1497 West 40 South
Lindon, Utah - 84042
Phone (801) 225-5711

3662 West 2100 South
Salt Lake City, Utah - 84120
Phone (801) 787-9138

1596 W. 2650 S. #108
Ogden, Utah - 84401
Phone (801) 399-9516

January 29, 2016

Mr. Martin Nobs
50 River Bluff Road
Elgin, IL 60120

Re: Rock Retaining Wall Design
Lot 15 Ski Lake Estates No. 3
6640 East 1100 South
Huntsville, Utah
Job No. 145150G

Gentlemen:

As you requested, we have completed our rock retaining wall design and slope stability analysis for the residence located on Lot 15 in the Ski Lake Estates in Huntsville, Utah. Earthtec Engineering has completed a geotechnical report[1], and addendum[2] to the subject site.

Proposed Construction

A representative of Earthtec Engineering visited the site on January 9, 2016 to observe the proposed rock wall location and surrounding lot's existing geometry and soils conditions. We understand that a 2 to 7 foot rock wall will be constructed to retain a slope between the roadway and proposed driveway. The approximate retaining wall location is shown on Figure No. 1, *Aerial Photograph Showing Location of Retaining Wall and Slope Cross-Sections.*

Cross-Section A-A' starts in the building pad of the proposed residence and is relatively flat for approximately 35 feet to the base of the proposed rock retaining wall. The single tier wall at the maximum height will be 7 feet in exposed height. From the top of the rock wall there will be a slope up to the existing roadway.

Stability Analyses

Our engineering analyses focused on evaluating the stability of the proposed rock retaining wall. Based on our visual observations of the site from our hand excavated test hole and previous subsurface investigations, the natural soils at the site appear to consist of topsoil overlying lean clay (CL), silty sand (SM), and sandstone. The properties of the soils observed at the wall location were estimated our laboratory direct shear test for the clay and sand, and by referenced laboratory testing. Our direct shear[3] results for the silty sand soil has an internal friction angle of 34 degrees and cohesion of 240 pounds per square foot. Our direct shear[4] results for the clay soil has an internal friction angle of 21 degrees and cohesion of 345 pounds per square foot. The referenced laboratory testing by the Bureau of Reclamation[5] estimates silty sand has an internal friction angle between than 33 and 35 degrees and cohesion between 280 and 560 pounds per square foot and clay has an internal friction angle between than 26 and 30 degrees and cohesion between 240 and 320 pounds per square foot Accordingly, we estimated the following parameters for use in the stability analyses:

[1] "Geotechnical Study, Lot 15 Ski Lake Estates No. 3, 6640 East 1100 South, Huntsville, Utah", EE Project No. 145150G, June 23, 2014.
[2] "Addendum I to Geotechnical Study, Lot 15 Ski Lake Estates No. 3, 6640 East 1100 South, Huntsville, Utah", EE Project No. 145150G, July 13, 2015.
[3] See Figure No. 2
[4] See Figure No. 3
[5] US Bureau of Reclamation, 1987, "Design Standards No. 13, Embankment Dams, Denver Colorado"

Material	Internal Friction Angle (degrees)	Apparent Cohesion (psf)	Moist Unit Weight (pcf)	Saturated Unit Weight (pcf)
Silty SAND (SM)	34	240	100	134
Lean CLAY (CL)	20	200	113	130
Cobble or Gravel Fill	34	0	135	135
Retaining Wall	0 (or 45)	1000 (or 0)	145	145

For the seismic (pseudostatic) analysis, a peak horizontal ground acceleration of 0.3854g for the 2% probability of exceedance in 50 years was obtained for site (grid) locations of 41.247 degrees north latitude and -111.788 degrees west longitude. Typically, one-third to one-half this value is utilized in analysis. Accordingly, a value of 0.193 was used as the pseudostatic coefficient for the stability analysis.

Using these input parameters, the internal (rock-to-rock) stability of the wall was evaluated considering sliding, overturning, and bearing capacity to achieve respective minimum factors of safety of 1.5, 2.0 and 2.0 for static conditions and 1.1, 1.5 and 1.5 for seismic conditions. The backcut angle was assumed to be slightly flatter than 1H:2V (Horizontal:Vertical), because of the location of the rock wall and the existing slope. The results of this analysis (see Figure No. 4, *Rock Wall Stability Evaluation*) indicate that a single tier maximum exposed height of about of 7 feet can be achieved using boulder sizes ranging from 48 inches (bottom row) to 24 inches (top row).

We evaluated the global stability surrounding the proposed rock retain wall using the computer program XSTABL. This program uses a limit equilibrium (Bishop's modified) method for calculating factors of safety against sliding on an assumed failure surface and evaluates numerous potential failure surfaces, with the most critical failure surface identified as the one yielding the lowest factor of safety of those evaluated. A water table was conservatively placed at approximately at 10 feet below the ground surface, although groundwater was not encountered during any of field explorations.

To model the load imposed on the slope by the roadway, a 500 psf load was modeled at the approximate roadway location. Typically, the required minimum factors of safety are 1.5 for static conditions and 1.1 for seismic (pseudostatic) conditions. The results of our analyses indicate that the slope configuration described above meets both these requirements. The slope stability data are attached as Figure Nos. 5 and 6, *Stability Results*. Any modifications to the slope, including the construction of retaining walls, should be properly designed and engineered.

