TETRA TECH BAS GEOSCIENCE

Project No. URP 13-04E
October 13, 2014

Mr. Russ Caruso
United Rock Products
1245 E Arrow Highway
Irwindale, California 91706

Subject: **STABILITY OF PERIMETER SLOPES**
Olive Pit
Irwindale, California

Dear Mr. Caruso,

Presented herein is Tetra Tech BAS GeoScience's (Tt-BASg) assessment of the impact of the proposed mining slopes on the stability of the existing perimeter slopes at the Olive Pit, Irwindale.

The characteristic cross-section was selected at the location of the steepest and highest existing slopes. This happened to be a section at the east-facing slope near the southwest corner of the pit. The proposed mining will produce a slope descending from the toe of the existing slopes to the bottom of the quarry.

At the characteristic cross-section the existing slope is 150 feet high and inclined at 1.2(H):1(V). An effect of a bench or no bench at the toe of the existing slopes at elevation 250 feet was evaluated. The mining slopes descend at 2(H):1(V) to the bottom of the quarry at elevation 0 feet. Slope stability analyses were performed using SLOPE/W (Geo Slope Office, 2012), performing a two-dimensional analysis using Spencer's method, considering initially circular failure surfaces and specified entry-exit method and allowing for optimization. Shear strength parameters were assigned in accordance with the Irwindale Guidelines (ISSC, 2003) assuming that the properties of the alluvial materials at the Olive Pit are comparable to those of materials in URP Pit #2 and Pit #3. Thus, for the in-place natural soils the following drained parameters representing peak strength conditions were used for both static and seismic analyses:

<u>Friction angle, f':</u>

For $\sigma' \leq 2000$ psf, $\phi' = 50°$
For $\sigma' > 2000$ psf, $\phi' = 50° - \Delta\phi' \log(\sigma'/2000)$, with $\Delta\phi' = 10°$

<u>Cohesion, c':</u>

For the Upper Layer, $c_{upper}' = 350$ psf
From the top of the Lower Layer to 140 feet below the ground surface,

$$c' = c_u' + (c_l' - c_u)(z - z_u)/(140 - z_u) \text{ psf}$$

where:

c'	=	drained cohesion (psf)
c_u'	=	325 psf
c_l'	=	1000 psf
z	=	depth below the natural ground surface (ft)
z_u	=	thickness of the upper layer (ft)
σ'	=	effective normal stress acting on the shear surface (psf)
Φ'	=	drained friction angle (degrees)
$\Delta\Phi'$	=	reduction in friction angle per ten-fold increase in effective stress

As recommended in the Irwindale Guidelines, the Lower Layer was divided into 5 layers with a drained cohesion assigned to each layer per the above equation. The upper layer was conservatively assumed to be 40 feet thick based on the field observations.

Groundwater and water level in the mining pit were assumed at the approximate current elevation of 190 feet rather than the historic high elevation of 330 feet. It is noted that for the stability analyses the presence of higher water has a stabilizing effect on slope and therefore lower water level was conservatively considered in the herein presented analyses.

Seismic demand for the analyses was determined from the USGS Probabilistic Seismic Hazard Deaggregation website (http://geohazards.usgs.gov/deaggint/2008/) for a 475-year return period seismic event, i.e., event with 10 percent probability of exceedance in 50 years. Such an event was estimated to be a modal earthquake of magnitude of M_w 6.6 located at a distance of approximately 8.6 miles resulting in peak horizontal ground acceleration (PHGA) of approximately 0.47g for the assumed shear wave velocity v_s = 550 m/sec, corresponding to a soil site class C.

Permanent seismic deformation analyses were conducted for the investigated slope configurations using the empirical method developed by Bray and Travasarou (2007).

The following table summarizes the performed analyses:

	Static Stability	Yield Acceleration	Permanent Seismic Displacement	Appendix pages		
Acceptance criterion	FS > 1.5	n/a	< 2 cm	n/a		
Existing slope - 150'high - 1.2(H):1(V)	1.99	0.485	1.8 cm	A-1	A-2	B-1
Entire slope = existing + mining slope - 400 feet high - No bench Mining slope - 250 feet high - 2(H):1(V)	1.966	0.320	4.1 cm	A-3	A-4	B-2
Same as above but with a bench 30' wide at el.250'	2.037	0.325	4.0 cm	A-5	A-6	B-3
Same as above but with a bench 50' wide at el.250'	2.092			A-7		

Based on the presented analyses the following observations and conclusion can be made:

- The static stability of the existing slopes is not adversely impacted by the construction of the mining slope. Even with the mining slope excavated below the existing slope the critical slip surface remains within the existing slope and does not extend into the mining slope.

- Static stability of the existing slope and the entire slope consisting of the existing slope and the future mining slope is adequate with Factors of Safety greater than 1.5.

- The presence and width of a bench cut at the toe of the existing slopes up to 50 feet wide has a negligible effect on the slope stability.

- Seismic analyses performed for seismic event with return period of 475 years indicated potential for less than 2 cm of permanent seismic deformation for the existing slope and less about 4 cm for the entire slope. It is noted that the City of Irwindale Guidelines (Irwindale Slope Stability Committee, 2003, Guidelines for Stability Analyses of Open Pit Mines dated December 24) require that the calculated permanent seismic deformation is less than 2 cm. As described above, the permanent seismic deformations were determined using the empirical method developed by Bray and Travasarou (2007). It is our experience that notably smaller permanent seismic deformations are typically obtained when more rigorous site-specific analyses are performed. Consequently, it is our opinion that given that the acceptable magnitude of permanent seismic deformation was only marginally

exceeded, the rigorous analyses would yield acceptable deformation. Such analyses can be performed upon request.

