ENGINEERING •GEOTECHNICAL •ENVIRONMENTAL (ESA I & II) •
MATERIALS TESTING •SPECIAL INSPECTIONS •
ORGANIC CHEMISTRY • PAVEMENT
DESIGN •GEOLOGY

GEOTECHNICAL ENGINEERING STUDY

Asgard Heights Subdivision

About 3685 East 3300 North
Liberty, Utah

CMT PROJECT NO. 16942

FOR:
Mr. Dan Mabey
1715 Canyon Circle
Farmington, Utah 84025

August 19, 2021

CMT ENGINEERING
LABORATORIES

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Farmington, Utah 84025

Subject: Geotechnical Engineering Study
Asgard Heights Subdivision
About 3685 East 3300 North
Liberty, Utah
CMT Project No. 16942

Mr. Mabey:

Submitted herewith is the report of our geotechnical engineering study for the subject site. This report contains the results of our findings and an engineering interpretation of the results with respect to the available project characteristics. It also contains recommendations to aid in the design and construction of the earth related phases of this project.

On July 14, 2021, a CMT Engineering Laboratories (CMT) staff professional was on-site and supervised the excavation of 7 test pits extending to depths of about 5.5 to 7.5 feet below the existing ground surface. Soil samples were obtained during the field operations and subsequently transported to our laboratory for further testing and observation.

Conventional spread and/or continuous footings may be utilized to support the proposed residences, provided the recommendations in this report are followed. A detailed discussion of design and construction criteria is presented in this report.

We appreciate the opportunity to work with you at this stage of the project. CMT offers a full range of Geotechnical Engineering, Geological, Material Testing, Special Inspection services, and Phase I and II Environmental Site Assessments. With offices throughout Utah, Idaho and Arizona, our staff is capable of efficiently serving your project needs. If we can be of further assistance or if you have any questions regarding this project, please do not hesitate to contact us at 801-590-0394.

Sincerely,
CMT Engineering Laboratories

LICENSED PROFESSIONAL ENGINEER
374995
JEFFREY J.
EGBERT
8/19/21
STATE OF UTAH

Jeffrey J. Egbert, P.E., LEED A.P., M. ASCE
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Reviewed by:

Andrew M. Harris, P.E.
Geotechnical Division Manager

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1.0 INTRODUCTION

1.1 General

CMT Engineering Laboratories (CMT) was retained to conduct a geotechnical subsurface study for the proposed development of a residential subdivision. The parcel is situated at about 3685 East 3300 North in Liberty, Utah, as shown in the **Vicinity Map** below.

VICINITY MAP

1.2 Objectives, Scope and Authorization

The objectives and scope of our study were planned in discussions between Mr. Dan Mabey, property owner, and Mr. Andrew Harris of CMT Engineering Laboratories (CMT). In general, the objectives of this study were to define and evaluate the subsurface soil and groundwater conditions at the site, and provide appropriate foundation, earthwork, pavement and seismic recommendations to be utilized in the design and construction of the proposed development.

In accomplishing these objectives, our scope of work has included performing field exploration, which consisted of the excavating/logging/sampling of 7 test pits, performing laboratory testing on representative samples of the subsurface soils collected in the test pits, and conducting an office program, which consisted of correlating available data, performing engineering analyses, and preparing this summary report. This scope of work was authorized by returning a signed copy of our proposal dated July 13, 2021 and executed on July 14, 2021.

1.3 Description of Proposed Construction

We understand that the proposed structures will be single family residences which we project will have two levels of wood frame construction above grade and a single level of reinforced concrete below grade (basement). We project that maximum structural loads for the residences will be on the order of 4,000 pounds per lineal foot for walls and 50,000 pounds for columns. Floor slab loads are anticipated to be relatively light, with an average uniform loading not exceeding 100 pounds per square foot. If the structural loading conditions are different than we have projected, please notify us so that any appropriate modifications to our conclusions and recommendations contained herein can be made.

We anticipate that asphalt-paved residential streets will be constructed as part of the development. Traffic is projected to consist of a light volume of automobiles and pickup trucks, one or two daily medium-weight delivery trucks, a weekly garbage truck, and an occasional fire truck.

Site development will require some earthwork in the form of minor cutting and filling. A site grading plan was not available at the time of this report, but we project that maximum cuts and fills may be on the order of 3 to 4 feet. If deeper cuts or fills are planned, CMT should be notified to provide additional recommendations, if needed.

1.4 Executive Summary

Proposed residences can be supported upon conventional spread and continuous wall foundations. The most significant geotechnical aspects regarding site development include the following:

1. Approximately 3 to 6 inches of topsoil on the surface with some roots extending up to 1.5 feet in depth. Topsoil should be removed from below structures and pavements;
2. Subsurface natural soils consist of GRAVEL (GP-GM, GP-GC, GC) extending to the maximum depth explored of about 7.5 feet;
3. Groundwater was not encountered in the test pits; and
4. Foundations and floor slabs may be placed on suitable, undisturbed natural gravel soils or on properly placed and compacted structural fill extending to suitable, undisturbed natural soils.

CMT must assess that topsoil, undocumented fills, debris, disturbed or unsuitable soils have been removed and that suitable soils have been encountered prior to placing site grading fills, footings, slabs, and pavements.

In the following sections, detailed discussions pertaining to the site are provided, including subsurface descriptions, geologic/seismic setting, earthwork, foundations, lateral resistance, lateral pressure, floor slabs, and pavements.

2.0 FIELD EXPLORATION

In order to define and evaluate the subsurface soil and groundwater conditions, 7 test pits were excavated with a backhoe at the site to depths of approximately 5.5 to 7.5 feet below the existing ground surface. Locations of the test pits are shown on **Figure 1, Site Plan**, included in the Appendix. The field exploration was performed under the supervision of an experienced member of our geotechnical staff.

The subsurface soils encountered in the test pits were classified in the field based upon visual and textural examination, logged and described in general accordance with ASTM[1] D-2488. Representative soil samples were collected by obtaining disturbed "grab" samples from within the test pits. The samples were sealed in plastic bags for transport to the laboratory. The field classifications were supplemented by subsequent examination and testing of select samples in our laboratory. Graphical representations of the subsurface conditions encountered are presented on each individual Test Pit Log, **Figures 2 through 8**, included in the Appendix. A Key to Symbols defining the terms and symbols used on the logs, is provided as **Figure 9** in the Appendix.

Upon completion of logging and sampling, the test pits were backfilled with the excavated soils. When backfilling, minimal to no effort was made to compact the backfill and no compaction testing was performed. Thus, the test pit backfill is considered undocumented fill and settlement of the backfill in the test pits over time should be anticipated.

