Geotechnical Engineering Services Report
Proposed Building
Lot 3, near S Parker Rd and Pine Ln
Parker, Colorado

Terradyne Project No.: C201056

Dallas Palmer
Trail Star Development, LLC.
425 N. Wilcox St. Suite 210
Parker, CO 80104

June 16, 2020

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June 16, 2020

Attn: Dallas Palmer
Trail Star Development, LLC.
425 N. Wilcox St. Suite 210
Parker, CO 80104

Re: **Geotechnical Engineering Services Report**
Proposed Commercial Building
Lot 3, near S Parker Rd and Pine Ln
Parker, CO 80138
Terradyne Project No.: C201056

Dear Mr. Palmer:

Terradyne Engineering, Inc. has completed a soil and foundation engineering report at the above referenced project site. The results of the exploration are presented in this report.

We appreciate and wish to thank you for the opportunity to service you on this project. Please do not hesitate to contact us if we can be of additional assistance during the Construction Materials Testing and Quality Control phases of construction.

Respectfully Submitted,

Very Truly Yours,
Terradyne Engineering, Inc.

COLORADO LICENSED PROFESSIONAL ENGINEER
YOSIEF W. ARAIA
53857
06/16/2020

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Yosief Araia, P.E.
Branch Manager

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EXECUTIVE SUMMARY

The soil conditions at the site of the proposed building at Lot 3, near S Parker Rd and Pine Ln, in Parker, Colorado were explored by drilling five (5) test borings to depths of 10 feet to 25 feet. Laboratory tests were performed on selected specimens to evaluate the engineering characteristics of various soil strata encountered in our borings.

The results of our exploration, laboratory testing and engineering evaluation indicate the soils underlying this site have low swell potential. Potential vertical movement on the order of 2-3 inches was estimated at the existing grade level for existing moisture conditions.

The proposed building structure may be supported by drilled straight shaft pier foundations, or shallow foundations. Straight shaft drilled piers, penetrating a minimum depth of 20 feet below existing grade. A minimum penetration of 5 feet into the claystone is required. Piers shall be sized for allowable end bearing capacity of 15,000 pounds per square foot and skin friction resistance of 1,200 pounds per square foot for the portion of pier embedded below a depth of 10-ft.
Spread / strip footings, supported on compacted in situ sandy lean clay may be designed for allowable net bearing pressures of 2,000 psf, based on dead load plus design live load considerations.

The floor slab, used with the drilled pier foundations or shallow foundations, may be supported on compacted subgrade or a structurally suspended floor slab may be utilized.

Groundwater seepage was not encountered in our borings at the time of our field exploration. Detailed descriptions of subsurface conditions and foundation design recommendations are included in this report.

This summary does not contain all the information that is included in the full report. The report should be read in its entirety to obtain a more complete understanding of the information provided.

1.0 PROJECT AUTHORIZATION AND SCOPE OF SERVICES

The services of Terradyne Engineering, Inc. were authorized on June 03, 2020 by Mr. Dallas Palmer of Trail Star development LLC, by approving our proposal No: CP201037 dated June 03, 2020.

Our scope of services included drilling five (5) soil test borings at the site to depths of approximately 10 feet to 25 feet below the existing ground surface, limited laboratory testing of select soil samples to evaluate pertinent physical properties, and to perform engineering analysis to develop foundation and pavement design criteria.

The scope of services did not include an environmental assessment for determining the presence or absence of wetlands, or hazardous or toxic materials in the soil, bedrock, surface water, groundwater, or air on or below, or around this site. Any statements in this report or on the boring logs regarding odors, colors, and unusual or suspicious items or conditions are strictly for informational purposes. Prior to development of this site, an environmental assessment is advisable.

2.0 PROJECT AND SITE DESCRIPTION

2.1 Project Description

The proposed project consists of a one to two story building having a footprint area of less than 10,000 square feet. Structural loading information is currently not available, however for the purpose of this report it is assumed that maximum wall loads on perimeter grade beams will be less than 3 kips per linear foot and maximum concentrated loads will be less than 100 kips. Detailed site grading information is not currently available, therefore we have assumed that the building will be constructed at or slightly above existing grades.
The foundation recommendations presented in this report are based on the available project information, project location, and the subsurface materials described in this report. If any of the noted information is incorrect, please inform Terradyne in writing so that we may amend the recommendations presented in this report, if appropriate and, if desired by the client. Terradyne will not be responsible for the implementation of its recommendations when it is not notified of changes in the project.

2.2 Site Location and Description

The site for the proposed project is on Lot 3, near S Parker Rd and Pine Ln, in Parker, Colorado. The proposed site is located within a commercial development that is bound by Pine Ln on the north S Twenty mile Rd on the west, Baldwin Gulch Trl on the south, and S Parker Rd lies to the east of the property.

The foundation recommendations presented in this report are based on the available project information, project location, and the subsurface materials described in this report. If any of the noted information is incorrect, please inform Terradyne in writing so that we may amend the recommendations presented in this report if appropriate and if desired by the client. Terradyne will not be responsible for the implementation of its recommendations when it is not notified of changes in the project.

3.0 SUBSURFACE CONDITIONS

3.1 Field and Laboratory Testing

The site subsurface conditions were explored with five (5) soil test borings advanced to depths of about 25 feet on borings B1 and B2, and to depths of 10 feet on borings B-3, B-4 and B-5, below the existing ground surface. The approximate boring locations are indicated on the Boring Location Plan enclosed in the Appendix. Copies of the Logs of Borings are also enclosed in the Appendix.

The borings were advanced utilizing continuous flight auger drilling methods and soil samples were routinely obtained during the drilling process. Drilling and sampling techniques were accomplished generally in accordance with ASTM procedures. Select soil samples were tested in the laboratory to determine material properties for our evaluation. Laboratory testing was accomplished generally in accordance with ASTM procedures.

3.2 Subsurface Conditions

As shown on the U.S. Geological Survey sheet of the Parker Quadrangle Geologic Map, the site is located within the Tdso, Interbedded olive claystone and sandstone formation. At this particular site the soil consists of sandy lean clay (CL), underlain by claystone down at final boring depth of about 25 feet.

The soils underlying the site may be grouped into two generalized strata with similar physical and engineering properties. The logs describe any noticeable changes that occur as depth increases related to soil type, moisture, color and hardness; interface between soil strata represent approximate boundaries. The transition between materials may be gradual. The soil stratigraphy at the boring location is presented on the Boring Logs. The engineering characteristics of the underlying soils, based on our field and laboratory test results, are summarized and presented in Table No. 1.

