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

GEOTECHNICAL STUDY
LOT 23 BIG SKY ESTATES NO. 1
2292 NORTH PANORAMA CIRCLE
WEBER COUNTY, UTAH

Project No. 155082G

May 5, 2015

Prepared For:

Lundin Homes
Attention: Mr. Karl Lundin
2485 Grant Avenue, Suite 212
Ogden, UT 84401

Prepared By:

EARTHTEC ENGINEERING
Ogden Office

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1.0 EXECUTIVE SUMMARY

This report presents the results of our geotechnical study for Lot 23 of the Big Sky Estates No. 1 subdivision located in unincorporated Weber County near Liberty, Utah. We understand the proposed building, as currently planned, will consist of a two to three story structure founded on spread footings with a walk-out basement.

Our field exploration included observing the excavation of two (2) test pits to depths of about 10 to 12½ feet below the existing ground surface. Groundwater was not encountered during our field investigation. The subsurface soils encountered generally consisted of topsoil overlying layers of Sandy Lean Clay (CL), Sandy Lean Clay with gravel (CL), and Clayey Gravel with sand (GC). All topsoil encountered should be removed beneath the entire building footprint and exterior flatwork.

Based on the results of our field exploration, laboratory testing, and engineering analyses, it is our opinion that the subject site is suitable for the proposed development, provided the recommendations presented herein are followed and implemented during design and construction. Conventional strip and spread footings may be used to support the structures, with foundations placed entirely on a minimum of 18 inches of properly placed, compacted, and tested structural fill or entirely on the native clayey gravel soils.

The referenced geologic map shows the property to be located in the Norwood Tuff Formation which has the potential to be landslide deposits. Scarps associated with landslides are not shown on the referenced geologic map on or near the subject lot. No scarps or other surficial features that could be attributed to landslide movement were observed on the lot at the time of our field work. However, there is a potential that landslide related movement could occur at this site. Further investigation including a deeper boring and long term monitoring will be required: to determine if a landslide is present at the site and if it is currently moving, to quantify the amount of movement, and to characterize the deposits within the affected area. Further investigation, testing, and long term monitoring is outside the scope of this report.

The stability of the existing slope at the property was analyzed as part of our study based upon the test pit information. Our analyses indicate that the proposed slope, meets the required minimum factors of safety. Any modifications to the slope, including the construction of retaining walls, may affect the slope stability and should be properly analyzed, designed, and engineered.

This executive summary provides a general synopsis of our recommendations. Details of our findings, conclusions and recommendations are provided within the body of this report. Failure to consult with Earthtec Engineering (Earthtec) regarding any changes made during design and/or construction of the project from those discussed herein relieves Earthtec from any liability arising from changed conditions at the site. We also strongly recommend that Earthtec observe the building excavations to verify the adequacy of our recommendations presented herein, and that Earthtec performs materials testing and special inspections for this project to provide continuity during construction.

2.0 INTRODUCTION

The project is located at 2292 North Panorama Circle in unincorporated Weber County near Liberty, Utah. The general location of the site is shown on Figure No. 1, *Vicinity Map*, at the end of this report.

The purposes of this study were to

- Evaluate the subsurface soil conditions at the site,
- Assess the engineering characteristics of the subsurface soils, and
- Provide geotechnical recommendations for general site grading and the design and construction of foundations, concrete floor slabs, driveway, and miscellaneous concrete flatwork.

The scope of work completed for this study included field reconnaissance, subsurface exploration, field and laboratory soil testing, geotechnical engineering analysis, and the preparation of this report.

3.0 PROPOSED CONSTRUCTION

We understand that the proposed project consists of constructing a single family residence. We anticipate that the future home will be conventionally framed and be two to three stories in height. The home will likely be founded on spread footings with a walk-out basement. We have based our recommendations in this report on the assumption that foundation loads for the proposed structures will not exceed 4,000 pounds per linear foot for bearing walls, 10,000 pounds for column loads, and 100 pounds per square foot for floor slabs. If structural loads will be greater Earthtec should be notified so that we may review our recommendations and make modifications, if necessary.

In addition to the construction described above, we anticipate that

- Utilities will be installed to service the proposed residence, and
- Exterior concrete flatwork will be placed in the form of a driveway and sidewalk.

4.0 GENERAL SITE DESCRIPTION

At the time of our subsurface investigation, the subject property consisted of an undeveloped lot that was heavily vegetated with native grasses, weeds, trees and oak brush. The subject property slopes downward to the east southeast at an approximate 35 to 46 percent grades. There is an approximate change in elevation of 165 feet across the property. An access road had been previously cut into the slope from the northeast corner of the property to approximately 50 feet southwest of the northeast corner of the lot. The subject site is bounded on the north by a residential house, on the east and south by undeveloped lots, and on the west by Panorama Circle.

5.0 SUBSURFACE EXPLORATION

5.1 Soil Exploration

Under the direction of a qualified member of our geotechnical staff, subsurface explorations were conducted at the site on April 20, 2015 by excavating two (2) exploratory test pits to depths of about 10 to 12½ feet below the existing ground surface using a track-mounted excavator. The approximate locations of the test pits are shown on Figure No. 2, *Aerial Photograph Showing Location of Test Pits and Slope Cross-Section*. Graphical representations and detailed descriptions of the soils encountered are shown on Figure Nos.

3 through 4, *Test Pit Log,* at the end of this report. The stratification lines shown on the logs represent the approximate boundary between soil units; the actual transition may be gradual. Due to potential natural variations inherent in soil deposits, care should be taken in interpolating between and extrapolating beyond exploration points. A key to the symbols and terms on the logs is presented on Figure No. 5, *Legend.*

The soil samples collected were classified by visual examination in the field following the guidelines of the Unified Soil Classification System (USCS). The samples were transported to our Ogden, Utah laboratory where they will be retained for 30 days following the date of this report and then discarded, unless a written request for additional holding time is received prior to the 30 day limit.

6.0 LABORATORY TESTING

Representative soil samples collected during our field exploration were tested in the laboratory to assess pertinent engineering properties and to aid in refining field classifications, if needed. Tests performed included natural moisture content, dry density tests, liquid and plastic limits determinations, full and mechanical (partial) gradation analyses, one dimensional consolidation-swell tests, and a direct shear test. The table below summarizes the laboratory test results, which are also included on the attached test pit logs at the respective sample depths, on Figure Nos. 6 and 7, *Consolidation-Swell Test,* on Figure No. 8, *Direct Shear Test*, and on Figure No. 11, *Grain Size Distribution.*

Table 1: Laboratory Test Results

Test Pit No.	Depth (ft.)	Natural Moisture (%)	Natural Dry Density (pcf)	Atterberg Limits		Grain Size Distribution (%)			Soil Type
				Liquid Limit	Plasticity Index	Gravel (+ #4)	Sand	Silt/Clay (- #200)	
TP-1	3½	21	94	31	14	3	34	63	CL
TP-1	11	5	---	24	14	47	29	24	GC
TP-2	4	21	95	31	15	17	32	51	CL

* NP = Non-Plastic

As part of the consolidation test procedure, water was added to the samples to assess moisture sensitivity when the samples were loaded to an equivalent pressure of approximately 1,000 psf. The consolidation test indicated the sandy lean clay soils have a moderate potential for compressibility and a slight to moderate potential for collapse (settlement) under increased moisture contents and anticipated load conditions.

7.0 SUBSURFACE CONDITIONS

7.1 Soil Types

On the surface of the site, we encountered topsoil which is estimated to extend about 1 to 2½ feet in depth at the test pit locations. Below the topsoil we encountered layers of Sandy Lean Clay (CL), Sandy Lean Clay with gravel (CL), and Clayey Gravel with sand (GC) extending to the maximum depth explored of about 10 to 12½ feet below the existing ground surface. Based on our experience and observations during field exploration, the lean clay and soils visually appeared to be medium stiff in consistency and the clayey gravel soils visually had a relative density of medium dense.

7.2 Groundwater Conditions

Groundwater was not encountered during our field exploration. Note that groundwater levels will fluctuate in response to the season, precipitation, snow melt, irrigation, and other on and off-site influences. Quantifying these fluctuations would require long term monitoring, which is beyond the scope of this study. The contractor should be prepared to dewater excavations as needed.

8.0 SITE GRADING

8.1 General Site Grading

All surface vegetation and unsuitable soils (such as topsoil, organic soils, undocumented fill, soft, loose, or disturbed native soils, and any other inapt materials) should be removed from below foundations, floor slabs, and exterior concrete flatwork. We encountered topsoil on the surface of the site which we estimated to extend about 1 to 2½ feet below the existing ground surface. All topsoil encountered (including soil with roots larger than about ¼ inch in diameter) and any fill material, should be completely removed, even if found to extend deeper than 2½ feet, along with any other unsuitable soils that may be encountered.

Fill placed over large areas, even if only a few feet in depth, can cause consolidation in the underlying native soils resulting in settlement of the fill. If more than 3 feet of grading fill will be placed above the existing surface (to raise site grades), Earthtec should be notified so that we may provide additional recommendations, if required. Such recommendations will likely include placing the fill several weeks (or possibly more) prior to construction to allow settlement to occur.

8.2 Temporary Excavations

Temporary excavations that are less than 4 feet in depth and above groundwater should have side slopes no steeper than ½H:1V (Horizontal:Vertical). Temporary excavations where water is encountered in the upper 4 feet or that extend deeper than 4 feet below site grades should be sloped or braced in accordance with OSHA[1] requirements for Type C soils.

8.3 Fill Material Composition

The native soils are not suitable for use as structural fill. Excavated soils, including the topsoil, may be stockpiled for use as fill in landscape areas.

