

# S-23-102 (Keeler Mill Road) Bridge Replacement over Armstrong Creek

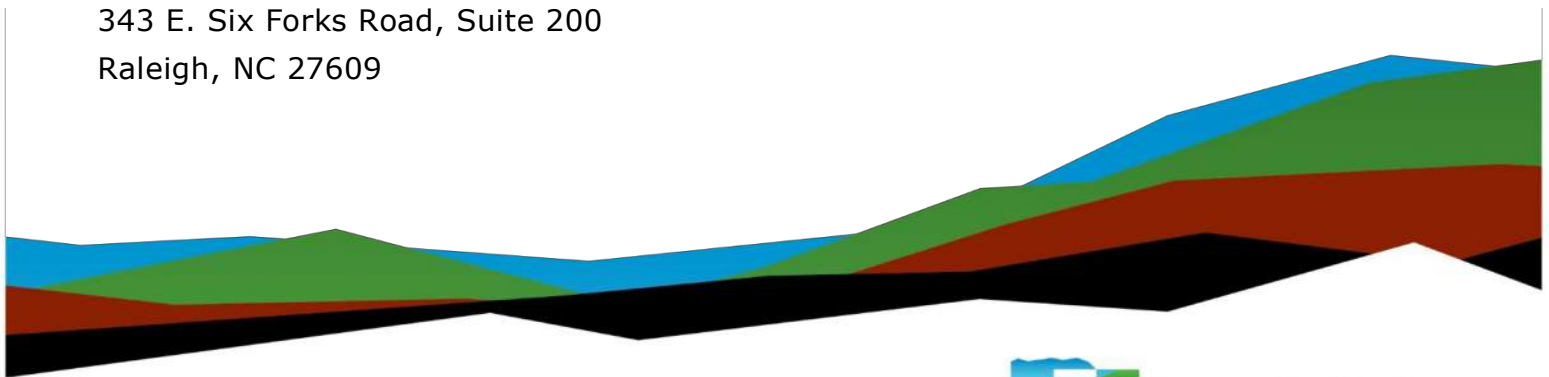
## Greenville County, SC

### Geotechnical Baseline Report

October 30, 2024 | SCDOT Project ID: P041161  
Terracon Project No.: 8623P180 Revision 1

#### Prepared for:

HNTB Corporation  
343 E. Six Forks Road, Suite 200  
Raleigh, NC 27609





72 Pointe Circle  
Greenville, SC 29615  
P (864) 292-2901  
[Terracon.com](http://Terracon.com)

October 30, 2024

HNTB Corporation  
343 E. Forks Road, Suite 200  
Raleigh, NC 27609

Attn: Mr. Spencer Franklin, PE, Senior Vice President  
P: 919-546-8997

Re: Geotechnical Baseline Report  
S-23-102 Bridge Replacement over Armstrong Creek  
Greenville County, South Carolina  
SCDOT Project ID.: P041161  
Terracon Project No.: 8623P180 Revision 1

Dear Mr. Franklin:

Terracon Consultants Inc. (Terracon) has completed the exploration, testing and limited engineering analysis services for the referenced project. The services were conducted in general accordance with our Task Order Number 001, dated May 25, 2023.

## **Introduction**

HNTB Corporation (HNTB) has contracted Terracon to perform subsurface exploration, laboratory testing and limited preliminary engineering recommendations for the replacement of the S-23-102 bridge over Armstrong Creek in Greenville County, South Carolina. This will be a complete bridge replacement. The results of subsurface exploration and laboratory testing have been separately presented in a Geotechnical Subsurface Data Report (GSDR). For convenience, those data are also provided here in this Geotechnical Baseline Report (GBR) along with a characterization of the subsurface conditions for the project. Limited preliminary geotechnical design and construction considerations associated with the requested scope of work are included in this GBR. This GBR was prepared in general accordance with the 2022 SCDOT Geotechnical Design Manual (GDM).

## **Project Description**

The project site is located at the S-23-102 (Keeler Mill Road) crossing over Armstrong Creek in Greenville County, South Carolina. Site location and exploration plans are presented in Appendix A of this report. Based on the preliminary conceptual plans by HNTB dated

## Geotechnical Baseline Report

S-23-102 Bridge Replacement over Armstrong Creek | Greenville County, SC  
October 30, 2024 | Terracon Project No. 8623P180 R1 | SCDOT Project ID: P041161



9/4/2024, the replacement bridge will be constructed on a new road alignment adjacent to and west of the current alignment. The current plan indicates the new bridge will be a 100-ft long single span bridge constructed with AASHTO Type BIII-36 Box Beams.

## Geotechnical Testing

The geotechnical exploration for this project was performed between June 3 and June 4, 2024. The results of our fieldwork and our associated laboratory testing are included in Appendices A and B.

### Field Exploration

Our field exploration consisted of the following:

- Two (2) Standard Penetration Test (SPT) Borings (S-23-102-1 and S-23-102-2)
- One (1) offset boring near S-23-102-2 for bulk sample collection
- One (1) Downhole Shear Wave Velocity Test (DHT-1) performed in casing installed within Boring S-23-102-1
- Two (2) Cone Penetration Test soundings (S-23-102-1C and S-23-102-2C).

The tests were performed at the approximate locations as approved by SCDOT. A description of our testing methods and graphical logs outlining the soil conditions at each test location are presented in Appendix A. The test locations were established in the field by Terracon and surveyed by Thomas & Hutton, LLC after completion. Station and offset are based on the plans provided at the time the tests were performed.

### Laboratory Testing

The following laboratory tests were performed on the soil samples from borings collected at the site.

- Eighteen (18) Natural Moisture Content Tests
- Six (6) Atterberg Limits Tests
- Eight (8) Fines Content Tests
- Four (4) Grain Size Tests with Hydrometer
- One (1) Remolded, Consolidated-Undrained (CU) Triaxial Compression Test with Pore Pressure Readings
- One (1) Standard Proctor Test
- One (1) Corrosivity Suite (pH, chloride content, sulfate content, and resistivity tests)
- Four (4) Compressive Strength of Rock Cores

The general scope of the laboratory testing frequency was prescribed by the SCDOT. The laboratory testing assignment was performed by our engineers. The laboratory procedures and results of the laboratory tests are presented in Appendix B.



# Subsurface Conditions

## Regional Geology

The bridge site is located on route S-23-102 (Keeler Mill Rd) on the outskirts of the town of Travelers Rest in Greenville County, South Carolina. The site lies generally within Piedmont Physiographic Province. More specifically, the site is mapped within the Six Mile Thrust Sheet. According to regional geologic mapping and published geologic reports, the project area is mapped in an area with intrusive rocks referred to as the Caesars Head Granite (SOch) consisting of biotite granitoid gneiss or gneissic granitoid (Nelson, et.al. 1998). The bridge end bents and approach embankments contain existing fill above alluvial and/or residual soils, very dense residual soils classified as Intermediate Geomaterials (IGM) and bedrock.

## Soil and Rock Stratification

The soils encountered at this site typically consist of fill in the upper 6 feet, followed by alluvial soils consisting of gravel, sands, and silty sands to about 12 to 23 feet below ground surface. Both the existing fill and alluvium were generally loose to very loose. Below the alluvium, residual soils were encountered and continued to 33.5 to 49 feet below ground surface, with some residual soils exhibiting SPT results of more than 100 bpf, followed by bedrock. Bedrock was present to the maximum depth explored of 64 feet at Boring S-23-102-1 and 43.5 feet at S-23-102-2. Groundwater was not encountered in boring S-23-102-1 but was encountered at a depth of 11.5 feet below the existing ground surface in boring S-23-102-2 after drilling.

Geology	Approximate Elevation of Layer Bottom (ft, NAVD88)	USCS Soil Type	Measured Field N Value	Plasticity Index	Fines Content	REC / RQD
Asphalt / Gravel	915 to 916	--	--	--	--	--
Fill	911	SM	4 to 15	NP <sup>2</sup>	17 to 23	--
Alluvium	894 to 905	SM, SP-SM, SW-SM, GP-GM	1 to 8	NP	6 to 35	--
Residuum	884 to 868	SM	5 to 100+	NP	15 to 22	--
Rock	PMDE <sup>1</sup>	--	--	--	--	72 to 100% / 63 to 100%

1. PMDE = Present to Maximum Depth Explored  
2. NP = non-plastic

## Seismic Conditions

According to SCDOT Seismic Design Specifications for Highway Bridges version 2.0, the proposed bridge will be an Operational Classification II (OC II). Per SCDOT GDM 2022, the proposed bridge shall be designed to meet the performance limits for an OCII bridge.

### Acceleration Design Response Spectrum (ADRS)

The shear wave and compression wave velocity results, as measured at Boring S-23-102-1 using downhole seismic tests, were provided to SCDOT. SCDOT used these velocity measurements to develop Acceleration Design Response Spectrum (ADRS) curves by determining the seismic hazard and evaluating the local site effects on the response spectra.

SCDOT provided "3-Point Acceleration Design Response Spectrum" curves along with a table that included pseudo-spectral accelerations (PSA) for 5% critical damping and at selected frequencies, consistent with a Geologically Realistic (B-C Boundary) condition (shear wave velocity,  $V_s = 2,500$  feet per second). PSA values were provided for the:

- Functional Evaluation Earthquake (FEE): 15% probability of exceedance in 75 years
- Safety Evaluation Earthquake (SEE): 3% probability of exceedance in 75 years

The table below provides the maximum considered earthquake peak ground acceleration (PGA), the short period acceleration ( $S_{DS}$ ), and one-second period acceleration ( $S_{D1}$ ) for the FEE and SEE earthquakes at the ground surface. A copy of the "3-Point Acceleration Design Response Spectrum" provided by SCDOT is included in Appendix C.

Seismic Design Parameter	FEE	SEE
PGA	0.04	0.08
$S_{DS}$	0.09	0.17
$S_{D1}$	0.01	0.02

## Design and Construction Considerations

### Foundations

Steel H-piles driven to practical refusal on rock (i.e., >20 blows per inch [bpi] with appropriately sized hammer) are expected to be feasible for the proposed bridge end abutments. Per 16.3.1 of the SCDOT GDM (2022):



*For driven piles bearing in rock with an RQD greater than 10 percent, the nominal resistance of the pile is typically limited by the structural capacity of the foundation element itself. This is especially true with prestressed concrete piles driven into rock, and why prestressed concrete piles typically have pile points when driven to bearing in rock. In many cases steel piles are fitted with “reinforced tips” to avoid damage to the foundation element. If the depth to rock with RQD greater than 10 percent is less than 10 feet, then the pile should be installed as a drilled pile. Therefore, piles should be driven to rock when the depth to top of rock is greater than 10 feet. For rock with RQD less than 10 percent and soils with 100 or more blows per foot of penetration, it has been the experience of SCDOT that piles can be driven into these materials. Penetrations typically range from 5 to 10 feet.*

Per the preliminary plans, the estimated bottom of pile cap is at about Elevation 913 feet, within about 3 feet of the existing grades along the alignment. The depth to very dense residual soils/IGM is predicted to be between about 23 to 30 feet below the estimated bottom of abutment pile cap. The very dense residual soils/IGM is about 7 feet thick at Abutment No. 1 and 15 feet at Abutment No. 2 overlying bedrock with a minimum RQD of 63% at the top of rock; therefore, per the above excerpt from the GDM, piles may likely be driven to refusal to the top of rock at Abutment No. 1, whereas refusal of the piles in apparent IGM may occur before reaching the bedrock at Abutment No. 2. Reinforced pile tips will be needed to minimize potential pile damage while penetrating through IGM to the top of rock. Pile drivability using the wave equation should be performed as part of subsequent detailed geotechnical evaluations.

Piles driven to practical refusal within the IGM or to top of rock can be designed to the factored structural capacity of the pile. The table below provides the maximum factored pile structural capacity assuming an AASHTO permitted factored pile capacity of  $0.5A_sF_y$ , using 50 ksi steel piles. An efficiency factor ( $\eta$ ) of 1.0 can be used if the pile spacing divided by the pile dimension is greater than 2.5 (Per Section 16.3.3 of the GDM).

Pile Size	Area of Steel ( $A_s$ ) in <sup>2</sup>	Maximum Factored Pile Load (tons) <sup>1</sup>
HP14x73 (21.4 in <sup>2</sup> )	21.4	267
HP14x89 (26.1 in <sup>2</sup> )	26.1	326
1. Max Load= $0.5 \cdot A_s \cdot F_y$		

The nominal geotechnical resistance of the piles considering refusal upon competent rock is typically set at 4 times the minimum compressive strength measured in the rock at the end bents (8,500 psi) times the cross-sectional area of the pile, 367 tons and 443 tons for HP 14x73 and HP14x89 piles, respectively. Piles driven to practical refusal in IGM will have lower nominal resistance; however, as indicated above for piles driven to practical refusal, the pile design will be governed by the maximum factored structural capacity of the pile rather than geotechnical capacity.

According to the conceptual bridge plans by HNTB dated 8/2024, about 5 feet of fill is expected at the end bent embankments to support the approach slab, with excavation of the existing soil profile below the new bridge to establish a bench shelf. Foundations should typically be installed after the approach embankment construction to reduce potential downdrag settlement issues. However, it is noted that piles driven to practical refusal on rock or within IGM are not considered sensitive to down drag settlement. The pile design should account for drag loads from the settling alluvium at the site; however, this additional drag load is not expected to control the pile foundation design.

We have noted variability in the top of rock and thickness of IGM, as seen in **Soil and Rock Stratification**. Therefore, we expect variability in tip elevations at each bent location. Resistance of piles driven to practical refusal in IGM or to top of rock will be limited by their structural resistance. Therefore, reinforced pile tips are recommended to penetrate to IGM and rock. Pile drivability using the wave equation should be performed along with estimating stresses during driving and, in general, verifying the ability of the Contractor’s selected hammer to drive the piles to the desired penetration while preventing overstressing.

Corrosion Testing

Corrosion testing was performed on a composite sample obtained from split spoons in the upper 2 to 12 feet. Corrosion testing included pH, resistivity, chlorides, and sulfates content as summarized in Table below. Corrosion test results are included in Appendix B.

Corrosion Test	Results Bent 1, Boring S-23-102-2 Composite Sample from 2 to 12 feet	Indication of Corrosivity <sup>1</sup>
pH	6.6	Less than 5.5
Resistivity	1,746 ohm-cm	Less than 2,000 ohm-cm
Chloride	127 ppm	Greater than 500 ppm
Sulfate	87 ppm	Greater than 1,000 ppm

1. AASHTO LRFD bridge design specifications, Ninth Edition 2020, Section 10.7.5.

Based on the criteria for electro-chemical properties in the GDM Section 7.18, the electro-chemical classification of the project site is aggressive. Interpretation of these data should be communicated with the project’s structural engineer.

Embankment Construction

Based on the conceptual plans by HNTB, fill will be placed to support the bridge approach slabs and extend beyond the bridge, whereas cut excavation is expected in front of the end abutments to create a shelf leading to the creek banks with relatively short (less than 5 feet tall) 2H:1V rip rap lined slopes shown at the end abutment positions. Bulk samples were obtained between End Bent 1 and Interior Bent 3 from the top 5 feet of existing embankment

## Geotechnical Baseline Report

S-23-102 Bridge Replacement over Armstrong Creek | Greenville County, SC  
October 30, 2024 | Terracon Project No. 8623P180 R1 | SCDOT Project ID: P041161



material. Per our scope, a bulk sample was tested for soil classification and was also remolded to about 95% of the Standard-effort Proctor prior to being tested for shear strength envelopes under CU Triaxial Compression with pore pressure readings. Test results are presented in Appendix B and summarized in the table below.

Sample No.	Station	Offset (ft)	Sample Depth (ft)	USCS Soil Type	Compaction		Shear Strength <sup>1</sup>	
					Optimum Moisture (%)	Max Dry Density (pcf)	Total	Effective
S-23-102-2 Offset	788+32	22 R	0 – 5	SC	14.9	111.7	c=5.4 psi $\phi=21^{\circ}$	c'=1.8 psi $\phi'=33^{\circ}$

1. Based on a maximum deviator stress failure criterion

## Seismic Induced Soil Shear Strength Loss (SSL)

A few feet of very loose silty sands were noted below the existing fill at both boring locations and appear to be likely at or below the predicted ground water elevation of about 912 feet (coincident with approximate creek level). These low consistency/density soils are susceptible to soil shear strength loss (SSL) during design seismic events. Additional soil and ground water evaluation and SSL screening should be performed to assess potential for liquefaction related settlement and stability impacts on the planned bridge foundations and embankment slopes.