Table No. 1

Stratum		Depth Range Feet	Liquid Limit Range	Plasticity Index	Blows Per Foot
1.	Sandy Lean Clay (CL)	0 - 14	24 - 33	10 - 23	13 - 32
2.	Weathered Claystone	14 - 25	44 - 47	29 - 32	48 - 50/6”

The above description generally highlights the major soil stratification features and soil characteristics. The test boring logs should be consulted for specific information at the boring locations.

3.3 Groundwater

Ground water was not encountered in the borings upon completion of drilling, indicating that the continuous ground water level at the boring locations at the time of the exploration was either below the terminated depths of the borings, or that the soils encountered are relatively impermeable. Although groundwater was not encountered in the borings at this time, it is possible for a groundwater table to be present within the depths explored during other times of the year depending upon climatic and rainfall conditions. The groundwater levels presented in this report are the levels that were measured at the time of our field activities. We recommend that the Contractor determine the actual groundwater levels at the site at the time of the construction activities.

4.0 EVALUATION AND RECOMMENDATIONS

4.1 Vertical Movements

There are many plastic clays that swell when water is added to them and shrink when water is removed. Foundations constructed on these clays are subjected to large uplifting forces caused by the swelling.

Two factors contribute to potential shrink-swell problems within a building site. Problems can arise if a) the soil has expansive or shrinkage properties or b) environmental conditions cause the moisture levels in the soil to change.

Evaluation of the Shrink-Swell Potential of the Soils: Subsurface sampling, laboratory testing and data analysis is used to evaluate the shrink-swell potential of the soils under the foundations.

The Mechanism of Swelling: The mechanism of swelling in expansive clays is influenced by a number of factors. The expansion in clays is a result of changes in the soil-water system that disturbs the internal stress equilibrium. Clay particles have negative electrical charges on their surfaces and positively charged ends. The negative charges are balanced by actions in the soil-water and give rise to an electrical interparticle force field. In addition, adsorptive forces exist between the clay crystals and water molecules, and Van Der Waals surface forces exist between particles. Thus, there exists an internal electro-chemical force system that must be in equilibrium with the externally applied stresses and capillary tension in the soil water. If the soil-water chemistry is altered, either by changing the amount of water or chemical composition in the soil, the inter-particle force field will change. If the change in internal forces is not balanced by a corresponding change in the state of stress, the particle spacing changes until equilibrium is reached. This change in particle spacing manifests itself as a shrinkage or swelling.

Antecedent Rainfall Ratio: This is defined as the total monthly rainfall for the current and previous months prior to laying the slab, divided by twice the average monthly rate measured for the period. The intent of this ratio is to give a relative measure of ground moisture conditions at the time the slab is placed. Thus, if a slab is placed at the end of a wet period, the slab shall be expected to experience some loss of support around the perimeter as the wet soil begins to dry out and shrink. The opposite effect could be anticipated if the slab is placed at the end of an extended dry period; as the wet season occurs, uplift around the perimeter may occur as the soil at the edge of the slab gains in moisture content.

Age of Slab: The length of time since the slab was cast provides an indication of the type of swelling the soil profile may have beneath the slab.

Initial Moisture Condition and Moisture Variation: A volume change in an expansive soil mass is the result of increases or decreases in water content. The initial moisture content influences the swell and shrink potential of a soil. However, moisture content alone is useless as an indicator or predictor of shrink-swell potential. The relationship between moisture content and other soil characteristics, such as the Plastic Limit and Liquid Limit, must also be known.

If the moisture content is below or near the Plastic Limit, the soils may have a high potential to swell. Expansive soils with Liquidity Index[1] in the range of 0.20 to 0.40 tend to experience little additional swell.

[1] $$\text{LIQUIDITY INDEX} \equiv \frac{\text{NATURAL WATER CONTENT} - \text{PLASTIC LIMIT}}{\text{LIQUID LIMIT} - \text{PLASTIC LIMIT}}$$

The availability of water in an expansive soil profile is influenced by many environmental and manmade factors. Generally, the upper few feet of the profile are subjected to the widest ranges of moisture variation, and are the least restrained from movement by overburden. This upper stratum of the profile is referred to as the active zone. Moisture variation in the active zone of a natural soil profile is affected by climatic cycles at the surface and fluctuating groundwater levels at the lower moisture boundary. The superficial boundary moisture conditions are changed by placing a barrier, such as a building floor slab or pavement, between the soil and atmospheric environment. Other causes of moisture variation result from altered drainage conditions or manmade sources of water, such as irrigation or leaky plumbing. The latter factors are difficult to quantify and incorporate into the analysis, but shall be controlled to the extent possible for each situation. For example, proper drainage and attention to landscaping are simple means of minimizing moisture fluctuations near structures, and shall always be taken into consideration.

Manmade Conditions That Can Be Altered: There are a number of factors that can influence whether a soil might shrink or swell and the magnitude of this movement. For the most part, the owner and/or designer have some control over whether these factors can be avoided, and if not avoided, the degree to which these factors may influence the shrink-swell process.

Lot Drainage: How a lot is graded affects the accumulation of surface water around the slab. Most builders are aware of the importance of grading the soil away from the structure so that rainwater does not collect and pond adjacent to the foundation. If allowed to accumulate next to the foundation, water may infiltrate the expansive soils underlying the foundation, which could cause the foundation to settle. Similarly, runoff from surface water drainage patterns and swales must not collect adjacent to the foundation.

Topography: As it swells, soil heaves perpendicularly to the ground surface or slope, but as it shrinks, it recedes in the direction of gravity and gradually moves downslope in a sawtooth fashion over a number of shrink-swell cycles. In addition to this shrink-swell influence, soil will exhibit viscoelastic properties and creep downhill under the steady influence of the weight of the soil. Therefore, to avoid a structure constructed on this slope from moving downhill with the soil, it must be designed to compensate for this lateral soil influence.

Pre-Construction Vegetation: A large amount of vegetation, especially large trees, on a site prior to construction may have desiccation at the site. Constructing over a desiccated soil can produce some dramatic instances of heave and associated structural distress and damage as it becomes wet.

Post-Construction Vegetation: The type, amount, and location of vegetation that has grown since construction can cause localized desiccation. Planting trees or large shrubs near a building can result in the loss of foundation support as the vegetation robs moisture from the foundation soil. Conversely, the opposite effect can occur if flowerbeds or shrubs are planted next to the foundation and these beds are kept well-watered or flooded. This practice can result in swelling of the soil around the perimeter where the soil remains wet.

Summation: It is beyond the scope of this investigation to do more than point out the factors that may influence the amount and type of swell a slab-on-grade foundation may be subjected to during its lifetime. The design engineer must be aware of these factors in developing his design, using his engineering experience and judgment as a guide.