Structural fill is defined as fill material that will ultimately be subjected to any kind of structural loading, such as those imposed by footings, floor slabs, pavements, etc. We recommend that a professional engineer or geologist verify that the structural fill to be used on this project meets the requirements, stated below. We recommend that structural fill consist of the imported sandy/gravelly soils meeting the following requirements in the table below:

Table 2: Structural Fill Recommendations

Sieve Size/Other	Percent Passing (by weight)
4 inches	100
3/4 inches	70 – 100
No. 4	40 – 80
No. 40	15 – 50
No. 200	0 – 20
Liquid Limit	35 maximum
Plasticity Index	15 maximum

In some situations, particles larger than 4 inches and/or more than 30 percent coarse gravel may be acceptable, but would likely make compaction more difficult and/or significantly reduce the possibility of successful compaction testing. Consequently, more strict quality control measures than normally used may be required, such as using thinner lifts and increased or full time observation of fill placement.

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[1] OSHA Health And Safety Standards, Final Rule, CFR 29, part 1926.

We recommend that utility trenches below any structural load be backfilled using structural fill. Note that most local governments and utility companies require Type A-1-a or A-1-b (AASHTO classification) soils (which overall is stricter than our recommendations for structural fill) be used as backfill above utilities in certain areas. All backfill soil should have a maximum particle size of 4 inches, a maximum Liquid Limit of 35 and a maximum Plasticity Index of 15.

If required (i.e. fill in submerged areas), we recommend that free draining granular material (clean sand and/or gravel) meet the following requirements in the table below:

Table 3: Free-Draining Fill Recommendations

Sieve Size/Other	Percent Passing (by weight)
3 inches	100
No. 10	0 – 25
No. 40	0 – 15
No. 200	0 – 5
Plasticity Index	Non-plastic

Three inch minus washed rock (sometimes called river rock or drain rock) and pea gravel materials usually meet these requirements and may be used as free draining fill. If free draining fill will be placed adjacent to soil containing a significant amount of sand or silt/clay, precautions should be taken to prevent the migration of fine soil into the free draining fill. Such precautions should include either placing a filter fabric between the free draining fill and the adjacent soil material, or using a well graded, clean filtering material approved by the geotechnical engineer.

8.4 Fill Placement and Compaction

Fill should be placed on level, horizontal surfaces. Where fill will be placed on existing slopes steeper than 5H:1V, the existing ground should be benched prior to placing fill. We recommend bench heights of 1 to 4 feet, with the lowest bench being a minimum 3 feet below adjacent grade and at least 10 feet wide.

The thickness of each lift should be appropriate for the compaction equipment that is used. We recommend a maximum lift thickness prior to compaction of 4 inches for hand operated equipment, 6 inches for most "trench compactors" and 8 inches for larger rollers, unless it can be demonstrated by in-place density tests that the required compaction can be obtained throughout a thicker lift. The full thickness of each lift of structural fill placed should be compacted to at least the following percentages of the maximum dry density, as determined by ASTM D-1557:

In landscape and other areas not below structurally loaded areas:	90%
Less than 5 feet of fill below structurally loaded areas:	95%
Between 5 and 10 feet of fill below structurally loaded areas:	98%

Generally, placing and compacting fill at moisture contents within ±2 percent of the optimum moisture content, as determined by ASTM D-1557, will facilitate compaction. Typically, the further the moisture content deviates from optimum the more difficult it will be to achieve the required compaction.

Fill should be tested frequently during placement and we recommend early testing to demonstrate that placement and compaction methods are achieving the required compaction. The contractor is responsible to ensure that fill materials and compaction efforts are consistent so that tested areas are representative of the entire fill.

8.5 Stabilization Recommendations

The native clay soils may rut and pump during grading and construction. The likelihood of rutting and/or pumping, and the depth of disturbance, is proportional to the moisture content in the soil, the load applied to the ground surface, and the frequency of the load. Consequently, rutting and pumping can be minimized by avoiding concentrated traffic, minimizing the load applied to the ground surface by using lighter equipment, partially loaded equipment, tracked equipment, by working in dry times of the year, and/or by providing a working surface for equipment.

During grading the soil in any obvious soft spots should be removed and replaced with granular material. If rutting or pumping occurs traffic should be stopped in the area of concern. The soil in rutted areas should be removed and replaced with granular material. In areas where pumping occurs the soil should either be allowed to sit until pore pressures dissipate (several hours to several days) and the soil firms up, or be removed and replaced with granular material. Typically, we recommend removal to a minimum depth of 24 inches.

For granular material, we recommend using angular well-graded gravel, such as pit run, or crushed rock with a maximum particle size of four inches. We suggest that the initial lift be approximately 12 inches thick and be compacted with a static roller-type compactor. A finer granular material such as sand, gravelly sand, sandy gravel or road base may also be used. Materials which are more angular and coarse may require thinner lifts in order to achieve compaction. We recommend that the fines content (percent passing the No. 200 sieve) be less than 15%, the liquid limit be less than 35, and the plasticity index be less than 15.

Using a geosynthetic fabric, such as Mirafi 600X or equivalent, may also reduce the amount of material required and avoid mixing of the granular material and the subgrade. If a fabric is used, following removal of disturbed soils and water, the fabric should be placed over the bottom and up the sides of the excavation a minimum of 24 inches. The fabric should be placed in accordance with the manufacturer's recommendations, including proper overlaps. The granular material should then be placed over the fabric in compacted lifts. Again, we suggest that the initial lift be approximately 12 inches thick and be compacted with a static roller-type compactor.

9.0 SLOPE STABILITY

We evaluated the overall stability of the existing slope at the subject property. The properties of the native soils at the site were estimated using laboratory testing on samples recovered during our field investigations and our experience with similar soils. Our direct shear testing on the native Sandy Lean Clay with gravel (CL) soils encountered during our field investigation indicated the soils have an internal friction angle of about 32 degrees and cohesion of about 155 psf. Accordingly, we used an internal friction angle of 32 degrees, an apparent cohesion of 155 psf, a saturated unit weight of 125 pcf, and a moist unit weight of 105 pcf for our analyses.

Based on tests performed by the Bureau of Reclamation[2], "Clayey gravels, poorly graded gravel-sandy-clay" has an internal friction angle of 36 to 38 degrees. Accordingly, we used an internal friction angle of 36 degrees, an apparent cohesion of 75 psf, a saturated unit

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[2] U.S. Bureau of Reclamation, 1987, "Design Standards No. 13, Embankment Dams," Denver, Colorado.

weight of 130 pcf, and a moist unit weight of 115 pcf for the clayey gravel soils for our analyses.

For the seismic (pseudostatic) analysis, a peak horizontal ground acceleration of 0.4694g for the 2% probability of exceedance in 50 years was obtained for site (grid) locations of 41.301 degrees north latitude and -111.851 degrees west longitude. Typically, one-third to one-half this value is utilized in analysis. Accordingly, a value of 0.156 was used as the pseudostatic coefficient for the stability analysis.

We evaluated the global stability of the existing site using the computer program XSTABLE. 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. The configuration analyzed was based on our observations during the field investigation and the topography map of the site that was provided to us by Mr. Karl Lundin with Lundin Homes.

The configuration of the existing slope was analyzed at Cross-Section A-A' and starts at the west portion of the lot just above Panorama Circle. The lot then sloped downhill to the east to Panorama Circle, which was relatively flat. The lot then continued to slope downhill to the east inclined at approximately 1V:3H (Vertical:Horizontal) slope for approximate 60 feet. An approximate 8 foot high slope inclined at approximately 1V:1H (Vertical:Horizontal) slope was then modeled followed by a relatively flat area (existing driveway). The lot then sloped downhill to the east inclined at approximately 1V:3H to 1V:2.5H (Vertical:Horizontal) slope.

A water table was conservatively placed at approximately 20 feet below the ground surface, although groundwater was not encountered during our field exploration.

To model the load imposed on the slope by typical residential building, a 1,500 psf load was modeled approximately 60 feet east of the Panorama Circle and to model the load imposed by the roadway, a 400 psf load was modeled on the driveway that had been previously cut into the slope. 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 slope configuration described above meets both these requirements. The slope stability data are attached as Figure Nos. 9 and 10, *Stability Results*. Any modifications to the slope, including the construction of retaining walls, should be properly designed and engineered.

It should be clearly understood that slope movements or even failure can occur if the slope is undermined, the slope soils become saturated, or the site is underlain by a formation prone to landslides, such as the Norwood Tuff. Further investigation including a deeper boring and long term monitoring will be required: to determine if a landslide is present at the site and if it is currently moving, to quantify the amount of movement, and to characterize the deposits within the affected area. 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 soils. Surface water should be directed away from the top and bottom of the slope, the slope should be vegetated with drought resistant plants, and sprinklers should not be placed on the face of the slope.

10.0 SEISMIC AND GEOLOGIC CONSIDERATIONS

10.1 Seismic Design

The residential structures should be designed in accordance with the International Residential Code (IRC). The IRC designates this area as a seismic design class D_1.

The site is located at approximately 41.301 degrees north latitude and -111.851 degrees west longitude from the approximate center of the site. The IRC site value for this property is 0.79g. The design spectral response acceleration parameters are given below.

Table 4: Design Acceleration for Short Period

S_S	F_a	Site Value (S_{DS})
		2/3 S_S*F_a
1.13 g	1.05	0.79 g

S_S = Mapped spectral acceleration for short periods
F_a = Site coefficient from Table 1613.5.3(1)
S_{DS} = ⅔S_{MS}= ⅔ (F_a·S_s) = 5% damped design spectral response acceleration for short periods

10.2 Faulting

The subject property is located within the Intermountain Seismic Belt where the potential for active faulting and related earthquakes is present. Based upon published geologic maps[3], no active faults traverse through or immediately adjacent to the site. The site is not located within local fault study zone. The nearest mapped fault trace is the Ogden Valley Southwestern Margin Fault Zone located about ¾ miles southwest of the site.