## Closure

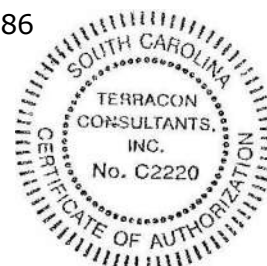
We appreciate the opportunity to be of service to you on this project. If you have any questions concerning this report or we may be of further service, please contact us.

Sincerely,

**Terracon Consultants, Inc.**

Maggie McKenney, EIT  
Senior Staff Engineer

Jonathan Ard, PE  
Manger Regional Services  
SC Registration No. 30886





## **Appendix A**

### **Field Exploration**

- Exhibit A-1 – Site Location Map
- Exhibit A-2 – Exploration Plans (2 Pages)
- Exhibit A-3 – Subsurface Profile
- Exhibit A-4 – Summary of Boring Data
- Exhibit A-5 – GeoScoping Form (2 Pages)
- Exhibit A-6 – Field Exploration Description (3 Pages)
- Exhibit A-7 – Soil/Rock Description Terms (2 Pages)
- Exhibit A-8 – Soil/Rock Symbols
- Exhibit A-9 – Boring Logs (4 Pages)
- Exhibit A-10 – Rock Core Photograph Logs (2 pages)
- Exhibit A-11 – Geophysical Testing Results
- Exhibit A-12 – CPT Sounding Logs (2 Pages)

Note: All exhibits are one page unless noted above

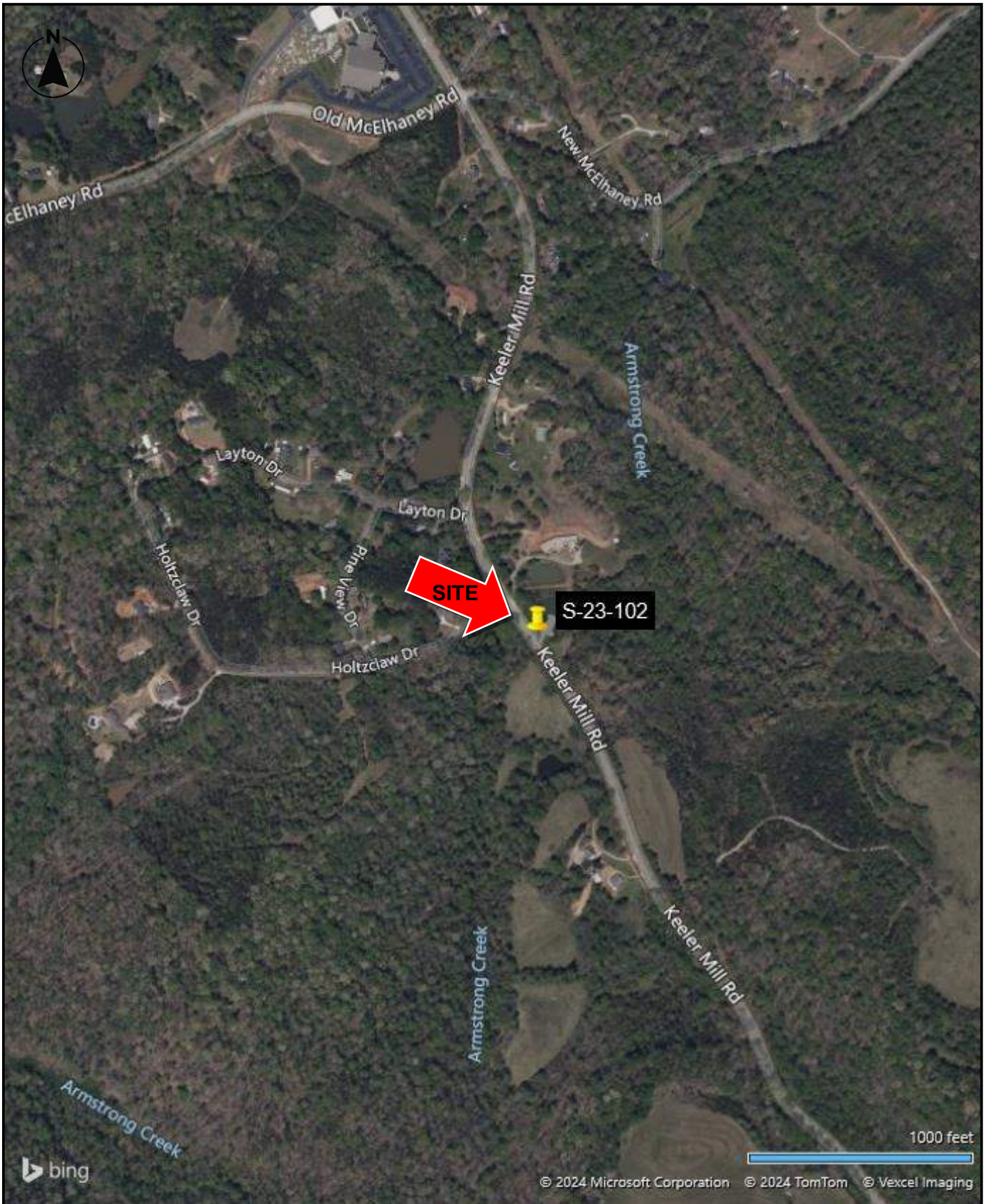


DIAGRAM IS FOR GENERAL LOCATION ONLY, AND  
IS NOT INTENDED FOR CONSTRUCTION PURPOSES

AERIAL PHOTOGRAPHY PROVIDED  
BY MICROSOFT BING MAPS

Project Number	8623P180
Scale	AS SHOWN
Client	HNTB
Date	9/13/2024

**Terracon**  
72 Pointe Cir  
Greenville, South Carolina 29615

### SITE LOCATION

S-23-102 BRO Armstrong Creek  
Keeler Mill Road  
Greenville County, SC

Exhibit

A-1






DIAGRAM IS FOR GENERAL LOCATION ONLY, AND  
IS NOT INTENDED FOR CONSTRUCTION PURPOSES

AERIAL PHOTOGRAPHY PROVIDED  
BY MICROSOFT BING MAPS

Project Number	8623P180
Scale	AS SHOWN
Client	HNTB
Date	9/13/2024

  
72 Pointe Cir  
Greenville, South Carolina 29615

## EXPLORATION PLAN

S-23-102 BRO Armstrong Creek  
Keeler Mill Road  
Greenville County, SC

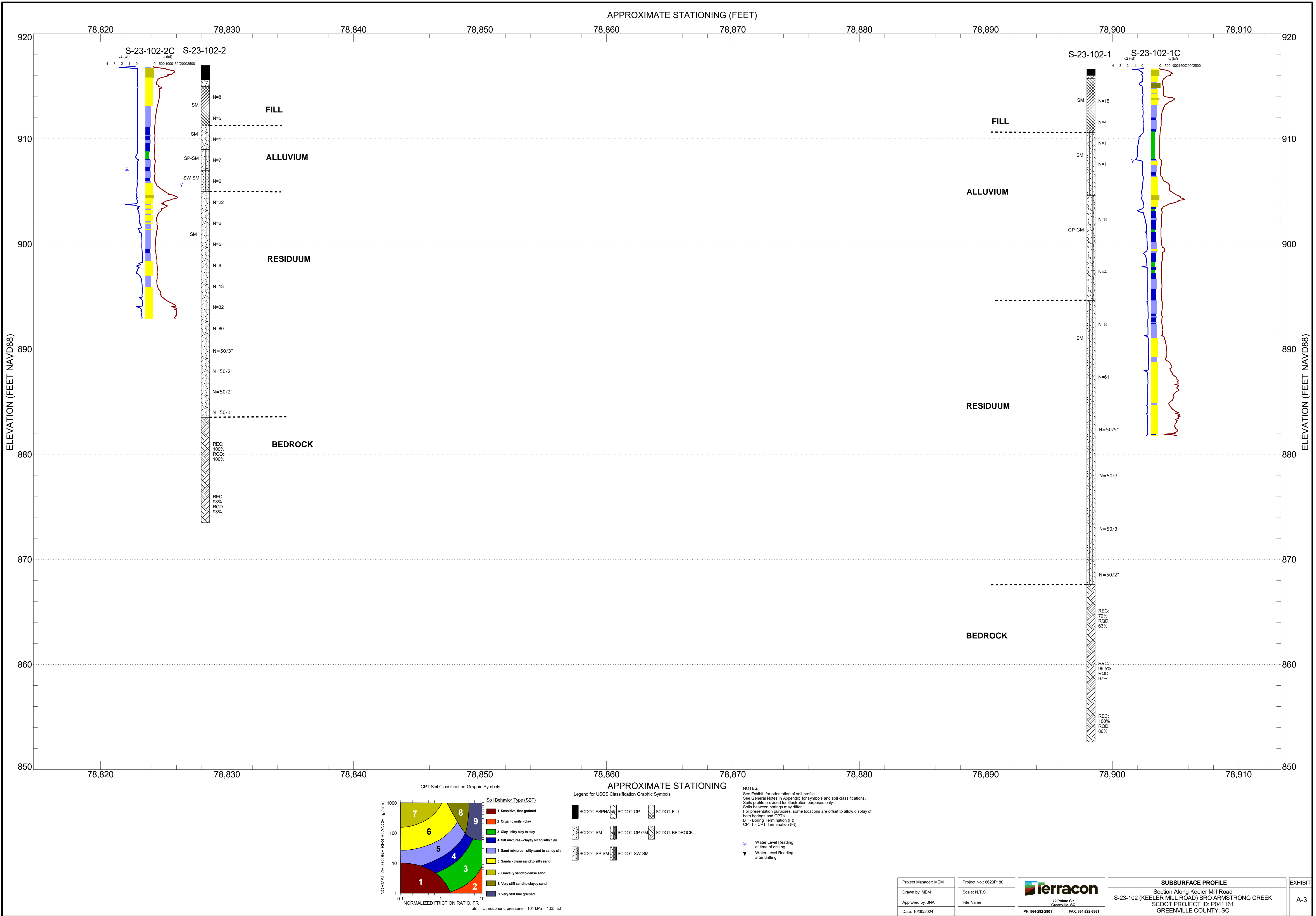
Exhibit

A-2





THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. RINK FENCE OPT & STB FENCE AT 8623P180T SCDOT BRIDGE PACK 19 S-25-102 OVER ARMSTRONG CREEK INTERNAL.GPJ TERRACON\_DATATEMPLATE.GDT 10/30/24



## Summary of Boring Data – Exhibit A-4

S-23-102 Bridge Replacement over Armstrong Creek | Greenville County, SC  
Terracon Project No. 8623P180 | SCDOT Project ID: P041161



### Summary of Boring Data

Boring No.	Ground Elevation (ft)	Test Depth (ft)	Northing (ft)	Easting (ft)	Latitude (°)	Longitude (°)	Station (ft) <sup>1</sup>	Offset (ft) <sup>1</sup>
S-23-102-1	916.6	64	1134339.18	1552628.53	34.942001	-82.492658	788+98	15 R
S-23-102-2	917.0	43.5	1134280.59	1552666.86	34.941841	-82.492527	788+28	15 R
S-23-102-1C	916.7	35	1134343.25	1552625.23	34.942012	-82.492669	789+03	15 R
S-23-102-2C	916.9	24	1134277.11	1552669.39	34.941832	-82.492518	788+24	15 R

1. Plans were provided by HNTB after the field exploration and survey. Station and offset values are estimated based on overlay in Google Earth <sup>TM</sup>.
2. A bulk sample was collected about 8 feet northeast of S-23-102-2.

## GeoScoping Form

PROJECT INFORMATION			
Project ID:	P041161	Date of Trip:	6/3/2024
County:	Greenville	Location:	Travelers Rest
Rd/ Route:	S-23-102	Local Name:	Keeler Mill Road
Attendees:	M. McKenney		

EXISTING BRIDGE INFORMATION			
Bridge Length:	60 ft	Bridge Width:	27.5 ft
Superstructure Type:	Concrete framing and decking	Substructure Type:	Timber and Steel H-Piles
Begin Bridge Sta <sup>1</sup> :	788+16	End Bridge Sta <sup>1</sup> :	789+16
Begin Bridge Embankment Sta <sup>1</sup> :	787+16	End Bridge Embankment Sta <sup>1</sup> :	790+16
Structure Number:	03308	Posted Weight Limit:	9 tons
Crossing:	Armstrong Creek	Skew:	N/A
Latitude:	34.941910°	Longitude:	-82.492621°
Existing Fill Height:	approx 6 ft	Approx Existing Slope Angle:	2H:1V
1. Begin & End Bridge Embankment 100 ft down Sta. or up Sta., respectively. Sta. estimated from overlay of bridge plan provided by HNTB.			

EXISTING ROADWAY EMBANKMENT INFORMATION			
Begin Project Sta:	786+30	Begin Bridge Embankment Sta:	787+16
Accessibility Issues:	None Observed		
Ground Cover:	Asphalt pavement and grassed shoulders		
Existing Fill Height:	6 feet, sloping	Approx Existing Slope Angle:	2H:1V
Local Development:	developed - residential		
Topography:	graded slope to creek		
Traffic Control Necessary:	Yes, lane closure		
Surface Soils:	silty sand	Muck:	No
Exposed Rock in Stream Bed:	Yes	Exposed Rock in banks:	No
Wetlands on Site:	Yes	Wetland Adjacent:	Yes
Depth FG to Water:	10 feet	Water Depth:	2 to 3 feet
Depth to Existing Ground:	approximately 13 feet at center of bridge		
Scour Condition at EB:	Critical	Scour Condition at IB:	Critical
End Bridge Embankment Sta:	790+16	End Project Sta:	792+40
Accessibility Issues:	None Observed		
Ground Cover:	Asphalt pavement and grassed shoulders		
Existing Fill Height:	6 feet, sloping	Approx Existing Slope Angle:	2H:1V
Local Development:	developed - residential		
Topography:	graded slope to creek		
Traffic Control Necessary:	Yes, lane closure		
Surface Soils:	silty sand	Muck:	No
Exposed Rock in Stream Bed:	Yes	Exposed Rock in banks:	No
Wetlands on Site:	Yes	Wetland Adjacent:	Yes
Depth FG to Water:	10 feet	Water Depth:	2 to 3 feet
Depth to Existing Ground:	approximately 13 feet at center of bridge		
Scour Condition at EB:	Critical	Scour Condition at IB:	Critical

# GeoScoping Form

UTILITIES INFORMATION	
Attached:	N/A
Above Ground:	Overhead power was observed on the southwest side of the road
Underground:	An underground waterline was observed in the southwest shoulder

Comments:



## Field Exploration Description Overview

The testing locations were proposed to and approved by SCDOT and located in the field by Terracon using measurements from existing structures shown on the provided drawings. The borings were surveyed by Thomas and Hutton after testing and drilling was complete. The locations, as shown in the Exploration Plans, are shown to the scale indicated.

A field log of each test location was prepared by our engineer. The final boring logs included with this report represent the engineer's description of the encountered conditions modified as necessary based on laboratory test results of the individual samples.

### Soil Test Borings (STB)

All boring and sampling operations were conducted in general accordance with the following procedures:

- SCDOT Geotechnical Design Manual 2022
- Preconstruction Design Memorandum (PCDM) 11 - Supplemental Design Criteria for Low Volume Bridge Replacement Projects
- ASTM D5783, "Standard Guide for Use of Direct Rotary Drilling with Water-Based Drilling Fluid for Geo-environmental Exploration"
- ASTM D6151, "Standard Practice for Using Hollow-Stem Augers for Geotechnical Exploration and Soil Sampling"
- ASTM D1586 "Test Method for Penetration Test and Split-Barrel Sampling of Soils"
- ASTM D4220 "Standard Practices for Preserving and Transporting Soil"
- ASTM D2113 "Standard Practice for Rock Core Drilling and Sampling of Rock for Site Exploration"
- ASTM D5079 "Standard Practices for Preserving and Transporting Rock Core Samples"

Each soil test boring was advanced using rotary wash drilling techniques. The sampling program is summarized in the following table:

Test ID	Total Depth	Interval of Continuous Sampling
S-23-102-1	64 feet w/ 15 feet rock coring	2 to 10 feet
S-23-102-2	43.5 feet w/ 10 feet rock coring	2 to 33.5 feet
S-23-102-2 Offset	5 feet	Bulk Sample <sup>1</sup>
S-23-102-1C	35 feet (refusal)	CPT - No sampling
S-23-102-2C	24 feet (refusal)	CPT - No sampling

1. Bulk sample was obtained with a manual hand auger.

## Exhibit A-6 – Field Exploration Description

S-23-102 Bridge Replacement over Armstrong Creek | Greenville County, SC  
Terracon Project No. 8623P180 | SCDOT Project ID: P041161



Soil samples were obtained with a standard 1.4-inch I.D., 2-inch O.D., split-barrel sampler, also known as a standard split-spoon. The sampler is advanced into the soil a total of 18 to 24 inches by striking the drill rod using a 140-pound automatic hammer falling 30 inches. The number of blows required to advance the sampler for each of three to four, 6-inch increments is recorded. The sum of the number of blows for the second and third increments is called the "Standard Penetration Value", or N-value ( $N_{meas}$ , blows per foot). The N-value, when properly evaluated, is an index to the soil strength.