4.2 Site Preparation

In any areas where soil-supported floor slabs or pavement are to be constructed, vegetation and all loose or organic material shall be stripped and removed from the site. Subsequent to stripping operations, the subgrade shall be proofrolled to identify soft zones. Any soft zone detected shall be removed to a firm subgrade soils and replaced with compacted suitable soils to reach subgrade level. Upon the acceptance of proofrolling operations the subgrade shall be scarified to a minimum depth of 8 inches, moisture conditioned and compacted to a 95 percent of maximum dry density as determined by ASTM D 698, between optimum and 4 percentage points above of optimum moisture content. The exposed subgrade shall not be allowed to dry out prior to placing structural fill.

Select fill material used at this site shall be clayey sand (SC), lean clay with gravel (CL) or clayey gravel (GC) with maximum liquid limit of 35 percent and plasticity index (PI) between 5 and 20. The fill shall be compacted to at least 95 percent of the maximum dry density as determined by ASTM D 698, within ± 2 percentage points of optimum moisture content

4.3 Foundation Recommendations

The most positive means of limiting movements due to swelling soils is to support the building structure on drilled pier foundation system. The use of a shallow foundation system is also feasible, provided that the recommended Site Preparation is performed.

The floor slab, utilized with the drilled pier foundation system or shallow spread footings, may consist of a structurally suspended floor system, or a soil supported floor slab may be considered if some floor movement can be tolerated and the recommended site work activities to reduce the swell potential are performed.

4.3.1 Drilled Pier Foundations

The proposed structure at the subject property shall be supported by a drilled pier foundation system. The drilled straight shaft pier system should be designed and constructed in accordance with the following criteria.

Drilled piers shall be founded at a minimum depth of 20 feet below the existing grade. Piers should be designed for a maximum allowable end bearing pressure of 15,000 PSF, and allowable skin friction (side shear) of 1200 PSF for the portion embedded below a depth of 10-ft, all other skin friction should be ignored.

If groundwater is encountered during the installation of the piers, dewatering will be required during drilled pier installation. Concrete should be onsite at the time of drilling and placed immediately after the pier is drilled and inspected thus minimizing the potential for dewatering. A tremie pipe should be utilized for concrete placement. Concrete should not be placed in more than 3 inches of water. Concrete should not be allowed to freefall more than 6 feet. Concrete should be placed utilizing full depth vibratory consolidation methods to minimize segregation and voids.

The installation of the piers should be observed by a representative of the geotechnical engineer to verify piers are bearing in suitable strata. The piers should be inspected for plumb, hole clean out, and placement of reinforcing steel.

Please ensure that the requirements contained herein are reflected in any construction plans developed for this site.

Uplift Forces: Moisture variation in the soils at this site can cause vertical movements of the subsurface soils. This potential vertical movement can mobilize an uplift force along the shaft of a drilled pier. The uplift force acting on the shaft may be estimated by using Equation No. 1.

$F_u = 22d$ - - - - - (1)

where F_u = uplift force in kips

d = Diameter of the shaft in feet

If resistance to the uplift force is not provided, the pier will move vertically as the clay soils shrink and swell. For straight shaft piers resistance can be provided by skin friction along the shaft as it is extended below a depth of 10 feet plus the load that is carried by the pier. Therefore straight shaft piers may need to extend to a deeper depth based on the uplift force.

Tension steel will be required in each pier shaft to withstand a net force equal to the uplift force, minus the sustained compressive load carried by that footing. We recommend that each pier be reinforced with tension steel to withstand this net force or one percent of the cross-sectional area of the shaft, whichever is greater.

Pier Spacing: The minimum clear spacing between any two piers should not be less than 2d (edge to edge), where d is the pier diameter. If the spacing between the piers is closer than 2d, stress concentrations will occur between the two piers. The concentrated stress may be higher than the allowable bearing capacity. Hence, these piers should be designed for a lower bearing capacity than the maximum allowable. For construction purposes, the minimum pier spacing may be as close as 3 feet, provided the first pier has been drilled and concreted and the concrete has achieved its final set prior to drilling the adjacent pier.

Casing: Groundwater seepage was not observed in our boring during drilling operations. However, groundwater seepage may be encountered at the time of pier construction, especially after periods of heavy rainfall at some pier locations. Zones of sloughing soils may occur during pier construction. We recommend that the bid documents require the foundation contractor to specify unit costs for different lengths of casing that may be required.

If groundwater seepage occurs, the use of casing should help minimize groundwater inflow into the pier excavation, although it may not alleviate seepage from the soils. If seepage persists even after casing installation, the water should be pumped from the excavation prior to placing concrete. If groundwater inflow is too severe to be controlled by pumping, the concrete shall be tremied to the full depth of the excavation to effectively displace the water. In this case, a "clean-out" bucket shall be used to remove the soil from the pier bottom before placing steel and concrete.
If casing is used, removal of the casing should be performed with extreme care and proper supervision to minimize mixing of the surrounding soil and water with the concrete.
It is recommended that the design and construction of drilled piers should generally follow methods outlined in the manual titled Drilled Shafts: Construction Procedures and Design Methods (Publication No: FHWA IF 99 025, August 1999).

4.3.2 Shallow Foundations

Spread / Strip footings for building columns and continuous wall footings for load bearing walls may be supported on compacted in situ soils, at a minimum depth of 3 feet below finished grade. Spread / Strip footings, may be designed for allowable net bearing pressures of 2,000 pounds per square foot, based on dead load plus design live load considerations.

Based on the anticipated loads and subsurface condition, we anticipate that properly designed and constructed footings supported on the recommended materials should experience maximum total and differential settlements of about 2 inches. Footings should be properly reinforced. If soft or loose soils are encountered at the design bearing level, they should be undercut to stiff or dense soils and the excavation backfilled with concrete.

Horizontal loads acting on shallow foundations are resisted by friction along the foundation base and by passive pressure against the footing face, which is perpendicular to the line of applied force. For lateral loads, the coefficient of friction between the base of the footing and the subgrade soils is 0.35. For sustained loads the ultimate passive earth pressure, in psf, can be computed by using an equivalent fluid pressure of 240 pcf/ft. For transient loads, the ultimate passive earth pressure, in psf, can be taken as 2000 psf. Passive resistance should be neglected in the top 2 feet depth. A minimum factor of safety of 3 is recommended for sustained loading conditions, and 2 for transient loading conditions.

