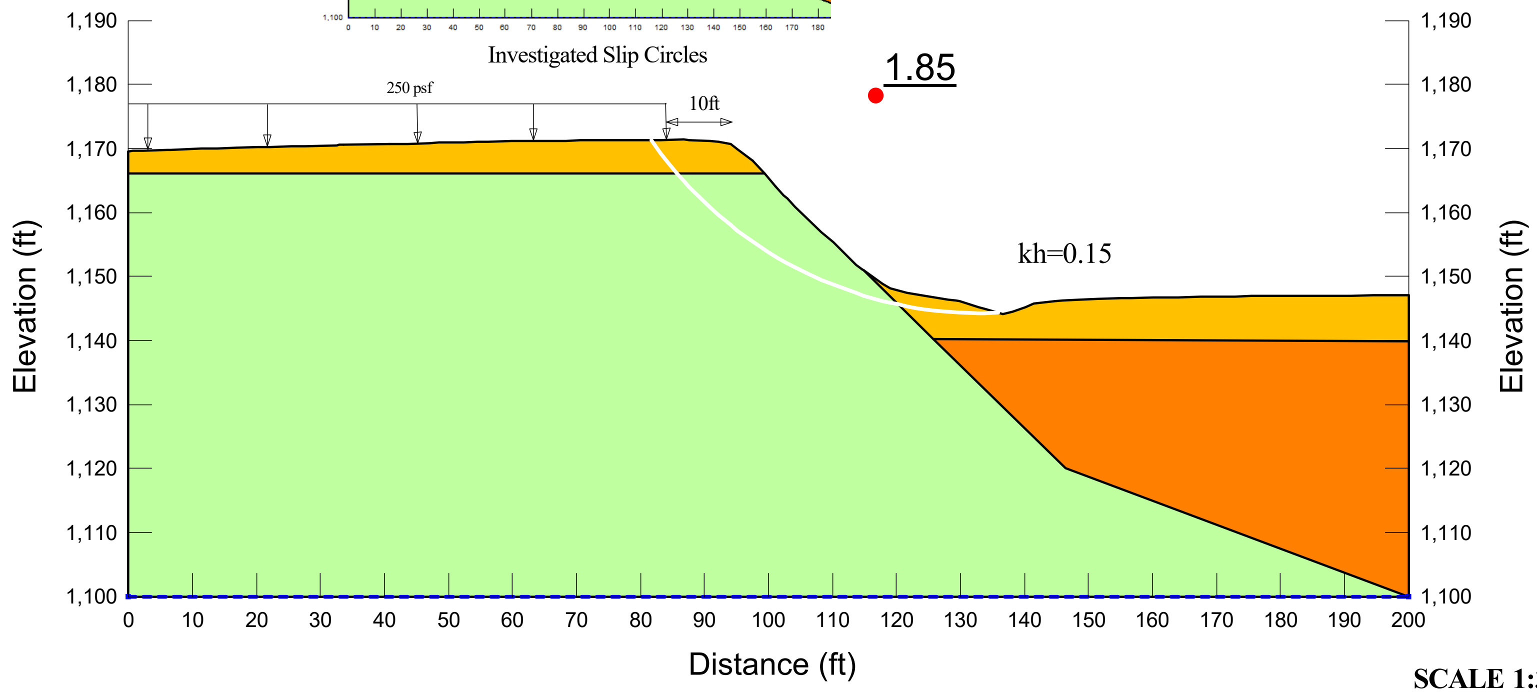
Figure B.1

Project No. SC0766U | JULY 2021

\\hbeach-01\data\PRJ4\CAWP\SC0766U - Honor Rancho Compressor Modernization\Amendment 2 - Stability\Slope_W_Calculations\B\B-B.gsz



Investigated Slip Circles



SCALE 1:360

Color	Name	Model	Unit Weight (pcf)	Strength Function	Cohesion' (psf)	Phi' (°)
	Alluvium	Mohr-Coulomb	120		0	30
	Fill	Mohr-Coulomb	120		0	30
	Saugus Formation	Shear/Normal Fn.	139	Hoek-Brown		

CROSS SECTION B-B' - PSEUDOSTATIC (kh=0.15)

SLOPE STABILITY ANALYSES
HONOR RANCHO COMPRESSOR MODERNIZATION
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Figure B.2

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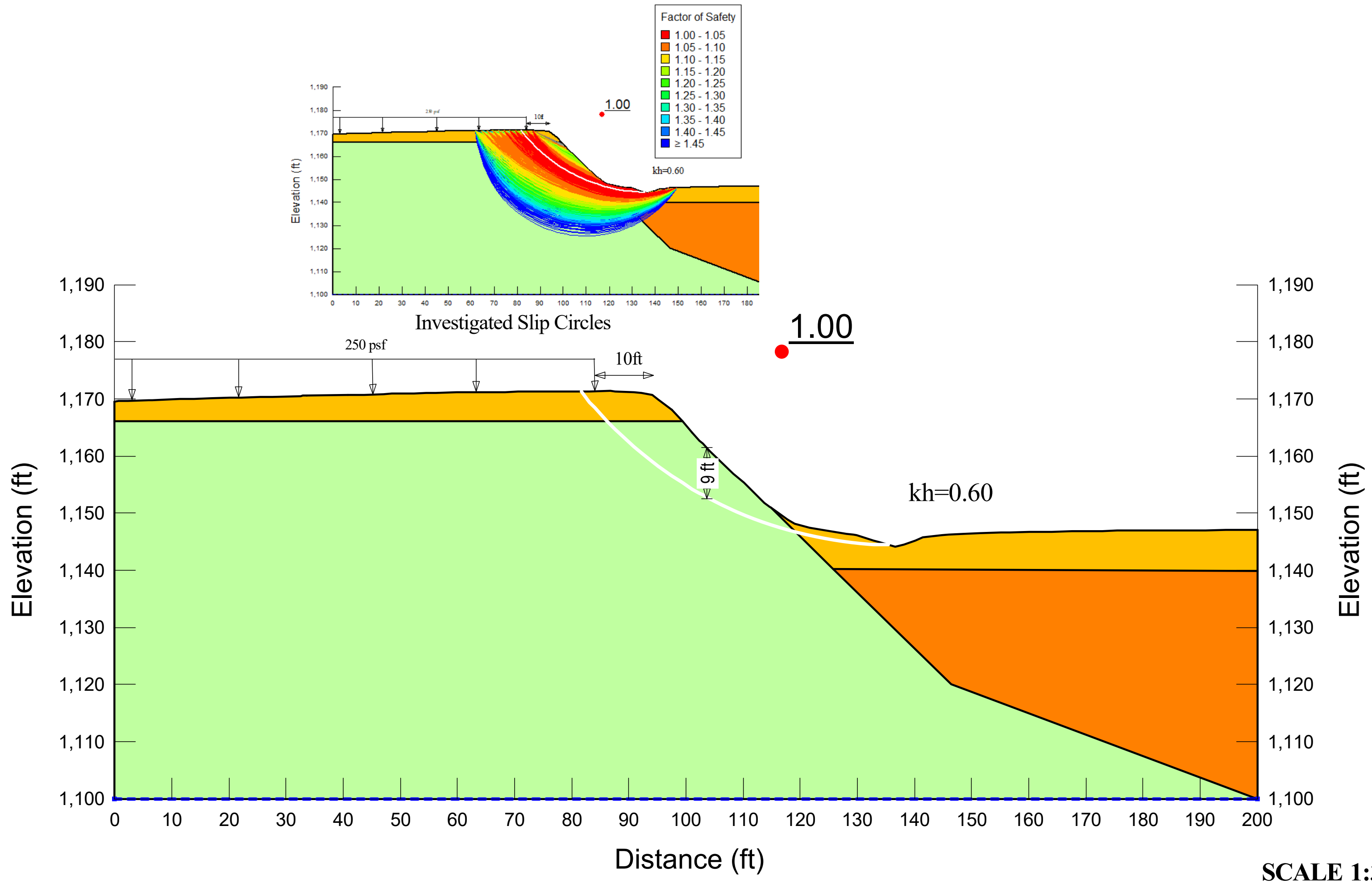
JULY 2021