We appreciate the opportunity to provide our professional services on this project. If you have any questions regarding this report or if we can be of further service, please do not hesitate to contact us.

Respectfully submitted,
Tetra Tech BAS GeoScience

Fernando Cuenca, Ph.D.
Project Engineer

Peter Skopek, Ph.D., G.E.
Principal Engineer

Attachments: Appendix A – Slope Stability Analyses
Appendix B – Slope Deformation Analyses

Distribution: Russ Caruso, United Rock Products (pdf by email Russ.Caruso@Sully-Miller.com)
Crystal Howard, Enviromine (pdf by email crystal@enviromineinc.com)

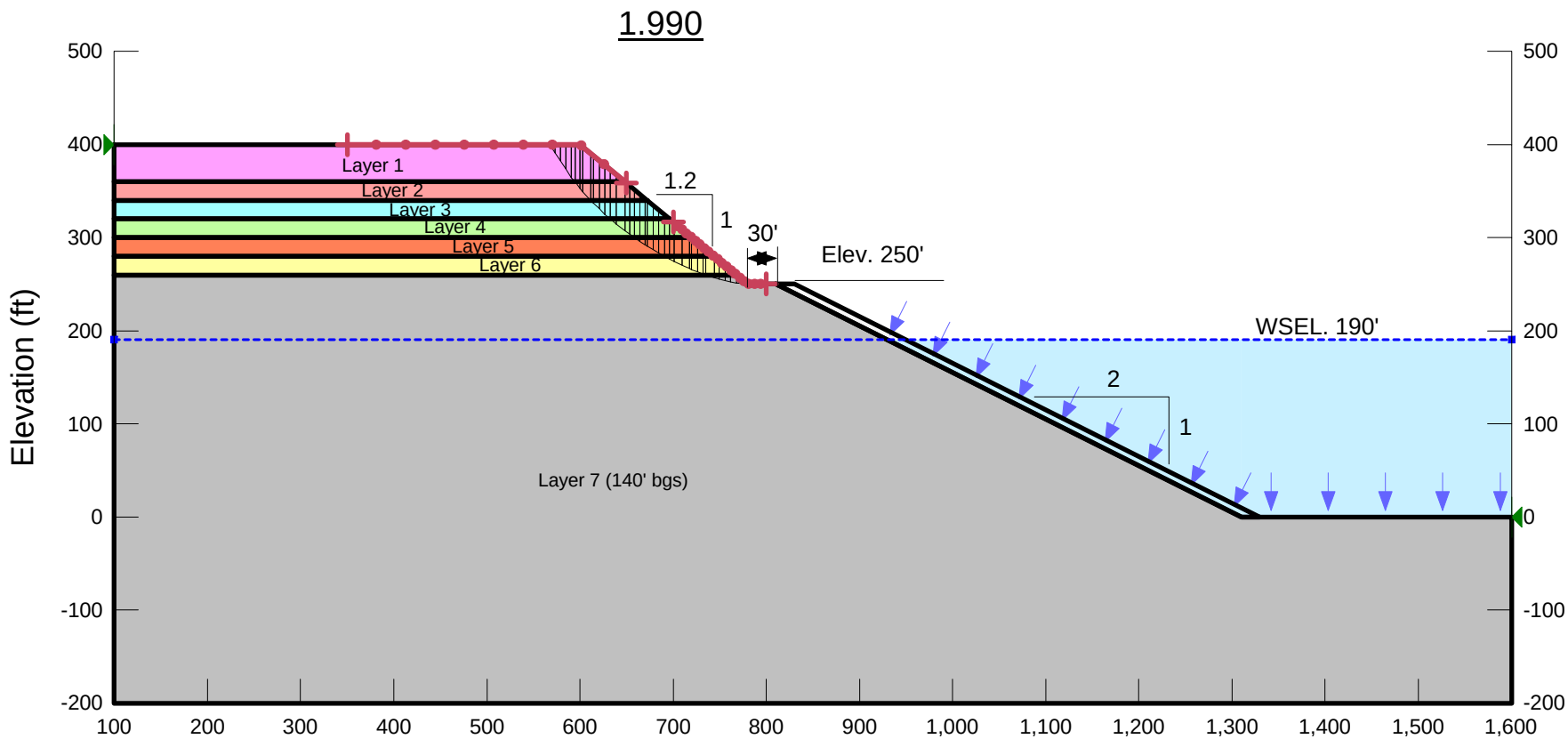
Filename: Olive Pit - Perimeter Slope Stability 2014-10-10.doc

APPENDIX A
SLOPE STABILITY ANALYSES

OLIVE PIT PERIMETER CHARACTERISTIC SLOPE STABILITY ANALYSIS

(West Section)

Description: Global slope stability
Method: Spencer
PWP Conditions Source: Piezometric Line
Optimize Critical Slip Surface Location: Yes
Horz Seismic Coef.: 0



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Strength Function: Upper Layer/Layer 1

