



ECS Mid-Atlantic, LLC

Geotechnical Engineering Report

Bonsack Fire Station

1455 Mexico Way NE
Roanoke, Virginia

ECS Project No. 12:19596

June 9, 2022





ECS MID-ATLANTIC, LLC

Geotechnical • Construction Materials • Environmental • Facilities

"Setting the Standard for Service"

June 9, 2022

Mr. George Assaid
Roanoke County
1206 Kessler Mill Road
Salem, VA 24153

ECS Project No. 12:19596

Reference: Geotechnical Engineering Report
Bonsack Fire Station
Roanoke, Virginia

Dear Mr. Assaid:

ECS Mid-Atlantic, LLC (ECS) has completed the subsurface exploration, laboratory testing, and geotechnical engineering analyses for the above-referenced project. Our services were performed in general accordance with our agreed to 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 Roanoke County 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 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,

ECS Mid-Atlantic, LLC

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- Site Location Diagram
- Boring Location Diagram
- Subsurface Cross-Sections

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- Reference Notes for Boring Logs
- Subsurface Exploration Procedure: Standard Penetration Testing (SPT)
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EXECUTIVE SUMMARY

This Executive Summary is intended as a very brief overview of the primary geotechnical conditions that are expected to affect design and construction. Information gleaned from the Executive Summary should not be utilized in lieu of reading the entire geotechnical report.

- No grading plans were available at the time of this report but based on the existing grades and a finish floor elevation of 1060 feet, it appears that the maximum cuts and fills will be in the range of about 15 feet and 2 feet, respectively, to reach design grades. It is our understanding that a slope will be cut into the 2.25-acre parcel approximately 20 feet in height at a slope of 2H:1V. Auger refusal on apparent hard rock was encountered within some of our borings, and small rock outcrops were visible in some areas. Given the proposed earth work anticipated to reach site grades, rock excavation at this site will likely be required. Rock cut material used for structural fill will need to be processed and crushed prior to placement.
- The proposed structures can be supported by conventional shallow foundations consisting of column and/or strip footings bearing on the existing soils for maximum column loads of up to 150 kips. Such foundations can be designed for a net allowable bearing pressure of 2,500 psf based on anticipated design loads. The building can be designed based on a seismic site classification of C as currently configured.
- For protection against potential shrink-swell action, footings should bear at least 30 inches below final exterior grades.
- ECS should be provided with the opportunity to review our recommendations and complete additional geotechnical exploration and recommendations based on actual loading conditions and final layout.

Refer to the text of the report for site specific design and construction recommendations.

1.0 INTRODUCTION

The purpose of this study was to provide geotechnical information for the design of the foundations for the proposed construction and related infrastructure. The project will include an 11,600 square foot, three bay fire station, pavements, fuel storage, and stormwater management. The recommendations developed for this report are based on project information supplied by you.

Our services were provided in accordance with our Proposal No. 14969-P, dated February 3, 2022, as authorized by W.L. Heath Honaker on April 20, 2022, which includes our Terms and Conditions of Service.

This report contains the procedures and results of our subsurface exploration and laboratory testing programs, review of existing site conditions, engineering analyses, and recommendations for the design and construction of the project.

The report includes the following items.

- a. Observations from our site reconnaissance including current site conditions, surface drainage features, and surface topographic conditions
- b. A review of the published geologic conditions and their relevance to your planned development
- c. A subsurface characterization and a description of the field exploration and laboratory tests performed. Groundwater concerns relative to the planned construction, if any, will be summarized.
- d. Final logs of the soil borings and records of the field exploration prepared in accordance with the standard practice for geotechnical engineering. A boring location plan will be included, and the results of the laboratory tests will be plotted on the final boring logs or included on a separate test report sheet.
- e. Recommended allowable soil bearing pressure(s) for conventional shallow foundations (spread footings) and estimates of predicted foundation settlement. If required, we will provide recommendations for suitable intermediate foundations/ground improvement options or deep foundations in the event estimated settlements of shallow foundations are not tolerable.
- f. Recommendations for slab-on-grade construction, including recommendations for subgrade improvements, subgrade modulus, and underslab subdrainage recommendations, if necessary
- g. Recommendations for site retaining walls including lateral earth pressures, sliding resistance coefficients, and allowable bearing pressures
- h. Evaluation of the on-site soil characteristics encountered in the soil borings. Specifically, we will discuss the suitability of the on-site materials for reuse as engineered fill to support grade slabs and pavements. We will also include compaction requirements and suitable material guidelines.
- i. Recommendations for seismic site classification in accordance with the International Building Code (IBC 2018)

- j. Recommendations for design of flexible pavement (asphalt) and rigid pavement (concrete) based on laboratory CBR values
- k. Recommendations for additional testing and/or consultation that might be required to complete the geotechnical assessment and related engineering for this project

2.0 PROJECT INFORMATION

2.1 PROJECT LOCATION/CURRENT SITE USE/PAST SITE USE

The site is located at 1455 Mexico Way NE within the corporate city limits of Roanoke, Virginia. At the time of our visit, the ground surface over the site was grass with scattered trees and pavement. The overall site is bounded to the south by Mexico Way, to the east by Parkway Church on the Mountain, to the west by an Airgas store, and to the north by a wooded area.



Figure 2.1.1. Site Location

At the time of our visit the site was generally grass-covered with a wooded area near the northeast corner of the site. Mexico Way runs through the southern and southwestern portions of the site. The property slopes generally from southwest to northeast, with the central section being relatively flat. A few rock outcrops less than a foot wide were visible at the ground surface. With the exception of the wooded area in the northeast, most of the site is generally open. Elevations range from +1055 msl in the southwest corner to +1086 msl in the northeast corner.

Historical images indicate the site was bisected by a dirt path running southwest to northeast from the 1990s until 2005, when some grading took place as part of the construction of the Parkway Church. A drainage ditch with riprap was installed in the northeast portion of the site between September of 2005 and April of 2006 and remains in place. Existing fill could be present on site which was not detected by the borings.

2.2 PROPOSED CONSTRUCTION

The following information explains our understanding of the planned development including proposed fire station and related infrastructure.

SUBJECT	DESIGN INFORMATION / ASSUMPTIONS
Building Footprint	Approximately 11,600 square feet in plan view
# of Stories	One-story 3 bay fire station
Usage	Public Service
Framing	Cast-in-place concrete with minor reinforced masonry
Column Loads*	150 kips
Wall Loads*	5 kips per linear foot (klf) maximum
Lowest Finish Floor Elevation	EL. 1060 ft (up to 15 feet below present site grades)

*Assumed load are based on reasonable material and product loads. If final design loads exceed our assumed loads, this report needs to be revised to update our foundation recommendations, bearing capacity, and settlement calculations.

Two options for stormwater facilities are shown on the concept plan, an above ground facility at the north end of the site or an underground facility on the southern end. Invert elevations for these facilities were not provided at the time of this report.

Pavement types may include both asphalt and concrete.

3.0 FIELD EXPLORATION AND LABORATORY TESTING

Our exploration procedures are explained in greater detail in Appendix B including the insert titled Subsurface Exploration Procedures. Our scope of work included drilling 16 borings. Our borings were located with a handheld GPS unit while referencing Google Earth aerial imaging (showing desired boring locations provided by your office) and estimating angles from existing site features. Their approximate locations are shown on the Boring Location Diagram in Appendix A.

3.1 SITE GEOLOGY

The project site is located within the Valley and Ridge Geologic Province of Virginia. Our review of the Geology of the Roanoke and Stewartsburg Quadrangles, Virginia (1981) indicates the site is underlain by the Cambrian-aged Rome Formation, which consists of interbedded phyllitic mudstone, sandstone, siltstone, and conglomerate, with frequent 10 to 50-foot carbonate intervals consisting primarily of thinly laminated dolomite and phyllitic mudstone.

The carbonate rock types encountered in this geology are subject to development of karst features such as sinkholes. Carbonate materials solution in water over long periods of time, resulting in loss of rock material. The solution process typically occurs along planes of more soluble material and causes the formation of interconnected seams and cavities within carbonate formations.

3.2 SUBSURFACE CHARACTERIZATION

The subsurface conditions encountered were generally consistent with published geological mapping. The following sections provide generalized characterizations of the soil strata. Please note that the ground surface elevations were not surveyed by a licensed surveyor; these elevations are approximate based on Google-Earth©; therefore, elevation ranges are approximate +/- several feet. Please refer to the boring logs in Appendix B.

Approximate Depth (ft)	Stratum	Description	Ranges of SPT ⁽¹⁾ N-values (bpf)
0-1.2 (Surface cover)	n/a	Topsoil 4-6", Asphalt 6" and Gravel 8"	N/A
0.3-1.2 to 3-21.5	I	Residuum, Medium Dense to Very Dense SILTY FINE TO MEDIUM SAND (SM), Medium Dense CLAYEY FINE TO MEDIUM SAND (SC), Stiff to Hard SANDY SILT (ML), Firm to Stiff SANDY LEAN CLAY/LEAN CLAY WITH SAND (CL), Firm to Very Stiff SANDY FAT CLAY/FAT CLAY/FAT CLAY WITH SAND (CH), Dry to Wet	7 to 72
3-5.5 to 5.5-7.5	II	Weathered Rock Sampled as SILTY FINE TO MEDIUM SAND (WR), Dry	50+
5.5-21.5+	III	Hard rock, likely pinnacled when encountered at shallow depths	N/A

Notes:

(1) Standard Penetration Testing

A graphical presentation of the subsurface conditions is shown on the Subsurface Cross Section Diagrams included in Appendix A.

3.3 GROUNDWATER OBSERVATIONS

Water levels were measured in our borings in Appendix B. Groundwater was only observed in B-04 at the time of drilling and was observed at a depth of 18 feet below the ground surface, corresponding to EL. +1042 ft msl. Variations in the long-term water table may occur as a result of changes in precipitation, evaporation, surface water runoff, construction activities, and other factors.

3.4 LABORATORY TESTING

The laboratory testing consisted of selected tests performed on samples obtained during our field exploration operations. Classification and index property tests were performed on representative soil samples. The laboratory testing program included natural moisture content tests (ASTM D2216), grain size analyses tests (ASTM D6913), and Atterberg Limits tests (ASTM D4318). Standard Proctor tests (ASTM VTM-1) and California Bearing Ratio (CBR) tests (VTM-8) were performed on bulk soil samples. The results of all laboratory testing conducted are included in the Appendix of this report.

Each sample was visually classified on the basis of texture and plasticity in accordance with ASTM D2488 Standard Practice for Description and Identification of Soils (Visual-Manual Procedures) and including USCS classification symbols, and ASTM D2487 Standard Practice for Classification for Engineering Purposes (Unified Soil Classification System (USCS)). 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

4.1 KARST RISK COMMENTARY

The site is mapped to be underlain by geologic parent rock which is known to be carbonate in nature. There are mapped karst features within one mile of the site. However, based on our exploration the subsurface did not exhibit karst overburden soil characteristics. Additionally, during our site reconnaissance karst surface features were not observed on the property or immediate vicinity. Therefore, we define the risk of future sinkhole development on this site as low.

4.2 FOUNDATIONS

Provided subgrades and Structural Fills are prepared as recommended in this report, the proposed structure can be supported by shallow foundations including column footings and continuous wall footings. We recommend the foundation design use the following parameters:

Design Parameter	Column Footing	Wall Footing
Net Allowable Bearing Pressure ⁽¹⁾	2,500 psf	2,500 psf
Acceptable Bearing Soil Material	Stiff Stratum I or II	Stiff Stratum I or II
Minimum Width	24 inches	16 inches
Minimum Interior Footing Embedment Depth (below slab or finished grade)	24 inches	18 inches
Minimum Exterior Footing Depth (below final exterior grade) ⁽²⁾	30 inches	30 inches
Estimated Total Settlement ⁽³⁾	Less than 1- inch	Less than 1- inch
Estimated Differential Settlement ⁽⁴⁾	Less than $\frac{3}{4}$ inches between columns	Less than $\frac{3}{4}$ inches

Notes:

- (1) Net allowable bearing pressure is the applied pressure in excess of the surrounding overburden soils above the base of the foundation.
- (2) For bearing considerations and expansive soil concerns.
- (3) Based on assumed structural loads. If final loads are different, ECS must be contacted to update foundation recommendations and settlement calculations.
- (4) Based on maximum column/wall loads and variability in borings. Differential settlement can be re-evaluated once the foundation plans are more complete.

Potential Undercuts: Most of the soils at the foundation bearing elevation are anticipated to be suitable for support of the proposed structure. If soft or unsuitable soils are observed at the footing bearing elevations, the unsuitable soils should be undercut and removed. Any undercut should be backfilled with lean concrete ($f'_c \geq 200$ psi at 28 days) or compacted VDOT No. 21-A Stone up to the original design bottom of footing elevation; the original footing shall be constructed at the designed footing elevations. Due to karst potential on the site, we do not recommend the use of VDOT No. 57 Stone for undercut backfilling.

If shallow foundation is subject to lateral loading, the following engineering parameters can be utilized:

SOIL PARAMETER	ESTIMATED VALUE
Coefficient of Passive Earth Pressure (K_p)	2.2
Soil Moist Unit Weight (γ)	110 pcf
Cohesion (C)	800 psf
Interface Friction Angle [Concrete on Soil] (ϕ_f)	18°
Sliding Friction Coefficient [Concrete on Soil] (μ)	0.32
Passive equivalent fluid pressure	242H (psf)

4.3 SLABS ON GRADE

Provided subgrades and structural fills are prepared as discussed herein, the proposed floor slabs can be constructed as Ground Supported Slabs (or Slab-On-Grade). Based on a lowest finished floor elevation of

EL. 1060 feet, it appears that the slabs will bear on newly compacted fill or Stratum I. The following graphic depicts our soil-supported slab recommendations:

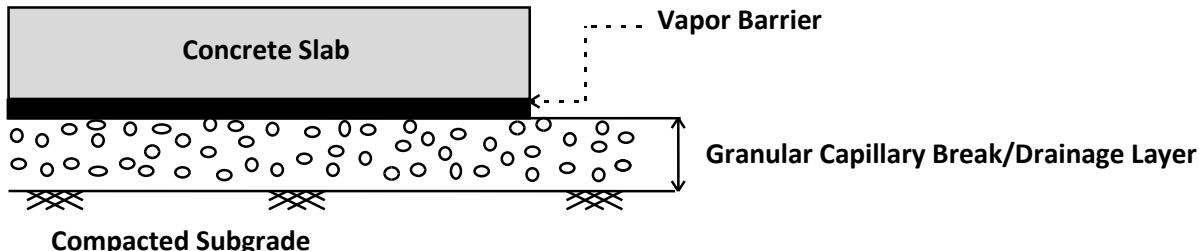


Figure 4.2.1

1. Drainage Layer Thickness: 4 inches
2. Drainage Layer Material: GRAVEL (GP, GW), SAND (SP, SW)

Soft or yielding soils may be encountered in some areas. Those soils should be removed and replaced with compacted Structural Fill in accordance with the recommendations included in this report.

Subgrade Modulus: Provided the Structural Fill and Granular Drainage Layer are constructed in accordance with our recommendations, the slab may be designed assuming a modulus of subgrade reaction, k_1 of 100 pci (lbs./cu. inch). The modulus of subgrade reaction value is based on a 1 foot by 1 foot plate load test basis.

Vapor Barrier: Before the placement of concrete, a vapor barrier may be placed on top of the granular drainage layer to provide additional protection against moisture penetration through the floor slab. When a vapor barrier is used, special attention should be given to surface curing of the slab to reduce the potential for uneven drying, curling and/or cracking of the slab. Depending on proposed flooring material types, the structural engineer and/or the architect may choose to eliminate the vapor barrier.

Slab Isolation: Soil-supported slabs should be isolated from the foundations and foundation-supported elements of the structure so that differential movement between the foundations and slab will not induce excessive shear and bending stresses in the floor slab. Where the structural configuration prevents the use of a free-floating slab such as in a drop down footing/monolithic slab configuration, the slab should be designed with suitable reinforcement and load transfer devices to preclude overstressing of the slab.

4.4 BELOW GRADE WALLS

We recommend that below grade walls be designed to withstand at-rest lateral earth pressures and surcharge loads from adjacent building foundations, and/or streets. These recommendations apply to a "drained" condition which is where there is drainage material behind below grade walls that prevents hydrostatic water pressures on the back of the below grade wall.

To accomplish a drained condition, drainage materials such as a free draining gravel, geocomposite drainage panels, weep holes, and an underslab drainage system should be used.

We recommend that walls that are restrained from movement at the top be designed for a linearly increasing lateral earth pressure. The following figure depicts our recommended at-rest lateral earth pressure condition for a “drained below-grade wall” with restrained wall top:

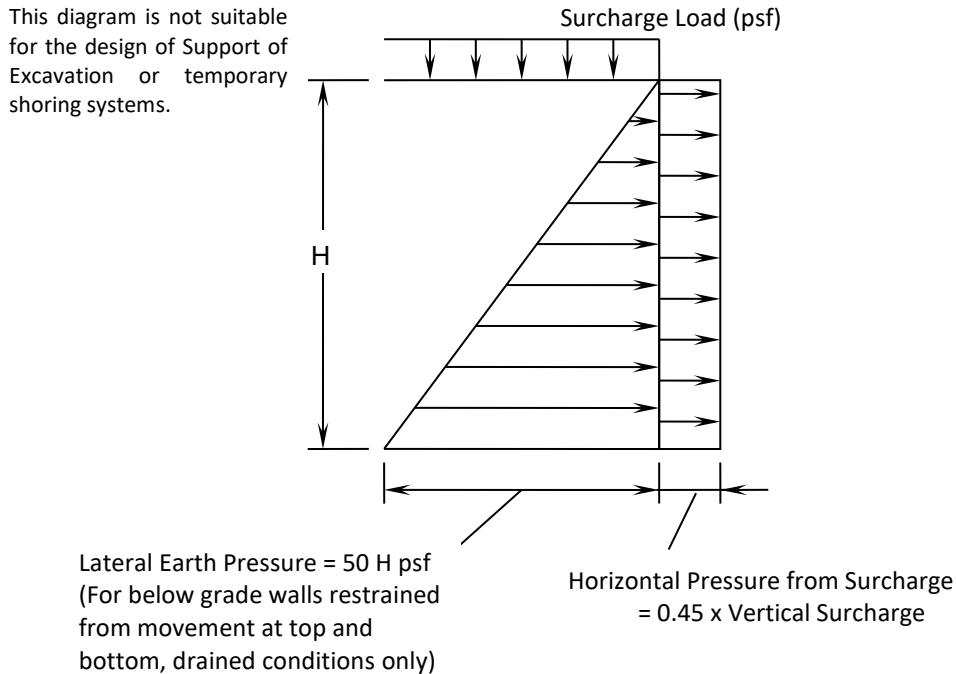


Figure 4.3.1

Surcharge loads imposed within a 45 degree slope from the base of the restrained wall should be considered in the below grade wall design. These surcharge loads should be based on an at-rest pressure coefficient, k_0 , of 0.45. 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 below grade walls.