3.0 LABORATORY TESTING

Selected samples of the subsurface soils were subjected to various laboratory tests to assess pertinent engineering properties, as follows:

1. Moisture Content, ASTM D-2216, Percent moisture representative of field conditions
2. Atterberg Limits, ASTM D-4318, Plasticity and workability
3. Gradation Analysis, ASTM D-1140/C-117, Grain Size Analysis

Laboratory test results are presented on the test pit logs (**Figures 2 through 8**) and in the following Lab Summary table:

LAB SUMMARY

TEST PIT	DEPTH (feet)	SAMPLE TYPE	SOIL CLASS	MOISTURE CONTENT(%)	GRADATION			ATTERBERG LIMITS		
					GRAV.	SAND	FINES	LL	PL	PI
TP-1	4	Bag	GP-GM	1	80	11	9			
TP-4	3.5	Bag	GP-GC	2	69	25	6	25	17	8
TP-5	2.5	Bag	GC	5	67	12	21	28	20	8
TP-7	3	Bag	GC	3	57	26	17			

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[1] American Society for Testing and Materials

4.0 GEOLOGIC & SEISMIC CONDITIONS

4.1 Geologic Setting

The subject site is located in the east-central portion of Weber County in north-central Utah on the western margin of Ogden Valley. The Ogden Valley is a small valley on the eastern side of the Wasatch Mountain Range in the Wasatch Hinterlands section of the Middle Rocky Mountain Physiographic Province of north-central Utah. The Wasatch Hinterlands are described by Stokes[2] as "a belt of mixed, moderately rugged topography" located between the Wasatch Mountains to the west and the Uinta Mountains to the east. Stokes further describes the area as having "varied and unorganized topography with hilly areas dominating valley areas." The subject site sits at an elevation of approximately 5,094 feet above sea level.

Much of northwestern Utah, including the portions of the Ogden Valley, was also previously covered by the Pleistocene age Lake Bonneville. The Great Salt Lake, located to the west, is a remnant of this ancient fresh water lake. Lake Bonneville reached a high-stand elevation of between approximately 5,160 and 5,200 feet above sea level at between 18,500 and 17,400 years ago. Approximately 17,400 years ago, the lake breached its basin in southeastern Idaho and dropped by almost 300 feet relatively fast as water drained into the Snake River. Following this catastrophic release, the lake level continued to drop slowly over time, primarily driven by drier climatic conditions, until reaching the current level of the Great Salt Lake. Shoreline terraces formed at the high-stand elevation of the lake and several subsequent lower lake levels are visible in places on the mountain slopes surrounding the valleys of northwestern Utah. Much of the sediment within the valley was deposited as lacustrine sediments during both the transgressive (rise) and regressive (fall) phases of Lake Bonneville.

The geology of the Huntsville, Utah 7.5 minute quadrangle, including the location of the subject site, has been mapped by Sorensen[3]. The surficial geology at the location of the subject site and adjacent areas is mapped as "Silt Deposits" (Map Unit Qs) dated to be Pleistocene. Unit Qs is described in the referenced map as "Tan silt and sand forming extensive flats in Ogden Valley; deposited during high stands of Lake Bonneville, but may include older alluvial units; thickness 0-60m." No fill is mapped at the site. Refer to the **Geologic Map**, shown on the following page.

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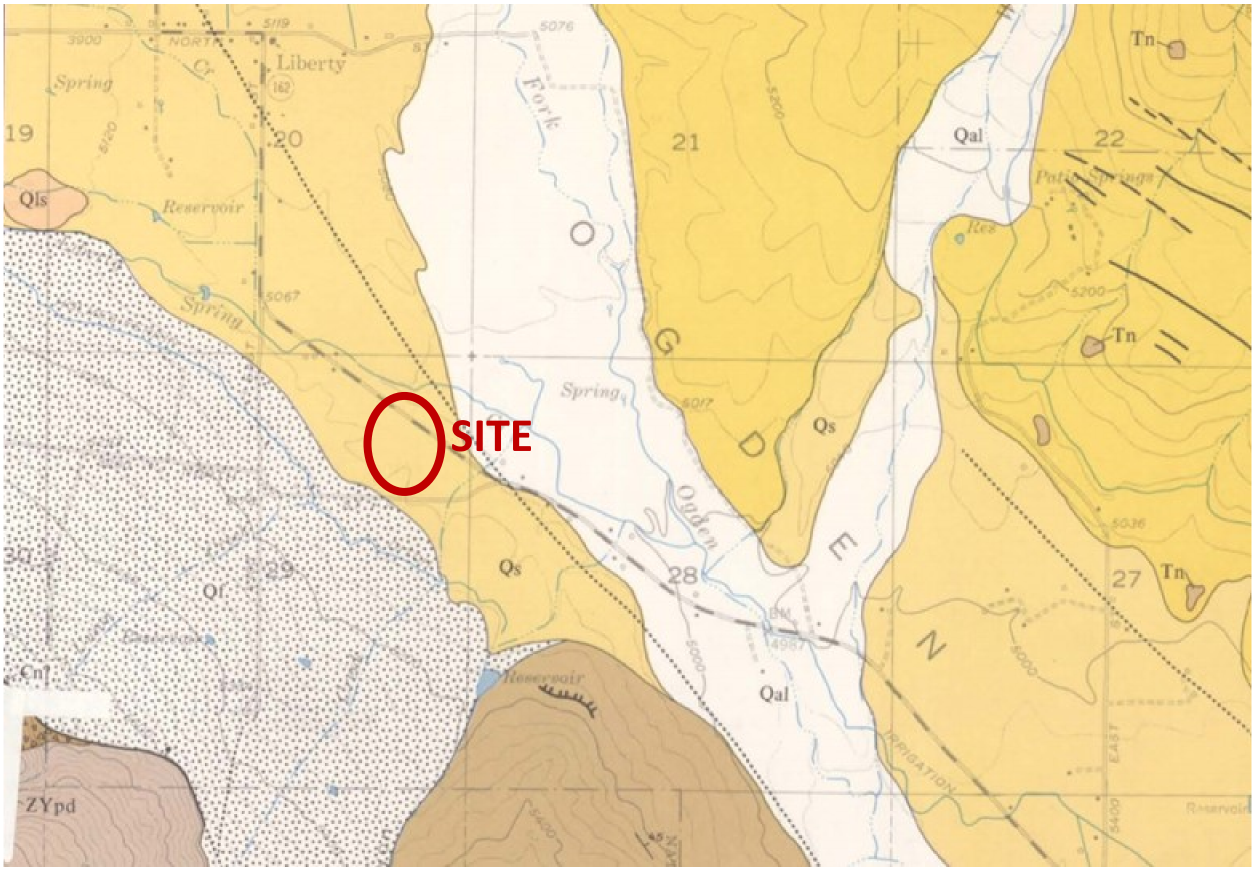
[2] Stokes, W.L., 1986, *Geology of Utah*; Utah Museum of Natural History, University of Utah, and Utah Geological and Mineral Survey, Department of Natural Resources, p. 243

[3] Sorensen, M.L., Crittenden, M.D., 1979, Geologic Map of the Huntsville Quadrangle, Weber and Cache Counties, Utah; U.S. Geological Survey Geologic Quadrangle Map GQ-1503, Scale 1:24,000.