Conclusions and Recommendations

Based on the results of our analyses, the rock retaining walls at this site will be stable if constructed as follows (see Figure No. 7):

- The rock walls can be constructed using a single tier rock wall system with a maximum exposed height of 7 feet.

- The rock wall should be composed of boulders with a minimum nominal size (diameter) of 48 inches for the lowest row of rocks, grading in size to 24 inches for the top row of rocks.
- The bottom row of rock boulders can be embedded below the ground surface.
- The rock walls facing should slope at 1H:2V or flatter.
- We recommend that the backfill soil retained by the rock wall should consist of a cobble or gravel fill material meeting the following recommendations:

Sieve Size/Other	Percent Passing (by weight)
6 inches	100
No. 4	40 - 100
No. 40	20 – 50
No. 200	0 - 10
Liquid Limit	35 maximum
Plasticity Index	15 maximum

- Soils used as backfill should be placed in loose lifts not exceeding a thickness of 12 inches, not exceeding a thickness of 12 inches, and compacted to until minimal deflection.
- Boulders used in the rock wall should be durable (i.e. not sandstone, limestone and other rocks which have weakened planes that could cause rocks to split) and placed in a manner that will not significantly weaken their internal integrity. There should be maximum rock-to-rock contact when placing the rock boulders and no rocks should bear on a downward sloping face of any supporting rocks. Larger gaps may be filled with smaller rocks or sealed with a cement grout.
- Drainage behind the wall is recommended, as shown on Figure No. 7. The drain should consist of a perforated 4-inch minimum diameter pipe wrapped in fabric and placed at the bottom and behind the lowest row of boulders. The pipe should daylight at one or both ends of the wall and discharge to an appropriate drainage device or area. Clean gravel up to 2 inches in maximum size, with less than 10% passing the No. 4 sieve and less than 5% passing the No. 200 sieve, should be placed around the drain pipe. A Miradrain (or equivalent), should be placed between the gravel or cobble fill and the adjacent soils at 1H:2½V or flatter. This drainage system should be constructed to within one foot of the ground surface.
- The rock wall at this site has been designed to retain a slope with a roadway. Additional structures and loads should not be placed on the slope above the rock wall system without proper engineering of the rock walls. Future grading of the slope above the proposed rock wall system should not occur until the slope has been properly engineered.

Inspection Scheduling

Finally, we recommend that a representative of Earthtec Engineering visit the site during construction to observe implementation and compliance with our design and recommendation. We proposed the following inspections:

1. Site visit at the first row of rock for inspection of rock bedding recommendations, embedment, and drain construction.

2. Final to verify the compaction, type of fill, retaining wall batter, exposed heights, and back slope geometry.

Closure

Note that wall movements or even failure can occur if the retaining walls are undermined or the backfill soils become saturated. Therefore, we recommend that irrigation lines not be placed within the backfill or directly on top of the wall. Surface drainage at the bottom of the walls should also be directed away from the wall. A drainage system should be inspected periodically so that drains work as designed. The property owner should be made aware of the risks should these or other conditions occur that could saturate or erode/undermine the soil behind the wall.

The conclusions and recommendations presented in this letter are based on the information provided by the client, the soil conditions observed, and our experience with similar conditions. If conditions are different during construction than presented herein, please advise us so that any appropriate modifications can be made. Our observations, analyses, conclusions and recommendations were conducted within the limits prescribed by our client, with the usual thoroughness and competence of the engineering profession in the area at this time. No warranty or representation is intended in our proposals, contracts, or reports.

We appreciate the opportunity of providing our services on this project. If we can answer questions or be of further service, please call.