Uplift resistance of shallow foundations formed in an open excavation should be taken as the weight of the foundation and soil above it. For design purposes, the uplift resistance should be based on effective unit weights of 120 and 150 pounds per cubic foot (pcf) for soil and concrete respectively. In areas where ground water is anticipated or in areas prone to flooding, the uplift resistance should be based on submerged unit weights of 57 and 87.5 pounds per cubic foot (pcf) for soil and concrete respectively. A factor of safety of 3 is recommended for sustained loading conditions, and 2 for transient loading conditions.

It is important that footings be excavated, bearing soils observed by the soils engineer or his representative, formwork and reinforcing steel installed, and concrete placed as quickly as possible. If footings are to remain open for more than a day or if rain is expected, then the use of concrete mud mats to reduce moisture changes or other damage to the bearing soils should be considered. Extreme care should be taken to prevent the weakening of the foundation bearing materials because of prolonged atmospheric exposure, construction activity disturbance or an increase in moisture content. Backfill placed above footings should be placed and compacted under controlled conditions. Failure to properly compact the backfill will promote ponding of water in the backfilled excavation which will most likely result in undesirable movement of the foundations.

4.3.3 Floor Slab

Floor slabs utilized in conjunction with the drilled pier foundation system may consist of soil supported floor slabs or structurally suspended floor slabs. It should be noted that greater potential for floor slab movements is associated with soil supported floor slabs.

If some differential movement can be tolerated, the floor slab may consist of an independent slab-on-grade, supported on modified subgrade. If the floor slab is rigidly connected to the building walls, then it is likely that a hinge crack will develop in the slab parallel to the wall at a short distance from the wall. The severity of the cracking will be dependent on the amount of movement that occurs, the rigidity of the floor slab and the rigidity of the connection.

If the floor slab is constructed on the existing site soils, the design potential vertical movement is on the order of 1 to 2 inches, assuming that the soils are allowed to increase in moisture content from a relatively dry condition to a relatively wet condition. The potential vertical movement may be reduced to approximately 1 inch by preparing the building subgrade in accordance with methods described in the site preparation section of this report.

It is recommended that a vapor barrier such as polyethylene sheeting be provided directly beneath the soil supported slabs if moisture migration through the floor concrete is a concern. Adequate construction joints and reinforcement should be provided to reduce the potential for cracking of the floor slab due to differential movement. Proper expansion and control joints in the slab should be provided to reduce the potential for cracking. A drainage layer consisting of clean crushed gravel may be provided below the floor and connected to a sump with pump.

If potential movements associated with soil supported floor slabs are not acceptable, it is recommended that the floor slabs utilized with the drilled pier foundation consist of a structurally suspended slab. Structurally supported slab and grade beams should be isolated from the subgrade soils by providing a minimum 3-inch positive void beneath the slab and the grade beams. Using cardboard carton forms specially manufactured for this purpose can produce these voids. Care should be exercised so that the forms are not crushed, damaged, or saturated prior to placement of the concrete. In addition, barriers that will not rapidly decay should be placed or constructed along the sides of the cardboard carton forms to prevent soil intrusion into the void after the carton forms decay.

4.4 Fill Materials

Fill should be free of organic or other deleterious materials and should have a maximum particle size of 3 inches. Low swell potential select fill should have a maximum liquid limit of 35 and plasticity index between 5 and 15.

Select fill should be placed in maximum 8-inch loose lifts and compacted to a minimum of 95 percent of the maximum dry density as determined by ASTM D 698 (Standard Proctor). The moisture content at the time of compaction should be in the range of optimum to 4 percent above the optimum value as defined by ASTM D 698. On-site moisture conditioned fill should be placed in maximum 8-inch loose lifts and compacted to between 93% to 98% of the maximum dry density as determined by ASTM D 698 (Standard Proctor) in the moisture content range of 3 percent or more above the optimum value as defined by ASTM D 698.The referenced moisture content and density should be maintained until construction is complete.

4.5 Seismic Considerations

Based on the 2012 International Building Code, Table 1613.3.2 Site Class Definitions read in conjunction with and Table 20.3-1, chapter 20 of ASCE 7. The site soils can be characterized as Site Class C.

4.6 Additional Considerations and Recommendations

The following information has been developed after review of numerous problems concerning foundations throughout the area. It is presented here for your convenience. If these features are incorporated in the overall design and specifications for the project, performance of the project will be improved.

1. Prior to construction, the area to be covered by buildings should be prepared so that water will not pond beneath or around the buildings after periods of rainfall. In addition, water should not be allowed to pond on or around pavements.

2. Roof drainage should be collected and transmitted by pipe to a storm drainage system or to an area where the water can drain away from buildings and pavements without entering the soils supporting buildings and pavements.

3. Sidewalks should not be structurally connected to buildings. They should be sloped away from buildings so that water will be drained away from structures.

4. Paved areas and the general ground surface should be sloped away from buildings on all sides so that water will always drain away from the structures. Water should not be allowed to pond near buildings after the floor slabs and foundations have been constructed.

5. Backfill for utility lines that are located in pavement, sidewalk and building areas should consist of low swell potential fill. The backfill should be compacted as described in the "Fill Material" section of this report. Lesser lift thickness may be required to obtain adequate compaction.

6. Care should be exercised to make sure that ditches for utility lines do not serve as conduits that transmit water beneath structures or pavements. The top of the ditch should be sealed to inhibit the inflow of surface water during periods of rainfall.

7. Flower beds and planting areas should not be constructed along building perimeters. Constructing sidewalks or pavements adjacent to buildings would be preferable. If required, flower beds and planting areas could be constructed beyond the sidewalks away from the buildings. If it is desired to have flower beds and planting areas adjacent to a building, the use of above grade concrete box planters, or other methods which reduce the likelihood of large changes in moisture content of soils adjacent to or below structures should be considered.

8. Water sprinkling systems should not be located where water will be sprayed onto building walls and subsequently drain downward and flow into the soils beneath foundations.

9. Trees in general, should not be planted closer to a structure than the mature height of the tree. A tree planted closer to a structure than the recommended distance may extend its roots beneath the structure, allowing removal of subgrade moisture and/or causing structural distress.

10. Utilities which project through slab-on-grade floors, particularly where expansive soils or soils subject to settlement are present, should be designed with some degree of flexibility and/or with a sleeve to reduce the potential for damage to the utilities should movement occur.

5.0 PAVEMENT GUIDELINES

Terradyne understands current plans are that the parking and drive areas will likely consist of flexible and/or rigid pavements. Therefore, we have prepared the following recommendations for the design and construction of appropriate pavement systems. The “AASHTO Guide for Design of Pavement Structures” published by the American Association of State Highway and Transportation Officials was used to develop the pavement thickness recommendations in this report. This method of design considers pavement performance, traffic, roadbed soil, pavement materials, environment, drainage and reliability. Each of these items is incorporated into the design methodology.