4.5 SEISMIC DESIGN CONSIDERATIONS

Seismic Site Classification: The International Building Code (IBC) 2015 requires site classification for seismic design based on the upper 100 feet of a soil profile. At least two methods are utilized in classifying sites, namely the shear wave velocity (v_s) method and the Standard Penetration Resistance (N-value) method. The second method (N-value) was used in classifying this site.

SEISMIC SITE CLASSIFICATION			
Site Class	Soil Profile Name	Shear Wave Velocity, V_s , (ft./s)	N value (bpf)
A	Hard Rock	$V_s > 5,000$ fps	N/A
B	Rock	$2,500 < V_s \leq 5,000$ fps	N/A
C	Very dense soil and soft rock	$1,200 < V_s \leq 2,500$ fps	>50

SEISMIC SITE CLASSIFICATION			
Site Class	Soil Profile Name	Shear Wave Velocity, Vs, (ft./s)	N value (bpf)
D	Stiff Soil Profile	600 ≤ Vs ≤ 1,200 fps	15 to 50
E	Soft Soil Profile	Vs < 600 fps	<15

Based upon our interpretation of the subsurface conditions, the appropriate Seismic Site Classification is "C" as shown in the preceding table.

Ground Motion Parameters: In addition to the seismic site classification, ECS has determined the design spectral response acceleration parameters following the IBC methodology. The Mapped Responses were estimated from the USGS website <https://www.usgs.gov/natural-hazards/earthquake-hazards/design-ground-motions>. The design responses for the short (0.2 sec, S_{DS}) and 1-second period (S_{D1}) are noted in bold at the far right end of the following table.

GROUND MOTION PARAMETERS [IBC 2018 Method]								
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	0.184	F_a	1.3	$S_{MS}=F_a S_s$	0.24	$S_{DS}=2/3 S_{MS}$	0.16
1.0	S_1	0.063	F_v	1.5	$S_{M1}=F_v S_1$	0.094	$S_{D1}=2/3 S_{M1}$	0.063

The Site Class definition should not be confused with the Seismic Design Category designation which the Structural Engineer typically assesses. If a higher site classification is beneficial to the project, we can provide additional testing methods that may yield more favorable results.

4.6 PAVEMENTS

Subgrade Characteristics: Based on the results of our borings, it appears that the pavement subgrades in cuts will consist mainly of SANDY LEAN CLAY (CL) and SILT (ML) material. We anticipate pavement subgrades in fill areas will consist of similar materials from on-site cuts.

California Bearing Ratio (CBR) testing was performed in our lab. The soils tested demonstrated CBR values of 13.4 and 10.3, with an average of 11.9. Maximum swell was 0.57%. For design purposes, we recommend a design CBR value of 7.9, two-thirds of the average laboratory value.

Traffic Loading Information: We were not provided traffic loading information; therefore, we have assumed loadings typical of this type of project. Specifically, for Light-Duty Pavements, we have assumed 250 vehicle passes per day with 5 percent or less of light truck traffic for an EAL₁₈ loading of approximately 50,000. For Heavy-Duty Pavements, we have assumed two heavy trucks in and out of each of the three

truck bays each day, for an EAL₁₈ loading of approximately 230,000. When traffic loading becomes available, ECS should be contacted to revise our preliminary pavement design.

Pavement Design Recommendations: Our pavement design was performed in general accordance with the *AASHTO Guide for Design of Pavement Structures*, considering the *VDOT Guidelines for 1993 AASHTO Pavement Design*. The preliminary pavement sections below are guidelines that may or may not comply with local jurisdictional minimums.

MATERIAL	PROPOSED PAVEMENT SECTIONS			
	FLEXIBLE PAVEMENT		RIGID PAVEMENT	
	Heavy Duty	Light Duty	Heavy Duty	Light Duty
Portland Cement Concrete ($f'_c = 4000$ psi)	-	-	6 in	4 in
Asphaltic Concrete Surface Course (SM-12.5)	1.5 in	2 in	-	-
Asphaltic Concrete Base Course (IM-19.0)	2 in	-	-	-
Graded Aggregate Base Course (AASHTO #21A/21B)	8 in	8 in	4 in	4 in

In general, heavy duty sections are areas that will be subjected to trucks, buses, or other similar vehicles including main drive lanes of the development. Light duty sections are appropriate for vehicular traffic and parking areas.

Large, front loading trash dumpsters frequently impose concentrated front wheel loads on pavements during loading. This type of loading typically results in rutting of asphalt pavement and ultimately pavement failures. For preliminary design purposes, we recommend that the pavement in trash pickup areas consist of a 6-inch thick, 4,000 psi, reinforced concrete slab over 6-inches of dense graded aggregate.

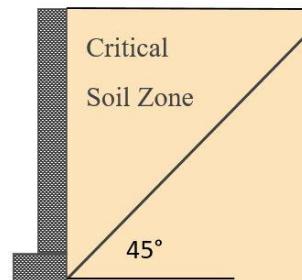
Prior to subbase placement and paving, we recommend that CBR testing of the subgrade soils (both natural and fill soils) be performed to determine the soil engineering properties for final pavement design.

4.7 SITE RETAINING WALLS

Unlike below grade walls, site retaining walls are free to rotate at the top (not restrained). For these walls the "Active" (k_a) soil condition should be used along with a triangular distribution of earth pressures. In addition, site retaining walls should be designed to withstand lateral earth pressures exerted by the backfill and any surcharge loads within the "Critical Soil Zone". The Critical Zone is defined as the area between the back of the retaining wall footing and an imaginary line projected upward and rearward at a 45-degree angle (see figure below).

The lateral earth pressures developed behind site retaining walls are a function of the backfill soil type, backfill slope angle, and any surcharge loads. For the design of site retaining walls, we recommend the soil parameters provided below.

RETAINING WALL BACKFILL IN THE CRITICAL SOIL ZONE	
Soil Parameter	Estimated Value
Soil Classification	Silty SAND (SM) or more granular
Fines Content	Max. 20% >#200 Sieve
Coefficient of Active Earth Pressure (K_a)	0.31
Retained Soil Moist Unit Weight (γ)	125 pcf
Cohesion (C)	0 psf
Angle of Internal Friction (ϕ)	32°
Friction Coefficient [Concrete on Soil] (μ)	0.40
Active Equivalent Fluid Pressure	39H (psf)



FOUNDATION SOILS	
Soil Parameter	Estimated value
Allowable Soil Bearing Pressure	2,500 psf
Minimum Wall Embedment Below Grade	30 inches
Coefficient of Passive Earth Pressure (K_p)	2.2
Soil Moist Unit Weight (γ)	110 pcf
Cohesion (C)	800 psf
Interface Friction Angle [Concrete on Soil] (ϕ_i)	18°
Sliding Friction Coefficient [Concrete on Soil] (μ)	0.3
Passive Equivalent Fluid Pressure	240H (psf)

It is critical that the soils used for backfill of the 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 suitable 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 should 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 140-N 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 and separated from the soils beyond with a non-woven geotextile. Alternatively, the wall drain can consist of a suitable geocomposite drainage board material. The wall drain should be hydraulically connected to the foundation drain.

5.0 SITE CONSTRUCTION RECOMMENDATIONS

5.1 SUBGRADE PREPARATION

5.1.1 Stripping and Grubbing

The subgrade preparation should consist of stripping all vegetation, rootmat, topsoil, existing fill, and any soft or unsuitable materials from the 5-foot expanded building and 2-foot expanded pavement limits, and 5 feet beyond the toe of Structural Fills. Borings performed in “undisturbed” areas of the site contained an observed 4 to 6 inches of topsoil. Deeper topsoil or organic laden soils may be present in wet, low-lying, and poorly drained areas. In wooded areas, the root balls may extend as deep as about 2 feet and will require additional localized stripping depth to completely remove the organics. ECS should be retained to verify that topsoil and unsuitable surficial materials have been removed prior to the placement of structural fill or construction of structures.

5.1.2 Proofrolling

Prior to fill placement or other construction on subgrades, the subgrades should be evaluated by an ECS field technician. The exposed subgrade should be thoroughly proofrolled with construction equipment having a minimum axle load of 10 tons [e.g. fully loaded tandem-axle dump truck]. Proofrolling should be traversed in two perpendicular directions with overlapping passes of the vehicle under the observation of an ECS technician. This procedure is intended to assist in identifying any localized yielding materials.

Where proofrolling identifies areas that are unstable or “pumping” subgrade those areas should be repaired prior to the placement of any subsequent Structural Fill or other construction materials. Methods of stabilization include undercutting, moisture conditioning, or chemical stabilization. The situation should be discussed with ECS to determine the appropriate procedure. Test pits may be excavated to explore the shallow subsurface materials to help in determining the cause of the observed unstable materials, and to assist in the evaluation of appropriate remedial actions to stabilize the subgrade.

5.2 EARTHWORK OPERATIONS

5.2.1 Existing Man-Placed Fill

Fill Removal in Building Areas: No onsite fill was encountered in our boring but may be encountered in unexplored areas. If encountered, all existing fill should be removed from below the planned pavement and building areas.

5.2.2 High Plasticity Soils

High plasticity soils are prevalent in the site vicinity. Ideally, such soils would be excluded from reuse as fill and be undercut and replaced in cut subgrades for slabs, pavements, and footings to avoid the potential for moisture-related volume change or instability when wet; however, we anticipate this would not be practical for the subject site. Therefore, it should be recognized that high plasticity soils are moisture sensitive and may be problematic during construction activities. Care should be taken to provide adequate drainage and maintenance of exposed subgrades. Due to the risk of shrink-swell, or moisture-related

volume change, we have provided a footing embedment depth recommendation in **Section 4.2 Foundations**.

5.2.3 Weathered Rock and Rock

Based on boring data obtained during the exploration, we anticipate that materials requiring difficult or rock excavation techniques will be encountered during site grading and excavation to planned subgrades. It is our understanding that a slope will be cut into the 2.25-acre parcel approximately 20 feet in height at a slope of 2H:1V. Auger refusal on apparent hard rock was encountered within some of our borings. Borings S-01 and P-02 in an area of proposed cut refused on hard rock at depths of 5.5 and 7.5 feet, respectively. Given the proposed earth work anticipated to reach site grades, rock excavation at this site will likely be required. Rock cut material used for structural fill will need to be processed and crushed prior to placement.

The excavation of weathered rock and rock can have a substantial impact on the cost and schedule of the proposed construction. This discussion considers two general classes of materials for purposes of describing excavability. Residuum and weathered rock will be used as the terms for the materials to be excavated.

In mass excavations for general site work, overburden soils with standard penetration test N-values of 40 bpf or less can usually be removed with conventional earth excavation equipment. Residual soils or soft weathered (Saprolitic) rock with N-values of 40 to 50 bpf can generally be removed with conventional earth moving equipment after first being loosened with a large single-tooth ripper attached to a large crawler tractor. Harder, less weathered rock will generally require the use of a large single-tooth ripper, dozers, and/or track-mounted backhoes for excavation. However, materials exhibiting N-values of 50 blows or greater for 6 inch of penetration, typically defined as refusal material, will be more difficult to excavate and generally require blasting and other rock excavation techniques. The actual excavability of the bedrock material will be greatly controlled by in-situ jointing and bedding and may vary from location to location.

In confined excavations, such as utility trenches, excavation of dense residual soils typically requires the use of large track-mounted backhoes. Excavation of harder phases of weathered rock typically requires the use of large track-mounted backhoes, pneumatic spades, or light blasting. Refusal materials (apparent rock) normally require blasting in trench excavations. Blasting in utility trenches should be done carefully to avoid damage to the surrounding materials. When the material to be excavated requires blasting, the contractor should comply with the jurisdictional requirements.

5.2.4 Structural Fill

Prior to placement of Structural Fill, representative bulk samples (about 50 pounds) of on-site and/or off-site borrow should be submitted to ECS for laboratory testing, which will typically include Atterberg limits, natural moisture content, grain-size distribution, and moisture-density relationships (i.e., Proctors) for compaction. Import materials should be tested prior to being hauled to the site to determine if they meet project specifications. Alternatively, Proctor data from other accredited laboratories can be submitted if the test results are within the last 90 days.

Satisfactory Structural Fill Materials: Materials satisfactory for use as Structural Fill should consist of inorganic soils with the following engineering properties and compaction requirements.

STRUCTURAL FILL INDEX PROPERTIES	
Subject	Property
Building and Pavement Areas (Borrow Soils)	LL < 50, PI < 25
Building and Pavement Areas (On-site Soils)	LL < 60, PI < 30
Max. Particle Size	4 inches
Max. organic content	3% by dry weight

STRUCTURAL FILL COMPACTION REQUIREMENTS	
Subject	Requirement
Compaction Standard	Standard Proctor, ASTM D698
Required Compaction	95% of Max. Dry Density
Moisture Content	+/-3 % points of the soil's optimum value
Loose Thickness	8 inches prior to compaction

Aggregates/Blast Rock: The gradation of the material removed by ripping or blasting is typically quite varied. Excavated rock and weathered rock are generally only suitable for use in the deeper parts of embankment fills, or outside the zone of Structural Fill.

When rock or intact weathered rock fragments are placed in non-structural areas, we recommend that the rock fragments be spread out evenly in layers. Many times the rock needs to be choked off with rock fines, and/or soil, so that voids between the rock fragments are filled. Where the material exhibits large voids between rock fragments, a geotextile may need to be placed over the rock prior to placement of additional materials. In general, the larger rock fragments should be placed at the bottom of the fill, but no fragment should exceed 1.5 feet in its maximum dimension. Between 2 feet and 10 feet below the final subgrade elevation, no rock fragment should exceed 8 inches in its maximum dimension. Within 2 feet of the subgrade elevation, no rock fragment should exceed 4 inches in maximum dimension.

In some situations, it can be cost effective to use an onsite rock crusher to produce material that meets the requirements of Structural Fill materials.

Fill Placement: Fill materials should not be placed on frozen soils, on frost-heaved soils, and/or on excessively wet soils. Borrow fill materials should not contain frozen materials at the time of placement, and all frozen or frost-heaved soils should be removed prior to placement of Structural Fill or other fill soils and aggregates. Excessively wet soils or aggregates should be scarified, aerated, and moisture conditioned.

5.3 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 the same day that excavations are made. If the bearing soils are softened by surface water intrusion or exposure, the softened soils must 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 should be placed on the bearing soils before the placement of reinforcing steel.

Footing Subgrade Observations: Most of the soils at the foundation bearing elevation are anticipated to be suitable for support of the proposed structure. It is important to have ECS observe the foundation subgrade prior to placing foundation concrete, to confirm the bearing soils are what was anticipated.

Slab Subgrade Verification: Prior to placement of a drainage layer, the subgrade should be prepared in accordance with the recommendations found in **Section 5.1.2 Proofrolling**.

5.4 UTILITY INSTALLATIONS

Utility Subgrades: The soils encountered in our exploration are expected to be generally suitable for support of utility pipes. The pipe subgrades should be observed and probed for stability by ECS. Any loose or unsuitable materials encountered should be removed and replaced with suitable compacted Structural Fill, or pipe stone bedding material.

Utility Backfilling: The granular bedding material (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 the springline of the pipe. Fill placed for support of the utilities, as well as backfill over the utilities, should satisfy the requirements for Structural Fill and Fill Placement.

Excavation Safety: All 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 our 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.