Respectfully;
EARTHTEC ENGINEERING

PROFESSIONAL ENGINEER
No. 5567049-2202
TIMOTHY ALLAN MITCHELL
1/29/16
STATE OF UTAH

Caleb R. Allred, E.I.T.
Project Engineer

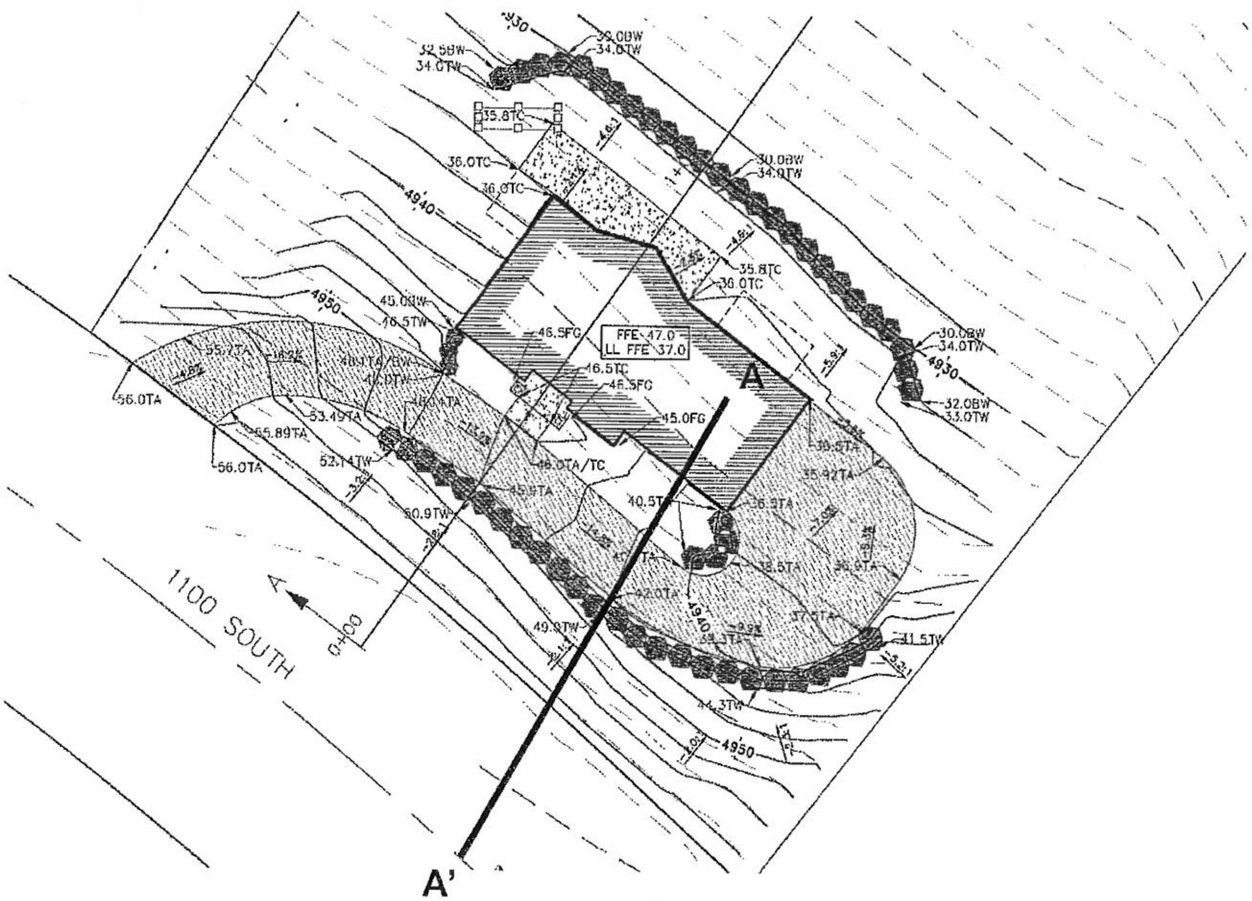
Timothy A. Mitchell, P.E.
Geotechnical Engineer

Attachments:

Figure No. 1,	*Site Plan Showing Location of Rock Wall and Slope Cross-Section*
Figure Nos. 2 - 3,	*Direct Shear Results*
Figure No. 4,	*Rock Wall Stability Evaluation*
Figure Nos. 5 - 6,	*Stability Results*
Figure No. 7,	*Rock Wall Design*
Appendix	Program Outputs