Terradyne has been requested to provide recommendations for “standard duty” and “heavy duty” pavement sections over a 20-year life for given 18-kip Equivalent Single Axle Loads (ESAL). The scope of services for this project did not include California Bearing Ratio (CBR) testing. Therefore, we have assumed the following pavement-related subgrade design parameters, which are considered to be typical for the area. For the purposes of this analysis, we have assumed a CBR value of about five (5) for the natural sandy lean clay subgrade and general fill soils. We have also assumed the following pavement design parameters:

Table No. 2

Pavement Design Parameters (Rigid and Flexible)	
Assumed Design CBR, percent	5
Reliability, percent	70
Initial Serviceability Index, Flexible Pavement	4.2
Initial Serviceability Index, Rigid Pavement	4.5
Terminal Serviceability Index	2.0
Standard Deviation, Flexible Pavement	0.45
Standard Deviation, Rigid Pavement	0.35

In large areas of pavement, or where pavements are subject to significant traffic, we recommend that a more detailed analysis of the subgrade and traffic conditions be made. The results of such a study will provide more accurate information necessary to design an economical and serviceable pavement.

5.1 Pavement Sections

Based on the design parameters assumed above and the given ESALs, we developed recommendations for both "standard duty" and "heavy duty" pavement sections. "Standard duty" pavements are intended for general parking areas with lightly loaded passenger vehicles only and have an approximate capacity of 11,279 ESAL as provided by AutoZone. "Heavy duty" pavements are intended for areas subject to channelized traffic, delivery areas and areas with garbage vehicle traffic and have an approximate ESAL capacity of 30,567 as provided by AutoZone.

Table No. 3

Recommended Flexible Pavement Sections		
Pavement Materials	**Standard Duty**	**Heavy Duty**
Asphaltic Concrete, in.	2	2
Flexible Base, in.	6	8
Moisture Conditioned Subgrade	8	8

Table No. 5

Recommended Rigid Pavement Sections		
Pavement Materials	**Standard Duty**	**Heavy Duty**
Reinforced Concrete Thickness	5	6
Moisture Conditioned Subgrade	8	8

We recommend that proper perimeter drainage be provided and maintained to reduce the infiltration of surface water into the pavement section from surrounding unpaved areas. We do not recommend the use of landscape beds or islands in paved areas as these features provide avenues for water to infiltrate the pavement section. The infiltration of water into the pavement section typically results in the degradation of the section with time as vehicular traffic traverses the affected area. If landscaping is desired, we recommend that above grade planter boxes that discharge water onto the top of the pavement be used.

Curbs used in paved areas should extend at least six (6) inches below the bottom of the base materials to help reduce the potential for water infiltration into the pavement section. Wick drains may also be installed behind the curbs to intercept and remove water from the pavement perimeter before the water infiltrates the pavement section. Furthermore, any concrete/asphalt interfaces should be sealed using a sealant that is compatible with both asphalt and concrete.

In areas of pavement that are subject to heavy wheel loads, substantial amounts of vehicle maneuvering, high traffic volumes, or are to serve as fire lanes, we recommend that heavy duty pavements be used. The heavy-duty pavements should be large enough to properly accommodate all vehicular traffic and loads. In areas where dumpsters or waste bins are located, heavy-duty concrete pavements are often constructed and should be large enough to hold both the dumpster and the wheels of the garbage collection vehicle. The concrete paving should extend beyond areas that undergo extensive turning, stopping, or maneuvering. The pavement design engineer should consider these and other similar situations when planning and designing pavement areas.

Flexible Pavement: Asphalt

Base Course: Aggregate base course (if used on the site) should consist of a blend of sand and gravel that meets specifications for quality and gradation. The use of materials meeting Colorado

Department of Transportation (CDOT) Class 5 or 6 base course specifications is recommended. The base material shall be placed and compacted in accordance with CDOT specifications.

Table No. 6

Sieve Size	Mass Percent Passing Square Mesh Sieves	
	LL not greater than 30	
	Class 5	Class 6
37.5mm (2")	100	
25mm (1")	95-100	100
19mm (3/4")		95
4.75mm (#4)	30-70	30-65
2.36mm (#8)		25-55
75 m (#200)	3-15	3-12

The base course should have maximum Liquid Limit of 30 and Plasticity Index of 10. The base course should be moisture conditioned within ±2 percentage points of optimum moisture content, placed in lifts not exceeding 8-inches loose measure and compacted to at least 95 percent of maximum dry density.
Asphaltic Concrete: All asphalt pavements shall conform to specifications in CDOT section 401 Standard Specifications for Road and Bridge Construction.

Rigid Pavement: Concrete

Reinforced Concrete: Concrete should be designed to exhibit a flexural strength (3 point loading) of at least 650 psi at 28 days. As an option, a 28 day compressive strength requirement of 4,000psi may be used, with air entrainment between 4 and 6 percent.

Concrete pavement slabs shall be provided with adequate steel reinforcement. Proper finishing of concrete pavements requires the use of sawed and sealed joints which shall be designed in accordance with current Portland Cement Association guidelines. Dowel bars shall be used to transfer loads at transverse joints. Related civil design factors such as drainage, cross-sectional especially for open jointed areas which may allow surface water infiltration into the subgrade.

5.2 Subgrade Preparation

It is important that any existing organic and compressible soils (the upper soils which contain organic materials such as leaves, roots, etc.) be removed and the exposed subgrade be properly prepared prior to placing structural fill for the roadway embankment areas. A Plasticity Index of less than 25 shall be used. The maximum particle size shall be less than 4 inches in diameter.

The subgrade shall be proof rolled using a rubber tired equipment with a gross vehicle weight not less than 30,000 pounds, such as a fully loaded water truck. A minimum of three passes shall be made. Areas with excessive deformation or pumping shall be removed and replaced to achieve a stable subgrade. When using flexible pavement, proof rolling shall be conducted prior to the placement of aggregate base.

In any areas where pavement is to be placed, vegetation and all loose or organic material shall be stripped and removed from the site. Subsequent to stripping operations, the subgrade shall be proofrolled to identify soft zones. Any soft zone detected shall be removed to a firm subgrade soils and replaced with compacted satisfactory soils to reach subgrade level. Upon the acceptance of proofrolling operations the subgrade shall be scarified to a minimum depth of 8 inches, moisture conditioned and compacted to a minimum of 95 percent of maximum dry density as determined by ASTM D 698, the Standard Proctor, between optimum and 4 percentage points above of optimum moisture content. The exposed subgrade shall not be allowed to dry out prior to placing structural fill.