Layer 2
Unit Weight: 130
Strength Function: Layer 2

Layer 3
Unit Weight: 130
Strength Function: Layer 3

Layer 4
Unit Weight: 130
Strength Function: Layer 4

Layer 5
Unit Weight: 130
Strength Function: Layer 5

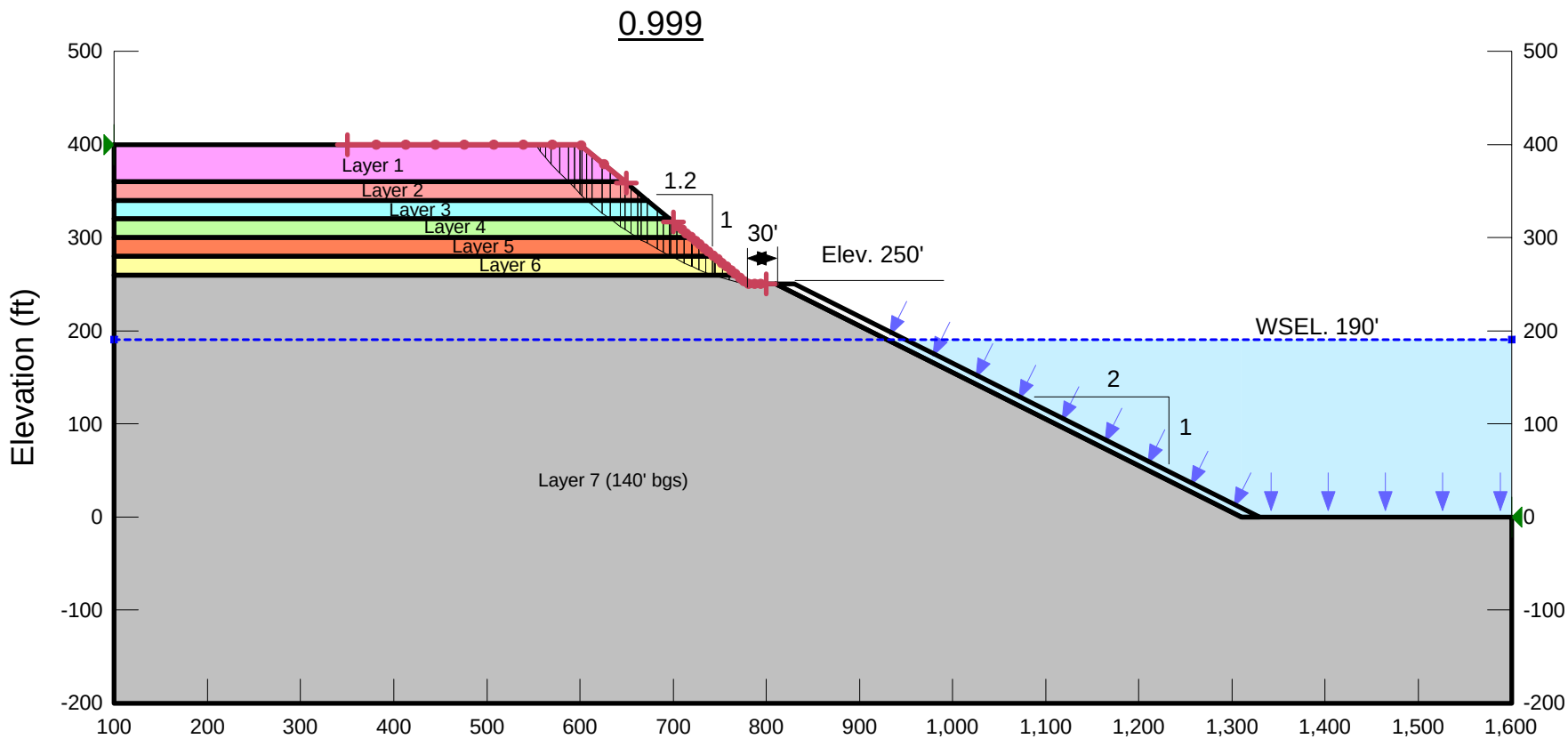
Layer 6
Unit Weight: 130
Strength Function: Layer 6

Layer 7
Unit Weight: 130
Strength Function: Layer 7

Figure A-1

OLIVE PIT PERIMETER CHARACTERISTIC SLOPE STABILITY ANALYSIS

Description: Global slope stability- Existing Slope (West Section)
Method: Spencer
PWP Conditions Source: Piezometric Line
Optimize Critical Slip Surface Location: Yes
Horz Seismic Coef.: 0.485



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Strength Function: Upper Layer/Layer 1

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Unit Weight: 130
Strength Function: Layer 2

