GEOTECH
CONSULTANTS, INC.

2401 10th Ave E
Seattle, Washington 98102
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May 26, 2022

JN 20069

Dale Vogel and Nancy Bird
P.O. Box 1360
Mercer Island, Washington 98040
via email: dalejvogel@outlook.com; carly.birdvogel@gmail.com

Subject: **Slope Stability Update**
Proposed New Residence
4304 E Mercer Way
Mercer Island, Washington

Dear Mr. Vogel and Ms. Bird:

As you are aware, the City of Mercer Island and their Geotechnical Third-Party Engineer have recently interpreted that the International Building Code (IBC) is implying that slope stability analyses are to be conducted considering the strong ground motions of the Maximum Considered Earthquake (MCE). The MCE is a very low probability earthquake event, with a theoretical 2% potential of occurring in 50 years, which is a one-in-2,475-years event.

We have had numerous discussions with the building department about this interpretation. They are aware that we do not agree with this very conservative interpretation. To their credit, they did listen to our arguments, but they were unable to get responses from any of the participants who wrote that section of the Code, even after several attempts.

We have re-assessed the stability of the steep slope to the east of your proposed house using the MCE ground motions as determined for the 2018 IBC. Using a technique presented by the Federal Highway Administration, we reduced the peak ground acceleration due to the effects of wave scatter near slopes. The reference and calculation for this procedure is attached, as well as the resulting slope stability analyses.

CONCLUSIONS

The higher design ground accelerations for the MCE have resulted in a theoretical failure that could extend beneath the eastern foundation of the proposed house. The potential for this ever occurring is extremely low. However, if the house must be stabilized against this low probability earthquake, stabilization to a depth of 5 feet below the planned eastern foundation would be necessary.

Considering the sandy nature of the soils, and following discussions with the project team, it appears that the most economical method to achieve this depth of stabilization is to install closely-spaced, driven soldier piles underneath the eastern foundation of the house. These soldier piles would laterally restrain the soil to a depth of 5 feet below the ground surface in the unlikely event that the eastern slope would fail during the low probability earthquake.

The driven soldier piles can also provide vertical support for the eastern wall of the house, eliminating the need for pipe piles along that foundation.

The following section has design recommendations for the closely-spaced soldier pile wall.

STABILIZATION WALL

As discussed in the ***General*** section, a stabilization wall is recommended along the eastern side of the planned structure. Based on the results of our slope stability analyses, we recommend that the wall be designed for a retention depth of approximately 5 feet, measured from the existing grade along the proposed development area.

The stabilization wall should consist of closely spaced, driven soldier piles spaced no further apart than 2 feet edge-to-edge. The soil within the stabilization zone will arch between the piles if a failure does in fact occur on the eastern slope. The piles could be installed by driving them to depth with a large hydraulic impact hammer. These driven beams are typically cheaper to install than drilled piles, but are limited in steel section size, length, and pile-to-pile spacings.

The stabilization wall should be designed for an active soil pressure equal to that pressure exerted by an equivalent fluid with a unit weight of 40 pcf if it retains level soil. Under the IBC, a seismic surcharge does not need to be applied to the design of the wall, as even following a shallow slide, the depth of retention for the stabilization wall would be less than 6 feet. An ultimate (no safety factor included) passive soil pressure equal to that pressure exerted by a fluid with a density of 350 pcf will resist the lateral movement of the piles below the stabilization depth. This passive resistance can be assumed to act over twice the wide of the wide-flange beams. Typically, a safety factor of 1.5 is applied to the ultimate passive resistance for static conditions, and 1.1. to 1.2 for seismic loading conditions.

If the wide-flange beams are driven into the dense soils, to a depth of at least 15 feet, they can support an allowable compressive capacity of at least 10 tons.

Please contact us if you have any questions regarding this letter.

Respectfully submitted,

GEOTECH CONSULTANTS, INC.

