ECS Southwest, LLP

Geotechnical Engineering Report

Sherwin Williams – Liberty Hill

12360 W. SH 29
Liberty Hill, Texas

ECS Project Number 17:6314

July 31, 2023

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Mr. Gavin Melia
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ECS Project No. 17:6314

Reference: Geotechnical Engineering Report
Sherwin Williams – Liberty Hill
12336 W. SH 29
Liberty Hill, Texas

Dear Mr. Melia:

ECS Southwest, LLP (ECS) has completed the subsurface exploration, laboratory testing, and geotechnical engineering analyses for the referenced project. Our services were performed in general accordance with our agreed scope of work. This report presents our understanding of the geotechnical aspects of the project along with the results of the field exploration and laboratory testing conducted, and our design and construction recommendations.

It has been our pleasure to be of service to Liberty Hill Development Group, LLC during the design phase of this project. We would appreciate the opportunity to remain involved during the continuation of the design phase, and we would like to provide our services during construction phase operations as well to verify the subsurface conditions assumed for this report. Should you have any questions concerning the information contained in this report, or if we can be of further assistance to you, please contact us.

Respectfully submitted,

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EXECUTIVE SUMMARY

The following summarizes the main findings of the exploration, particularly those that may have a cost impact on the planned development. Further, our principal geotechnical recommendations are summarized. Information gleaned from the executive summary should not be utilized in lieu of reading the entire geotechnical report.

- The predominant geotechnical and geological constraint that need to be addressed at the site are the expansive soils, the settlement potential of existing undocumented fills, and the potential to encounter very hard bedrock in excavations at shallow depths.

- The earthwork, foundation, and utility contractors should be prepared with heavy-duty rock excavation equipment and tooling to complete excavations of the limestone at this site. The depths to limestone and its character should be expected to vary across the site.

- We estimate the existing PVR in the site area to be about 1½ inches. Recommendations for PVR reduction can be found in Section 4.1 "Potential Vertical Rise & Subgrade Improvements".

- Fills soils were observed in some of the borings extending to depths ranging from about 2 to 2½ feet below the existing grade within the proposed building footprint. The placement methods and degree of compaction is unknown. As such, it is recommended that the existing fill materials be re-worked or removed and replaced, according to this report's Section 4.1 "Potential Vertical Rise & Subgrade Improvements".

- The proposed building can be founded on a monolithic beam and slab-on-grade foundation system or a shallow footing foundation system. Recommendations for shallow foundations can be found in Section 4.2 "Shallow Foundations".

- Light-duty pavements can consist of 2 inches asphaltic concrete on 8 inches base on a prepared subgrade, or 5 inches concrete on a prepared subgrade. Moderate-duty pavements can consist of 2½ inches asphaltic concrete on 10 inches base on a prepared subgrade, or 5½ inches concrete on a prepared subgrade. Heavy-duty pavements can consist of 6½ inches concrete on a prepared subgrade.

- It is recommended that ECS conduct a geotechnical review of the project plans (prior to issuance for construction) to check to see that ECS' geotechnical recommendations have been properly interpreted and implemented.

- To prevent misinterpretation of our recommendations, ECS should be retained to perform quality control testing and documentation during construction of the earthwork and foundations for the project.

1.0 INTRODUCTION

The purpose of this study was to provide geotechnical information for the design of foundations and associated appurtenances for the proposed single-story building development at the subject site. Geotechnical recommendations for associated retaining wall improvements and pavements are also included in this project.

Our services were provided in accordance with ECS Proposal No. 17-8509-R1 dated June 22, 2023, which included our Terms and Conditions of Service. This study was authorized by Mr. Gavin Melia of Liberty Hill Development Group, LLC on June 26, 2023, via signature of the proposal acceptance page from above referenced proposal.

The report includes the following items.

- A brief review and description of our field and laboratory test procedures and the results of testing conducted.
- A review of surface topographical features and site conditions.
- A review of area and site geologic conditions.
- A review of subsurface soil stratigraphy with pertinent available physical properties.
- A final copy of our soil test boring logs.
- Recommendations for site preparation, grading, and drainage.
- Recommendations for foundation design and construction.
- Recommendations for retaining wall design and construction.
- Recommendations for pavement design and construction.

2.0 PROJECT INFORMATION

2.1 PROJECT LOCATION/CURRENT SITE USE/PAST SITE USE

The subject site is located at 12360 W. SH 29 in Liberty Hill, Texas. The location is depicted in the figure below and on the Site Location Diagram in Appendix A.

The subject 0.851-acre site is generally undeveloped and contains some trees. Based on our review of historical imagery, it appears that the site underwent some clearing and grading operations between January 2022 and May 2022. The site appears to have been historically undeveloped prior to the clearing/grading operations. The provided topographic information indicates that the site is generally flat and gently slopes down towards the center of the site with elevations ranging from about 1,012 feet in the northern and southern portions of the site to about 1,010 feet in the central portion of the site.

2.2 PROPOSED CONSTRUCTION

It is understood that the proposed development will include an approximate 4,500 SF footprint retail building, paved drive areas, and associated appurtenances. We were provided with the Site Development Plans prepared by Triangle Engineering, LLC dated July 13, 2023. Proposed structural loading information were not available at the time of this report, and it is anticipated that the proposed building will be supported by a monolithic beam and slab-on-grade foundation system or a shallow footing foundation system.

SUBJECT	DESIGN INFORMATION / ASSUMPTIONS
Building Footprint	Approximately 4,500 square feet
# of Stories	1 story above grade
Usage	Retail Building
Column Loads	Not provided, < 30 kips assumed
Wall Loads	Not provided, < 2 kips/lf assumed
Building First Floor Finish Floor Elevation	1012.63 feet, up to about 2½ feet fill required to achieve finished pad grade

If ECS' understanding of the project is not correct, especially if the structural loads are different, please contact ECS so that we may review these changes and revise our recommendations as appropriate.

3.0 FIELD EXPLORATION AND LABORATORY TESTING

Our subsurface findings and procedures are included in Appendix B. Our scope of work included drilling two soil borings to completion depths of about 15 feet each in the proposed building area, and two soil borings to completion depths of about 5 feet each beneath the existing ground surface in the proposed pavement area.

Our borings were located with a handheld GPS unit and their approximate locations are shown on the Boring Location Diagram in Appendix A. The approximate ground surface elevations shown on the boring logs were selected based on a review of the provided topographic information. The accuracy of this elevation data should be considered approximate.

3.1 SUBSURFACE CHARACTERIZATION

The *Geologic Map of the West Half of the Taylor, Texas 30 x 60 Minute Quadrangle* indicates that the northern portion of the site is underlain by the Cedar Park, Bee Cave, and Bull Creek Members, undivided, of the Walnut Formation (Kwcpbc), which generally consists of limestone, argillaceous limestone, and marl. The southern portion of the site is underlain by the Upper Glen Rose Formation (Kgru), which generally consists of alternating layers of limestone and marl. The approximate location of the site on the geologic map is provided on the Site Geologic Diagram in Appendix A.

The following table provides generalized characterizations of the soil/rock strata encountered during ECS' subsurface exploration. For specific information refer to the boring logs in Appendix B.

Approximate Range of Depth (feet)	Stratum	Material Description	PI (1) Range	PI (1) Average
0 – (2-2½)	IA (2)	FILL: (CL) SANDY LEAN CLAY, (SC) CLAYEY SAND WITH GRAVEL; brown to light brown; firm to stiff; medium dense	--	--
(0-2½) – (1½-4)	I	(CH) FAT CLAY; dark brown; stiff to very stiff	--	59
(1½-4) – (8½-15)	II	(GC) CLAYEY GRAVEL, light brown and light gray, medium dense to very dense	--	18
(3½-8½) – 13½	III(3)	LIMESTONE; light brown and light gray; very hard	--	--
(13½) – (15)	IIA (4)	(GC) CLAYEY GRAVEL, light gray, very dense	--	--

Notes: Depths are approximate.
(1) Plasticity Index
(2) Encountered in boring locations B-01, B-02, and B-04
(3) Encountered in boring locations B-01 and B-04
(4) Encountered in boring location B-01

3.2 GROUNDWATER OBSERVATIONS

Groundwater level observations were made in the borings during drilling operations. In air rotary drilling operations, water is not introduced into the boreholes and the groundwater position can often be determined by observing water flowing into the excavation. Furthermore, visual observation of soil samples retrieved can often be used in evaluating the groundwater conditions. Groundwater was not encountered during or upon completion of excavation of the borings at the site. Upon completion of field operations, the boreholes were backfilled with soil cuttings generated during our field operations.

Water levels in open excavations may require several hours to several days to stabilize depending on the permeability of the soils and that groundwater levels at the site may be subject to seasonal conditions, recent rainfall, drought or temperature effects. Clays and intact limestone are generally not conducive to the presence of groundwater; however, gravels, sands and silts, and open fractures and solution features; where present, can store and transmit “perched” groundwater flow or seepage.

The groundwater conditions at this site are expected to be significantly influenced by surface water runoff and rainfall and should be evaluated just prior to construction. Specifically, rainfall that enters the site, either directly from overland flow or adjacent properties, begins to percolate through surficial soils and within granular seams and fissures. This groundwater flow continues downhill with the water table occasionally surfacing to form wet springs and intermittent streams. In low-lying areas and areas adjacent to existing creeks or ponds, shallow groundwater tables can be present continuously.

3.3 LABORATORY TESTING

The laboratory testing was performed by ECS on selected samples obtained during our field exploration operations. Classification and index property tests were performed on representative soil samples obtained from the test borings to aid in classifying soils and to quantify and correlate engineering properties. The soil samples were tested for moisture content (ASTM D2216), Atterberg Limits (ASTM D4318), and gradation tests (percent passing No. 200 sieve – ASTM D1140). The results of our laboratory testing are presented in Appendix C.

A geotechnical engineer visually classified soil samples from the test borings based on texture and plasticity in general accordance with ASTM D2487 (Unified Soil Classification System (USCS)) and ASTM D2488 (Description and Identification of Soils-Visual/Manual Procedures). After classification, the samples were grouped in the major zones noted on the boring logs in Appendix B. The group symbols for each soil type are indicated in parentheses along with the soil descriptions. The stratification lines between strata on the logs are approximate; in situ, the transitions may be gradual.

4.0 DESIGN RECOMMENDATIONS

The following recommendations have been developed following the previously described project characteristics and subsurface conditions. If there are any changes to the project characteristics or if different subsurface conditions are encountered during construction, ECS should be consulted so that the recommendations of this report can be reviewed.

4.1 POTENTIAL VERTICAL RISE & SUBGRADE IMPROVEMENTS

Structural damage and/or cosmetic/operational distress can be caused by volume changes in clay soils. The soils found at this site consist of clayey sand and do not exhibit significant volume change capability dependent on potentially changing soil water conditions during or after construction. Clayey soils can shrink when they lose water and swell (increase in volume) when they gain water. The potential of clayey soils to shrink and swell is related to; amongst other things, the Plasticity Index (PI). Clayey soils with a higher PI generally have a greater potential for soil volume changes due to moisture content variations.

We have estimated potential heave for this site utilizing the TxDOT PVR method (Tex-124-E). The Tex-124-E method provides an estimate of potential vertical rise (PVR) using the liquid limits, plasticity indices, grain size and existing water contents for soils. The PVR is estimated in the seasonally active zone at the site, which can be up to a depth of 12 feet or shallower where inert material such as limestone is present.

Estimated PVR values are based upon anticipated typical changes in soil moisture content from a dry to wet condition; however, soil movements in the field depend on the actual changes in moisture content. Thus, actual soil movements could be less than that calculated if little soil moisture variations occur, or the actual movement could exceed the estimated values if actual soil moisture content changes exceed those anticipated. These conditions are often the result of excessive droughts, flooding, "perched" groundwater infiltration, poor surface-drainage, excessive irrigation adjacent to building foundation, and/or leaking irrigation lines or plumbing.