Soil classification provides a general guide to the engineering properties of various soil types and enables the engineer to apply his experience to current situations. In our exploration, samples obtained during drilling operations are examined and visually classified by a geotechnical engineer using the procedures outlined in ASTM D2487 - Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System). Laboratory testing was also performed on select split-spoon samples to evaluate index properties for further classification. The soils are described according to color, texture, and relative density or consistency (based on standard penetration resistance). The designations shown on the logs are described in the 2022 SCDOT Geotechnical Design Manual, Chapter 6.

The borings were advanced either to the planned drilling depth at which they were terminated, or to refusal of the drilling equipment. Select borings were continued below this depth using diamond bit rock coring techniques. NQ2 sized cores were recovered from the borehole. The rock recovery ratios (REC, percentage of the total core run), Rock Quality Designation (RQD, percentage of the total core run of pieces greater than 4 inches) were recorded along with a description of the rock. An explanation of the rock descriptions shown on the logs is provided in the SCDOT GDM Chapter 6. Photos of the recovered rock core specimens are provided in the Rock Core Photograph Log.

As practical, groundwater readings were collected from each of the soil test borings after 24 hours. These water levels are indicated on the boring logs. The borings were advanced using mud rotary drilling techniques. As the drilling method introduces water into the borehole, time-of-drilling water levels may not be reliable.

At the conclusion of the work, the boreholes and sounding holes were backfilled with the drill cuttings and clean sand. The upper 20 feet of those in the embankments were grouted with a cement bentonite grout and capped with cold-patch asphalt.

### Cone Penetration Test (CPT) Soundings

Cone Penetration Test soundings were conducted in accordance with ASTM D5778 *Standard Test Method for Performing Electronic Friction Cone and Piezocone Penetration Testing of Soils*.

## **Downhole Shear Wave Velocity Test (DHT)**

One downhole seismic test was performed in a cased borehole drilled for this project. After the test boring was completed, the boring was filled with a fluid water/cement/bentonite grout and then a threaded PVC pipe casing (capped at the bottom end) was inserted into the borehole, providing a uniform bond between the soil and pipe exterior.

The downhole seismic test consisted of placing two downhole triaxial geophones at selected depth intervals in the borehole casing. The geophone was connected to a recording device (Seismic Source Daq Link 5 Seismograph) at the surface and clamped to the side of the casing at the selected test depth. The geophones are equipped with a spring-arm that is released at the bottom of the boring. The spring expands and forces the geophone against the casing wall. The interval between each geophone and each test depth was 3 feet for the entire depth of the cased borehole. An instrumented hammer was then used to strike a steel plate with cleats at the bottom (often called a shear wave golf shoe) that penetrated the ground and prevented sliding when struck. The steel plate was oriented to generate horizontal shear waves (SH) at the surface. An additional plate was also struck to better produce compression waves. The horizontal distance was measured and the plate was set exactly 10 feet from the borehole. The recorder was set to record the arrival times of the shear waves at the geophone locations. At least 15 blows (5 in each direction on the golf shoe, and 5 on the steel plate) were struck for each test depth to electronically stack and polarize the observed data, and to increase the signal-to-noise ratio. The data was stored on computer disks for processing and computation. The geophone was raised to the next depth interval and the process was repeated.

Shear Wave Velocity Test Results shows the downhole shear wave velocity and compressive wave velocity test results. The data was evaluated using the Fixed Interval method. S-wave arrival times using the Interval method were picked based on the onset of the signal (first break) as observed in the software package TomTime by GeoTom.

## SOIL DESCRIPTION TERMS

### Relative Density/Consistency Terms

<u>Relative Density</u> <sup>1</sup>			<u>Consistency</u> <sup>2</sup>		
Descriptive Term	Relative Density	SPT Blow Count	Descriptive Term	Unconfined Compression Strength (q <sub>u</sub> ) (tsf)	SPT Blow Count
Very Loose	0 to 15%	4 and less	Very Soft	0.25 and less	2 and less
Loose	16 to 35%	5 to 10	Soft	0.26 to 0.50	3 to 4
Medium Dense	36 to 65%	11 to 30	Firm	0.51 to 1.00	5 to 8
Dense	66 to 85%	31 to 50	Stiff	1.01 to 2.00	9 to 15
Very Dense	86 to 100%	51 and more	Very Stiff	2.01 to 4.00	16 to 30
			Hard	4.01 and more	31 and more

### Moisture Condition

<u>Descriptive Term</u>	<u>Criteria</u>
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually in coarse-grained soils below the water table

### Color

Describe the sample color while sample is still moist.

### Angularity<sup>1</sup>

<u>Descriptive Term</u>	<u>Criteria</u>
Angular	Particles have sharp edges and relatively plane sides with unpolished surfaces.
Subangular	Particles are similar to angular description but have rounded edges.
Subrounded	Particles have nearly plane sides but have well-rounded corners and edges.
Rounded	Particles have smoothly curved sides and no edges.

### HCl Reaction<sup>3</sup>

<u>Descriptive Term</u>	<u>Criteria</u>
None Reactive	No visible reaction
Weakly Reactive	Some reaction, with bubbles forming slowly
Strongly Reactive	Violent reaction, with bubbles forming immediately

### Cementation<sup>3</sup>

<u>Descriptive Term</u>	<u>Criteria</u>
Weakly Cemented	Crumbles or breaks with handling or little finger pressure
Cemented	Crumbles or breaks with considerable finger pressure
Strongly Cemented	Will not crumble or break with finger pressure

### Particle-Size Range<sup>1</sup>

<u>Gravel</u>	Diameter, mm	Sieve Size	<u>Sand</u>	Diameter, mm	Sieve Size
Fine	4.76 to 19.1	#4 to ¾ inch	Fine	0.074 to 0.42	#200 to #40
Coarse	19.1 to 76.2	¾ inch to 3 inch	Medium	0.42 to 2.00	#40 to #10
			Coarse	4.00 to 4.76	#10 to #4

### Primary Soil Type<sup>1, 2</sup>

The primary soil type will be shown in all capital letters.

### USCS Soil Designation

Indicate USCS soil designation as defined in ASTM D-2487 and D-2488

### AASHTO Soil Designation

Indicate AASHTO soil designation as defined in AASHTO M-145 and ASTM D-3282

<sup>1</sup>Applies to coarse-grained soils (major portion retained on No. 200 sieve)

<sup>2</sup>Applies to fine-grained soils (major portion passing No. 200 sieve)

<sup>3</sup>Use as required

## DESCRIPTION OF ROCK PROPERTIES

### WEATHERING

Fresh	Rock fresh, crystals bright, few joints may show slight staining. Rock rings under hammer if crystalline.
Very slight	Rock generally fresh, joints stained, some joints may show thin clay coatings, crystals in broken face show bright. Rock rings under hammer if crystalline.
Slight	Rock generally fresh, joints stained, and discoloration extends into rock up to 1 in. Joints may contain clay. In granitoid rocks some occasional feldspar crystals are dull and discolored. Crystalline rocks ring under hammer.
Moderate	Significant portions of rock show discoloration and weathering effects. In granitoid rocks, most feldspars are dull and discolored; some show clayey. Rock has dull sound under hammer and shows significant loss of strength as compared with fresh rock.
Moderately Severe	All rock except quartz discolored or stained. In granitoid rocks, all feldspars dull and discolored and majority show kaolinization. Rock shows severe loss of strength and can be excavated with geologist's pick.
Severe	All rock except quartz discolored or stained. Rock "fabric" clear and evident, but reduced in strength to strong soil. In granitoid rocks, all feldspars kaolinized to some extent. Some fragments of strong rock usually left.
Very severe	All rock except quartz discolored or stained. Rock "fabric" discernible, but mass effectively reduced to "soil" with only fragments of strong rock remaining.
Complete	Rock reduced to "soil". Rock "fabric" not discernible or discernible only in small, scattered locations. Quartz may be present as dikes or stringers.

### HARDNESS (for engineering description of rock – not to be confused with Moh's scale for minerals)

Very hard	Cannot be scratched with knife or sharp pick. Breaking of hand specimens requires several hard blows of geologist's pick.
Hard	Can be scratched with knife or pick only with difficulty. Hard blow of hammer required to detach hand specimen.
Moderately hard	Can be scratched with knife or pick. Gouges or grooves to ¼ in. deep can be excavated by hard blow of point of a geologist's pick. Hand specimens can be detached by moderate blow.
Medium	Can be grooved or gouged 1/16 in. deep by firm pressure on knife or pick point. Can be excavated in small chips to pieces about 1-in. maximum size by hard blows of the point of a geologist's pick.
Soft	Can be gouged or grooved readily with knife or pick point. Can be excavated in chips to pieces several inches in size by moderate blows of a pick point. Small thin pieces can be broken by finger pressure.
Very soft	Can be carved with knife. Can be excavated readily with point of pick. Pieces 1-in. or more in thickness can be broken with finger pressure. Can be scratched readily by fingernail.

### Joint, Bedding, and Foliation Spacing in Rock<sup>a</sup>

Spacing	Joints	Bedding/Foliation
Less than 2 in.	Very close	Very thin
2 in. – 1 ft.	Close	Thin
1 ft. – 3 ft.	Moderately close	Medium
3 ft. – 10 ft.	Wide	Thick
More than 10 ft.	Very wide	Very thick

<sup>a</sup>Spacing refers to the distance normal to the planes, of the described feature, which are parallel to each other or nearly so.

### Rock Quality Designation (RQD)<sup>a</sup>

RQD, as a percentage	Diagnostic Description
Exceeding 90	Excellent
90 – 75	Good
75 – 50	Fair
50 – 25	Poor
Less than 25	Very poor

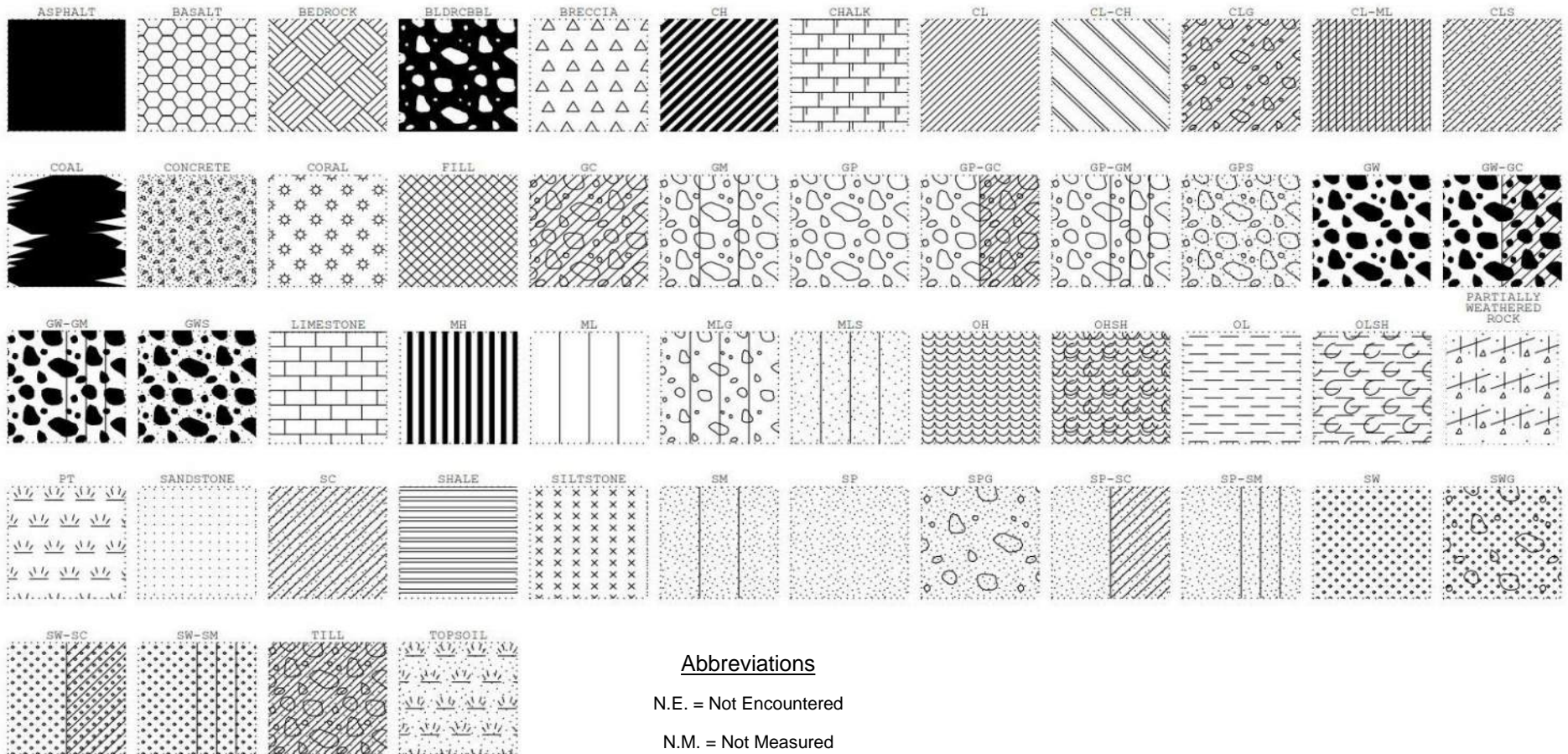
<sup>a</sup>RQD (given as a percentage) = length of core in pieces 4 in. and longer/length of run.

### Joint Openness Descriptors

Openness	Descriptor
No Visible Separation	Tight
Less than 1/32 in.	Slightly open
1/32 to 3/8 in.	Moderately open
1/8 to 3/8 in.	Open
3/8 in. to 0.1 ft.	Moderately wide
Greater than 0.1 ft.	Wide

References: American Society of Civil Engineers. Manuals and Reports on Engineering Practice - No. 56. Subsurface Investigation for Design and Construction of Foundations of Buildings. New York: American Society of Civil Engineers, 1976. U.S. Department of the Interior, Bureau of Reclamation, Engineering Geology Field Manual.





Project Manager:	MEM
Drawn by:	KJZ
Checked by:	SG
Approved by:	DJC

Project No.	8623P180
Scale:	N.T.S.
File Name:	Soil – Rock – Log
Date:	Jul 2023



72 Pointe Circle  
PH. (864) 292-2901  
Greenville, SC 29615  
FAX. (864) 292-6361

## SOIL AND ROCK SYMBOLS

Exhibit A-8

# SCDOT Soil Test Log

<b>Project ID:</b>	P041161				<b>County:</b>	Greenville		<b>Boring No.:</b>	S-23-102-1		
<b>Site Description:</b>		S-23-102 BRO Armstrong Creek						<b>Route:</b>	S-23-102		
<b>Eng./Geo.:</b>	S. Greaber		<b>Boring Location:</b>	788+98		<b>Offset:</b>	15 R		<b>Alignment:</b>	Proposed	
<b>Elev.:</b>	916.6 ft		<b>Latitude:</b>	34.9420005		<b>Longitude:</b>	-82.4926575		<b>Date Started:</b>	6/3/2024	
<b>Total Depth:</b>	64 ft		<b>Soil Depth:</b>	49 ft		<b>Core Depth:</b>	15 ft		<b>Date Completed:</b>	6/3/2024	
<b>Bore Hole Diameter (in):</b>			4		<b>Sampler Configuration</b>		<b>Liner Required:</b>	Y (N)		<b>Liner Used:</b>	Y (N)
<b>Drill Machine:</b>		DR#554		<b>Drill Method:</b>	RW/RC		<b>Hammer Type:</b>	Automatic		<b>Energy Ratio:</b>	88.5%
<b>Core Size:</b>		NQ2		<b>Driller:</b>	B. Burnette		<b>Groundwater:</b>	TOB	N.M.		<b>24HR</b> N.M.