5/26/2022

Marc R. McGinnis, P.E.
Principal

Attachments:

- Peak Acceleration Reduction
- Slope Stability Analyses

cc: **McClellan Architects –** Karen Kline
via email: *karen@mccarch.com*

Peak Acceleration Reduction Due to Wave Scattering Near Slope Face

$$k_{av} = \alpha \cdot k_{max} \quad \text{6-2}$$

where α = a slope height reduction factor and k_{av} is the average peak acceleration in the potential failure mass, taking into account spatial incoherence (or wave scattering).

The following relationship is presented in NCHRP Report 611 for the value of α for slopes and embankments of up to 100 ft in height founded upon Site Class C, D, and E soil conditions:

$$\alpha = 1 + 0.01 \cdot H \cdot (0.5 \cdot \beta - 1) \quad \text{6-3}$$

where H = slope height (feet) and β is a function of the shape of the acceleration response spectrum and is given by:

$$\beta = F_v \cdot S_1 / k_{max} \quad \text{6-4}$$

where F_v = AASHTO site factor for the spectral acceleration at 1 second and S_1 = the spectral acceleration at 1 second for Site Class B.

(Source*: LRFD Seismic Analysis and Design of Transportation Geotechnical Features and Structural Foundations, NHI Course No. 130094*; Federal Highway Administration; August 2011.)

Calculation: For Site Class D, k_{max} (MCEg) = 0.665g under ASCE 7-16 (2018 IBC)

H= 20 feet

Fv for Site Class B = 0.8 (ASCE 7-16)

S1 = 0.491 (ASCE 7-16)

β = 0.8 * 0.491 / 0.665 = 0.591 (ASCE 7-16)

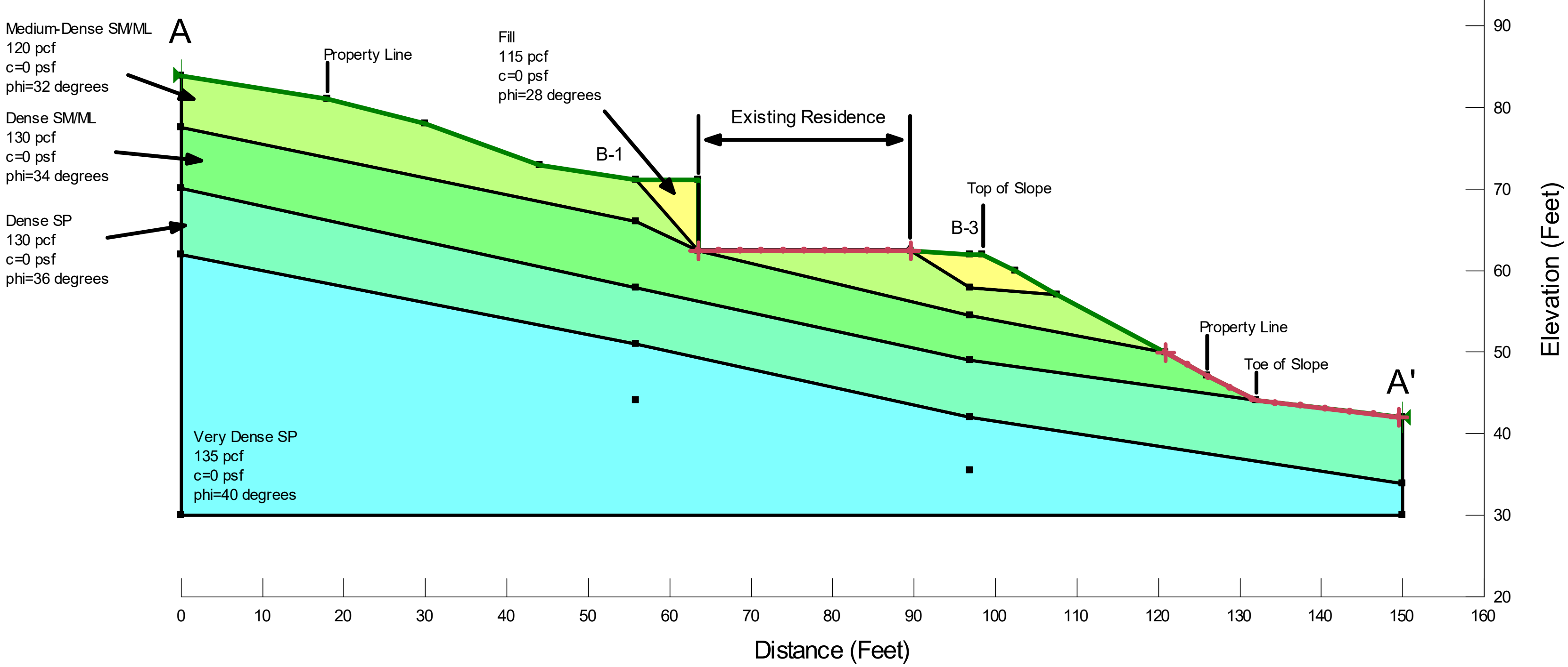
α = 1+0.01 * 20’ * (0.5*0.591-1) = 0.859