Layer 3
Unit Weight: 130
Strength Function: Layer 3

Layer 4
Unit Weight: 130
Strength Function: Layer 4

Layer 5
Unit Weight: 130
Strength Function: Layer 5

Layer 6
Unit Weight: 130
Strength Function: Layer 6

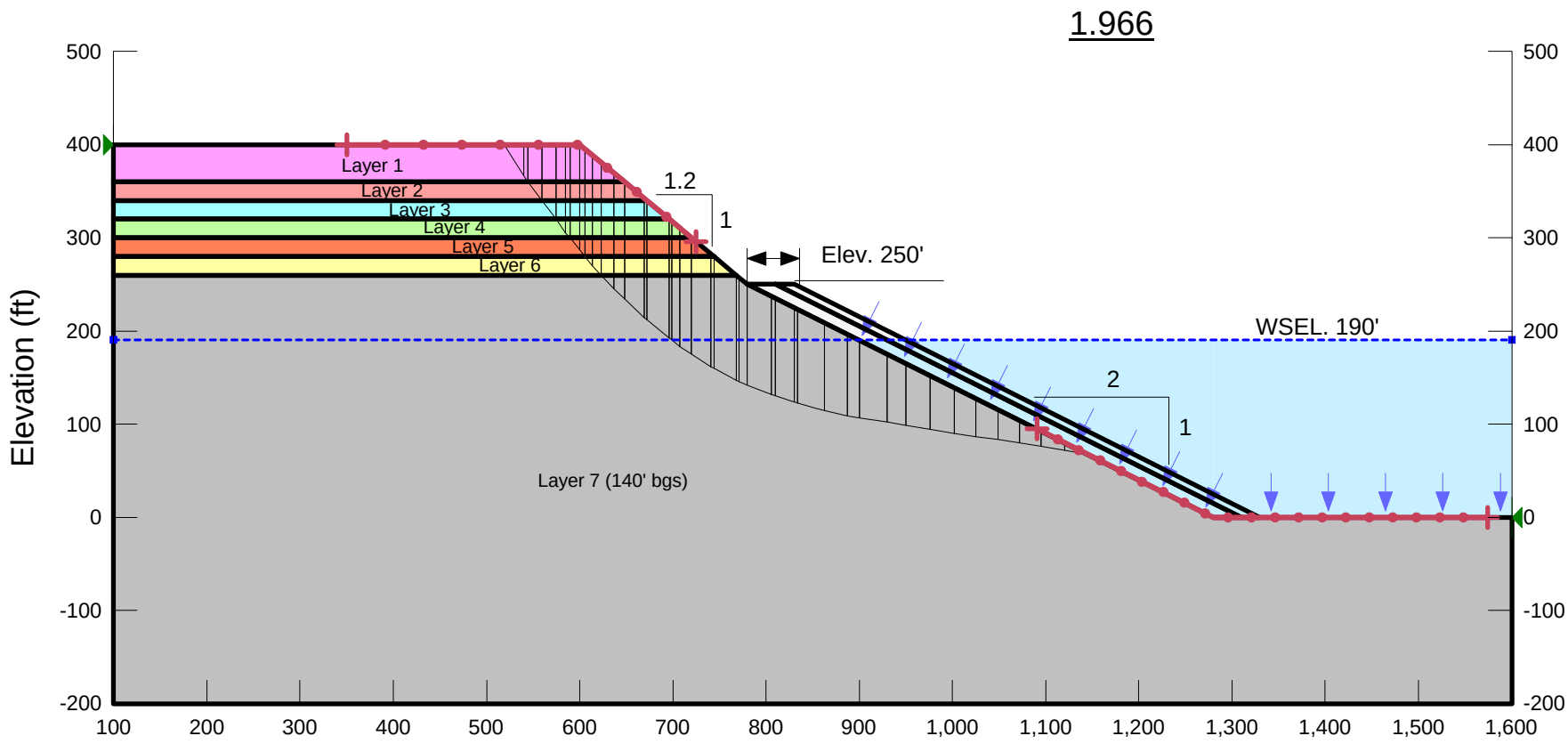
Layer 7
Unit Weight: 130
Strength Function: Layer 7

Figure A-2

OLIVE PIT PERIMETER CHARACTERISTIC SLOPE STABILITY ANALYSIS

(West Section)

Description: Global slope stability
Method: Spencer
PWP Conditions Source: Piezometric Line
Optimize Critical Slip Surface Location: Yes
Horz Seismic Coef.: 0



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Strength Function: Upper Layer/Layer 1

Layer 2
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Strength Function: Layer 2

Layer 3
Unit Weight: 130
Strength Function: Layer 3

Layer 4
Unit Weight: 130
Strength Function: Layer 4

Layer 5
Unit Weight: 130
Strength Function: Layer 5

Layer 6
Unit Weight: 130
Strength Function: Layer 6

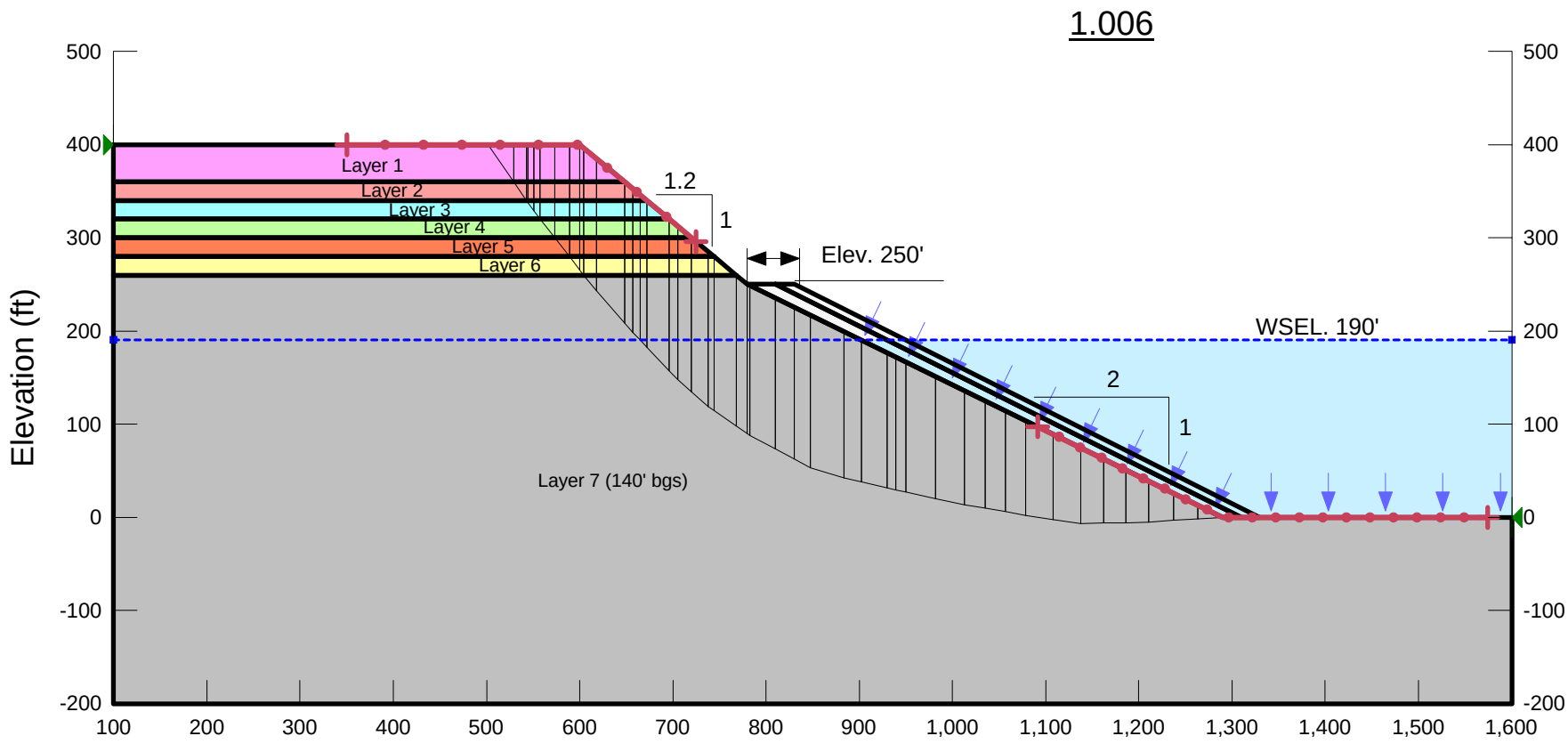
Layer 7
Unit Weight: 130
Strength Function: Layer 7