\\hbeach-01\data\PRJ4\CAWP\SC0766U - Honor Rancho Compressor Modernization\Amendment 2 - Stability\Slope_W_Calculations\B\B-B.gsz



SCALE 1:360

Color	Name	Model	Unit Weight (pcf)	Strength Function	Cohesion' (psf)	Phi' (°)
	Alluvium	Mohr-Coulomb	120		0	30
	Fill	Mohr-Coulomb	120		0	30
	Saugus Formation	Shear/Normal Fn.	139	Hoek-Brown		

CROSS SECTION B-B' - PSEUDOSTATIC (kh=0.60)

SLOPE STABILITY ANALYSES
HONOR RANCHO COMPRESSOR MODERNIZATION
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Figure B.3

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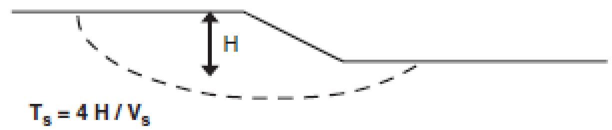
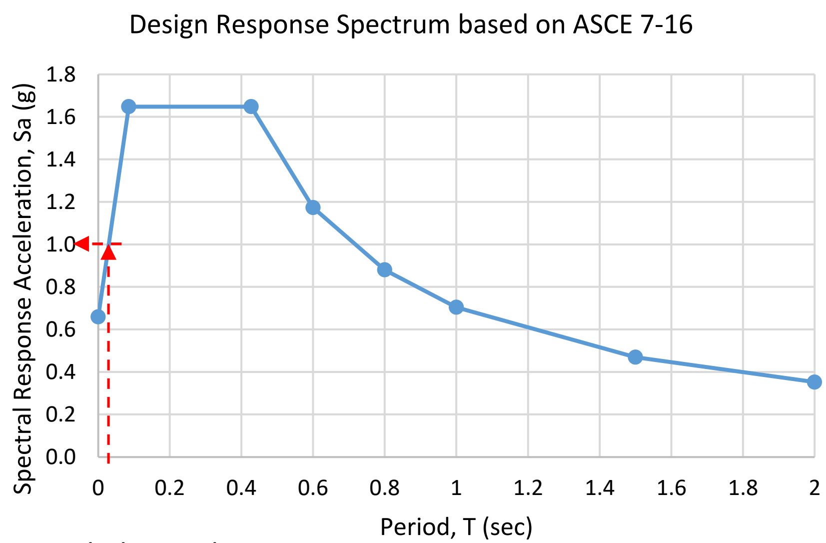
\\hbeach-01\data\PRJ4\CAWP\SC0766U - Honor Rancho Compressor Modernization\Amendment 2 - Stability\Slope_W_Calculations\B\B-B.gsz

B-B’, ky=0.60

M_W=7.0
Vs=610m/s=2000ft/s
S_{DS} = 1.65

Ts=4*9/2000=0.02
Degraded period=0.03





Degraded period=0.03

Simplified Procedure for Estimating Earthquake Induced Deviatoric Slope Displacements
by Jonathan D. Bray and Thaleia Travasarou
Journal of Geotechnical and Geonvironmental Engineering, ASCE, V. 133(4), pp. 381-392, April 2007

SEE NOTES BELOW FOR GUIDANCE IN THE USE OF SPREADSHEET

Input Parameters			
Yield Acceleration (k_y)	0.6		Based on pseudostatic analysis
Initial Fundamental Period (Ts)	0.02	seconds	1D: Ts=4H/Vs 2D: Ts=2.6H/Vs
Degraded Period (1.5Ts)	0.03	seconds	
Moment Magnitude (Mw)	7.00		
Spectral Acceleration (Sa(1.5Ts))	1	g	
Additional Input Parameters			
Probability of Exceedance #1 (P1)	84	%	
Probability of Exceedance #2 (P2)	50	%	
Probability of Exceedance #3 (P3)	16	%	
Displacement Threshold (d_threshold)	15	cm	
Intermediate Calculated Parameters			
Non-Zero Seismic Displacement Est (D)	3.22	cm	eq. (5) or (6)
Standard Deviation of Non-Zero Seismic D	0.66		
Results			
Probability of Negligible Displ. (P(D=0))	0.54		eq. (3)
D1	<1	cm	calc. using eq. (7)
D2	<1	cm	calc. using eq. (7)
D3	4.1	cm	calc. using eq. (7)
P(D>d_threshold)	0.00		eq. (7)

Estimated range of Slope Displacement: 1 to 5cm ~ 0.5 to 2”
Estimated Slope Displacement: 3.5cm ~ 1.5”

CROSS SECTION B-B’
SEISMIC SLOPE DEFORMATION ANALYSIS
HONOR RANCHO COMPRESSOR MODERNIZATION
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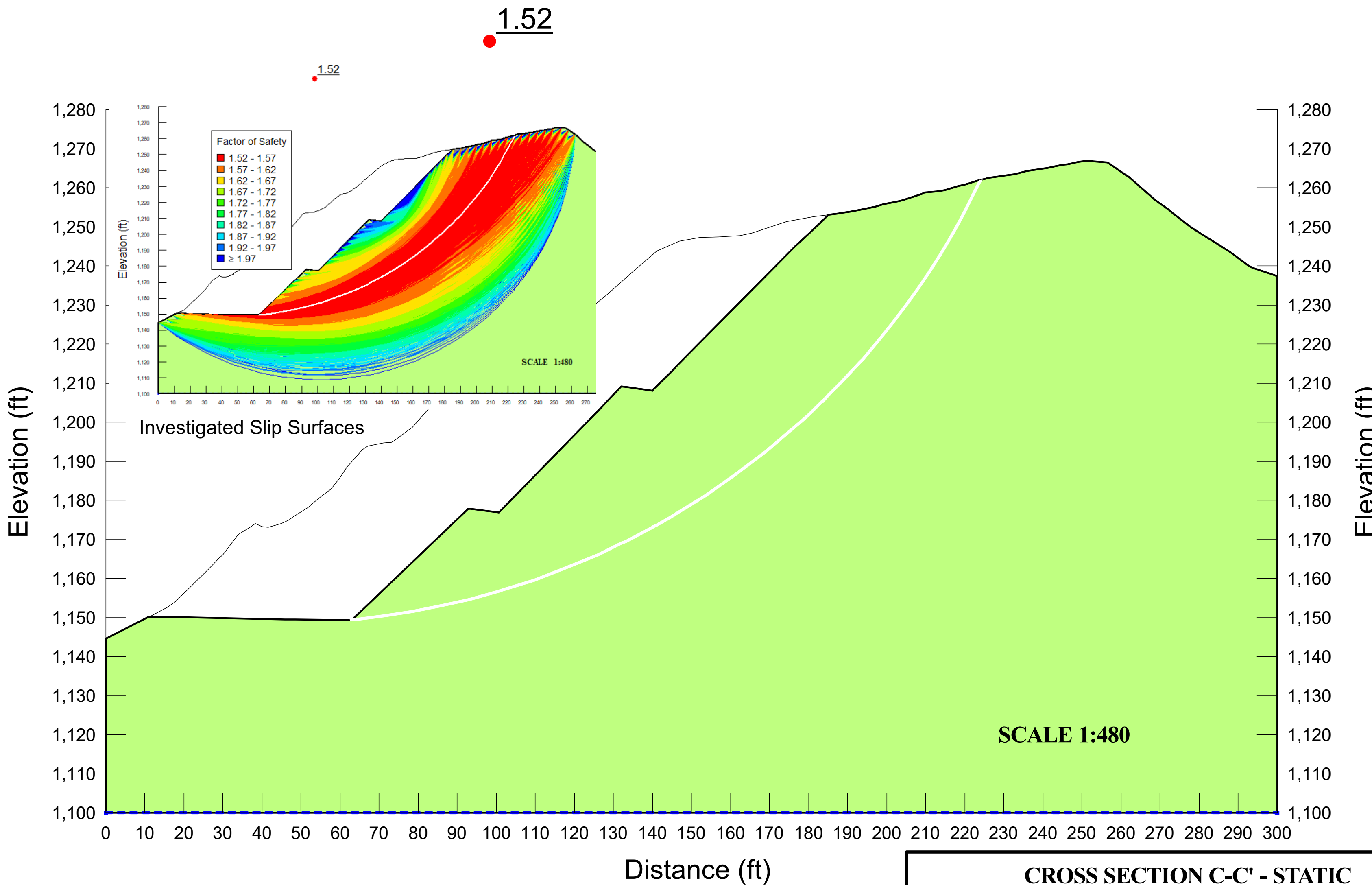
Figure **B.4**



