GSH

REPORT
GEOTECHNICAL STUDY
LOT 2R THE RESERVE AT
CRIMSON RIDGE SUBIDIVISON
1013 NORTH VALLEY VIEW DRIVE
WEBER COUNTY, UTAH

Submitted To:

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Re: Report
Geotechnical Study
Lot 2R The Reserve at Crimson Ridge Subdivision
1013 North Valley View Drive
Weber County, Utah
(41.2774° N; 111.8298° W)

1. INTRODUCTION

1.1 GENERAL

This report presents the results of our geotechnical study performed for Lot 2R of the Reserve at Crimson Ridge Subdivision located at 1013 North Valley View Drive in Weber County, Utah. The general location of the site with respect to major roadways, as of 2014, is presented on Figure 1, Vicinity Map. A more detailed layout of the site showing the proposed improvements is presented on Figure 2, Site Plan. The locations of the borings drilled and test pits excavated in conjunction with this study are also presented on Figure 2.

1.2 OBJECTIVES AND SCOPE

The objectives and scope of our study were planned in discussions among Mr. Joe Sadler of Habitations Residential Design Group, Dr. James Anderson, and Mr. Andrew Harris of GSH Geotechnical, Inc. (GSH).

In general, the objectives of this study were to:

1. Define and evaluate the subsurface soil and groundwater conditions across the site.

2. Provide appropriate foundation, earthwork, and slope stability recommendations as well as geoseismic information to be utilized in the design and construction of the proposed home.

In accomplishing these objectives, our scope has included the following:

1. A field program consisting of the excavating, logging, and sampling of 3 borings and 3 test pits.

2. A laboratory testing program.

3. An office program consisting of the correlation of available data, engineering analyses, and the preparation of this summary report.

1.3 AUTHORIZATION

Authorization was provided by returning a signed copy of our Professional Services Agreement No. 15-0504Nrev1 dated February 5, 2016.

1.4 PROFESSIONAL STATEMENTS

Supporting data upon which our recommendations are based are presented in subsequent sections of this report. Recommendations presented herein are governed by the physical properties of the soils encountered in the exploration test pits/borings, projected groundwater conditions, and the layout and design data discussed in Section 2, Proposed Construction, of this report. If subsurface conditions other than those described in this report are encountered and/or if design and layout changes are implemented, GSH must be informed so that our recommendations can be reviewed and amended, if necessary.

Our professional services have been performed, our findings developed, and our recommendations prepared in accordance with generally accepted engineering principles and practices in this area at this time.

2. PROPOSED CONSTRUCTION

The proposed project consists of constructing a single-family residence, pool house, and boat house on Lot 2R of the Reserve at Crimson Ridge Subdivision in Weber County, Utah. Construction will likely consist of reinforced concrete footings and basement/crawlspace foundation walls supporting 1 to 3 wood-framed levels above grade. Projected maximum column and wall loads are on the order of 10 to 25 kips and 1 to 3 kips per lineal foot, respectively.

Site development will require a moderate amount of earthwork in the form of site grading. We estimate in general that maximum cuts and fills to achieve design grades will be on the order of 2 to 8 feet. Larger cuts and fills may be required in isolated areas. To facilitate grading at the site, the upslope walls of the structures must be designed as retaining walls. Additionally, a series of rockery landscape walls are planned upslope of the proposed structure.

3. INVESTIGATIONS

3.1 FIELD PROGRAM

In order to define and evaluate the subsurface soil and groundwater conditions at the site, 3 borings were drilled to depths of about 21.5 to 51.5 feet below existing grade. The borings were drilled using a truck-mounted drill rig equipped with hollow-stem augers. Additionally, 3 test pits were excavated to depths of about 6.5 to 9.0 feet below existing grade. The test pits were excavated using a track-mounted excavator. Boring and test pit locations are presented on Figure 2.

The field portion of our study was under the direct control and continual supervision of an experienced member of our geotechnical staff. During the course of the excavating and drilling operations, a continuous log of the subsurface soil conditions encountered was maintained. In addition, samples of the typical soils encountered were obtained and placed in sealed bags and plastic containers for subsequent laboratory testing and examination. The soils were classified in the field based upon visual and textural examination. These classifications have been supplemented by subsequent inspection and testing in our laboratory. Detailed graphical representation of the subsurface conditions encountered is presented on Figures 3A through 3C, Boring Log, and on Figures 4A through 4C, Test Pit Log. Soils were classified in accordance with the nomenclature described on Figure 5, Key to Boring Log (USCS) and on Figure 6, Key to Test Pit Log (USCS).

A 3.0-inch outside diameter, 2.42-inch inside diameter drive sampler (Dames & Moore) and a 2.0-inch outside diameter, 1.38-inch inside diameter drive sampler (SPT) were utilized in the subsurface soil sampling at select locations within the boring. The blow counts recorded on the boring logs were those required to drive the sampler 12 inches with a 140-pound hammer dropping 30 inches.

A 2.42-inch inside diameter thin-wall drive sampler was utilized in the subsurface sampling of the test pits at the site.

Following completion of drilling and excavation operations, one and one-quarter-inch diameter slotted PVC pipe was installed in borings B-1, B-2, and B-3 in order to provide a means of monitoring the groundwater fluctuations. The borings were backfilled with auger cuttings. Following completion of excavating and logging, each test pit was backfilled. Although an effort was made to compact the backfill with the trackhoe, backfill was not placed in uniform lifts and compacted to a specific density. Consequently, the backfill soils must be considered as non-engineered and settlement of the backfill with time is likely to occur.

3.2 LABORATORY TESTING

3.2.1 General

In order to provide data necessary for our engineering analyses, a laboratory testing program was performed. The program included moisture, density, Atterberg limits, partial gradations, consolidation, and direct shear tests. The following paragraphs describe the tests and summarize the test data.

3.2.2 Moisture and Density

To provide index parameters and to correlate other test data, moisture and density tests were performed on selected samples. The results of these tests are presented on the boring logs, Figures 3A through 3C, and on the test pit logs, Figure 4A through 4C.

3.2.3 Atterberg Limit Tests

To aid in classifying the soils, Atterberg limit tests were performed on samples of the fine-grained cohesive soils. Results of the test are tabulated below:

Boring/ Test Pit No.	Depth (feet)	Liquid Limit (percent)	Plastic Limit (percent)	Plasticity Index (percent)	Soil Classification
B-1	5.0	35	18	17	SC
B-2	10.0	87	26	61	CH
B-3	37.5	36	14	22	CL
TP-1	5.0	52	16	36	CH
TP-2	0.5	45	30	15	ML
TP-2	1.0	36	18	18	CL
TP-2	3.0	43	18	25	CL
TP-3	3.0	28	18	10	SC

3.2.4 Partial Gradation Tests

To aid in classifying the granular soils, partial gradation tests were performed. Results of the tests are tabulated below:

Boring/ Test Pit No.	Depth (feet)	Percent Passing No. 200 Sieve	Soil Classification
B-1	5.0	21.4	SC
B-2	10.0	73.5	CH
B-3	45.0	18.8	SC
B-3	50.0	23.3	SC
TP-1	2.5	62.3	CL
TP-1	5.0	82.4	CH
TP-3	1.0	56.9	CL
TP-3	3.0	23.6	SC

3.2.5 Consolidation Tests

To provide data necessary for our settlement analyses, consolidation tests were performed on each of 2 representative samples of the fine grained soils encountered at the site. Based upon data obtained from the consolidation tests, the silty clay/clayey silt soils are moderately over-consolidated and will exhibit moderate strength and compressibility characteristics under the anticipated loadings. Additionally, the in-situ clays exhibit a moderate swell potential when wetted, resulting in a swell pressure measured at about 1,200 pounds per square foot. Detailed results of the test are maintained within our files and can be transmitted, at the client's request.

3.2.6 Laboratory Direct Shear Test

To determine the shear strength of the soils encountered at the site, a laboratory direct shear test was performed on a sample of the site soils. The results of the test are tabulated on the following page.

Boring No.	Depth (feet)	Soil Type	In-Situ Moisture Content (percent)	Dry Density (pcf)	Internal Friction Angle (degrees)	Apparent Cohesion (psf)
B-1	15.0	CL	32	91	28	250
B-2	22.5	CL	22	97	28	930
B-3	25.0	SC	81	31	36	155

4. SITE CONDITIONS

4.1 GEOLOGIC SETTING

A geologic hazards reconnaissance study[1] dated July 8, 2016 was prepared for the subject property by Western Geologic, LLC, and a copy of that report is included in the attached Appendix.

4.2 SURFACE

The subject property is a vacant, generally rectangular shaped lot located at 1013 North Valley View Drive in Weber County, Utah. The topography of the site slopes downward to the northeast at grades of about 10H:1V (Horizontal:Vertical) to about 2.5H:1V (Horizontal:Vertical) with an overall change in elevation of about 85 feet across the site. Vegetation at the site consists primarily of native weeds, grasses, brush, and numerous mature trees, particularly over the slope area. The site is bordered on the east by Valley View Drive, and on the west, north, and south by undeveloped property.

4.3 SUBSURFACE SOIL

Subsurface conditions encountered at the test pit and boring locations varied slightly across the site. Topsoil and disturbed soils were observed in the upper 1.5 to 3.0 feet at the boring and test pit locations. Non-engineered fill extending about 5.0 foot below existing site grades was encountered at boring B-2. Natural soils were observed beneath the non-engineered fill and topsoil/disturbed soils to the full depth penetrated, about 6.5 to 51.5 feet below surrounding grades and consisted of silty clay with varying fine to coarse sand content, fine to coarse sandy clay with varying amounts of gravel, clayey silt, clayey fine to coarse sand, weathered bedrock (weathered claystone/siltstone), and occasional mixture of these soils.

1 "Report, Geologic Hazards Evaluation, The Reserve at Crimson Ridge, Lot 2-R, 1013 North Valley View Drive, Liberty, Weber County, Utah," Western Geologic, LLC, July 8, 2016.