Figure A-3

OLIVE PIT PERIMETER CHARACTERISTIC SLOPE STABILITY ANALYSIS

(West Section)

Description: Global slope stability
Method: Spencer
PWP Conditions Source: Piezometric Line
Optimize Critical Slip Surface Location: Yes
Horz Seismic Coef.: 0.32



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Strength Function: Upper Layer/Layer 1

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Unit Weight: 130
Strength Function: Layer 2

Layer 3
Unit Weight: 130
Strength Function: Layer 3

Layer 4
Unit Weight: 130
Strength Function: Layer 4

Layer 5
Unit Weight: 130
Strength Function: Layer 5

Layer 6
Unit Weight: 130
Strength Function: Layer 6

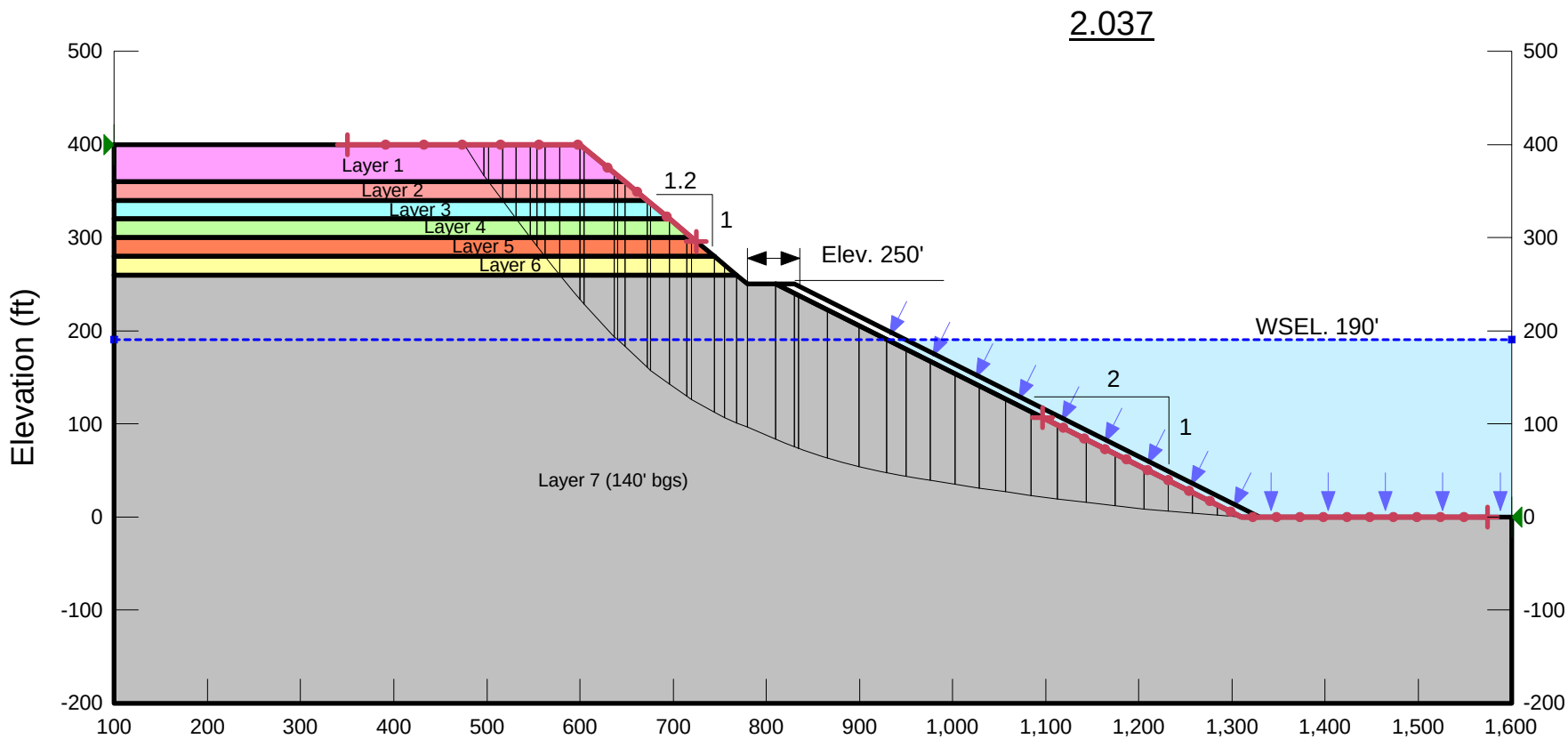
Layer 7
Unit Weight: 130
Strength Function: Layer 7