Elevation (ft)	Depth (ft)	MATERIAL DESCRIPTION	Graphic Log	Sample Depth (ft)	Sample No./Type	1st 6"	2nd 6"	3rd 6"	4th 6"	N Value	<div> ● SPT N VALUE ●  PL X MC X LL X  ▲ FINES CONTENT (%)  + RQD (%) ■ REC (%) </div>
	0.0	Existing Roadway									
	0.6	Asphalt (6.75 inches)									
	0.9	Aggregate Base Course (4 inches)									
	4.0	FILL - Medium dense, dry, reddish brown, subangular, non-reactive, weakly cemented, fine to coarse, Silty SAND (SM) (A-2-4) 5 YR 5/3		2.0							
		NMC=12		4.0	SS-1	8	10	5	5	15	
911.6	6.0	very loose, moist, yellowish red, subangular, non-reactive, weakly cemented, fine to coarse, Silty SAND (SM) (A-2-4) 5YR 5/6		6.0	SS-2	1	2	2	3	4	
		LL=PL=PI=0, NMC=18, %200=23		8.0	SS-3	1	WOH	1	WOH	1	
		ALLUVIUM - No recovery			SS-4	WOH/12"	1	3	1		
906.6	12.0	Very loose, moist, dark reddish gray, subangular, non-reactive, weakly cemented, fine to coarse, silty SAND with gravel (SM) (A-1-b) 5YR 4/2		13.5	SS-5	12	7	1		8	
		LL=PL=PI=0, NMC=26, %200=18									
901.6		Loose, dry, yellowish red, subrounded, non-reactive, weakly cemented, fine to coarse, Poorly graded GRAVEL with silt and sand (GP-GM) (A-1-a) 5YR 4/6 with creek bed rocks		18.5	SS-6	2	1	3		4	
		NMC=11, %200=6									
896.6	22.0	No recovery		23.5	SS-7	4	4	4		8	
		RESIDUUM - Loose, moist, yellowish red, subangular, non-reactive, weakly cemented, fine to medium, Silty SAND (SM) (A-2-4) 5YR 5/8									
891.6	27.0	LL=PL=PI=0, NMC=28, %200=22		28.5	SS-8	16	27	34		61	
		Very dense, moist, reddish gray, subangular, non-reactive, weakly cemented, fine to medium, Silty SAND (SM) (A-2-4) 5YR 5/2 trace mica									
886.6		NMC=19									

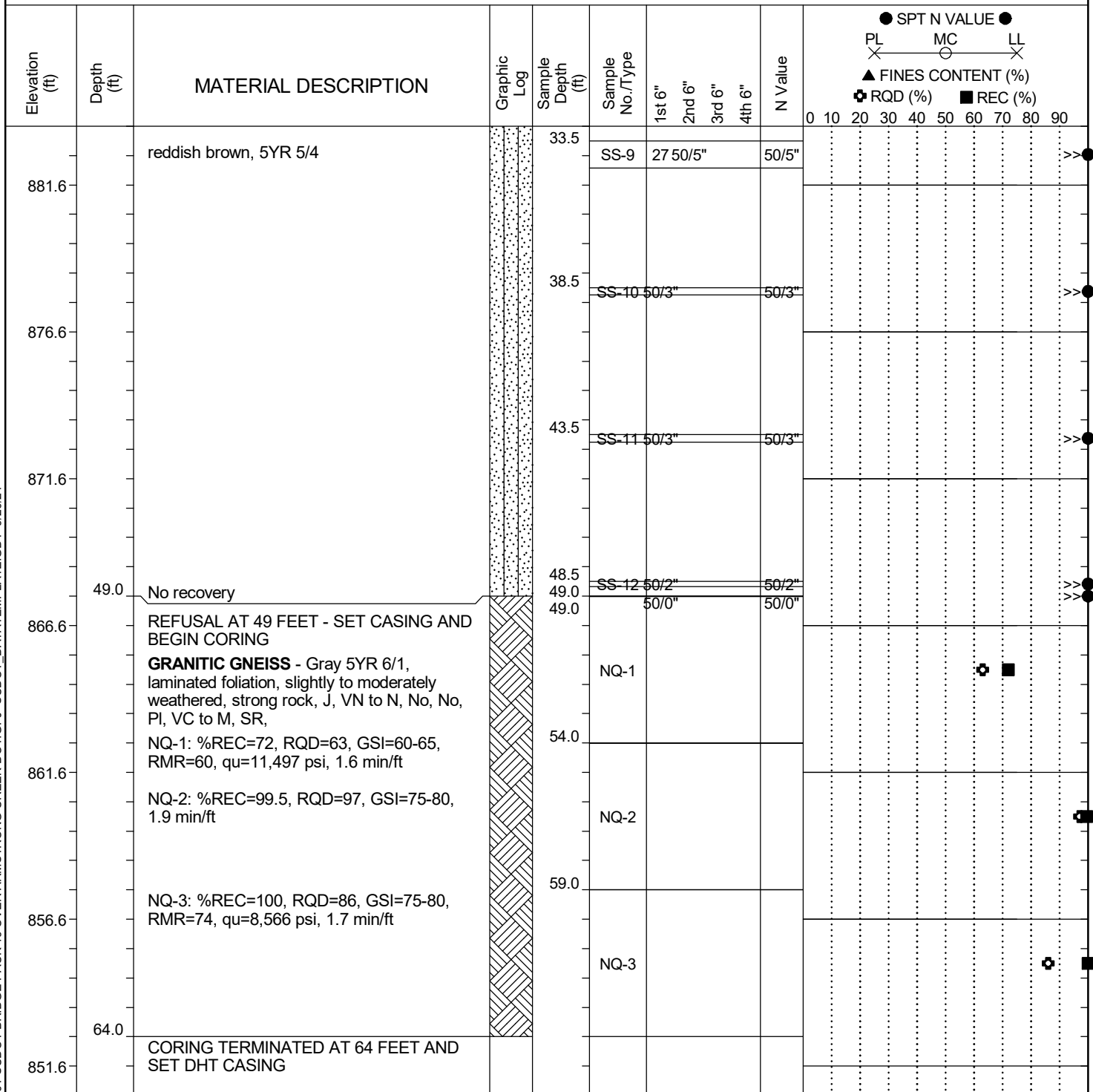
## LEGEND

Continued Next Page

SAMPLER TYPE		DRILLING METHOD	
SS - Split Spoon	NQ - Rock Core, 1-7/8"	HSA - Hollow Stem Auger	RW - Rotary Wash
UD - Undisturbed Sample	CU - Cuttings	CFA - Continuous Flight Augers	RC - Rock Core
AWG - Rock Core, 1-1/8"	CT - Continuous Tube	DC - Driving Casing	

# SCDOT Soil Test Log

<b>Project ID:</b>	P041161	<b>County:</b>	Greenville	<b>Boring No.:</b>	S-23-102-1
<b>Site Description:</b>	S-23-102 BRO Armstrong Creek			<b>Route:</b>	S-23-102
<b>Eng./Geo.:</b>	S. Greaber	<b>Boring Location:</b>	788+98	<b>Offset:</b>	15 R
<b>Elev.:</b>	916.6 ft	<b>Latitude:</b>	34.9420005	<b>Longitude:</b>	-82.4926575
<b>Date Started:</b>	6/3/2024				
<b>Total Depth:</b>	64 ft	<b>Soil Depth:</b>	49 ft	<b>Core Depth:</b>	15 ft
<b>Date Completed:</b>	6/3/2024				
<b>Bore Hole Diameter (in):</b>	4	<b>Sampler Configuration</b>		<b>Liner Required:</b>	Y (N)
<b>Liner Used:</b>	Y (N)				
<b>Drill Machine:</b>	DR#554	<b>Drill Method:</b>	RW/RC	<b>Hammer Type:</b>	Automatic
<b>Energy Ratio:</b>	88.5%				
<b>Core Size:</b>	NQ2	<b>Driller:</b>	B. Burnette	<b>Groundwater:</b>	TOB N.M.
<b>24HR:</b>	N.M.				



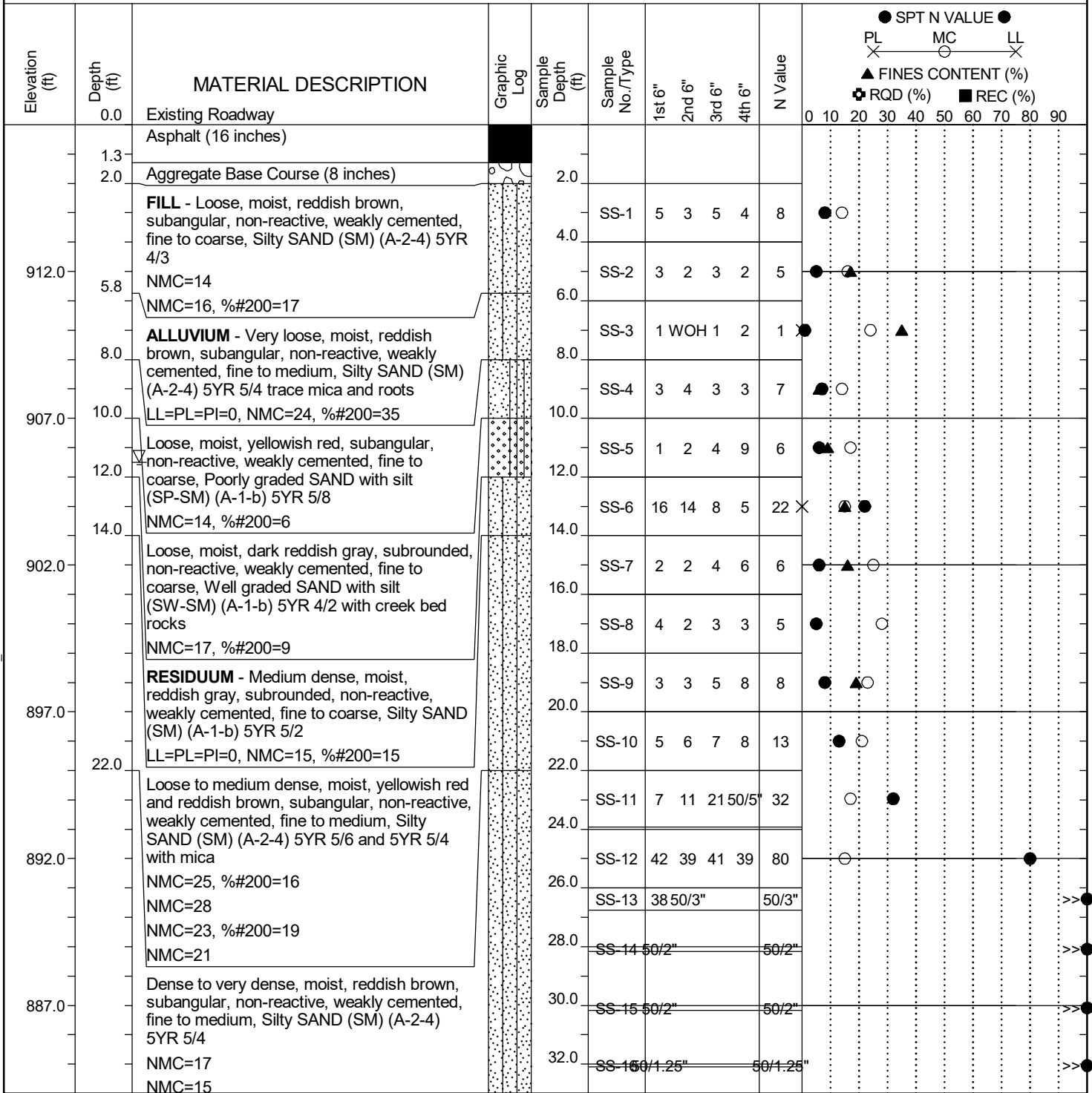
## LEGEND

SAMPLER TYPE		DRILLING METHOD	
SS	- Split Spoon	HSA	- Hollow Stem Auger
UD	- Undisturbed Sample	CFA	- Continuous Flight Augers
AWG	- Rock Core, 1-1/8"	DC	- Driving Casing
NQ	- Rock Core, 1-7/8"	RW	- Rotary Wash
CU	- Cuttings	RC	- Rock Core
CT	- Continuous Tube		



# SCDOT Soil Test Log

<b>Project ID:</b>	P041161	<b>County:</b>	Greenville	<b>Boring No.:</b>	S-23-102-2
<b>Site Description:</b>	S-23-102 BRO Armstrong Creek			<b>Route:</b>	S-23-102
<b>Eng./Geo.:</b>	S. Greaber	<b>Boring Location:</b>	788+28	<b>Offset:</b>	15 R
<b>Elev.:</b>	917.0 ft	<b>Latitude:</b>	34.9418411	<b>Longitude:</b>	-82.4925268
<b>Date Started:</b>	6/4/2024				
<b>Total Depth:</b>	43.5 ft	<b>Soil Depth:</b>	33.5 ft	<b>Core Depth:</b>	10 ft
<b>Date Completed:</b>	6/4/2024				
<b>Bore Hole Diameter (in):</b>	4	<b>Sampler Configuration</b>	<b>Liner Required:</b> Y (N)		<b>Liner Used:</b> Y (N)
<b>Drill Machine:</b>	DR#554	<b>Drill Method:</b>	RW/RC	<b>Hammer Type:</b>	Automatic
<b>Energy Ratio:</b>	88.5%				
<b>Core Size:</b>	NQ2	<b>Driller:</b>	B. Burnette	<b>Groundwater:</b>	TOB 11.5 ft
<b>24HR</b>	N.M.				



## LEGEND

Continued Next Page

SAMPLER TYPE		DRILLING METHOD	
SS - Split Spoon	NQ - Rock Core, 1-7/8"	HSA - Hollow Stem Auger	RW - Rotary Wash
UD - Undisturbed Sample	CU - Cuttings	CFA - Continuous Flight Augers	RC - Rock Core
AWG - Rock Core, 1-1/8"	CT - Continuous Tube	DC - Driving Casing	

# SCDOT Soil Test Log

<b>Project ID:</b>	P041161	<b>County:</b>	Greenville	<b>Boring No.:</b>	S-23-102-2
<b>Site Description:</b>	S-23-102 BRO Armstrong Creek			<b>Route:</b>	S-23-102
<b>Eng./Geo.:</b>	S. Greaber	<b>Boring Location:</b>	788+28	<b>Offset:</b>	15 R
<b>Elev.:</b>	917.0 ft	<b>Latitude:</b>	34.9418411	<b>Longitude:</b>	-82.4925268
<b>Date Started:</b>	6/4/2024				
<b>Total Depth:</b>	43.5 ft	<b>Soil Depth:</b>	33.5 ft	<b>Core Depth:</b>	10 ft
<b>Date Completed:</b>	6/4/2024				
<b>Bore Hole Diameter (in):</b>	4	<b>Sampler Configuration</b>	<b>Liner Required:</b> Y (N)		<b>Liner Used:</b> Y (N)
<b>Drill Machine:</b>	DR#554	<b>Drill Method:</b>	RW/RC	<b>Hammer Type:</b>	Automatic
<b>Energy Ratio:</b>	88.5%				
<b>Core Size:</b>	NQ2	<b>Driller:</b>	B. Burnette	<b>Groundwater:</b>	TOB 11.5 ft
<b>24HR</b>	N.M.				