SITE PLAN SHOWING LOCATION OF ROCK WALL AND SLOPE CROSS-SECTION

LOT 15 SKI LAKE ESTATES NO. 3
6640 EAST 1100 SOUTH
HUNTSVILLE, UTAH

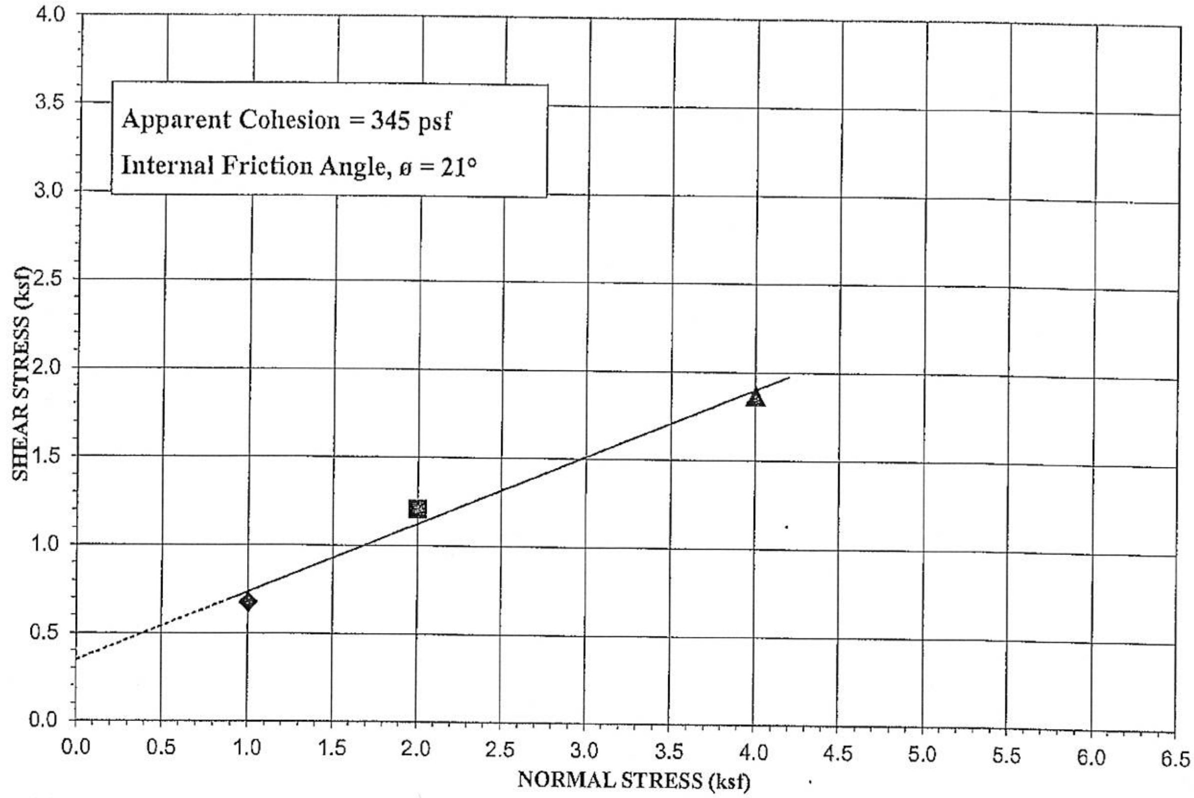


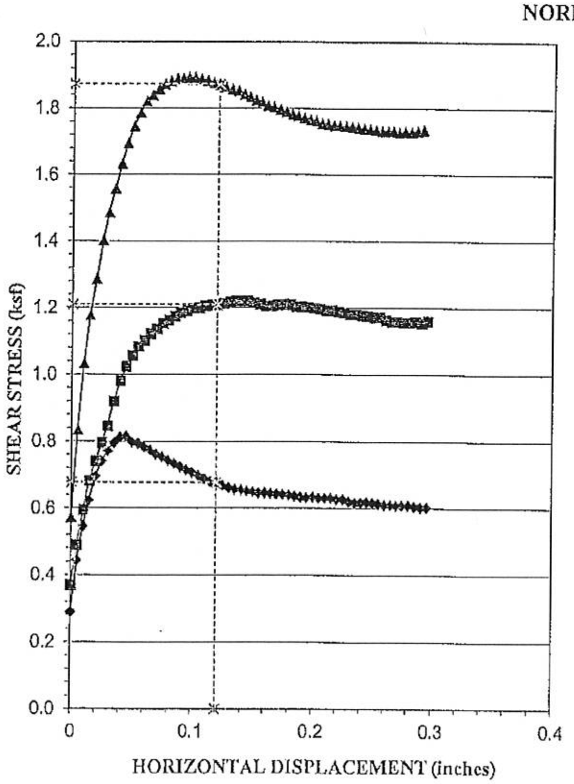
Site Plan Provided by Client

Approximate Slope Cross-Section Analyzed

PROJECT NO.: 145150G	Earthtec Engineering	FIGURE NO.: 1

DIRECT SHEAR TEST





Source: TP-1	Depth: 3½ ft		
Type of Test:	Consolidated Drained/Saturated		
Test No. (Symbol)	1 (◆)	2 (■)	3 (▲)
Sample Type	Undisturbed		
Initial Height, in.	1	1	1
Diameter, in.	2.4	2.4	2.4
Dry Density Before, pcf	88.2	84.7	86.7
Dry Density After, pcf	89.4	78.3	88.6
Moisture % Before	25.9	25.9	25.9
Moisture % After	34.3	44.2	32.5
Normal Load, ksf	1.0	2.0	4.0
Shear Stress, ksf	0.68	1.21	1.87
Strain Rate	.0000566 IN/SEC		