Kav = α * Kmax = 0.859 * 0.665 = 0.57

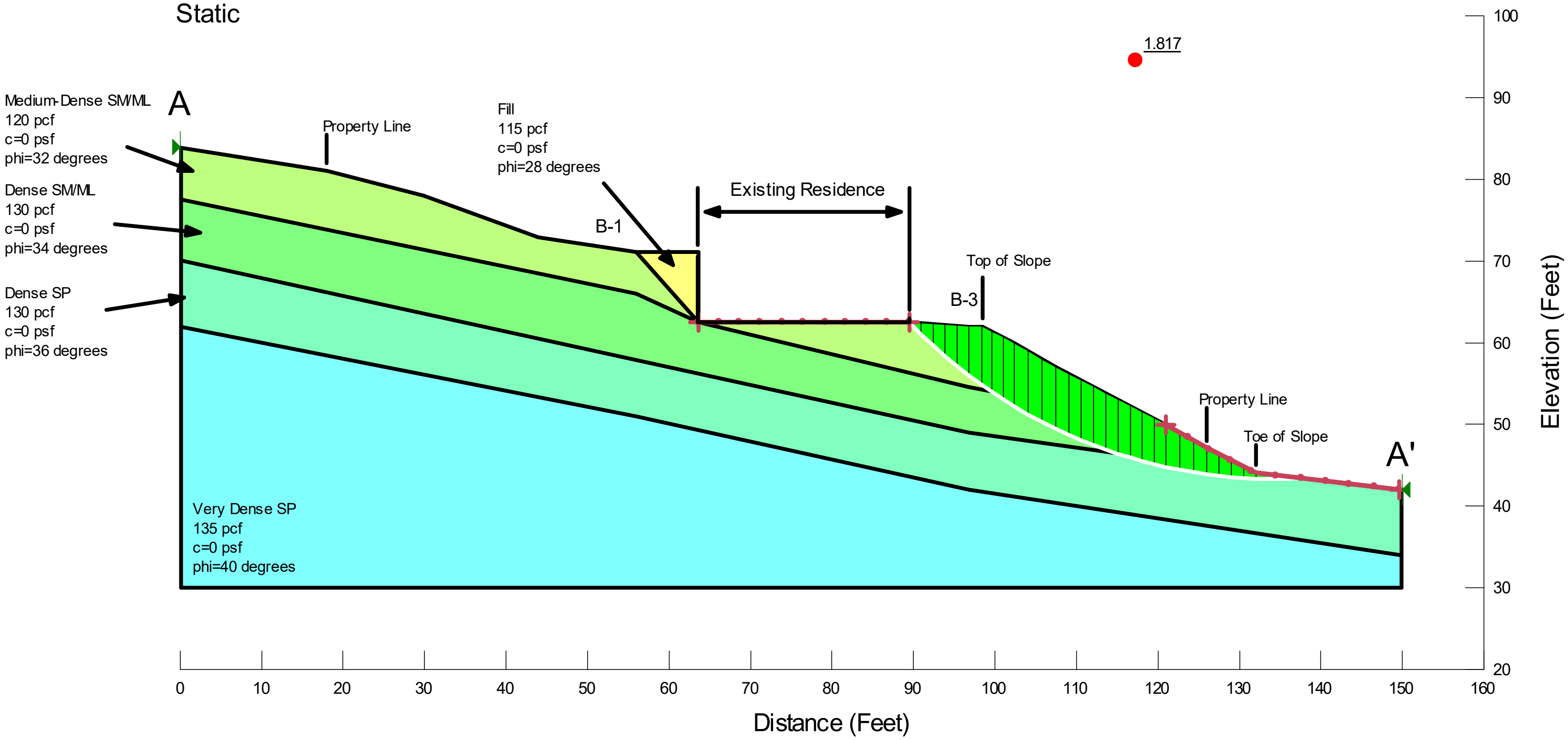
Kh = 0.5 * 0.57 = 0.285g (ASCE 7-16)