The natural granular soils encountered were very dense, saturated, light brown in color, and will generally exhibit moderately high strength and low compressibility characteristics under the anticipated vertical loading.

The natural silt/clay soils encountered were medium stiff to hard, dry to saturated, brown to gray in color, and will generally exhibit moderate strength and compressibility characteristics under the anticipated vertical loading.

For a more detailed description of the subsurface soils encountered, please refer to Figures 3A through 3C, Boring Log, and Figures 4A through 4C, Test Pit Log. The lines designating the interface between soil types on the test pit and boring logs generally represent approximate boundaries. In-situ, the transition between soil types may be gradual.

4.4 GROUNDWATER

Static groundwater measurements were taken on Friday July 8, 2016, (37 days following drilling of individual borings). The results of these measurements are tabulated below.

Boring No.	Static Groundwater Level Below Existing Grade (feet) July 8, 2016
B-1	12.5
B-2	14.9
B-3	17.5

Seasonal and longer-term groundwater fluctuations of 1.0 to 2.0 feet should be anticipated. The highest seasonal levels will generally occur during the late spring and summer months. Depending on the time of year construction occurs, the moderately shallow groundwater levels could affect construction of the building.

5. DISCUSSIONS AND RECOMMENDATIONS

5.1 SUMMARY OF FINDINGS

The results of our analyses indicate that the proposed structure may be supported upon conventional spread and/or continuous wall foundations established upon a minimum of 2 feet of granular structural fill extending to suitable natural soils.

The most significant geotechnical aspects of the site are:

1. The surficial non-engineered fills encountered at boring B-2 and resulting from the test pits/trench associated with the geotechnical/geological study;
2. The moderate strength characteristics of the natural silts and clays
3. The moderate swell potential of the natural silts and clays; and
4. Maintaining stability of the slope at the property.

All non-engineered fill materials must be removed in their entirety from beneath all structures and flatwork and replaced with properly placed and compacted structural fill.

Due to the moderate strength characteristics and moderate swell potential of the natural silt and clay soils at the site, a minimum of 2 feet of structural replacement fill is required beneath all footings floor slabs, and flatwork. Additionally, to control the potential for differential movement beneath the proposed pool, the pool must be established on a reinforced concrete mat slab constructed over a minimum of 2 feet of structural replacement fill.

A subdrain system must be installed upslope of the home, pool house, boat house and rockery landscape walls to reduce the potential for surface water infiltration, as discussed further within this report. A foundation subdrain must be constructed for all exterior foundations. Additionally, a subdrain system with lateral tie-ins must be constructed beneath/around the proposed pool.

Maintaining stability of the slopes at the site is critical to construction at the site. The upslope walls of all structures must be designed as retaining walls. Additionally, a series of rockery landscape walls are planned upslope of the structures. Though these rockery walls are planned a landscape walls less than 4 feet in height, consideration must be given to proper construction of the rockery walls.

The on-site soils are not appropriate to be used as structural site grading fill, however, they may be used as general grading fill in landscape areas.

A geotechnical engineer from GSH will need to verify that all mass movement deposit soils, fill material (if encountered) and topsoil/disturbed soils have been completely removed and suitable natural soils encountered prior to the placement of structural site grading fills, floor slabs, foundations, or rigid pavements.

In the following sections, detailed discussions pertaining to earthwork, foundations, lateral pressure and resistance, floor slabs, slope stability, and the geoseismic setting of the site are provided.

5.2 EARTHWORK

5.2.1 Site Preparation

Initial site preparation will consist of the removal of surface vegetation, topsoil, and other deleterious materials from beneath an area extending out at least 3 feet from the perimeter of the proposed building, pavements, and exterior flatwork areas.

Additional site preparation will consist of the removal of existing non-engineered fills (if encountered) from an area extending out at least 3 feet from the perimeter of residential structures and 1 foot beyond rigid pavements.

Non-engineered fills/disturbed soil may remain in asphalt pavement and sidewalk areas as long as they are free of deleterious materials and properly prepared. Below rigid pavements non-engineered fills/disturbed soils must be removed. Additionally, the surface of any existing engineered fills must be prepared prior to placing additional site grading fills.

Proper preparation shall consist of scarifying, moisture conditioning, and re-compacting the upper 12 inches to the requirements for structural fill. As an option to proper preparation and recompaction, the upper 12 inches of non-engineered fill (where encountered) may be removed and replaced with granular subbase over unfrozen proofrolled subgrade. Even with proper preparation, pavements established overlying non-engineered fills may encounter some long-term movements unless the non-engineered fills are completely removed.

It must be noted that from a handling and compaction standpoint, onsite soils containing high amounts of fines (silts and clays) are inherently more difficult to rework and are very sensitive to changes in moisture content requiring very close moisture control during placement and compaction. This will be very difficult, if not impossible, during wet and cold periods of the year. Additionally, the onsite soils are likely above optimum moisture content for compacting at present and would require some drying prior to recompacting.

Subsequent to stripping and prior to the placement of structural site grading fill, pavements, driveway, and parking slabs on grade, the prepared subgrade must be proofrolled by passing moderate-weight rubber tire-mounted construction equipment over the surface at least twice. If excessively soft or loose soils are encountered, they must be removed to a maximum depth of 2 feet and replaced with structural fill. Beneath footings, all loose and disturbed soils must be totally removed. Fill soils must be handled as described above.

Surface vegetation, debris, and other deleterious materials shall generally be removed from the site. Topsoil, although unsuitable for utilization as structural fill, may be stockpiled for subsequent landscaping purposes.

A representative of GSH must verify that suitable natural soils and/or proper preparation of existing fills have been encountered/met prior to placing site grading fills, footings, slabs, and pavements.

5.2.2 Excavations

For granular (cohesionless) soils, construction excavations above the water table, not exceeding 4 feet, shall be no steeper than one-half horizontal to one vertical (0.5H:1V). For excavations up to 10 feet, in granular soils and above the water table, the slopes shall be no steeper than one horizontal to one vertical (1H:1V). Excavations encountering saturated cohesionless soils will be very difficult and will require very flat sideslopes and/or shoring, bracing and dewatering. Excavations deeper than 10 feet are not anticipated at the site.

Temporary excavations up to 10 feet deep in fine-grained cohesive soils (if encountered), above or below the water table, may be constructed with sideslopes no steeper than one-half horizontal to one vertical (0.5H:1V).

To reduce disturbance of the natural soils during excavation, it is recommended that smooth edge buckets/blades be utilized.

All excavations must be inspected periodically by qualified personnel. If any signs of instability or excessive sloughing are noted, immediate remedial action must be initiated.

5.2.3 Structural Fill

Structural fill will be required as site grading fill, as backfill over foundations and utilities, and possibly as replacement fill beneath some footings. All structural fill must be free of sod, rubbish, construction debris, frozen soil, and other deleterious materials.

Structural site grading fill is defined as fill placed over fairly large open areas to raise the overall site grade. The maximum particle size within structural site grading fill should generally not exceed 4 inches; although, occasional particles up to 6 to 8 inches may be incorporated provided that they do not result in "honeycombing" or preclude the obtainment of the desired degree of compaction. In confined areas, the maximum particle size should generally be restricted to 2.5 inches.

Only granular soils are recommended in confined areas such as utility trenches, below footings, etc. Generally, we recommend that all imported granular structural fill consist of a well-graded mixture of sands and gravels with no more than 20 percent fines (material passing the No. 200 sieve) and less than 30 percent retained on the 3/4 inch sieve. The plasticity index of import fine-grained soil shall not exceed 18 percent.

To stabilize soft subgrade conditions or where structural fill is required to be placed closer than 1.0 foot above the water table at the time of construction, a mixture of coarse gravels and cobbles and/or 1.5- to 2.0-inch gravel (stabilizing fill) should be utilized. It may also help to utilize a stabilization fabric, such as Mirafi 600X or equivalent, placed on the native ground if 1.5- to 2.0-inch gravel is used as stabilizing fill.

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On-site soils are not recommended as structural fill but may be used as non-structural grading fill in landscape areas. Non-structural site grading fill is defined as all fill material not designated as structural fill and may consist of any cohesive or granular soils not containing excessive amounts of degradable material.

5.2.4 Fill Placement and Compaction

All structural fill shall be placed in lifts not exceeding 8 inches in loose thickness. Structural fills shall be compacted in accordance with the percent of the maximum dry density as determined by the ASTM[2] D-1557 (AASHTO[3] T-180) compaction criteria in accordance with the table below:

Location	Total Fill Thickness (feet)	Minimum Percentage of Maximum Dry Density
Beneath an area extending at least 5 feet beyond the perimeter of the structure	0 to 10	95
Site Grading Fills outside area defined above	0 to 5	90
Site Grading Fills outside area defined above	5 to 10	95
Trench Backfill	--	96
Pavement granular base/subbase	--	96

Structural fills greater than 10 feet thick are not anticipated at the site.

Subsequent to stripping and prior to the placement of structural site grading fill, the subgrade shall be prepared as discussed in Section 5.2.1, Site Preparation, of this report. In confined areas, subgrade preparation shall consist of the removal of all loose or disturbed soils.

If utilized for stabilizing fill, coarse gravel and cobble mixtures should be end-dumped, spread to a maximum loose lift thickness of 15 inches, and compacted by dropping a backhoe bucket onto the surface continuously at least twice. As an alternative, the fill may be compacted by passing moderately heavy construction equipment or large self-propelled compaction equipment at least twice. Subsequent fill material placed over the coarse gravels and cobbles shall be adequately compacted so that the "fines" are "worked into" the voids in the underlying coarser gravels and cobbles.