GEOLOGIC MAP

4.2 Faulting

No active surface fault traces are shown on the referenced geologic map crossing, adjacent to, or projecting toward the subject site. The nearest mapped active fault is the Ogden Valley north fork fault 0.4 miles to the northeast. Note that the site will likely experience significant shaking if an earthquake were to occur along this fault segment.

4.3 Seismicity

4.3.1 Site Class

Utah has adopted the International Building Code (IBC) 2018, which determines the seismic hazard for a site based upon 2014 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). For site class definitions, IBC 2018 Section 1613.2.2 refers to Chapter 20, Site Classification Procedure for Seismic Design, of ASCE[4] 7-16, which stipulates that the average values of shear wave velocity, blow count and/or shear strength within the upper 100 feet (30 meters) be utilized to determine seismic site class.

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[4] American Society of Civil Engineers

Considering our explorations only extended to a depth of about 7.5 feet, it is our opinion the site best fits Site Class D – Stiff Soil Profile (without data, or default), which we recommend for seismic structural design.

4.3.2 Seismic Design Category

The 2014 USGS mapping utilized by the IBC provides values of peak ground, short period and long period spectral accelerations for the Site Class B/C boundary and the Risk-Targeted Maximum Considered Earthquake (MCE_R). This Site Class B/C boundary represents average bedrock values for the Western United States and must be corrected for local soil conditions. The Seismic Design Categories in the International Residential Code (IRC 2018 Table R301.2.2.1.1) are based upon the Site Class as addressed in the previous section. For Site Class D (default) at site grid coordinates of 41.3140 degrees north latitude and -111.8576 degrees west longitude, $\mathbf{S_{DS}}$ is 0.836 and the **Seismic Design Category** is D_2.

4.3.3 Liquefaction

Liquefaction is defined as the condition when saturated, loose, sandy soils lose their support capabilities because of excessive pore water pressure which develops during a seismic event. Clayey soils, even if saturated, will generally not liquefy during a major seismic event.

A special liquefaction study was not performed for this site. We encountered unsaturated, medium dense (estimated) gravel soils within the depths we explored. In our opinion, the soils we encountered have a very low liquefaction potential.

4.4 Other Geologic Hazards

No landslide deposits or features, including lateral spread deposits, are mapped on or adjacent to the site on the referenced geologic map. The site is not located within a mapped or active potential debris flow, stream flooding[5], or rock fall hazard area.

5.0 SITE CONDITIONS

5.1 Surface Conditions

At the time the test pits were excavated the site consisted of undeveloped land vegetated with grasses, weeds, brush and trees. A small creek channel runs through the site from the northeast to the southwest. The site grade slopes downward to the north-northwest with an overall gradient of about 130 feet. Based upon aerial photos readily available online dating back to 1993, the site appears to have remained relatively unchanged since that time. The site is bounded on the north, east, and west by undeveloped land and a few residences, and on the south by Nordic Valley Road (see **Vicinity Map** in **Section 1.1** above).

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[5] https://msc.fema.gov/portal/search?AddressQuery=100%20South%20Highway%2039%2C%20Huntsville%2C%20UTah#searchresultsanchor

5.2 Subsurface Soils

At the locations of the test pits we encountered approximately 3 to 6 inches of topsoil at the surface, but roots were noted to extend up to about 1.5 feet below the surface. Natural soils observed beneath the topsoil consisted of Poorly Graded GRAVEL with silt (GP-GM), Poorly Graded GRAVEL with clay (GP-GC), and Clayey GRAVEL (GC), all with varying amounts of sand, and cobble, extending to the maximum depth explored of about 7.5 feet.

The natural gravel soils were dry to moist, brown to light brown in color, and estimated to be medium dense. These soils are projected to exhibit moderately high strength and low compressibility characteristics.

For a more descriptive interpretation of subsurface conditions, please refer to the test pit logs, **Figures 2 through 8**, which graphically represent the subsurface conditions encountered. The lines designating the interface between soil types on the logs generally represent approximate boundaries - in situ, the transition between soil types may be gradual.

5.3 Groundwater

Groundwater was not encountered at the time of our field explorations within the maximum depth explored of about 7.5 feet below the existing ground surface. Therefore, groundwater is not anticipated to be encountered during construction.

Groundwater levels can fluctuate as much as 1.5 to 2 feet seasonally. Numerous other factors such as heavy precipitation, irrigation of neighboring land, and other unforeseen factors, may also influence ground water elevations at the site. The detailed evaluation of these and other factors, which may be responsible for ground water fluctuations, and the magnitude of potential fluctuations, is beyond the scope of this study.

5.4 Site Subsurface Variations

Based on the results of the subsurface explorations and our experience, variations in the continuity and nature of subsurface conditions should be anticipated. Due to the heterogeneous characteristics of natural soils, care should be taken in interpolating or extrapolating subsurface conditions between or beyond the exploratory locations.

Also, when logging and sampling of the test pits was completed, the test pits were backfilled with the excavated soils but minimal to no effort was made to compact these soils. Thus, the test pit backfill is considered undocumented fill and settlement of the backfill in the test pits over time should be anticipated.

6.0 SITE PREPARATION AND GRADING

6.1 General

All deleterious materials should be stripped from the site prior to commencement of construction activities. This includes vegetation, topsoil, loose and disturbed soils, etc. Based upon the conditions observed in the test pits there is topsoil on the surface of the site which we estimated to be about 3 to 6 inches in thickness. When stripping and grubbing, topsoil should be distinguished by the apparent organic content and not solely by color; thus we estimate that topsoil stripping will need to include the upper 3 to 6 inches. However, deep, large roots may be encountered where trees and larger bushes are located or were previously located at the site; such large roots should be removed.