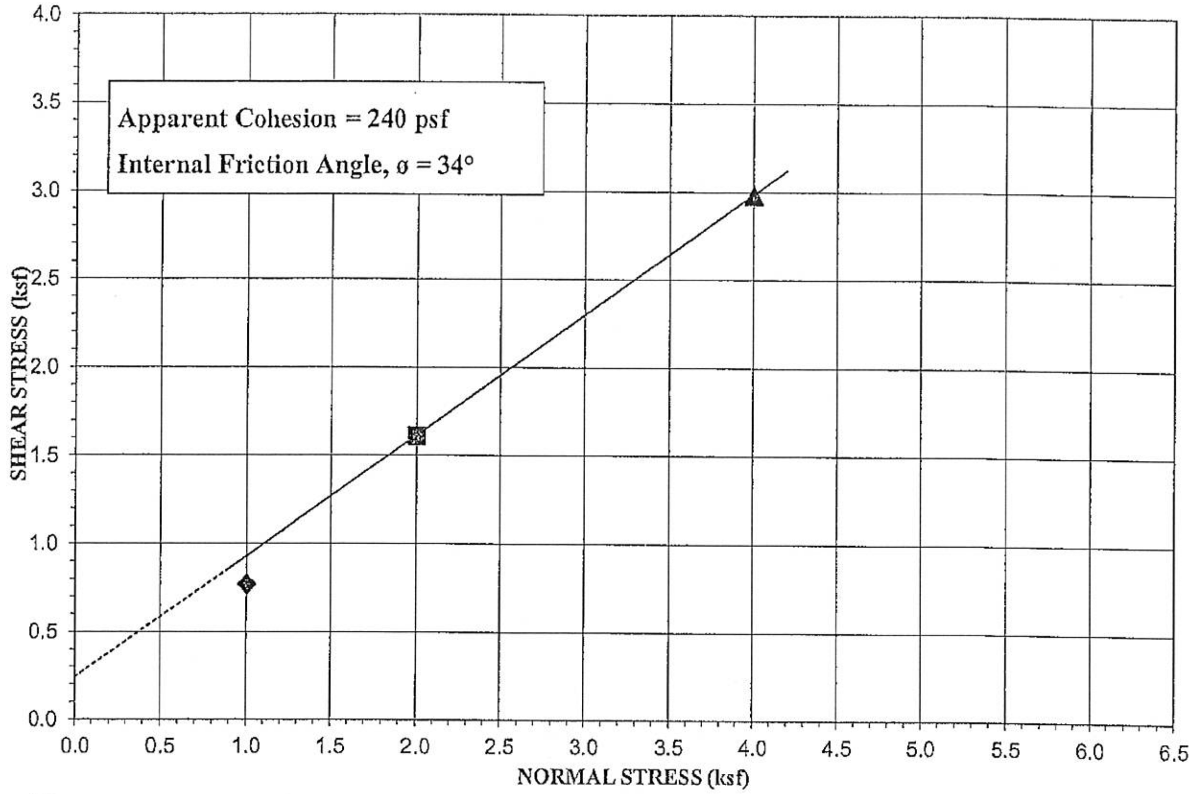
Sample Properties	
Cohesion, psf	345
Friction Angle, ϕ	21
Liquid Limit, %	79
Plasticity Index, %	49
Percent Gravel	0
Percent Sand	29
Percent Passing No. 200 sieve	71
Classification	Fat CLAY with sand (CH)

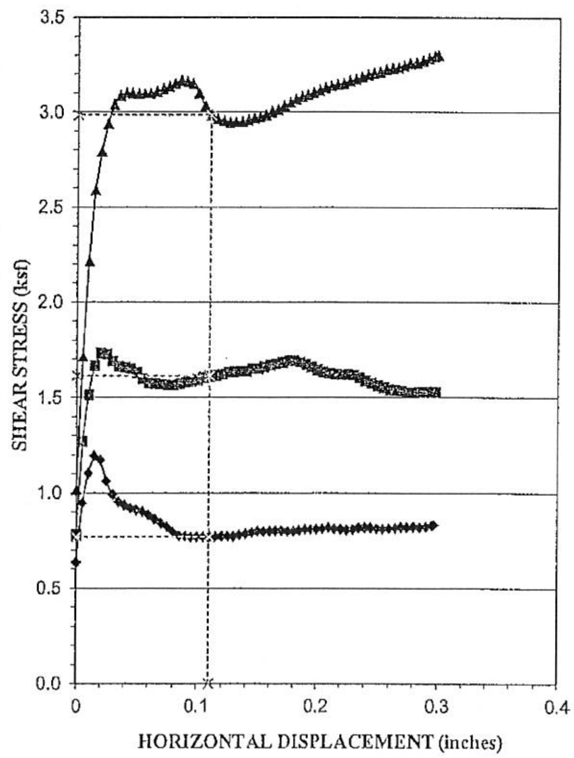
PROJECT: Lot 15, Ski Lake Estates No. 3

PROJECT NO.: 145150G

FIGURE NO.: 2

DIRECT SHEAR TEST





Source: TP-3	Depth: 11.0 ft		
Type of Test:	Consolidated Drained/Saturated		
Test No. (Symbol)	1 (◆)	2 (■)	3 (▲)
Sample Type	Remolded		
Initial Height, in.	1	1	1
Diameter, in.	2.4	2.4	2.4
Dry Density Before, pcf	95.5	95.5	95.3
Dry Density After, pcf	95.9	80.2	98.7
Moisture % Before	16.2	16.2	16.2
Moisture % After	42.7	70.7	36.2
Normal Load, ksf	1.0	2.0	4.0
Shear Stress, ksf	0.77	1.61	2.98
Strain Rate	.00005240 IN/SEC		

Sample Properties	
Cohesion, psf	240
Friction Angle, ϕ	34
Liquid Limit, %	33
Plasticity Index, %	NP
Percent Gravel	0
Percent Sand	70
Percent Passing No. 200 sieve	30
Classification	Silty SAND (SM)