We estimate the existing PVR in the proposed building area to be about 1½ inch. To reduce the PVR in the building pad area to about 1 inch or ¾ inch, it is recommended that the existing ground surface be undercut as required to allow for at least 1½ feet or 2½ feet of select fill beneath finished pad grade, respectively.

Fills soils were observed in some of the borings extending to depths ranging from about 2 to 2½ feet below the existing grade within the proposed building footprints. The presence of undocumented fill raises concerns regarding the composition of the fill and consistency/relative density of the fill materials. Support of foundations and floor slabs on undocumented fill soils may result in excessive vertical movements and related distress. Therefore, without density test results for ECS' evaluation, the existing fill soil in the proposed building areas should be removed and re-worked/re-compacted (provided the soil meets General Fill requirements) or replaced with Select Fill.

In this general area, it is common for structural and geotechnical engineers to consider a PVR of about ¾ inch to 1 inch and less to be within acceptable tolerances for properly designed and constructed foundation systems. However, this movement does not take into consideration the movement criteria required or perceived by the facility owner or occupants. These "operational" performance criteria may be, and often are, more restrictive than the structural criteria or tolerances.

Grade-supported foundation or floor slab movements that approach ¾ inch to 1 inch may cause doors to stick, cracks in sheetrock or brittle floor covering, cracks in exterior finishes and other forms of cosmetic distress. Measures can and should be taken during the design and construction of the facility to help reduce the extent and severity of these types of distress. However, these magnitudes of movement typically do not cause "structural distress."

4.2 SHALLOW FOUNDATIONS

The proposed building can be supported on a monolithic beam and slab-on-grade foundation and/or shallow footing foundation system.

4.2.1 Slab-on-Grade Foundations

The rigidity of a slab-on-grade foundation system can reduce the effects of differential soil movement due to compression of soils due to structural loads or shrink-swell due to expansive soils. This type of slab can be designed with conventionally reinforced perimeter and interior stiffening grade beams, and/or with post-tensioning adequate to provide sufficient rigidity to the slab element. The grade beam width and depth will be determined by the project Structural Engineer. Grade beams may be thickened and widened at column or load bearing wall locations to support concentrated load areas, if necessary. Grade beams and floor slabs should be reinforced as required to reduce cracking and support bending moments caused by loading and minor movements of foundation soils.

The design values below are based on the subsurface conditions encountered during this exploration and the recommendations for building pad grading provided herein. If the project information changes, we should be contacted to review; and if necessary, provide alternate design parameters based on the changed conditions. These parameters are provided to assist the Structural Engineer in design of a foundation that is stiffened using grade beams (ribs), post tensioning, or a combination thereof.

POST-TENSIONED SLAB PARAMETERS PTI 3RD EDITION WITH 2008 SUPPLEMENTS	
Design Parameter	**1 Inch PVR Design Values**
e_m Edge	4.4 Feet
e_m Center	8.7 Feet
y_m Edge	1.2 Inches
y_m Center	0.8 Inches

BRAB/WRI SLAB PARAMETERS	
Design Parameter	**1 Inch PVR Design Values**
Effective PI	25
Climatic Rating	18
Unconfined Compressive Strength (TSF)	1.5
Soil-Climate Support Index (1-C)	0.11

Grade beams and widened column areas at least 10 inches wide and 18 inches deep bearing in compacted fill can be designed using a net allowable bearing capacity of 3,000 psf. To utilize the parameters listed above, the subgrade should be prepared in accordance with Section 5.0 "Site Construction Recommendations" of this report, including improving to a 1-inch PVR in the proposed building area.

Foundations at the site should be expected to undergo some vertical movements. These movements can potentially cause cosmetic distress and should be accounted for in the design process. Contraction, control, or expansion joints should be designed and placed in various portions of the structures. Properly planned placement of these joints will assist in controlling the degree and location of material cracking which normally occurs due to material shrinkage, thermal effects, soil movements, and other related structural conditions.

Where moisture sensitive floor coverings or equipment will be installed, we recommend that at least a 10-mil vapor retarder be used beneath the slabs. The vapor retarder should conform to ASTM E1745, Class C or better and should have a maximum water vapor permeance of 0.044 when tested in accordance with ASTM E96. Consideration to specifying a thicker, more durable vapor retarder should also be made where anticipated construction traffic dictates. Please refer to the latest edition of ACI 302.2R-06 Guide for Concrete Slabs that Receive Moisture-Sensitive Flooring Materials and ASTM E1643 Standard Practice for Installation of Water Vapor Retarders Used in Contact with Earth or Granular Fill Under Concrete Slabs for additional guidance on this issue.

4.2.2 Shallow Footing Foundations

The proposed building can be supported by a shallow footing foundation system. An allowable bearing capacity of 3,000 psf can be used for design of spread footings at least 12 inches wide and deep and bearing on compacted fill. Perimeter footings should extend at least 18 inches beneath finished grade to reduce the potential for moisture intrusion into the building pad materials. It is recommended that the building area be improved to a ¾-inch, as-built PVR if shallow footings are utilized.

For resistance to lateral loads, an ultimate coefficient of friction of 0.44 is recommended between the base of the foundation elements and underlying ground surface. In addition, for footings cast directly against excavation sidewalls, a passive resistance equal to an equivalent fluid applying 280 pcf acting against the foundation may be used to resist lateral forces. The passive resistance should be neglected in the upper 18 inches unless the ground immediately in front of the footing is covered with concrete or another impervious pavement. The recommended lateral resistance values are ultimate values, and a factor of safety should be used in design.

Where utility trenches or other excavations are located adjacent to foundations, the bottom of the footing should be located below an imaginary 1:1 (horizontal to vertical) plane projected upward from the nearest bottom edge of the utility trench.

The uplift resistance of a shallow foundation formed in an open excavation will be limited to the weight of the foundation concrete and the soil above it. For design purposes, the ultimate uplift resistance should be based on effective unit weights of 105 and 150 pcf for soil and concrete, respectively. This value should be reduced by an appropriate factor of safety to arrive at the allowable uplift load. If there is a chance of submergence, the buoyant unit weights should be used.

Post-construction total and differential (over a 40-foot distance) settlements for foundations constructed as recommended herein are anticipated to be about 1 inch and ½ inch, respectively. Contraction, control, or expansion joints should be designed and placed in various portions of the structure. Properly planned placement of these joints will assist in controlling the degree and location of material cracking which normally occurs due to material shrinkage, thermal effects, soil movements, and other related structural conditions.

4.3 SLAB-ON-GRADE FLOORS

The design of grade-supported floor slab should take into consideration the interaction between the slab and the supporting soils in resisting moments and shears induced by applied loads. Several design methods use the modulus of subgrade reaction, k_1, to account for soil properties in design. The k_1-value presented in the following table can be used for the design of flat, grade-supported floor slabs for this project. The k_1-value assumes that the PVR has been mitigated and that the fill materials have been properly placed and compacted beneath the slab and that site drainage is good. Adequate construction joints and reinforcement should be provided to reduce the potential for cracking of the floor slabs due to differential movement.

Subgrade Type	k_1-Value, PCI
Select Fill	100
Select Fill below 6 Inches Compacted TxDOT Item 247 Type A, Grade 1-2 Base	150
12 Inches Compacted TxDOT Item 247 Type A, Grade 1-2 Base	200

Where moisture sensitive floor coverings or equipment will be installed, we recommend that at least a 10-mil vapor retarder be used beneath the slab. The vapor retarder should conform to ASTM E1745, Class C or better and should have a maximum water vapor permeance of 0.044 when tested in accordance with ASTM E96. Consideration to specifying a thicker, more durable vapor retarder should also be made where anticipated construction traffic dictates. If a vapor retarder is considered to provide moisture protection, special attention should be given to the surface curing of the slabs to reduce uneven drying of the slabs and associated cracking and/or slab curling. Please refer to the latest edition of ACI 302.2R-06 Guide for Concrete Slabs that Receive Moisture-Sensitive Flooring Materials and ASTM E1643 Standard Practice for Installation of Water Vapor Retarders Used in Contact with Earth or Granular Fill Under Concrete Slabs for additional guidance on this issue.

4.4 PERIMETER CONDITIONS

The upper 18 inches of soil placed along the exterior of the foundation area should consist of lean clayey soils placed and compacted in accordance with this report. The purpose of this clay backfill is to reduce the opportunity for surface or subsurface water infiltration beneath the structure. This clay layer may be replaced with asphalt or concrete pavement that extends to the edge of the structure foundation. Additionally, where penetrations into the structure such as utility trenches occur, a clay plug (or synthetic alternative) should be placed at the building lines to reduce the opportunity for infiltrating water, regardless of the selected building pad materials. A typical clay plug detail is provided in Appendix D of the report.

Positive drainage away from the structure should also be provided. Soil areas within 10 feet of the building should slope at a minimum of 5 percent away from the structure. Adjacent pavements and concrete hardscape should slope at 1½ to 2 percent away from the structure. Roof leaders and downspouts should discharge onto paved surfaces sloping away from the structure or into a closed pipe system which outfalls to the street gutter pan or directly to the storm drain system.

Additionally, irrigation of lawn and landscaped areas should be moderate, with no excessive wetting or drying of soils around the perimeter of the structures allowed. Trees and bushes/shrubs planted near the perimeter of the structures can withdraw large amounts of water from the soils and should be planted at least one-half their anticipated mature height away from the building. Where flatwork is placed against or near the structure, a positive seal should be installed and adequately maintained to reduce water intrusion.

Routine maintenance is required to ensure that the recommendations contained in this report are followed and maintained. Greater potential movements could occur with extreme wetting or drying of the soils due to poor drainage, ponding of water, plumbing leaks, lack of irrigation, and/or lack of routine maintenance, etc.

4.5 SEISMIC DESIGN CONSIDERATIONS

Seismic Site Classification: The International Building Code (IBC) 2021 requires site classification for seismic design based on the upper 100 feet of a soil profile. Methods are utilized in classifying sites, namely the shear wave velocity (v_s) method and the Standard Penetration Resistance (N-value) method. The seismic site class definitions for the average of shear wave velocity or SPT N-value in the upper 100 feet of the soil profile are shown in the following table:

SEISMIC SITE CLASSIFICATION			
Site Class	**Soil Profile Name**	**Shear Wave Velocity, Vs, (ft./s)**	**N value (bpf)**
A	Hard Rock	Vs > 5,000 fps	N/A
B	Rock	2,500 < Vs ≤ 5,000 fps	N/A
C	Very Dense Soil and Soft Rock	1,200 < Vs ≤ 2,500 fps	>50
D	Stiff Soil Profile	600 ≤ Vs ≤ 1,200 fps	15 to 50
E	Soft Soil Profile	Vs < 600 fps	<15

Based on the 2021 International Building Code (IBC) Site Class Definitions, in our opinion the site soil can be characterized as Site Class D. The Site Class definition should not be confused with the Seismic Design Category designation which the Structural Engineer typically assesses. Our deepest borings at the project site extended to depths of 15 feet beneath the existing ground surface, whereas IBC site classifications are based on characterization of the upper 100 feet of the soil profile.

In addition to the seismic site classification, ECS has determined the design spectral response acceleration parameters following the ASCE 7-16 methodology. The Mapped Reponses were estimated from the SEAOC OSHPD Seismic Design Maps https://seismicmaps.org/ using the following coordinates: lat. 30.660° N, long. 97.891° W. The design responses for the short (0.2 sec, S_{DS}) and 1-second period (S_{D1}) are noted at the far-right end of the following table.

GROUND MOTION PARAMETERS [ASCE 7-16 Design Code]								
Period (sec)	**Mapped Spectral Response Accelerations (g)**		**Values of Site Coefficient for Site Class**		**Maximum Spectral Response Acceleration Adjusted for Site Class (g)**		**Design Spectral Response Acceleration (g)**	
Reference	Figures 1613.3.1 (1) & (2)		Tables 1613.3.3 (1) & (2)		Eqs. 16-37 & 16-38		Eqs. 16-39 & 16-40	
0.2	S_S	0.054	F_a	1.6	$S_{MS}=F_aS_s$	0.086	$S_{DS}=2/3\ S_{MS}$	0.057
1.0	S_1	0.034	F_v	2.4	$S_{M1}=F_vS_1$	0.082	$S_{D1}=2/3\ S_{M1}$	0.054

4.6 PAVEMENT SECTIONS

ECS has prepared the following recommendations for the design and construction of both flexible and rigid pavement systems for use on the subject project. 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.