Attachment
Slope Stability Analysis
JN 20069
Bird-Vogel

20069 - Bird-Vogel and McDonald
Static



20069 - Bird-Vogel and McDonald
Static



Static

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File Information

File Version: 8.15
Title: 20069 Slope Stability - Vogel
Created By: Matt McGinnis
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Directory: C:\Users\MattM\Geotech Consultants\Shared Documents - Documents\2020 Jobs\20069 Bird-Vogel-McDonald (MRM)\
Last Solved Date: 5/9/2022
Last Solved Time: 9:20:34 AM

Project Settings

Length(L) Units: Feet
Time(t) Units: Seconds
Force(F) Units: Pounds
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D
Element Thickness: 1

Analysis Settings

Static

Kind: SLOPE/W
Method: Morgenstern-Price
Settings
- Side Function
  - Interslice force function option: Half-Sine
- PWP Conditions Source: (none)

Slip Surface
- Direction of movement: Left to Right
- Use Passive Mode: No
- Slip Surface Option: Entry and Exit
- Critical slip surfaces saved: 1
- Resisting Side Maximum Convex Angle: 1 °
- Driving Side Maximum Convex Angle: 5 °
- Optimize Critical Slip Surface Location: No
- Tension Crack
  - Tension Crack Option: (none)

F of S Distribution

F of S Calculation Option: Constant

Advanced

Number of Slices: 30
F of S Tolerance: 0.001
Minimum Slip Surface Depth: 0.1 ft
Search Method: Root Finder
Tolerable difference between starting and converged F of S: 3
Maximum iterations to calculate converged lambda: 20
Max Absolute Lambda: 2

Materials

Fill

Model: Mohr-Coulomb
Unit Weight: 115 pcf
Cohesion': 0 psf
Phi': 28 °
Phi-B: 0 °

Medium-Dense SM/ML

Model: Mohr-Coulomb
Unit Weight: 120 pcf
Cohesion': 100 psf
Phi': 32 °
Phi-B: 0 °

Dense SM/ML

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion': 50 psf
Phi': 34 °
Phi-B: 0 °

Dense SP

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion': 0 psf
Phi': 36 °
Phi-B: 0 °

Very Dense SP

Model: Mohr-Coulomb
Unit Weight: 135 pcf
Cohesion': 0 psf
Phi': 40 °
Phi-B: 0 °

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (63.5, 62.5) ft
Left-Zone Right Coordinate: (89.5, 62.5) ft

Left-Zone Increment: 10
Right Projection: Range
Right-Zone Left Coordinate: (121, 50) ft
Right-Zone Right Coordinate: (149.5, 42.05556) ft
Right-Zone Increment: 10
Radius Increments: 10