APPENDIX A – Diagrams & Reports

Site Location Diagram
Boring Location Diagram
Subsurface Cross-Sections

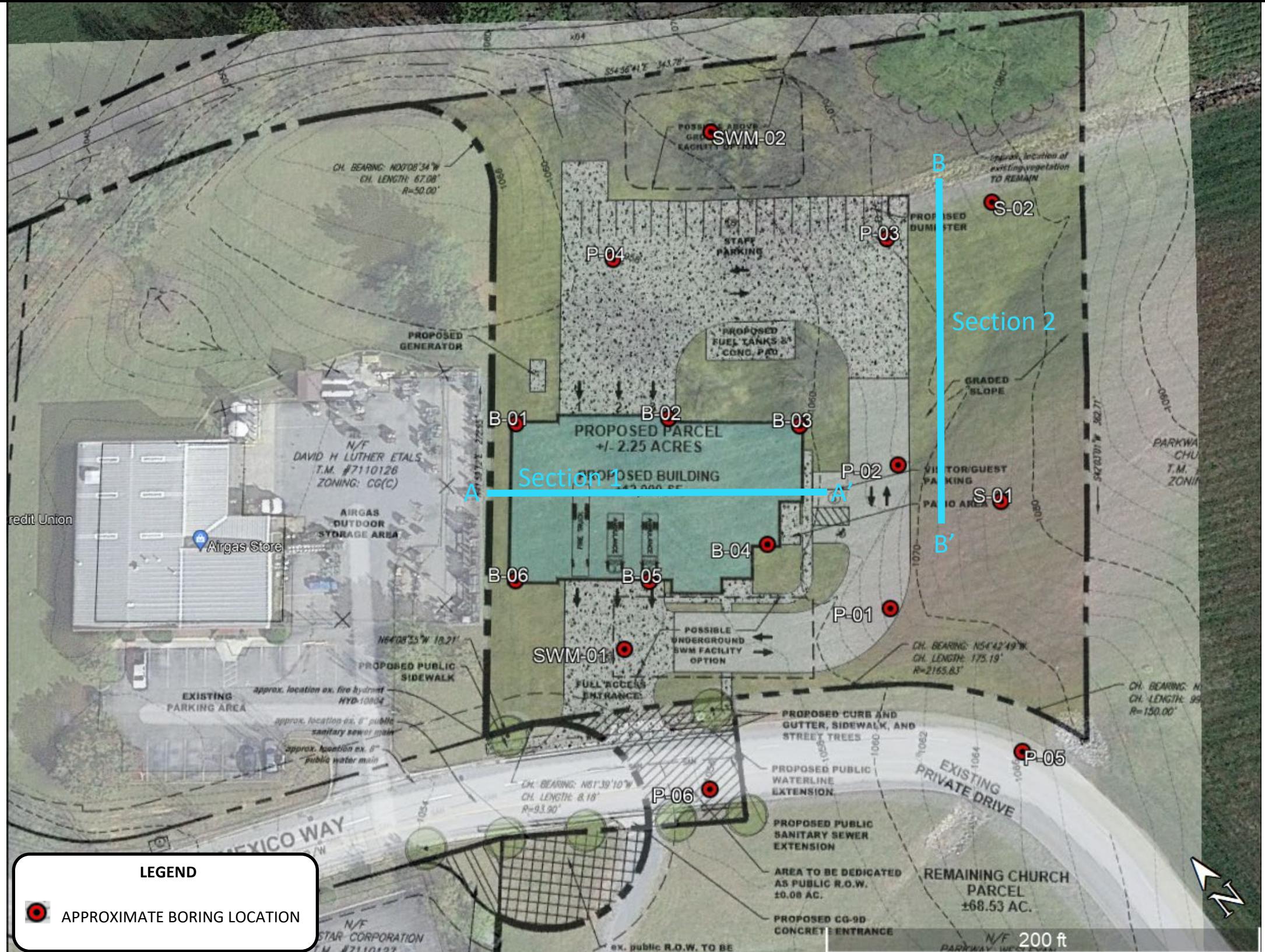
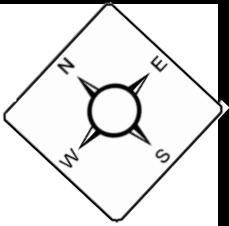


SITE LOCATION DIAGRAM BONSACK FIRE STATION



1455 MEXICO WAY NE, ROANOKE, VIRGINIA
ROANOKE COUNTY - PARKS & RECREATION

ENGINEER
BSW
SCALE
AS NOTED
PROJECT NO.
12:19596
SHEET
1 OF 1
DATE
5/23/2022



BORING LOCATION DIAGRAM

BONSACK FIRE STATION

1455 MEXICO WAY NE, ROANOKE, VA

ROANOKE COUNTY – PARKS AND RECREATION

**ENGINEER
BSW**

SCALE
AS NOTED

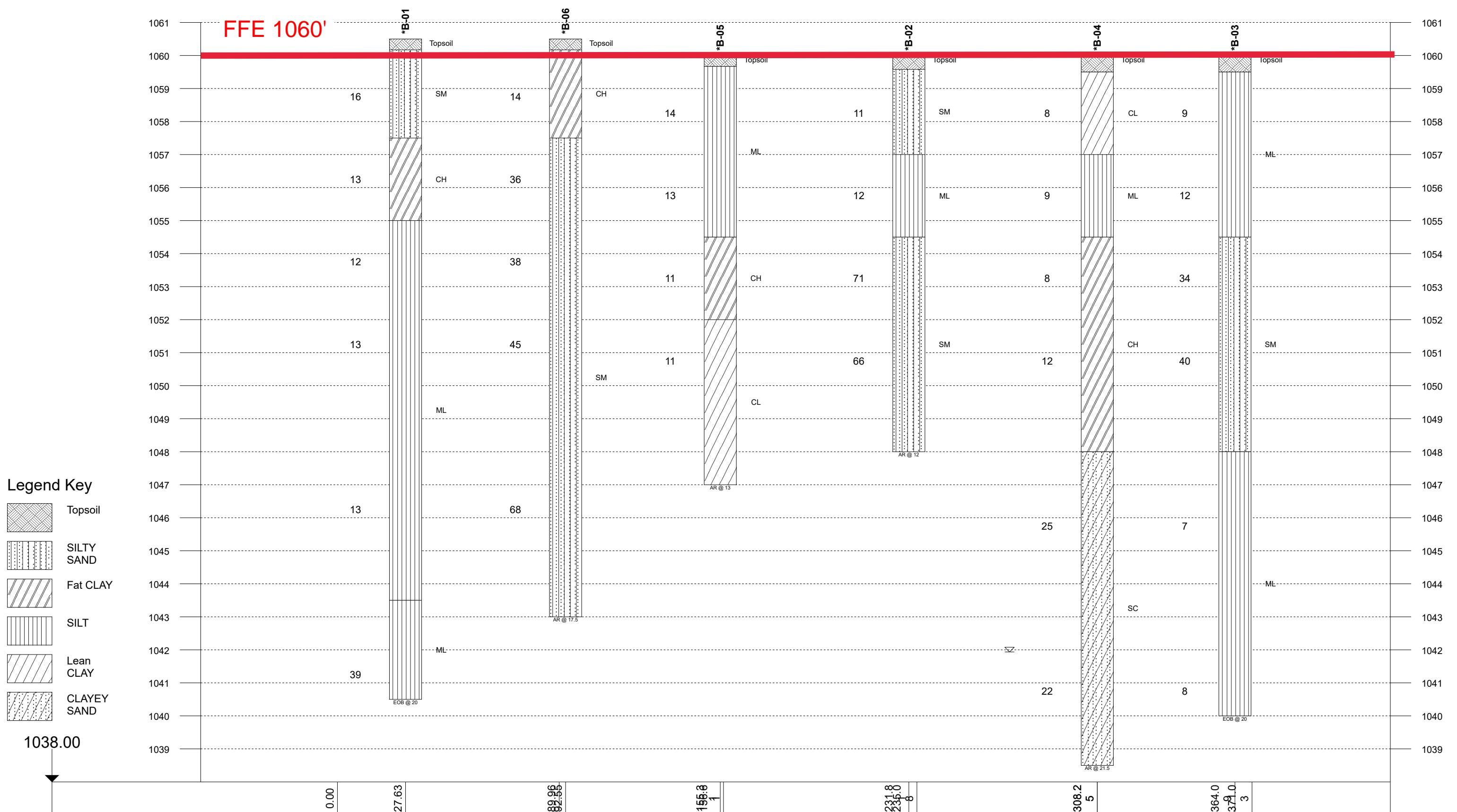
PROJECT NO.
12:19596

SHEET
1 OF 1

DATE
06/07/2022

The logo for the ECS (Electrochemical Society) is displayed. It consists of the letters 'ECS' in a bold, blue, sans-serif font. The 'E' and 'C' are on top, and the 'S' is on the bottom right, all enclosed within a blue rectangular border. Above the 'E', there is a thin horizontal grey bar, and below the 'S', there is another thin horizontal grey bar.

FFE 1060'



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
X	●	△	▽ WL (Completion)	Possible Fill
	[FINES CONTENT %]		▽ WL (Seasonal High Water)	Probable Fill
◀	BOTTOM OF CASING		▽ WL (Stabilized)	Rock
◀	LOSS OF CIRCULATION			



GENERALIZED SUBSURFACE SOIL PROFILE Section line 1 A-A'

Bonsack Fire Station

Roanoke County - Parks & Recreation

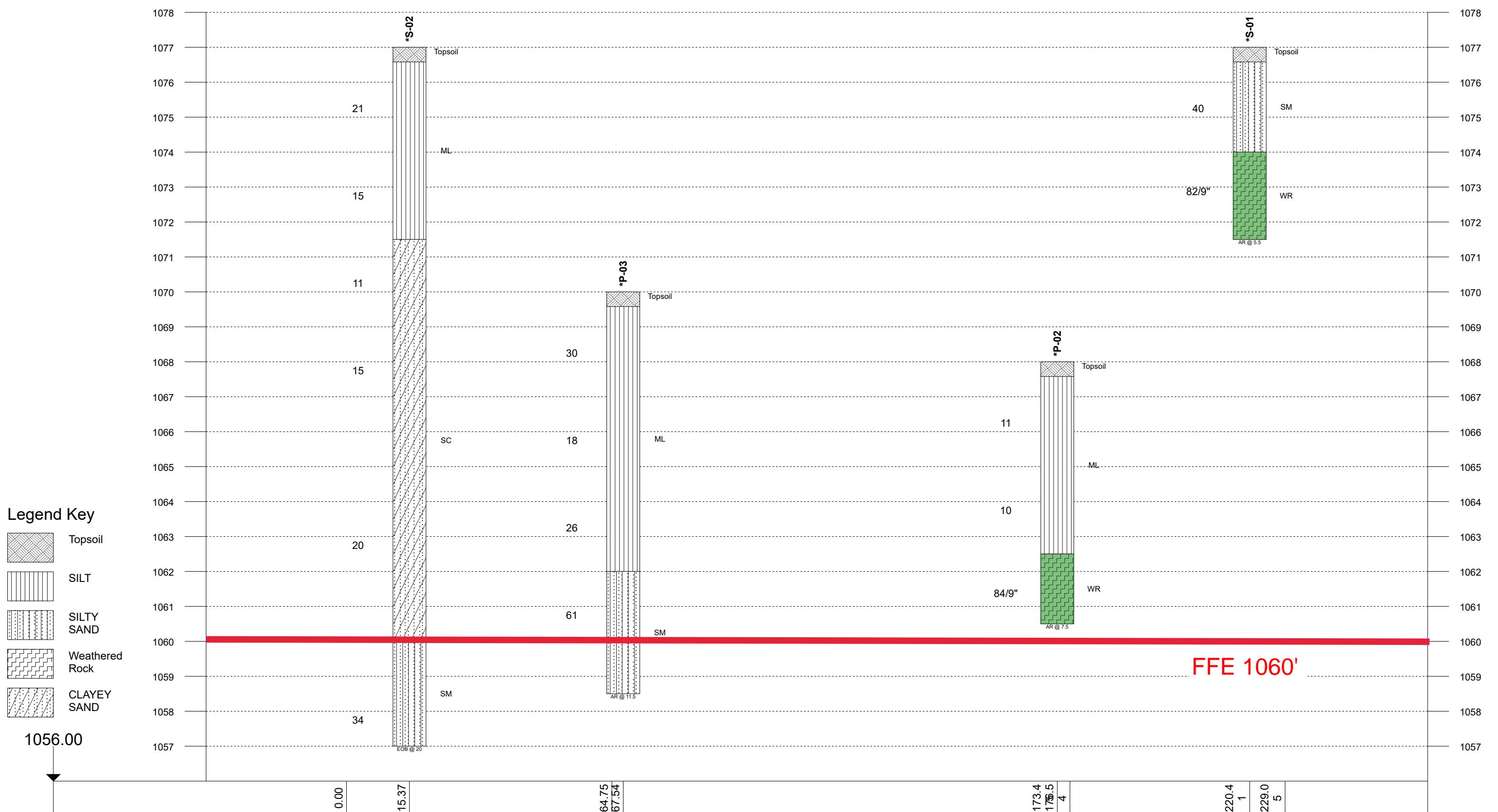
1455 Mexico Way NE, Roanoke, Virginia 24012

Project No:

12:19596

Date:

06/08/2022



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
X	●	△	▽ WL (Completion)	Possible Fill
	[FINES CONTENT %]		▽ WL (Seasonal High Water)	Probable Fill
◀	BOTTOM OF CASING		▽ WL (Stabilized)	Rock
◀	LOSS OF CIRCULATION			



GENERALIZED SUBSURFACE SOIL PROFILE Section line 2 B-B'

Bonsack Fire Station

Roanoke County - Parks & Recreation

1455 Mexico Way NE, Roanoke, Virginia 24012

Project No: 12:19596 Date: 06/08/2022

APPENDIX B – Field Operations

Reference Notes for Boring Logs

Subsurface Exploration Procedure: Standard Penetration Testing (SPT)

Boring Logs B-01 through B-06, P-01 through P-04, S-01, S-02, SWM-01, and SWM-02

REFERENCE NOTES FOR BORING LOGS

MATERIAL^{1,2}

	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	¼ inch to 3 inches (19 mm to 75 mm)	
	Fine	4.75 mm to 19 mm (No. 4 sieve to ¼ 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

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

²To 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.

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

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

⁵Standard 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.

⁶The 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.

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

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



SUBSURFACE EXPLORATION PROCEDURE: STANDARD PENETRATION TESTING (SPT) ASTM D 1586 Split-Barrel Sampling

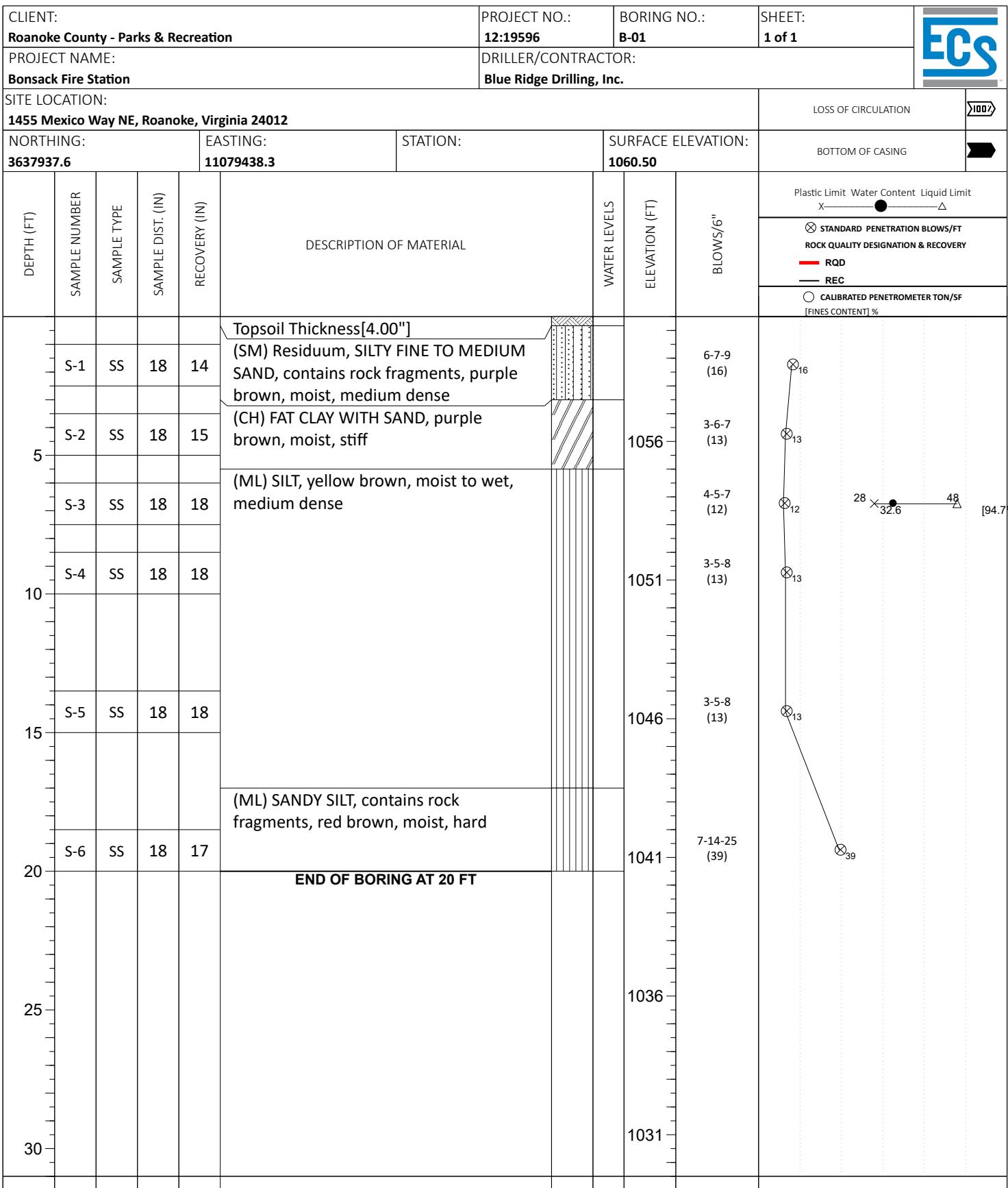
Standard Penetration Testing, or **SPT**, is the most frequently used subsurface exploration test performed worldwide. This test provides samples for identification purposes, as well as a measure of penetration resistance, or N-value. The N-Value, or blow counts, when corrected and correlated, can approximate engineering properties of soils used for geotechnical design and engineering purposes.

SPT Procedure:

- Involves driving a hollow tube (split-spoon) into the ground by dropping a 140-lb hammer a height of 30-inches at desired depth
- Recording the number of hammer blows required to drive split-spoon a distance of 12 inches (in 3 or 4 Increments of 6 inches each)
- Auger is advanced* and an additional SPT is performed
- One SPT test is typically performed for every two to five feet
- Obtain two-inch diameter soil sample



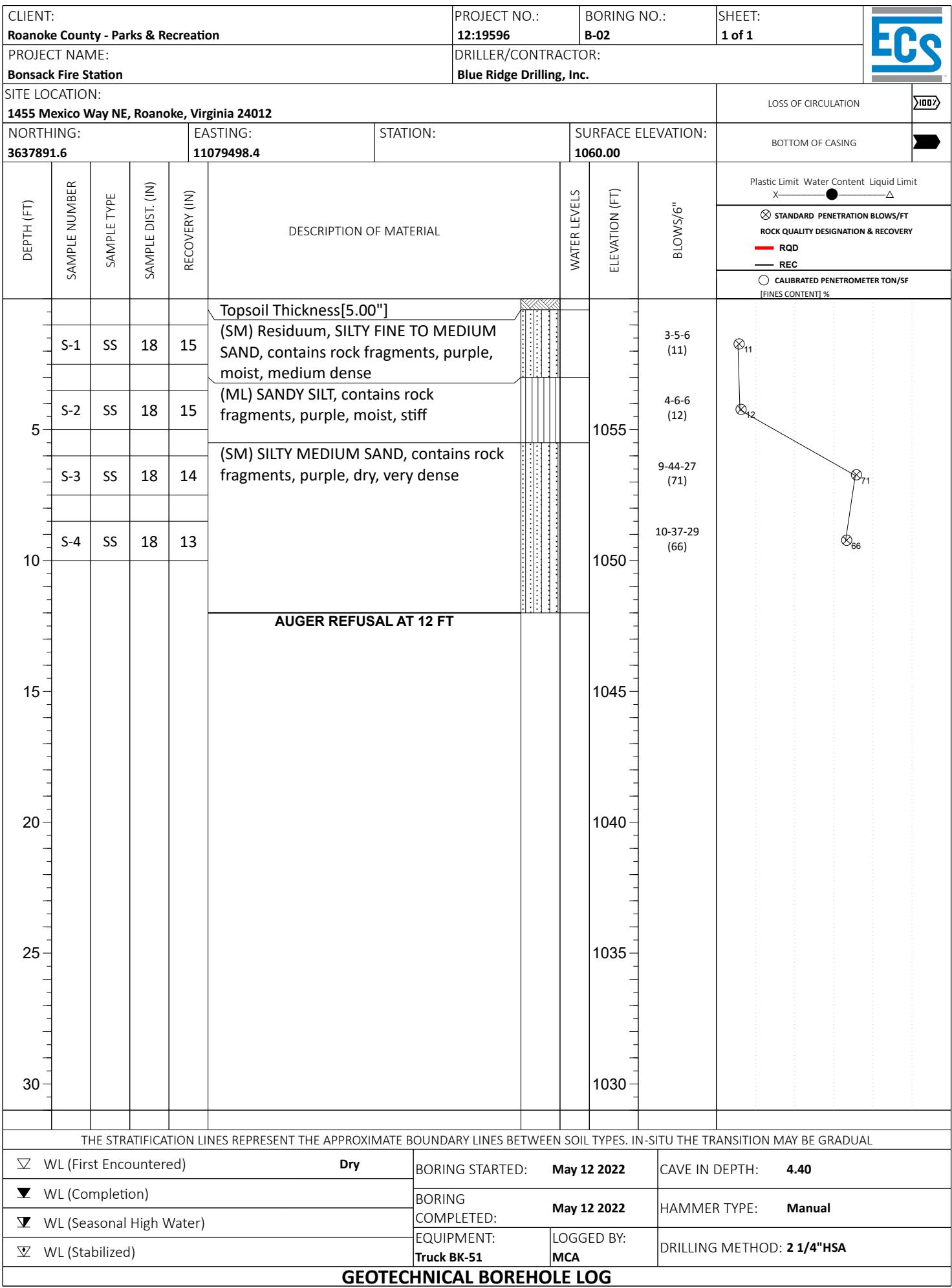
**Drilling Methods May Vary—* The predominant drilling methods used for SPT are open hole fluid rotary drilling and hollow-stem auger drilling.