10.3 Liquefaction Potential

According to current liquefaction maps[4] for Weber County, the site is located within an area designated as "Very Low" in liquefaction potential. Liquefaction can occur when saturated subsurface soils below groundwater lose their inter-granular strength due to an increase in soil pore water pressures during a dynamic event such as an earthquake. The potential for liquefaction is based on several factors, including 1) the grain size distribution of the soil, 2) the plasticity of the fine fraction of the soil (material passing the No. 200 sieve), 3) relative density of the soil, 4) earthquake strength (magnitude) and duration, and 5) overburden pressures. In addition, the soils must be near saturation for liquefaction to occur.

Loose, saturated sands are most susceptible to liquefaction, but some loose, saturated gravels and relatively sensitive silt to low-plasticity silty clay soils can also liquefy during a seismic event. Subsurface soils were composed of medium stiff, clays and medium dense clayey gravels. The soils encountered at this project do not appear liquefiable, but the liquefaction susceptibility of underlying soils (deeper than our explorations) is not known and would require deeper explorations to quantify.

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[3] U.S. Geological Survey, Quaternary Fault and Fold Database of the United States, November 3, 2010.
[4] Utah Geological Survey, Liquefaction-Potential Map For A Part Of Weber County, Utah, Public Information Series 28, August 1994.

10.4 Geologic Setting

The subject lot is located in the western portion of the Ogden Valley in the foothills to the south of Liberty, Utah and to the northwest of Eden, Utah. The Ogden Valley is part of the Wasatch Hinterlands Section of the Middle Rocky Mountain Physiographic Province. The Wasatch Hinterlands is a belt of hilly terrain with a few valleys located directly east of the Wasatch Range, crossed and drained by several west-flowing river systems, and is generally an area of active erosion and little deposition[5]. The Ogden River and its tributaries have been the primary factor in the formation of the Ogden Valley as the streams and rivers eroded and down-cut the valley over time. The Ogden River has been dammed to the southeast of the site forming Pineview Reservoir. The subject lot does not appear to be located within the flood plain of the Ogden River or any of its tributaries.

The surficial geology at the site and surrounding area has been mapped as Norwood Tuff as indicated on the geologic map by Martin L. Sorsen and Max D. Crittenden, Jr. (1979)[6]. The referenced map shows the surficial geology at the location of the lot to consist of the lower Oligocene and upper Eocene age Norwood Tuff (Map Unit Tn). The referenced mapping describes the Norwood Tuff Formation as "Fine to medium bedded, fine grained, friable, white to buff weathering tuff and sandy tuff, probably waterlain and in part reworked." The Norwood Tuff Formation is prone to localized landslides and slumps. The referenced geologic map shows a localized headscarp within the Norwood Tuff Formation approximately ¾ miles northwest of the subject lot. Scarps associated with landslides are not shown on the referenced geologic map on or near the subject lot. No scarps or other surficial features that could be attributed to landslide movement were observed on the lot at the time of our field work. However, there is a potential that landslide related movement could occur at this site. Recent aerial photographs[7] (1993-2015) of the site and surrounding area do not show any apparent scarps, lineaments, or other surficial features that would be indicative of slope movement on or surrounding the subject lot. No other geologic hazards appear to pose a significant risk to the subject lot and the proposed development.

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[5] Stokes, W.L., 1986, *Geology of Utah*; Utah Museum of Natural History, University of Utah and Utah Geological and Mineral Survey, Department of Natural Resources, p. 243.

[6] Geologic Map of the Huntsville Quadrangle, Weber and Cache Counties, Utah.

[7] www.earth.google.com

However, further investigation testing and long term monitoring will be required: to determine if a landslide is present at the site and if it is currently moving, to quantify the amount of movement, and to characterize the deposits within the affected area. Further investigation, testing and long term monitoring is outside the scope of this report.

11.0 FOUNDATIONS

11.1 General

The foundation recommendations presented in this report are based on the soil conditions encountered during our field exploration, the results of laboratory testing of samples of the native soils, the site grading recommendations presented in this report, and the foundation loading conditions presented in Section 3.0, *Proposed Construction*, of this report. If loading conditions and assumptions related to foundations are significantly different, Earthtec should be notified so that we can re-evaluate our design parameters and estimates (higher loads may cause more settlement), and to provide additional recommendations if necessary.

Conventional strip and spread footings may be used to support the proposed structures after appropriate removals as outlined in Section 8.1. Foundations should not be installed on topsoil, undocumented fill, debris, combination soils, organic soils, frozen soil, or in ponded water. If foundation soils become disturbed during construction they should be removed or recompacted.

11.2 Strip/Spread Footings

We recommend that conventional strip and spread foundations be constructed entirely on a minimum of 18 inches of structural fill extending to undisturbed native soils or entirely on the native clayey gravel soils. Foundations should not be constructed on the native sandy Lean Clay (CL) soils or combination soils (part on native clayey gravel soils and part on structural fill). For foundation design we recommend the following:

- Footings founded on native clayey gravel soils or structural fill may be designed using a maximum allowable bearing capacity of 2,000 pounds per square foot. The values for vertical foundation pressure can be increased by one-third for wind and seismic conditions per Section 1806.1 when used with the Alternative Basic Load Combinations found in Section 1605.3.2 of the 2012 International Building Code.

- Continuous and spot footings should be uniformly loaded and should have a minimum width of 20 and 30 inches, respectively.

- Exterior footings should be placed below frost depth which is determined by local building codes. In general 30 inches of cover is adequate for most sites; however local code should be verified by the end design professional. Interior footings, not subject to frost (heated structures), should extend at least 18 inches below the lowest adjacent grade.

- Foundation walls and footings should be properly reinforced to resist all vertical and lateral loads and differential settlement.

- The bottom of footing excavations should be compacted with at least 4 passes of an approved non-vibratory roller prior to erection of forms or placement of structural fill to densify soils that may have been loosened during excavation and to identify soft spots. If soft areas are encountered, they should be stabilized as recommended in Section 8.5.

- Footing excavations should be observed by the geotechnical engineer prior to beginning footing construction to evaluate whether suitable bearing soils have been exposed and whether excavation bottoms are free of loose or disturbed soils.

- Structural fill used below foundations should extend laterally a minimum of 6 inches for every 12 vertical inches of structural fill placed. For example, if 18 inches of structural fill are required to bring the excavation to footing grade, the structural fill should extend laterally a minimum of 9 inches beyond the edge of the footings on both sides.

11.3 Estimated Settlements

If the proposed foundations are properly designed and constructed using the parameters provided above, we estimate that total settlements should not exceed one inch and differential settlements should be one-half of the total settlement over a 25-foot length of continuous foundation, for non-earthquake conditions. Additional settlement could occur during a seismic event due to ground shaking, if more than 3 feet of grading fill is placed above the existing ground surface, and/or if foundation soils are allowed to become wetted.

11.4 Lateral Earth Pressures

Below grade walls act as soil retaining structures and should be designed to resist pressures induced by the backfill soils. The lateral pressures imposed on a retaining structure are dependent on the rigidity of the structure and its ability to resist rotation. Most retaining walls that can rotate or move slightly will develop an active lateral earth pressure condition. Structures that are not allowed to rotate or move laterally, such as subgrade basement walls, will develop an at-rest lateral earth pressure condition. Lateral pressures applied to structures may be computed by multiplying the vertical depth of backfill material by the appropriate equivalent fluid density. Any surcharge loads in excess of the soil weight applied to the backfill should be multiplied by the appropriate lateral pressure coefficient and added to the soil pressure. For static conditions the resultant forces is applied at about one-third the wall height (measured from bottom of wall). For seismic conditions, the resultant forces are applied at about two-third times the height of the wall both measured from the bottom of the wall. The lateral pressures presented in the table below are based on drained, horizontally placed structural fill (as outlined in this report) and native clayey gravel soils as backfill material using a 32° friction angle and a dry unit weight of 125 pcf.

Table 5: Lateral Earth Pressures (Static and Dynamic)

Condition	Case	Lateral Pressure Coefficient	Equivalent Fluid Pressure (pcf)
Active	Static	0.31	40
	Seismic	0.45	59
At-Rest	Static	0.47	61
	Seismic	0.69	89
Passive	Static	3.25	423
	Seismic	4.65	604

*Seismic values combine the static and dynamic values

These pressure values do not include any surcharge, and are based on a relatively level ground surface at the top of the wall and drained conditions behind the wall. It is important that water is not allowed to build up (hydrostatic pressures) behind retaining structures. Retaining walls should incorporate drainage behind the walls as appropriate, and surface water should be directed away from the top and bottom of the walls.

Lateral loads are typically resisted by friction between the underlying soil and footing bottoms. Resistance to sliding may incorporate the friction acting along the base of foundations, which may be computed using a coefficient of friction of soils against concrete of 0.55 for structural fill and native clayey gravel soils meeting the recommendations presented herein. For allowable stress design, the lateral resistance may be computed using Section 1807 of the 2012 International Building Code and all sections referenced therein. Retaining wall lateral resistance design should further reference Section 1807.2.3

for reference of Safety Factors. Retaining systems are assumed to be founded upon and backfilled with granular structural fill. The values for lateral foundation pressure can be increased by one-third for wind and seismic conditions per Section 1806.1 when used with the Alternative Basic Load Combinations found in Section 1605.3.2 of the 2012 International Building Code.

The pressure and coefficient values presented above are ultimate; therefore an appropriate factor of safety may need to be applied to these values for design purposes. The appropriate factor of safety will depend on the design condition and should be determined by the project structural engineer.