Slip Surface Limits

Left Coordinate: (0, 84) ft
Right Coordinate: (150, 42) ft

Seismic Coefficients

Horz Seismic Coef.: 0

Points

	X (ft)	Y (ft)
Point 1	0	84
Point 2	18	81
Point 3	30	78
Point 4	44	73
Point 5	56	71
Point 6	63.5	71
Point 7	89.5	62.5
Point 8	96.8	62
Point 9	102.4	60
Point 10	121	50
Point 11	126	47
Point 12	132	44
Point 13	150	42
Point 14	0	30
Point 15	150	30
Point 16	56	66
Point 17	56	58
Point 18	56	51
Point 19	56	44
Point 20	96.8	58
Point 21	96.8	54.5
Point 22	96.8	49
Point 23	96.8	42
Point 24	96.8	35.5
Point 25	107.5	57
Point 26	63.5	62.5
Point 27	0	77.5
Point 28	0	70
Point 29	150	34
Point 30	0	62

Point 31	98.4	62

Regions

	Material	Points	Area (ft²)
Region 1	Fill	7,8,31,9,25,20	40.9
Region 2	Fill	5,6,26	31.875
Region 3	Medium-Dense SM/ML	4,5,26,16,27,1,2,3	360.75
Region 4	Dense SM/ML	16,26,21,10,11,12,22,17,28,27	824.27
Region 5	Dense SP	12,13,29,23,18,30,28,17,22	1,094.8
Region 6	Very Dense SP	29,15,14,30,18,23	2,582.8
Region 7	Medium-Dense SM/ML	26,7,20,25,10,21	189.82