Elevation (ft)	Depth (ft)	MATERIAL DESCRIPTION	Graphic Log	Sample Depth (ft)	Sample No./Type	1st 6"	2nd 6"	3rd 6"	4th 6"	N Value	<div> ● SPT N VALUE ●  PL X MC LL  ▲ FINES CONTENT (%)  ⊕ RQD (%) ■ REC (%) </div>
882.0	33.5	No recovery		33.5		50/0"				50/0"	>>●
		REFUSAL AT 33.5 FEET - SET CASING AND BEGIN CORING		33.5							
		<b>GRANITIC GNEISS</b> - Gray 5YR 6/1, laminated foliation, slightly weathered, strong rock, J, VN to N, No, No, Pl, C to M, SR			NQ-1						■
		NQ-1: %REC=100, RQD=100, GSI=90, RMR=77, qu=12,281 psi, 2.1 min/ft		38.5							
		NQ-2: %REC=93, RQD=93, GSI=85-90, RMR=77, qu=13,547 psi, 3.4 min/ft			NQ-2						■
	43.5	CORING TERMINATED AT 43.5 FEET									
872.0											
867.0											
862.0											
857.0											
852.0											

## LEGEND

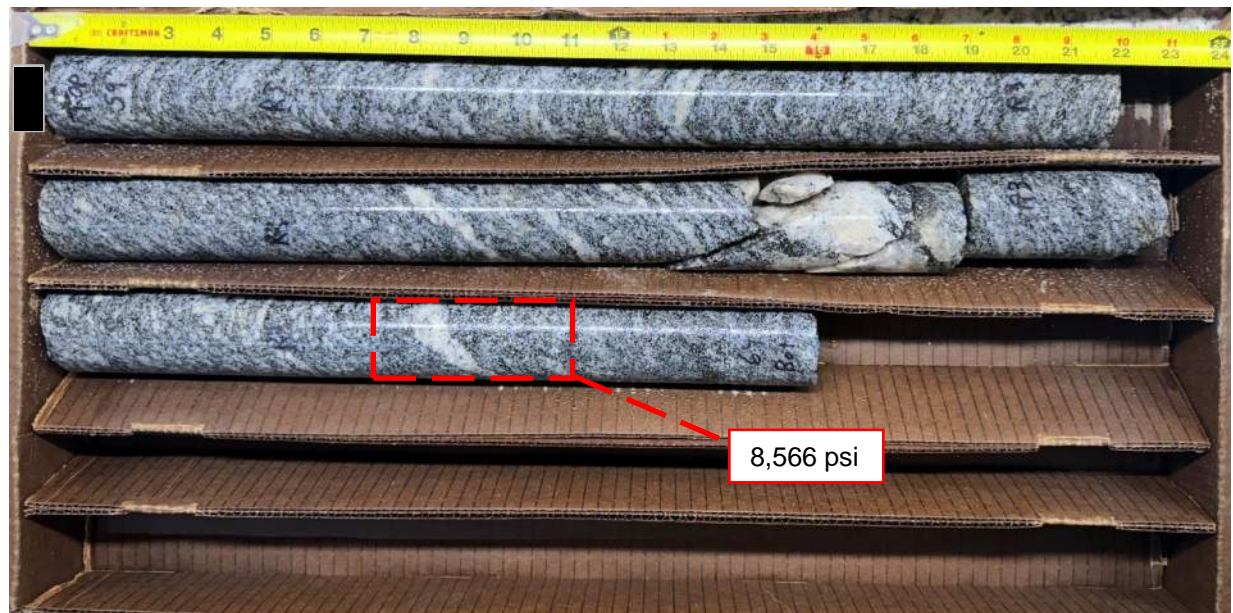
SAMPLER TYPE		DRILLING METHOD	
SS - Split Spoon	NQ - Rock Core, 1-7/8"	HSA - Hollow Stem Auger	RW - Rotary Wash
UD - Undisturbed Sample	CU - Cuttings	CFA - Continuous Flight Augers	RC - Rock Core
AWG - Rock Core, 1-1/8"	CT - Continuous Tube	DC - Driving Casing	

**Rock Core Photograph Logs – Exhibit A-10**

S-23-102 BRO over Armstrong Creek | Greenville County, SC  
Terracon Project No. 8623P180 | SCDOT Project ID: P041161



S-23-102-1, NQ-1 and NQ-2 (49 to 59 feet)

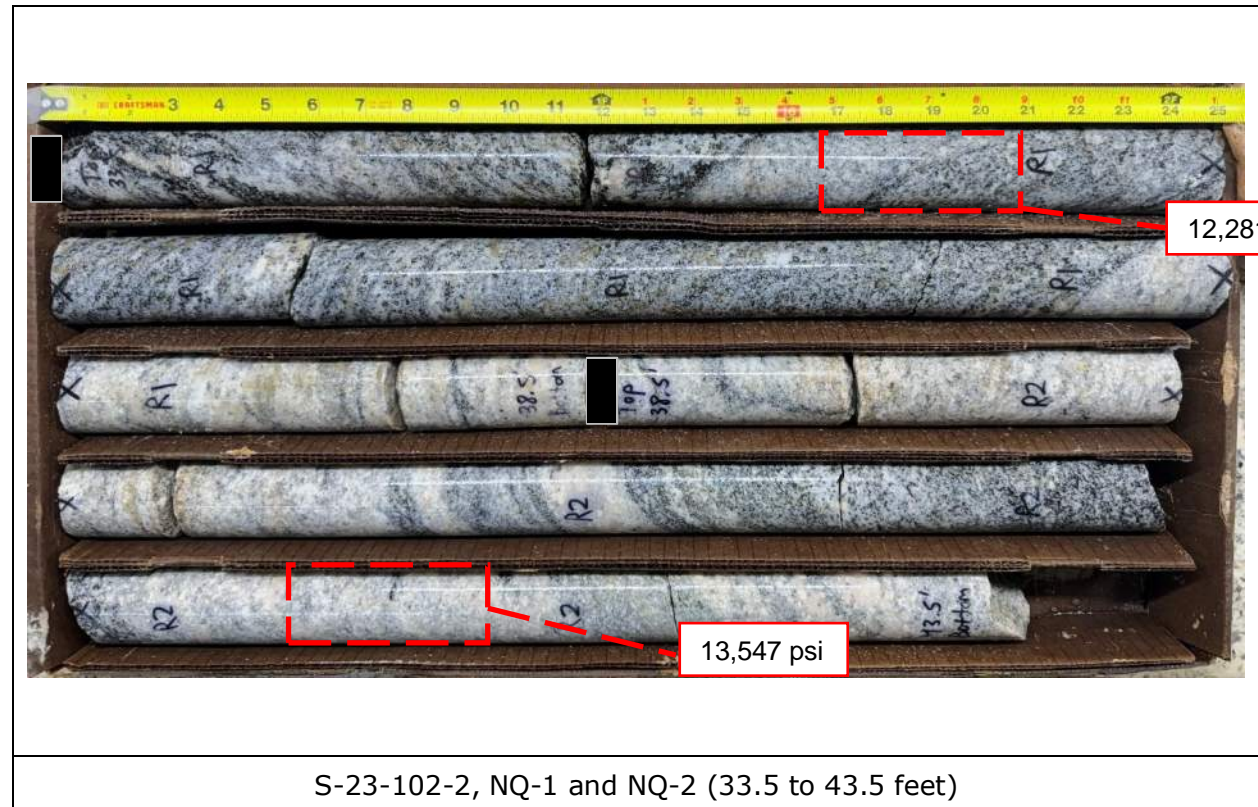


S-23-102-1, NQ-3 (59 to 64 feet)

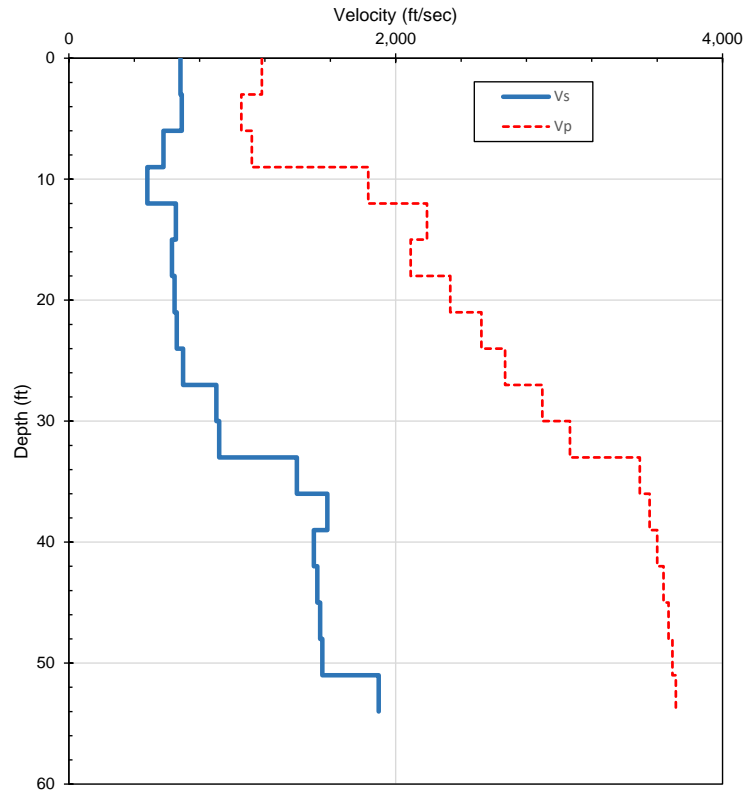


**Rock Core Photograph Logs – Exhibit A-10**

S-23-102 BRO over Armstrong Creek | Greenville County, SC  
Terracon Project No. 8623P180 | SCDOT Project ID: P041161




# Downhole Seismic Velocity Fixed Interval Method



Depth (ft)	Vp (ft/sec)	Vs (ft/sec)	Δi (ft)	Δt (sec)	Est. In-Situ Unit Wt (pcf)
3	1181	683	3	0.00439	125
6	1055	691	3	0.00434	100
9	1119	579	3	0.00518	
12	1831	480	3	0.00625	
15	2191	655	3	0.00458	
18	2092	630	3	0.00476	
21	2335	647	3	0.00464	
24	2525	660	3	0.00454	130
27	2670	698	3	0.00430	
30	2897	902	3	0.00333	
33	3067	919	3	0.00326	
36	3493	1395	3	0.00215	
39	3553	1582	3	0.00190	
42	3601	1499	3	0.00200	169
45	3639	1520	3	0.00197	
48	3669	1537	3	0.00195	
51	3694	1551	3	0.00193	
54	3714	1896	3	0.00158	
100  1800  46  0.02556  Unit Weight of Soil estimated from SPT results Unit Weight of Rock based on average results from compression tests					
Sum of Data Over Profile			54	0.06305	
Weighted Average Shear Wave Velocity Over Profile			856 ft/sec		
Est. Weighted Average Shear Wave Velocity Over 100-Ft <sup>1</sup>			1,129 ft/sec		

1. Assuming shear wave of 1800 f/s for rock below 54 feet.

Project Mgr: MM	Project No. 8623P180	<div> Consulting Engineers and Scientists</div> <div>72 Pointe Circle Greenville, South Carolina Ph: (864) 292-2901 Fax: (864) 292-6361</div>	GEOPHYSICAL TESTING RESULTS DOWNHOLE SEISMIC TEST		TEST NO. S-23-102-1
Prepared by: MM	Scale: NA		S-23-102 (Keeler Mill Road) Bridge Replacement over Armstrong Creek GREENVILLE COUNTY, SOUTH CAROLINA		
Checked by: SG	Date: 9/12/2024		P041161		EXHIBIT A-11
Approved by:					

CPT Sounding ID S-23-102-1C

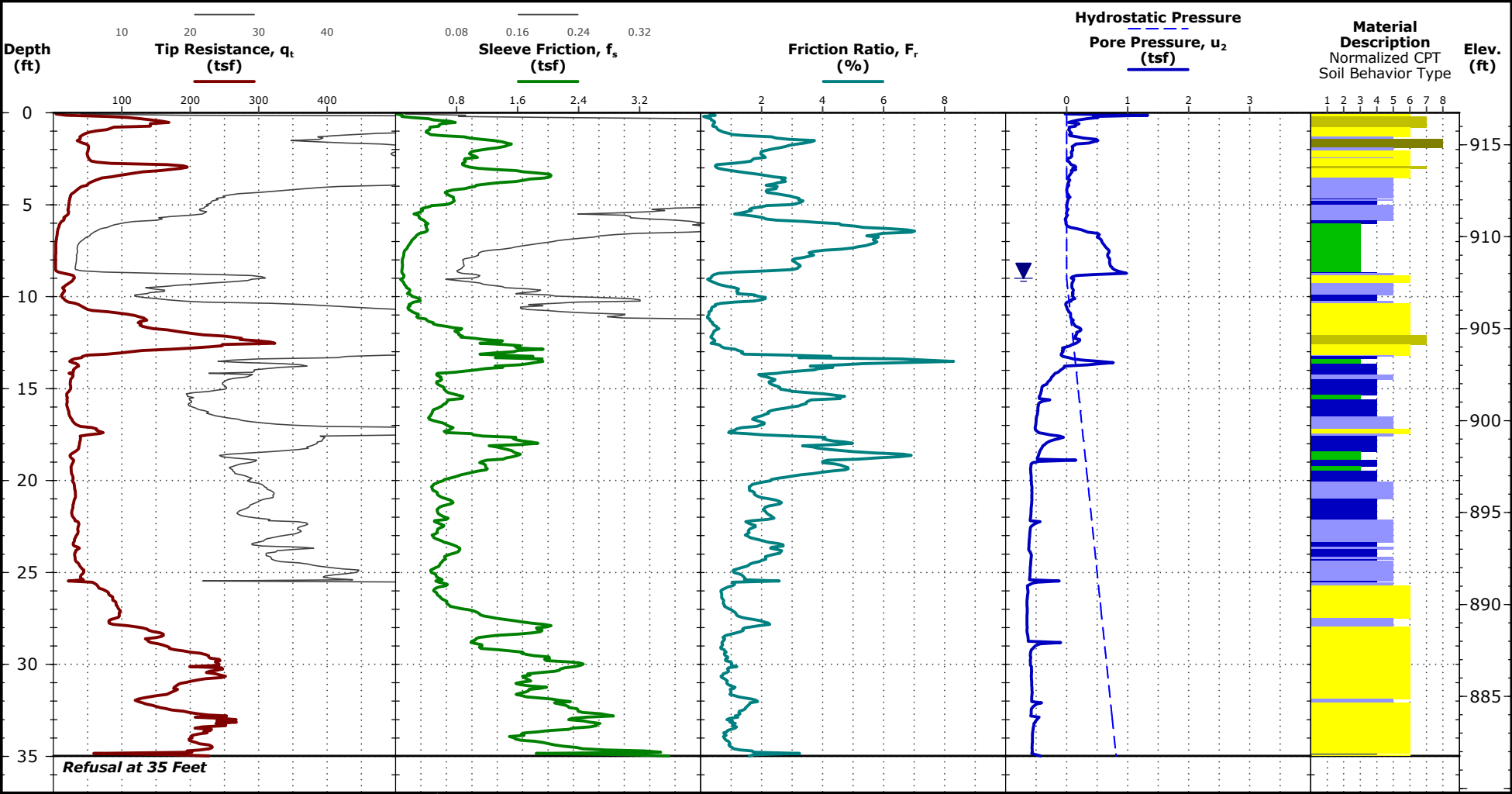


72 Pointe Cir  
Greenville, SC

Elevation: 916.74 (ft)  
Elevation Reference: Elevations were provided by others.

Latitude: 34.942012° Longitude: -82.492669°  
Station: 789+03 Offset: 15 R

CPT Started: 8/20/2024  
CPT Completed: 8/20/2024



See [Exploration and Testing Procedures](#) for a description of field and laboratory procedures used and additional data, if any.  
See [Supporting Information](#) for explanation of symbols and abbreviations.