We have based our analysis on the following ESAL information and pavement-related subgrade design parameters, which are considered to be typical for the area. A CBR (California Bearing Ratio) value of 3 percent was selected for design purposes. The CBR value was estimated based on ECS' knowledge and experience with similar soils and projects in this area.

Reliability	70
Initial Serviceability Index, Flexible Pavements	4.2
Initial Serviceability Index, Rigid Pavements	4.5
Terminal Serviceability Index, All Pavements	2.0
Standard Deviation, Flexible Pavements	0.45
Standard Deviation, Rigid Pavements	0.35

Based on the design parameters listed above, we developed recommendations for "light-duty," "moderate-duty" and "heavy-duty" pavement sections. "Light-duty" pavements are intended for general parking areas with passenger vehicles only and have an approximate capacity of 20,000 ESAL. "Moderate-duty" pavements are intended for areas subject to channelized traffic and fire lanes and have an approximate capacity of 80,000 ESAL. "Heavy-duty" pavements are intended for areas subject to heavier vehicles with extensive turning, starting and stopping, such as pavement aprons associated with trash enclosures, and have an approximate capacity of 250,000 ESAL. If the owner or other members of the design team feel that the ESAL values used for design are not appropriate, ECS should be notified in writing, so new information can be reviewed, and if necessary, the pavement recommendations revised accordingly.

The minimum recommended thickness for both hot mixed asphalt concrete (HMAC) and reinforced Portland cement concrete (PCC) pavement sections are presented in the table below for the described "light", "moderate" and "heavy" traffic conditions.

Recommended Pavement Section Options						
Component	**Light-Duty 20,000 ESALs**		**Moderate-Duty 80,000 ESALs**		**Heavy-Duty 250,000 ESALs**	
	Rigid	**Asphalt**	**Rigid**	**Asphalt**	**Rigid**	**Asphalt**
Portland Cement Reinforced Concrete (PCC)	5.0 in	--	5.5 in	--	6.5 in	--
Hot Mixed Asphalt Concrete (HMAC)	--	2.0 in	--	2.5 in	--	--
Crushed Limestone Base (CLB)	--	8.0 in	--	10.0 in	--	--

The pavement sections described above are for general-purpose usage for the anticipated subgrade conditions and were designed using the AASHTO Pavement and Analysis System. An aggressive maintenance program to keep joints and cracks sealed to prevent moisture infiltration will help extend the pavement life.

We recommend that rigid pavement sections be used in heavy truck traffic areas. The concrete pavement should extend throughout the areas that require extensive turning and maneuvering of the delivery vehicles, etc. Waste dumpster pads, loading areas and other heavily loaded pavement areas that are not designed to accommodate these conditions often experience localized pavement failures, particularly if flexible pavement sections are used.

4.6.1 Pavement Materials

Recommendations regarding material requirements for the various pavement sections are summarized below:

Portland Cement Concrete - Concrete used for paving should have a minimum compressive strength of 3,500 psi at 28-days. The air content at the point of placement should range from 2 to 4 percent. The concrete pavements should be reinforced and jointed per current ACI recommendations.

Hot Mix Asphalt Concrete (HMAC) Surface Course - The asphalt concrete surface course should be plant mixed, hot laid Type D (Fine Graded Surface) or Type C (Coarse Graded Surface Course) meeting the specifications requirements of TxDOT Item 340 and specific criteria for the job mix formula. The mix should be compacted to between 92 and 97 percent of the maximum theoretical density as determined by Tex-227-F.

Crushed Limestone Base Course - Crushed limestone base should be placed in maximum 6-inch compacted lifts. The base materials should be compacted to at least 98 percent of the maximum dry density as determined by TxDOT Tex-113-E. Flexible base materials should be moisture conditioned to between -2 and +3 percentage points of the optimum moisture content. Flexible base materials should meet the requirements specified in 2014 TxDOT Standard Specification Item 247, Type A, Grade 1-2.

4.6.2 Rigid Pavement Considerations

Joints are typically placed in rigid pavements to control cracking, to facilitate construction, and to isolate a section of pavement from a structure or an adjacent pavement section. Joints used to control cracking are typically known as contraction or control joints as they are intended to control cracking that arises out of the shrinkage of concrete as it cures. Construction joints are used to provide clean breaks between pavement sections that result from the construction process. Isolation joints (or expansion joints) are used to separate the pavement from other structures or pavements and typically include the use of compressible materials in the joint as opposed to contraction or construction joints. Contraction joints should be spaced no greater than 15 feet between the nearest parallel joints with joint depths of at least one-quarter of the slab thickness. Contraction and construction joints should be no wider than one-eighth of an inch whereas isolation joints may be up to one inch wide.

Steel reinforcement is commonly used where subgrade conditions are not likely to provide uniform support to the concrete pavement. Generally, sites with expansive soils present are often unable to provide such support to rigid pavement sections. Therefore, reinforcing steel can be used to span between construction and isolation (expansion) joints and should consist of at-minimum No. 3 bars spaced 18 inches on-centers each way. The rebar should be Grade 60 steel.

As with steel reinforcement, in situations where the subgrade may not provide uniform support to the pavement, dowels are commonly used to transfer loads across joints. Smooth dowels can be used for this purpose and should be utilized as recommended in the following table.

Dowel Design Information				
Slab Thickness, In.	**Dowel Diameter, In.**	**Min. Dowel Embedment Each Side, In.**	**Min. Dowel Length, In.**	**Dowel Spacing On-Centers, In**
5.0	⅝	5	10	12
5.5	¾	6	12	12
6.5	⅞	7	16	12

The joint and reinforcing design of a rigid pavement system is largely a function of geometry for the pavement area. The proper length of concrete panels (defined as the distance between discontinuous pavement sections, e.g., between construction or isolation joints, or a combination of the two) and the location of contraction, construction, and isolation (expansion) joints are not included as a function of the above concrete pavement guidelines. Rather, these features should be determined based on the geometry and construction sequencing of the pavement. Actual joint spacing should be based on actual pavement areas and final panel lengths so that joints are evenly spaced. Joints should be designed to form approximately square panels where geometrically feasible.

The values provided herein are guidelines and the recommendations selected by the project civil engineer and guidelines not provided or mentioned herein should not exceed the American Concrete Institute (ACI) 330R recommendations.

4.6.3 Pavement Drainage, Subdrainage, and Trenching

Longitudinal cracks and apparent distress due to expansive soils may appear in the pavement after construction and the introduction of landscape irrigation. These cracks and distress are not pavement failures with respect to traffic support, although they may be aesthetically undesirable. In addition, without regular maintenance, the cracks can allow additional moisture intrusion and rapid degradation of the pavement section. The pavement sections are primarily designed to support the traffic and will not resist the forces generated by swelling soils.

Positive drainage should be provided on and around pavement areas to avoid ponding of water. Irrigation of lawn and landscaped areas adjacent to the pavements should be moderate, with no excessive wetting or drying of soils. If landscaped islands are provided, they should be designed to restrict excess water from migrating to the pavement subgrade by using self-contained beds, raised planter boxes, vertical moisture barriers, and/or edge drains. Curbs should extend through the base course and at least 4 inches into the underlying subgrade. Good perimeter surface drainage guiding surface water away from the pavement area is also recommended.

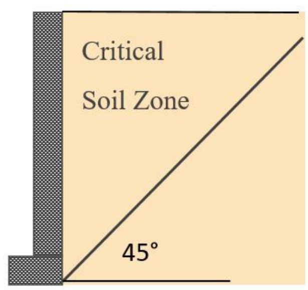
4.7 RETAINING WALLS

The magnitude of the lateral earth pressures on retaining walls is dependent upon the in-situ material behind the wall; and if displaced, the type of material used to backfill the “critical zone” behind the wall. The magnitude of the earth pressure is also dependent upon whether the critical zone is allowed to drain water freely. The critical zone can be considered as the area behind the structure within a boundary created by a 45-degree angle extending from the outside edge of the foundation heel upward to the ground surface.

The lateral earth pressures for drained, level soil backfill are expressed in terms of pounds per cubic foot (psf/ft) “equivalent fluid” weight applied in a triangular distribution pattern as listed below. If the walls are free to deflect or rotate slightly at the top, they may be designed using “active” lateral earth pressures. If the walls are laterally restrained at the top, “at-rest” lateral earth pressures should be used for the retaining wall design. Where multiple material types are used within the critical zone, the higher values below should be used. The equivalent fluid weights shown in the table do not include safety factors and do not account for surcharges. Lateral loads from uniform surcharges on the wall backfill can be calculated by multiplying the vertical surcharge by the below earth pressure coefficients and should be considered as rectangular loads acting on the full wall height. An increase of 1 pcf and 1.5 pcf should be added to the active and at-rest earth pressures; respectively, for each degree of inclination of backfill.

For the design of site retaining walls, we recommend the following tabulated soil parameters.

RETAINING WALL BACKFILL IN THE CRITICAL SOIL ZONE					
Soil Parameter	**Estimated Value**				
Soil Classification	Undisturbed or Compacted Native Soil	Select Fill	ASTM C33 Size #56, #57 or #467 Stone	Compacted Manufactured Sand (< 8% Fines)	Undisturbed Limestone
Retained Soil Moist Unit Weight (γ)	120 pcf	120 pcf	110 pcf	120 pcf	135 pcf
Angle of Internal Friction (ϕ)	24°	28°	30°	30°	36°
Coefficient of Active Earth Pressure (K_a)	0.42	0.36	0.33	0.33	0.26
Coefficient of At-Rest Earth Pressure (K_o)	0.59	0.53	0.50	0.50	0.41
Active Equivalent Fluid Pressure	51 (psf/ft)	43 (psf/ft)	37 (psf/ft)	40 (psf/ft)	35 (psf/ft)
At-Rest Earth Equivalent Fluid Pressure	71 (psf/ft)	64 (psf/ft)	55 (psf/ft)	60 (psf/ft)	55 (psf/ft)



RETAINING WALL FOUNDATIONS	
Parameter	**Estimated Value**
Allowable Bearing Pressure on at least 2 feet of compacted fill	2,500 psf
Minimum Wall Embedment Below Grade	12 inches
Ultimate Sliding Friction Coefficient [Concrete on Soil or Bedrock] (μ)	0.44
Ultimate Passive Equivalent Fluid Pressure (Neglect in upper 12 inches)	280 (psf/ft)

It is critical that the soils used for backfilling retaining walls meet the soil parameters recommended above. If the soils available do not meet those parameters, then ECS should be contacted to provide revised values, and to confirm that only appropriate soils will be used for wall backfill.

Care should be used to avoid the operation of heavy equipment to compact the wall backfill since it may overload and damage the wall. In addition, such loads are not typically considered in the design of site retaining walls and are not provided for in our recommendations.

Wall Drainage: Retaining walls should be provided with a wall and foundation drainage system to relieve hydrostatic pressures which may develop behind the walls. This system can consist of weepholes through the wall and/or a 4-inch perforated, closed joint drain line located along the backside of the walls above the top of the footing. The drain line should be surrounded by a minimum of 6 inches of AASHTO #57 Stone wrapped with an approved non-woven geotextile, such as Mirafi 140N, Mirafi 160N or equivalent. Wall drains can consist of a 12-inch-wide zone of free draining gravel, such as AASHTO #57 Stone, employed directly behind the wall to within 2 feet of the ground surface and separated from the soils beyond with a non-woven geotextile.

Alternatively, the wall drain can consist of a geocomposite drainage board material such as MiraDRAIN 2000 or reviewed equivalent. The wall drain should be hydraulically connected to the foundation drain. The drainboard should extend from the base of the wall to within two feet of the ground surface and should be installed in accordance with manufacturer specifications. A subdrain collector pipe surrounded with at least 5 cubic feet per foot size #57 stone (wrapped in a geotextile) should be installed at the base of the drainboard; or alternatively, an engineered system can be selected with sufficient capacity for direct connectivity to a closed pipe system. The groundwater should be conducted to an appropriate discharge or sump pump facility.