Following stripping and grubbing the site should be observed by a CMT geotechnical engineer to assess that suitable natural soils have been exposed and any deleterious materials, loose and/or disturbed soils have been removed, prior to placing site grading fills, footings, slabs, and pavements.

Fill placed over large areas to raise overall site grades can induce settlements in the underlying natural soils. If more than 5 feet of site grading fill is anticipated over the natural ground surface, we should be notified to assess potential settlements and provide additional recommendations as needed. These recommendations may include placement of the site grading fill far in advance to allow potential settlements to occur prior to construction.

6.2 Temporary Excavations

Excavations deeper than 8 feet are not anticipated at the site. Groundwater was not encountered within the depths explored, about 5.5 to 7.5 feet at the time of our field explorations, and thus is not anticipated to be encountered in excavations.

The natural soils encountered at this site consisted of gravel. For sandy/gravelly (cohesionless) soils, temporary construction excavations not exceeding 4 feet in depth should be no steeper than one-half horizontal to one vertical (0.5H:1V). For excavations up to 8 feet and above groundwater, side slopes should be no steeper than one horizontal to one vertical (1H:1V). Excavations encountering saturated cohesionless soils will be very difficult to maintain, and will require very flat side slopes and/or shoring, bracing and dewatering.

In clayey (cohesive) soils, temporary construction excavations not exceeding 4 feet in depth may be constructed with near-vertical side slopes. Temporary excavations up to 8 feet deep, above or below groundwater, may be constructed with side slopes no steeper than one-half horizontal to one vertical (0.5H:1V).

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. All excavations should be made following OSHA safety guidelines.

6.3 Fill Material

Following are our recommendations for the various fill types we anticipate will be used at this site:

FILL MATERIAL TYPE	DESCRIPTION | RECOMMENDED SPECIFICATION
Structural Fill	Placed below structures, flatwork and pavement. Well-graded sand/gravel mixture, with maximum particle size of 4 inches, a minimum 70% passing 3/4-inch sieve, a maximum 20% passing the No. 200 sieve, and a maximum Plasticity Index of 10.
Site Grading Fill	Placed over larger areas to raise the site grade. Sandy to gravelly soil, with a maximum particle size of 6 inches, a minimum 70% passing 3/4-inch sieve, a maximum 50% passing No. 200 sieve, and a maximum Plasticity Index of 15.
Non-Structural Fill	Placed below non-structural areas, such as landscaping. On-site soils or imported soils, with a maximum particle size of 8 inches, including silt/clay soils not containing excessive amounts of degradable/organic material (see discussion below).
Stabilization Fill	Placed to stabilize soft areas prior to placing structural fill and/or site grading fill. Coarse angular gravels and cobbles 1 inch to 8 inches in size. May also use 1.5-inch to 2.0-inch gravel placed on stabilization fabric, such as Mirafi RS280i, or equivalent (see **Section 6.6**).

On-site gravel soils may be suitable for use as structural fill, if processed to meet the requirements given above, and may also be used in site grading fill and non-structural fill situations.

Silt/clay soils, if encountered, are not suitable for use as structural fill, but may be used as site grading fill and non-structural fill. Note that silt/clay soils are moisture-sensitive, which means they are inherently more difficult to work with in proper moisture conditioning (they 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. We also recommend the site grading fill thickness using on-site silt/clay soils not exceed a maximum of 3 feet below structures, to minimize potential settlements.

All fill material should be approved by a CMT geotechnical engineer prior to placement.

6.4 Fill Placement and Compaction

The various types of compaction equipment available have their limitations as to the maximum lift thickness that can be compacted. For example, hand operated equipment is limited to lifts of about 4 inches and most "trench compactors" have a maximum, consistent compaction depth of about 6 inches. Large rollers, depending on soil and moisture conditions, can achieve compaction at 8 to 12 inches. The full thickness of each lift should be compacted to at least the following percentages of the maximum dry density as determined by ASTM D-1557 (or AASHTO[6] T-180) in accordance with the following recommendations:

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[6] American Association of State Highway and Transportation Officials

LOCATION	TOTAL FILL THICKNESS (FEET)	MINIMUM PERCENTAGE OF MAXIMUM DRY DENSITY
Beneath an area extending at least 4 feet beyond the perimeter of structures, and below flatwork and pavement (applies to structural fill and site grading fill) extending at least 2 feet beyond the perimeter	0 to 5 5 to 8	95 98
Site grading fill outside area defined above	0 to 5 5 to 8	92 95
Utility trenches within structural areas	--	96
Roadbase and subbase	-	96
Non-structural fill	0 to 5 5 to 8	90 92

Structural fills greater than 8 feet thick are not anticipated at the site. For best compaction results, we recommend that the moisture content for structural fill/backfill be within 2% of optimum. Field density tests should be performed on each lift as necessary to verify that proper compaction is being achieved.

6.5 Utility Trenches

For the bedding zone around the utility, we recommend utilizing sand bedding fill material that meets current APWA[7] requirements.

All utility trench backfill material below structurally loaded facilities (foundations, floor slabs, flatwork, pavements, etc.) should be placed at the same density requirements established for structural fill in the previous section.

Most utility companies and local governments are requiring Type A-1a or A-1b (AASHTO Designation) soils (sand/gravel soils with limited fines) be used as backfill over utilities within public rights of way, and the backfill be compacted over the full depth above the bedding zone to at least 96% of the maximum dry density as determined by AASHTO T-180 (ASTM D-1557). Some of the natural gravel soils (GP-GM, GP-GC) at this site may meet these specifications.

Where the utility does not underlie structurally loaded facilities and public rights of way, natural soils may be utilized as trench backfill above the bedding layer, provided they are properly moisture conditioned and compacted to the minimum requirements stated above in **Section 6.4**.

6.6 Stabilization

To stabilize soft subgrade conditions (if encountered), a mixture of coarse, clean, angular gravels and cobbles and/or 1.5- to 2.0-inch clean gravel should be utilized, as indicated above in **Section 6.3**. Often the amount of gravelly material can be reduced with the use of a geotextile fabric such as Mirafi RS280i or equivalent. Its use

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[7] American Public Works Association

will also help avoid mixing of the subgrade soils with the gravelly material. After excavating the soft/disturbed soils, the fabric should be spread across the bottom of the excavation and up the sides a minimum of 18 inches. Otherwise, it should be placed in accordance with the manufacturer's recommendation, including proper overlaps. The gravel material can then be placed over the fabric in compacted lifts as described above.

7.0 FOUNDATION RECOMMENDATIONS

The following recommendations have been developed on the basis of the previously described project characteristics, including the maximum structural loads discussed in **Section 1.3**, the subsurface conditions observed in the field and the laboratory test data, and standard geotechnical engineering practice.