**Notes**  
Test Location: See [Exploration Plan](#)

**CPT Equipment**  
CPT Rig: CR#CPT03  
Operator: AM/BR  
CPT sensor calibration reports available upon request  
Probe No. 6025 with net area ratio of .84  
Manufactured by Geoprobe Systems- Calibrated 4/17/2024  
Tip and sleeve areas of 10 cm<sup>2</sup> and 150 cm<sup>2</sup>

**Water Level Observation**  
▼ 9 ft estimated water depth  
(used in normalizations and correlations)

**Normalized Soil Behavior Type (Robertson 1990)**

- 1 Sensitive, fine grained
- 2 Organic soils - clay
- 3 Clay - silty clay to clay
- 4 Silt mixtures - clayey silt to silty clay
- 5 Sand mixtures - silty sand to sandy silt
- 6 Sands - clean sand to silty sand
- 7 Gravelly sand to dense sand
- 8 Very stiff sand to clayey sand
- 9 Very stiff fine grained

CPT Sounding ID S-23-102-2C

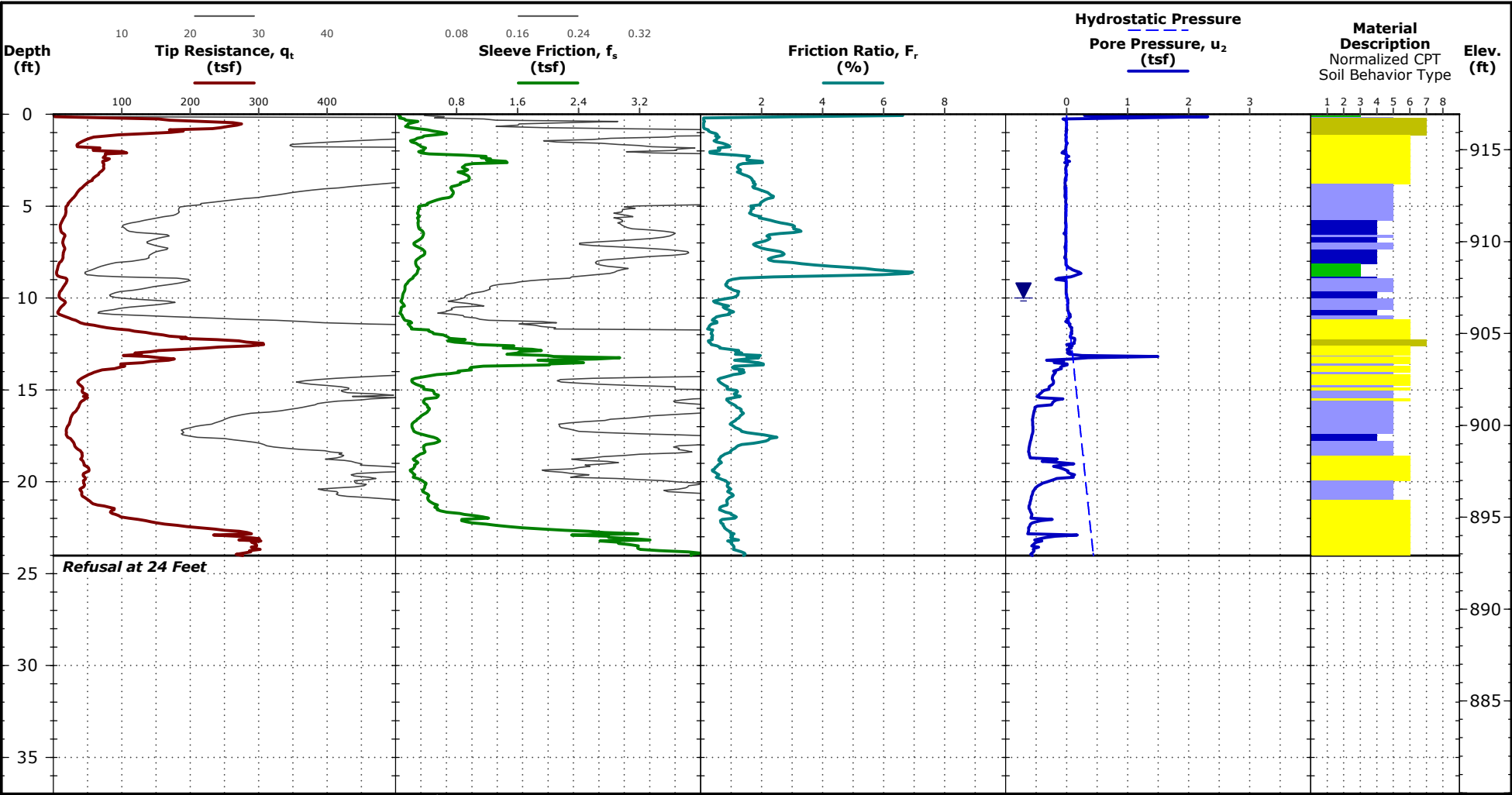


72 Pointe Cir  
Greenville, SC

Elevation: 916.93 (ft)  
Elevation Reference: Elevations were provided by others.

Latitude: 34.941832° Longitude: -82.492518°  
Station: 788+24 Offset: 15 R

CPT Started: 8/20/2024  
CPT Completed: 8/20/2024



See [Exploration and Testing Procedures](#) for a description of field and laboratory procedures used and additional data, if any.  
See [Supporting Information](#) for explanation of symbols and abbreviations.

Notes

Test Location: See [Exploration Plan](#)

CPT Equipment

CPT Rig: CR#CPT03  
Operator: AM/BR  
CPT sensor calibration reports available upon request  
Probe No. 6025 with net area ratio of .84  
Manufactured by Geoprobe Systems- Calibrated 4/17/2024  
Tip and sleeve areas of 10 cm<sup>2</sup> and 150 cm<sup>2</sup>

Water Level Observation

▼ 10 ft estimated water depth  
(used in normalizations and correlations)

Normalized Soil Behavior Type (Robertson 1990)

- 1 Sensitive, fine grained
- 2 Organic soils - clay
- 3 Clay - silty clay to clay
- 4 Silt mixtures - clayey silt to silty clay
- 5 Sand mixtures - silty sand to sandy silt
- 6 Sands - clean sand to silty sand
- 7 Gravelly sand to dense sand
- 8 Very stiff sand to clayey sand
- 9 Very stiff fine grained

## **Appendix B – Laboratory Testing**

S-23-102 Bridge Replacement over Armstrong Creek | Greenville County, SC  
Terracon Project No. 8623P180 | SCDOT Project ID: P041161



# **Appendix B**

## **Laboratory Testing**

Exhibit B-1 – Laboratory Testing Description  
Summary of Laboratory Data  
Laboratory Data Sheets (20 Pages)

Note: All exhibits are one page unless noted above.



## Exhibit B-1 – Laboratory Testing Description

S-23-102 Bridge Replacement over Armstrong Creek | Greenville County, SC  
Terracon Project No. 8623P180 | SCDOT Project ID: P041161



### Laboratory Testing Description

The samples collected during the field exploration were taken to our laboratory for additional testing. The laboratory testing scope was developed by the SCDOT and laboratory assignment was performed by Terracon. The laboratory tests were conducted on selected soil samples from the borings and the bulk sample locations. The test results are presented in this appendix.

The laboratory test results were used to confirm the soil descriptions presented on the boring logs in Appendix A. Laboratory tests were performed in general accordance with the applicable ASTM, AASHTO, SCDOT or other accepted standards.

Selected soil samples obtained from the site were tested for the following engineering properties:

■ Rock Compressive Strength	ASTM D7012
■ Moisture Content	AASHTO T265/(ASTM D2216)
■ Atterberg Limits	AASHTO T89/T90(ASTM D4318)
■ Wash 200	AASHTO T11/(ASTM D1140)
■ Proctor (Standard effort)	AASHTO T99/ (ASTM D698)
■ Triaxial Shear CU w/ PP	AASHTO T297/(ASTM D4767)
■ Grain Size Distribution	ASTM D6913
■ Hydrometer	ASTM D7928
■ Corrosion Series	AASHTO D422
	AASHTO T289/ASTM G51
	AASHTO T290/ASTM C1580
	AASHTO T291

Summary of Laboratory Results

Boring ID	Depth (Ft.)	Soil Classification USCS & AASHTO	Liquid Limit	Plastic Limit	Plasticity Index	% Gravel	% Sand	% Fines	% Silt	% Clay	Water Content (%)	Proctor Dry Density (pcf)/Opt. Moisture (%)
S-23-102-1	2-4	SILTY SAND(SM) / A-2-4									11.8	
S-23-102-1	4-6	SILTY SAND(SM) / A-2-4 (0)	NP	NP	NP	8.1	68.7	23.1			18.2	
S-23-102-1	8-10	SILTY SAND WITH GRAVEL(SM) / A-1-B (0)	NP	NP	NP	15.9	66.5	17.6	9.3	8.4	25.7	
S-23-102-1	13.5-15	POORLY GRADED GRAVEL W/ SILT & SAND / A-1-A				49.1	45.1	5.8	3.3	2.5	10.8	
S-23-102-1	23.5-25	SILTY SAND(SM) / A-2-4 (0)	NP	NP	NP	0.3	77.3	22.4			28.1	
S-23-102-1	28.5-30	SILTY SAND(SM) / A-2-4									19.3	
S-23-102-2	2-4	SILTY SAND(SM) / A-2-4									13.7	
S-23-102-2	4-6	SILTY SAND / A-2-4				1.5	81.3	17.2			16.3	
S-23-102-2	6-8	SILTY SAND(SM) / A-2-4 (0)	NP	NP	NP	0.0	64.8	35.2	16.5	18.8	23.8	
S-23-102-2	8-10	POORLY GRADED SAND W/ SILT / A-1-B				1.5	92.3	6.2			13.6	
S-23-102-2	10-12	WELL GRADED SAND W/ SILT / A-1-B				14.2	76.8	9.0	5.1	3.8	17.0	
S-23-102-2	12-14	SILTY SAND(SM) / A-1-B (0)	NP	NP	NP	14.1	71.0	14.9			15.4	
S-23-102-2	14-16	SILTY SAND / A-2-4				0.9	83.2	15.9			25.2	
S-23-102-2	16-18	SILTY SAND / A-2-4									27.7	
S-23-102-2	18-20	SILTY SAND / A-2-4				1.6	79.0	19.4			22.6	
S-23-102-2	20-22	SILTY SAND / A-2-4									21.1	
S-23-102-2	22-23.92	SILTY SAND / A-2-4									17.2	
S-23-102-2	24-26	SILTY SAND / A-2-4									14.5	
S-23-102-2 Offsite	0-5	CLAYEY SAND(SC) / A-2-4 (0)	33	23	10	2.2	68.4	29.4				111.7 / 14.9