2 American Society for Testing and Materials
3 American Association of State Highway and Transportation Officials

5.2.5 Utility Trenches

All utility trench backfill material below structurally loaded facilities (flatwork, floor slabs, roads, etc.) shall be placed at the same density requirements established for structural fill. If the surface of the backfill becomes disturbed during the course of construction, the backfill shall be proofrolled and/or properly compacted prior to the construction of any exterior flatwork over a backfilled trench. Proofrolling may be performed by passing moderately loaded rubber tire-mounted construction equipment uniformly over the surface at least twice. If excessively loose or soft areas are encountered during proofrolling, they must be removed (to a maximum depth of 2 feet below design finish grade) and replaced with structural fill.

Most utility companies and City-County governments are now requiring that Type A-1-a/A-1-b (AASHTO Designation – basically granular soils with limited fines) soils be used as backfill over utilities. These organizations are also requiring that in public roadways the backfill over major utilities be compacted over the full depth of fill to at least 96 percent of the maximum dry density as determined by the AASHTO T-180 (ASTM D-1557) method of compaction. We recommend that as the major utilities continue onto the site that these compaction specifications are followed.

Natural or imported silt/clay soils are not recommended for use as trench backfill, particularly in structurally loaded areas.

5.3 SLOPE STABILITY

5.3.1 Parameters

The properties of the soils at this site were estimated using the results of our laboratory testing, published correlations, and our experience with similar soils. Accordingly, we estimated the following parameters for use in the stability analyses:

Material	Internal Friction Angle (degrees)	Apparent Cohesion (psf)	Saturated Unit Weight (pcf)
Natural Clay/Silt	26	200	115
Concrete	0	28,800	150
Boulders	0 (45)	8000 (0)	145

For the seismic analysis, a peak horizontal ground acceleration of 0.279 using IBC 2012 guidelines and adjusted for Site Class effects (for Site Class D soils) was obtained for site (grid) locations of 41.2774 degrees latitude (north) and 111.8298 degrees longitude (west). To model sustained accelerations at the site, one-half of this value is typically used. Accordingly, a value of 0.14 was used as the pseudostatic coefficient in the seismic analyses.

5.3.2 Stability Analyses

Using these input parameters, the internal (rock-to-rock) stability of the walls was evaluated considering sliding, overturning, and bearing capacity to achieve respective minimum factors of safety of 1.5, 2.0, and 3.0 for static conditions and 1.1, 1.5, and 1.5 for seismic conditions. The results of this analysis (see attached Figure 7) indicate that a maximum rock wall height of about 6 feet can be achieved in 1 tier using boulder sizes ranging from 24 inches (top row) to 36 inches (bottom row) retaining relatively level backfill.

We evaluated the global stability of the existing slope using the computer program *SLIDE*. This program uses a limit equilibrium (Simplified Bishop) 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. We analyzed the following configuration based on the cross-section provided in the referenced geologic study and proposed grading plan provided by Habitations Residential Design Group (see geological study in appendix for cross-section information and location):

- An approximately 6 foot high slopes graded at about 10H:1V (Horizontal:Vertical) followed by 2 building pads for the home and pool house followed by a series of 5 tiers of rockery walls about 4 feet tall per tier and separated by 6 feet measured from wall face to wall face. Above the rockery walls the slope continues to the edge of the property at a grade of about 2.5H:1V (Horizontal:Vertical). The overall change in elevation is about 145 feet across the site. To simulate the load imposed on the slope by the proposed home, a load of 1,500 psf was modeled over the proposed building areas. In addition, a phreatic surface was included in our analyses to account for encountered groundwater.

Typically, the required minimum factors of safety are 1.5 for static conditions and 1.0 for seismic (pseudostatic) conditions. The results of our analyses indicate that the proposed slope configurations and rockery walls analyzed will meet both these requirements provided our recommendations are followed (see Figures 8 and 9).

Slope movements or even failure can occur if the slope soils are undermined or become saturated. Groundwater was encountered during the course of our field investigation as shallow as 12.5 feet below existing site grades. Further saturation of the slope soils can adversely affect the stability of the slope. Measures must be implemented to reduce the potential for saturation of the soils at the site. Surface drainage at the bottom and top of the slope should be directed to prevent ponding at the toe or crest of the slope. Subdrains must be constructed behind the rockery walls as discussed below. Additionally, cut-off drains on the slope above the home, above the pool house, and above the rockery walls are recommended to reduce the potential for infiltration of surface water at the site, as discussed further in Section 5.8, Subdrains. Landscape irrigation on this and surrounding areas may also create additional seasonal groundwater fluctuations. The limitations of landscape irrigation at the site are discussed further in Section 5.9, Site Irrigation. The property owner and the owner's representatives should be made aware of the risks should these or other conditions occur that could saturate or erode/undermine the slope soils.

Changes to the grading at the site and any retaining walls must be properly engineered to maintain stability of the slopes. The upslope walls of structures at this site must be properly engineered to act as retaining walls and must be a minimum of 12 inches thick. The footing must be appropriately sized by the structural engineer to act as a cantilevered concrete retaining wall. GSH must review the final grading plans for the project prior to initiation of any construction.

5.3.3 Rockery Wall Recommendations

Based on the results of our analyses, the block retaining walls at this site will be stable if constructed as follows (also see Figure 10, attached):

- The five tier rockery walls may be constructed to a maximum exposed height of 4 feet per tier, with each tier separated by a minimum of 6 feet from wall face to wall face. The rockery wall tiers must be composed of boulders with a minimum nominal size (diameter) of 36 inches for the lowest row of boulders, grading in size to 24 inches for the top row of boulders, with the lowest row of boulders embedded a minimum of 1 foot below the ground surface.

- The rockery wall facing should slope at 1.0H:2.0V or flatter.

- Boulders used in the rock walls should be durable (i.e. not limestone, soft sandstone, conglomerate, or 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 walls must be provided, as shown on Figure 10. The drain shall 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 shall 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 percent passing the No. 4 sieve and less than 5 percent passing the No. 200 sieve, shall be placed around the drain pipe. A fabric, such as Mirafi 140N or equivalent, shall be placed between the clean gravel and the adjacent soils. A zone of clean gravel and fabric at least 12 inches wide shall also extend above the drain, upward and behind the boulders to about 2 feet below the top of the wall, as shown on Figures 16 and 17.

- Structural site grading fill must be placed per the recommendations discussed with this study.

It should be noted that rockery walls are constructed of natural materials and are therefore subject to natural weathering processes and environmental attacks that may compromise the stability of the rockery wall. Boulders used during construction are subject to natural weathering by seasonal changes, wind, frost action, chemical reaction, water, etc. Additionally, the stability of rockery walls can be affected by other onsite and offsite influences such as saturation of retained soils, saturation of supporting soils, root action of vegetation and trees adjacent to the wall, and animal activities including burrowing and nesting. Rockery walls and the associated slopes must be closely monitored for signs of excessive weathering, drainage characteristics, signs of movement in the boulder, obstruction of drain outlets, etc. Frequent maintenance, repair, and inspection must be performed on the wall at least weekly and more often if any signs of erosion or movement are noticed. If any signs of erosion or movement are noticed, GSH must be contacted immediately to provide recommendations.

5.4 SPREAD AND CONTINUOUS WALL FOUNDATIONS

5.4.1 Design Data

The proposed structure may be supported upon conventional spread and continuous wall foundations established upon a minimum of 2 feet of structural fill extending to suitable natural soils. For design, the following parameters are provided:

Minimum Recommended Depth of Embedment for Frost Protection	- 30 inches
Minimum Recommended Depth of Embedment for Non-frost Conditions	- 15 inches
Recommended Minimum Width for Continuous Wall Footings	- 16 inches
Minimum Recommended Width for Isolated Spread Footings	- 24 inches
Recommended Net Bearing Pressure for Real Load Conditions	- 1,500 pounds per square foot
Bearing Pressure Increase for Seismic Loading	- 50 percent

The term "net bearing pressure" refers to the pressure imposed by the portion of the structure located above lowest adjacent final grade. Therefore, the weight of the footing and backfill to lowest adjacent final grade need not be considered. Real loads are defined as the total of all dead plus frequently applied live loads. Total load includes all dead and live loads, including seismic and wind.

5.4.2 Installation

Footings shall not be installed upon mass movement soil deposits, soft or disturbed soils, non-engineered fill, construction debris, frozen soil, or within ponded water. If the granular structural fill upon which the footings are to be established becomes disturbed, it shall be recompacted to the requirements for structural fill or be removed and replaced with structural fill.

The width of structural fill, where placed below footings, shall extend laterally at least 6 inches beyond the edges of the footings in all directions for each foot of fill thickness beneath the footings. For example, if the width of the footing is 2 feet and the thickness of the structural fill beneath the footing is 2.0 feet, the width of the structural fill at the base of the footing excavation would be a total of 4.0 feet, centered below the footing.

5.4.3 Settlements

Maximum settlements of foundations designed and installed in accordance with recommendations presented herein and supporting maximum anticipated loads as discussed in Section 2, Proposed Construction, are anticipated to be 1 inch or less.

Approximately 40 percent of the quoted settlement should occur during construction.

5.5 LATERAL RESISTANCE

Lateral loads imposed upon foundations due to wind or seismic forces may be resisted by the development of passive earth pressures and friction between the base of the foundations and the supporting soils. In determining frictional resistance, a coefficient of 0.40 should be utilized for foundations placed over granular structural fill. Passive resistance provided by properly placed and compacted granular structural fill above the water table may be considered equivalent to a fluid with a density of 300 pounds per cubic foot. Below the water table, this granular soil should be considered equivalent to a fluid with a density of 150 pounds per cubic foot.

A combination of passive earth resistance and friction may be utilized provided that the friction component of the total is divided by 1.5.

5.6 LATERAL PRESSURES

The lateral pressure parameters, as presented within this section, are for backfills which will consist of drained granular soil placed and compacted in accordance with the recommendations presented herein. The lateral pressures imposed upon subgrade facilities will, therefore, be basically dependent upon the relative rigidity and movement of the backfilled structure. For active walls, such as retaining walls which can move outward (away from the backfill), granular backfill may be considered equivalent to a fluid with a density of 35 pounds per cubic foot in computing lateral pressures. For more rigid walls (moderately yielding), generally not exceeding 8 feet in height, granular backfill may be considered equivalent to a fluid with a density of 45 pounds per cubic foot. The above values assume that the surface of the soils slope behind the wall is no steeper than 4 horizontal to 1 vertical and that the granular fill within 3 feet of the wall will be compacted with hand-operated compacting equipment.