12.0 FLOOR SLABS AND FLATWORK

Concrete floor slabs and exterior flatwork may be supported on the native soils after appropriate removals and grading as outlined in Section 8.1 are completed. We recommend placing a minimum 4 inches of free-draining fill material (see Section 8.3) beneath floor slabs to facilitate construction, act as a capillary break, and aid in distributing floor loads. For exterior flatwork, we recommend placing a minimum 4 inches of roadbase material. Prior to placing the free-draining fill or roadbase materials, the native subgrade should be proof-rolled to identify soft spots, which should be stabilized as discussed above in Section 8.5.

For slab design, we recommend using a modulus of subgrade reaction of 100 pounds per cubic inch. A 6-mil polyethylene vapor retarder shall be applied over the porous layer with the basement the basement floor constructed over the polyethylene, as per Section R405 of the 2012 International Residential Code. To help control normal shrinkage and stress cracking, we recommend that floor slabs have adequate reinforcement for the anticipated floor loads with the reinforcement continuous through interior floor joints, frequent crack control joints, and non-rigid attachment of the slabs to foundation and bearing walls. Special precautions should be taken during placement and curing of all concrete slabs and flatwork. Excessive slump (high water-cement ratios) of the concrete and/or improper finishing and curing procedures used during hot or cold weather conditions may lead to excessive shrinkage, cracking, spalling, or curling of slabs. We recommend all concrete placement and curing operations be performed in accordance with American Concrete Institute (ACI) codes and practices.

13.0 DRAINAGE

13.1 Surface Drainage

As part of good construction practice, precautions should be taken during and after construction to reduce the potential for water to collect near foundation walls. Accordingly, we recommend the following:

- Adequate compaction of foundation backfill should be provided i.e. a minimum of 90% of ASTM D-1557. Water consolidation methods should not be used.
- The ground surface should be graded to drain away from the building in all directions. We recommend a minimum fall of 8 inches in the first 10 feet.
- Roof runoff should be collected in rain gutters with downspouts designed to discharge well outside of the backfill limits, or at least 10 feet from foundations, whichever is greater.
- Sprinklers should be aimed away, and all sprinkler components (valves, lines, sprinkler heads) should be placed at least 5 feet from foundation walls. Sprinkler systems should be well maintained, checked for leaks frequently, and repaired promptly. Overwatering at any time should be avoided.
- Any additional precautions which may become evident during construction.

13.2 Subsurface Drainage

Section R405.1 of the 2012 International Residential Code states, "Drains shall be provided around all concrete and masonry foundations that retain earth and enclose habitable or usable spaces located below grade." Section R310.2.2 of the 2012 International Residential Code states, "Window wells shall be designed for proper drainage by connecting to the building's foundation drainage system." An exception is allowed when the foundation is installed on well drained ground consisting of Group 1 soils, which include those defined by the Unified Soil Classification System as GW, GP, SW, SP, GM, and SM. The soils observed in the explorations at the depth of foundation consisted of Non-Group 1 soils.

If the structure is founded on structural fill foundation drains are not required for the lot. If foundation drains are constructed on the native clayey gravel soils, the recommendations presented below should be followed during design and construction of the foundation drains:

- A perforated 4-inch minimum diameter pipe should be enveloped in at least 12 inches of free-draining gravel and placed adjacent to the perimeter footings. The perforations should be oriented such that they are not located on the bottom side of the pipe, as much as possible. The free-draining gravel should consist of primarily ¾- to 2-inch size gravel having less than 5 percent passing the No. 4 sieve, and should be wrapped with a separation fabric such as Mirafi 140N or equivalent.

- The highest point of the perforated pipe bottom should be equal to the bottom elevation of the footings. The pipe should be uniformly graded to drain to an appropriate outlet (storm drain, land drain, other gravity outlet, etc.) or to one or more sumps where water can be removed by pumping.

- A perforated 4-inch minimum diameter pipe should be installed in all window wells and connected to the foundation drain.
- To facilitate drainage beneath basement floor slabs we recommend that the minimum thickness of free-draining fill beneath the slabs be increased to at least 10 inches (approximately equal to the bottom of footing elevations). A separation fabric such as Mirafi 140N or equivalent should be placed beneath the free-draining gravel. Connections should be made to allow any water beneath the slabs to reach the perimeter foundation drain.

- The drain system should be periodically inspected and clean-outs should be installed for the foundation drain to allow occasional cleaning/purging, as needed. Proper drain operation depends on proper construction and maintenance.

14.0 GENERAL CONDITIONS

The exploratory data presented in this report was collected to provide geotechnical design recommendations for this project. The explorations may not be indicative of subsurface conditions outside the study area or between points explored and thus have a limited value in depicting subsurface conditions for contractor bidding. Variations from the conditions portrayed in the test pits may occur and which may be sufficient to require modifications in the design. If during construction, conditions are different than presented in this report, Earthtec should be advised immediately so that the appropriate modifications can be made.

The findings and recommendations presented in this geotechnical report were prepared in accordance with generally accepted geotechnical engineering principles and practice in this area of Utah at this time. No warranty or representation is intended in our proposals, contracts, letters, or reports.

This geotechnical report is based on relatively limited subsurface explorations and laboratory testing. Subsurface conditions may differ in some locations of the site from those described herein, which may require additional analyses and possibly modified recommendations. Thus we strongly recommend consulting with Earthtec regarding any changes made during design and construction of the project from those discussed herein. Failure to consult with Earthtec regarding any such changes relieves Earthtec from any liability arising from changed conditions at the site.

To maintain continuity, Earthtec should also perform materials testing and special inspections for this project. The recommendations presented herein are based on the assumption that an adequate program of tests and observations will be followed during construction to verify compliance with our recommendations. We also assume that we will review the project plans and specifications to verify that our conclusions and recommendations are incorporated and remain appropriate (based on the actual design). Earthtec should be retained to review the final design plans and specifications so comments can be made regarding interpretation and implementation of our geotechnical recommendations in the design and specifications. Earthtec also should be retained to provide observation and testing services during grading, excavation, foundation construction, and other earth-related construction phases of the project.

We appreciate the opportunity of providing our services on this project. If we can answer questions or be of further service, please contact Earthtec at your convenience.

Respectfully;
EARTHTEC ENGINEERING

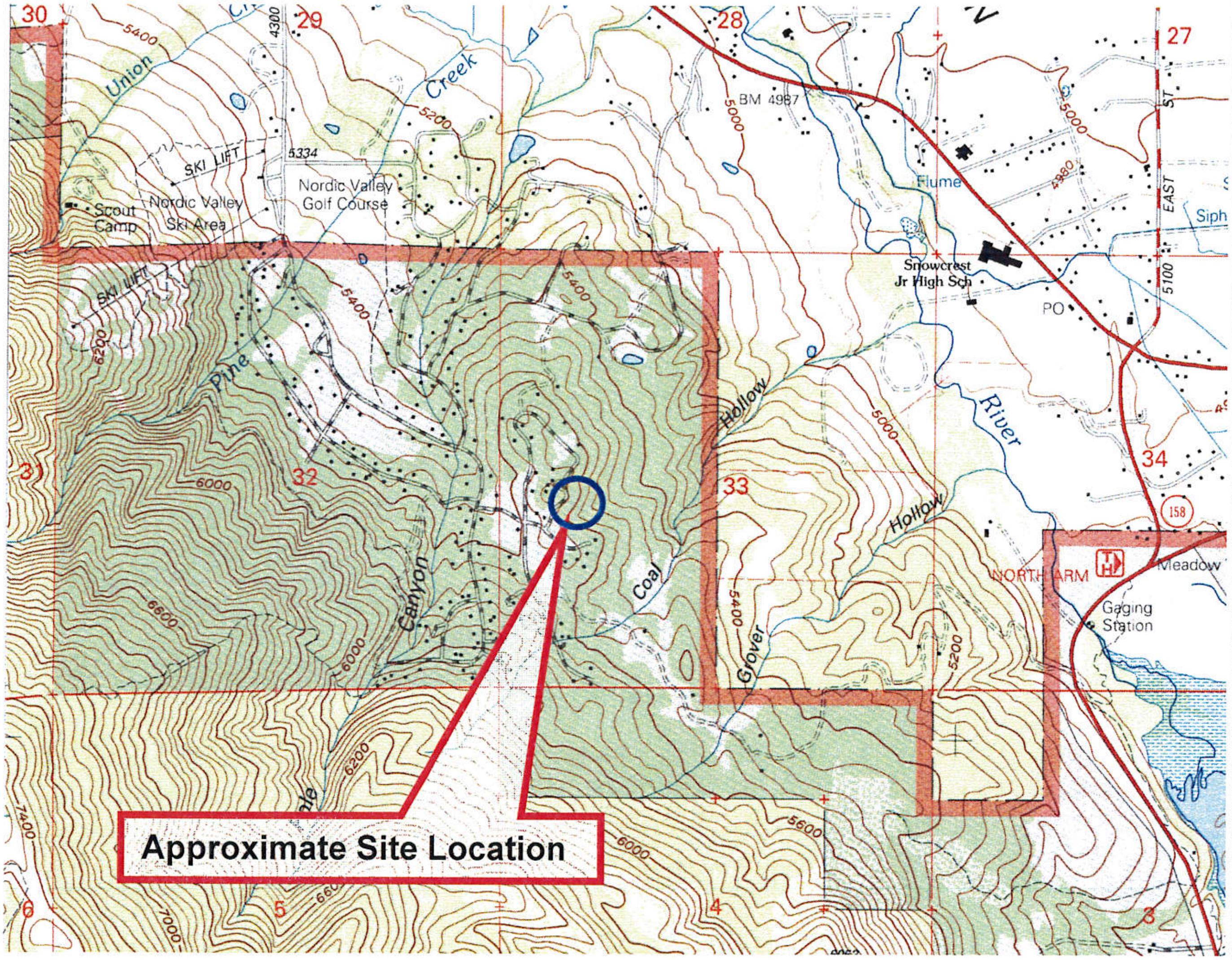
Shawn A. Stuart, E.I.T.
Staff Geotechnical Engineer