# INDEX PROPERTIES VERSUS DEPTH

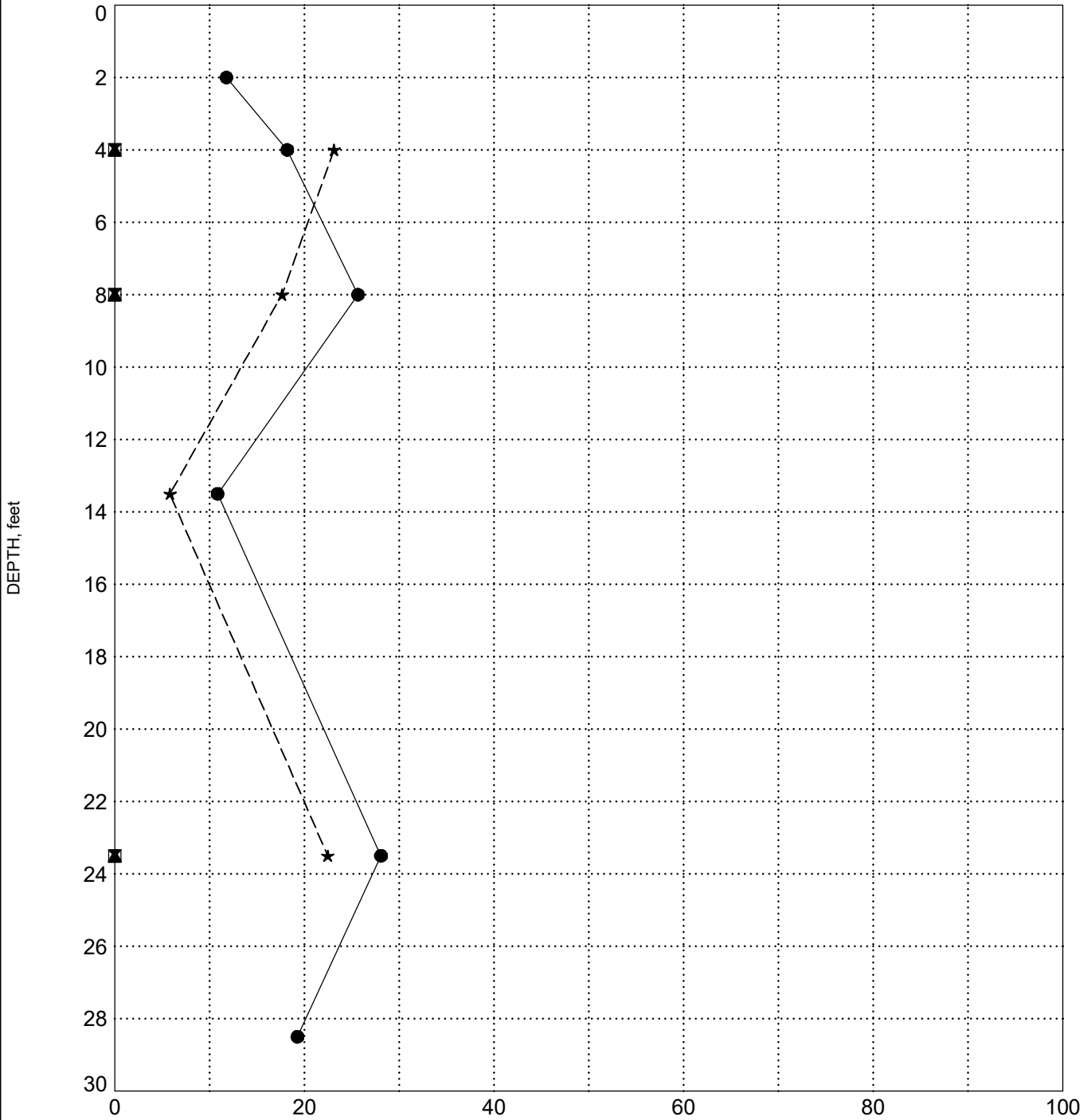
PROJECT ID P041161

PROJECT NAME S-23-102 BRO Armstrong Creek

PROJECT COUNTY Greenville

SURFACE ELEVATION: 916.6

## BORING S-23-102-1



LEGEND	
●	Water Content
■	Plastic Limit
▲	Liquid Limit
★	Fines



# INDEX PROPERTIES VERSUS DEPTH

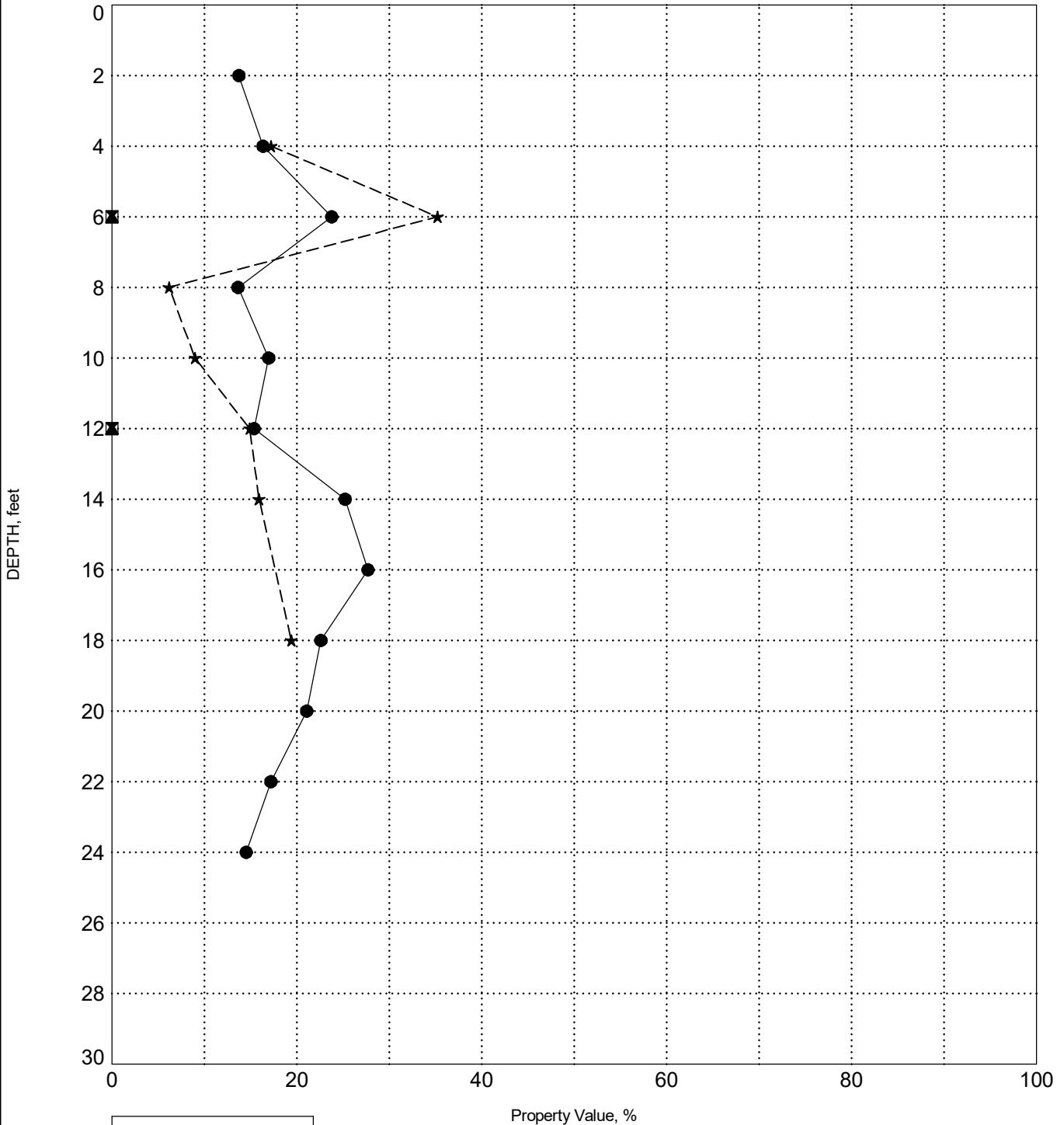
PROJECT ID P041161

PROJECT NAME S-23-102 BRO Armstrong Creek

PROJECT COUNTY Greenville

SURFACE ELEVATION: 917.0

## BORING S-23-102-2



LEGEND	
●	Water Content
■	Plastic Limit
▲	Liquid Limit
★	Fines



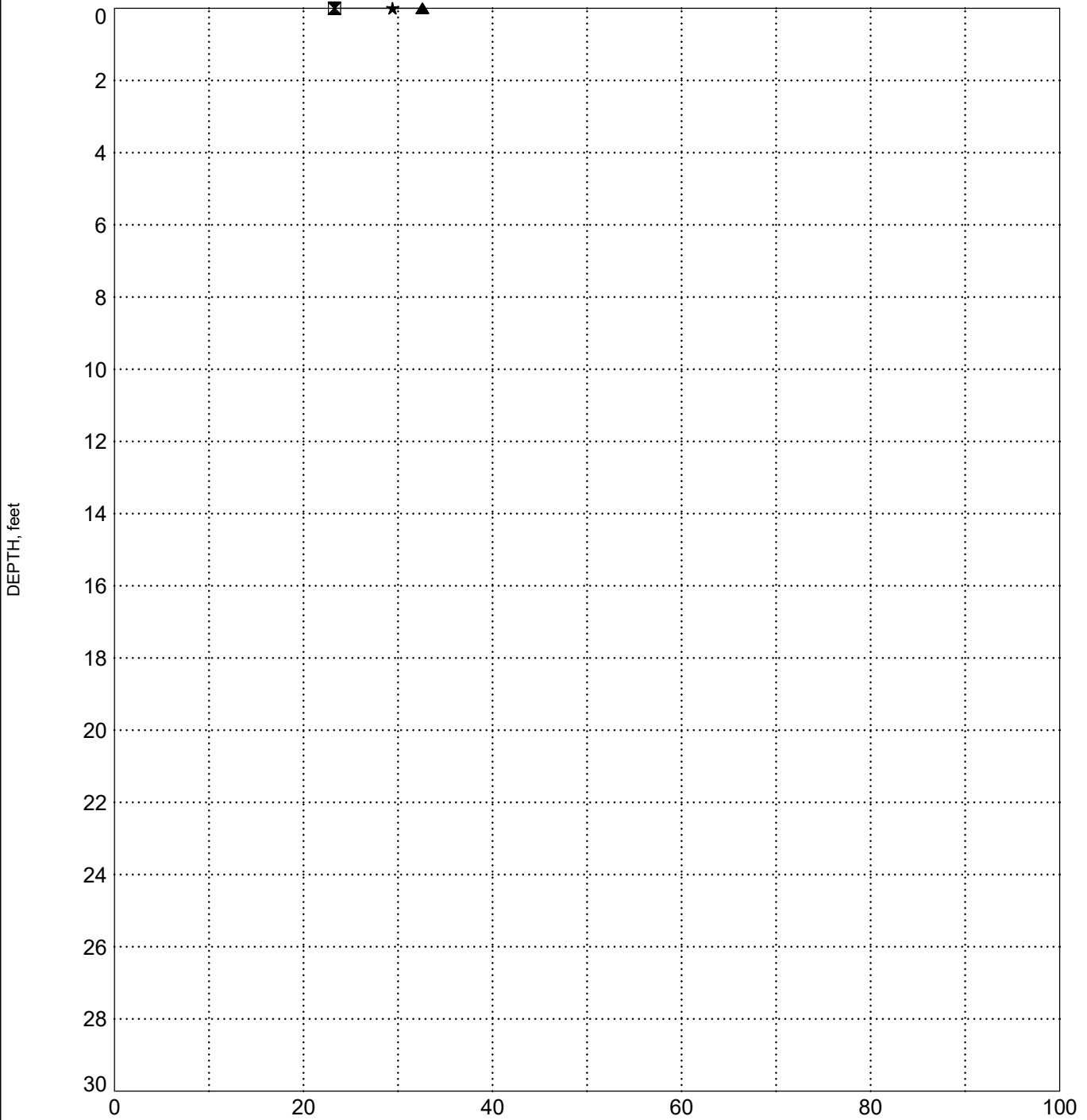
# INDEX PROPERTIES VERSUS DEPTH

PROJECT ID P041161

PROJECT NAME S-23-102 BRO Armstrong Creek

PROJECT COUNTY Greenville

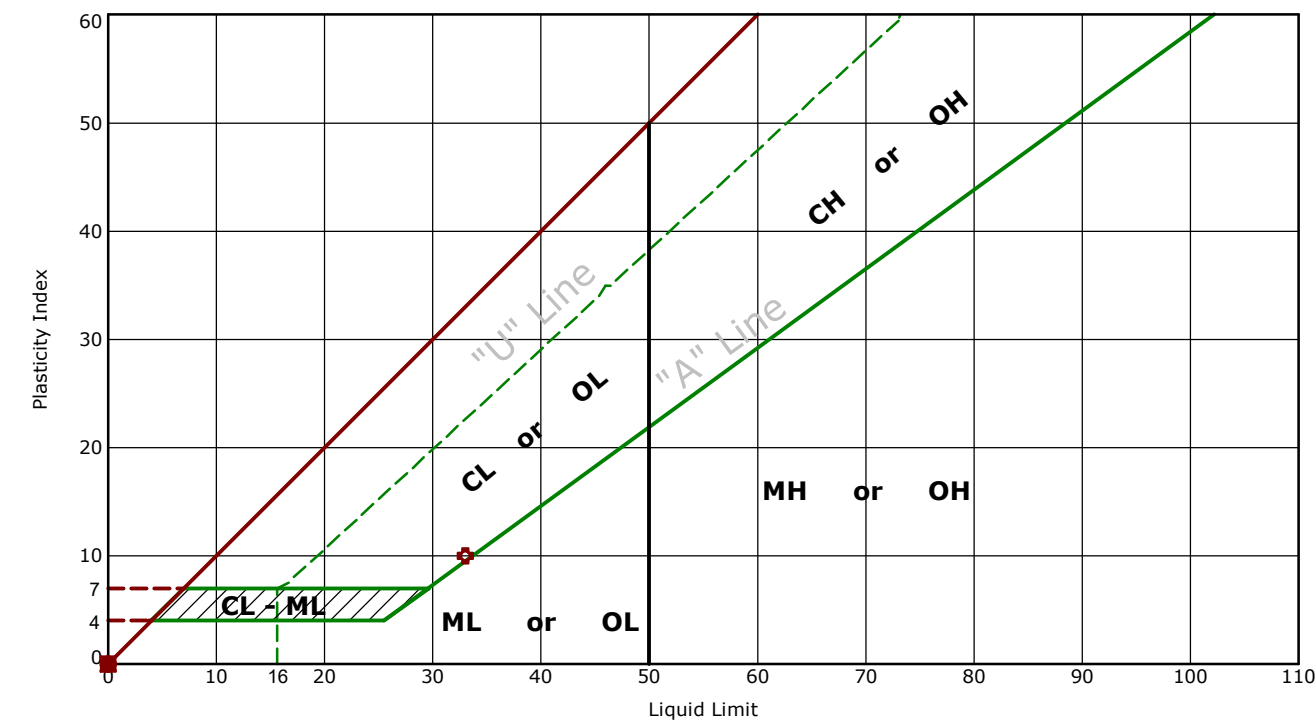
## BORING S-23-102-2 Offset



LEGEND	
●	Water Content
⊠	Plastic Limit
▲	Liquid Limit
★	Fines

# Atterberg Limit Results

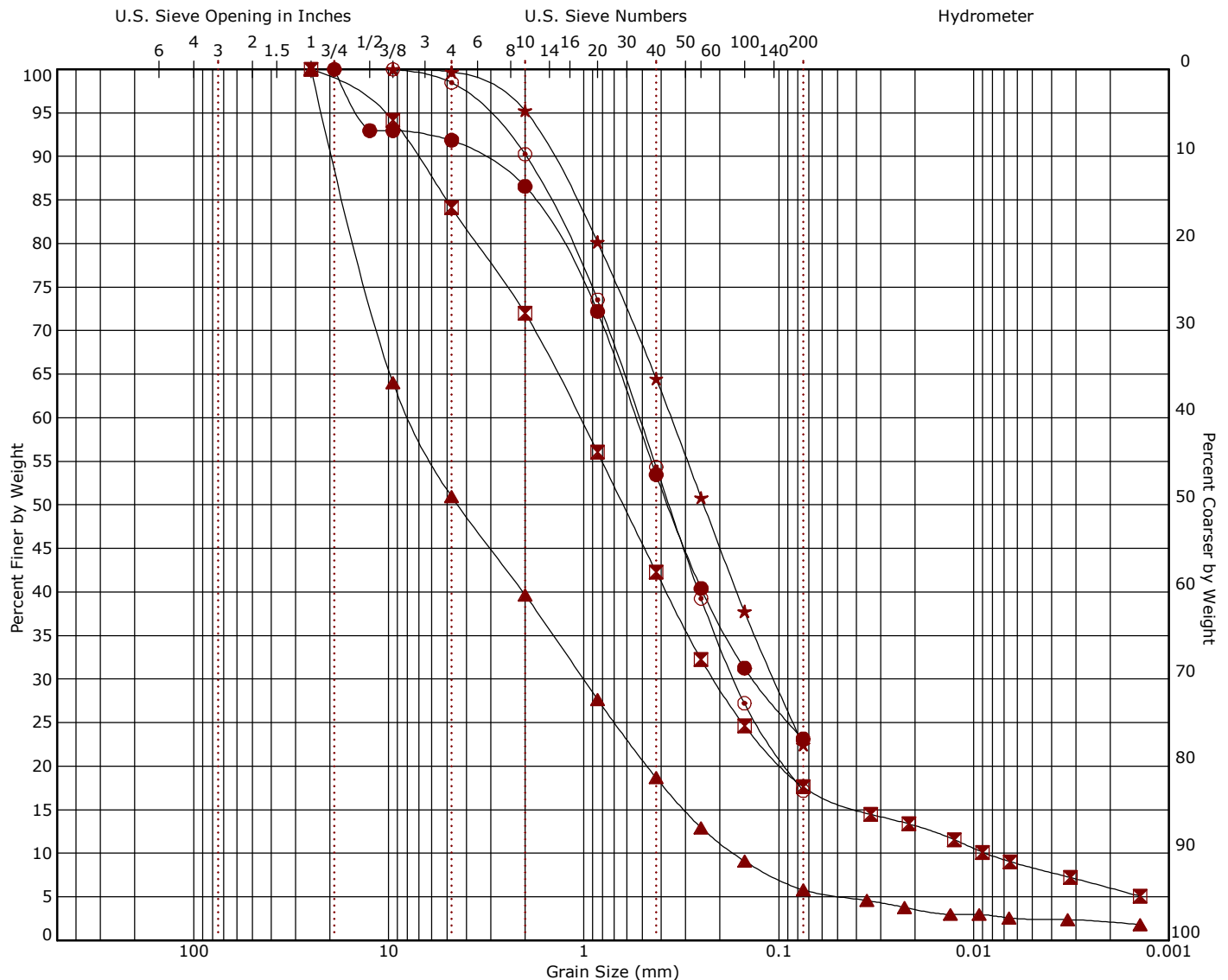
ASTM D4318



	Boring ID	Depth (Ft)	LL	PL	PI	Fines	AASHTO	Description
●	S-23-102-1	4 - 6	NP	NP	NP	23.1	A-2-4 (0)	SILTY SAND
⊠	S-23-102-1	8 - 10	NP	NP	NP	17.6	A-1-b (0)	SILTY SAND with GRAVEL
▲	S-23-102-1	23.5 - 25	NP	NP	NP	22.4	A-2-4 (0)	SILTY SAND
★	S-23-102-2	6 - 8	NP	NP	NP	35.2	A-2-4 (0)	SILTY SAND
⊙	S-23-102-2	12 - 14	NP	NP	NP	14.9	A-1-b (0)	SILTY SAND
⊕	S-23-102-2 Offset	0 - 5	33	23	10	29.4	A-2-4 (0)	CLAYEY SAND

## Grain Size Distribution

### ASTM D422 / ASTM C136



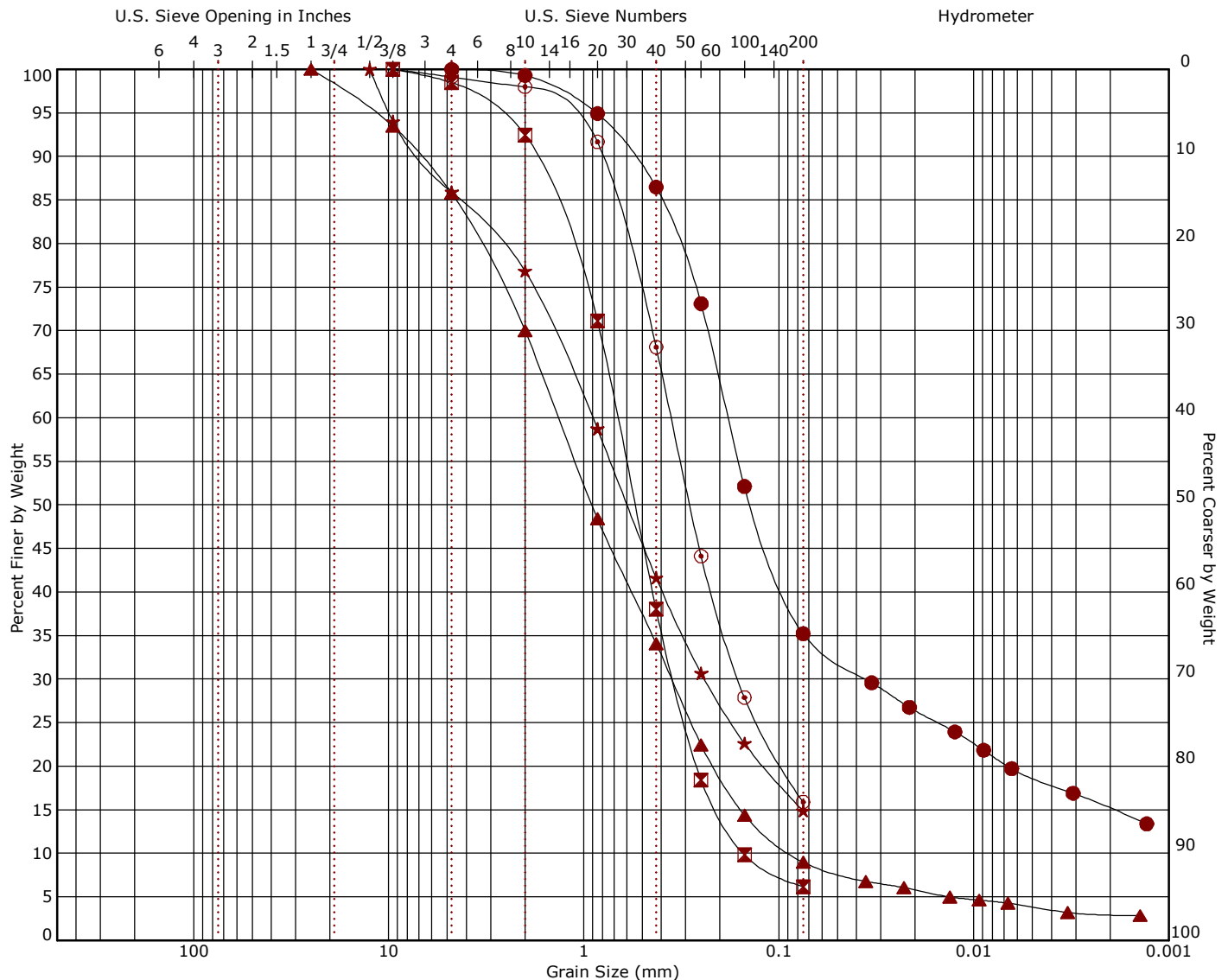
**Cobbles** | **Gravel** (coarse, fine) | **Sand** (coarse, medium, fine) | **Silt or Clay**