Figure A-4

OLIVE PIT PERIMETER CHARACTERISTIC SLOPE STABILITY ANALYSIS

(West Section)

Description: Global slope stability
Method: Spencer
PWP Conditions Source: Piezometric Line
Optimize Critical Slip Surface Location: Yes
Horz Seismic Coef.: 0



Layer 1
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Strength Function: Upper Layer/Layer 1

Layer 2
Unit Weight: 130
Strength Function: Layer 2

Layer 3
Unit Weight: 130
Strength Function: Layer 3

Layer 4
Unit Weight: 130
Strength Function: Layer 4

Layer 5
Unit Weight: 130
Strength Function: Layer 5

Layer 6
Unit Weight: 130
Strength Function: Layer 6

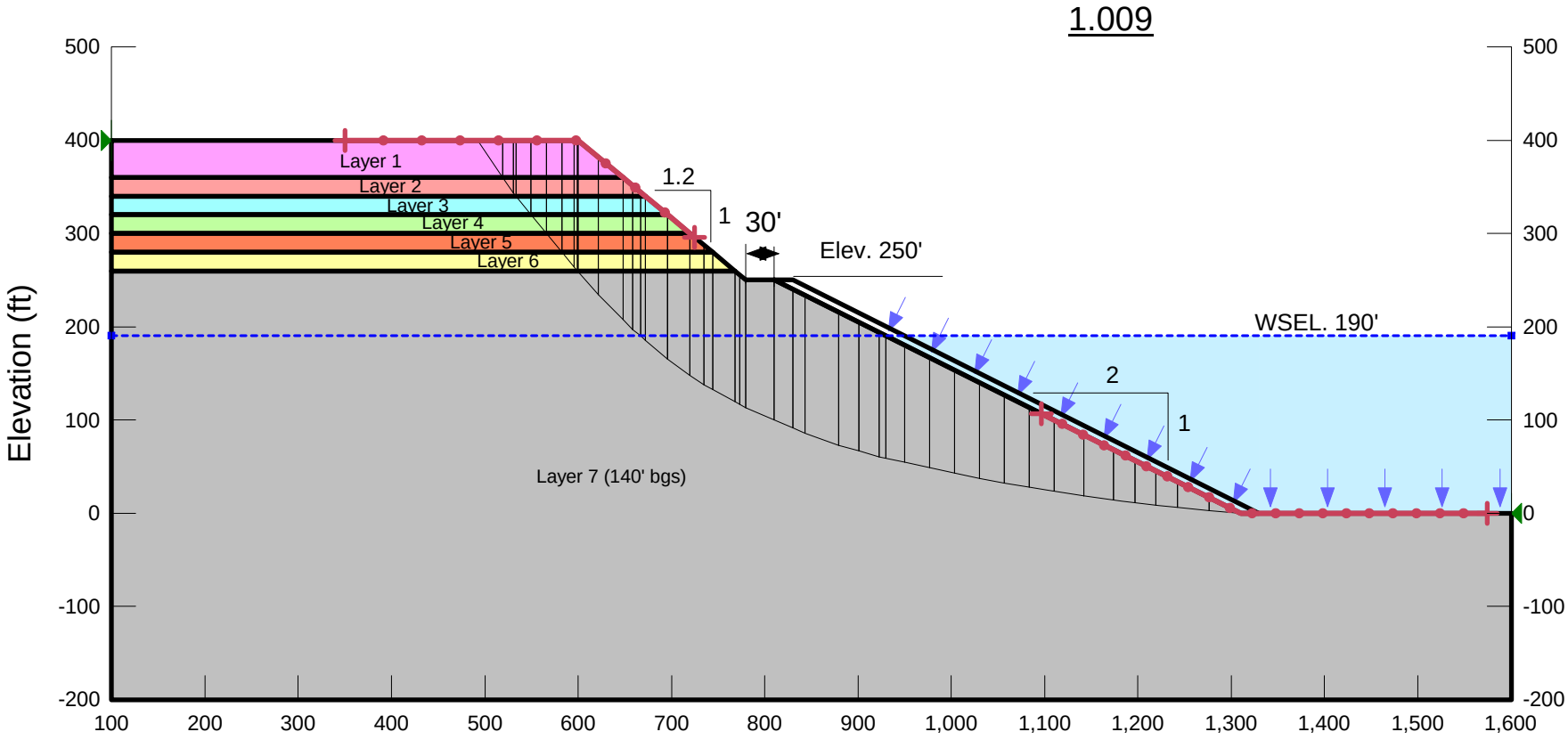
Layer 7
Unit Weight: 130
Strength Function: Layer 7