No. 5567049-2202
TIMOTHY ALLAN MITCHELL
5/6/15

Timothy A. Mitchell, P.E.
Geotechnical Engineer

VICINITY MAP

LOT 23 BIG SKY ESTATES NO. 1
2292 NORTH PANORAMA CIRCLE
WEBER COUNTY, UTAH



(cida.usgs.gov)

N

Not to Scale

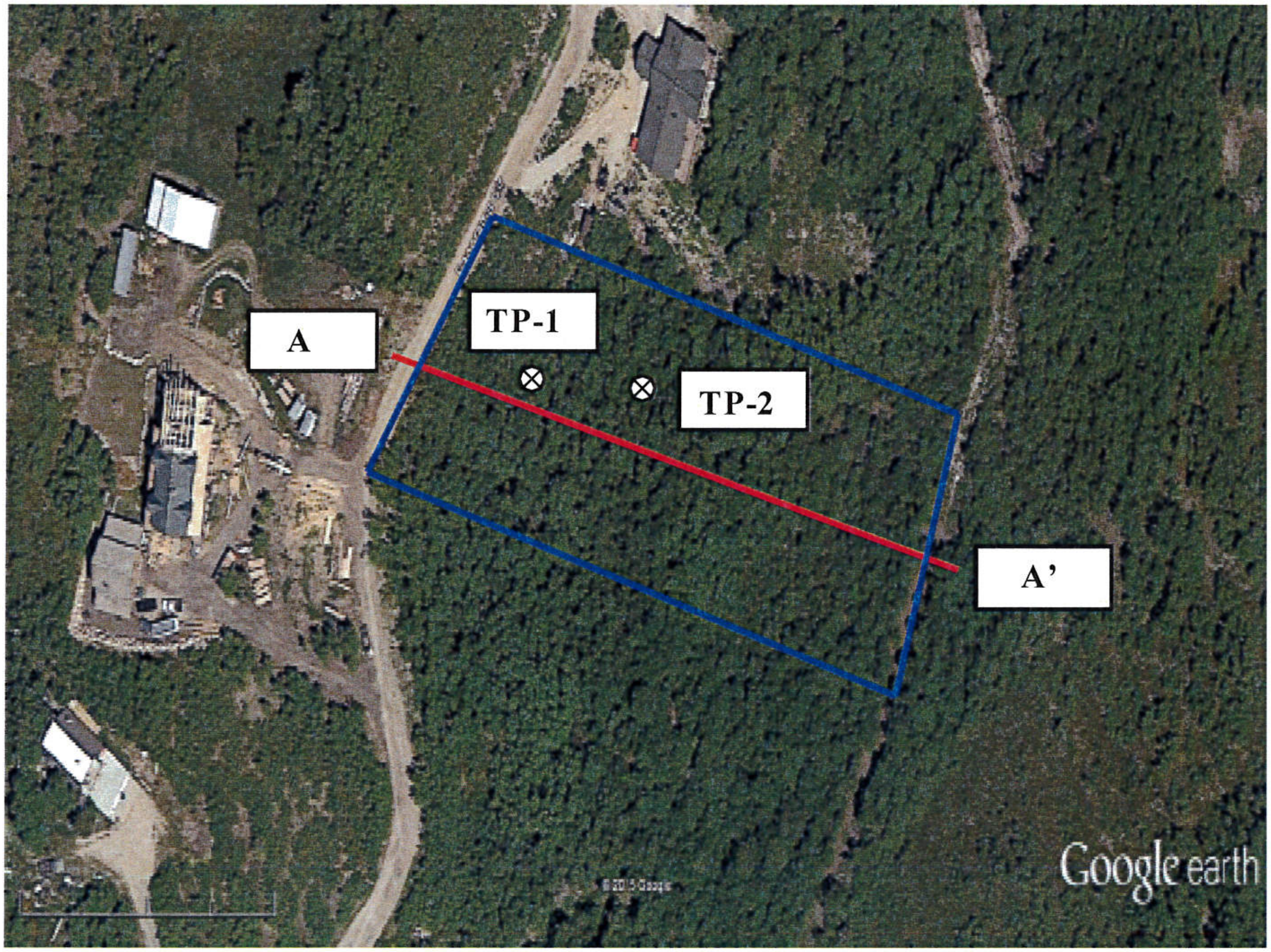
PROJECT NO.: 155082G

Earthtec Engineering

FIGURE NO.: 1

AERIAL PHOTOGRAPH SHOWING LOCATION OF TEST PITS AND SLOPE CROSS-SECTION

LOT 23 BIG SKY ESTATES NO. 1
2292 NORTH PANORAMA CIRCLE
WEBER COUNTY, UTAH



⊗ **Approximate Location of Test Pits**

▬ **Approximate Slope Cross-Section Analyzed**

▬ **Approximate Boundary Location**

(Aerial photograph provided by Google Earth)

N

Not to Scale

PROJECT NO.: 155082G	Earthtec Engineering	**FIGURE NO.:** 2

TEST PIT LOG

NO.: TP-1

PROJECT: Lot 23 Big Sky Estates No. 1
PROJECT NO.: 155082G
CLIENT: Lundin Homes
DATE: 04/20/15
LOCATION: See Figure 2
ELEVATION: Not Measured
OPERATOR: C.E. Butters Construction
LOGGED BY: S. Stuart
EQUIPMENT: Trackhoe
DEPTH TO WATER; INITIAL ▽ :
AT COMPLETION ▼ :

Depth (Ft.)	Graphic Log	USCS	Description	Samples	TEST RESULTS							
					Water Cont. (%)	Dry Dens. (pcf)	LL	PI	Gravel (%)	Sand (%)	Fines (%)	Other Tests
0			TOPSOIL, clay, moist, black, organic rich									
1			Sandy Lean CLAY, medium stiff (estimated), moist, brown, moderate root material (1/4 inch or smaller), minor pinhole texture, cobbles									
2												
3		CL										
4				■	21	93	31	14	3	34	63	C
5			Clayey GRAVEL with sand, medium dense (estimated), moist, brown to light brown, boulders									
6												
7												
8												
9		GC										
10												
11				☒	5		24	14	47	29	24	
12												
13			MAXIMUM DEPTH EXPLORED APPROXIMATELY 12½ FEET									
14												

Notes: No groundwater encountered.

Tests Key

CBR = California Bearing Ratio
C = Consolidation
R = Resistivity
DS = Direct Shear
SS = Soluble Sulfates
UC = Unconfined Compressive Strength

PROJECT NO.: 155082G

Earthtec Engineering

FIGURE NO.: 3

TEST PIT LOG
NO.: TP-2

PROJECT: Lot 23 Big Sky Estates No. 1
CLIENT: Lundin Homes
LOCATION: See Figure 2
OPERATOR: C.E. Butters Construction
EQUIPMENT: Trackhoe
DEPTH TO WATER; INITIAL ▽ **:**

PROJECT NO.: 155082G
DATE: 04/20/15
ELEVATION: Not Measured
LOGGED BY: S. Stuart
AT COMPLETION ▼ **:**

Depth (Ft.)	Graphic Log	USCS	Description	Samples	TEST RESULTS							
					Water Cont. (%)	Dry Dens. (pcf)	LL	PI	Gravel (%)	Sand (%)	Fines (%)	Other Tests
0 1 2			TOPSOIL, clay, moist, black, organic rich									
3 4 5 6 7		CL	Sandy Lean CLAY with gravel, medium stiff (estimated), moist, brown, moderate root material (1/4 inch or smaller), minor pinhole texture, cobbles	■	21	95	31	15	17	32	51	C, DS
8 9 10		GC	Clayey GRAVEL with sand, medium dense (estimated), moist, brown to light brown, boulders									
11 12 13 14			MAXIMUM DEPTH EXPLORED APPROXIMATELY 10 FEET									

Notes: No groundwater encountered.

Tests Key
CBR = California Bearing Ratio
C = Consolidation
R = Resistivity
DS = Direct Shear
SS = Soluble Sulfates
UC = Unconfined Compressive Strength

PROJECT NO.: 155082G

Earthtec Engineering

FIGURE NO.: 4

LEGEND

PROJECT: Lot 23 Big Sky Estates No. 1
CLIENT: Lundin Homes
DATE: 04/20/15
LOGGED BY: S. Stuart

UNIFIED SOIL CLASSIFICATION SYSTEM

MAJOR SOIL DIVISIONS			USCS SYMBOL	TYPICAL SOIL DESCRIPTIONS
COARSE GRAINED SOILS (More than 50% retaining on No. 200 Sieve)	GRAVELS (More than 50% of coarse fraction retained on No. 4 Sieve)	CLEAN GRAVELS (Less than 5% fines)	GW	Well Graded Gravel, May Contain Sand, Very Little Fines
			GP	Poorly Graded Gravel, May Contain Sand, Very Little Fines
		GRAVELS WITH FINES (More than 12% fines)	GM	Silty Gravel, May Contain Sand
			GC	Clayey Gravel, May Contain Sand
	SANDS (50% or more of coarse fraction passes No. 4 Sieve)	CLEAN SANDS (Less than 5% fines)	SW	Well Graded Sand, May Contain Gravel, Very Little Fines
			SP	Poorly Graded Sand, May Contain Gravel, Very Little Fines
		SANDS WITH FINES (More than 12% fines)	SM	Silty Sand, May Contain Gravel
			SC	Clayey Sand, May Contain Gravel
FINE GRAINED SOILS (More than 50% passing No. 200 Sieve)	SILTS AND CLAYS (Liquid Limit less than 50)		CL	Lean Clay, Inorganic, May Contain Gravel and/or Sand
			ML	Silt, Inorganic, May Contain Gravel and/or Sand
			OL	Organic Silt or Clay, May Contain Gravel and/or Sand
	SILTS AND CLAYS (Liquid Limit Greater than 50)		CH	Fat Clay, Inorganic, May Contain Gravel and/or Sand
			MH	Elastic Silt, Inorganic, May Contain Gravel and/or Sand
			OH	Organic Clay or Silt, May Contain Gravel and/or Sand
HIGHLY ORGANIC SOILS			PT	Peat, Primarily Organic Matter