Color	Name	Model	Unit Weight (pcf)	Strength Function
	Saugus Formation	Shear/Normal Fn.	139	Hoek-Brown

CROSS SECTION C-C' - STATIC

SLOPE STABILITY ANALYSES

HONOR RANCHO COMPRESSOR MODERNIZATION

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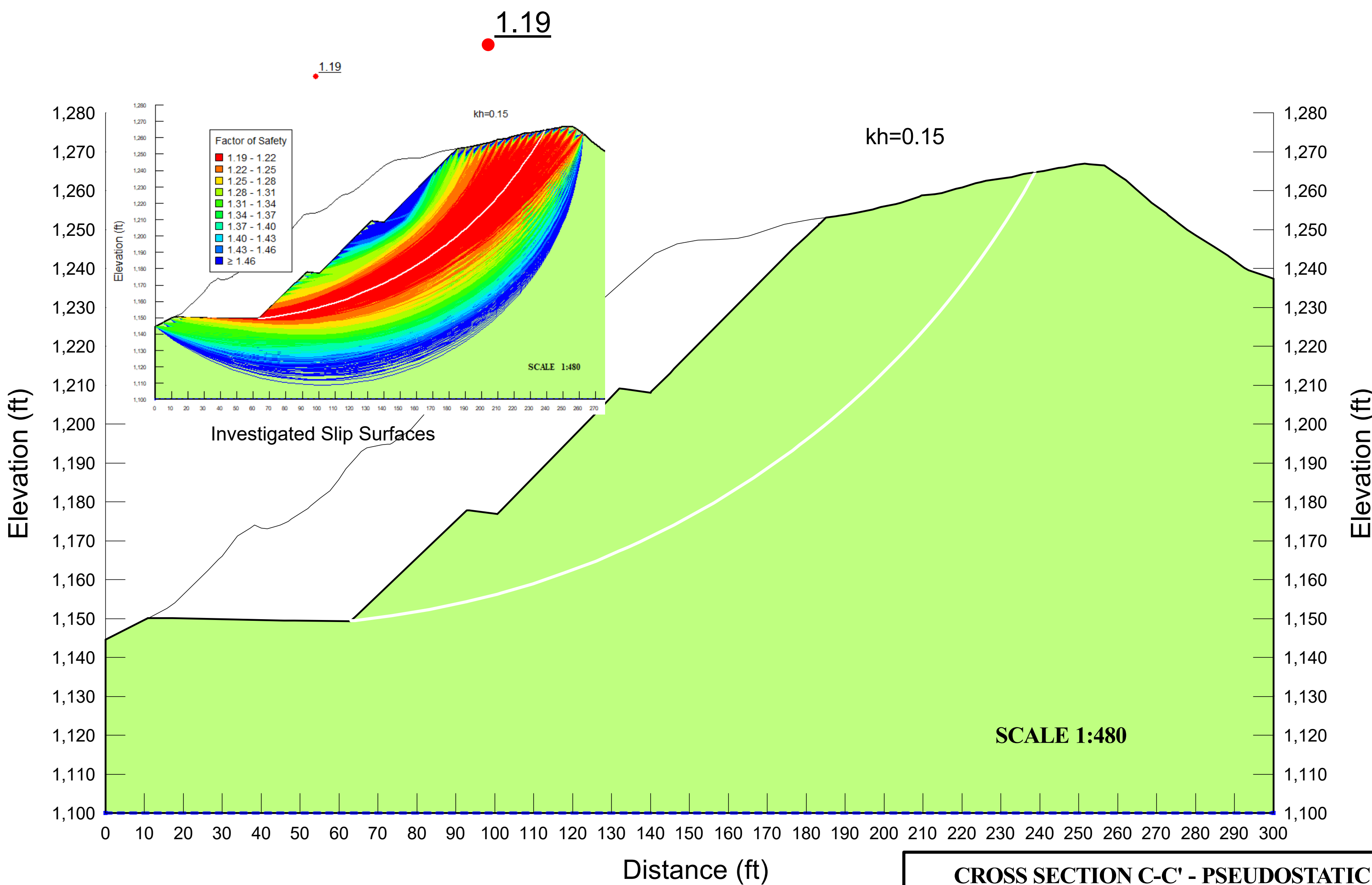
Figure C.1

\\lbeach-01\data\PRJ4\CAWP\SC0766U - Honor Rancho Compressor Modernization\Amendment 2 - Stability\Slope_W_Calculations\C-C_bench.gsz



Color	Name	Model	Unit Weight (pcf)	Strength Function
	Saugus Formation	Shear/Normal Fn.	139	Hoek-Brown

CROSS SECTION C-C' - PSEUDOSTATIC (kh=0.15)
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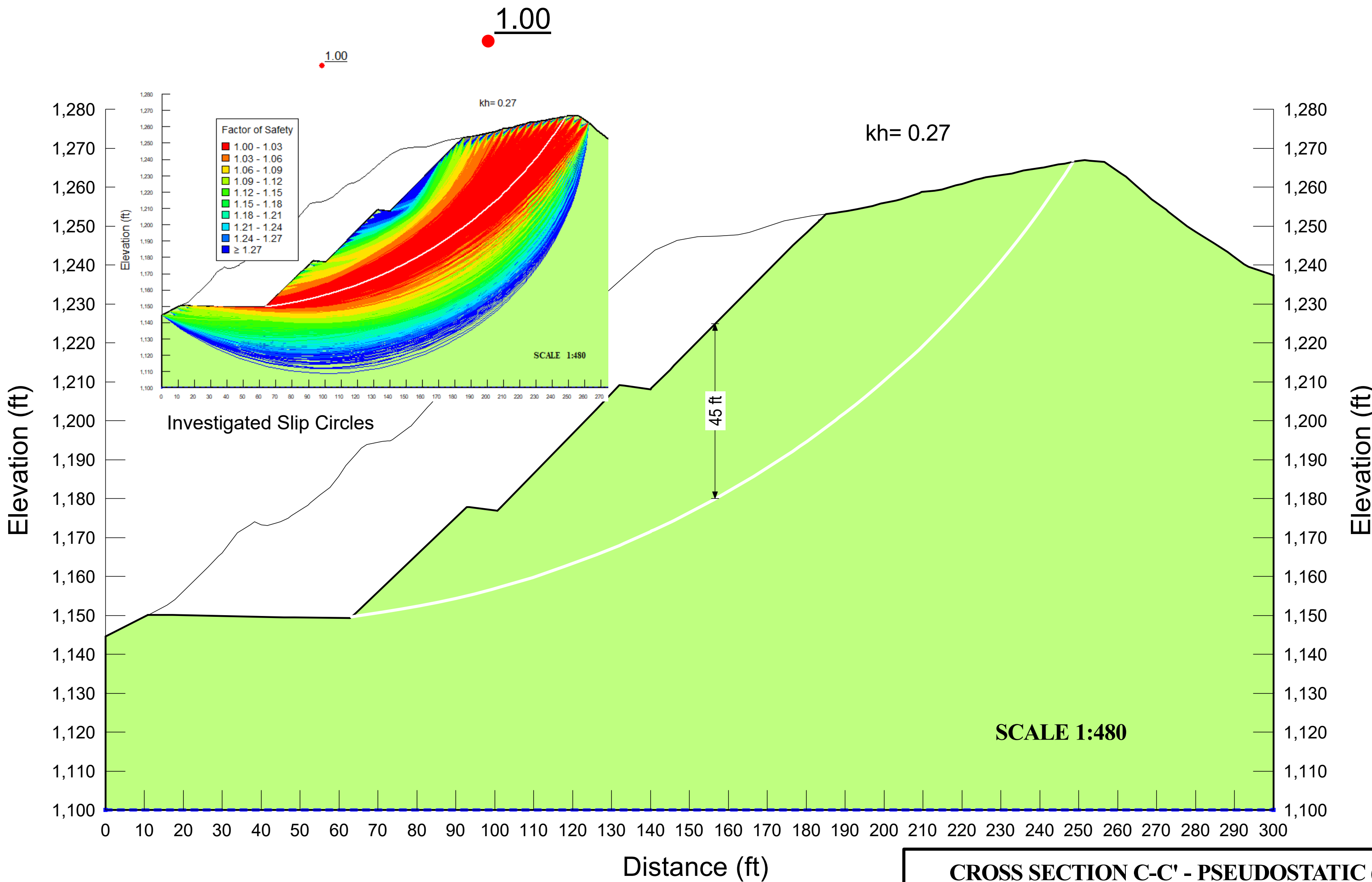
Figure C.2