5.0 SITE CONSTRUCTION RECOMMENDATIONS

5.1 SUBGRADE PREPARATION

In a dry and undisturbed state, the soil at the site is expected to provide good subgrade support for fill placement and construction operations. However, when wet, this soil will degrade quickly with disturbance from contractor operations. Therefore, good site drainage should be maintained during earthwork operations, which would help maintain the integrity of the soil. We recommend that an attempt be made to enhance the natural drainage without interrupting its pattern.

The soils at the site are moisture and disturbance-sensitive and contain fines that are considered moderately erodible. Therefore, the contractor should carefully plan his operation to reduce exposure of the subgrade to weather and construction equipment traffic and provide and maintain good site drainage during earthwork operations to help maintain the integrity of the surficial soils. Erosion and sedimentation should be controlled per sound engineering practice and current jurisdictional requirements.

In preparing the site for construction, loose or soft existing soils, vegetation, organic soil, existing pavements, foundations or utilities, or other deleterious materials should be removed from proposed building and paving areas, and areas receiving new fill. Undocumented fills should be reworked or removed and replaced in accordance with Section 4.1 “Potential Vertical Rise and Subgrade Improvements”.

After stripping and required cuts have been completed, the subgrade soils should be scarified, moisture conditioned and compacted to at least 95 percent of the maximum dry density as determined by TxDOT Tex-114-E to a depth of at least 8 inches. The soils should be moisture conditioned to between optimum and +4 percentage points of the optimum moisture content just prior to compaction. Where limestone bedrock is encountered and verified by ECS, the material need not be ripped or compacted unless desired for constructability purposes.

5.1.1 Removals, Stripping and Grubbing

The subgrade preparation should consist of stripping deleterious materials (as described above) 10 feet from the perimeter of the building and 5 feet beyond pavement limits and beyond the toe of fills. ECS should be called on to check that topsoil and deleterious surficial materials have been removed before the placement of fill or construction of structures.

5.1.2 Proof Rolling

After stripping and removing deleterious surface materials, cutting to the proposed grade, and before compacting the subgrade or placing structural fill, the exposed subgrade should be reviewed by the Geotechnical Engineer or authorized representative. The exposed subgrade should be proof rolled with previously approved construction equipment having a minimum axle load of 25 tons (e.g., fully loaded tandem-axle dump truck). The areas subject to proof rolling should be traversed by the equipment in two perpendiculars (orthogonal) directions with overlapping passes of the vehicle under the observation of the Geotechnical Engineer or authorized representative. This procedure is intended to assist in identifying localized yielding materials. If yielding or “pumping” subgrade is identified by the proof rolling, those areas should be marked for repair before the placement of subsequent structural fill or other construction materials. Subgrade repair methods, such as undercutting, moisture conditioning, geogrid or lime/cement treatment, should be discussed with the Geotechnical Engineer to determine the appropriate procedure about the existing conditions causing the yielding.

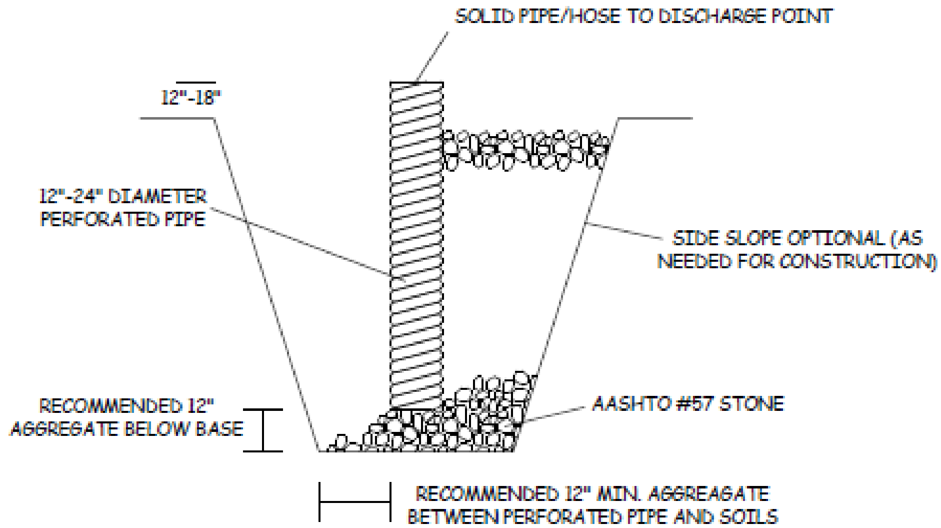
If the area is deemed too small for a piece of equipment to traverse, the excavated area should be probed by the Geotechnical Engineer or authorized representative.

5.1.3 Site Temporary Dewatering

The contractor should make their own assessment of temporary dewatering needs based upon the limited subsurface groundwater information presented in this report. Soil sampling is not continuous, and thus soil and groundwater conditions may vary between sampling intervals (typically 5 feet). If the contractor believes additional subsurface information is needed to assess dewatering needs, they should obtain such information at their own expense. ECS makes no warranties or guarantees regarding the adequacy of the provided information to determine dewatering requirements; such recommendations are beyond our scope of services.

Dewatering systems are a critical component of many construction projects. Dewatering systems should be selected, designed, and maintained by a qualified and experienced (specialty or other) contractor familiar with the succinct geotechnical and other aspects of the project. The failure to properly design and maintain a dewatering system for a given project can result in delayed construction, unnecessary foundation subgrade undercuts, detrimental phenomena such as “running sand” conditions, internal erosion (i.e., “piping”), the migration of “fines” down-gradient towards the dewatering system, localized settlement of nearby infrastructure, foundations, slabs-on-grade and pavements, etc. Water discharged from a site dewatering system should be discharged in accordance with local, state and federal requirements.

Strategies for Addressing Perched Groundwater: The typical primary strategy for addressing perched groundwater seeping into excavations is pumping from trenches (or French drains) and sump pits with sump pumps. A typical sump pump drain (found in a sump pit or along a French drain) is depicted on the following page. The inlet of the sump pump is placed at the bottom of the corrugated pipe and the discharge end of the sump is directed to an appropriate stormwater drain.



Sump Pit/Pump Diagram

A typical French drain consists of an 18 to 24-inch-wide bed of AASHTO #57 (or similar open graded aggregate) aggregate wrapped in a medium duty, non-woven geotextile such as Mirafi 140N or 160N and (often) containing a 4 to 6-inch diameter, Schedule 40 PVC perforated or slotted pipe. Actual dimensions should be as determined necessary by ECS during construction. After the installation has been completed, the geotextile should be wrapped over the top of the aggregate and pipe followed by placement of backfill. The top of the drain should be positioned at least 18 inches beneath the design subgrade elevations. Drains should not be routed within the expanded building limits.

Pumping wells or a vacuum system could also be used to address perched groundwater. These techniques often are only effective during the initial depletion of the perched water quantity and may quickly be ineffective at addressing accumulation of water from rain, lake level, etc.

5.2 EARTHWORK OPERATIONS

It is recommended that the building pad be improved according to report Section 4.1 “Potential Vertical Rise & Subgrade Improvements” to achieve an as-built PVR of about 1 inch or ¾ inch and to reduce settlement potential. The stripping and removal operations and fill placement to finished pad grade should extend at least 5 feet beyond the building perimeter and beneath adjacent movement sensitive concrete flatwork. The upper 18 inches of fill outside of the building areas should consist of a properly compacted low permeability clay soil to reduce infiltration of moisture into the adjacent select fill materials.

After stripping and grubbing, undercutting/removals, subgrade preparation (including proof rolling) and evaluation has been completed, fill placement may begin. Fills in the building pad area should consist of materials meeting the requirements of the Select Fill section below. Fills in pavement and landscape areas can consist of materials meeting the requirements of the General Fill section below. Consideration should be given to creating an “all weather” working surface with the upper 6 inches of the select fill building pad. Such a working surface should consist of compacted 2014 TxDOT Item 247 Type A, Grade 1-2 Flexible Base material. The use of an “all weather” working surface can significantly improve the accessibility of the site to construction traffic during periods of wet weather.

Soil moisture levels should be preserved (by various methods that can include covering with plastic, watering, etc.) until new fill, pavements, or slabs are placed. Fill soils should be placed in 8 inches loose lifts for mass grading operations and 4-inch lifts for trench excavations where walk-behind or "jumping jack" compaction equipment is used.

Upon completion of the filling operations, care should be taken to maintain the soil moisture content before the construction of floor slabs and pavements. If the soil becomes desiccated, the affected material should be removed and replaced, or these materials should be scarified, moisture conditioned, and re-compacted.

Utility cuts should not be left open for extended periods and should be properly backfilled. Backfilling should be accomplished with properly compacted on-site soils, rather than granular materials. If granular materials are used, a utility trench cut-off at the building line is recommended to help prevent water from migrating through the utility trench backfill to beneath the proposed structure.

Field density and moisture tests should be performed on each lift as necessary to check that adequate compaction is achieved. As a guide, one test per 5,000 square feet per lift is recommended in the building area (two tests minimum per lift) and one test per 10,000 square feet per lift is recommended in the pavement areas (two tests minimum per lift. Utility trench backfill should be tested at a rate of one test per lift per every 100 linear feet of the trench (two tests minimum per lift). Certain jurisdictional requirements may require testing in addition to that noted previously. Therefore, these specifications should be reviewed, and more stringent specifications should be followed.

5.2.1 Weathered Rock and Rock

Shallow limestone was encountered at the site during our subsurface exploration and rock excavation techniques will be necessary for this project. For purposes of contract terms, we recommend that "rock" be defined as follows: "Rock shall be defined as those natural materials which cannot be excavated in an open excavation with a Caterpillar Model No. D-8, heavy-duty track-type tractor, weighted at not less than 285 hp (flywheel power) and equipped with a single-shank hydraulic ripper, capable of exerting not less than 45,000 lbs. breakout force, or equivalent machinery. For footings, utility trenches and pits, rock shall be defined as those materials that cannot be excavated with a Caterpillar Model No. 215D LC track-type hydraulic excavator, equipped with a 42-inch wide short-tip radius rock bucket, rated at not less than 120 hp flywheel power with bucket-curling force of not less than 25,000 lbs. and stick-crowd force of not less than 18,000 lbs."

Depending on the excavation methods, the rock at this site may excavate in relatively large, blocky and platy pieces, which are difficult to compact for long-term performance. Excavated stratum II bedrock materials may be appropriate for fill within the building and paving limits. Rock excavated from the site and used as earthwork fill should have a well-graded grain size distribution with rock and soil particles ranging from clay or silt size particles to a maximum size of 4 inches in diameter. Particles larger than this should be decomposed by mechanical compaction equipment to achieve the desired grain size distribution.

Once appropriately broken down, this material may then be placed and compacted to at least 95% of the Maximum Dry Density at -1 to +3 percent above the optimum moisture content as obtained using Tex-114-E.

5.3 MATERIAL SPECIFICATIONS

The subgrade preparation option provided in Section 4.1 "Potential Vertical Rise & Subgrade Improvements" portion of this report outlines the requirements to reduce the PVR in the building area. This section is intended to outline the material requirements of those recommendations.

5.3.1 General Fill

General fill should consist of on-site or imported soils, provided they meet the requirements described below. General fill materials should be free of organics, construction debris, deleterious materials, and should be free of rocks larger than 4 inches in greatest dimension. Proposed general fill should be evaluated and tested by ECS prior to placement in the field.

ECS recommends that general fill be placed in horizontal loose lifts of not more than 8 inches in thickness. Lift thickness should be decreased when using light compaction equipment. General fill should be compacted to at least 95% of the maximum dry density at moisture contents within the range of optimum to +4 percentage points of the optimum moisture content (Tex-114-E).

5.3.2 Select Fill

Select fill materials should be free of organics, construction debris, deleterious materials, and free of rocks larger than 4 inches in greatest dimension. Select fill should have a Plasticity Index of between 5 and 20. Select fill should be evaluated and tested by ECS prior to placement in the field.