SAMPLER DESCRIPTIONS

◩	SPLIT SPOON SAMPLER (1 3/8 inch inside diameter)
⧗	MODIFIED CALIFORNIA SAMPLER (2 inch outside diameter)
▥	SHELBY TUBE (3 inch outside diameter)
◨	BLOCK SAMPLE
⊠	BAG/BULK SAMPLE

WATER SYMBOLS

▽	Water level encountered during field exploration
▼	Water level encountered at completion of field exploration

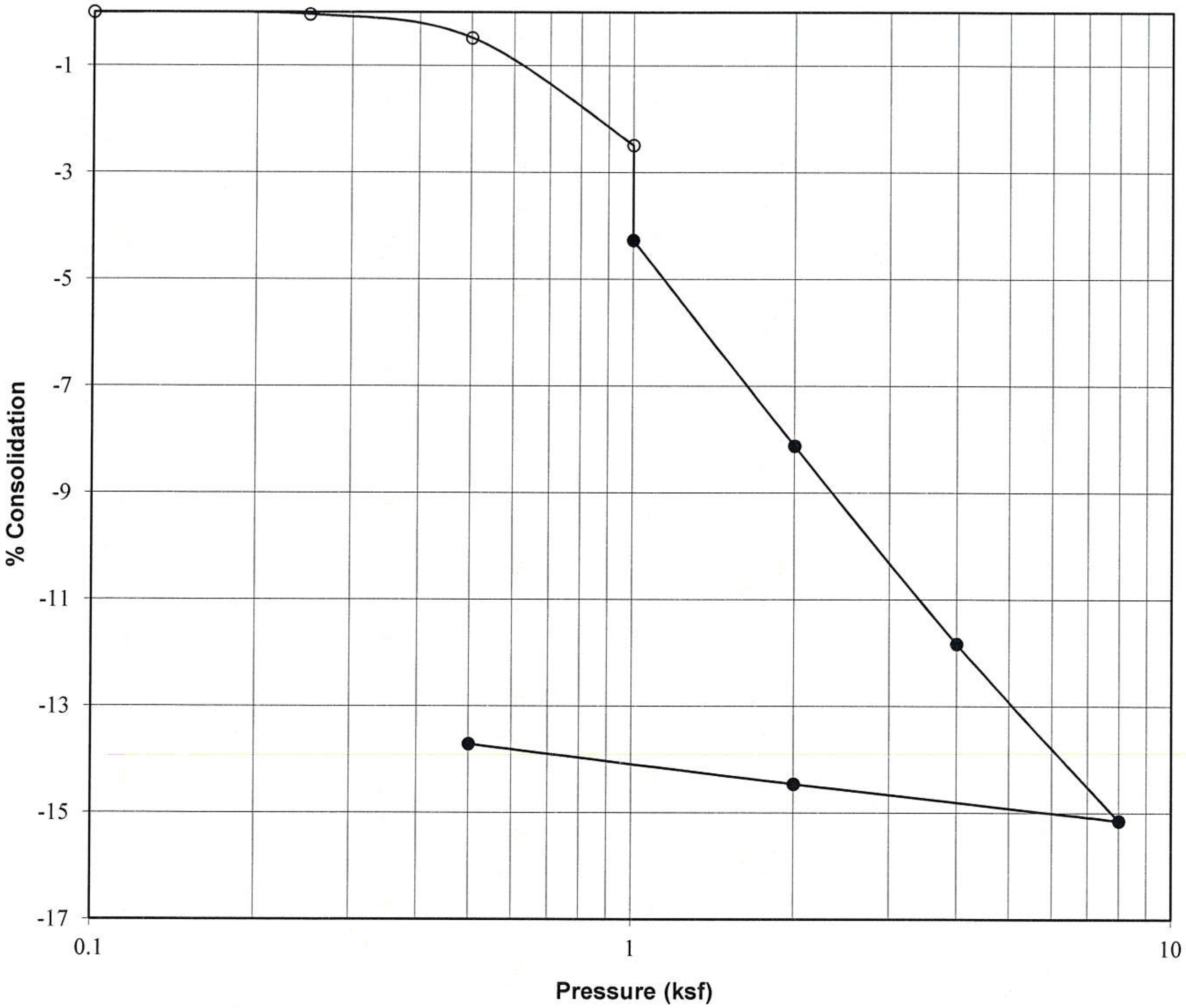
NOTES:
1. The logs are subject to the limitations, conclusions, and recommendations in this report.
2. Results of tests conducted on samples recovered are reported on the logs and any applicable graphs.
3. Strata lines on the logs represent approximate boundaries only. Actual transitions may be gradual.
4. In general, USCS symbols shown on the logs are based on visual methods only: actual designations (based on laboratory tests) may vary.