Figure A-5

OLIVE PIT PERIMETER CHARACTERISTIC SLOPE STABILITY ANALYSIS

(West Section)

Description: Global slope stability
Method: Spencer
PWP Conditions Source: Piezometric Line
Optimize Critical Slip Surface Location: Yes
Horz Seismic Coef.: 0.325



Layer 1
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Strength Function: Upper Layer/Layer 1

Layer 2
Unit Weight: 130
Strength Function: Layer 2

Layer 3
Unit Weight: 130
Strength Function: Layer 3

Layer 4
Unit Weight: 130
Strength Function: Layer 4

Layer 5
Unit Weight: 130
Strength Function: Layer 5

Layer 6
Unit Weight: 130
Strength Function: Layer 6

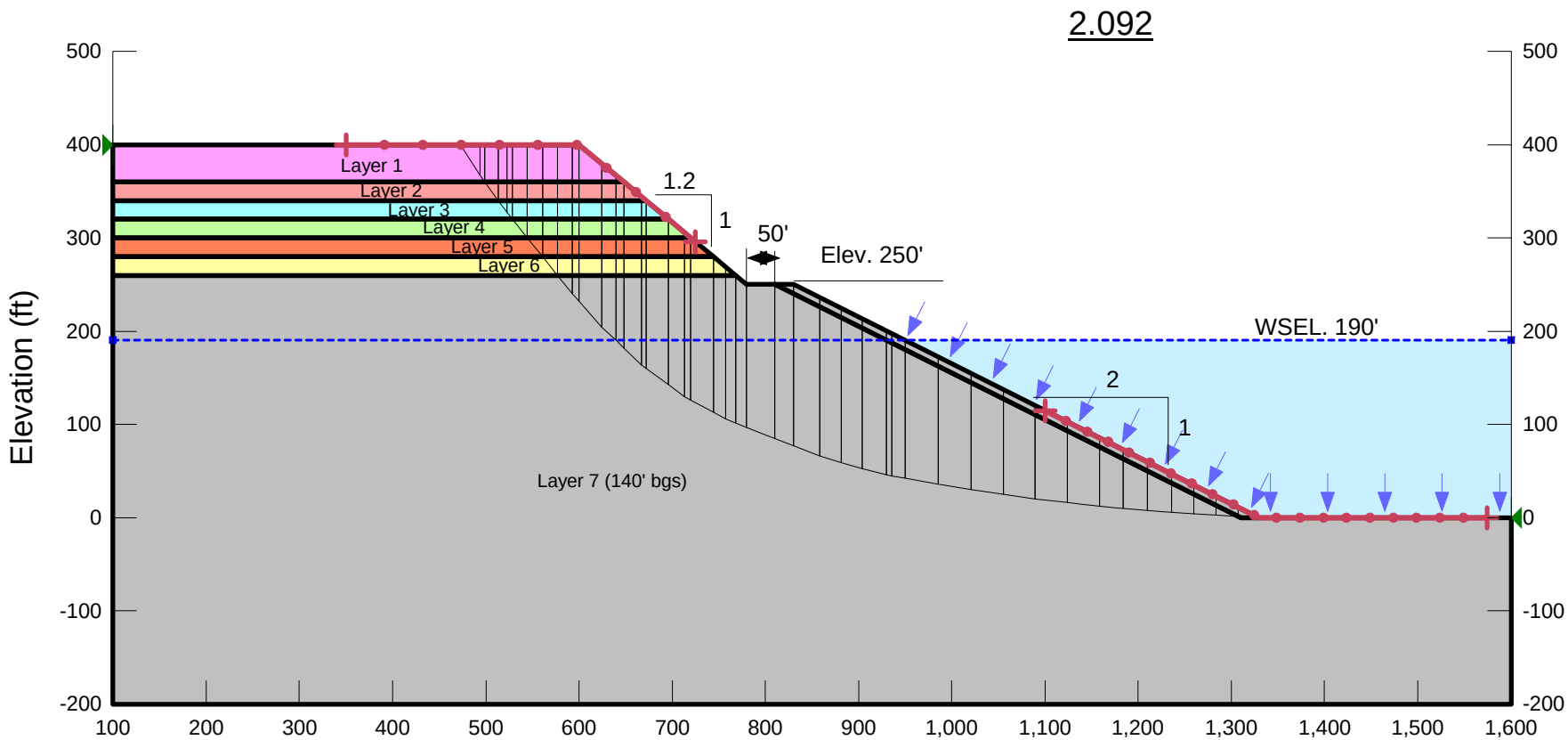
Layer 7
Unit Weight: 130
Strength Function: Layer 7

Figure A-6

OLIVE PIT PERIMETER CHARACTERISTIC SLOPE STABILITY ANALYSIS

(West Section)

Description: Global slope stability
Method: Spencer
PWP Conditions Source: Piezometric Line
Optimize Critical Slip Surface Location: Yes
Horz Seismic Coef.: 0



Layer 1
Unit Weight: 130
Strength Function: Upper Layer/Layer 1

Layer 2
Unit Weight: 130
Strength Function: Layer 2

Layer 3
Unit Weight: 130
Strength Function: Layer 3

Layer 4
Unit Weight: 130
Strength Function: Layer 4

Layer 5
Unit Weight: 130
Strength Function: Layer 5

Layer 6
Unit Weight: 130
Strength Function: Layer 6

Layer 7
Unit Weight: 130
Strength Function: Layer 7

Figure A-7

APPENDIX B
SLOPE DEFORMATION ANALYSES

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 Coefficient (ky)	0.485		Based on pseudostatic analysis
Initial Fundamental Period (Ts)	0.07	seconds	1D: Ts=4H/Vs 2D: Ts=2.6H/Vs
Degraded Period (1.5Ts)	0.11	seconds	
Moment Magnitude (M_w)	6.6		
Spectral Acceleration (Sa(1.5Ts))	0.94	g	