In lieu of importing select fill soils on-site directly, lime treatment of soils with higher plasticity index may be completed to lower the PI and to manufacture the select fill soils. Adequate lime should be mixed with these soils in accordance with TxDOT Item 260 to generate a PI between 5 and 20 for the treated materials. ECS recommends that soils proposed for lime-treatment be tested for sulfates prior to adding lime.

ECS recommends that select fill be placed in horizontal loose lifts of not more than 8 inches in thickness. Select fill should be compacted to at least 95% of the maximum dry density at moisture contents within the range of -1 to +3 percentage points of the optimum moisture content (Tex-114-E).

5.4 FOUNDATION AND SLAB OBSERVATIONS

Protection of Foundation Excavations: Exposure to the environment may weaken the soils at the footing bearing level if the foundation excavations remain open for too long a time. Therefore, foundation concrete should be placed as soon as possible after the excavations are made. If the bearing soils are softened by surface water intrusion or exposure, the softened soils should be removed from the foundation excavation bottom immediately prior to placement of concrete. If the excavation must remain open overnight, or if rainfall becomes imminent while the bearing soils are exposed, a 1 to 3-inch thick “mud mat” of “lean” concrete is suggested to be placed on the bearing soils before the placement of reinforcing steel.

Footing and Slab Subgrade Observations: It is important to have ECS observe the foundation subgrade prior to placing foundation concrete, to confirm the bearing soils are what was anticipated.

5.5 UTILITY INSTALLATIONS

Utility Subgrades: The soils encountered in our exploration are expected to be generally appropriate for support of utility pipes. The pipe subgrades should be observed and probed by ECS. Loose or deleterious materials encountered should be removed and replaced with compacted General Fill, or pipe stone bedding material.

Utility Backfilling: The granular bedding material (often AASHTO #57 stone) should be at least 4 inches thick, but not less than that specified by the civil engineer’s project drawings and specifications. We recommend that the bedding materials be placed up to at least the springline of the pipe. Utility trenches in the building pad should be backfilled above the utility bedding and shading materials with similar materials to original building pad construction, and general fill materials outside the building pad area. The backfill materials should be placed in lifts not to exceed 8 inches loose measure, or 6 inches compacted measure. Thinner lifts may be required when using handheld compaction equipment. Backfill materials should be moisture conditioned and compacted in accordance with the select fill and general fill sections of this report.

Excavation Safety: Excavations and slopes should be constructed and maintained in accordance with OSHA excavation safety standards. The contractor is solely responsible for designing, constructing, and maintaining stable temporary excavations and slopes. The contractor’s responsible person, as defined in 29 CFR Part 1926, should evaluate the soil exposed in the excavations as part of the contractor’s safety procedures. In no case should slope height, slope inclination, or excavation depth, including utility trench excavation depth, exceed those specified in local, state, and federal safety regulations. ECS is providing this information solely as a service to our client. ECS is not assuming responsibility for construction site safety or the contractor’s activities; such responsibility is not being implied and should not be inferred.

6.0 CLOSING

ECS has prepared this report to guide the geotechnical-related design and construction aspects of the project. We performed these services in accordance with the standard of care expected of professionals in the industry performing similar services on projects of like size and complexity at this time in the region. No other representation, expressed or implied, and no warranty or guarantee is included or intended in this report.

The description of the proposed project is based on information provided to ECS by the Client. If any of this information is inaccurate or changes, either because of our interpretation of the documents provided or site or design changes that may occur later, ECS should be contacted so we can review our recommendations and provide additional or alternate recommendations that reflect the proposed construction.

We recommend that ECS review the project plans and specifications so we can confirm that those plans/specifications are in accordance with the recommendations of this geotechnical report.

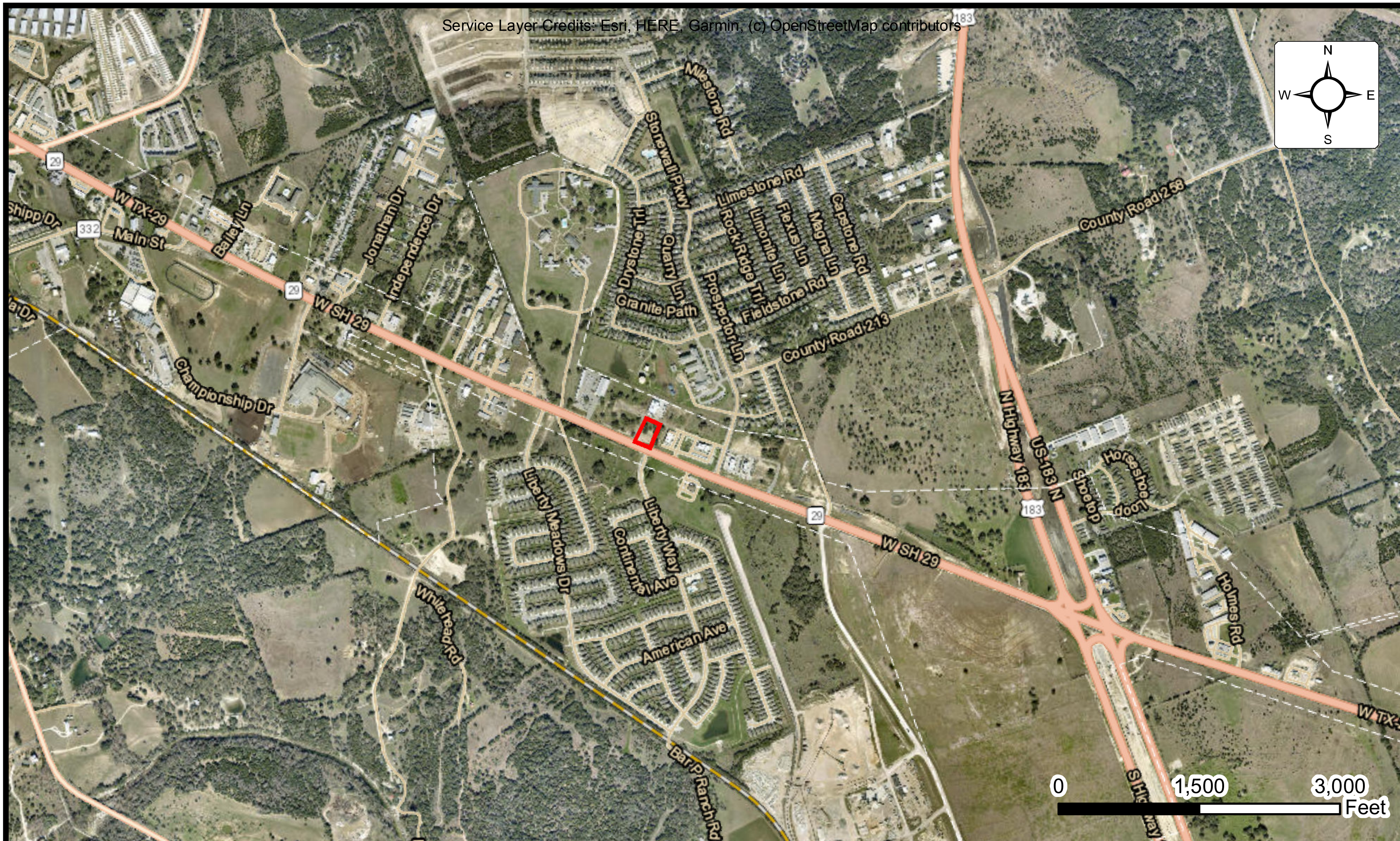
Field observations, and quality assurance testing during earthwork and foundation installation are an extension of, and integral to, the geotechnical design. We recommend that ECS be retained to apply our expertise throughout the geotechnical phases of construction, and to provide consultation and recommendation should issues arise.

ECS is not responsible for the conclusions, opinions, or recommendations of others based on the data in this report.

The analysis and recommendations submitted in this report are based upon the data obtained from the soil borings and tests performed at the locations as indicated on the Boring Location Diagram and other information referenced in this report. This report does not reflect any variations, which may occur between the borings. In the performance of the subsurface exploration, specific information is obtained at specific locations at specific times. However, it is a well-known fact that variations in subsurface conditions exist on most sites between boring locations and also such situations as groundwater levels vary from time to time. The nature and extent of variations may not become evident until the course of construction. If variations then appear evident, after performing on-site observations during the construction period and noting characteristics and variations, a reevaluation of the recommendations for this report will be necessary.

Appendix A - Drawings and Reports

Site Location Diagram
Boring Location Diagram
Site Geologic Diagram
Generalized Subsurface Soil Profile