Project No. SC0766U | JULY 2021

\\hbeach-01\data\PRJ4\CAWP\SC0766U - Honor Rancho Compressor Modernization\Amendment 2 - Stability\Slope_W_Calculations\C\C-C_bench.gsz



Color	Name	Model	Unit Weight (pcf)	Strength Function
	Saugus Formation	Shear/Normal Fn.	139	Hoek-Brown

CROSS SECTION C-C' - PSEUDOSTATIC (kh=0.27)
SLOPE STABILITY ANALYSES
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Figure C.3

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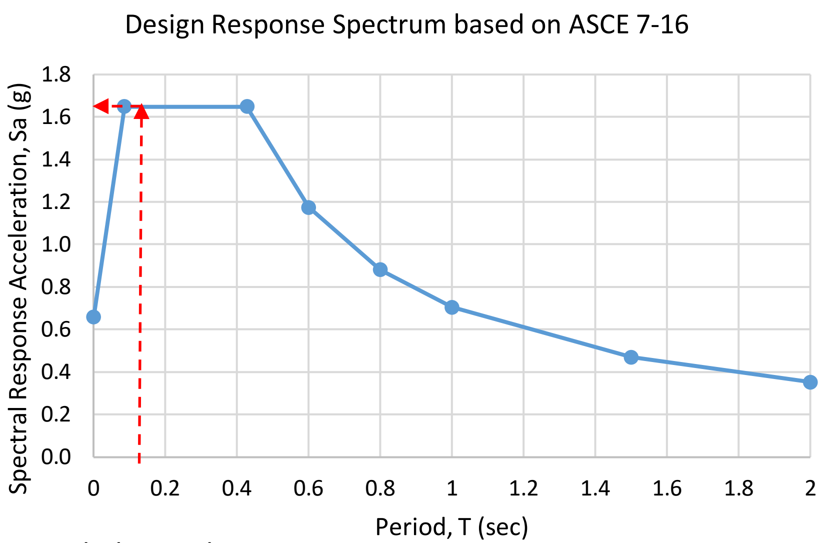
\\lbeach-01\data\PRJ4\CAWP\SC0766U - Honor Rancho Compressor Modernization\Amendment 2 - Stability\Slope_W_Calculations\C-C_bench.gsz

C-C’, ky=0.27

Ts=4*45/2000=0.09
Degraded period=0.14

M_W=7.0
Vs=610m/s=2000ft/s
S_{DS} = 1.65



Degraded period=0.14

Simplified Procedure for Estimating Earthquake Induced Deviatoric Slope Displacements
by Jonathan D. Bray and Thaleia Travasarou
Journal of Geotechnical and Geonvironmental Engineering, ASCE, V. 133(4), pp. 381-392, April 2007

SEE NOTES BELOW FOR GUIDANCE IN THE USE OF SPREADSHEET

Input Parameters			
Yield Acceleration (k_y)	0.27		Based on pseudostatic analysis
Initial Fundamental Period (Ts)	0.09	seconds	1D: Ts=4H/Vs 2D: Ts=2.6H/Vs
Degraded Period (1.5Ts)	0.14	seconds	
Moment Magnitude (Mw)	7.00		
Spectral Acceleration (Sa(1.5Ts))	1.65	g	
Additional Input Parameters			
Probability of Exceedance #1 (P1)	84	%	
Probability of Exceedance #2 (P2)	50	%	
Probability of Exceedance #3 (P3)	16	%	
Displacement Threshold (d_threshold)	15	cm	
Intermediate Calculated Parameters			
Non-Zero Seismic Displacement Est (D)	26.04	cm	eq. (5) or (6)
Standard Deviation of Non-Zero Seismic D	0.66		
Results			
Probability of Negligible Displ. (P(D=0))	0.00		eq. (3)
D1	13.5	cm	calc. using eq. (7)
D2	26.0	cm	calc. using eq. (7)
D3	50.2	cm	calc. using eq. (7)
P(D>d_threshold)	0.80		eq. (7)

Estimated range of Slope Displacement: 13 to 50cm ~ 0.5 to 1.6ft
Estimated Slope Displacement: 26cm ~ 1ft