For seismic loading, a uniform pressure shall be added. The uniform pressures based on different wall heights are provided in the following table:

Wall Height (feet)	Seismic Loading Active Case (psf)	Seismic Loading Moderately Yielding (psf)
4	25	55
6	40	85
8	55	115

5.7 FLOOR SLABS

Floor slabs may be established upon a minimum of 2 feet of structural fill extending to suitable natural soils. Under no circumstances shall floor slabs be established over mass movement deposit soils, non-engineered fills, loose or disturbed soils, sod, rubbish, construction debris, other deleterious materials, frozen soils, or within ponded water. In order to provide a capillary break and facilitate curing of the concrete, it is recommended that floor slabs be directly underlain by 4 inches of "free-draining" fill, such as "pea" gravel or three-quarters- to one-inch minus clean gap-graded gravel.

Settlement of lightly loaded floor slabs (average uniform pressure of 100 to 150 pounds per square foot or less) is anticipated to be less than 1/4 inch.

The tops of all floor slabs in habitable areas must be established at least 4 feet above the highest anticipated normal water level or 1.5 feet above the maximum groundwater level controlled by land drains.

5.8 POOLS

A pool and pool house are planned upslope of the proposed home at the site. Measures must be taken to reduce the potential for differential movement across the pool. The pool must be established on a reinforced concrete mat slab constructed over a minimum of 2 feet of compacted structural replacement fill. The mat slab must be a minimum of 6 inches thick and reinforced to minimize movement to 0.25 inches or less. Above the mat slab and immediately below the pool, a drainage layer consisting of a minimum of 12 inches of free-draining gravel must be placed. Within this layer of free-draining gravel, the pool subdrain must be constructed with lateral tie-ins at a maximum of 20 feet on center connecting to the exterior foundation subdrain discussed below.

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5.9 SUBDRAINS

5.9.1 General

We recommend that the perimeter foundation subdrains and a cutoff drain above the home, upslope of the pool house, and above the rockery walls be installed as indicated below.

5.9.2 Foundation Subdrains

Foundation subdrains should consist of a 4-inch diameter perforated or slotted plastic or PVC pipe enclosed in clean gravel. The invert of a subdrain should be at least 2 feet below the top of the lowest adjacent floor slab. The gravel portion of the drain should extend 2 inches laterally and below the perforated pipe and at least 1 foot above the top of the lowest adjacent floor slab. The gravel zone must be installed immediately adjacent to the perimeter footings and the foundation walls. To reduce the possibility of plugging, the gravel must be wrapped with a geotextile, such as Mirafi 140N or equivalent. Above the subdrain, a minimum 4-inch-wide zone of "free-draining" sand/gravel should be placed adjacent to the foundation walls and extend to within 2 feet of final grade. The upper 2 feet of soils should consist of a compacted clayey cap to reduce surface water infiltration into the drain. As an alternative to the zone of permeable sand/gravel, a prefabricated "drainage board," such as Miradrain or equivalent, may be placed adjacent to the exterior below-grade walls. Prior to the installation of the footing subdrain, the below-grade walls should be dampproofed. The slope of the subdrain should be at least 0.3 percent. The gravel placed around the drain pipe should be clean 0.75-inch to 1.0-inch minus gap-graded gravel and/or "pea" gravel. The foundation subdrains can be discharged into the area subdrains, storm drains, or other suitable down-gradient location.

We recommend final site grading slope away from the structures at a minimum 2 percent for hard surfaces (pavement) and 5 percent for soil surfaces within the first 10 feet from the structures.

5.9.3 Cutoff Drain

To reduce potential infiltration of surface water and groundwater into the subsurface soils at the site, a cutoff drain should be installed upslope of the home, upslope of the pool house, and upslope of the rockery walls. Final location of the required cutoff drains must be reviewed by GSH prior to construction. The drain should consist of a perforated 4-inch minimum diameter pipe wrapped in fabric and placed near the bottom of a minimum 24 inch wide trench excavated to a depth of at least 15 feet below existing grade and lined in filter fabric. The pipe should daylight at one or both ends of the drain and discharge to an appropriate drainage device or area. Clean gravel up to 2 inches in maximum size, with less than 10 percent passing the No. 4 sieve and less than 5 percent passing the No. 200 sieve, should be placed around the drain pipe. A fabric, such as Mirafi 140N or equivalent, should be placed between the clean gravel and the adjacent soils. A zone of clean gravel wrapped in fabric at least 24 inches wide should also extend above the drain, to within 2 feet of the ground surface, with fabric placed over the top of the gravel. The upper 2 feet of soils should consist of a compacted clayey cap to reduce surface water infiltration into the drain.

5.10 SITE IRRIGATION

Proper site drainage is important to maintaining slope stability at the site. Saturation of soils at the site may result in slope movement or failure. Therefore, we recommend that no irrigation lines should be placed on the slope. Landscaping at the site should be planned to utilize drought resistant plants that require minimal watering. Plants or lawn may be placed on the slope, with plants watered using direct drip systems targeted only for each plant, and any lawn areas watered using sprinklers placed in a manner such that watering is a minimum of 30 feet back from the crest of the slope. Overwatering should be strictly avoided. The surface of the site should be graded to prevent the accumulation or ponding of surface water at the site. The property owner and the owner's representatives should be made aware of the risks should these or other conditions occur that could saturate or erode/undermine the slope soils.

To reduce the potential for saturation of the site soils, overwatering at the site should be strictly avoided. Watering at the site should be limited to a maximum equivalent rainfall of 0.5 inches per week. Irrigation at the site should be strictly avoided during periods of natural precipitation.

5.11 GEOSEISMIC SETTING

5.11.1 General

Utah municipalities have adopted the International Building Code (IBC) 2012. The IBC 2012 code determines the seismic hazard for a site based upon 2008 mapping of bedrock accelerations prepared by the United States Geologic Survey (USGS) and the soil site class. The USGS values are presented on maps incorporated into the IBC code and are also available based on latitude and longitude coordinates (grid points).

The structure must be designed in accordance with the procedure presented in Section 1613, Earthquake Loads, of the IBC 2012 edition.

5.11.2 Faulting

Based upon our review of available literature, no active faults are known to pass through the site. The nearest active fault is the Wasatch Fault Zone Weber Section, approximately 6.0 miles west of the site.

5.11.3 Soil Class

For dynamic structural analysis, the Site Class D – Stiff Soil Profile as defined in Chapter 20 of ASCE 7 (per Section 1613.3.2, Site Class Definitions, of IBC 2012) can be utilized.

5.11.4 Ground Motions

The IBC 2012 code is based on 2008 USGS mapping, which provides values of short and long period accelerations for the Site Class B boundary for the Maximum Considered Earthquake (MCE). This Site Class B boundary represents average bedrock values for the Western United States and must be corrected for local soil conditions. The following table summarizes the peak ground and short and long period accelerations for the MCE event and incorporates the appropriate soil amplification factor for a Site Class D soil profile. Based on the site latitude and longitude (41.2774 degrees north and -111.8298 degrees west, respectively), the values for this site are tabulated below:

Spectral Acceleration Value, T	Site Class B Boundary [mapped values] (% g)	Site Coefficient	Site Class D [adjusted for site class effects] (% g)	Design Values (% g)
Peak Ground Acceleration	37.1	F_a = 1.129	41.9	27.9
0.2 Seconds (Short Period Acceleration)	S_S = 92.7	F_a = 1.129	S_{MS} = 104.7	S_{DS} = 69.8
1.0 Second (Long Period Acceleration)	S_1 = 31.7	F_v = 1.766	S_{M1} = 56	S_{D1} = 37.3

5.11.5 Liquefaction

The site is located in an area that has been identified by the Utah Geologic Survey as having "very low" liquefaction potential. Liquefaction is defined as the condition when saturated, loose, finer-grained sand-type soils lose their support capabilities because of excessive pore water pressure which develops during a seismic event. Clay soils, even if saturated, will generally not liquefy.

Liquefaction of the site soils is not anticipated during the design seismic event due to the cohesive (clayey) nature of the site soils.

5.12 SITE OBSERVATIONS

As stated previously, prior to placement of foundations, floor slabs, pavements, and site grading fills, a geotechnical engineer from GSH must verify that all non-engineered fill materials, topsoil, and disturbed soils have been removed and/or properly prepared and suitable subgrade conditions encountered. Additionally, GSH must observe fill placement and verify in-place moisture content and density of fill materials placed at the site.

5.13 CLOSURE

If you have any questions or would like to discuss these items further, please feel free to contact us at (801) 393-2012.

Respectfully submitted,

GSH Geotechnical, Inc.