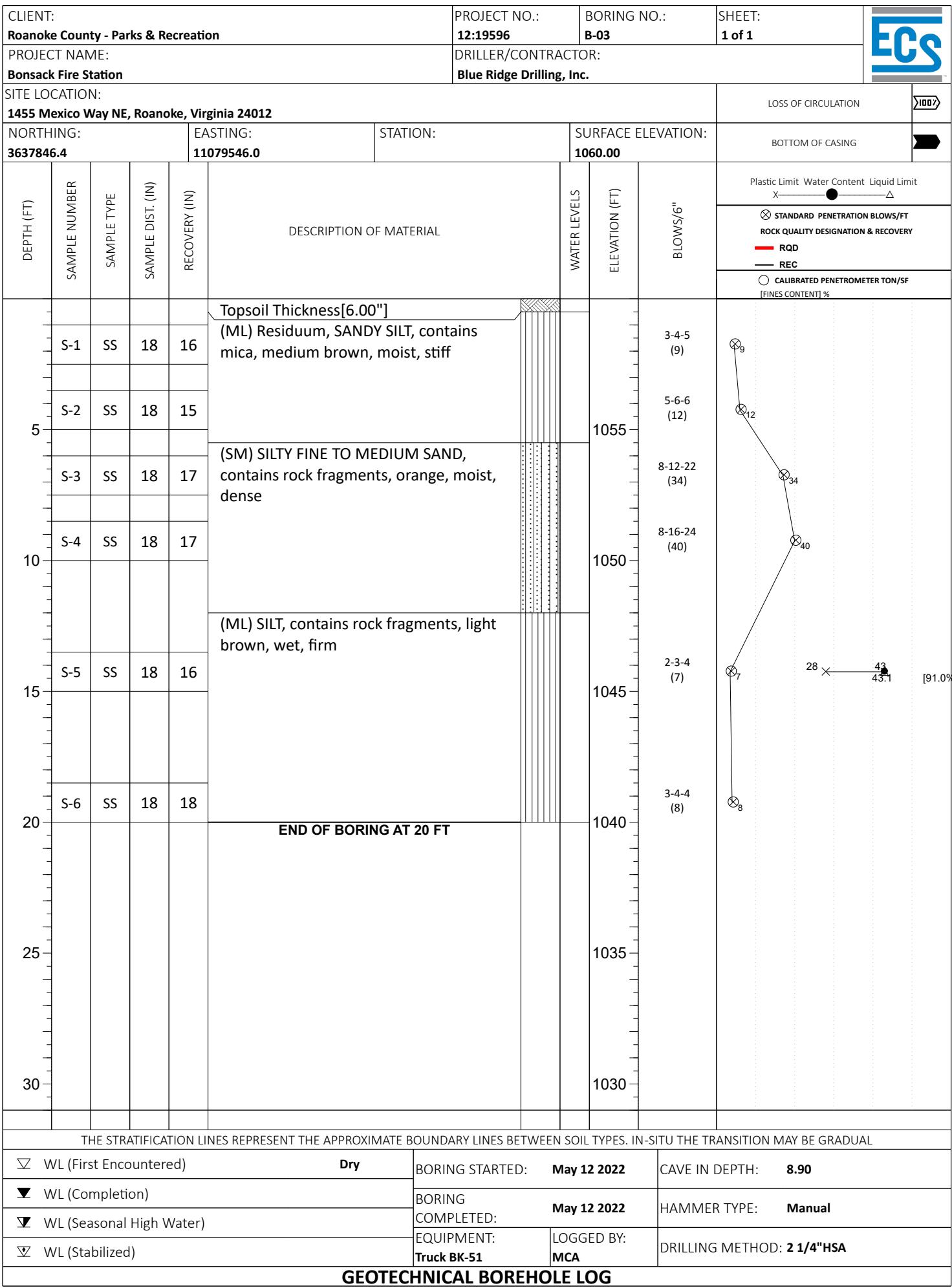


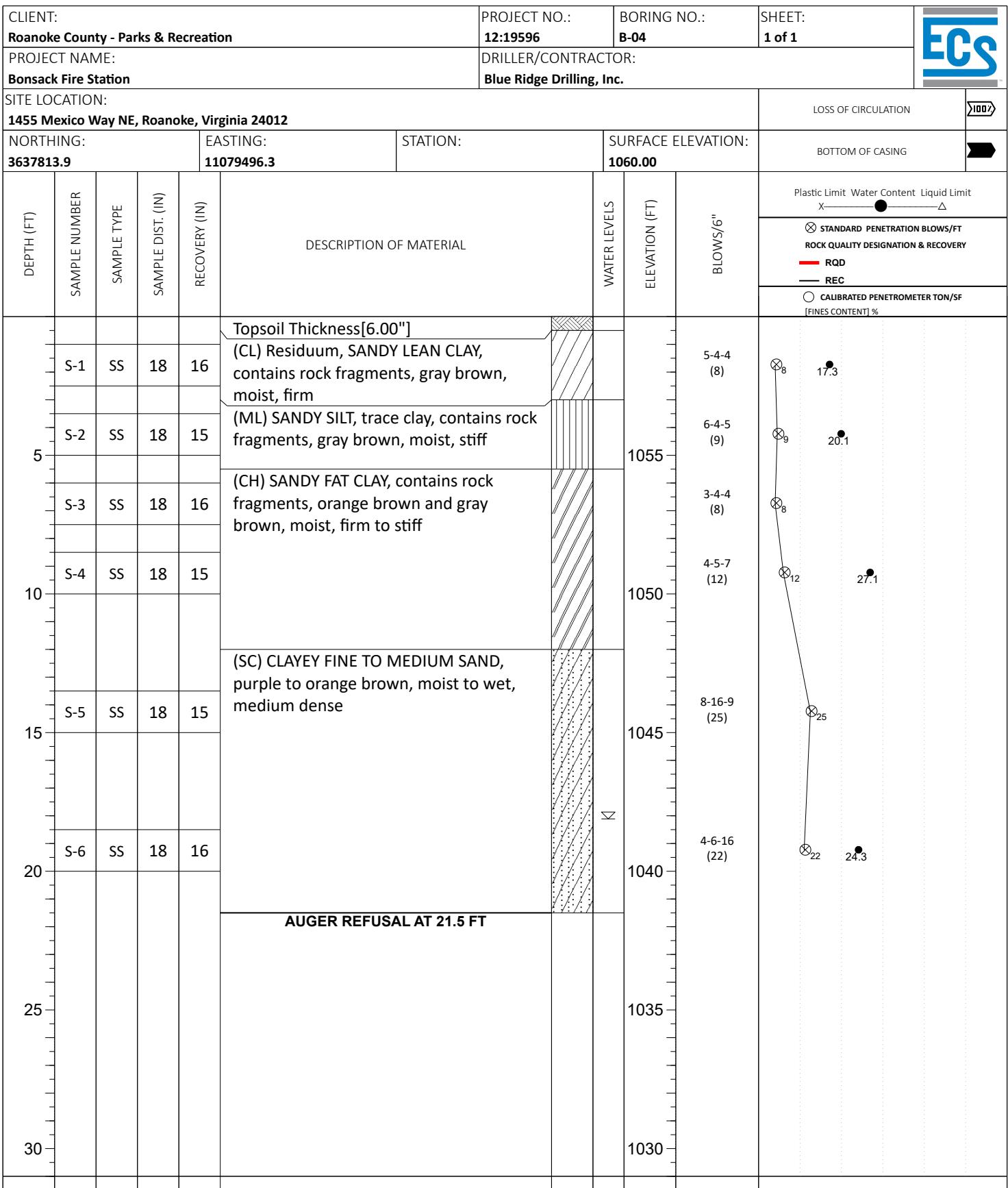
THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES. IN-SITU THE TRANSITION MAY BE GRADUAL

WL (First Encountered)	Dry	BORING STARTED: May 12 2022	CAVE IN DEPTH: 11.30
WL (Completion)		BORING COMPLETED: May 12 2022	HAMMER TYPE: Manual
WL (Seasonal High Water)		EQUIPMENT: Truck BK-51	LOGGED BY: MCA
WL (Stabilized)			DRILLING METHOD: 2 1/4" HSA