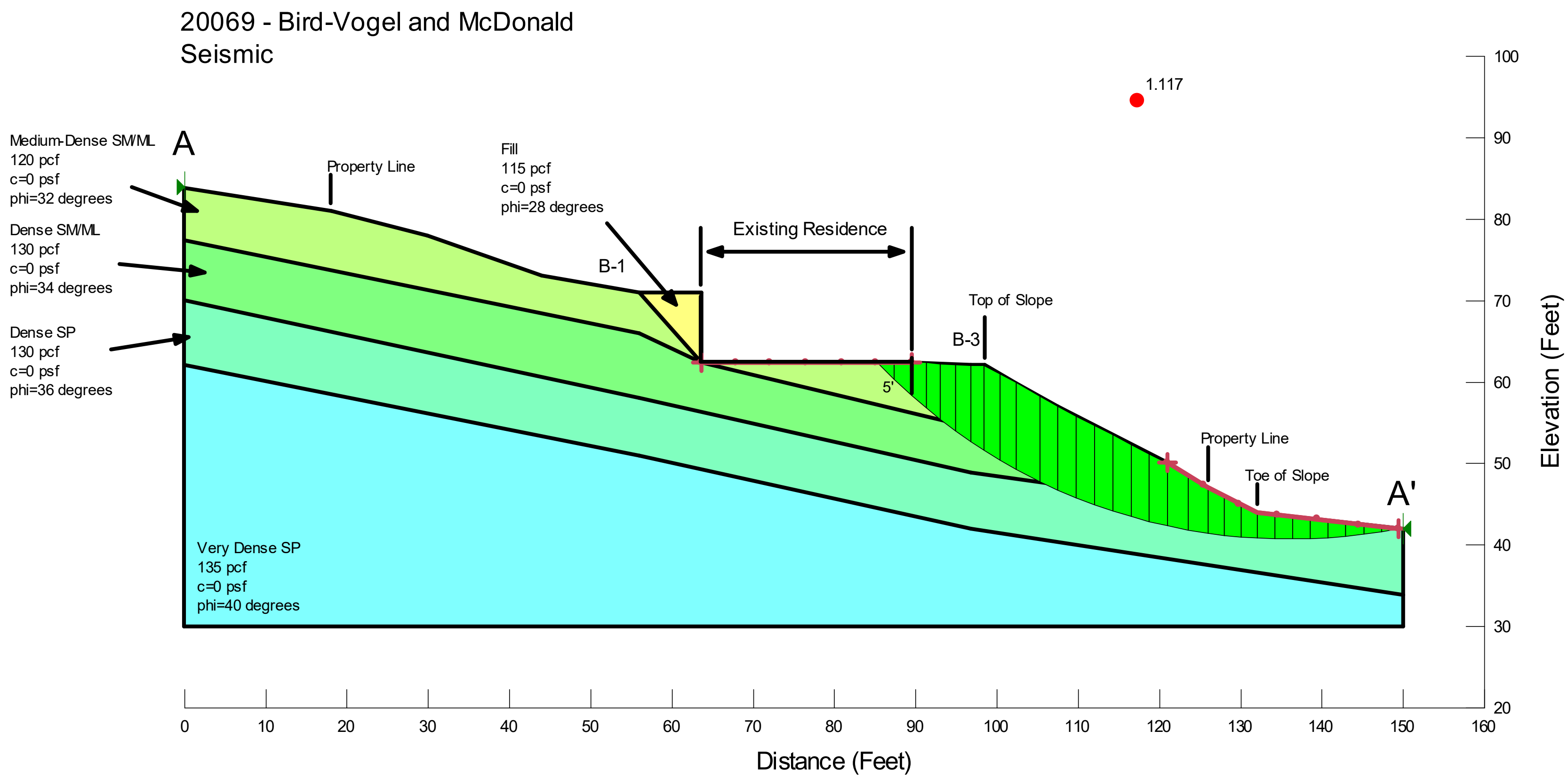
Current Slip Surface

Slip Surface: 1,280
F of S: 1.817
Volume: 227.41913 ft³
Weight: 28,156.042 lbs
Resisting Moment: 1,255,353.6 lbs-ft
Activating Moment: 691,159.48 lbs-ft
Resisting Force: 18,139.161 lbs
Activating Force: 9,982.9282 lbs
F of S Rank (Analysis): 1 of 1,331 slip surfaces
F of S Rank (Query): 1 of 1,331 slip surfaces
Exit: (137.51501, 43.387221) ft
Entry: (89.5, 62.5) ft
Radius: 62.330975 ft
Center: (134.48555, 105.64453) ft

Slip Slices

	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
Slice 1	90.23	61.763765	0	19.835087	12.394338	100
Slice 2	91.69	60.337988	0	137.98202	86.220737	100
Slice 3	93.15	59.001513	0	246.14294	153.80718	100
Slice 4	94.61	57.746843	0	346.47185	216.49964	100
Slice 5	96.07	56.56769	0	440.75272	275.41286	100
Slice 6	97.6	55.408872	0	540.72478	337.88234	100
Slice 7	99.011313	54.398302	0	609.30952	380.73885	100
Slice 8	100.31697	53.519977	0	643.06519	433.75295	50
Slice 9	101.70566	52.635453	0	675.46926	455.60977	50
Slice 10	103.25	51.713781	0	701.93712	473.46256	50
Slice 11	104.95	50.764026	0	721.8795	486.91387	50
Slice 12	106.65	49.882269	0	737.82786	497.67118	50
Slice 13	108.26226	49.104425	0	752.68814	507.69456	50
Slice	109.78679	48.421874	0	766.52338	517.02655	50