Andrew M. Harris, P.E.
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AMH/MSH:mmh

Encl.	Figure	1,	Vicinity Map
	Figure	2,	Site Plan
	Figures	3A	Boring Log
	Figures	4A	through 4C, Test Pit Logs
	Figure	5,	Key to Boring Log (USCS)
	Figure	6,	Key to Test Pit Log (USCS)
	Figure	7	Rockery Wall Stability Evaluation
	Figures	8	and 9, Stability Results
	Figure	10	Rockery Wall Detail
	Appendix,		Geologic Hazards Reconnaissance Study

Addressee (email)

DR. JAMES ANDERSON
JOB NO. 2070-01N-16

FIGURE 1
VICINITY MAP

GSH

REFERENCE:
DELORME STREET ATLAS

DR. JAMES ANDERSON
JOB NO. 2070-01N-16

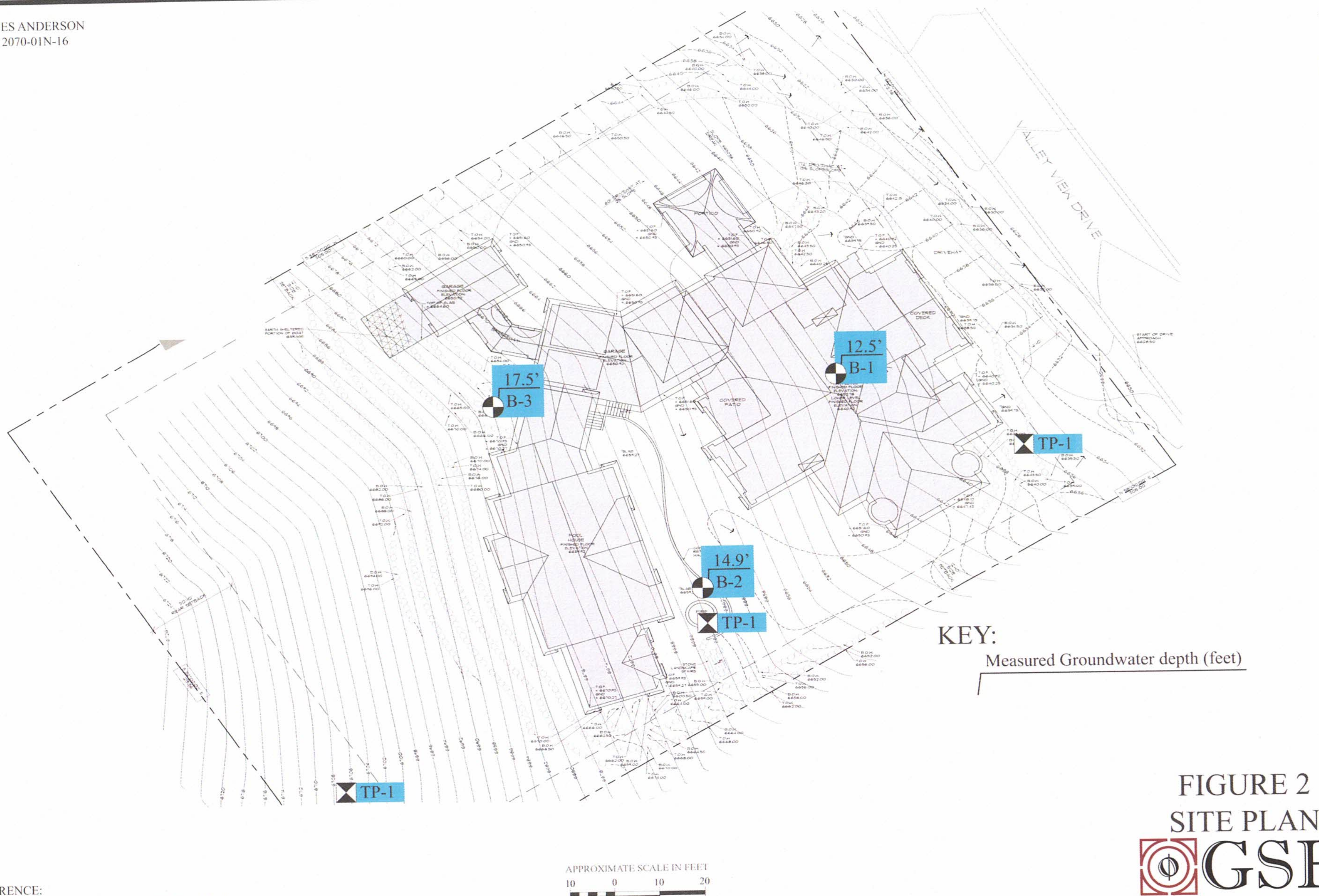


FIGURE 2
SITE PLAN
GSH

REFERENCE:
ADAPTED FROM DRAWING ENTITLED SITE PLAN

BORING LOG

Page: 1 of 1

BORING: B-1

CLIENT: Dr. James Anderson | PROJECT NUMBER: 2070-01N-16

PROJECT: Lot 2 Crimson Ridge Subdivision | DATE STARTED: 6/1/16 | DATE FINISHED: 6/1/16

LOCATION: Lot 2 Crimson Ridge Subdivision | GSH FIELD REP.: JM

DRILLING METHOD/EQUIPMENT: 3-3/4" ID Hollow-Stem Auger | HAMMER: Automatic | WEIGHT: 140 lbs | DROP: 30"

GROUNDWATER DEPTH: Not Encountered (6/2/16), 12.5' (7/8/16) | ELEVATION: ---

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
		Ground Surface	0								
	CL	SILTY CLAY with trace fine to coarse sand; trace fine and coarse gravel; major roots (topsoil) to 3'; brown to dark brown									moist stiff
				14	X	25	84				
	SC	CLAYEY FINE TO COARSE SAND brown	5	11	X	15		21	35	17	
				11	X						
	CL	SILTY CLAY with trace fine to coarse sand; gray	10	15	X	28	91				
		grades with coarse gravel		24	X						very stiff
	CL	SILTY CLAY/WEATHERED CLAYSTONE with trace fine to coarse sand; trace fine and coarse gravel; gray	15	80	X						moist hard
				71	X						
			20	86	X	26	91				
		End of Exploration at 21.5' No groundwater encountered at time of drilling									
			25								

See Subsurface Conditions section in the report for additional information.

FIGURE 3A

GSH

BORING LOG

BORING: B-2

CLIENT: Dr. James Anderson	PROJECT NUMBER: 2070-01N-16
PROJECT: Lot 2 Crimson Ridge Subdivision	DATE STARTED: 6/2/16 DATE FINISHED: 6/2/16
LOCATION: Lot 2 Crimson Ridge Subdivision	GSH FIELD REP.: JM
DRILLING METHOD/EQUIPMENT: 3-3/4" ID Hollow-Stem Auger	HAMMER: Automatic WEIGHT: 140 lbs DROP: 30"
GROUNDWATER DEPTH: 22.0' (6/2/16), 14.9' (7/8/16)	ELEVATION: ---

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
		Ground Surface	0								
	CL FILL	SILTY CLAY, FILL with trace fine to coarse sand; trace fine and coarse gravel; trace organics; gray									moist very stiff
	CH	SILTY CLAY with trace fine to coarse sand; trace fine and coarse gravel; gray	5	19		35	70				
				28		31	84				
			10	22		41		74	87	61	
	CL	SILTY CLAY/CLAYSTONE/SILTSTONE with trace fine to coarse sand; gray		50+							moist hard
			15	50+							
				50+							
			20	86							
▼											saturated
				50+		22	97				
			25								

See Subsurface Conditions section in the report for additional information.

GSH

BORING LOG

BORING: B-2

CLIENT: Dr. James Anderson

PROJECT NUMBER: 2070-01N-16

PROJECT: Lot 2 Crimson Ridge Subdivision

DATE STARTED: 6/2/16

DATE FINISHED: 6/2/16

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
			25	50+	X						hard
				50+	X	24	100				
			30	50+	X	22	83				
		End of Exploration at 31.5' Installed 1.25" diameter slotted PVC pipe to 30.0'									
			35								
			40								
			45								
			50								

See Subsurface Conditions section in the report for additional information.

FIGURE 3B
(continued)

GSH

BORING LOG

BORING: B-3

CLIENT: Dr. James Anderson | PROJECT NUMBER: 2070-01N-16

PROJECT: Lot 2 Crimson Ridge Subdivision | DATE STARTED: 6/2/16 | DATE FINISHED: 6/2/16

LOCATION: Lot 2 Crimson Ridge Subdivision | GSH FIELD REP.: JM

DRILLING METHOD/EQUIPMENT: 3-3/4" ID Hollow-Stem Auger | HAMMER: Automatic | WEIGHT: 140 lbs | DROP: 30"

GROUNDWATER DEPTH: 32.0' (6/2/16), 17.5' (7/8/16) | ELEVATION: ---

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
		Ground Surface	0								
	CL	SILTY CLAY with trace fine to coarse sand; trace organics; brown to black									moist very stiff
				19							
			5	43							
	CL	SILTY CLAY/CLAYSTONE/SILTSTONE with trace fine to coarse sand; whitish-gray		62		19	94				moist hard
			10	50+							
				50+		23	100				
	CL	FINE TO COARSE SANDY CLAY with trace fine and coarse gravel; light brown to brown	15	50+							moist hard
				50+							
			20	86							
				52							
		grades gray	25								

See Subsurface Conditions section in the report for additional information.

FIGURE 3C

GSH

BORING LOG

BORING: B-3

CLIENT: Dr. James Anderson | PROJECT NUMBER: 2070-01N-16

PROJECT: Lot 2 Crimson Ridge Subdivision | DATE STARTED: 6/2/16 | DATE FINISHED: 6/2/16

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
		grades gray	25	30	X	31	81				very stiff
		grades light brown		50+	X						hard
			30	50+	X						
▼				50/4"	X						saturated
			35	50/3"	X						
				50/4"	X				36	22	
			40	50/6"	X						
				50/5"	X						
	SC	CLAYEY FINE TO COARSE SAND light brown	45	50/5"	X	11		19			saturated very dense
				50/6"	X						
			50	50/5"	X	13		23			
		End of Exploration at 51.5'									

See Subsurface Conditions section in the report for additional information.

FIGURE 3C
(continued)

BORING LOG

BORING: B-3

CLIENT: Dr. James Anderson

PROJECT NUMBER: 2070-01N-16

PROJECT: Lot 2 Crimson Ridge Subdivision

DATE STARTED: 6/2/16 DATE FINISHED: 6/2/16

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
			52								
		Installed 1.25" diameter slotted PVC pipe to 30.0'									
			55								
			60								
			65								
			70								
			75								

See Subsurface Conditions section in the report for additional information.