CROSS SECTION C-C’
SEISMIC SLOPE DEFORMATION ANALYSIS
HONOR RANCHO COMPRESSOR MODERNIZATION
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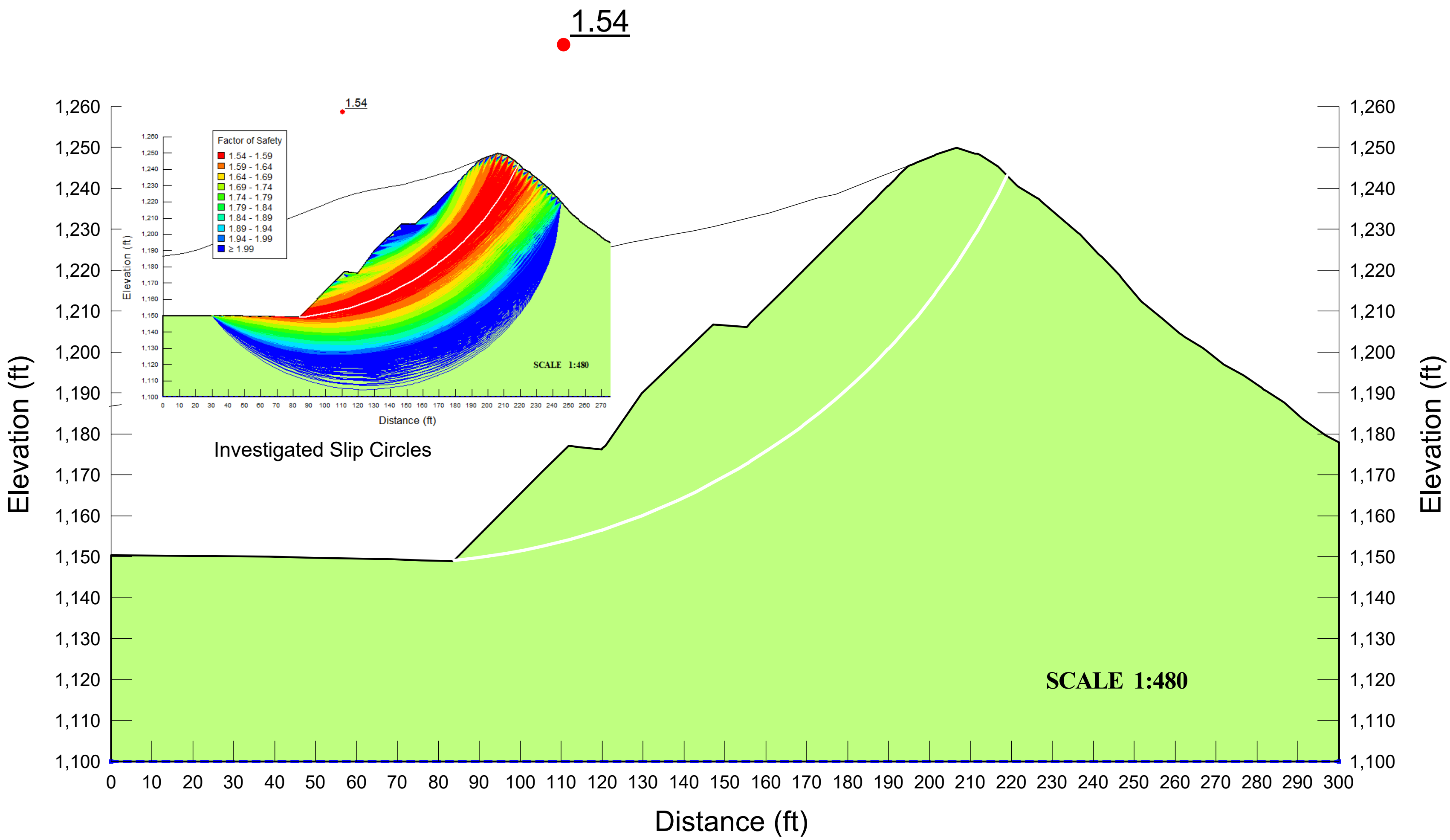
Figure **C.4**

Project No: SC0766U | JULY 2021



Color	Name	Model	Unit Weight (pcf)	Strength Function
	Saugus Formation	Shear/Normal Fn.	139	Hoek-Brown

CROSS SECTION D-D' - STATIC

SLOPE STABILITY ANALYSES

HONOR RANCHO COMPRESSOR MODERNIZATION

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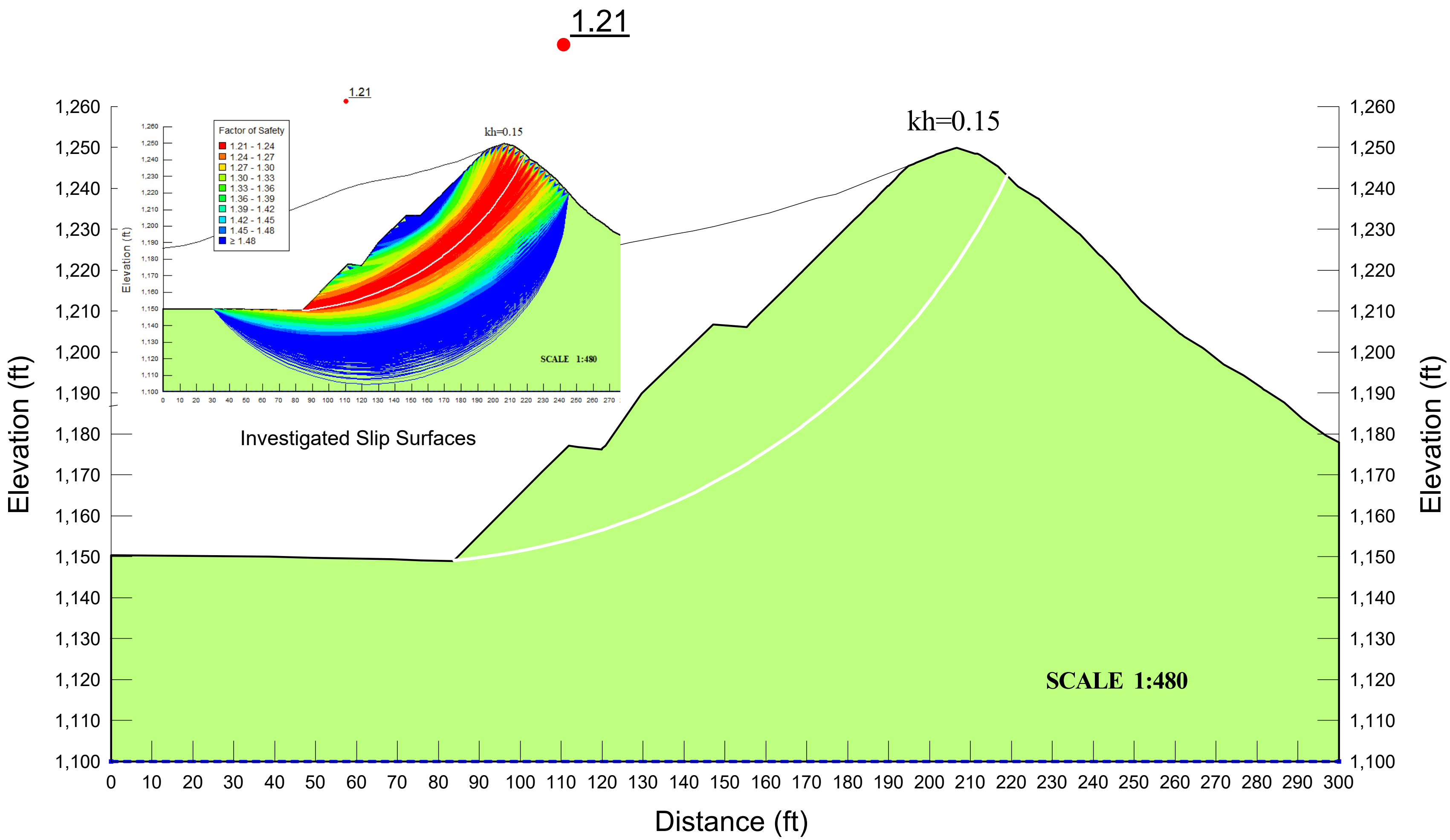
JULY 2021

Figure D.1

\\hbeach-01\data\PRJ4\CAWP\SC0766U - Honor Rancho Compressor Modernization\Amendment 2 - Stability\Slope_W_Calculations\D\D-D_bench.gsz



Color	Name	Model	Unit Weight (pcf)	Strength Function
	Saugus Formation	Shear/Normal Fn.	139	Hoek-Brown

CROSS SECTION D-D' -PSEUDOSTATIC (kh=0.15)