14						
Slice 15	111.31132	47.787541	0	775.98843	523.4108	50
Slice 16	112.83585	47.199855	0	780.39978	526.3863	50
Slice 17	114.36038	46.65742	0	778.98962	525.43513	50
Slice 18	115.85732	46.167253	0	770.45491	559.76826	0
Slice 19	117.32666	45.726766	0	755.68208	549.03517	0
Slice 20	118.79599	45.325282	0	733.32464	532.79154	0
Slice 21	120.26533	44.962027	0	702.78772	510.60516	0
Slice 22	121.83333	44.617099	0	648.97937	471.51111	0
Slice 23	123.5	44.295111	0	569.69179	413.90532	0
Slice 24	125.16667	44.019874	0	478.75789	347.83797	0
Slice 25	126.75	43.800046	0	392.56145	285.21259	0
Slice 26	128.25	43.630822	0	313.47006	227.74933	0
Slice 27	129.75	43.498259	0	227.75581	165.47428	0
Slice 28	131.25	43.402122	0	136.60815	99.251631	0
Slice 29	132.91917	43.340026	0	78.177134	56.799012	0
Slice 30	134.75751	43.320928	0	51.310724	37.279423	0
Slice 31	136.59585	43.35608	0	18.011954	13.086451	0



20069 - Bird-Vogel and McDonald
Seismic
1.117
Medium-Dense SM/ML
120 pcf
c=0 psf
phi=32 degrees
Dense SM/ML
130 pcf
c=0 psf
phi=34 degrees
Dense SP
130 pcf
c=0 psf
phi=36 degrees
A
Property Line
Fill
115 pcf
c=0 psf
phi=28 degrees
B-1
Existing Residence
Top of Slope
B-3
5'
Property Line
Toe of Slope
A'
Very Dense SP
135 pcf
c=0 psf
phi=40 degrees
Distance (Feet)
Elevation (Feet)
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
20 30 40 50 60 70 80 90 100

Seismic

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Project Settings

- Length(L) Units: Feet
- Time(t) Units: Seconds
- Force(F) Units: Pounds
- Pressure(p) Units: psf
- Strength Units: psf
- Unit Weight of Water: 62.4 pcf
- View: 2D
- Element Thickness: 1

Analysis Settings

Seismic

- Kind: SLOPE/W
- Method: Morgenstern-Price
- Settings
  - Side Function
    - Interslice force function option: Half-Sine
  - PWP Conditions Source: (none)
- Slip Surface
  - Direction of movement: Left to Right
  - Use Passive Mode: No
  - Slip Surface Option: Entry and Exit
  - Critical slip surfaces saved: 1
  - Resisting Side Maximum Convex Angle: 1 °
  - Driving Side Maximum Convex Angle: 5 °
  - Optimize Critical Slip Surface Location: No
  - Tension Crack
    - Tension Crack Option: (none)
- F of S Distribution

F of S Calculation Option: Constant

Advanced

Number of Slices: 30
F of S Tolerance: 0.001
Minimum Slip Surface Depth: 0.1 ft
Search Method: Root Finder
Tolerable difference between starting and converged F of S: 3
Maximum iterations to calculate converged lambda: 20
Max Absolute Lambda: 2

Materials

Fill

Model: Mohr-Coulomb
Unit Weight: 115 pcf
Cohesion': 0 psf
Phi': 28 °
Phi-B: 0 °

Medium-Dense SM/ML

Model: Mohr-Coulomb
Unit Weight: 120 pcf
Cohesion': 100 psf
Phi': 32 °
Phi-B: 0 °

Dense SM/ML

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion': 50 psf
Phi': 34 °
Phi-B: 0 °

Dense SP

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion': 0 psf
Phi': 36 °
Phi-B: 0 °

Very Dense SP

Model: Mohr-Coulomb
Unit Weight: 135 pcf
Cohesion': 0 psf
Phi': 40 °
Phi-B: 0 °

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (63.5, 62.5) ft
Left-Zone Right Coordinate: (89.5, 62.5) ft

Left-Zone Increment: 6
Right Projection: Range
Right-Zone Left Coordinate: (121, 50) ft
Right-Zone Right Coordinate: (149.5, 42.05556) ft
Right-Zone Increment: 6
Radius Increments: 6