PROJECT: Lot 15 Ski Lakes Estates No. 3

PROJECT NO.: 145150G

Earthtec Engineering

FIGURE NO.: 3

ROCK WALL STABILITY EVALUATION

Project:	Lot 15 , Ski Lake Estates No. 3	Date:	1/28/2016
Location:	Huntsville, Utah	By:	CRA
Backfill slope angle, b:	16 degrees	Foundation soil γ :	120 pcf
Backcut angle (from vertical):	21.8 degrees	Foundation soil Φ :	34 degrees
Batter angle (from vertical):	26.6 degrees	Found. soil cohesion:	0 psf
Soil/wall interface friction:	0 degrees	Retained soil γ :	120 pcf
Surcharge pressure:	150 psf (Usually 0 for ß>0)	Retained soil Φ :	32 degrees
FS against sliding (Stat/Seis):	1.5 1.1	Retain. soil cohesion:	0 psf
FS against overturning (St/Se):	2.0 1.5	Rock boulder γ :	145 psf
FS for bearing (Static/Seismic):	2.0 1.5	Rock boulder Φ :	45 degrees
Horizontal seismic coeff., k_h:	0.193 (typically 1/2 PGA)	Embedment depth:	0 feet
Vertical seismic coeff., k_v:	0 (typically 0)	Average rock wall γ :	145 pcf
Rock to Rock interface factor:	0.67 (typically 2/3)	Min. top rock size:	24 inches
Mononobe-Okabe theta, θ =	0.190656	Min.bottom rock size:	48 inches
Mononobe-Okabe K_{ae} =	0.416252	Coulomb K_a =	0.208 (no surcharge)
		Passivie Resist. K_p =	1.203 F.S. = 1.5 (typ.)

STATIC

Wall Ht, H (ft)	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
P_a (lbs/ft)	104	186	290	418	569	743	940	1161
Wall Wt, W (lbs/ft)	1305	1740	2175	2610	3045	3480	3915	4350
Wall $x_{centroid}$ (ft)	2.50	3.00	3.50	4.00	4.51	5.01	5.51	6.01
$P_{sliding}$ (lbs/ft)	124	212	323	457	614	795	999	1226
$P_{resisting}$ (lbs/ft)	756	925	1022	1030	931	707	340	-188
$FS_{base\ sliding}$	6.1	4.4	3.2	2.3	1.5	0.9	0.3	-0.2
$FS_{interface\ shear}$	7.1	5.5	4.5	3.8	3.3	2.9	2.6	2.4
$M_{overturn}$ (ft-lbs/ft)	134	300	565	953	1487	2189	3084	4195
$M_{resisting}$ (ft-lbs/ft)	3705	6047	8955	12438	16505	21165	26428	32304
$FS_{overturn}$	27.7	20.2	15.8	13.1	11.1	9.7	8.6	7.7
Eccentricity, e (ft)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bearing Pressure	316	416	515	611	704	796	885	971
Bearing Capacity	1871	2377	2883	3388	3894	4400	4906	5411
$FS_{bearing}$	5.9	5.7	5.6	5.5	5.5	5.5	5.5	5.6

SEISMIC

Wall Ht, H (ft)	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
P_{ae} (lbs/ft)	222	396	620	893	1217	1591	2014	2488
$P_{sliding}$ (lbs/ft)	448	677	944	1251	1597	1983	2408	2872
$P_{resisting}$ (lbs/ft)	2032	2613	3116	3524	3818	3980	3994	3840
$FS_{base\ sliding}$	4.5	3.9	3.3	2.8	2.4	2.0	1.7	1.3
$FS_{interface\ shear}$	4.0	3.0	2.4	2.0	1.7	1.5	1.3	1.2
$M_{overturn}$ (ft-lbs/ft)	642	1281	2219	3509	5203	7353	10012	13231
$M_{resisting}$ (ft-lbs/ft)	3568	5791	8536	11806	15607	19943	24819	30240
$FS_{overturn}$	5.6	4.5	3.8	3.4	3.0	2.7	2.5	2.3
Eccentricity (ft)	0.39	0.83	1.25	1.64	2.01	2.36	2.68	2.96
Bearing Pressure	486	895	1396	1972	2605	3277	3969	4665
$FS_{bearing}$	3.9	2.7	2.1	1.7	1.5	1.3	1.2	1.2