FIGURE 3C
(continued)

TEST PIT LOG

GSH

Page: 1 of 1

TEST PIT: TP-1

CLIENT: Dr. James Anderson | PROJECT NUMBER: 2070-01N-16

PROJECT: Lot 2 Crimson Ridge Subdivision | DATE STARTED: 6/2/16 | DATE FINISHED: 6/2/16

LOCATION: Lot 2 Crimson Ridge Subdivision | GSH FIELD REP.: AA

EXCAVATING METHOD/EQUIPMENT: CAT 430D - Backhoe

GROUNDWATER DEPTH: Not Encountered (6/2/16) | ELEVATION: ---

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
		Ground Surface	0							
	CH	SILTY CLAY with trace fine sand; major roots (topsoil) to 3'; dark brown								dry medium stiff
				▮	22	99				
		trace roots		▮	16		62			moist stiff
		grades reddish-brown		▮						
			5	▮	21		82	52	36	
		roots grade out; gray								saturated
		End of Exploration at 6.5' No significant sidewall caving No groundwater encountered at time of excavation								
			10							
			15							
			20							
			25							

See Subsurface Conditions section in the report for additional information.

FIGURE 4A

TEST PIT LOG

GSH

TEST PIT: TP-2

CLIENT: Dr. James Anderson — PROJECT NUMBER: 2070-01N-16

PROJECT: Lot 2 Crimson Ridge Subdivision — DATE STARTED: 6/2/16 — DATE FINISHED: 6/2/16

LOCATION: Lot 2 Crimson Ridge Subdivision — GSH FIELD REP.: AA

EXCAVATING METHOD/EQUIPMENT: CAT 430D - Backhoe

GROUNDWATER DEPTH: Not Encountered (6/2/16) — ELEVATION: ---

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
		Ground Surface	0							
	ML	CLAYEY SILT with trace fine sand; trace organics; black		▮				45	15	moist stiff
	CL	SILTY CLAY with trace fine sand; dark brown		▮	21	84		36	18	
		grades brown		▮				43	25	
			5							
				▮	30	85				hard
		End of Exploration at 6.5' No significant sidewall caving No groundwater encountered at time of excavation								
			10							
			15							
			20							
			25							

See Subsurface Conditions section in the report for additional information.

FIGURE 4B

TEST PIT LOG

GSH

Page: 1 of 1

TEST PIT: TP-3

CLIENT: Dr. James Anderson | PROJECT NUMBER: 2070-01N-16

PROJECT: Lot 2 Crimson Ridge Subdivision | DATE STARTED: 6/2/16 | DATE FINISHED: 6/2/16

LOCATION: Lot 2 Crimson Ridge Subdivision | GSH FIELD REP.: AA

EXCAVATING METHOD/EQUIPMENT: CAT 430D - Backhoe

GROUNDWATER DEPTH: Not Encountered (6/2/16) | ELEVATION: ---

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
		Ground Surface	0							
	CL	SILTY CLAY with trace fine to coarse sand; trace fine and coarse gravel; dark brown								moist stiff
				■	26		57			
		grades with interbedded clayey sand layers								
				■	24		16	28	10	
				■						
			5							medium stiff
	CL	FINE TO COARSE SANDY CLAY with trace fine and coarse gravel; brown		■						moist very stiff
		End of Exploration at 9.0' No significant sidewall caving No groundwater encountered at time of excavation	10							
			15							
			20							
			25							

See Subsurface Conditions section in the report for additional information.

FIGURE 4C

CLIENT: Dr. James Anderson PROJECT: Lot 2 Crimson Ridge Subdivision PROJECT NUMBER: 2070-01N-16	**KEY TO BORING LOG**

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫

COLUMN DESCRIPTIONS

① **Water Level:** Depth to measured groundwater table. See symbol below.

② **USCS:** (Unified Soil Classification System) Description of soils encountered; typical symbols are explained below.

③ **Description:** Description of material encountered; may include color, moisture, grain size, density/consistency,

④ **Depth (ft.):** Depth in feet below the ground surface.

⑤ **Blow Count:** Number of blows to advance sampler 12" beyond first 6", using a 140-lb hammer with 30" drop.

⑥ **Sample Symbol:** Type of soil sample collected at depth interval shown; sampler symbols are explained below.

⑦ **Moisture (%):** Water content of soil sample measured in laboratory; expressed as percentage of dryweight of

⑧ **Dry Density (pcf):** The density of a soil measured in laboratory; expressed in pounds per cubic foot.

⑨ **% Passing 200:** Fines content of soils sample passing a No. 200 sieve; expressed as a percentage.

⑩ **Liquid Limit (%):** Water content at which a soil changes from plastic to liquid behavior.

⑪ **Plasticity Index (%):** Range of water content at which a soil exhibits plastic properties.

⑫ **Remarks:** Comments and observations regarding drilling or sampling made by driller or field personnel. May include other field and laboratory test results using the following abbreviations:

CEMENTATION:	MODIFIERS:	MOISTURE CONTENT (FIELD TEST):
Weakly: Crumbles or breaks with handling or slight finger pressure.	**Trace** <5%	**Dry:** Absence of moisture, dusty, dry to the touch.
Moderately: Crumbles or breaks with considerable finger pressure.	**Some** 5-12%	**Moist:** Damp but no visible water.
Strongly: Will not crumble or break with finger pressure.	**With** > 12%	**Saturated:** Visible water, usually soil below water table.

Descriptions and stratum lines are interpretive; field descriptions may have been modified to reflect lab test results. Descriptions on the logs apply only at the specific boring locations and at the time the borings were advanced; they are not warranted to be representative of subsurface conditions at other locations or times.

UNIFIED SOIL CLASSIFICATION SYSTEM (USCS)

MAJOR DIVISIONS			USCS SYMBOLS	TYPICAL DESCRIPTIONS
COARSE-GRAINED SOILS More than 50% of material is larger than No. 200 sieve size.	**GRAVELS** More than 50% of coarse fraction retained on No. 4 sieve.	**CLEAN GRAVELS** (little or no fines)	GW	Well-Graded Gravels, Gravel-Sand Mixtures, Little or No Fines
			GP	Poorly-Graded Gravels, Gravel-Sand Mixtures, Little or No Fines
		GRAVELS WITH FINES (appreciable amount of fines)	GM	Silty Gravels, Gravel-Sand-Silt Mixtures
			GC	Clayey Gravels, Gravel-Sand-Clay Mixtures
	SANDS More than 50% of coarse fraction passing through No. 4 sieve.	**CLEAN SANDS** (little or no fines)	SW	Well-Graded Sands, Gravelly Sands, Little or No Fines
			SP	Poorly-Graded Sands, Gravelly Sands, Little or No Fines
		SANDS WITH FINES (appreciable amount of fines)	SM	Silty Sands, Sand-Silt Mixtures
			SC	Clayey Sands, Sand-Clay Mixtures
FINE-GRAINED SOILS More than 50% of material is smaller than No. 200 sieve size.	**SILTS AND CLAYS** Liquid Limit less than 50%		ML	Inorganic Silts and Very Fine Sands, Rock Flour, Silty or Clayey Fine Sands or Clayey Silts with Slight Plasticity
			CL	Inorganic Clays of Low to Medium Plasticity, Gravelly Clays, Sandy Clays, Silty Clays, Lean Clays
			OL	Organic Silts and Organic Silty Clays o f Low Plasticity
	SILTS AND CLAYS Liquid Limit greater than 50%		MH	Inorganic Silts, Micacious or Diatomacious Fine Sand or Silty Soils
			CH	Inorganic Clays of High Plasticity, Fat Clays
			OH	Organic Silts and Organic Clays of Medium to High Plasticity
HIGHLY ORGANIC SOILS			PT	Peat, Humus, Swamp Soils with High Organic Contents

Note: Dual Symbols are used to indicate borderline soil classifications.

STRATIFICATION:

DESCRIPTION	THICKNESS
Seam	up to 1/8"
Layer	1/8" to 12"

Occasional: One or less per 6" of thickness

Numerous; More than one per 6" of thickness

TYPICAL SAMPLER GRAPHIC SYMBOLS

- Bulk/Bag Sample
- Standard Penetration Split Spoon Sampler
- Rock Core
- No Recovery
- 3.25" OD, 2.42" ID D&M Sampler
- 3.0" OD, 2.42" ID D&M Sampler
- California Sampler
- Thin Wall

WATER SYMBOL

Water Level

FIGURE 5

GSH

CLIENT: Dr. James Anderson
PROJECT: Lot 2 Crimson Ridge Subdivision
PROJECT NUMBER: 2070-01N-16

KEY TO TEST PIT LOG

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪

COLUMN DESCRIPTIONS

① **Water Level:** Depth to measured groundwater table. See symbol below.

② **USCS:** (Unified Soil Classification System) Description of soils encountered; typical symbols are explained below.

③ **Description:** Description of material encountered; may include color, moisture, grain size, density/consistency,

④ **Depth (ft.):** Depth in feet below the ground surface.

⑤ **Sample Symbol:** Type of soil sample collected at depth interval shown; sampler symbols are explained below.

⑥ **Moisture (%):** Water content of soil sample measured in laboratory; expressed as percentage of dryweight of

⑦ **Dry Density (pcf):** The density of a soil measured in laboratory; expressed in pounds per cubic foot.

⑧ **% Passing 200:** Fines content of soils sample passing a No. 200 sieve; expressed as a percentage.

⑨ **Liquid Limit (%):** Water content at which a soil changes from plastic to liquid behavior.

⑩ **Plasticity Index (%):** Range of water content at which a soil exhibits plastic properties.

⑪ **Remarks:** Comments and observations regarding drilling or sampling made by driller or field personnel. May include other field and laboratory test results using the following abbreviations:

CEMENTATION:

Weakly: Crumbles or breaks with handling or slight finger pressure.
Moderately: Crumbles or breaks with considerable finger pressure.
Strongly: Will not crumble or break with finger pressure.

MODIFIERS:

Trace	<5%
Some	5-12%
With	> 12%

MOISTURE CONTENT (FIELD TEST):

Dry: Absence of moisture, dusty, dry to the touch.
Moist: Damp but no visible water.
Saturated: Visible water, usually soil below water table.