7.1 Foundation Recommendations

Based on our geotechnical engineering analyses, the proposed residences may be supported upon conventional spread and/or continuous wall foundations placed on suitable, undisturbed natural gravel soils and/or on structural fill extending to suitable natural gravel soils. Footings may be designed using a net bearing pressure of 2,500 psf.

The term "net bearing pressure" refers to the pressure imposed by the portion of the structure located above lowest adjacent final grade, thus the weight of the footing and backfill to lowest adjacent final grade need not be considered. The allowable bearing pressure may be increased by 1/3 for temporary loads such as wind and seismic forces.

We also recommend the following:

1. Exterior footings subject to frost should be placed at least 30 inches below final grade.
2. Interior footings not subject to frost should be placed at least 16 inches below grade.
3. Continuous footing widths should be maintained at a minimum of 18 inches.
4. Spot footings should be a minimum of 24 inches wide.

7.2 Installation

Under no circumstances shall foundations be placed on undocumented fill, topsoil with organics, sod, rubbish, construction debris, other deleterious materials, frozen soils, or within ponded water. If other unsuitable soils are encountered, they must be completely removed and replaced with properly compacted structural fill.

Deep, large roots may be encountered where trees and larger bushes are located or were previously located at the site; such large roots should be removed. The base of footing excavations should be observed by a CMT geotechnical engineer to assess that suitable bearing soils have been exposed.

All structural fill should meet the requirements for such, and should be placed and compacted in accordance with **Section 6** above. The width of structural replacement fill below footings should be equal to the width of the footing plus 1 foot for each foot of fill thickness. For instance, if the footing width is 2 feet and the structural fill depth beneath the footing is 2 feet, the fill replacement width should be 4 feet, centered beneath the footing.

The minimum thickness of structural fill below footings should be equivalent to one-third the thickness of structural fill below any other portion of the foundations. For example, if the maximum depth of structural fill is 6 feet, all footings for the new structure should be underlain by a minimum 2 feet of structural fill.

7.3 Estimated Settlement

Foundations designed and constructed in accordance with our recommendations could experience some settlement, but we anticipate that total settlements of footings founded as recommended above will not exceed 1 inch, with differential settlements on the order of 0.5 inches over a distance of 25 feet. We expect approximately 50% of the total settlement to initially take place during construction.

7.4 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 footings and the supporting soils. In determining frictional resistance, a coefficient of 0.40 for natural gravel soils and structural fill, may be utilized for design. Passive resistance provided by properly placed and compacted structural fill above the water table may be considered equivalent to a fluid with a density of 350 pcf. A combination of passive earth resistance and friction may be utilized if the passive pressure component of the total is divided by 1.5.

8.0 LATERAL EARTH PRESSURES

We project that basement walls up to 8 feet tall will be constructed at this site. The lateral earth pressure values given below anticipate that native gravel soils will be used as backfill material, placed and compacted in accordance with the recommendations presented herein. If other soil types will be used as backfill, we should be notified so that appropriate modifications to these values can be provided, as needed.

The lateral pressures imposed upon subgrade facilities will depend upon the relative rigidity and movement of the backfilled structure. Following are the recommended lateral pressure values, which also assume that the soil surface behind the wall is horizontal and that the backfill within 3 feet of the wall will be compacted with hand-operated compacting equipment.

CONDITION	STATIC (psf/ft)*	SEISMIC (psf)**
Active Pressure (wall is allowed to yield, i.e. move away from the soil, with a minimum 0.001H movement/rotation at the top of the wall, where "H" is the total height of the wall)	34	210
At-Rest Pressure (wall is not allowed to yield)	53	559
Passive Pressure (wall moves into the soil)	450	50

*Equivalent Fluid Pressure (applied at 1/3 Height of 8-foot High Wall)
**Uniform Pressure, Seismic Only (applied at 1/2 Height of 8-foot High Wall)

9.0 FLOOR SLABS

Floor slabs may be established upon suitable, undisturbed, natural gravel soils and/or on structural fill extending to suitable natural gravel soils (same as for foundations). Under no circumstances shall floor slabs be established directly on any topsoil, undocumented fills, loose or disturbed soils, sod, rubbish, construction debris, other deleterious materials, frozen soils, or within ponded water.

In order to facilitate curing of the concrete, we recommend that floor slabs be directly underlain by at least 4 inches of "free-draining" fill, such as "pea" gravel or 3/4-inch to 1-inch minus, clean, gap-graded gravel. To help control normal shrinkage and stress cracking, the floor slabs should have the following features:

1. Adequate reinforcement for the anticipated floor loads with the reinforcement continuous through interior floor joints;
2. Frequent crack control joints; and
3. Non-rigid attachment of the slabs to foundation walls and bearing slabs.

10.0 DRAINAGE RECOMMENDATIONS

10.1 Surface Drainage

It is important to the long-term performance of foundations and floor slabs that water not be allowed to collect near the foundation walls and infiltrate into the underlying soils. We recommend the following:

1. All areas around each residence should be sloped to provide drainage away from the foundations. We recommend a minimum slope of 4 inches in the first 10 feet away from the structure. This slope should be maintained throughout the lifetime of the structure.

2. All roof drainage should be collected in rain gutters with downspouts designed to discharge at least 10 feet from the foundation walls or well beyond the backfill limits, whichever is greater.

3. Adequate compaction of the foundation backfill should be provided. We suggest a minimum of 90% of the maximum laboratory density as determined by ASTM D-1557. Water consolidation methods should not be used under any circumstances.

4. Landscape sprinklers should be aimed away from the foundation walls. The sprinkling systems should be designed with proper drainage and be well-maintained. Over watering should be avoided.

5. Other precautions that may become evident during construction.

10.2 Foundation Subdrains

The soils encountered at this site primarily consisted of gravel (GP-GM, GP-GC, GC), which are Group 1 soils per IRC[8] 2018. Thus, perimeter foundation subdrains are not needed for this site.

11.0 PAVEMENTS

All pavement areas must be prepared as discussed above in **Section 6.1**. Under no circumstances shall pavements be established over topsoil, undocumented fills (if encountered), loose or disturbed soils, sod, rubbish, construction debris, other deleterious materials, frozen soils, or within ponded water.

In roadway areas, subsequent to stripping and prior to the placement of pavement materials, the exposed subgrade must be proof rolled by passing moderate-weight rubber tire-mounted construction equipment over the surface at least twice. If excessively soft or otherwise unsuitable soils are encountered, we recommend they be removed to a minimum of 18 inches below the subgrade level and replaced with structural fill.