Slip Surface Limits

Left Coordinate: (0, 84) ft
Right Coordinate: (150, 42) ft

Seismic Coefficients

Horz Seismic Coef.: 0.285

Points

	X (ft)	Y (ft)
Point 1	0	84
Point 2	18	81
Point 3	30	78
Point 4	44	73
Point 5	56	71
Point 6	63.5	71
Point 7	89.5	62.5
Point 8	96.8	62
Point 9	102.4	60
Point 10	121	50
Point 11	126	47
Point 12	132	44
Point 13	150	42
Point 14	0	30
Point 15	150	30
Point 16	56	66
Point 17	56	58
Point 18	56	51
Point 19	56	44
Point 20	96.8	58
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Point 26	63.5	62.5
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Point 29	150	34
Point 30	0	62

Point 31	98.4	62

Regions

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Region 1	Fill	7,8,31,9,25,20	40.9
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Region 3	Medium-Dense SM/ML	4,5,26,16,27,1,2,3	360.75
Region 4	Dense SM/ML	16,26,21,10,11,12,22,17,28,27	824.27
Region 5	Dense SP	12,13,29,23,18,30,28,17,22	1,094.8
Region 6	Very Dense SP	29,15,14,30,18,23	2,582.8
Region 7	Medium-Dense SM/ML	26,7,20,25,10,21	189.82

Current Slip Surface

Slip Surface: 290
F of S: 1.117
Volume: 387.78494 ft³
Weight: 48,655.95 lbs
Resisting Moment: 2,255,548.9 lbs-ft
Activating Moment: 2,019,319.6 lbs-ft
Resisting Force: 29,701.032 lbs
Activating Force: 26,569.153 lbs
F of S Rank (Analysis): 24 of 343 slip surfaces
F of S Rank (Query): 24 of 343 slip surfaces
Exit: (149.5, 42.055556) ft
Entry: (85.166667, 62.5) ft
Radius: 70.236552 ft
Center: (135.98834, 110.98021) ft

Slip Slices

	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
Slice 1	86.25	61.412928	0	27.951928	17.466303	100
Slice 2	88.416667	59.328105	0	190.01913	118.73713	100
Slice 3	90.385757	57.574021	0	315.20274	196.96053	100
Slice 4	92.157272	56.110132	0	410.39183	256.44128	100
Slice 5	93.982272	54.701531	0	510.04914	344.03249	50
Slice 6	95.860757	53.346535	0	599.97585	404.68882	50
Slice 7	97.6	52.170383	0	685.93705	462.67038	50
Slice 8	99.4	51.037788	0	743.70711	501.63678	50
Slice 9	101.4	49.861476	0	775.35113	522.98094	50
Slice 10	103.86467	48.542001	0	804.20012	542.43983	50
Slice 11	106.41467	47.284532	0	828.34834	601.83029	0
Slice 12	108.625	46.304646	0	854.43028	620.77994	0
Slice 13	110.875	45.39788	0	886.51261	644.08911	0
Slice	113.125	44.57972	0	918.27807	667.16807	0

14						
Slice 15	115.375	43.846922	0	947.46275	688.37198	0
Slice 16	117.625	43.196714	0	970.69827	705.25357	0
Slice 17	119.875	42.626736	0	983.52827	714.57512	0
Slice 18	122.25	42.112174	0	962.48773	699.28827	0
Slice 19	124.75	41.660161	0	895.64651	650.72528	0
Slice 20	127	41.328461	0	819.1204	595.12581	0
Slice 21	129	41.099411	0	740.27823	537.84362	0
Slice 22	131	40.928198	0	637.08363	462.86835	0
Slice 23	133.09375	40.81187	0	569.27298	413.60103	0
Slice 24	135.28125	40.755737	0	539.16189	391.72404	0
Slice 25	137.46875	40.767786	0	488.27524	354.75273	0
Slice 26	139.65625	40.84805	0	419.61765	304.87007	0
Slice 27	141.84375	40.996766	0	337.29617	245.06001	0
Slice 28	144.03125	41.214371	0	245.70656	178.51627	0
Slice 29	146.21875	41.501512	0	148.75016	108.07331	0
Slice 30	148.40625	41.859059	0	49.333088	35.842586	0