Site Location Diagram
SHERWIN WILLIAMS - LIBERTY HILL

12360 W SH-29, LIBERTY HILL, TEXAS
LIBERTY HILL DEVELOPMENT GROUP LLC

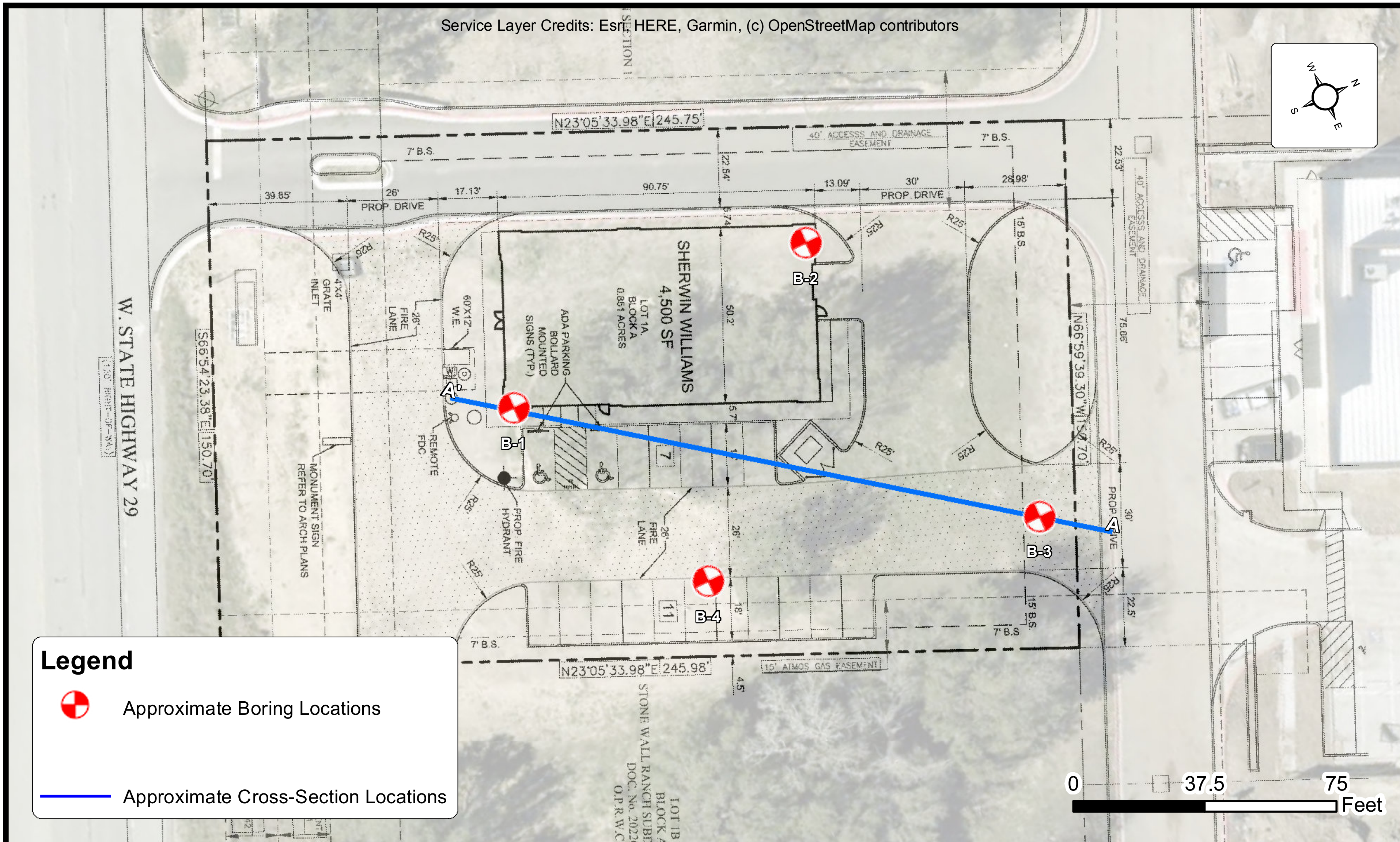
ENGINEER
CFR

SCALE
AS NOTED

PROJECT NO.
17:6314

SHEET
FIGURE 1

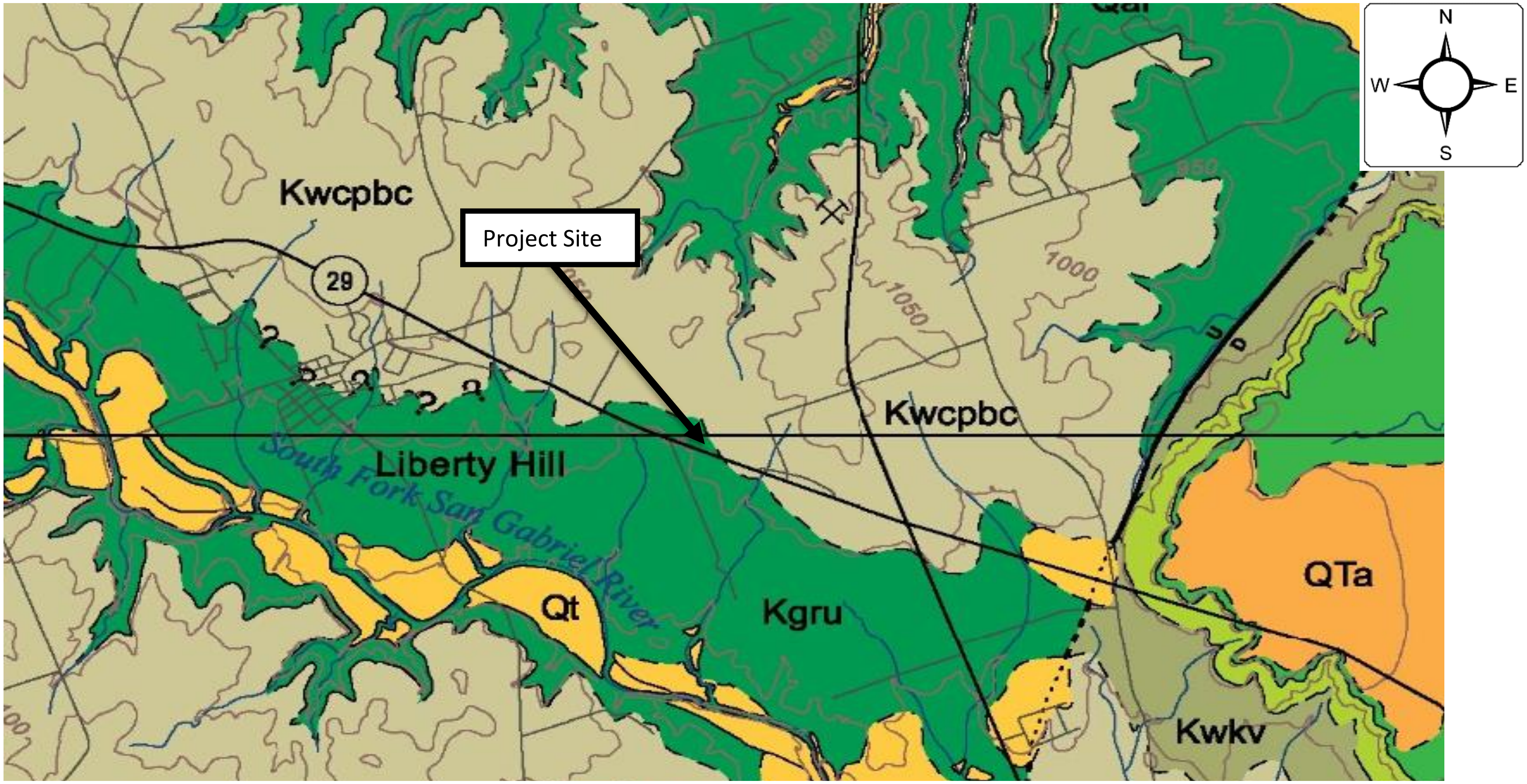
DATE
JULY 2023



BORING LOCATION DIAGRAM
SHERWIN WILLIAMS - LIBERTY HILL

12360 W SH-29, LIBERTY HILL, TEXAS
LIBERTY HILL DEVELOPMENT GROUP LLC

ENGINEER	CFR
SCALE	AS NOTED
PROJECT NO.	17:6314
FIGURE	FIGURE 2
DATE	JULY 2023



Cedar Park, Bee Cave and Bull Creek Members undivided of the Walnut Formation (Kwcpbc)
Upper Glen Rose Formation (Kgru)

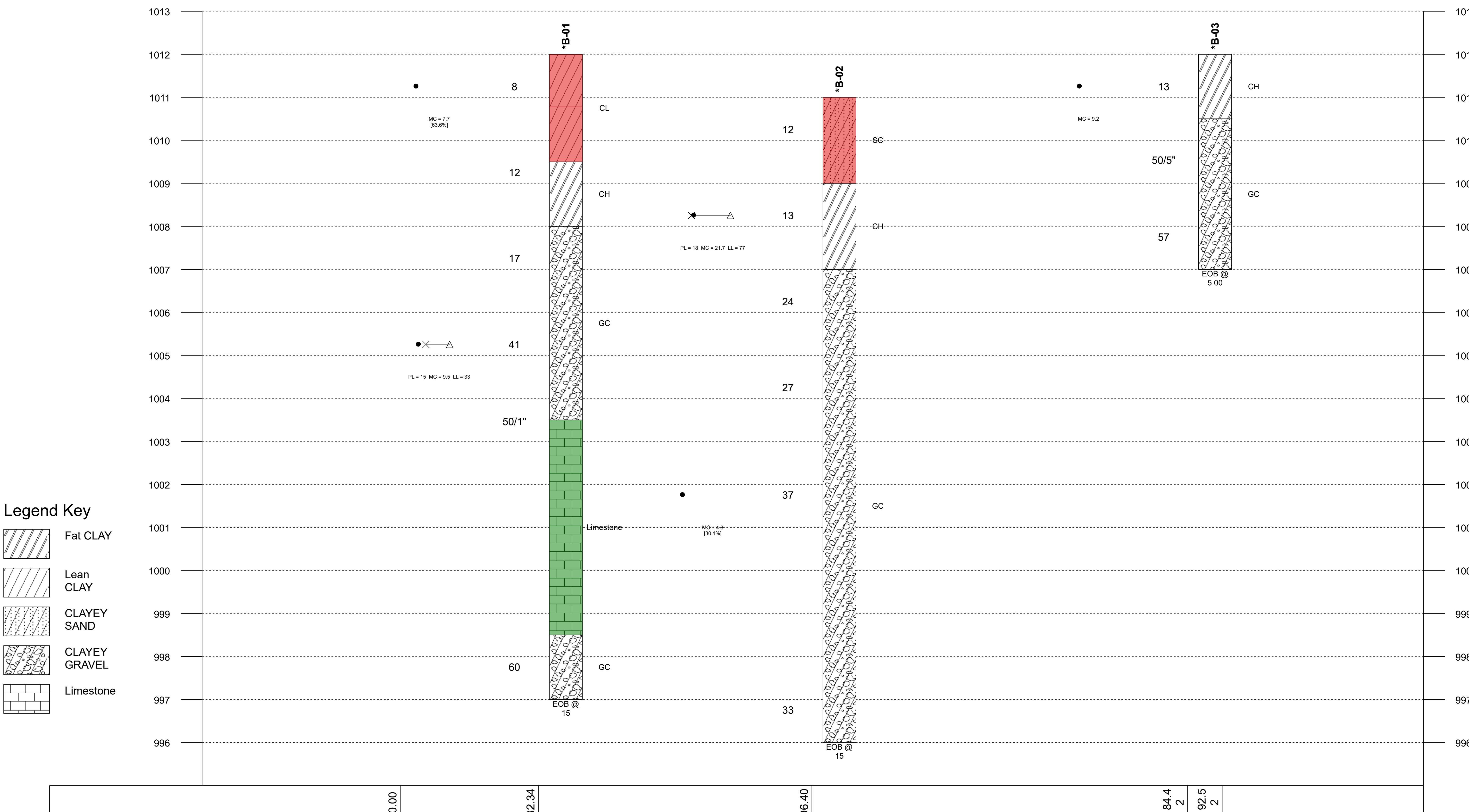
Geologic map of the West Half of the Taylor, Texas 30x60 Minute Quadrangle, Texas **UT Bureau of Economic Geology, 2005**

ECS

SITE GEOLOGIC DIAGRAM
SHERWIN WILLIAMS- LIBERTY HILL

12360 W SH-9, LIBERTY HILL, TEXAS
LIBERTY HILL DEVELOPMENT GROUP LLC

ENGINEER	CFR
SCALE	NTS
PROJECT NO.	17:6314
SHEET	FIGURE 3
DATE	JULY 2023



Notes:
1- EOB: END OF BORING AR: AUGER REFUSAL SR: SAMPLER REFUSAL.
2- THE NUMBER BELOW THE STRIPS IS THE DISTANCE ALONG THE BASELINE.
3- SEE INDIVIDUAL BORING LOG AND GEOTECHNICAL INFORMATION.
4- STANDARD PENETRATION TEST RESISTANCE (LEFT OF BORING) IN BLOWS PER FOOT (ASTM D1586).

Plastic Limit Water Content Liquid Limit	WL (First Encountered)	Fill
[FINES CONTENT %]	WL (Completion)	Possible Fill
BOTTOM OF CASING	WL (Estimated Seasonal High Water)	Probable Fill
LOSS OF CIRCULATION	WL (Stabilized)	Rock
CALIBRATED PENETROMETER		

GENERALIZED SUBSURFACE SOIL PROFILE

Cross Section A-A' Figure 4

Sherwin Williams - Liberty Hill

Liberty Hill Development Group, LLC

12360 W Hwy. 29, Liberty Hill, Texas, 78642

Project No: 17:6314 Date: JULY 2023

Appendix B – Field Operations

Exploration Procedures
Reference Notes
Boring Logs

SUBSURFACE EXPLORATION PROCEDURE

The field exploration was planned with the objective of characterizing the project site in general geotechnical and geological terms and to evaluate subsequent field and laboratory data to assist in the determination of geotechnical recommendations.

The subsurface conditions were explored by two borings drilled to completion depths of 15 feet each, and two borings drilled to completion depths of 5 feet each below the existing site grades. A truck-mounted drill rig using air rotary drilling methodology was utilized to advance the borings.

The boring locations were determined by the Client and identified in the field by ECS personnel using handheld GPS unit. The approximate as-drilled boring locations are shown on the Boring Location Diagram in Appendix A. The ground surface elevations noted in this report were obtained from the provided topographic information.

Representative soil samples were obtained by means of the split-barrel sampling procedure in general accordance with ASTM D1586. In the split-barrel sampling procedure, a 2-inch O.D., split-barrel sampler is driven into the soil a distance of 18 inches by means of a 140-pound hammer falling 30 inches. The number of blows required to drive the sampler through a 12-inch interval is termed the Standard Penetration Test (SPT) value and is indicated for each sample on the boring log.

Field logs of the soils encountered in the borings were maintained by the drill crew. After recovery, each geotechnical soil sample was removed from the sampler and visually classified. Representative portion of the soil samples were then wrapped in plastic and transported to our laboratory for further visual examination and laboratory testing. After completion of the drilling operations, the boreholes were backfilled with auger cuttings.