PROJECT NO.: 155082G

Earthtec Engineering

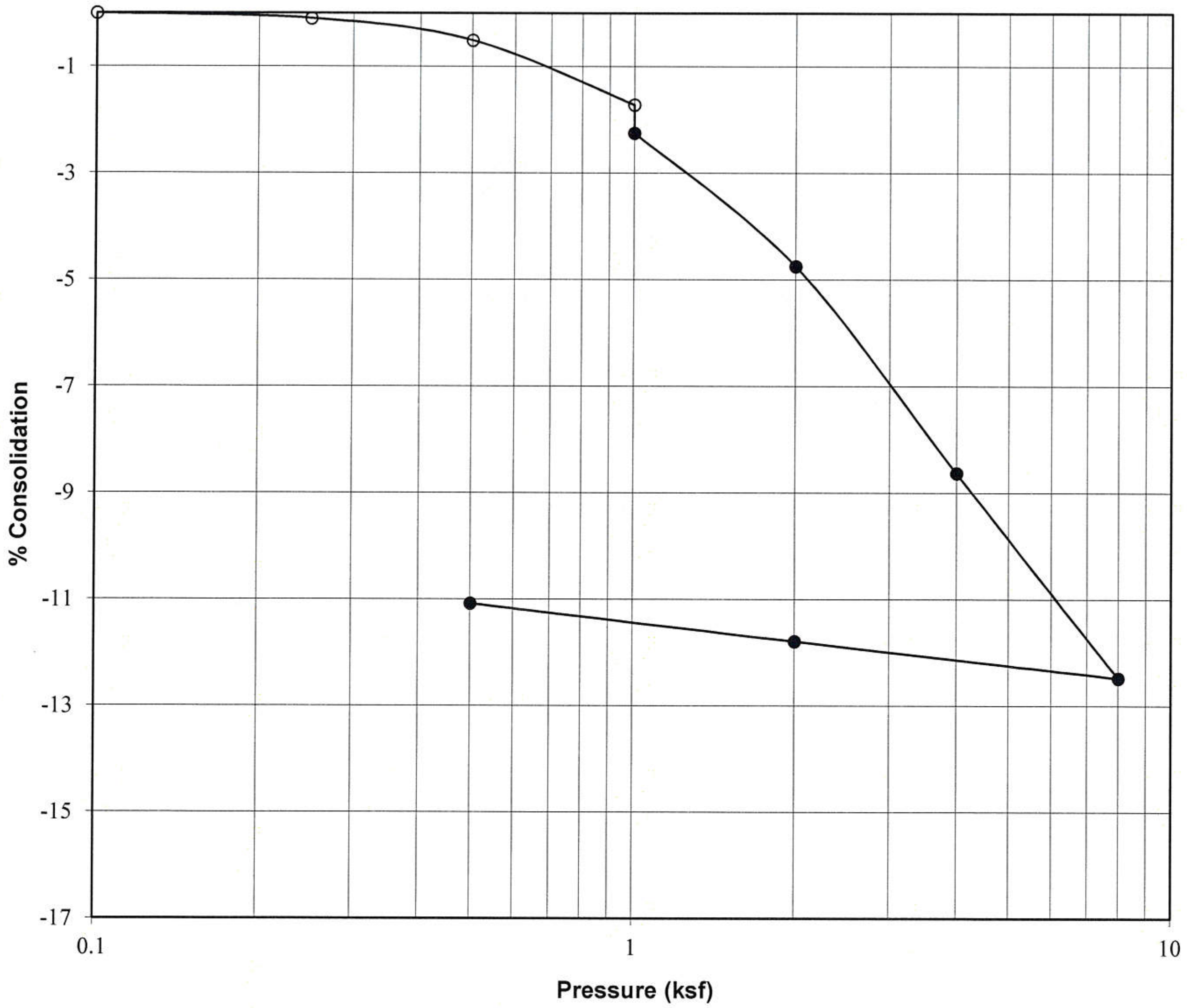
FIGURE NO.: 5

CONSOLIDATION - SWELL TEST



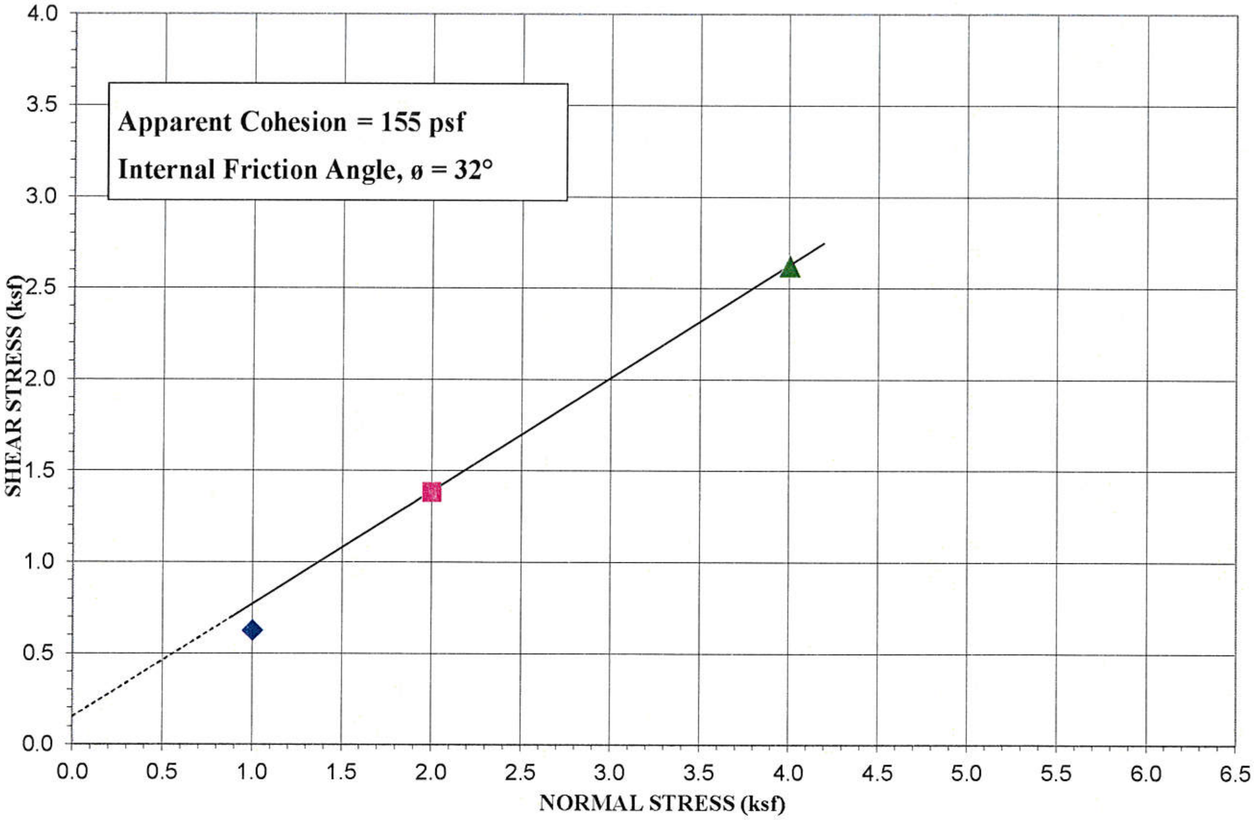
Project:	Lot 23 Big Sky Estates No. 1
Location:	TP-1
Sample Depth, ft:	3½
Description:	Block
Soil Type:	Sandy Lean CLAY (CL)
Natural Moisture, %:	21
Dry Density, pcf:	93
Liquid Limit:	31
Plasticity Index:	14
Water Added at:	1 ksf
Percent Collapse:	1.8

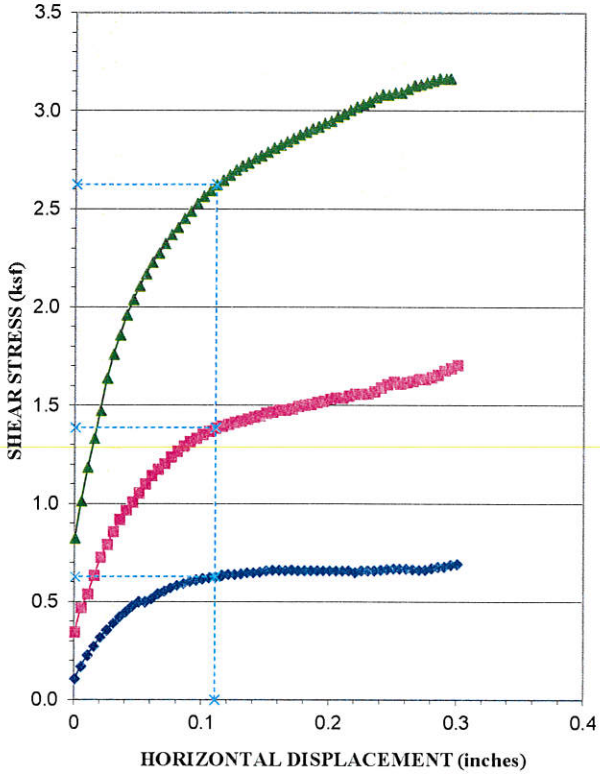
CONSOLIDATION - SWELL TEST



Project:	Lot 23 Big Sky Estates No. 1
Location:	TP-2
Sample Depth, ft:	4
Description:	Block
Soil Type:	Sandy Lean CLAY with gravel (CL)
Natural Moisture, %:	21
Dry Density, pcf:	95
Liquid Limit:	31
Plasticity Index:	15
Water Added at:	1 ksf
Percent Collapse:	0.5

DIRECT SHEAR TEST





Source: TP-2	Depth: 4.0 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	97.0	99.1	100.0
Dry Density After, pcf	102.7	104.1	105.6
Moisture % Before	21.3	21.3	21.3
Moisture % After	25.1	24.8	22.5
Normal Load, ksf	1.0	2.0	4.0
Shear Stress, ksf	0.63	1.39	2.62
Strain Rate	0.0001325 IN/SEC		
Sample Properties			
Cohesion, psf	155		
Friction Angle, ϕ	32		
Liquid Limit, %	31		
Plasticity Index, %	15		
Percent Gravel	17		
Percent Sand	32		
Percent Passing No. 200 sieve	51		
Classification	Sandy Lean CLAY with gravel (CL)		