SLOPE STABILITY ANALYSES

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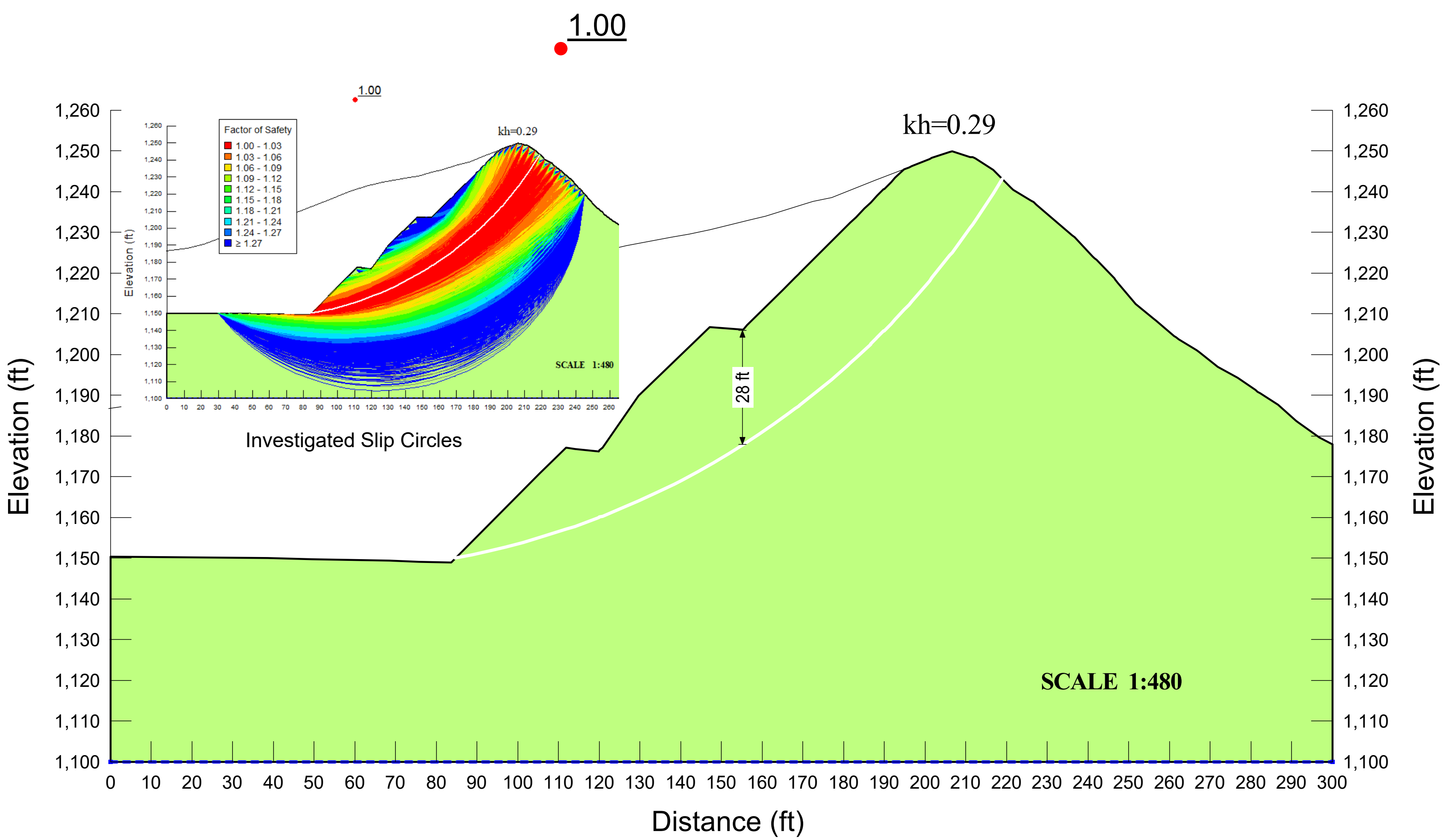
Figure D.2

Project No. SC0766U

JULY 2021

\\hbeach-01\data\PRJ4\CAWP\SC0766U - Honor Rancho Compressor Modernization\Amendment 2 - Stability\Slope_W_Calculations\D\D-D_bench.gsz



Color	Name	Model	Unit Weight (pcf)	Strength Function
	Saugus Formation	Shear/Normal Fn.	139	Hoek-Brown

CROSS SECTION D-D' -PSEUDOSTATIC (kh=0.29)

SLOPE STABILITY ANALYSES

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Figure D.3

Project No. SC0766U | JULY 2021

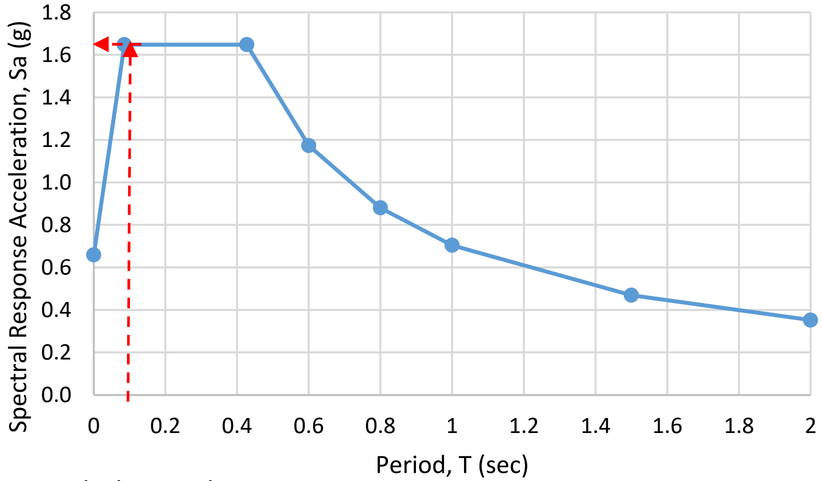
\\hbeach-01\data\PRJ4\CAWP\SC0766U - Honor Rancho Compressor Modernization\Amendment 2 - Stability\Slope_W_Calculations\D\D-D_bench.gsz

D-D’, ky=0.29

M_W=7.0
Vs=610m/s=2000ft/s
S_{DS} = 1.65

Ts=4*28/2000=0.06
Degraded period=0.09

Design Response Spectrum based on ASCE 7-16



Degraded period=0.09

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SEE NOTES BELOW FOR GUIDANCE IN THE USE OF SPREADSHEET

Input Parameters			
Yield Acceleration (k_y)	0.29		Based on pseudostatic analysis
Initial Fundamental Period (Ts)	0.06	seconds	1D: Ts=4H/Vs 2D: Ts=2.6H/Vs
Degraded Period (1.5Ts)	0.09	seconds	
Moment Magnitude (Mw)	7.00		
Spectral Acceleration (Sa(1.5Ts))	1.65	g	
Additional Input Parameters			
Probability of Exceedance #1 (P1)	84	%	
Probability of Exceedance #2 (P2)	50	%	
Probability of Exceedance #3 (P3)	16	%	
Displacement Threshold (d_threshold)	15	cm	
Intermediate Calculated Parameters			
Non-Zero Seismic Displacement Est (D)	22.05	cm	eq. (5) or (6)
Standard Deviation of Non-Zero Seismic D	0.66		
Results			
Probability of Negligible Displ. (P(D=0))	0.00		eq. (3)
D1	11.4	cm	calc. using eq. (7)
D2	22.0	cm	calc. using eq. (7)
D3	42.5	cm	calc. using eq. (7)
P(D>d_threshold)	0.72		eq. (7)

Estimated range of Slope Displacement: 10 to 43cm ~ 0.5 to 1.4ft
Estimated Slope Displacement: 22cm ~ 1ft