REFERENCE NOTES FOR BORING LOGS

MATERIAL[1,2]

	Material	
	ASPHALT	
	CONCRETE	
	GRAVEL	
	TOPSOIL	
	VOID	
	BRICK	
	AGGREGATE BASE COURSE	
GW	WELL-GRADED GRAVEL	gravel-sand mixtures, little or no fines
GP	POORLY-GRADED GRAVEL	gravel-sand mixtures, little or no fines
GM	SILTY GRAVEL	gravel-sand-silt mixtures
GC	CLAYEY GRAVEL	gravel-sand-clay mixtures
SW	WELL-GRADED SAND	gravelly sand, little or no fines
SP	POORLY-GRADED SAND	gravelly sand, little or no fines
SM	SILTY SAND	sand-silt mixtures
SC	CLAYEY SAND	sand-clay mixtures
ML	SILT	non-plastic to medium plasticity
MH	ELASTIC SILT	high plasticity
CL	LEAN CLAY	low to medium plasticity
CH	FAT CLAY	high plasticity
OL	ORGANIC SILT or CLAY	non-plastic to low plasticity
OH	ORGANIC SILT or CLAY	high plasticity
PT	PEAT	highly organic soils

DRILLING SAMPLING SYMBOLS & ABBREVIATIONS

SS	Split Spoon Sampler	PM	Pressuremeter Test
ST	Shelby Tube Sampler	RD	Rock Bit Drilling
WS	Wash Sample	RC	Rock Core, NX, BX, AX
BS	Bulk Sample of Cuttings	REC	Rock Sample Recovery %
PA	Power Auger (no sample)	RQD	Rock Quality Designation %
HSA	Hollow Stem Auger		

PARTICLE SIZE IDENTIFICATION

DESIGNATION		PARTICLE SIZES
Boulders		12 inches (300 mm) or larger
Cobbles		3 inches to 12 inches (75 mm to 300 mm)
Gravel:	Coarse	¾ inch to 3 inches (19 mm to 75 mm)
	Fine	4.75 mm to 19 mm (No. 4 sieve to ¾ inch)
Sand:	Coarse	2.00 mm to 4.75 mm (No. 10 to No. 4 sieve)
	Medium	0.425 mm to 2.00 mm (No. 40 to No. 10 sieve)
	Fine	0.074 mm to 0.425 mm (No. 200 to No. 40 sieve)
Silt & Clay ("Fines")		<0.074 mm (smaller than a No. 200 sieve)

COHESIVE SILTS & CLAYS

UNCONFINED COMPRESSIVE STRENGTH, QP[4]	SPT[5] (BPF)	CONSISTENCY[7] (COHESIVE)
<0.25	<2	Very Soft
0.25 - <0.50	2 - 4	Soft
0.50 - <1.00	5 - 8	Firm
1.00 - <2.00	9 - 15	Stiff
2.00 - <4.00	16 - 30	Very Stiff
4.00 - 8.00	31 - 50	Hard
>8.00	>50	Very Hard

RELATIVE AMOUNT[7]	COARSE GRAINED (%)[8]	FINE GRAINED (%)[8]
Trace	≤5	≤5
With	10 - 20	10 - 25
Adjective *(ex: "Silty")*	25 - 45	30 - 45

GRAVELS, SANDS & NON-COHESIVE SILTS

SPT[5]	DENSITY
<5	Very Loose
5 - 10	Loose
11 - 30	Medium Dense
31 - 50	Dense
>50	Very Dense

WATER LEVELS[6]

- WL (First Encountered)
- WL (Completion)
- WL (Seasonal High Water)
- WL (Stabilized)

FILL AND ROCK

FILL | POSSIBLE FILL | PROBABLE FILL | ROCK

[1]Classifications and symbols per ASTM D 2488-17 (Visual-Manual Procedure) unless noted otherwise.

[2]To be consistent with general practice, "POORLY GRADED" has been removed from GP, GP-GM, GP-GC, SP, SP-SM, SP-SC soil types on the boring logs.

[3]Non-ASTM designations are included in soil descriptions and symbols along with ASTM symbol [Ex: (SM-FILL)].

[4]Typically estimated via pocket penetrometer or Torvane shear test and expressed in tons per square foot (tsf).

[5]Standard Penetration Test (SPT) refers to the number of hammer blows (blow count) of a 140 lb. hammer falling 30 inches on a 2 inch OD split spoon sampler required to drive the sampler 12 inches (ASTM D 1586). "N-value" is another term for "blow count" and is expressed in blows per foot (bpf). SPT correlations per 7.4.2 Method B and need to be corrected if using an auto hammer.

[6]The water levels are those levels actually measured in the borehole at the times indicated by the symbol. The measurements are relatively reliable when augering, without adding fluids, in granular soils. In clay and cohesive silts, the determination of water levels may require several days for the water level to stabilize. In such cases, additional methods of measurement are generally employed.

[7]Minor deviation from ASTM D 2488-17 Note 14.

[8]Percentages are estimated to the nearest 5% per ASTM D 2488-17.

CLIENT:	PROJECT NO.:	BORING NO.:	SHEET:
Liberty Hill Development Group, LLC	**17:6314**	**B-01**	**1 of 1**

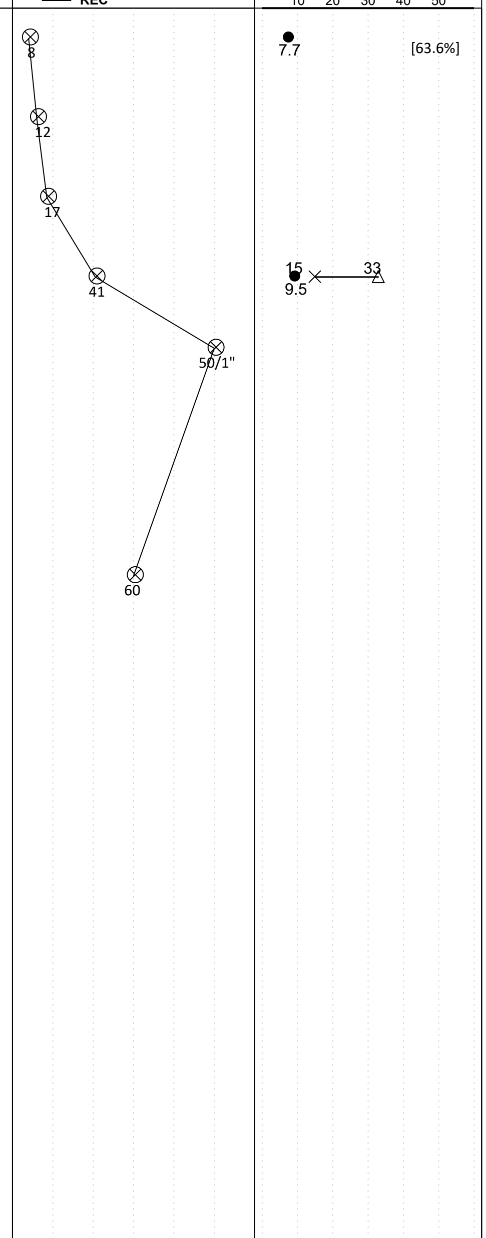
PROJECT NAME:	DRILLER/CONTRACTOR:
Sherwin Williams - Liberty Hill	**Austin Geo-Logic**

SITE LOCATION:
12360 W Hwy. 29, Liberty Hill, Texas, 78642

LOSS OF CIRCULATION
BOTTOM OF CASING

NORTHING:	EASTING:	STATION:	SURFACE ELEVATION:
			1012

DEPTH (FT)	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE DIST. (IN)	RECOVERY (IN)	DESCRIPTION OF MATERIAL	WATER LEVELS	ELEVATION (FT)	BLOWS/6"
	S-01	SS	18	18	(CL-FILL) SANDY LEAN CLAY, brown to light brown, firm to stiff			6-4-4 (8)
	S-02	SS	18	18	(CH) FAT CLAY WITH SAND, dark brown, stiff			5-6-6 (12)
5	S-03	SS	18	18	(GC) CLAYEY GRAVEL WITH SAND, light brown and light gray, medium dense to dense		1007	7-6-11 (17)
	S-04	SS	18	18				8-18-23 (41)
	~~S-05~~	~~SS~~	~~1~~	~~1~~	LIMESTONE, light gray, very hard			50/1" (50/1")
10							1002	
	S-06	SS	18	18	(GC) CLAYEY GRAVEL WITH SAND, light gray, very dense			41-28-32 (60)
15					**END OF BORING AT 15 FT**		997	
20							992	
25							987	
30							982	



THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES. IN-SITU THE TRANSITION MAY BE GRADUAL

WL (First Encountered)		BORING STARTED: **Jul 11 2023**	CAVE IN DEPTH:
WL (Completion)	**Dry**	BORING COMPLETED: **Jul 11 2023**	HAMMER TYPE: **Auto**
WL (Seasonal High Water)		EQUIPMENT: **Truck** / LOGGED BY:	DRILLING METHOD: **Air Rotary**
WL (Stabilized)			

GEOTECHNICAL BOREHOLE LOG

CLIENT: **Liberty Hill Development Group, LLC**	PROJECT NO.: **17:6314**	BORING NO.: **B-02**	SHEET: **1 of 1**
PROJECT NAME: **Sherwin Williams - Liberty Hill**	DRILLER/CONTRACTOR: **Austin Geo-Logic**		
SITE LOCATION: **12360 W Hwy. 29, Liberty Hill, Texas, 78642**		LOSS OF CIRCULATION	
NORTHING:	EASTING:	STATION:	SURFACE ELEVATION: **1011**
		BOTTOM OF CASING	

DEPTH (FT)	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE DIST. (IN)	RECOVERY (IN)	DESCRIPTION OF MATERIAL	WATER LEVELS	ELEVATION (FT)	BLOWS/6"	STANDARD PENETRATION BLOWS/FT	LIQUID LIMIT / PLASTIC LIMIT / WATER CONTENT % [FINES CONTENT] %
	S-01	SS	18	18	(SC-FILL) CLAYEY SAND WITH GRAVEL, brown to light brown, medium dense			5-5-7 (12)	12	
	S-02	SS	18	18	(CH) FAT CLAY WITH SAND, dark brown, stiff			6-6-7 (13)	13	18 / 21.7 / 77
5	S-03	SS	18	18	(GC) CLAYEY GRAVEL WITH SAND, light brown and light gray, medium dense to dense		1006	9-11-13 (24)	24	
	S-04	SS	18	18				6-12-15 (27)	27	
	S-05	SS	18	18				11-12-25 (37)	37	4.8 [30.1%]
10							1001			
	S-06	SS	18	18				9-18-15 (33)	33	
15					**END OF BORING AT 15 FT**		996			
20							991			
25							986			
30							981			

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES. IN-SITU THE TRANSITION MAY BE GRADUAL

WL (First Encountered)	BORING STARTED: **Jul 11 2023**	CAVE IN DEPTH:
WL (Completion) **Dry**	BORING COMPLETED: **Jul 11 2023**	HAMMER TYPE: **Auto**
WL (Seasonal High Water)	EQUIPMENT: **Truck** / LOGGED BY:	DRILLING METHOD: **Air Rotary**
WL (Stabilized)		

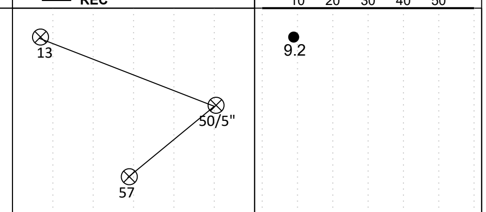
GEOTECHNICAL BOREHOLE LOG

CLIENT:	PROJECT NO.:	BORING NO.:	SHEET:
Liberty Hill Development Group, LLC	**17:6314**	**B-03**	**1 of 1**
PROJECT NAME: **Sherwin Williams - Liberty Hill**	DRILLER/CONTRACTOR: **Austin Geo-Logic**		
SITE LOCATION: **12360 W Hwy. 29, Liberty Hill, Texas, 78642**		LOSS OF CIRCULATION	
NORTHING:	EASTING:	STATION:	SURFACE ELEVATION: **1012**
			BOTTOM OF CASING