GEOTECHNICAL BOREHOLE LOG



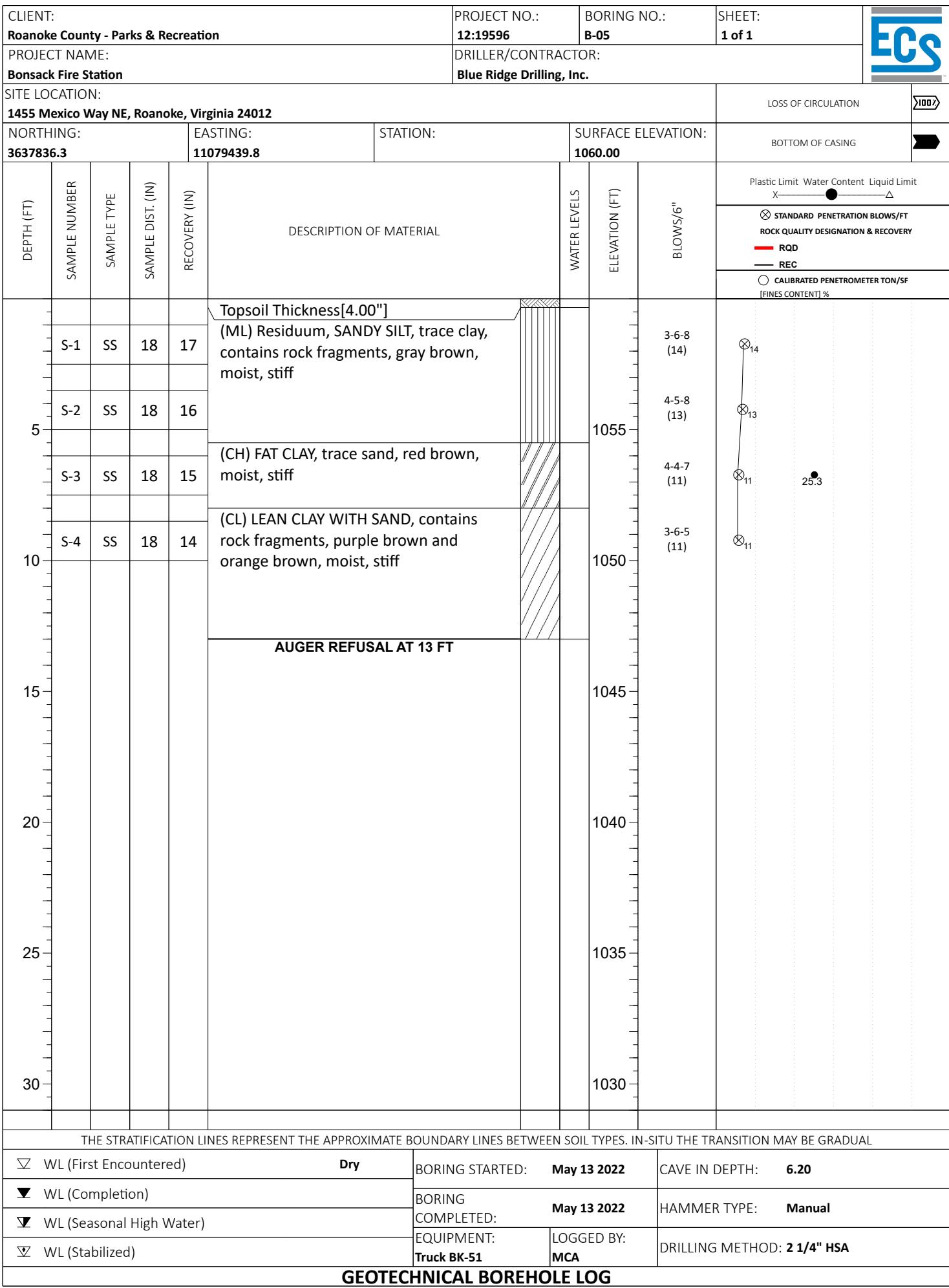


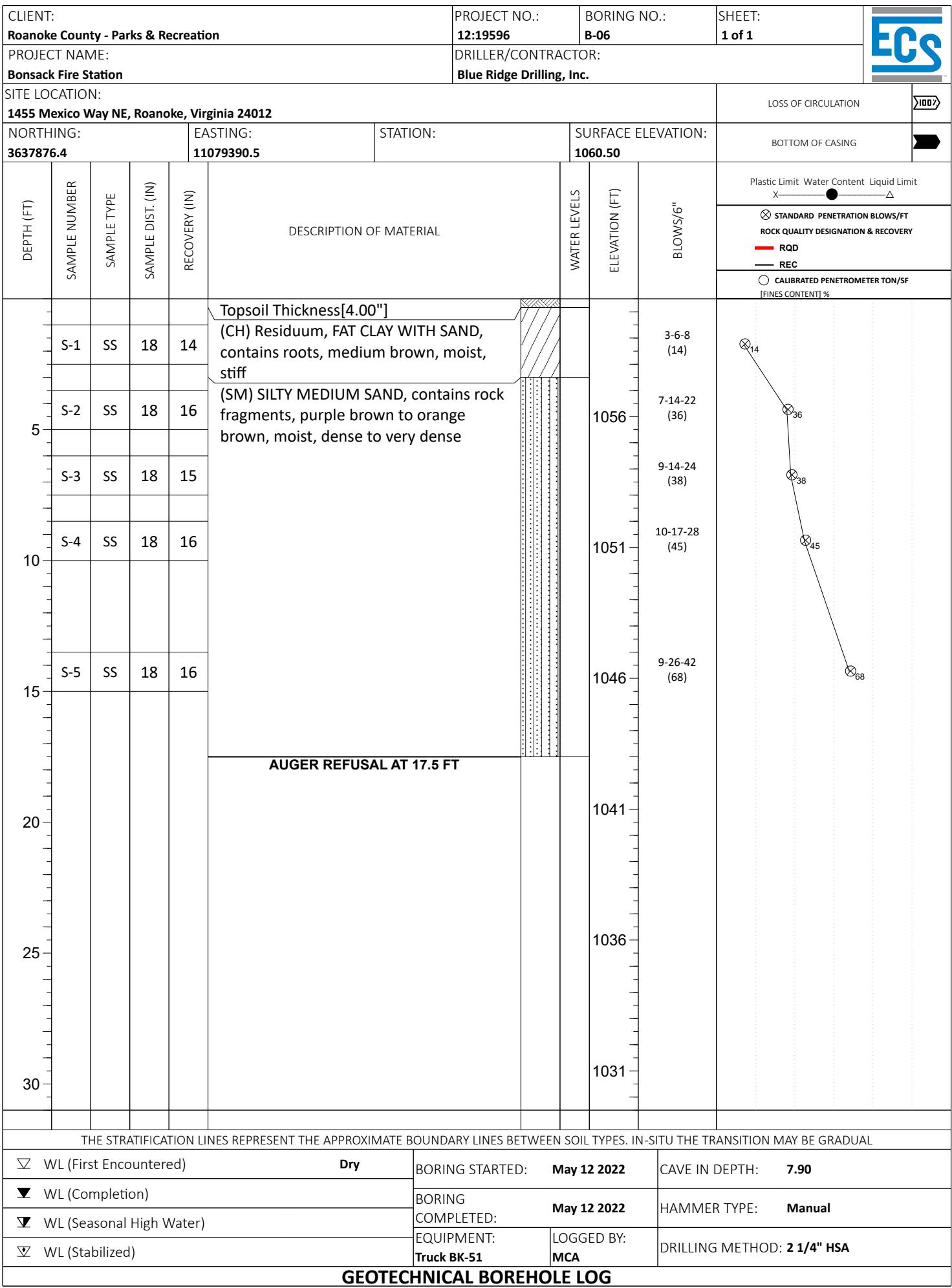


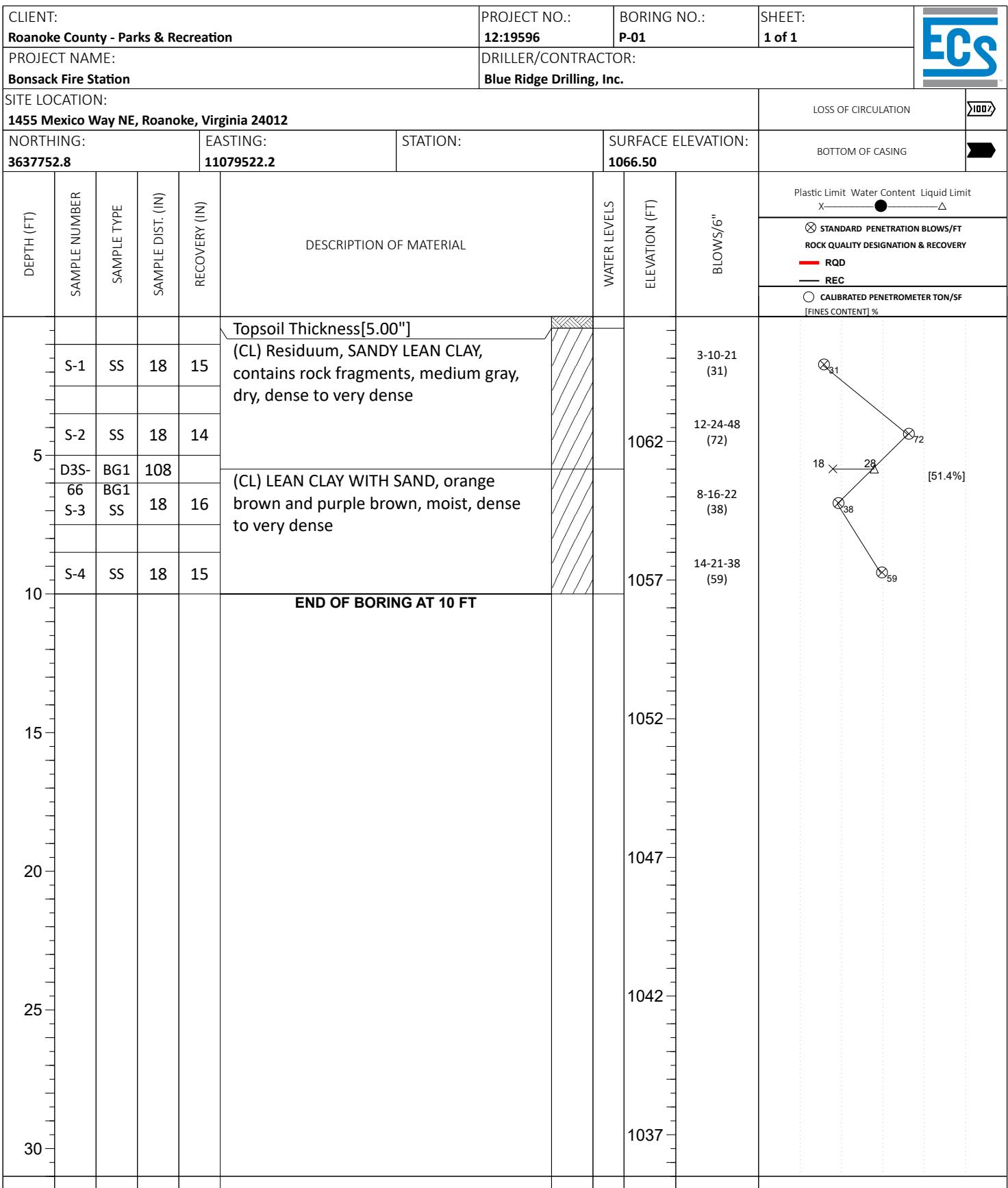
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WL (First Encountered)	18.00	BORING STARTED: May 12 2022	CAVE IN DEPTH: 15.60
WL (Completion)		BORING COMPLETED: May 12 2022	HAMMER TYPE: Manual
WL (Seasonal High Water)		EQUIPMENT: Truck BK-51	LOGGED BY: MCA
WL (Stabilized)			DRILLING METHOD: 2 1/4" HSA

GEOTECHNICAL BOREHOLE LOG



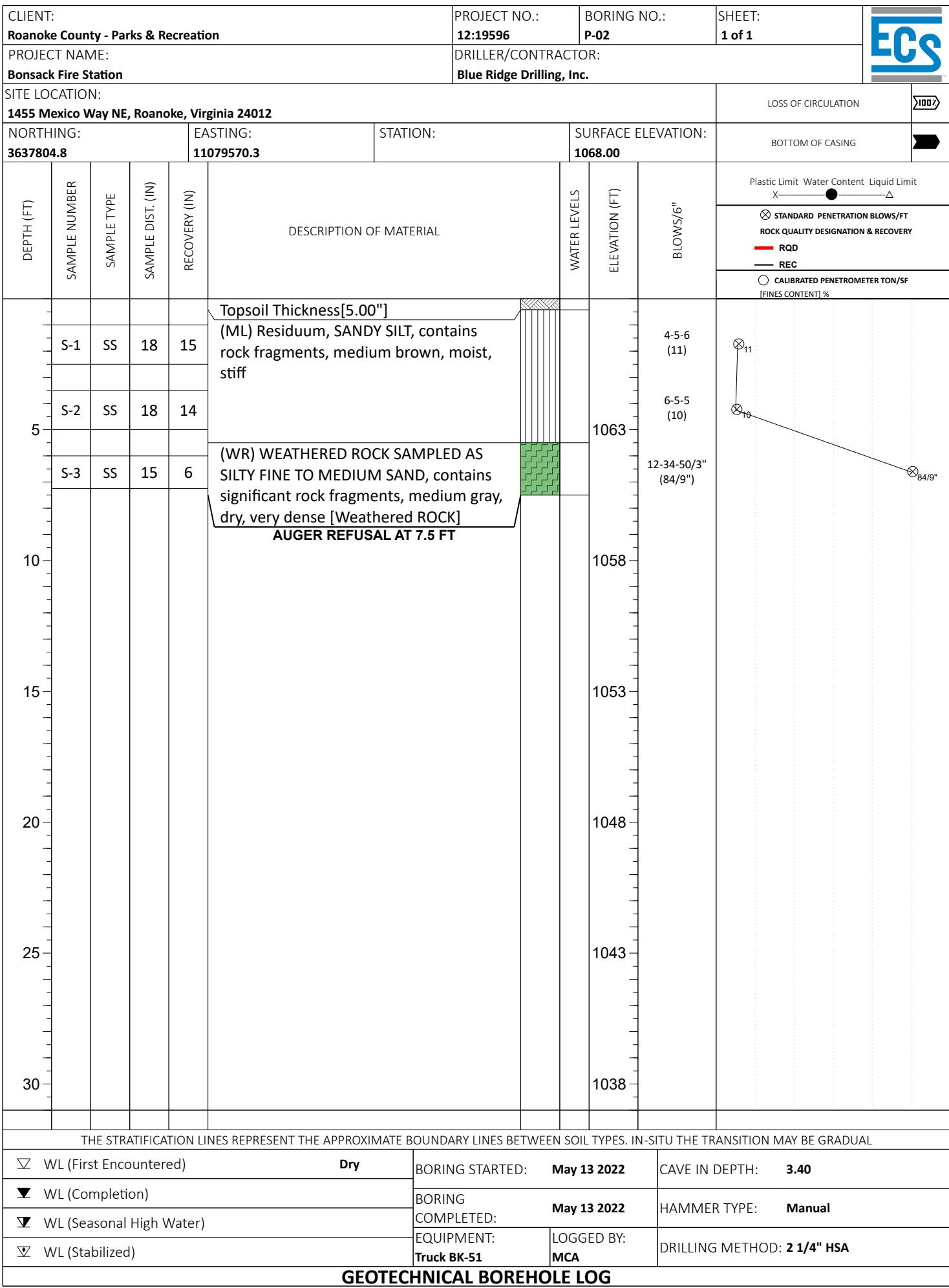


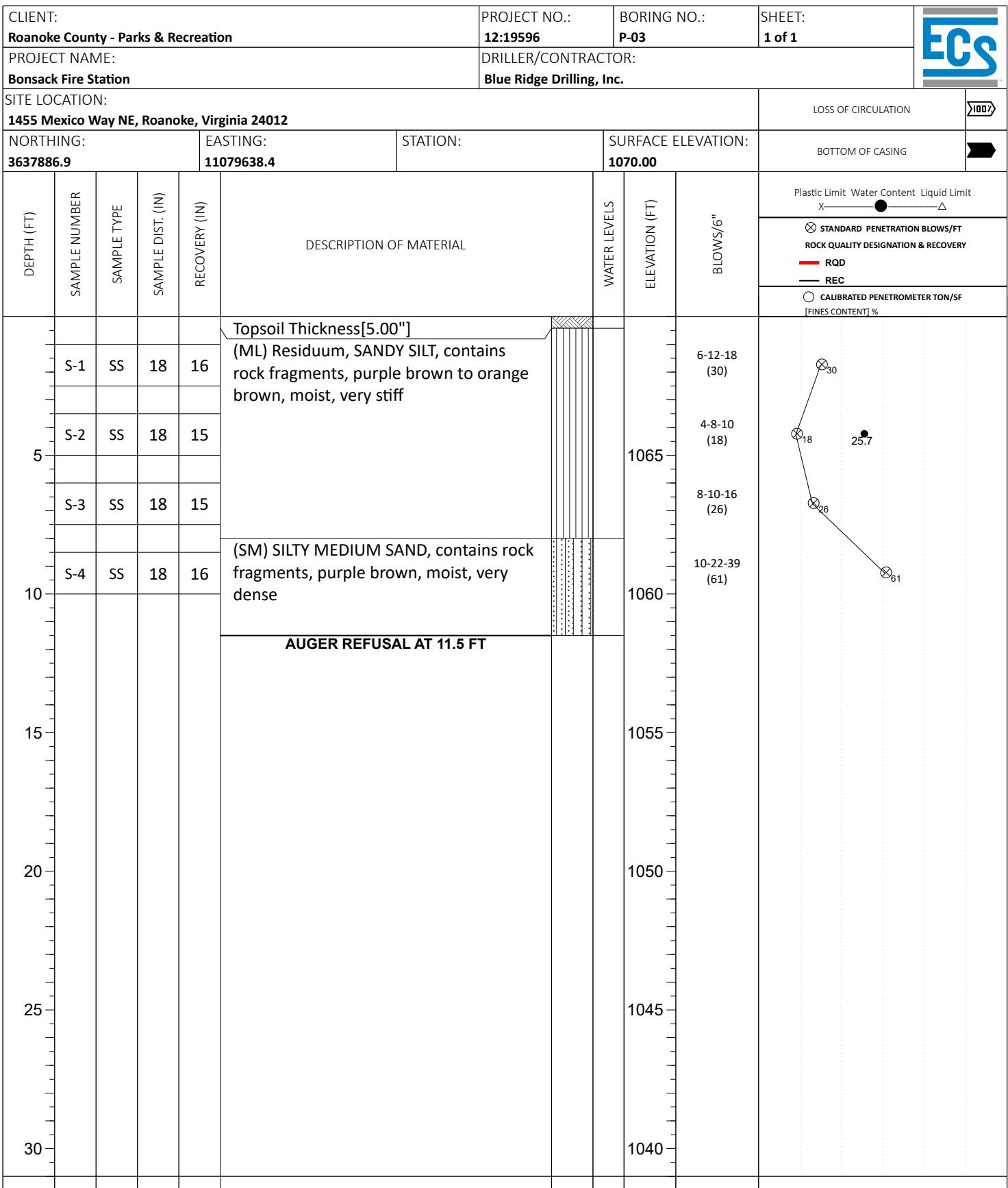


THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES. IN-SITU THE TRANSITION MAY BE GRADUAL

WL (First Encountered)	Dry	BORING STARTED: May 13 2022	CAVE IN DEPTH: 5.50
WL (Completion)		BORING COMPLETED: May 13 2022	HAMMER TYPE: Manual
WL (Seasonal High Water)		EQUIPMENT: Truck BK-51	LOGGED BY: MCA
WL (Stabilized)			DRILLING METHOD: 2 1/4" HSA

GEOTECHNICAL BOREHOLE LOG

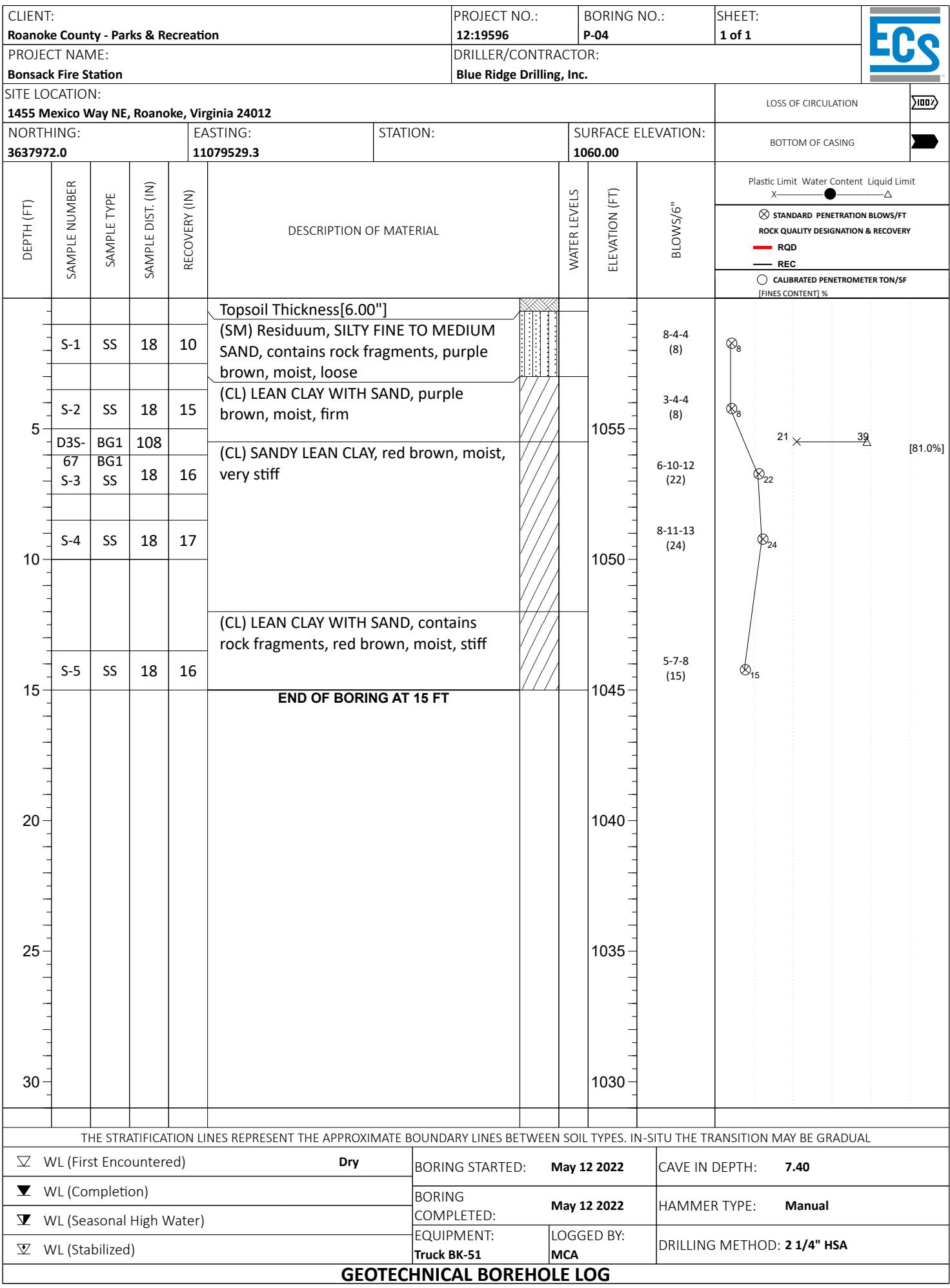




THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES. IN-SITU THE TRANSITION MAY BE GRADUAL

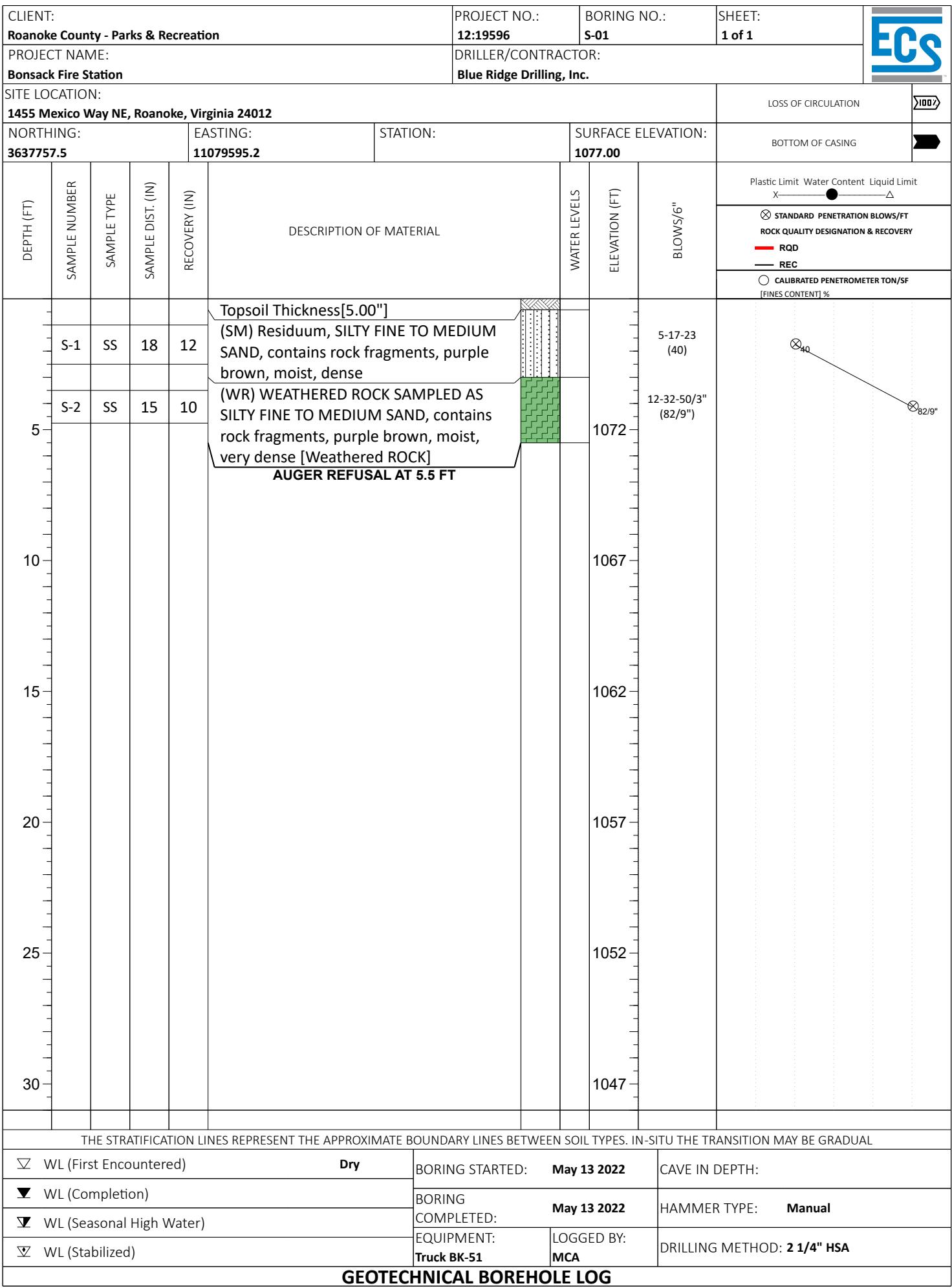
WL (First Encountered)	Dry	BORING STARTED: May 13 2022	CAVE IN DEPTH: 6.10
WL (Completion)		BORING COMPLETED: May 13 2022	HAMMER TYPE: Manual
WL (Seasonal High Water)		EQUIPMENT: Truck BK-51	LOGGED BY: MCA
WL (Stabilized)			DRILLING METHOD: 2 1/4" HSA