We anticipate the natural gravel soils will exhibit good pavement support characteristics when saturated or nearly saturated. Based on our laboratory testing experience with similar soils, our pavement design utilized a California Bearing Ratio (CBR) of 15 for the natural gravel soils.

Given the projected traffic as discussed above in **Section 1.3**, the following pavement sections are recommended for approximately 4 ESAL's (18-kip equivalent single-axle loads) per day:

MATERIAL	PAVEMENT SECTION THICKNESS (inches)	
Asphalt	**3**	**3**
Road-Base	**8**	**4**
Subbase	**0**	**5**
Total Thickness	**11**	**12**

Untreated base course (UTBC) should conform to city specifications, or to 1-inch-minus UDOT specifications for A–1-a/NP, and have a minimum CBR value of 70%. Material meeting our specification for structural fill can be used for subbase, as long as the fines content (percent passing No. 200 sieve) does not exceed 15%. Roadbase and subbase material should be compacted as recommended above in **Section 6.4**. Asphalt material generally should conform to APWA requirements, having a ½-inch maximum aggregate size, a 75-gyration Superpave mix containing no more than 15% of recycled asphalt (RAP) and a PG58-28 binder.

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[8] International Residential Code

12.0 QUALITY CONTROL

We recommend that CMT be retained as part of a comprehensive quality control testing and observation program. With CMT on-site we can help facilitate implementation of our recommendations and address, in a timely manner, any subsurface conditions encountered which vary from those described in this report. Without such a program CMT cannot be responsible for application of our recommendations to subsurface conditions which may vary from those described herein. This program may include, but not necessarily be limited to, the following:

12.1 Field Observations

Observations should be completed during all phases of construction such as site preparation, foundation excavation, structural fill placement and concrete placement.

12.2 Fill Compaction

Compaction testing by CMT is required for all structural supporting fill materials. Maximum Dry Density (Modified Proctor, ASTM D-1557) tests should be requested by the contractor immediately after delivery of any fill materials. The maximum density information should then be used for field density tests on each lift as necessary to ensure that the required compaction is being achieved.

12.3 Excavations

All excavation procedures and processes should be observed by a geotechnical engineer from CMT or their representative. In addition, for the recommendations in this report to be valid, all backfill and structural fill placed in trenches and all pavements should be density tested by CMT. We recommend that freshly mixed concrete be tested by CMT in accordance with ASTM designations.

13.0 LIMITATIONS

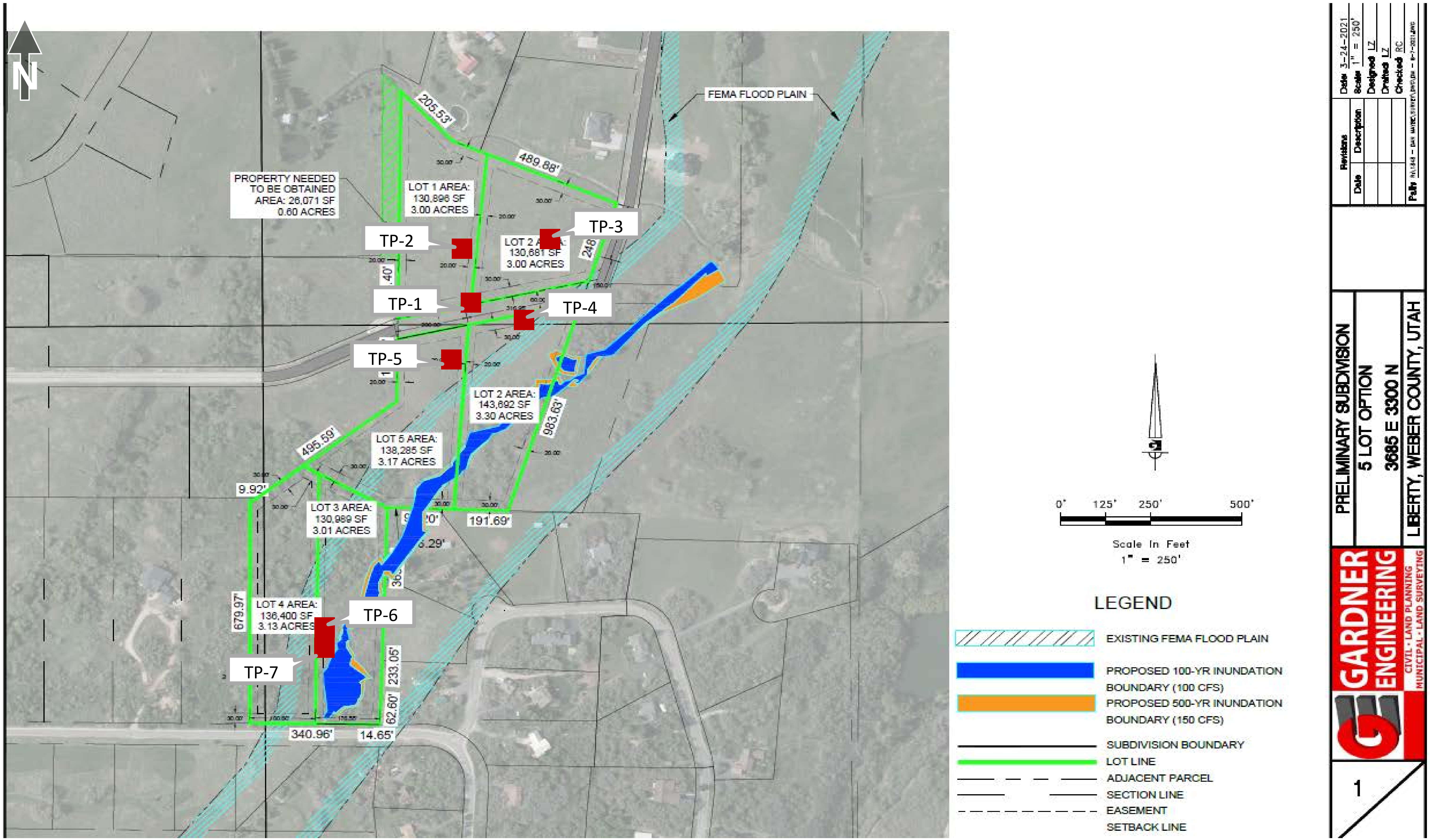
The recommendations provided herein were developed by evaluating the information obtained from the subsurface explorations and soils encountered therein. The exploration logs reflect the subsurface conditions only at the specific location at the particular time designated on the logs. Soil and ground water conditions may differ from conditions encountered at the actual exploration locations. The nature and extent of any variation in the explorations may not become evident until during the course of construction. If variations do appear, it may become necessary to re-evaluate the recommendations of this report after we have observed the variation.