5.3 Perimeter Drainage

It is important that proper perimeter drainage be provided so that infiltration of surface water from compacted areas surrounding the pavement is minimized, or if this is not possible, curbs shall extend through the base and into the subgrade. A crack sealant compatible to both asphalt and concrete shall be installed at the concrete-asphalt interfaces.

Surface water may infiltrate from the compacted areas surrounding the pavement. These areas shall be sloped away from the pavement areas and should be grass, concrete covered or rip-rapped. If a berm is provided before the sloped area, the berm should be sloped at least 1V to 8H. The sloped areas may be as steep as 1V to 3H. The sloped area will provide for drainage of the surface water away from the pavement areas.

6.0 CONSTRUCTION CONSIDERATIONS

It is recommended that Terradyne be retained to provide observation and testing of construction activities involved in the foundations and pavements, earthwork, and related activities of this project. Terradyne cannot accept any responsibility for any conditions, which deviated from those, described in this report, nor for the performance of the foundations and pavements if not engaged to also provide construction observation and testing for this project.

The upper fine-grained soils encountered at this site may be sensitive to disturbances caused by construction traffic and changes in moisture content. During wet weather periods, increases in the moisture content of the soil can cause significant reduction in the soil strength and support capabilities. In addition, soils, which become wet may be slow to dry and thus significantly retard the progress of grading and compaction activities. It will, therefore, be advantageous to perform earthwork and foundation construction activities during dry weather. Depth of tan limestone is relatively shallow in some areas; accordingly difficulty in underground utility trench excavation should be anticipated.

Due to the plastic nature of on-site soils, some of which may be left in place, consideration should be given to these soils to reduce their shrink/swell potential. Simply stated, clays expand or shrink by absorbing or losing moisture. Controlling the moisture content variation of a soil will therefore reduce its variation in volume. During construction, a positive surface drainage scheme should be implemented to prevent ponding of water on the subgrade. The pavement subgrades should not be allowed to dry out during construction. Drainage from the building's roof/gutter system should not be allowed to drain and/or pond behind the pavement curbs.

7.0 SHORING

Shoring of excavations and design of shoring systems are governed by federal, state, and local regulations. The design of shoring systems on this project is beyond the scope of our services. The owner or the contractor should retain a shoring design professional to design shoring systems for excavations on this site.