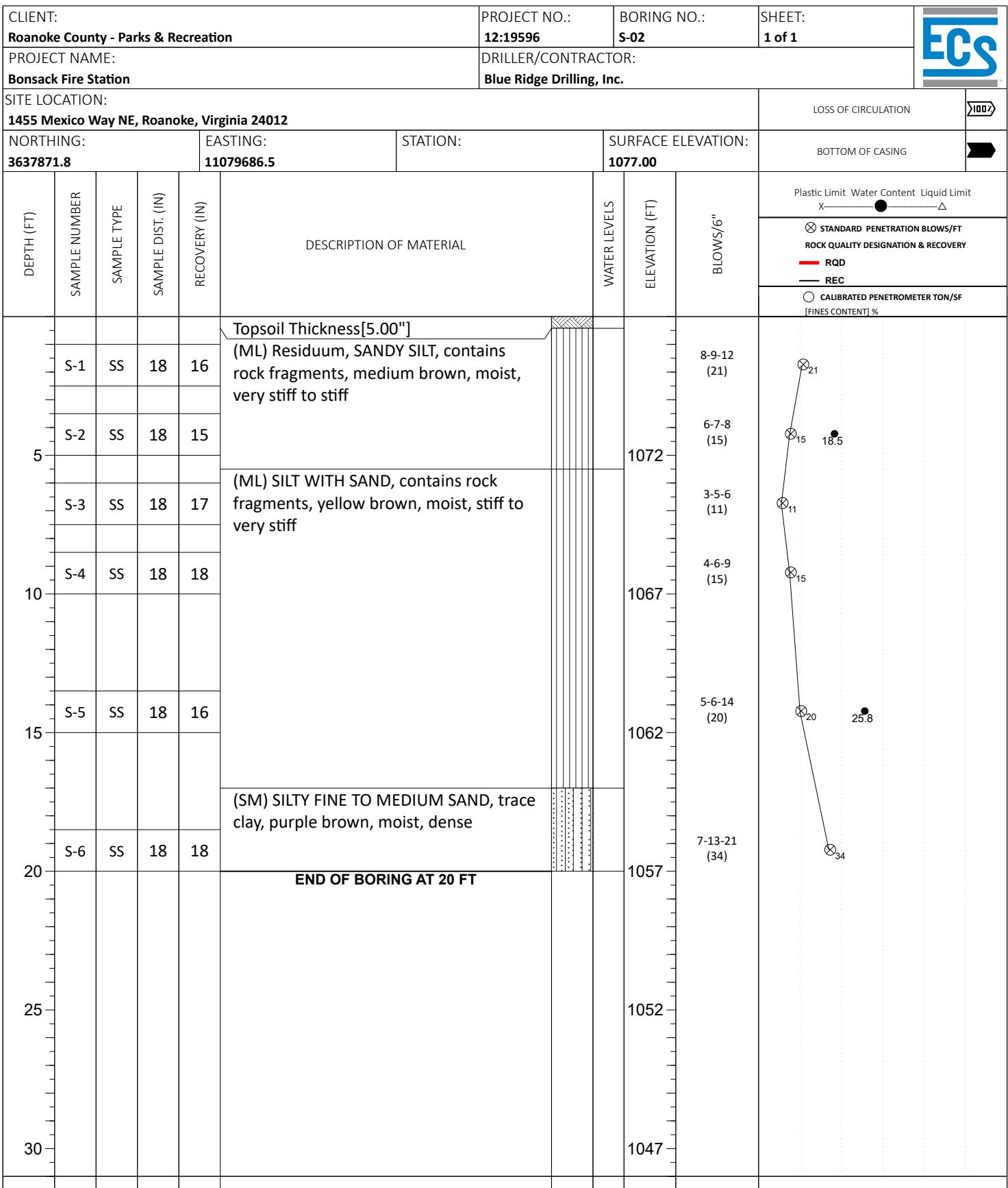
GEOTECHNICAL BOREHOLE LOG



CLIENT: Roanoke County - Parks & Recreation				PROJECT NO.: 12:19596	BORING NO.: P-05	SHEET: 1 of 1	ECS				
PROJECT NAME: Bonsack Fire Station				DRILLER/CONTRACTOR: Blue Ridge Drilling, Inc.							
SITE LOCATION: 1455 Mexico Way NE, Roanoke, Virginia 24012							LOSS OF CIRCULATION 				
NORTHING: 3637663.9		EASTING: 11079526.9		STATION:	SURFACE ELEVATION: 1066.00		BOTTOM OF CASING 				
DEPTH (FT)	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE DIST. (IN)	RECOVERY (IN)	DESCRIPTION OF MATERIAL	WATER LEVELS	ELEVATION (FT)	BLOWS/6"	Plastic Limit	Water Content	Liquid Limit
									X	●	△
<input checked="" type="checkbox"/> STANDARD PENETRATION BLOWS/FT ROCK QUALITY DESIGNATION & RECOVERY  RQD  REC <input type="checkbox"/> CALIBRATED PENETROMETER TON/SF [FINES CONTENT] %											
5							1061				
10							1056				
15							1051				
20							1046				
25							1041				
30							1036				
THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES. IN-SITU THE TRANSITION MAY BE GRADUAL											
<input checked="" type="checkbox"/> WL (First Encountered) <input checked="" type="checkbox"/> WL (Completion) <input checked="" type="checkbox"/> WL (Seasonal High Water) <input checked="" type="checkbox"/> WL (Stabilized)				BORING STARTED: May 13 2022			CAVE IN DEPTH:				
				BORING COMPLETED: May 13 2022			HAMMER TYPE: Manual				
				EQUIPMENT: Truck BK-51	LOGGED BY: MCA	DRILLING METHOD: 2 1/4" HSA					
GEOTECHNICAL BOREHOLE LOG											

CLIENT: Roanoke County - Parks & Recreation				PROJECT NO.: 12:19596	BORING NO.: P-06	SHEET: 1 of 1	ECS				
PROJECT NAME: Bonsack Fire Station				DRILLER/CONTRACTOR: Blue Ridge Drilling, Inc.							
SITE LOCATION: 1455 Mexico Way NE, Roanoke, Virginia 24012							LOSS OF CIRCULATION 				
NORTHING: 3637738.9		EASTING: 11079399.9		STATION:	SURFACE ELEVATION: 1056.00		BOTTOM OF CASING 				
DEPTH (FT)	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE DIST. (IN)	RECOVERY (IN)	DESCRIPTION OF MATERIAL	WATER LEVELS	ELEVATION (FT)	BLOWS/6"	Plastic Limit	Water Content	Liquid Limit
									X	●	△
<input checked="" type="checkbox"/> STANDARD PENETRATION BLOWS/FT ROCK QUALITY DESIGNATION & RECOVERY  RQD  REC <input type="checkbox"/> CALIBRATED PENETROMETER TON/SF [FINES CONTENT] %											
5							1051				
10							1046				
15							1041				
20							1036				
25							1031				
30							1026				
THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES. IN-SITU THE TRANSITION MAY BE GRADUAL											
<input checked="" type="checkbox"/> WL (First Encountered) <input checked="" type="checkbox"/> WL (Completion) <input checked="" type="checkbox"/> WL (Seasonal High Water) <input checked="" type="checkbox"/> WL (Stabilized)				BORING STARTED: May 13 2022			CAVE IN DEPTH:				
				BORING COMPLETED: May 13 2022			HAMMER TYPE: Manual				
				EQUIPMENT: Truck BK-51	LOGGED BY: MCA	DRILLING METHOD: 2 1/4" HSA					
GEOTECHNICAL BOREHOLE LOG											

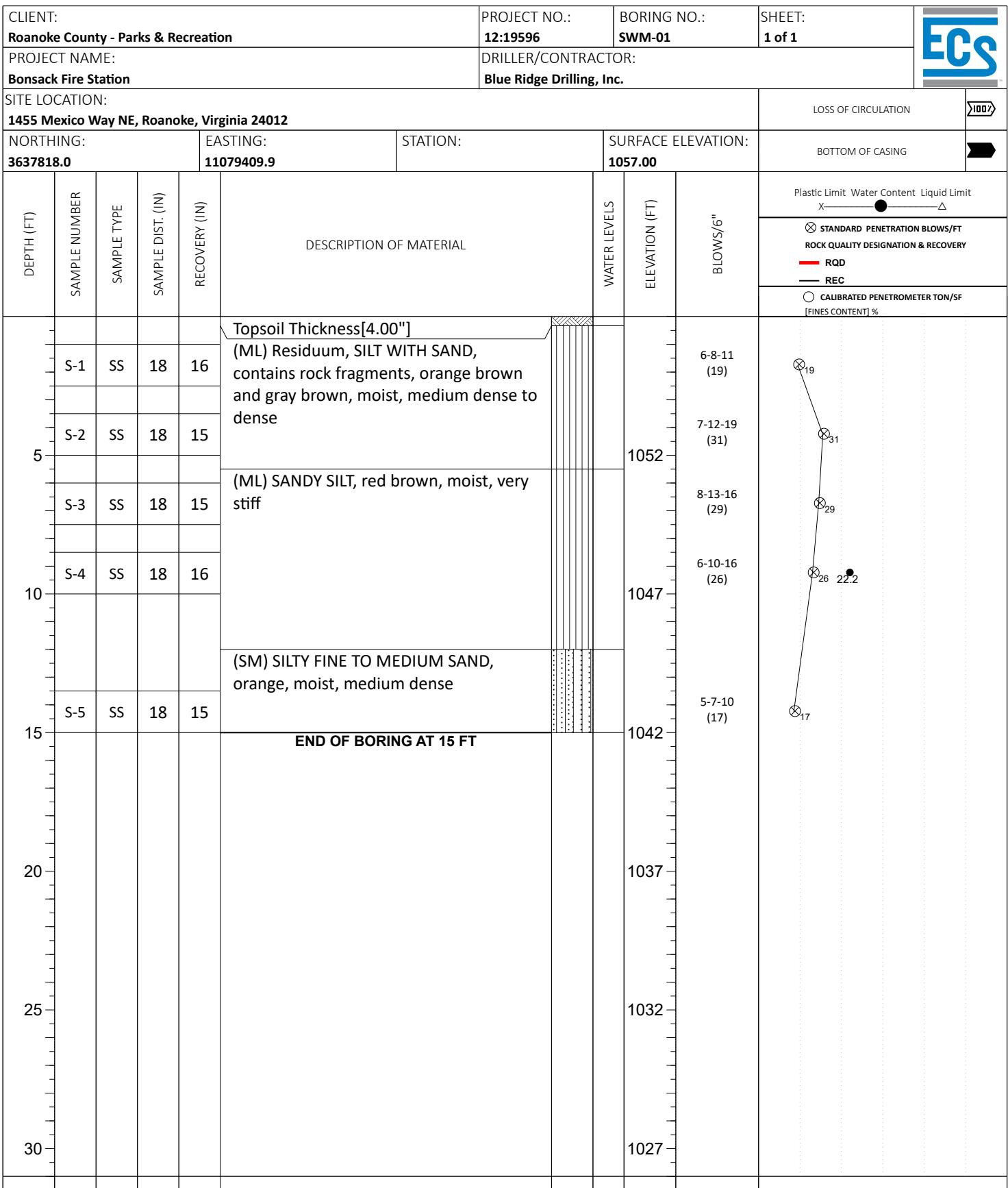




THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES. IN-SITU THE TRANSITION MAY BE GRADUAL

WL (First Encountered)	Dry	BORING STARTED: May 13 2022	CAVE IN DEPTH:
WL (Completion)		BORING COMPLETED: May 13 2022	HAMMER TYPE: Manual
WL (Seasonal High Water)		EQUIPMENT: Truck BK-51	LOGGED BY: MCA
WL (Stabilized)			DRILLING METHOD: 2 1/4" HSA

GEOTECHNICAL BOREHOLE LOG

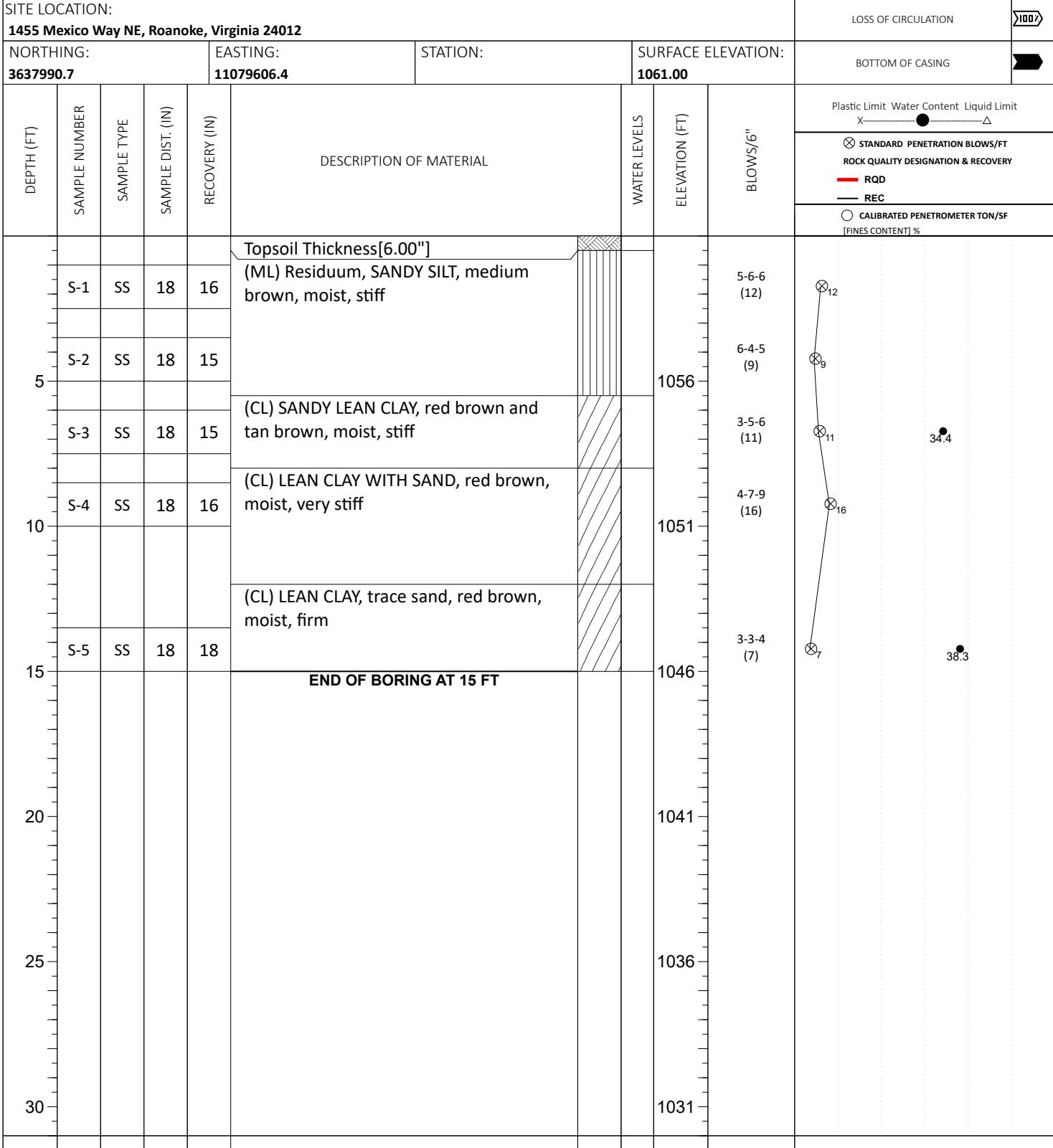


THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES. IN-SITU THE TRANSITION MAY BE GRADUAL

WL (First Encountered)	Dry	BORING STARTED: May 12 2022	CAVE IN DEPTH: 6.70
WL (Completion)		BORING COMPLETED: May 12 2022	HAMMER TYPE: Manual
WL (Seasonal High Water)		EQUIPMENT: Truck BK-51	LOGGED BY: MCA
WL (Stabilized)			DRILLING METHOD: 2 1/4" HSA

GEOTECHNICAL BOREHOLE LOG

CLIENT: Roanoke County - Parks & Recreation	PROJECT NO.: 12:19596	BORING NO.: SWM-02	SHEET: 1 of 1	ECS
PROJECT NAME: Bonsack Fire Station	DRILLER/CONTRACTOR: Blue Ridge Drilling, Inc.			