Our professional services have been performed, our findings obtained, and our recommendations prepared in accordance with generally accepted geotechnical engineering principles and practices. This warranty is in lieu of all other warranties, either expressed or implied.

We appreciate the opportunity to be of service to you on this project. If we can be of further assistance or if you have any questions regarding this project, please do not hesitate to contact us at (801) 590-0394. To schedule materials testing, please call (801) 381-5141.

APPENDIX

SUPPORTING DOCUMENTATION



CMT ENGINEERING LABORATORIES

Asgard Heights Subdivision About 3685 East 3300 North, Liberty, Utah	**SITE PLAN**	Date:	20-Jul-2021	Figure:
		CMT No.:	16942	1

Asgard Heights Subdivision

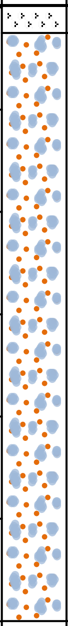
About 3685 E 3300 N, Liberty, UT

Test Pit Log

TP-1

Total Depth: 6'
Water Depth: (see Remarks)

Date: 7/14/21
Job #: 16942

Depth (ft)	GRAPHIC LOG	Soil Description	Sample Type	Sample #	Moisture (%)	Dry Density(pcf)	Gradation Gravel %	Sand %	Fines %	Atterberg LL	PL	PI
0		3" Topsoil with roots to 1.5'										
		Light Brown Angular Poorly Graded GRAVEL with silt (GP-GM), sand, cobbles, dry medium dense (estimated)										
1												
2												
3												
4			◣	1	1		80	11	9			
5												
		grades slightly moist										
6		END AT 6'										
7												
8												
9												
10												
11												
12												
13												
14												

Remarks: Groundwater not encountered during excavation.

Coordinates: 41.3144525°, -111.8581678°
Surface Elev. (approx): Not Given

Equipment: Rubber Tire Backhoe
Excavated By: Client Provided
Logged By: Olivia Roberts

CMT ENGINEERING LABORATORIES

Page: 1 of 1

Figure:
2

Asgard Heights Subdivision

About 3685 E 3300 N, Liberty, UT

Test Pit Log

TP-2

Total Depth: 6.5'
Water Depth: (see Remarks)

Date: 7/14/21
Job #: 16942

Depth (ft)	GRAPHIC LOG	Soil Description	Sample Type	Sample #	Moisture (%)	Dry Density(pcf)	Gradation			Atterberg		
							Gravel %	Sand %	Fines %	LL	PL	PI
0	▨	3" Topsoil with roots to 1' Light Brown Angular Poorly Graded GRAVEL with silt (GP-GM), sand, cobbles, dry medium dense (estimated)										
1	▨											
2	▨		◣	2								
3	▨											
4	▨											
5	▨	grades brown with more sand, slightly moist to moist										
6	▨		◣	3								
		END AT 6.5'										
7												
8												
9												
10												
11												
12												
13												
14												

Remarks: Groundwater not encountered during excavation.

Coordinates: 41.314892°, -111.8582396°
Surface Elev. (approx): Not Given

Equipment: Rubber Tire Backhoe
Excavated By: Client Provided
Logged By: Olivia Roberts

CMT ENGINEERING LABORATORIES

Figure:
3

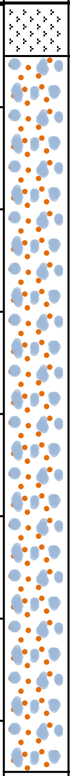
Asgard Heights Subdivision

About 3685 E 3300 N, Liberty, UT

Test Pit Log

TP-3

Total Depth: 7.5'
Water Depth: (see Remarks)
Date: 7/14/21
Job #: 16942



Depth (ft)	Soil Description	Sample Type	Sample #	Moisture (%)	Dry Density(pcf)	Gradation Gravel %	Gradation Sand %	Gradation Fines %	Atterberg LL	Atterberg PL	Atterberg PI
0	6" Topsoil with roots to 1.5'										
	Light Brown Angular Poorly Graded GRAVEL with silt (GP-GM), sand, cobbles, dry medium dense (estimated)										
3	grades slightly moist	◣	4								
6	grades moist										
7.5	END AT 7.5'										

Depth scale: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14

Remarks: Groundwater not encountered during excavation.

Coordinates: 41.3149834°, -111.857384°
Surface Elev. (approx): Not Given

Equipment: Rubber Tire Backhoe
Excavated By: Client Provided
Logged By: Olivia Roberts

Figure: 4

CMT ENGINEERING LABORATORIES

Asgard Heights Subdivision

About 3685 E 3300 N, Liberty, UT

Test Pit Log

TP-4

Total Depth: 6.5'
Water Depth: (see Remarks)

Date: 7/14/21
Job #: 16942

Depth (ft)	GRAPHIC LOG	Soil Description	Sample Type	Sample #	Moisture (%)	Dry Density(pcf)	Gradation Gravel %	Sand %	Fines %	Atterberg LL	PL	PI
0		3" Topsoil with roots to 1'										
		Light Brown to Brown Subangular Poorly Graded GRAVEL with clay (GP-GC), sand, cobble, dry medium dense (estimated)										
1												
2												
		grades slightly moist										
3												
			◣	5	2		69	25	6	25	17	8
4												
5												
6												
		END AT 6.5'										
7												
8												
9												
10												
11												
12												
13												
14												

Remarks: Groundwater not encountered during excavation.

Coordinates: 41.3142843°, -111.8576418°
Surface Elev. (approx): Not Given

Equipment: Rubber Tire Backhoe
Excavated By: Client Provided
Logged By: Olivia Roberts

Figure:

5

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Asgard Heights Subdivision

About 3685 E 3300 N, Liberty, UT

Test Pit Log

TP-5

Total Depth: 6'
Water Depth: (see Remarks)

Date: 7/14/21
Job #: 16942

Depth (ft)	GRAPHIC LOG	Soil Description	Sample Type	Sample #	Moisture (%)	Dry Density(pcf)	Gradation Gravel %	Gradation Sand %	Gradation Fines %	Atterberg LL	Atterberg PL	Atterberg PI
0	⁘	3-6" Topsoil with roots to 1.5'										
1 2	▨	Light Brown to Brown Subangular Clayey GRAVEL (GC) with sand, cobbles, dry medium dense (estimated)										
3	▨		◢	6	5		67	12	21	28	20	8
4 5	▨	grades with more clay, slightly moist	◢	7								
6		END AT 6'										
7 8 9 10 11 12 13 14												

Remarks: Groundwater not encountered during excavation.