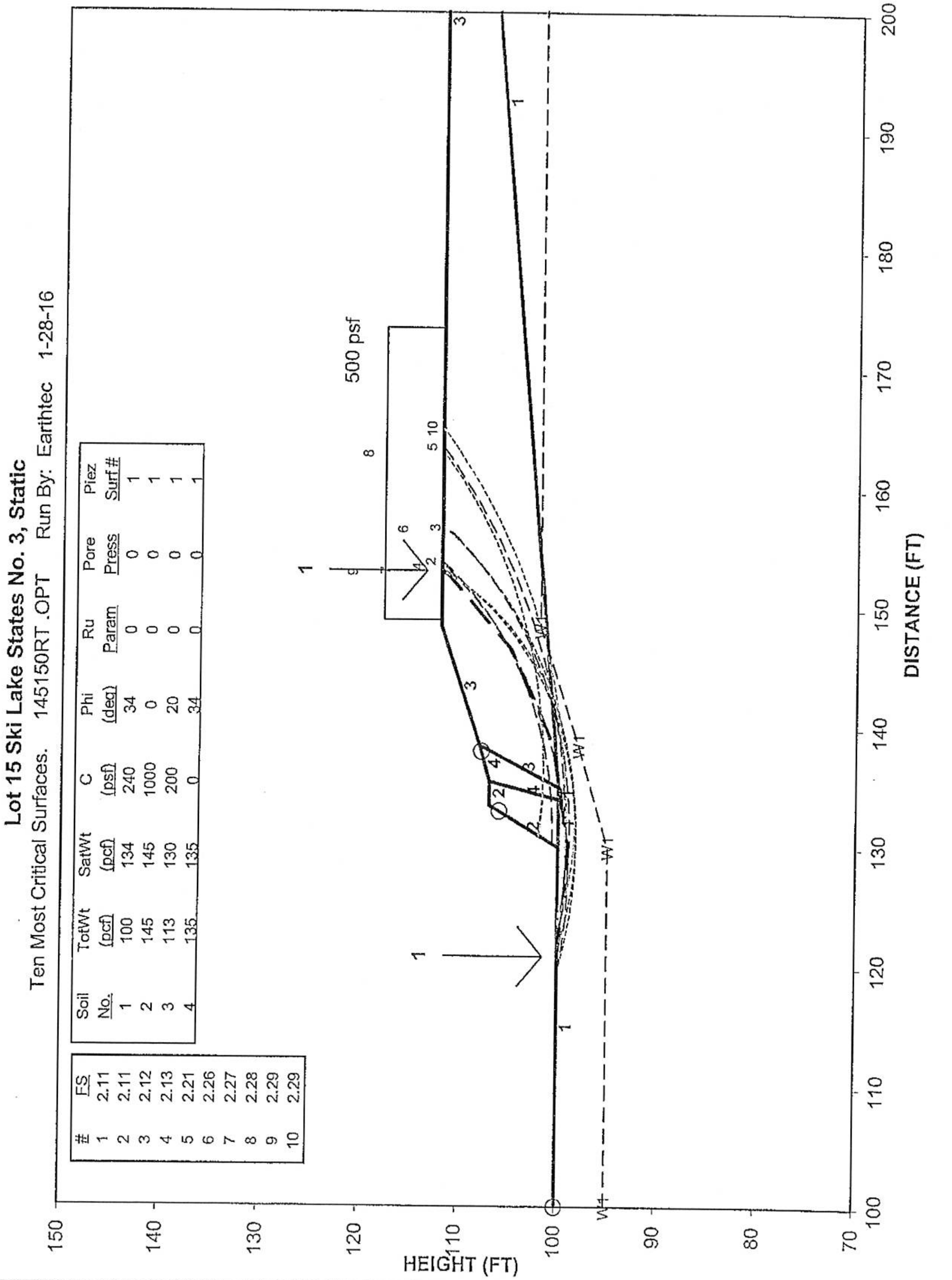
Max. Recommended Wall Height: 7 feet for 24-inch (top row) to 48-inch (bottom row) size boulders

Notes:

1. Equations from "Recommended Rockery Design & Construction Guidelines" Publication FHWA-CLF/TD-06-006, Nov. 2006.
2. Cohesion included in active pressure force by subtracting ($2 * c * \sqrt{K_a}$), but force is not allowed to be less than 0.
3. Other equations: W=[average rock diameter *H]* γ_{rock} ; $FS_{interface\ shear}$=(Rock to Rock interface factor)*[W*tan(Φ_{rock})/$P_{sliding}$]

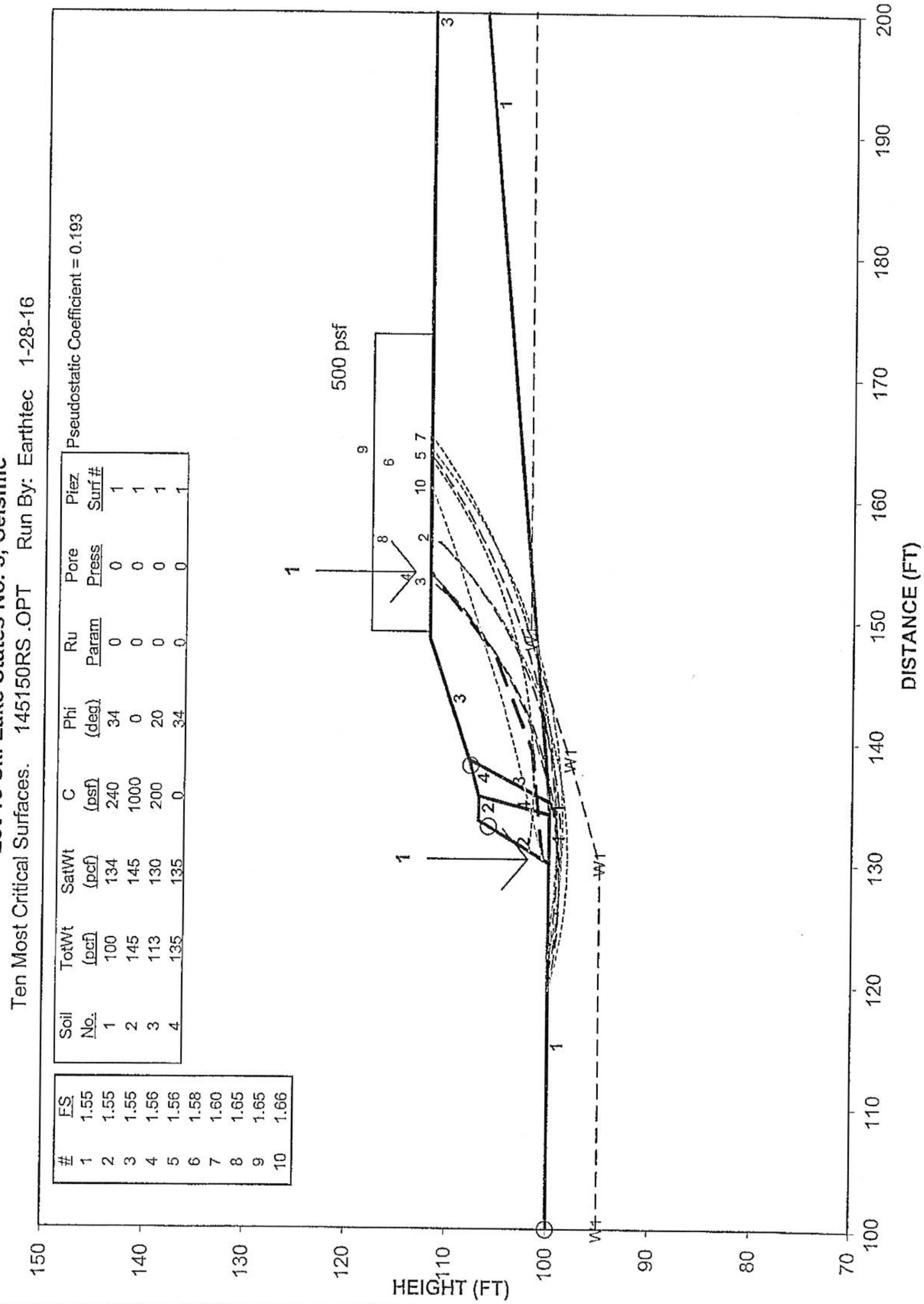
PROJECT NO.: 145150	Earthtec Engineering	FIGURE NO.: 4