CROSS SECTION D-D’
SEISMIC SLOPE DEFORMATION ANALYSIS
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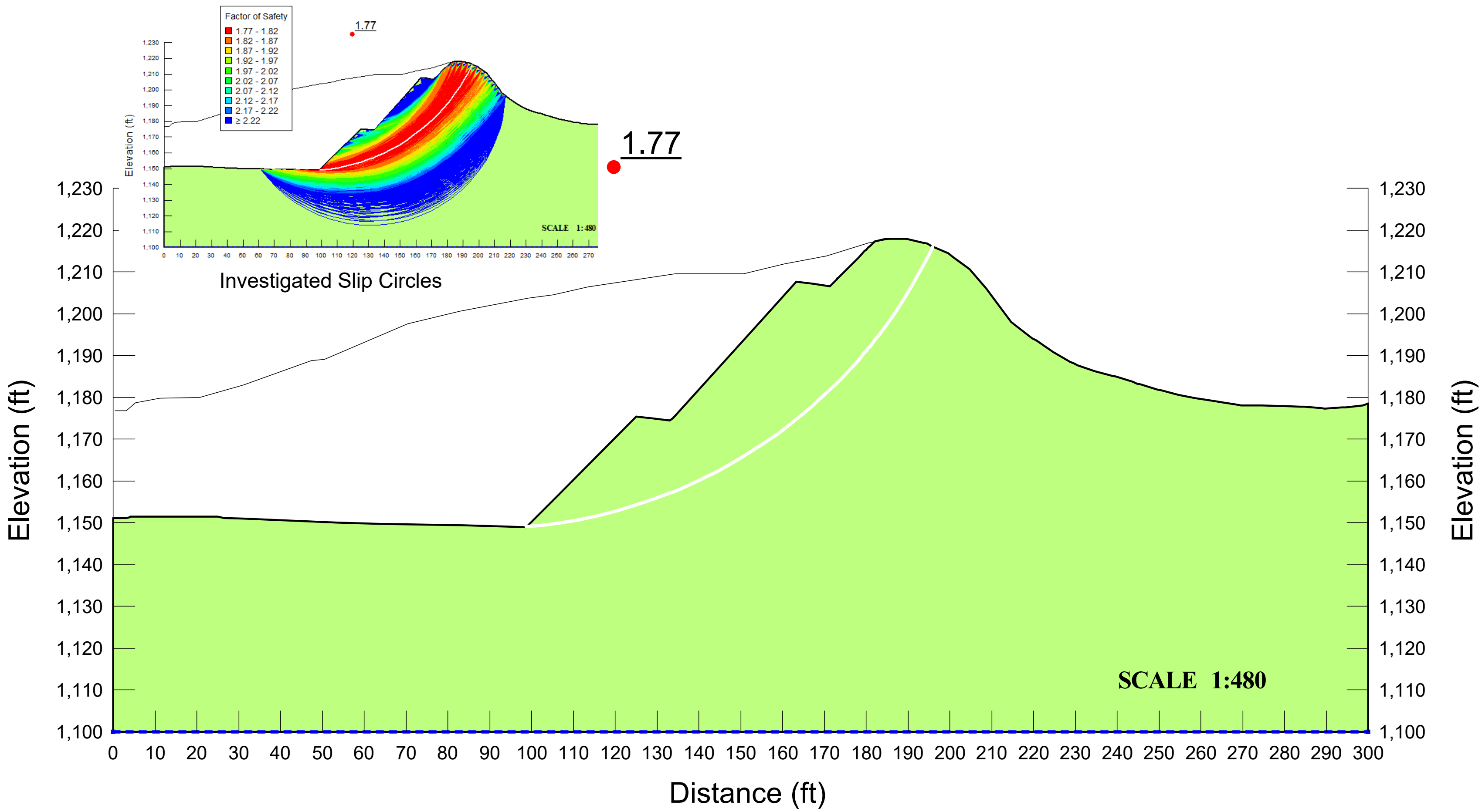
Figure **D.4**

Project No: SC0766U | JULY 2021



Color	Name	Model	Unit Weight (pcf)	Strength Function
	Saugus Formation	Shear/Normal Fn.	139	Hoek-Brown

CROSS SECTION E-E' - STATIC

SLOPE STABILITY ANALYSES

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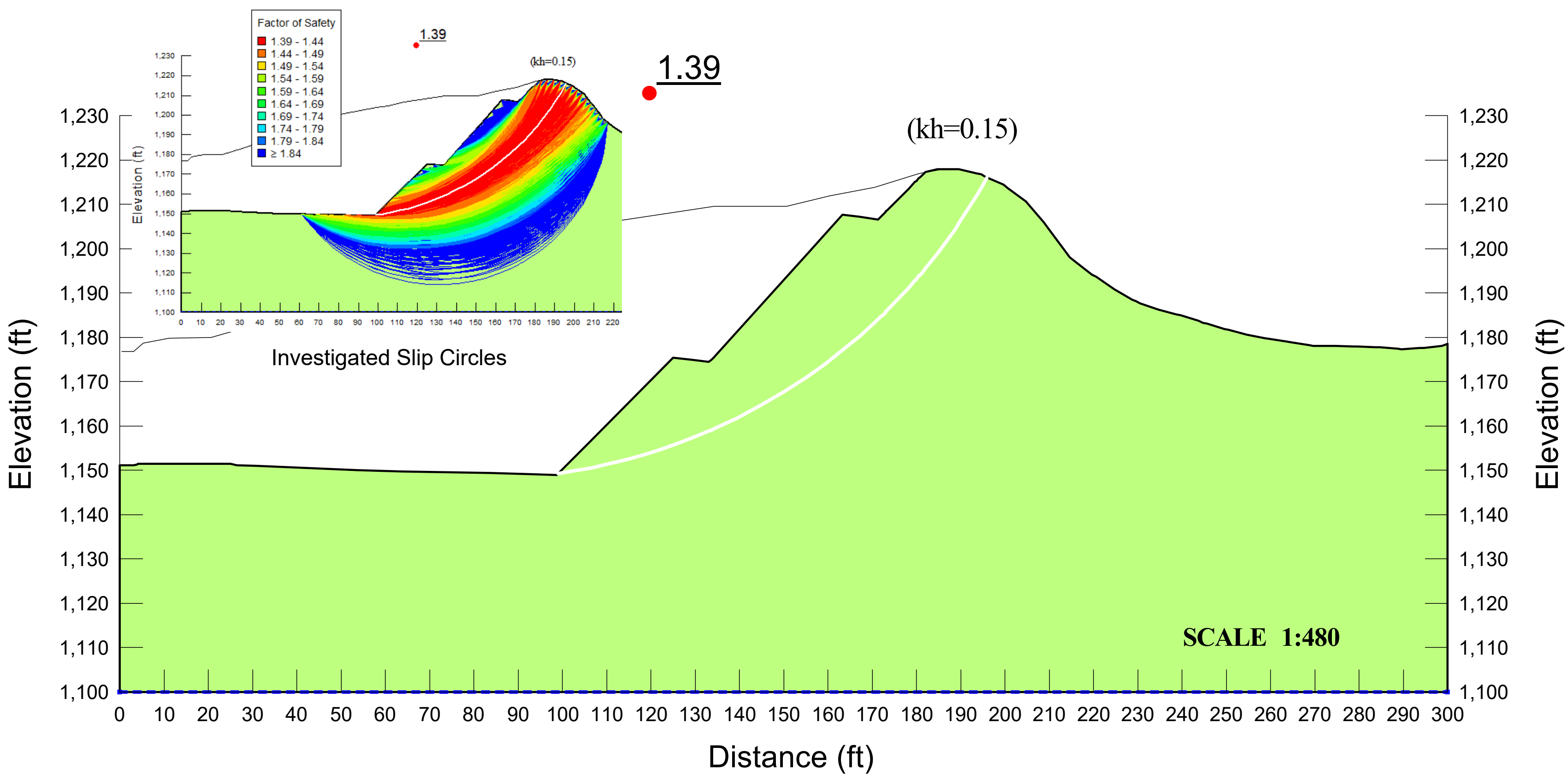
Figure E.1

Project No. SC0766U | JULY 2021

\\hbeach-01\data\PRJ4\CAWP\SC0766U - Honor Rancho Compressor Modernization\Amendment 2 - Stability\Slope_W_Calculations\E\E-E_bench.gsz



Color	Name	Model	Unit Weight (pcf)	Strength Function
	Saugus Formation	Shear/Normal Fn.	139	Hoek-Brown

CROSS SECTION E-E' -PSEUDOSTATIC (kh=0.15)