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

Intermediate Calculated Parameters			
Non-Zero Seismic Displacement Est (D)	1.82	cm	eq. (5) or (6)
Standard Deviation of Non-Zero Seismic D	0.66		

Results			
Probability of Negligible Displ. (P(D=0))	0.353		eq. (3)
D1	1.11	cm	calc. using eq. (7)
D2	<1	cm	calc. using eq. (7)
D3	2.85	cm	calc. using eq. (7)
P(D>d_threshold)	0.000		eq. (7)

Notes

1. Values highlighted in blue are input parameters
2. Probability of Exceedance is the desired probability of exceeding a particular displacement value.
3. Displacements D1, D2, and D3 correspond to P1, P2, and P3, respectively.
   (e.g., the probability of exceeding displacement D1 is P1)
4. Calculated seismic displacements are due to deviatoric deformation only (add in volumetrically induced movement).
5. ky may range between 0.01 and 0.5, Ts between 0 and 2 s, Sa between 0.002 and 2.7 g, M between 4.5 and 9
6. Rigid slope is assumed for Ts < 0.05 s
7. When a value for D is not calculated, D is < 1cm
8. ky may be estimated using the simplified equations shown below.
9. Examples of how Ts is estimated are shown below.
10. Vs = weighted avg. shear wave velocity for the sliding mass, e.g., for 2 layers, Vs = [(h1)(Vs1) + (h2)(Vs2)]/(h1 + h2)

FIGURE B-1

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 Coefficient (ky)	0.32		Based on pseudostatic analysis
Initial Fundamental Period (Ts)	0.37	seconds	1D: Ts=4H/Vs 2D: Ts=2.6H/Vs
Degraded Period (1.5Ts)	0.55	seconds	
Moment Magnitude (M_w)	6.6		
Spectral Acceleration (Sa(1.5Ts))	0.75	g	

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

Intermediate Calculated Parameters			
Non-Zero Seismic Displacement Est (D)	4.14	cm	eq. (5) or (6)
Standard Deviation of Non-Zero Seismic D	0.66		

Results			
Probability of Negligible Displ. (P(D=0))	0.136		eq. (3)
D1	3.63	cm	calc. using eq. (7)
D2	1.17	cm	calc. using eq. (7)
D3	7.48	cm	calc. using eq. (7)
P(D>d_threshold)	0.022		eq. (7)

Notes

1. Values highlighted in blue are input parameters
2. Probability of Exceedance is the desired probability of exceeding a particular displacement value.
3. Displacements D1, D2, and D3 correspond to P1, P2, and P3, respectively.
   (e.g., the probability of exceeding displacement D1 is P1)
4. Calculated seismic displacements are due to deviatoric deformation only (add in volumetrically induced movement).
5. ky may range between 0.01 and 0.5, Ts between 0 and 2 s, Sa between 0.002 and 2.7 g, M between 4.5 and 9
6. Rigid slope is assumed for Ts < 0.05 s
7. When a value for D is not calculated, D is < 1cm
8. ky may be estimated using the simplified equations shown below.
9. Examples of how Ts is estimated are shown below.
10. Vs = weighted avg. shear wave velocity for the sliding mass, e.g., for 2 layers, Vs = [(h1)(Vs1) + (h2)(Vs2)]/(h1 + h2)

FIGURE B-2

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 Coefficient (ky)	0.325		Based on pseudostatic analysis
Initial Fundamental Period (Ts)	0.37	seconds	1D: Ts=4H/Vs 2D: Ts=2.6H/Vs
Degraded Period (1.5Ts)	0.55	seconds	
Moment Magnitude (M_w)	6.6		
Spectral Acceleration (Sa(1.5Ts))	0.75	g	

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

Intermediate Calculated Parameters			
Non-Zero Seismic Displacement Est (D)	4.00	cm	eq. (5) or (6)
Standard Deviation of Non-Zero Seismic D	0.66		

Results			
Probability of Negligible Displ. (P(D=0))	0.148		eq. (3)
D1	3.46	cm	calc. using eq. (7)
D2	0.94	cm	calc. using eq. (7)
D3	7.17	cm	calc. using eq. (7)
P(D>d_threshold)	0.019		eq. (7)

Notes

1. Values highlighted in blue are input parameters
2. Probability of Exceedance is the desired probability of exceeding a particular displacement value.
3. Displacements D1, D2, and D3 correspond to P1, P2, and P3, respectively.
   (e.g., the probability of exceeding displacement D1 is P1)
4. Calculated seismic displacements are due to deviatoric deformation only (add in volumetrically induced movement).
5. ky may range between 0.01 and 0.5, Ts between 0 and 2 s, Sa between 0.002 and 2.7 g, M between 4.5 and 9
6. Rigid slope is assumed for Ts < 0.05 s
7. When a value for D is not calculated, D is < 1cm
8. ky may be estimated using the simplified equations shown below.
9. Examples of how Ts is estimated are shown below.
10. Vs = weighted avg. shear wave velocity for the sliding mass, e.g., for 2 layers, Vs = [(h1)(Vs1) + (h2)(Vs2)]/(h1 + h2)

FIGURE B-3