STABILITY RESULTS



PROJECT NO.: 145150	Earthtec Engineering	FIGURE NO.: 5

STABILITY RESULTS



PROJECT NO.: 145150	Earthtec Engineering	FIGURE NO.: 6

ROCK WALL DETAIL

LOT 15 , SKI LAKE ESTATES NO. 3, HUNTSVILLE

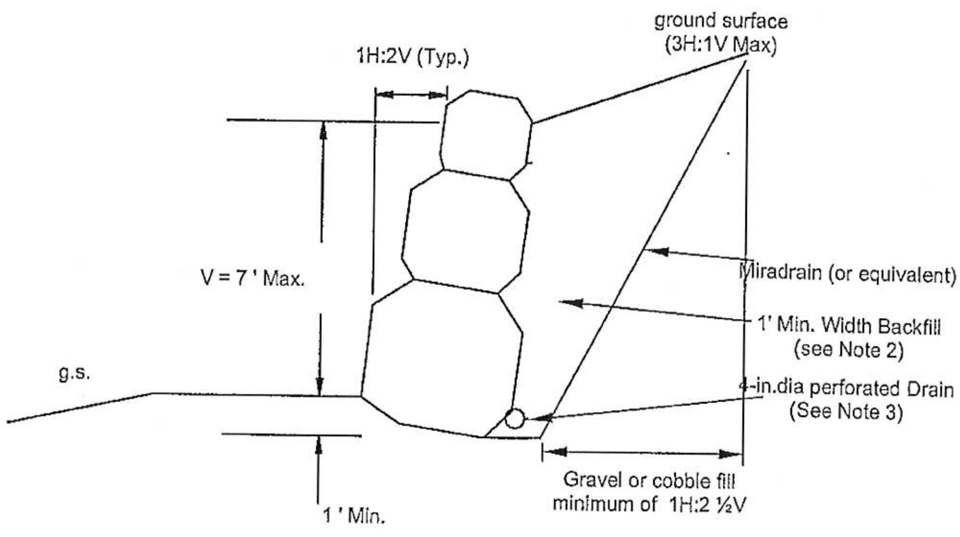
NOTES:

1. BACKFILL SOILS SHOULD CONSIST OF A COBBLE FILL AND BE PLACED IN LOOSE LIFTS NOT EXCEEDING A THICKNESS OF 12 INCHES, AND COMPACTED TO UNTIL MINIMAL DEFLECTION.

2. FREE-DRAINING BACKFILL SHALL CONSIST OF GRAVEL AND COBBLE HAVING LESS THAN 10% PASSING No. 200 SIEVE, AND OUTTER INTERFACE LINED WITH MIRADRAIN (OR EQUIV.)

3. PERFORATED DRAIN SHALL BE WRAPPED WITH FABRIC, SLOPED A MINIMUM 2% TO SIDE OF WALL, AND DISCHARGED TO APPROPRIATE DRAINAGE DEVICE.

4. BOULDER SIZES SHALL BE A MINIMUM 48 INCHES FOR THE BOTTOM ROW AND A MINIMUM 24 INCHES FOR THE UPPER ROW FOR EACH TIER.



NOT TO SCALE

PROJECT NO.: 145150	Earthtec Engineering	FIGURE NO.: 7