Coordinates: 41.3139932°, -111.8583955°
Surface Elev. (approx): Not Given

Equipment: Rubber Tire Backhoe
Excavated By: Client Provided
Logged By: Olivia Roberts

CMT ENGINEERING LABORATORIES

Figure: 6

Asgard Heights Subdivision

About 3685 E 3300 N, Liberty, UT

Test Pit Log

TP-6

Total Depth: 5.5'
Water Depth: (see Remarks)

Date: 7/14/21
Job #: 16942

Depth (ft)	GRAPHIC LOG	Soil Description	Sample Type	Sample #	Moisture (%)	Dry Density(pcf)	Gradation			Atterberg		
							Gravel %	Sand %	Fines %	LL	PL	PI
0	⁘	6" Topsoil with some roots to 1'										
1	▨	Light Brown to Brown Subangular Clayey GRAVEL (GC) with sand, cobbles, dry medium dense (estimated)										
2												
3												
4			◢	8								
5												
		END AT 5.5'										
6												
7												
8												
9												
10												
11												
12												
13												
14												

Remarks: Groundwater not encountered during excavation.

Coordinates: 41.3116857°, -111.8556407°
Surface Elev. (approx): Not Given

Equipment: Rubber Tire Backhoe
Excavated By: Client Provided
Logged By: Olivia Roberts

Figure:
7

CMT ENGINEERING LABORATORIES

Asgard Heights Subdivision

About 3685 E 3300 N, Liberty, UT

Test Pit Log

TP-7

Total Depth: 5.5'
Water Depth: (see Remarks)

Date: 7/14/21
Job #: 16942

Depth (ft)	GRAPHIC LOG	Soil Description	Sample Type	Sample #	Moisture (%)	Dry Density(pcf)	Gradation			Atterberg		
							Gravel %	Sand %	Fines %	LL	PL	PI
0	⁘	6" Topsoil with roots to 1'										
1 2	▨	Light Brown to Brown Subangular Clayey GRAVEL (GC) with sand, cobbles, dry medium dense (estimated)										
3	▨		◢	9	3		57	26	17			
4 5	▨											
6 7 8 9 10 11 12 13 14		END AT 5.5'										

Remarks: Groundwater not encountered during excavation.

Coordinates: 41.3116401°, -111.8596484°
Surface Elev. (approx): Not Given

Equipment: Rubber Tire Backhoe
Excavated By: Client Provided
Logged By: Olivia Roberts

CMT ENGINEERING LABORATORIES

Figure: 8

Asgard Heights Subdivision

Key to Symbols

About 3685 E 3300 N, Liberty, UT

Date: 7/14/21

Job #: 16942

① Depth (ft)	② GRAPHIC LOG	③ Soil Description	④ Sample Type	⑤ Sample #	⑥ Moisture (%)	⑦ Dry Density(pcf)	Gradation ⑧			Atterberg ⑨		
							Gravel %	Sand %	Fines %	LL	PL	PI

COLUMN DESCRIPTIONS

① **Depth (ft.):** Depth (feet) below the ground surface (including groundwater depth - see water symbol below).

② **Graphic Log:** Graphic depicting type of soil encountered (see ② below).

③ **Soil Description:** Description of soils encountered, including Unified Soil Classification Symbol (see below).

④ **Sample Type:** Type of soil sample collected at depth interval shown; sampler symbols are explained below-right.

⑤ **Sample #:** Consecutive numbering of soil samples collected during field exploration.

⑥ **Moisture (%):** Water content of soil sample measured in laboratory (percentage of dry weight of sample).

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

⑧ **Gradation:** Percentages of Gravel, Sand and Fines (Silt/Clay), obtained from lab test results of soil passing the No. 4 and No. 200 sieves.

⑨ **Atterberg:** Individual descriptions of Atterberg Tests are as follows:

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

PL = Plastic Limit (%): Water content at which a soil changes from liquid to plastic behavior.

PI = Plasticity Index (%): Range of water content at which a soil exhibits plastic properties (= Liquid Limit - Plastic Limit).

STRATIFICATION	
Description	**Thickness**
Seam	Up to ½ inch
Lense	Up to 12 inches
Layer	Greater than 12 in.
Occasional	1 or less per foot
Frequent	More than 1 per foot

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

MOISTURE CONTENT
Dry: Absence of moisture, dusty, dry to the touch.
Moist: Damp / moist to the touch, but no visible water.
Wet: Visible water, usually soil below groundwater.

UNIFIED SOIL CLASSIFICATION SYSTEM (USCS)

MAJOR DIVISIONS			USCS SYMBOLS	②	TYPICAL DESCRIPTIONS
COARSE-GRAINED SOILS More than 50% of material is larger than No. 200 sieve size.	**GRAVELS** The coarse fraction retained on No. 4 sieve.	**CLEAN GRAVELS** (< 5% 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 (≥ 12% fines)	GM	●	Silty Gravels, Gravel-Sand-Silt Mixtures
			GC	▨	Clayey Gravels, Gravel-Sand-Clay Mixtures
	SANDS The coarse fraction passing through No. 4 sieve.	**CLEAN SANDS** (< 5% fines)	SW	⁘	Well-Graded Sands, Gravelly Sands, Little or No Fines
			SP	⁘	Poorly-Graded Sands, Gravelly Sands, Little or No Fines
		SANDS WITH FINES (≥ 12% 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 Sandy Silts with No Plasticity 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 of 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, Soils with High Organic Contents

Note: Dual Symbols are used to indicate borderline soil classifications (i.e. GP-GM, SC-SM, etc.).

SAMPLER SYMBOLS

◧	Block Sample
◩	Bulk/Bag Sample
⧗	Modified California Sampler 3.5" OD, 2.42" ID
⧗	D&M Sampler
▯	Rock Core
◩	Standard Penetration Split Spoon Sampler
▥	Thin Wall (Shelby Tube)

WATER SYMBOL

▽	Encountered Water Level
▼	Measured Water Level

(see Remarks on Logs)

1. The results of laboratory tests on the samples collected are shown on the logs at the respective sample depths.
2. The subsurface conditions represented on the logs are for the locations specified. Caution should be exercised if interpolating between or extrapolating beyond the exploration locations.
3. The information presented on each log is subject to the limitations, conclusions, and recommendations presented in this report.

CMT ENGINEERING LABORATORIES

Figure:

9