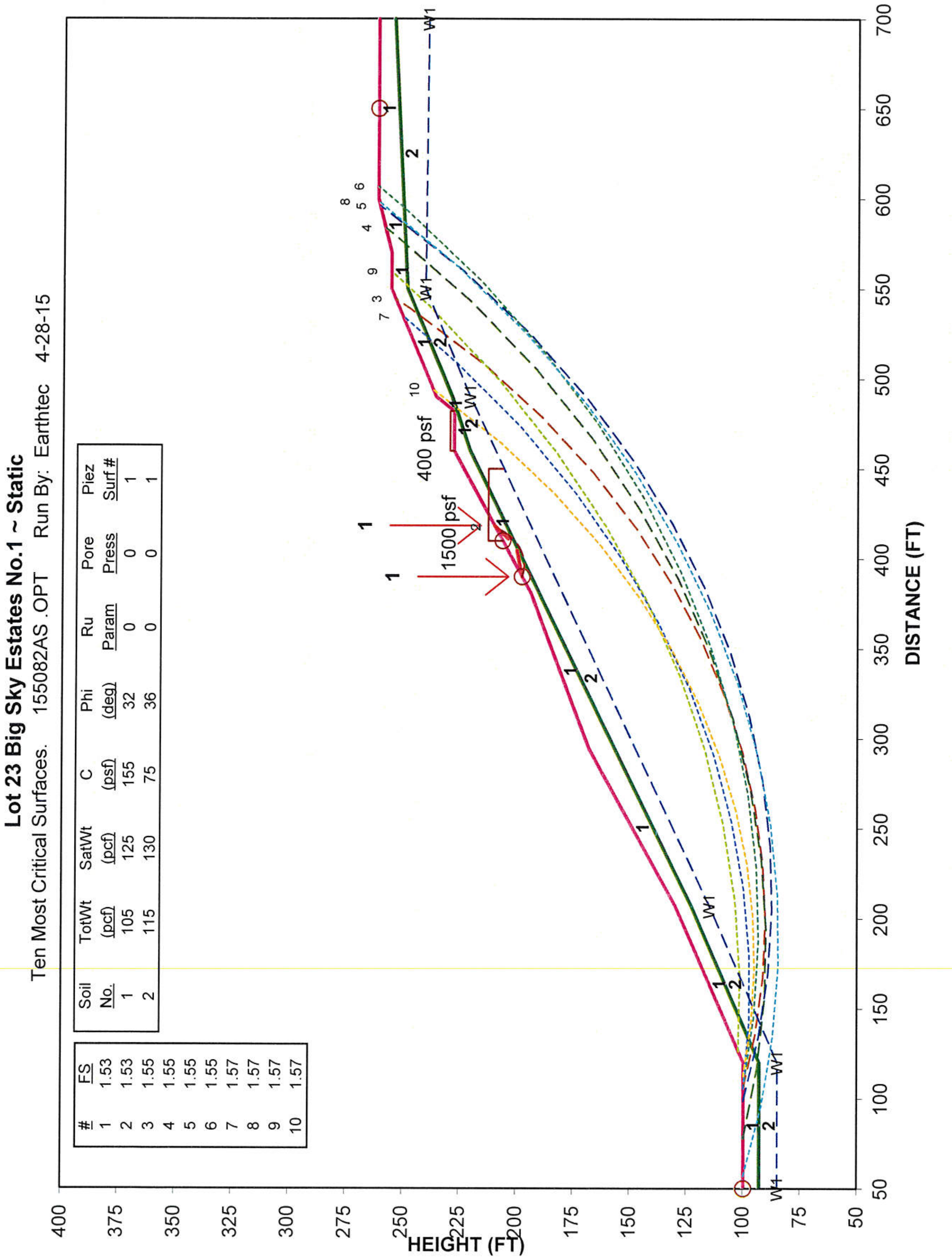
PROJECT: Lot 23 Big Sky Estates No. 1

PROJECT NO.: 155082G

Earthtec Engineering

FIGURE NO.: 8

STABILITY RESULTS



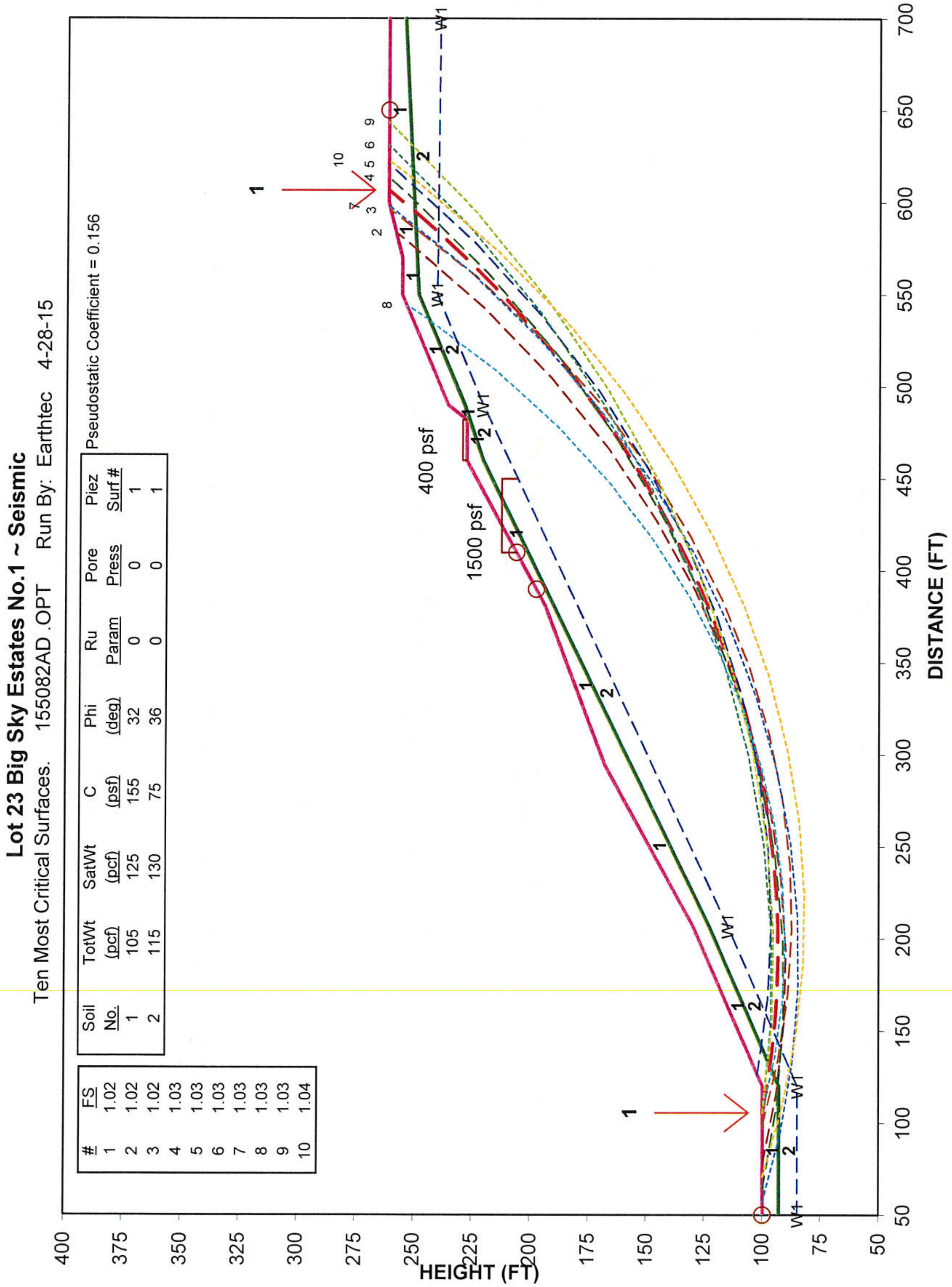
#	FS
1	1.53
2	1.53
3	1.55
4	1.55
5	1.55
6	1.55
7	1.57
8	1.57
9	1.57
10	1.57

Soil No.	TotWt (pcf)	SatWt (pcf)	C (psf)	Phi (deg)	Ru Param	Pore Press	Piez Surf #
1	105	125	155	32	0	0	1
2	115	130	75	36	0	0	1

PROJECT NO.: 155082

FIGURE NO.: 9

STABILITY RESULTS



Lot 23 Big Sky Estates No.1 ~ Seismic

Ten Most Critical Surfaces. 155082AD .OPT Run By: Earthtec 4-28-15

Soil No.	TotWt (pcf)	SatWt (pcf)	C (psf)	Phi (deg)	Ru Param	Pore Press	Piez Surf #
1	105	125	155	32	0	0	1
2	115	130	75	36	0	0	1

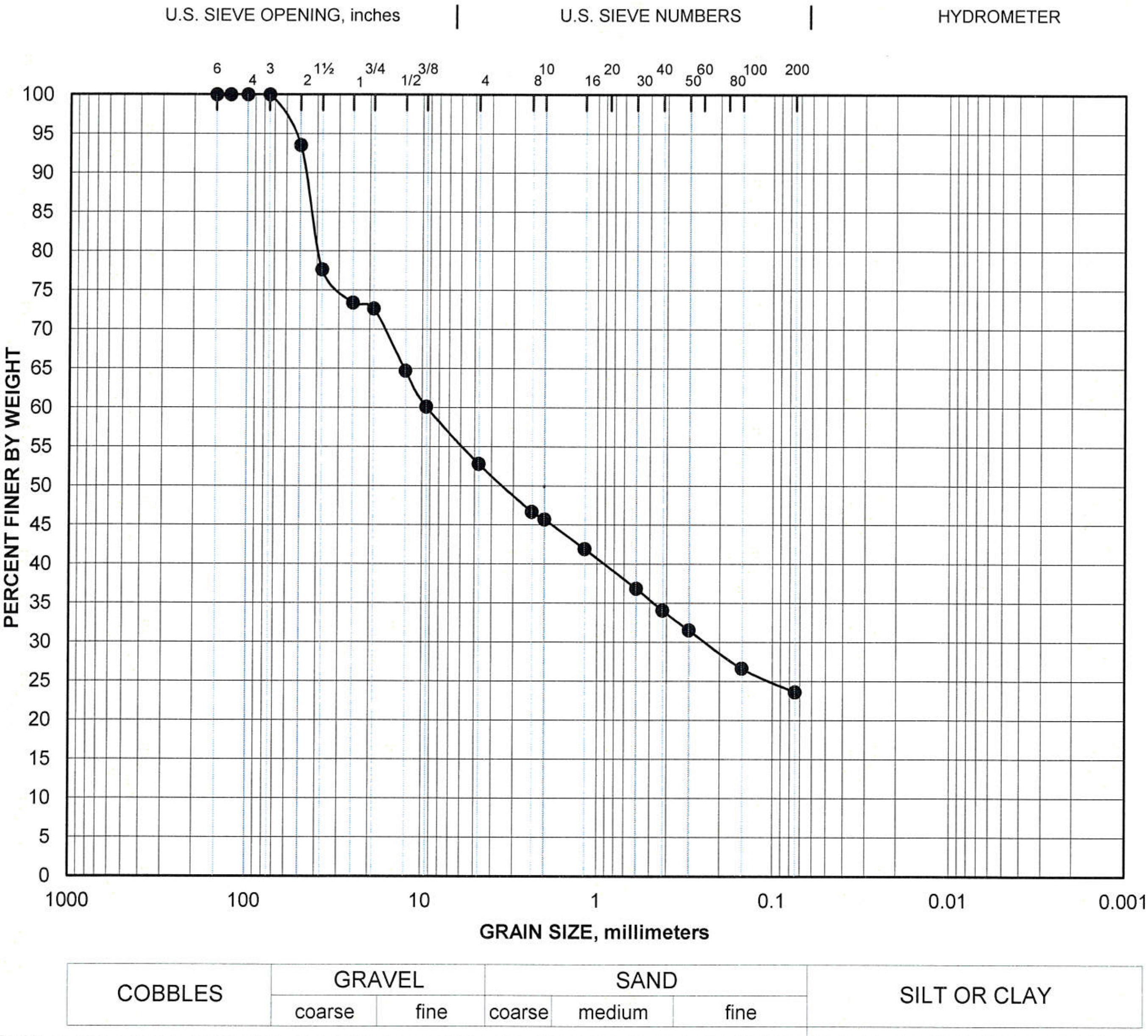
Pseudostatic Coefficient = 0.156

#	FS
1	1.02
2	1.02
3	1.02
4	1.03
5	1.03
6	1.03
7	1.03
8	1.03
9	1.03
10	1.04

PROJECT NO.: 155082

FIGURE NO.: 10

GRAIN SIZE DISTRIBUTION



Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**TP-1 @ 11'**	**Clayey GRAVEL with sand (GC)**	**5**	**24**	**10**	**14**		
■								
▲								
◆								
x								

Specimen Identification		D100	D85	D60	D30	D15	D10	%Gravel	%Sand	%Silt	%Clay
●	**TP-1 @ 11'**	**150**	**42.8**	**9.41**	**0.240**			**47**	**29**	**24**	
■											
▲											
◆											
x											

PROJECT NO.: 155082G	Earthtec Engineering	**FIGURE NO.:** 11