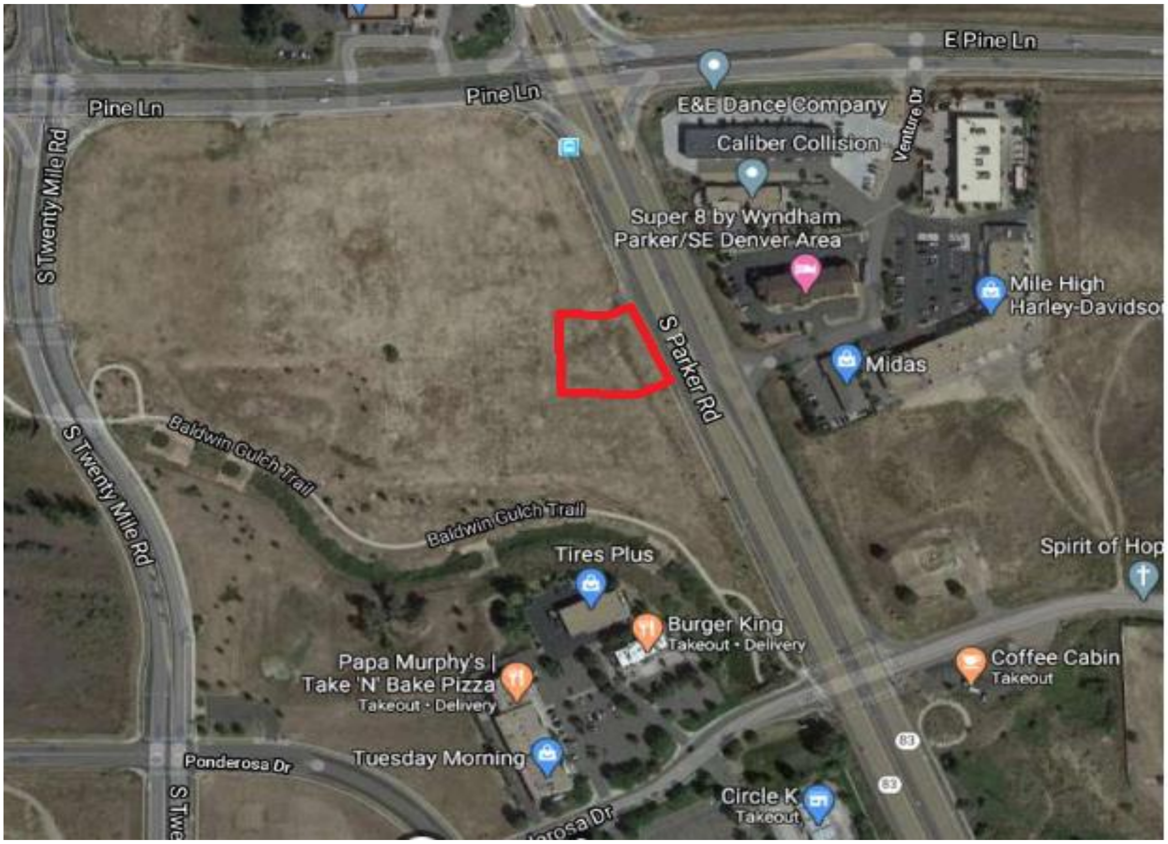
8.0 REPORT LIMITATIONS

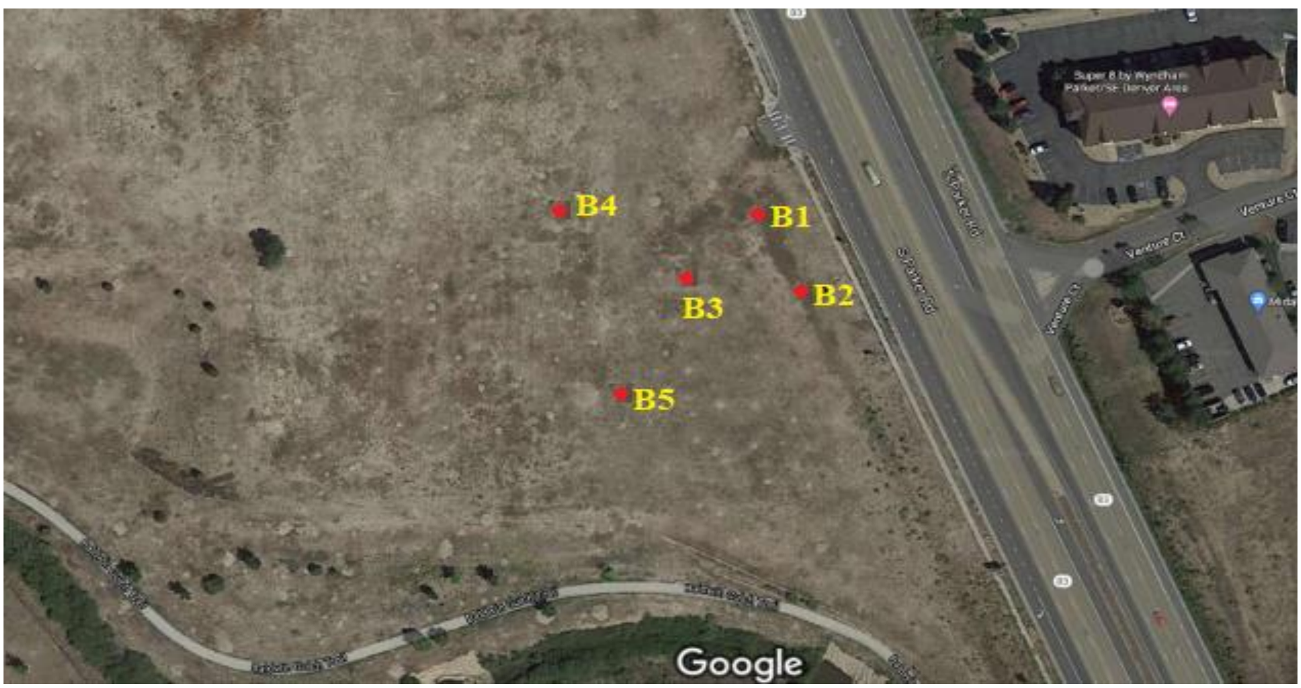
The analysis and recommendations submitted in this report are based upon the data obtained from the two borings drilled at the site. This report may not reflect the exact variations of the soil conditions across the site. The nature and extent of variations across the site may not become evident until construction commences. If variations appear evident, it will be necessary to re-evaluate our recommendations after performing on-site observations and tests to establish the engineering significance of any variations. The project geotechnical engineer should review the final plan for the proposed building so that he may determine if changes in the foundation recommendations are required. The project geotechnical engineer declares that the findings, recommendations or professional advice contained herein have been made and this report prepared in accordance with generally accepted professional engineering practice in the fields of geotechnical engineering and engineering geology. No other warranties are implied or expressed.

This report is valid until site conditions change due to disturbance (cut and fill grading) or changes to nearby drainage conditions or for 3 years from the date of this report, whichever occurs first. Beyond this expiration date, Terradyne shall not accept any liability associated with the engineering recommendations in the report, particularly if the site conditions have changed. If this report is desired for use for design purposes beyond this expiration date, we highly recommend drilling additional borings so that we can verify the subsurface conditions and validate the recommendations in this report.

This report has been prepared for the exclusive use of our client Dallas Palmer of Trail Star Development, LLC. for the specific application to the proposed building located on Lot 3, near S Parker Rd and Pine Ln, in Parker, Colorado.

APPENDIX





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Site and Boring Location Plan	Terradyne Engineering, Inc. 15403 E 17th Avenue, Suite E Aurora, CO 80011 303-463-9317		
Proposed Commercial Building **Lot 3 - near S Parker Rd and Pine Ln, Parker, CO**		**Scale:**	not to scale
	Figure 1	**Project No:**	**C201056**

Project: **Proposed Commercial Building** Project Location: **Lot 3, near S Parker Rd and Pine Ln, CO** Terradyne Project Number: **C201056**	# Log of Boring B-1 **Sheet 1 of 1**

Date(s) Drilled **June 9, 2020**		
Drilling Method **Solid Stem Auger**		Total Depth of Borehole **25 feet bgs**
Drill Rig Type **Lone Star**		Approximate Surface Elevation
Groundwater Level and Date Measured **No**	Sampling Method(s) **California**	
Borehole Backfill **Yes, with native soil**	Location **See Figure 1**	

Depth (feet)	Sample Type	N=blows/ft (SPT) T=inches/100 blows (THD)	PP (tsf)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Dry Unit Weight, pcf	Passing #200 Sieve, %	LL, %	PL, %	PI, %	UC, ksf	REMARKS AND OTHER TESTS
0					Sandy Lean Clay, Very Stiff, Dry to Moist, Brown, CL								
5	X	20				9		61.0					Swell 0.4 %
					Becomes Moist, Grayish Brown								
10	X	16				15			33	10	23		
15	X	48			Weathered Claystone, Hard, Moist, Gray	23		93.4	44	15	29		Swell 2.8 %
20	X	50/6"				19							
25	X	50/6"			Bottom of Boring	24							
30													
35													
40													

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TERRADYNE Engineers, Geologists & Environmental Scientists

Project: **Proposed Commercial Building**	Log of Boring B-2
Project Location: **Lot 3, near S Parker Rd and Pine Ln, CO**	**Sheet 1 of 1**
Terradyne Project Number: **C201056**	

Date(s) Drilled **June 9, 2020**		
Drilling Method **Solid Stem Auger**		Total Depth of Borehole **25 feet bgs**
Drill Rig Type **Lone Star**		Approximate Surface Elevation
Groundwater Level and Date Measured **No**	Sampling Method(s) **California**	
Borehole Backfill **Yes, with native soil**	Location **See Figure 1**	

Depth (feet)	Sample Type	N=blows/ft (SPT) T=inches/100 blows (THD)	PP (tsf)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Dry Unit Weight, pcf	Passing #200 Sieve, %	LL, %	PL, %	PI, %	UC, ksf	REMARKS AND OTHER TESTS
0					Sandy Lean Clay, Very Stiff, Dry to Moist, Brown, CL								
5	X	26				9			25	11	14		
					Becomes Moist, Grayish Brown								
10	X	29				10		54.8					Swell 0.5 %
15	X	50/6"			Weathered Claystone, Hard, Moist, Gray	17			47	15	32		
20	X	50/6"				19		93.4					Swell 2.2 %
25	X	50/6"				18							
					Bottom of Boring								
30													
35													
40													

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TERRADYNE Engineers, Geologists & Environmental Scientists

Figure 3

Project: **Proposed Commercial Building**	Log of Boring B-3
Project Location: **Lot 3, near S Parker Rd and Pine Ln, CO**	**Sheet 1 of 1**
Terradyne Project Number: **C201056**	