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

WL (First Encountered)	Dry	BORING STARTED: May 12 2022	CAVE IN DEPTH: 6.30
WL (Completion)		BORING COMPLETED: May 12 2022	HAMMER TYPE: Manual
WL (Seasonal High Water)		EQUIPMENT: Truck BK-51	LOGGED BY: MCA
WL (Stabilized)			DRILLING METHOD: 2 1/4" HSA

GEOTECHNICAL BOREHOLE LOG

APPENDIX C – Laboratory Testing

Laboratory Test Results Summary

Plasticity Chart

Grain Size Analyses

Moisture-Density Relationship Curves

CBR Test Results

Laboratory Testing Summary

Sample Location	Sample Number	Depth (feet)	^MC (%)	Soil Type	Atterberg Limits			**Percent Passing No. 200 Sieve	Moisture - Density		CBR (%)		#Organic Content (%)
					LL	PL	PI		<Maximum Density (pcf)	<Optimum Moisture (%)	0.1 in.	0.2 in.	
B-01	S-3	6-7.5	32.6	ML	48	28	20	94.7					
B-03	S-5	13.5-15	43.1	ML	43	28	15	91.0					
B-04	S-1	1-2.5	17.3										
B-04	S-2	3.5-5	20.1										
B-04	S-4	8.5-10	27.1										
B-04	S-6	18.5-20	24.3										
B-05	S-3	6-7.5	25.3										
P-01	D3S-66	1-10		CL	28	18	10	51.4	114.2	15.5	13.4	16.4	
P-03	S-2	3.5-5	25.7										
P-04	D3S-67	1-10		CL	39	21	18	81.0	105.5	18.7	10.3	9.3	

Notes: See test reports for test method, ^ASTM D2216-19, *ASTM D2488, **ASTM D1140-17, #ASTM D2974-20e1 < See test report for D4718 corrected values

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

Project: Bonsack Fire Station
Client: Roanoke County - Parks & Recreation

Project No.: 12:19596
Date Reported: 6/8/2022



Office / Lab
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(540)362-1202

Tested by	Checked by	Approved by	Date Received
JGeil	JMurphy	JMurphy	5/17/2022

Laboratory Testing Summary

Notes: See test reports for test method, [^]ASTM D2216-19, ^{*}ASTM D2488, ^{**}ASTM D1140-17, #ASTM D2974-20e1 < See test report for D4718 corrected values

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

Project: Bonsack Fire Station
Client: Roanoke County - Parks & Recreation

Project No.: 12:19596
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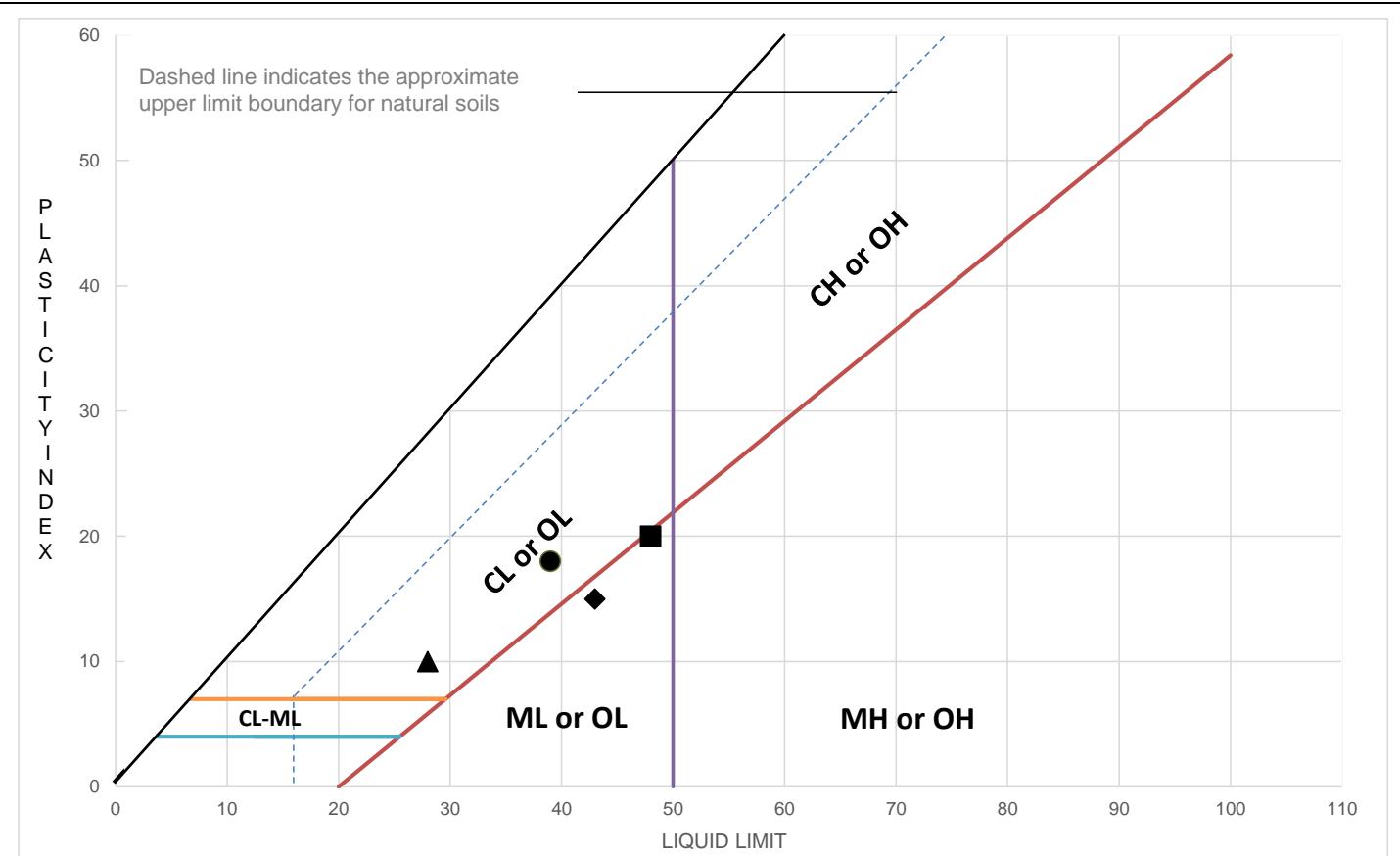


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JGeil	JMurphy	JMurphy	

LIQUID AND PLASTIC LIMITS TEST REPORT



TEST RESULTS (ASTM D4318-10 (MULTIPOINT TEST))

Project: Bonsack Fire Station
Client: Roanoke County - Parks & Recreation

Project No.: 12:19596
Date Reported: 6/8/2022



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Tested by	Checked by	Approved by	Date Received
JGeil	JMurphy	JMurphy	5/17/2022

PARTICLE SIZE DISTRIBUTION

Very Coarse GRAVEL SAND SILT CLAY

3" 2" 1.5" 1" 3/4" 1/2" 3/8" #4 #10 #20 #40 #60 #100 #140 #200

1000 100 10 1 0.1 0.01 0.0

Particle Size mm

TEST RESULTS (ASTM D6913M-17-METHOD A)

Sieving		Hydrometer Sedimentation	
Particle Size	% Passing	Particle Size mm	% Passing
3"	100		
2"	100		
1 1/2"	100		
1"	100		
3/4"	100		
3/8"	100		
#4	100		
#10	100		
#20	100		
#40	100		
#60	99		
#100	99		
#200	95		

Dry Mass of sample, g	48.6
Sample Proportions	% dry mass
Very coarse, >3" sieve	0
Gravel, 3" to # 4 sieve	0
Coarse Sand, #4 to #10 sieve	0
Medium Sand, #10 to #40	0
Fine Sand, #40 to #200	5
Fines <#200	95

USCS	ML	Liquid Limit	48	D90		D50		D10
AASHTO	A-7-6	Plastic Limit	28	D85		D30		Cu
USCS Group Name	Silt	Plasticity Index	20	D60		D15		Cc

Project: Bonsack Fire Station

Client: Roanoke County - Parks & Recreation

Sample Description: Yellow Brown SILT

Sample Source: B-01

Project No : 12:19596

Depth (ft): 6 - 7.5

Sample No.: S-3

Date Reported: 6/8/2022



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JGeil	JMurphy	JMurphy	5/17/2022	

PARTICLE SIZE DISTRIBUTION

TEST RESULTS (ASTM D6913M-17-METHOD A)

Sieving		Hydrometer Sedimentation	
Particle Size	% Passing	Particle Size mm	% Passing
3"	100		
2"	100		
1 1/2"	100		
1"	100		
3/4"	100		
3/8"	100		
#4	100		
#10	98		
#20	96		
#40	95		
#60	93		
#100	92		
#200	91		

Dry Mass of sample, g	57.9
Sample Proportions	% dry mass
Very coarse, >3" sieve	0
Gravel, 3" to # 4 sieve	0
Coarse Sand, #4 to #10 sieve	2
Medium Sand, #10 to #40	3
Fine Sand, #40 to #200	4
Fines <#200	91

USCS	ML	Liquid Limit	43	D90		D50		D10
AASHTO	A-7-6	Plastic Limit	28	D85		D30		Cu
USCS Group Name	Silt	Plasticity Index	15	D60		D15		Cc

Project: Bonsack Fire Station

Client: Roanoke County - Parks & Recreation

Sample Description: Orange Brown SILT

Sample Source: B-03

Project No : 12:19596

Depth (ft): 13.5 - 15

Sample No.: S-5

Date Reported: 6/8/2022



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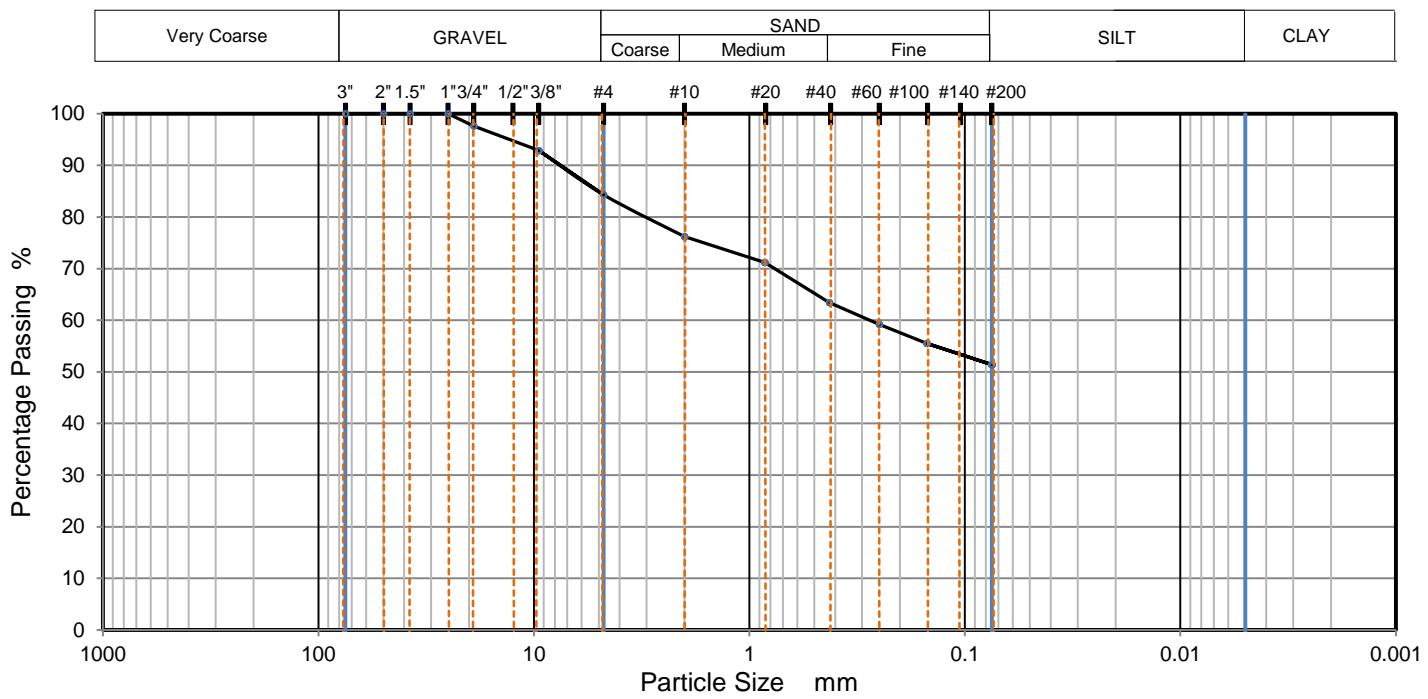
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Suite 101

(540)362-1202

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JGeil	JMurphy	JMurphy	5/17/2022	

PARTICLE SIZE DISTRIBUTION



TEST RESULTS (ASTM D6913M-17-METHOD A)

Sieving		Hydrometer Sedimentation	
Particle Size	% Passing	Particle Size mm	% Passing
3"	100		
2"	100		
1 1/2"	100		
1"	100		
3/4"	98		
3/8"	93		
#4	84		
#10	76		
#20	71		
#40	63		
#60	59		
#100	56		
#200	51		

Dry Mass of sample, g	31210.0
Sample Proportions	
Very coarse, >3" sieve	0
Gravel, 3" to # 4 sieve	16
Coarse Sand, #4 to #10 sieve	8
Medium Sand, #10 to #40	13
Fine Sand, #40 to #200	12
Fines <#200	51

USCS	CL	Liquid Limit	28	D90	7.520	D50		D10	
AASHTO	A-4	Plastic Limit	18	D85	5.026	D30		Cu	
USCS Group Name	Sandy lean clay with gravel	Plasticity Index	10	D60	0.277	D15		Cc	

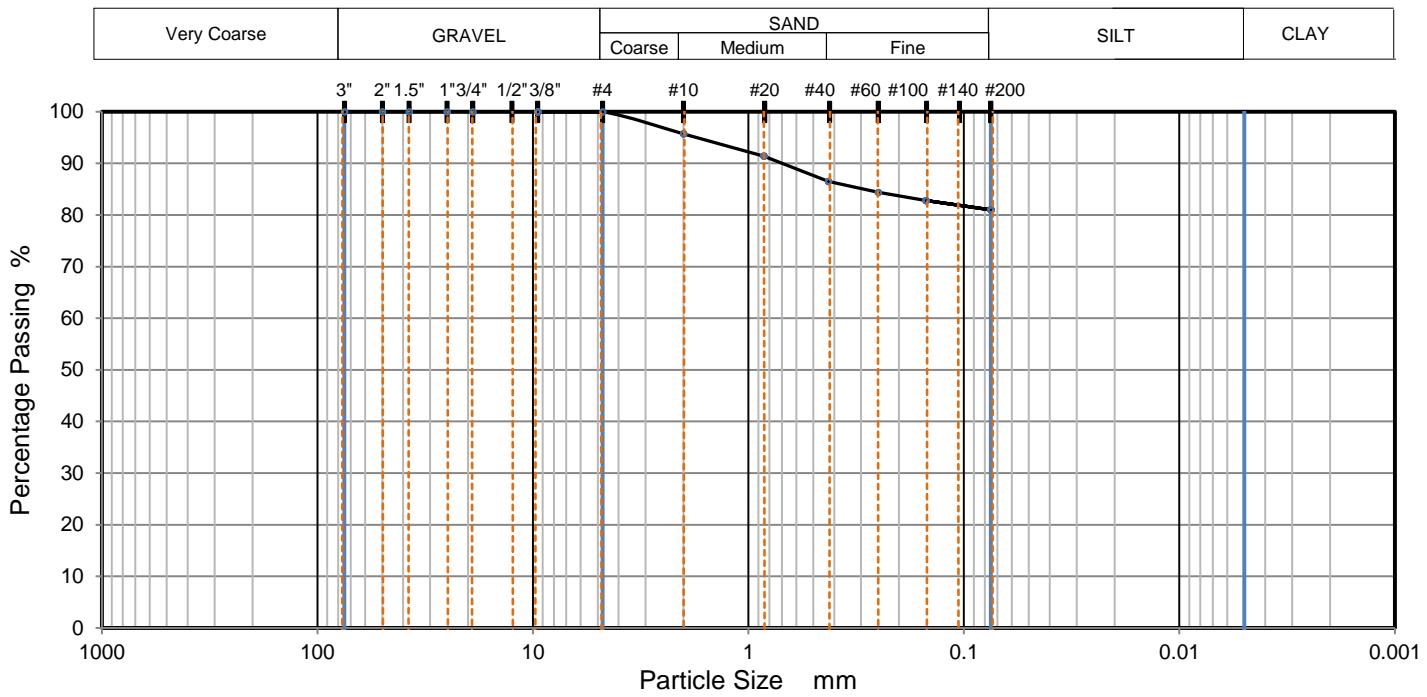
Project: Bonsack Fire Station
 Client: Roanoke County - Parks & Recreation
 Sample Description: Purple Brown SANDY LEAN CLAY with Gravel
 Sample Source: P-01

Project No.: 12:19596
 Depth (ft): 1 - 10
 Sample No.: D3S-66
 Date Reported: 6/8/2022

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PARTICLE SIZE DISTRIBUTION



TEST RESULTS (ASTM D6913M-17-METHOD A)

Sieving		Hydrometer Sedimentation	
Particle Size	% Passing	Particle Size mm	% Passing
3"	100		
2"	100		
1 1/2"	100		
1"	100		
3/4"	100		
3/8"	100		
#4	100		
#10	96		
#20	91		
#40	87		
#60	84		
#100	83		
#200	81		

Dry Mass of sample, g	100.7
Sample Proportions	% dry mass
Very coarse, >3" sieve	0
Gravel, 3" to # 4 sieve	0
Coarse Sand, #4 to #10 sieve	4
Medium Sand, #10 to #40	9
Fine Sand, #40 to #200	6
Fines <#200	81

USCS	CL	Liquid Limit	39	D90	0.697	D50		D10
AASHTO	A-6	Plastic Limit	21	D85	0.291	D30		Cu
USCS Group Name	Lean clay with sand	Plasticity Index	18	D60		D15		Cc