Descriptions and stratum lines are interpretive; field descriptions may have been modified to reflect lab test results. Descriptions on the logs apply only at the specific boring locations and at the time the borings were advanced; they are not warranted to be representative of subsurface conditions at other locations or times.

UNIFIED SOIL CLASSIFICATION SYSTEM (USCS)

MAJOR DIVISIONS			USCS SYMBOLS	TYPICAL DESCRIPTIONS
COARSE-GRAINED SOILS More than 50% of material is larger than No. 200 sieve size.	**GRAVELS** More than 50% of coarse fraction retained on No. 4 sieve.	**CLEAN GRAVELS** (little or no fines)	GW	Well-Graded Gravels, Gravel-Sand Mixtures, Little or No Fines
			GP	Poorly-Graded Gravels, Gravel-Sand Mixtures, Little or No Fines
		GRAVELS WITH FINES (appreciable amount of fines)	GM	Silty Gravels, Gravel-Sand-Silt Mixtures
			GC	Clayey Gravels, Gravel-Sand-Clay Mixtures
	SANDS More than 50% of coarse fraction passing through No. 4 sieve.	**CLEAN SANDS** (little or no fines)	SW	Well-Graded Sands, Gravelly Sands, Little or No Fines
			SP	Poorly-Graded Sands, Gravelly Sands, Little or No Fines
		SANDS WITH FINES (appreciable amount of fines)	SM	Silty Sands, Sand-Silt Mixtures
			SC	Clayey Sands, Sand-Clay Mixtures
FINE-GRAINED SOILS More than 50% of material is smaller than No. 200 sieve size.	**SILTS AND CLAYS** Liquid Limit less than 50%		ML	Inorganic Silts and Very Fine Sands, Rock Flour, Silty or Clayey Fine Sands or Clayey Silts with Slight Plasticity
			CL	Inorganic Clays of Low to Medium Plasticity, Gravelly Clays, Sandy Clays, Silty Clays, Lean Clays
			OL	Organic Silts and Organic Silty Clays o f Low Plasticity
	SILTS AND CLAYS Liquid Limit greater than 50%		MH	Inorganic Silts, Micacious or Diatomacious Fine Sand or Silty Soils
			CH	Inorganic Clays of High Plasticity, Fat Clays
			OH	Organic Silts and Organic Clays of Medium to High Plasticity
HIGHLY ORGANIC SOILS			PT	Peat, Humus, Swamp Soils with High Organic Contents

Note: Dual Symbols are used to indicate borderline soil classifications.

STRATIFICATION:

DESCRIPTION	THICKNESS
Seam	up to 1/8"
Layer	1/8" to 12"

Occasional: One or less per 6" of thickness

Numerous; More than one per 6" of thickness

TYPICAL SAMPLER GRAPHIC SYMBOLS

- Bulk/Bag Sample
- Standard Penetration Split Spoon Sampler
- Rock Core
- No Recovery
- 3.25" OD, 2.42" ID D&M Sampler
- 3.0" OD, 2.42" ID D&M Sampler
- California Sampler
- Thin Wall

WATER SYMBOL

- Water Level

FIGURE 6

GSH

ROCK WALL STABILITY EVALUATION

Project:	Lot 2R The Reserve at Crimson Ridge		Date:	8/16/2016	
Location:	Weber County, Utah		By:	AMH	
Backfill slope angle, β:	18	degrees (β)	Foundation soil γ :	115	pcf
Batter angle (from vertical):	26.6	degrees (α)	Foundation soil ϕ :	26	degrees
Soil/wall interface friction:	0	degrees (δ)	Found. soil cohesion:	200	psf
Surcharge pressure:	0	psf	Retained soil γ :	115	pcf
	static	**seismic**	Retained soil ϕ :	26	degrees
FS against sliding (Stat/Seis):	1.5	1.1	Retain. soil cohesion:	200	psf
FS against overturning (St/Se):	2.0	1.5	Rock boulder γ :	145	psf
FS for bearing (Static/Seismic):	2.5	1.5	Rock boulder ϕ :	45	degrees
Horizontal seismic coeff., k_h:	0.14	(typically ½ of PGA)	Embedment depth:	1	feet
Vertical seismic coeff., k_v:	0	(typically 0)	Average rock wall γ :	145	pcf
Rock to Rock interface factor:	1	(typically 2/3)	Min. top rock size:	24	inches
Bearing Capacity	11079	psf (Meyerhoff)	Min.bottom rock size:	36	inches

STATIC

Wall Ht, H (ft)	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0
Back of wall, ψ (°)	0.0	9.5	14.0	16.7	18.4	19.7	20.6	21.3
Wall Wt, W (lbs/ft)	725	1088	1450	1813	2175	2538	2900	3263
Wall $x_{centroid}$ (ft)	1.73	1.97	2.20	2.43	2.67	2.76	2.87	2.99
Wall $y_{centroid}$ (ft)	0.933	1.400	1.867	2.333	2.800	3.300	3.787	4.259
Coulomb K_a	0.5143	0.4326	0.3966	0.3761	0.3629	0.3537	0.3469	0.3416
F_a (lbs/ft)	1	1	1	1	27	154	313	502
$F_{sliding}$ (lbs/ft)	1	1	1	1	26	145	293	468
$F_{resisting}$ (lbs/ft)	354	530	707	884	1057	1212	1361	1502
$FS_{base\ sliding}$	**> 100**	**> 100**	**> 100**	**> 100**	**41.4**	**8.3**	**4.6**	**3.2**
$FS_{interface\ shear}$	**> 100**	**> 100**	**> 100**	**> 100**	**85.3**	**17.5**	**9.9**	**7.0**
$M_{overturn}$ (ft-lbs/ft)	0	1	1	2	51	339	781	1405
$M_{resisting}$ (ft-lbs/ft)	1257	2138	3189	4409	5769	6814	7890	9008
$FS_{overturn}$	**> 100**	**> 100**	**> 100**	**> 100**	**> 100**	**20.1**	**10.1**	**6.4**
Eccentricity, e (ft)	-0.23	-0.47	-0.70	-0.93	-1.14	-1.10	-1.05	-0.97
Bearing Pressure	354	700	1159	1730	2368	2660	2879	3015
$FS_{bearing}$	**31.3**	**15.8**	**9.6**	**6.4**	**4.7**	**4.2**	**3.8**	**3.7**

SEISMIC

Mononobe-Okabe K_{ae} =	0.8936	0.7911	0.7497	0.7273	0.7132	0.7036	0.6965	0.6911
F_{ae} (lbs/ft)	0	0	0	193	463	808	1228	1723
$F_{sliding}$ (lbs/ft)	102	152	203	438	744	1116	1556	2062
$F_{resisting}$ (lbs/ft)	354	530	707	857	989	1105	1204	1287
$FS_{base\ sliding}$	**3.5**	**3.5**	**3.5**	**2.0**	**1.3**	**1.0**	**0.8**	**0.6**
$FS_{interface\ shear}$	**7.1**	**7.1**	**7.1**	**4.1**	**2.9**	**2.3**	**1.9**	**1.6**
$M_{overturn}$ (ft-lbs/ft)	94	213	378	1144	2393	4097	6431	9491
$M_{resisting}$ (ft-lbs/ft)	1257	2139	3190	4195	5190	5825	6348	6753
$FS_{overturn}$	**13.3**	**10.1**	**8.4**	**3.7**	**2.2**	**1.4**	**1.0**	**0.7**
Eccentricity (ft)	-0.10	-0.27	-0.44	-0.24	0.12	0.74	1.53	2.54
Bearing Pressure	192	166	59	309	840	1869	3347	5343
$FS_{bearing}$	**57.7**	**66.8**	**189.1**	**35.8**	**13.2**	**5.9**	**3.3**	**2.1**

Max. Recommended Wall Height: 6 feet for 24-inch (top row) to 36-inch (bottom row) size boulders

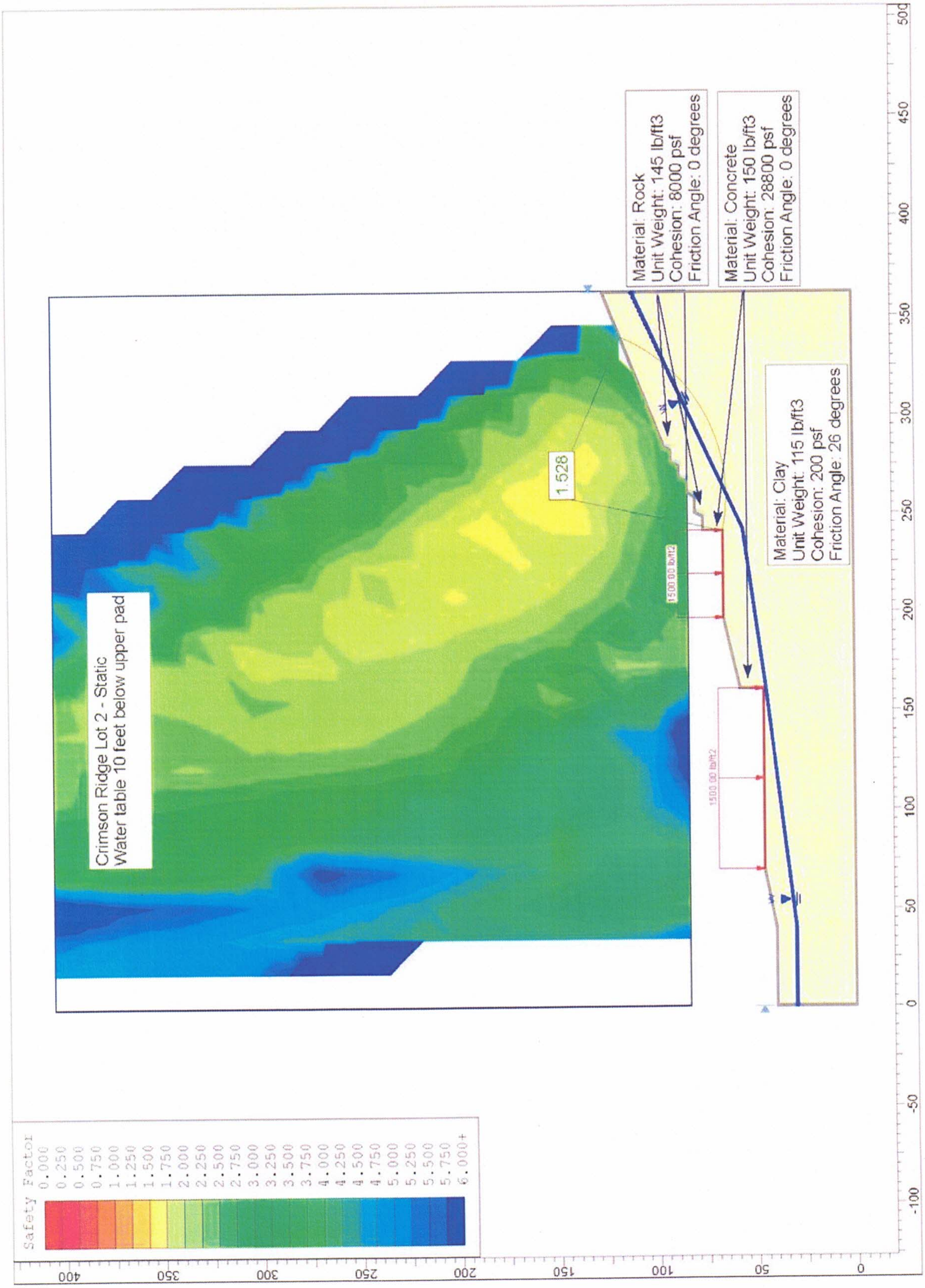
Notes:

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: $W=[\pi*(\text{average rock radius})^2 *H]* \gamma_{rock}$; $FS_{interface\ shear}=(\text{Rock to Rock interface factor})*[W*\tan(\phi_{rock})/P_{sliding}]$

PROJECT NO.: 2070-01N-16	GSH	**FIGURE NO.:** 7

STABILITY RESULTS

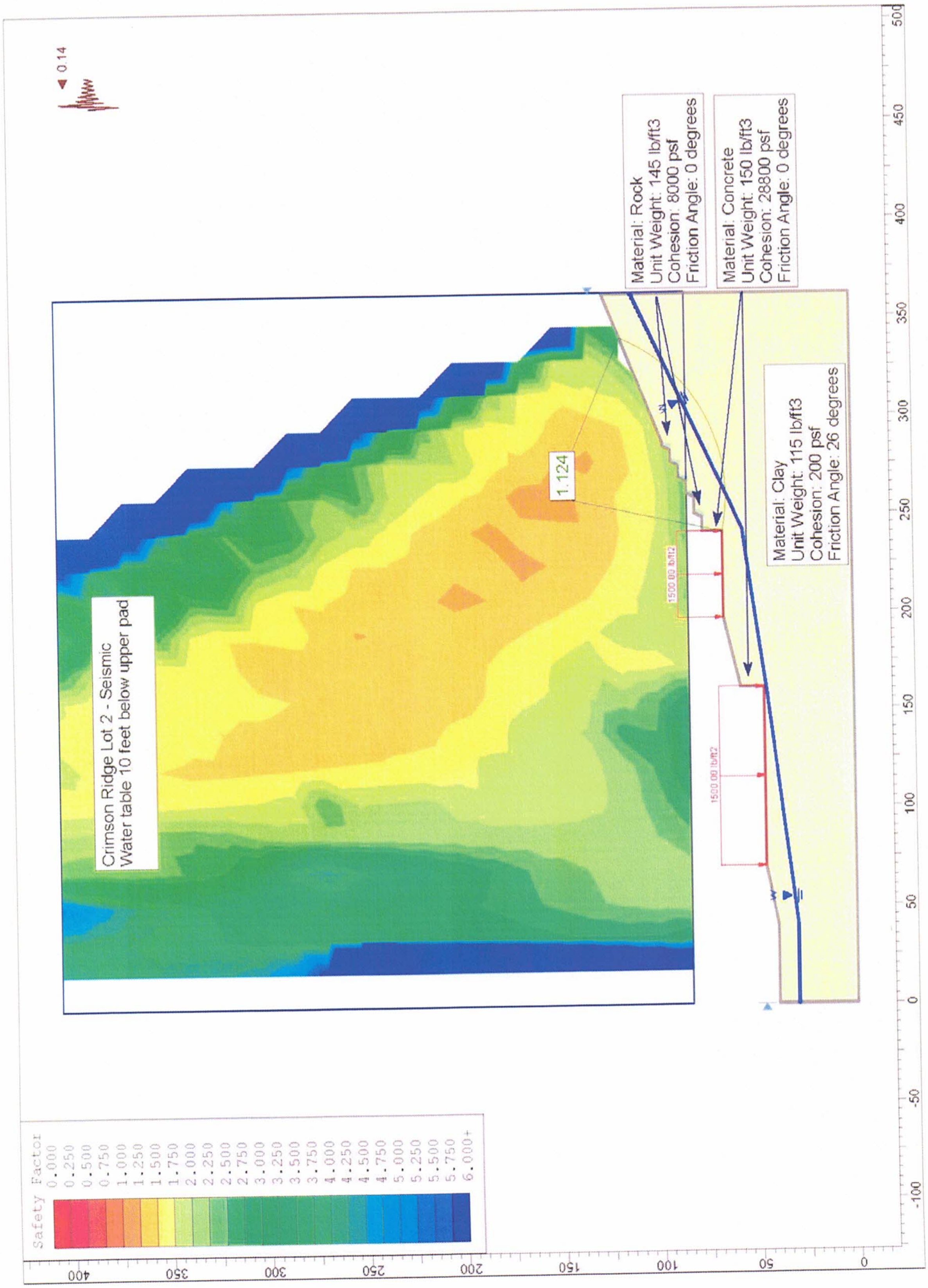
LOT 2 CRIMSON RIDGE SUBDIVISION



PROJECT NO.: 2070-01N-16	GSH	**FIGURE NO.:** 8

STABILITY RESULTS

LOT 2 CRIMSON RIDGE SUBDIVISION



PROJECT NO.: 2070-01N-16	GSH	FIGURE NO.: 9

ROCK WALL DETAIL

LOT 2R THE RESERVE AT CRIMSON RIDGE, WEBER COUNTY

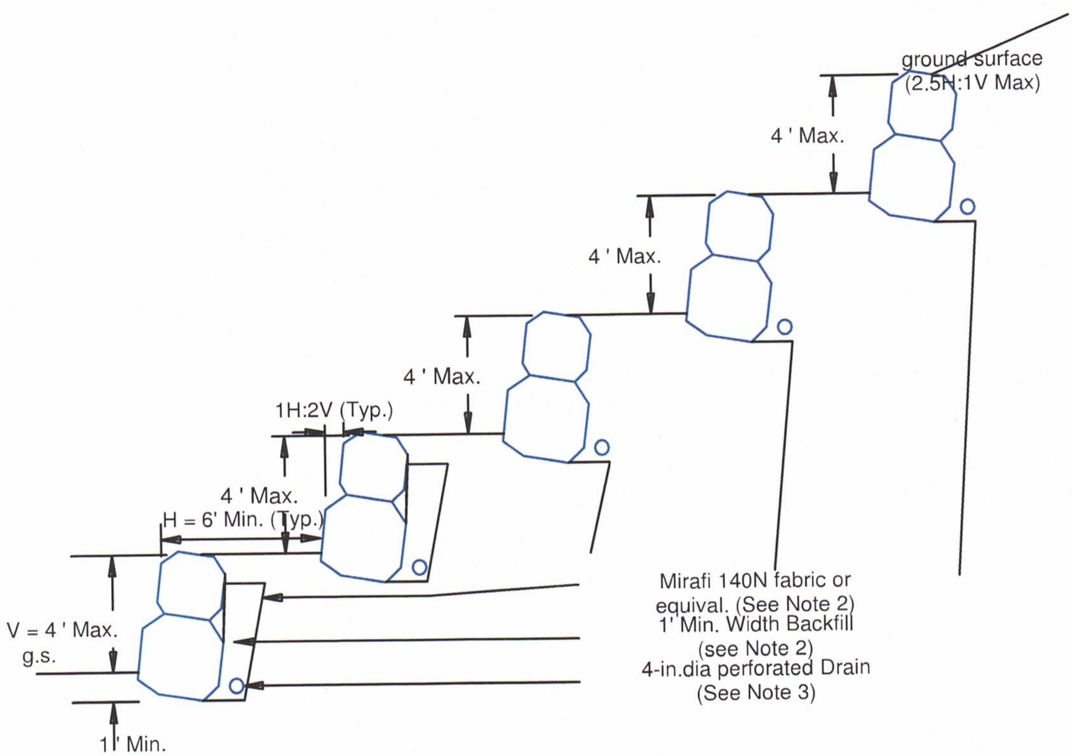
NOTES:

1. BACKFILL SOILS SHOULD BE PLACED IN LOOSE LIFTS NOT EXCEEDING A THICKNESS OF 12 INCHES, MOISTURE CONDITIONED TO WITHIN 2% OF OPTIMUM, AND COMPACTED TO A MINIMUM 95% OF THE MAXIMUM DRY DENSITY AS DETERMINED BY ASTM D1557.

2. FREE-DRAINING BACKFILL SHALL CONSIST OF GRAVEL HAVING LESS THAN 5% PASSING No. 200 SIEVE, OR MAY USE MIRADRAIN (OR EQUIVALENT) INSTEAD OF GRAVEL & FABRIC.

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 36 INCHES FOR THE BOTTOM ROW AND A MINIMUM 24 INCHES FOR THE UPPER ROW FOR EACH TIER.



NOT TO SCALE

PROJECT NO.: 2070-01N-16	GSH	FIGURE NO.: 10