Date(s) Drilled **June 10, 2020**		
Drilling Method **Solid Stem Auger**		Total Depth of Borehole **10 feet bgs**
Drill Rig Type **Lone Star**		Approximate Surface Elevation
Groundwater Level and Date Measured **No**	Sampling Method(s) **California**	
Borehole Backfill **Yes, with native soil**	Location **See Figure 1**	

Depth (feet)	Sample Type	N=blows/ft (SPT) T=inches/100 blows (THD)	PP (tsf)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Dry Unit Weight, pcf	Passing #200 Sieve, %	LL, %	PL, %	PI, %	UC, ksf	REMARKS AND OTHER TESTS
0					Sandy Lean Clay, Very Stiff, Dry to Moist, Brown, CL								
5	California	21				8		53.6					Swell 0.3 %
					Becomes Moist, Grayish Brown								
10	California	18				13			29	9	10		
					Bottom of Boring								
15													
20													
25													
30													
35													
40													

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Figure 4

Project: **Proposed Commercial Building**	# Log of Boring B-4
Project Location: **Lot 3, near S Parker Rd and Pine Ln, CO**	**Sheet 1 of 1**
Terradyne Project Number: **C201056**	

Date(s) Drilled **June 10, 2020**		
Drilling Method **Solid Stem Auger**		Total Depth of Borehole **10 feet bgs**
Drill Rig Type **Lone Star**		Approximate Surface Elevation
Groundwater Level and Date Measured **No**	Sampling Method(s) **California**	
Borehole Backfill **Yes, with native soil**	Location **See Figure 1**	

Depth (feet)	Sample Type	N=blows/ft (SPT) T=inches/100 blows (THD)	PP (tsf)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Dry Unit Weight, pcf	Passing #200 Sieve, %	LL, %	PL, %	PI, %	UC, ksf	REMARKS AND OTHER TESTS
0					Sandy Lean Clay, Very Stiff, Dry to Moist, Brown, CL								
5		22				8			24	12	12		
					Becomes Moist, Grayish Brown								
10		15				10		50.8					Swell 0.5 %
					Bottom of Boring								
15													
20													
25													
30													
35													
40													

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Figure 5

Project: **Proposed Commercial Building**

Project Location: **Lot 3, near S Parker Rd and Pine Ln, CO**

Terradyne Project Number: **C201056**

Log of Boring B-5

Sheet 1 of 1

Date(s) Drilled **June 10, 2020**		
Drilling Method **Solid Stem Auger**		Total Depth of Borehole **10 feet bgs**
Drill Rig Type **Lone Star**		Approximate Surface Elevation
Groundwater Level and Date Measured **No**	Sampling Method(s) **California**	
Borehole Backfill **Yes, with native soil**	Location **See Figure 1**	

Depth (feet)	Sample Type	N=blows/ft (SPT) T=inches/100 blows (THD)	PP (tsf)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Dry Unit Weight, pcf	Passing #200 Sieve, %	LL, %	PL, %	PI, %	UC, ksf	REMARKS AND OTHER TESTS
0					Sandy Lean Clay, Very Stiff, Dry to Moist, Brown, CL								
5	California	32				8		51.9					Swell 0.4 %
					Becomes Moist, Grayish Brown								
10	California	13				14			31	10	21		
					Bottom of Boring								
15													
20													
25													
30													
35													
40													

TERRADYNE Engineers, Geologists & Environmental Scientists

Project: **Proposed Commercial Building** Project Location: **Lot 3, near S Parker Rd and Pine Ln, CO** Terradyne Project Number: **C201056**	# Key to Log of Boring **Sheet 1 of 1**

Depth (feet)	Sample Type	N=blows/ft (SPT) T=inches/100 blows (THD)	PP (tsf)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Dry Unit Weight, pcf	Passing #200 Sieve, %	LL, %	PL, %	PI, %	UC, ksf	REMARKS AND OTHER TESTS
1	2	3	4	5	6	7	8	9	10	11	12	13	14

COLUMN DESCRIPTIONS

1. Depth (feet): Depth in feet below the ground surface.
2. Sample Type: Type of soil sample collected at the depth interval shown.
3. N=blows/ft (SPT) T=inches/100 blows (THD): N: Number of blows to advance SPT sampler 12 inches or distance shown, ORT: Penetration in inches of THD Cone for 100 blows
4. PP (tsf): The Relative Consistency of the soil, measured by Pocket Penetrometer in tons/square foot
5. Graphic Log: Graphic depiction of the subsurface material encountered.
6. MATERIAL DESCRIPTION: Description of material encountered. May include consistency, moisture, color, and other descriptive text.
7. Water Content, %: Water content of the soil sample, expressed as percentage of dry weight of sample.
8. Dry Unit Weight, pcf: Dry weight per unit volume of soil sample measured in laboratory, in pounds per cubic foot.
9. Passing #200 Sieve, %: The percent fines (soil passing the No. 200 Sieve) in the sample.
10. LL, %: Liquid Limit, expressed as a water content
11. PL, %: Plastic Limit, expressed as a water content.
12. PI, %: Plasticity Index, expressed as a water content.
13. UC, ksf: Unconfined compressive strength.
14. REMARKS AND OTHER TESTS: Comments and observations regarding drilling or sampling made by driller or field personnel.

FIELD AND LABORATORY TEST ABBREVIATIONS

SPT: Standard Penetration Test
THD: Texas Dept. of Transportation Cone Penetrometer Test
LL: Liquid Limit, percent
PL: Plastic Limit, percent
PI: Plasticity Index, percent
PP: Pocket Penetrometer
UC: Unconfined compressive strength test, Qu, in ksf

TYPICAL MATERIAL GRAPHIC SYMBOLS

Lean CLAY, CLAY w/SAND, SANDY CLAY (CL)

Claystone

TYPICAL SAMPLER GRAPHIC SYMBOLS

Grab Sample

Rock Core

2-inch-OD unlined split spoon (SPT)

THD Cone

Shelby Tube (Thin-walled, fixed head)

OTHER GRAPHIC SYMBOLS

Water level (at time of drilling, ATD)

Water level (after waiting)

Minor change in material properties within a stratum

Inferred/gradational contact between strata

Queried contact between strata

GENERAL NOTES

1: Soil classifications are based on the Unified Soil Classification System. Descriptions and stratum lines are interpretive, and actual lithologic changes may be gradual. Field descriptions may have been modified to reflect results of lab tests.
2: Descriptions on these logs apply only at the specific boring locations and at the time the borings were advanced. They are not warranted to be representative of subsurface conditions at other locations or times.

Figure 7