DEPTH (FT)	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE DIST. (IN)	RECOVERY (IN)	DESCRIPTION OF MATERIAL	WATER LEVELS	ELEVATION (FT)	BLOWS/6"
	S-01	SS	18	18	(CH) FAT CLAY WITH SAND, dark brown, stiff			5-5-8 (13)
	S-02	SS	11	11	(GC) CLAYEY GRAVEL WITH SAND, light brown and light gray, very dense			11-50/5" (50/5")
	S-03	SS	18	18				28-25-32 (57)
5					**END OF BORING AT 5.00 FT**		1007	
10							1002	
15							997	
20							992	
25							987	
30							982	

⊗ STANDARD PENETRATION BLOWS/FT
20 40 60 80 100
ROCK QUALITY DESIGNATION & RECOVERY
RQD
REC

△ LIQUID LIMIT
✕ PLASTIC LIMIT
○ CALIBRATED PENETROMETER TSF
1 2 3 4 5
● WATER CONTENT %
[FINES CONTENT] %
10 20 30 40 50



THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES. IN-SITU THE TRANSITION MAY BE GRADUAL

WL (First Encountered)		BORING STARTED: **Jul 11 2023**	CAVE IN DEPTH:
WL (Completion)	**Dry**	BORING COMPLETED: **Jul 11 2023**	HAMMER TYPE: **Auto**
WL (Seasonal High Water)		EQUIPMENT: **Truck** / LOGGED BY:	DRILLING METHOD: **Air Rotary**
WL (Stabilized)			

GEOTECHNICAL BOREHOLE LOG

CLIENT:	PROJECT NO.:	BORING NO.:	SHEET:
Liberty Hill Development Group, LLC	**17:6314**	**B-04**	**1 of 1**

PROJECT NAME:	DRILLER/CONTRACTOR:
Sherwin Williams - Liberty Hill	**Austin Geo-Logic**

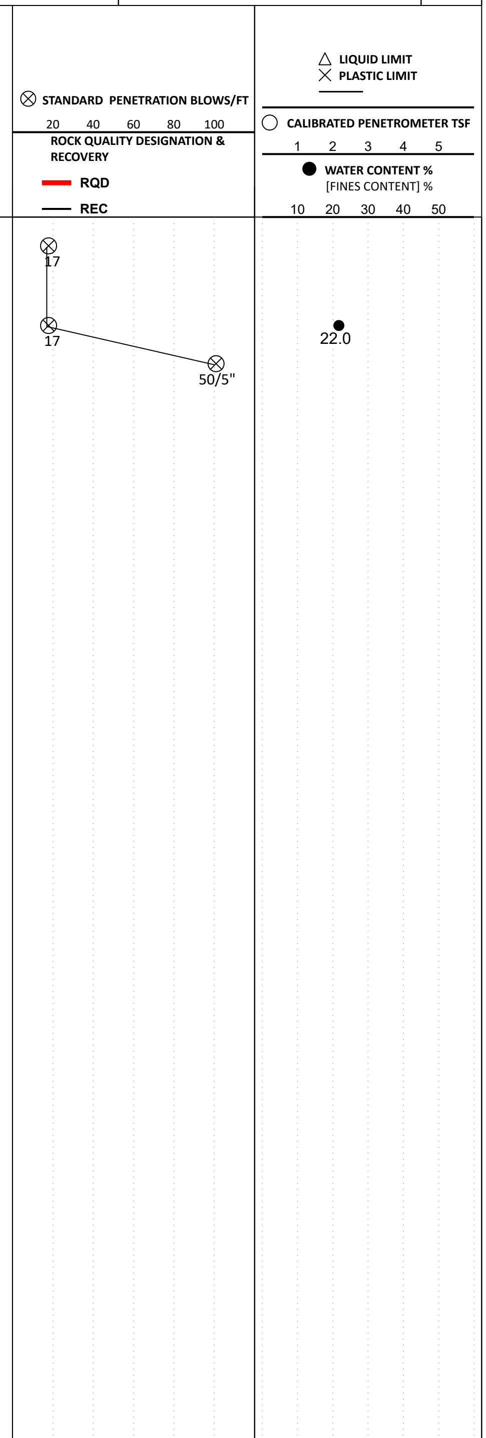
SITE LOCATION:
12360 W Hwy. 29, Liberty Hill, Texas, 78642

LOSS OF CIRCULATION

BOTTOM OF CASING

NORTHING:	EASTING:	STATION:	SURFACE ELEVATION:
			1011

DEPTH (FT)	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE DIST. (IN)	RECOVERY (IN)	DESCRIPTION OF MATERIAL	WATER LEVELS	ELEVATION (FT)	BLOWS/6"
	S-01	SS	18	18	(SC-FILL) CLAYEY SAND WITH GRAVEL, brown to light brown, medium dense			6-7-10 (17)
	S-02	SS	18	18	(CH) FAT CLAY WITH SAND, dark brown, very stiff			4-9-8 (17)
	S-03	SS	5	5	LIMESTONE, light brown and light gray, very hard			50/5" (50/5")
5					END OF BORING AT 5.00 FT		1006	
10							1001	
15							996	
20							991	
25							986	
30							981	



THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES. IN-SITU THE TRANSITION MAY BE GRADUAL

WL (First Encountered)		BORING STARTED: **Jul 11 2023**	CAVE IN DEPTH:
WL (Completion)	**Dry**	BORING COMPLETED: **Jul 11 2023**	HAMMER TYPE: **Auto**
WL (Seasonal High Water)		EQUIPMENT: **Truck** / LOGGED BY:	DRILLING METHOD: **Air Rotary**
WL (Stabilized)			

GEOTECHNICAL BOREHOLE LOG

Appendix C – Laboratory Testing

Laboratory Testing Summary
Grain Size Analysis/Analyses

Laboratory Testing Summary

Sample Source	Sample Number	Start Depth (feet)	End Depth (feet)	Sample Distance (feet)	MC[1] (%)	Soil Type[2]	Atterberg Limits[3]			Percent Passing No. 200 Sieve[4]	Moisture - Density (Corr.)[5]		CBR Value[6]	Organic Content (%)
							LL	PL	PI		Maximum Density (pcf)	Optimum Moisture (%)		
B-01	S-01	0.0	1.5	1.5	7.7	CL				63.6				
B-01	S-04	6.0	7.5	1.5	9.5	GC	33	15	18					
B-02	S-02	2.0	3.5	1.5	21.7	CH	77	18	59					
B-02	S-05	8.5	10.0	1.5	4.8	GC				30.1				
B-03	S-01	0.0	1.5	1.5	9.2	CH								
B-04	S-02	2.0	3.5	1.5	22.0	CH								

Notes: 1. ASTM D 2216, 2. ASTM D 2487, 3. ASTM D 4318, 4. ASTM D 1140, 5. See test reports for test method, 6. See test reports for test method

Definitions: MC: Moisture Content, Soil Type: USCS (Unified Soil Classification System), LL: Liquid Limit, PL: Plastic Limit, PI: Plasticity Index, CBR: California Bearing Ration, OC: Organic Content (ASTM D 2974)

Project No.: 17:6314
Project Name: Sherwin Williams - Liberty Hill
PM: Mateus Costa Segura
PE: Connor Roman
Printed On: July 27, 2023

ECS Southwest, LLP - Austin
14050 Summit Drive Suite 101,
Austin, TX 78728
Phone: 512-837-8005
Fax: 512-388-8914

Grain Size Distributions

Boring	Depth	% Fines	% Gravel	% Sand	USCS Soil Type
B-01	0-1.5	63.6	10.7	25.6	(CH) SANDY FAT CLAY
B-02	8.5-10	30.1	23.0	46.8	(SC) CLAYEY SAND WITH GRAVEL

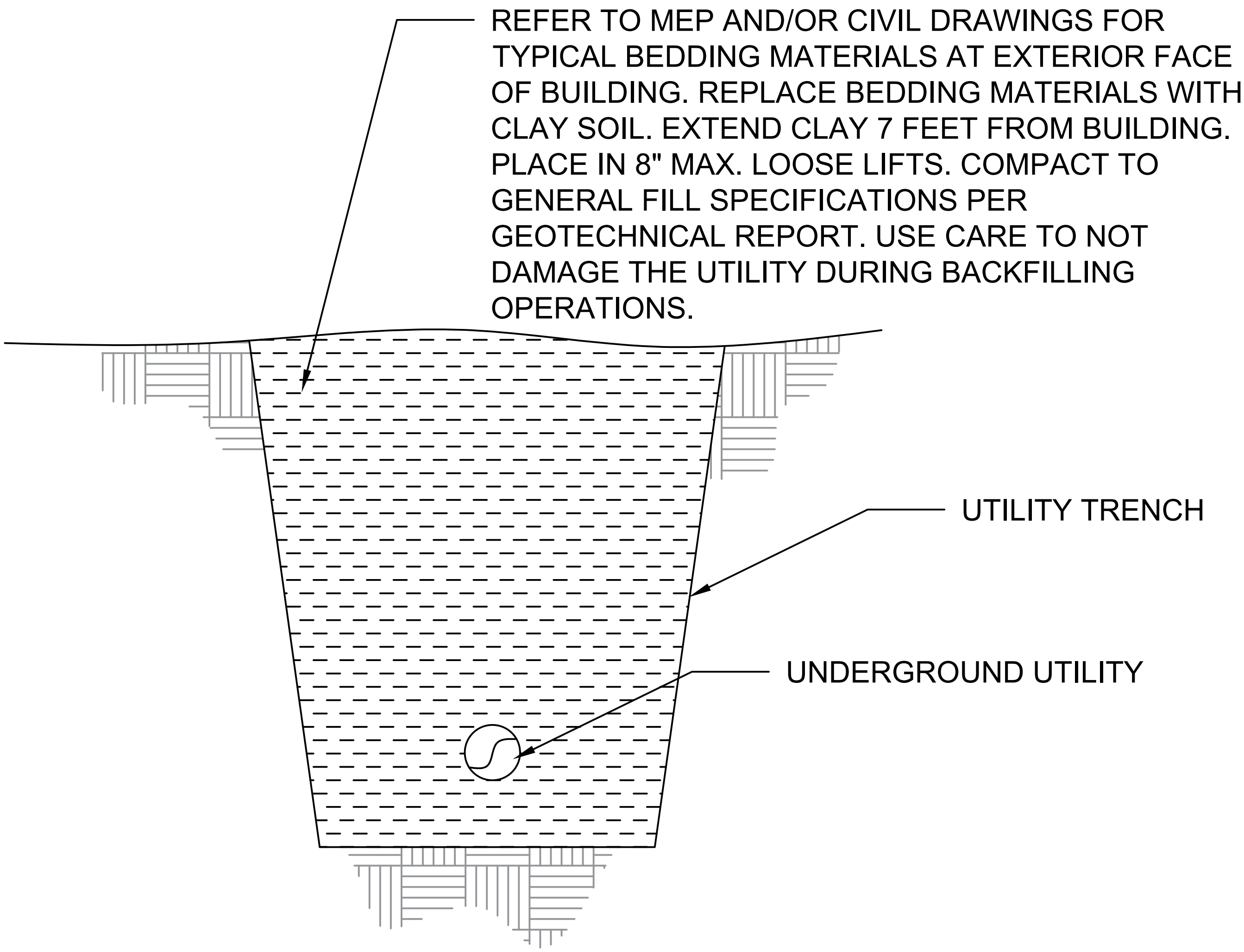
ECS Southwest, LLP
14050 Summit Drive, Suite 101
Austin, Texas 78728

Sherwin Williams - Liberty Hill
12360 W SH-29
Liberty Hill, Texas

Project Number: 17:6314| Date: July 2023

Appendix D – Supplemental Documents

Clay Plug Detail



Title: CLAY PLUG DETAIL	Project: **Sherwin Williams - Liberty Hill** 12360 SH-29 Liberty Hill, Texas	
ECS Southwest, LLP 14050 Summit Drive, Suite 101 Austin Texas 78728	Notes:	

Project No.: 17-6314	Date: JULY 2023	Scale: NTS	Figure No.: 5