SLOPE STABILITY ANALYSES

HONOR RANCHO COMPRESSOR MODERNIZATION

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Figure E.2

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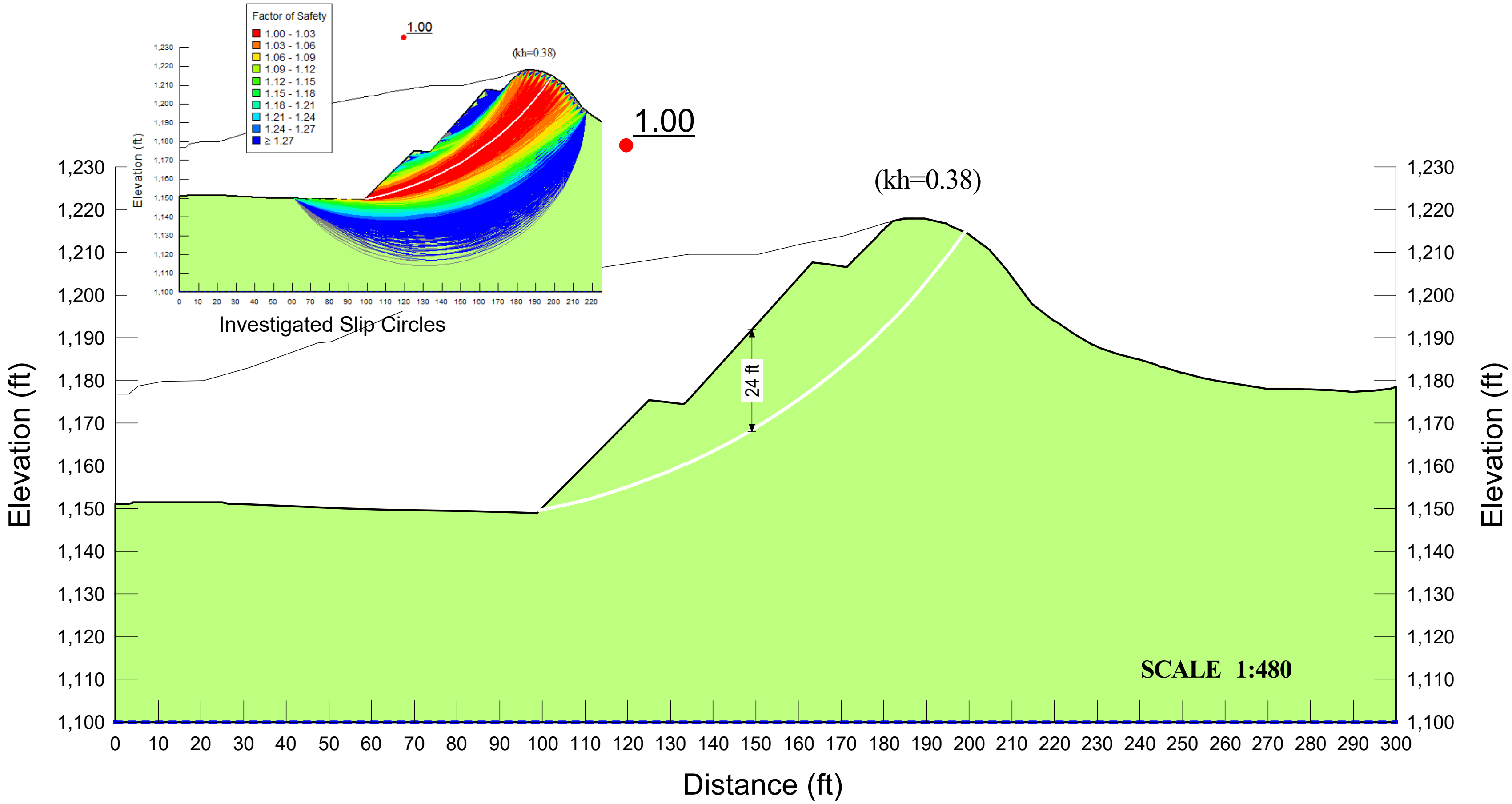
\\lbeach-01\data\PRJ4\CAWP\SC0766U - Honor Rancho Compressor Modernization\Amendment 2 - Stability\Slope_W_Calculations\E\E-E_bench.gsz



Color	Name	Model	Unit Weight (pcf)	Strength Function
	Saugus Formation	Shear/Normal Fn.	139	Hoek-Brown

CROSS SECTION E-E' -PSEUDOSTATIC (kh=0.38)

SLOPE STABILITY ANALYSES

HONOR RANCHO COMPRESSOR MODERNIZATION

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Figure E.3

Project No. SC0766U

JULY 2021

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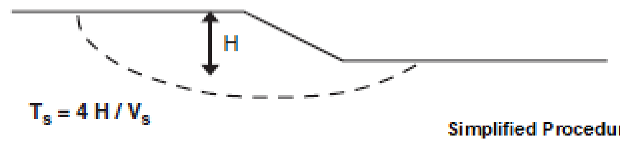
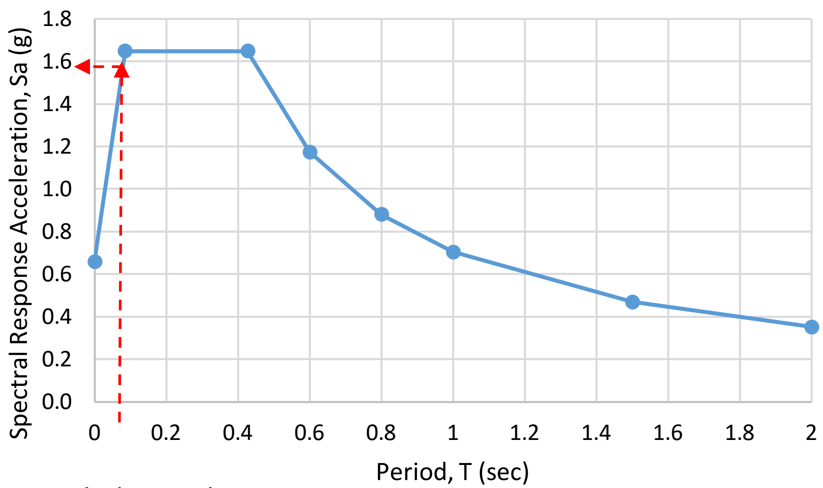
E-E', ky=0.38

M_W=7.0
Vs=610m/s=2000ft/s



Ts=4*24/2000=0.05
Degraded period=0.08

Design Response Spectrum based on ASCE 7-16



Degraded period=0.08

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Journal of Geotechnical and Geoenvironmental Engineering, ASCE, V. 133(4), pp. 381-392, April 2007

SEE NOTES BELOW FOR GUIDANCE IN THE USE OF SPREADSHEET

Input Parameters			
Yield Acceleration (k_y)	0.38		Based on pseudostatic analysis
Initial Fundamental Period (Ts)	0.05	seconds	1D: Ts=4H/Vs 2D: Ts=2.6H/Vs
Degraded Period (1.5Ts)	0.08	seconds	
Moment Magnitude (Mw)	7.00		
Spectral Acceleration (Sa(1.5Ts))	1.59	g	

Additional Input Parameters		
Probability of Exceedance #1 (P1)	84	%
Probability of Exceedance #2 (P2)	50	%
Probability of Exceedance #3 (P3)	16	%
Displacement Threshold (d_threshold)	15	cm

Intermediate Calculated Parameters			
Non-Zero Seismic Displacement Est (D)	29.51	cm	eq. (5) or (6)
Standard Deviation of Non-Zero Seismic D	0.66		

Results			
Probability of Negligible Displ. (P(D=0))	0.00		eq. (3)
D1	15.3	cm	calc. using eq. (7)
D2	29.5	cm	calc. using eq. (7)
D3	56.9	cm	calc. using eq. (7)
P(D>d_threshold)	0.85		eq. (7)

Estimated range of Slope Displacement: 15 to 57cm ~ 0.5 to 1.9ft
Estimated Slope Displacement: 30cm ~ 1ft

CROSS SECTION E-E'
SEISMIC SLOPE DEFORMATION ANALYSIS
HONOR RANCHO COMPRESSOR MODERNIZATION
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Figure **E.4**

Project No: SC0766U | JULY 2021