Project: Bonsack Fire Station

Client: Roanoke County - Parks & Recreation

Sample Description: Brown LEAN CLAY with Sand

Sample Source: P-04

Project No : 12:19596

Depth (ft): 1 - 10

Sample No.: D3S-67

Date Reported: 6/8/2022



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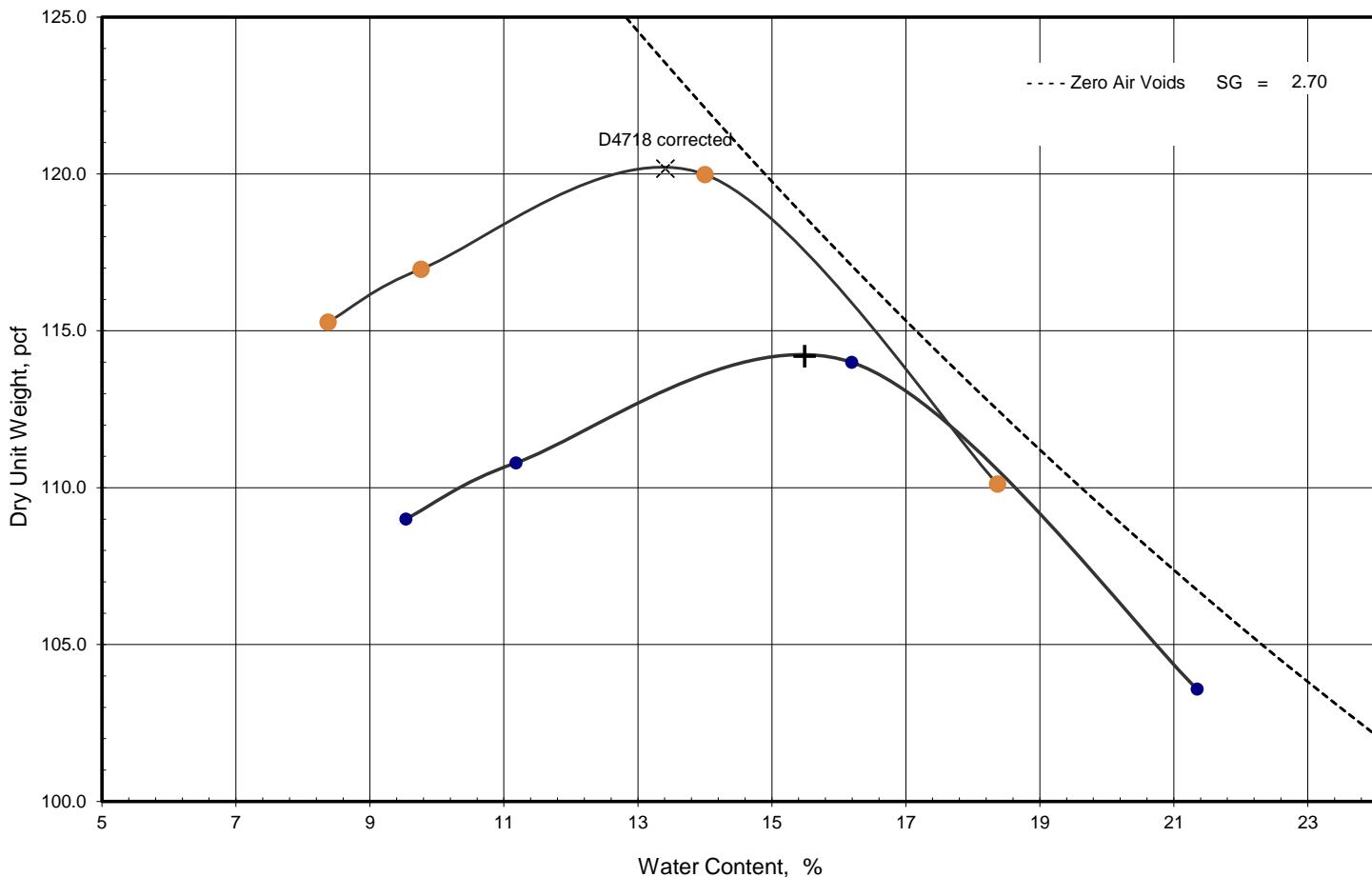
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Tested by	Checked by	Approved by	Date Received	Remarks
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**Laboratory Compaction Characteristics of Soil
Using Standard Effort**



Optimum Moisture Content

15.5 %

Maximum Dry Unit Weight

114.2 pcf

Corrected Opt. Moisture Content

13.4 %

Corrected Max. Dry Density

120.2 pcf

Cumulative material retained on:

3/4 in. sieve 2.4 %

3/8 in. sieve 7.1 %

#4 sieve 15.7 %

Preparation

ASTM dry preparation method

Type of rammer

Manual - 5.5lbf (24.5N)

VTM-1

Test Specification / Method

Specific gravity - D854 water pycnometer

2.70

Historical

Coarse Aggregate Specific Gravity -

2.70

Historical

15.67 % retained on #4 sieve.

Soil Description

Nat.
Moist. %

Liquid Limit

Plasticity
Index

%< #200

USCS

AASHTO

Purple Brown SANDY LEAN CLAY with Gravel

28

10

51.4

CL

A-4

Project: Bonsack Fire Station

Project No.: 12:19596

Client: Roanoke County - Parks & Recreation

Depth (ft.): 1 - 10

Sample / Source P-01

Sample No.: D3S-66

Test Reference/No.:

Date Reported: 6/8/2022



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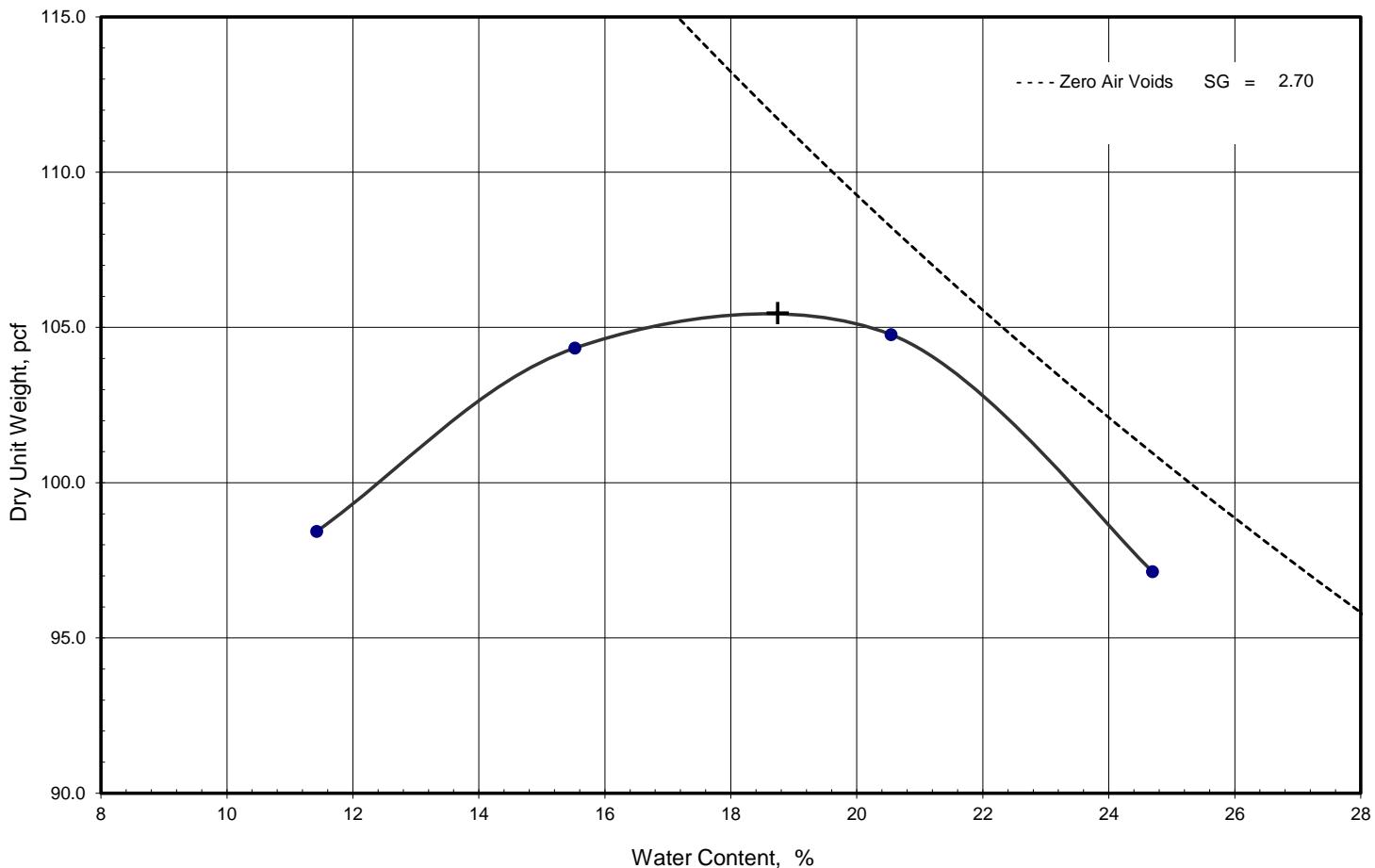
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Tested by	Checked by	Approved by	Date Received	Remarks
JGeil	JMurphy	JMurphy	5/17/2022	

**Laboratory Compaction Characteristics of Soil
Using Standard Effort**



Optimum Moisture Content	18.7	%	Preparation	ASTM dry preparation method		
Maximum Dry Unit Weight	105.5	pcf	Type of rammer	Manual - 5.5lbf (24.5N)		
			Test Specification / Method	VTM-1		
			Specific gravity - D854 water pycnometer	2.70	Historical	
Cumulative material retained on:			Coarse Aggregate Specific Gravity -			
	3/4 in. sieve	0.0	%			
	3/8 in. sieve	0.0	%			
	#4 sieve	0.0	%			
Soil Description	Nat. Moist. %	Liquid Limit	Plasticity Index	%< #200	USCS	AASHTO
Brown LEAN CLAY with Sand		39	18	81.0	CL	A-6

Project: Bonsack Fire Station
Client: Roanoke County - Parks & Recreation
Sample / Source P-04
Test Reference/No.:

Project No.: 12:19596
Depth (ft.): 1 - 10
Sample No.: D3S-67
Date Reported: 6/8/2022



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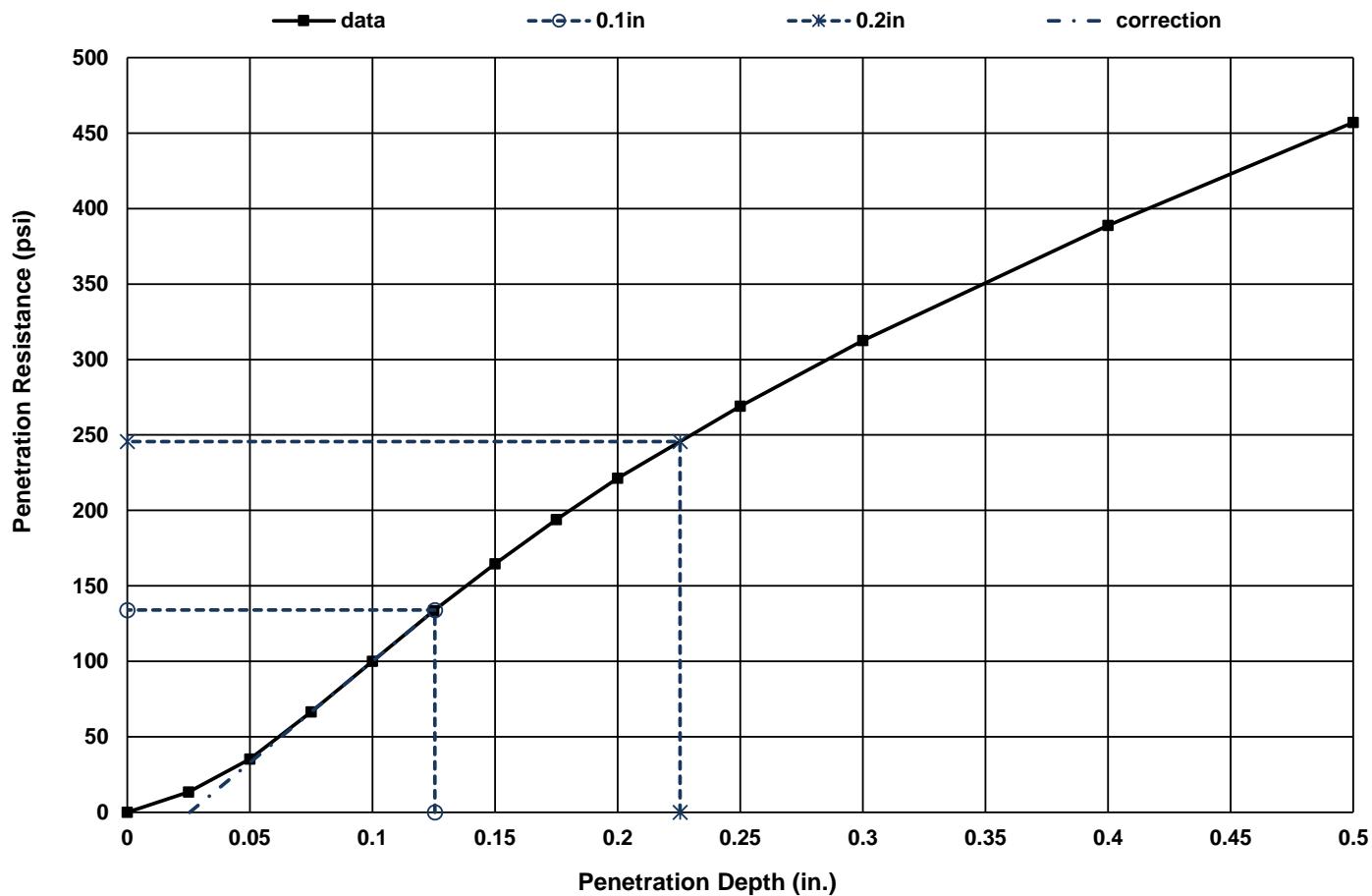
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Tested by	Checked by	Approved by	Date Received	Remarks
JGeil	JMurphy	JMurphy	5/17/2022	

California Bearing Ratios (CBR) of Laboratory-Compacted Soils



TEST RESULTS (VTM-8)

Molded			Soaked			CBR (%)		Linearity Correction (in.)	Surcharge (lbs.)		Swell (%)		
Density (pcf)	Percent of Max. Dens.	Moisture (%)	Density (pcf)	Percent of Max. Dens.	Moisture (%)	0.1 in.	0.2 in.		LL	PI	% Fines	% Gravel	
117.4	97.7	14.5	115.9	96.4	15.9	13.4	16.4	0.03	10		0.11		
Material Description						AASHTO	USCS	MAX. Dens. (pcf)	Optimum Moisture (%)	LL	PI	% Fines	% Gravel
Purple Brown SANDY LEAN CLAY with Gravel						A-4	CL	120.2	13.4	28	10	51.4	15.7

Project: Bonsack Fire Station

Client: Roanoke County - Parks & Recreation

Sample / Source P-01

Test Reference/No.: 1

Project No.: 12:19596

Depth (ft.): 1 - 10

Sample No.: D3S-66

Date Reported: 6/8/2022



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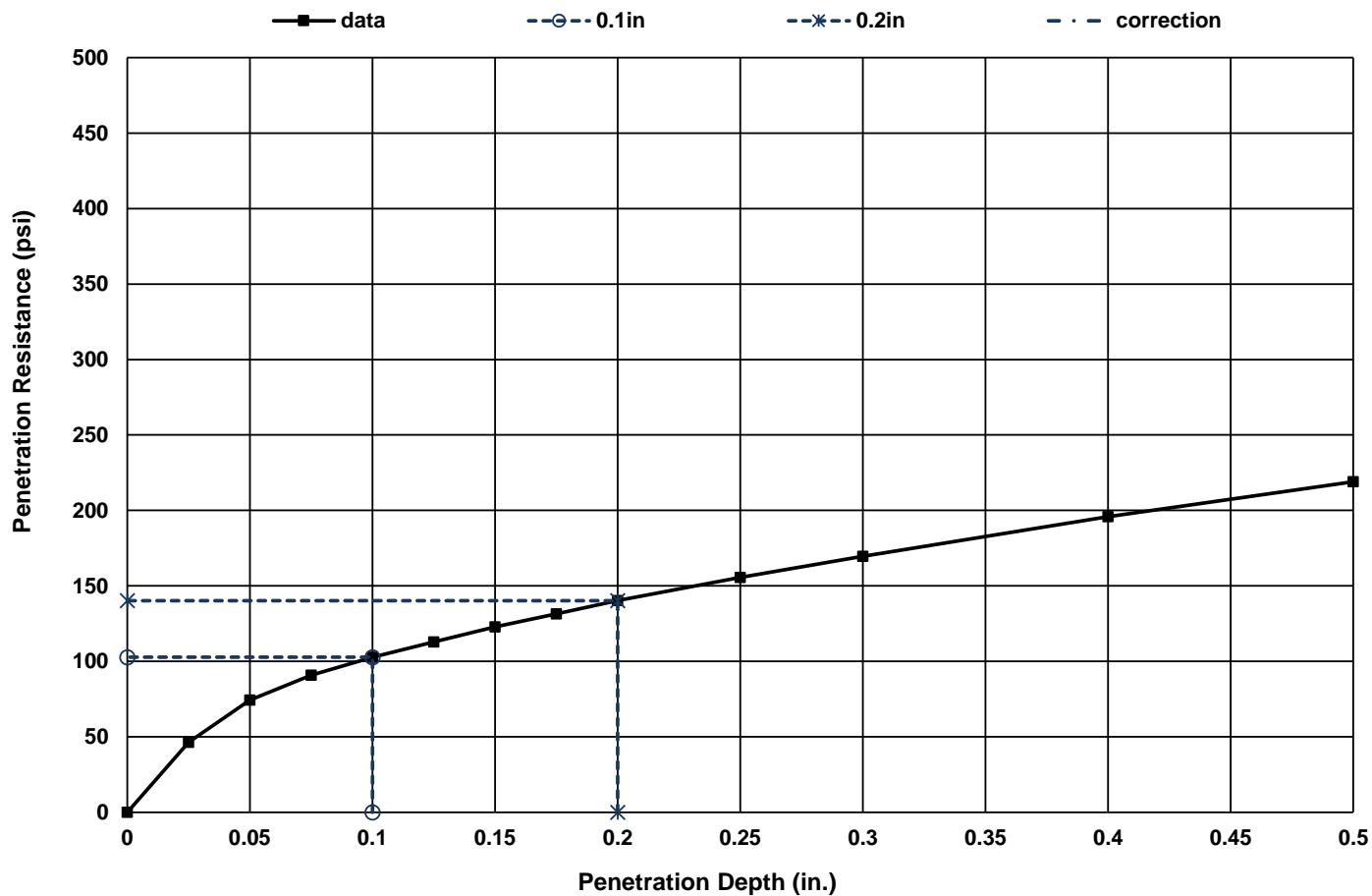
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Tested by	Checked by	Approved by	Date Received	Remarks
JGeil	JMurphy	JMurphy	5/17/2022	

California Bearing Ratios (CBR) of Laboratory-Compacted Soils



TEST RESULTS (VTM-8)

Molded			Soaked			CBR (%)		Linearity Correction (in.)	Surcharge (lbs.)		Swell (%)		
Density (pcf)	Percent of Max. Dens.	Moisture (%)	Density (pcf)	Percent of Max. Dens.	Moisture (%)	0.1 in.	0.2 in.		LL	PI	% Fines	% Gravel	
107.5	101.9	17.2	104.3	98.9	20.1	10.3	9.3	0.00	10		0.57		
Material Description						AASHTO	USCS	MAX. Dens. (pcf)	Optimum Moisture (%)	LL	PI	% Fines	% Gravel
Brown LEAN CLAY with Sand						A-6	CL	105.5	18.7	39	18	81.0	0.0

Project: Bonsack Fire Station

Client: Roanoke County - Parks & Recreation

Sample / Source P-04

Test Reference/No.: 1

Project No.: 12:19596

Depth (ft.): 1 - 10

Sample No.: D3S-67

Date Reported: 6/8/2022



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JGeil	JMurphy	JMurphy	5/17/2022	