Boring ID	Depth (Ft)	USCS Classification	USCS	AASHTO	LL	PL	PI	Cc	Cu
●S-23-102-1	4 - 6	SILTY SAND	SM	A-2-4 (0)	NP	NP	NP		
☒S-23-102-1	8 - 10	SILTY SAND with GRAVEL	SM	A-1-b (0)	NP	NP	NP	5.06	121.15
▲S-23-102-1	13.5 - 15	POORLY GRADED GRAVEL W/ SILT & SAND	GP-GM	A-1-a				0.78	45.45
★S-23-102-1	23.5 - 25	SILTY SAND	SM	A-2-4 (0)	NP	NP	NP		
⊙S-23-102-2	4 - 6	SILTY SAND	SM	A-2-4					

Boring ID	Depth (Ft)	D <sub>100</sub>	D <sub>60</sub>	D <sub>30</sub>	D <sub>10</sub>	%Cobbles	%Gravel	%Sand	%Fines	%Silt	%Clay
●S-23-102-1	4 - 6	19	0.541	0.135		0.0	8.1	68.7	23.1		
☒S-23-102-1	8 - 10	25	1.051	0.215	0.009	0.0	15.9	66.5		9.3	8.4
▲S-23-102-1	13.5 - 15	25	7.67	1.003	0.169	0.0	49.1	45.1		3.3	2.5
★S-23-102-1	23.5 - 25	9.5	0.357	0.106		0.0	0.3	77.3	22.4		
⊙S-23-102-2	4 - 6	9.5	0.521	0.169		0.0	1.5	81.3	17.2		

## Grain Size Distribution

ASTM D422 / ASTM C136



**Cobbles** | **Gravel** (coarse, fine) | **Sand** (coarse, medium, fine) | **Silt or Clay**

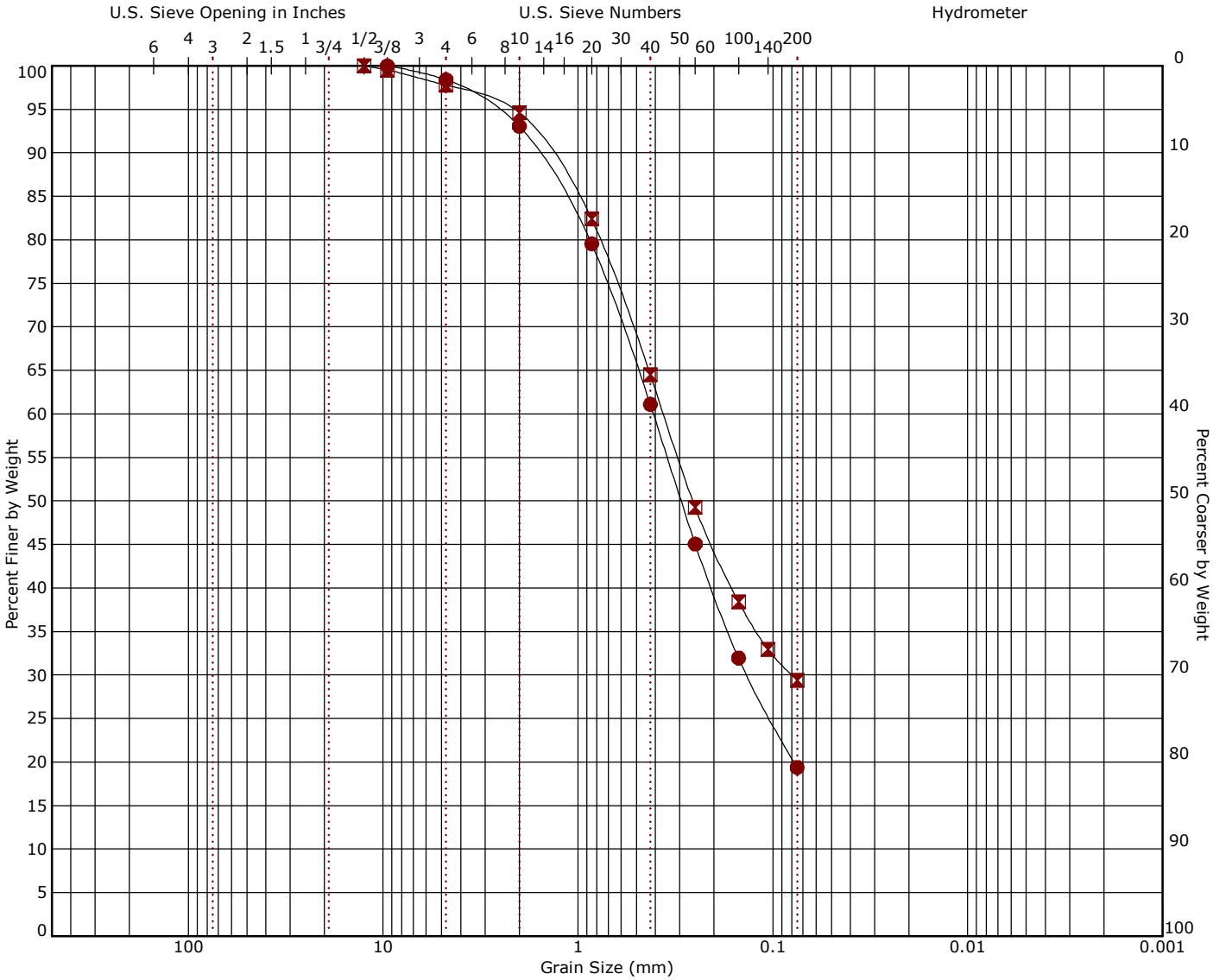
Boring ID	Depth (Ft)	USCS Classification	USCS	AASHTO	LL	PL	PI	Cc	Cu
● S-23-102-2	6 - 8	SILTY SAND	SM	A-2-4 (0)	NP	NP	NP		
⊠ S-23-102-2	8 - 10	POORLY GRADED SAND W/ SILT	SP-SM	A-1-b				1.15	4.44
▲ S-23-102-2	10 - 12	WELL GRADED SAND W/ SILT	SW-SM	A-1-b				1.08	15.75
★ S-23-102-2	12 - 14	SILTY SAND	SM	A-1-b (0)	NP	NP	NP		
⊙ S-23-102-2	14 - 16	SILTY SAND	SM	A-2-4					

Boring ID	Depth (Ft)	D <sub>100</sub>	D <sub>60</sub>	D <sub>30</sub>	D <sub>10</sub>	%Cobbles	%Gravel	%Sand	%Fines	%Silt	%Clay
● S-23-102-2	6 - 8	4.75	0.182	0.035		0.0	0.0	64.8		16.5	18.8
⊠ S-23-102-2	8 - 10	9.5	0.673	0.342	0.152	0.0	1.5	92.3	6.2		
▲ S-23-102-2	10 - 12	25	1.345	0.353	0.085	0.0	14.2	76.8		5.1	3.8
★ S-23-102-2	12 - 14	12.5	0.903	0.24		0.0	14.1	71.0	14.9		
⊙ S-23-102-2	14 - 16	9.5	0.355	0.16		0.0	0.9	83.2	15.9		



# Grain Size Distribution

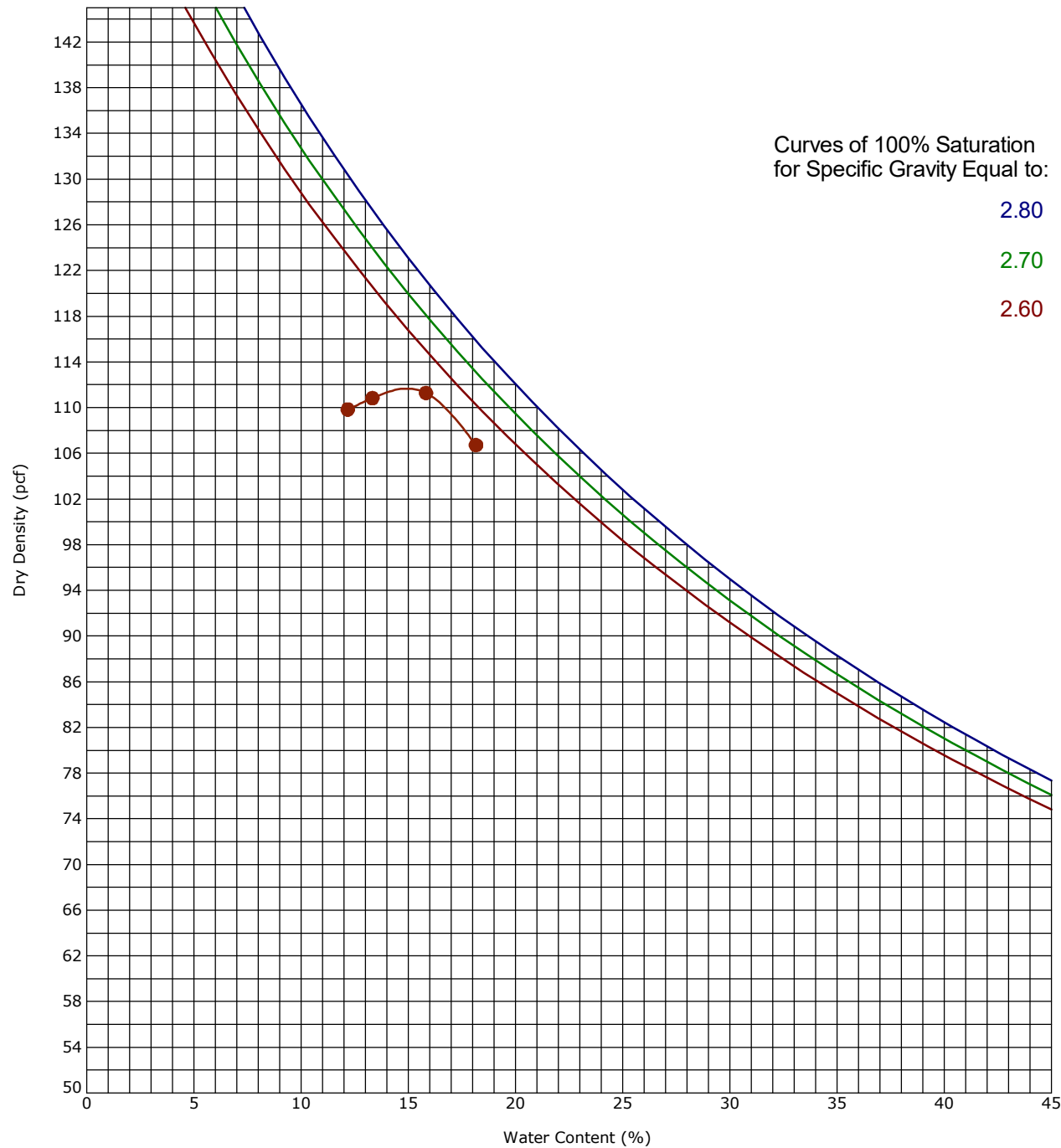
## ASTM D422 / ASTM C136



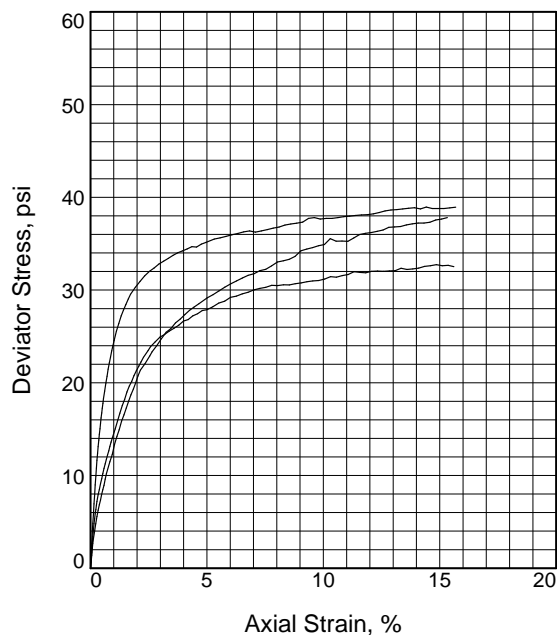
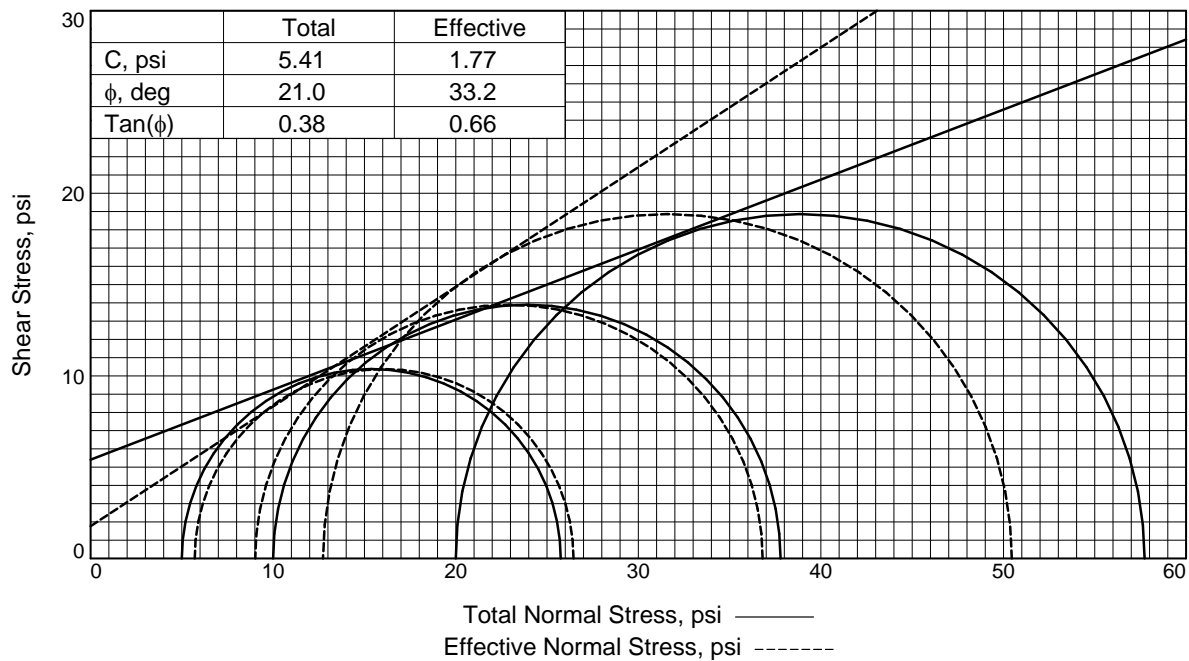
Cobbles		Gravel		Sand			Silt or Clay					
		coarse	fine	coarse	medium	fine						
Boring ID	Depth (Ft)	USCS Classification				USCS	AASHTO	LL	PL	PI	Cc	Cu
● S-23-102-2	18 - 20	SILTY SAND				SM	A-2-4					
✖ S-23-102-2	0 - 5	CLAYEY SAND				SC	A-2-4 (0)	33	23	10		
Offset												
Boring ID	Depth (Ft)	D <sub>100</sub>	D <sub>60</sub>	D <sub>30</sub>	D <sub>10</sub>	%Cobbles	%Gravel	%Sand	%Fines	%Silt	%Clay	
● S-23-102-2	18 - 20	9.5	0.41	0.135		0.0	1.6	79.0	19.4			
✖ S-23-102-2	0 - 5	12.5	0.363	0.079		0.0	2.2	68.4	29.4			
Offset												

# Moisture-Density Relationship

ASTM D698-Method B



Boring ID		Depth (Ft)		Description of Materials			
S-23-102-2 Offset		0 - 5		CLAYEY SAND(SC)			
Fines (%)	Fraction > mm size	LL	PL	PI	Test Method	Maximum Dry Density (pcf)	Optimum Water Content (%)
29	0.0	33	23	10	ASTM D698-Method B	111.7	14.9



Sample No.		1	2	3
Initial	Water Content, %	15.0	14.8	15.2
	Dry Density, pcf	106.3	106.3	106.1
	Saturation, %	69.1	68.3	69.8
	Void Ratio	0.5853	0.5861	0.5880
	Diameter, in.	2.80	2.80	2.80
	Height, in.	5.62	5.62	5.62
At Test	Water Content, %	20.5	20.7	20.5
	Dry Density, pcf	108.6	108.2	108.5
	Saturation, %	100.0	100.0	100.0
	Void Ratio	0.5527	0.5576	0.5530
	Diameter, in.	2.78	2.78	2.78
	Height, in.	5.58	5.57	5.55
Strain rate, in./min.		0.001	0.001	0.001
Back Pressure, psi		50.0	50.0	50.0
Cell Pressure, psi		55.0	60.0	70.0
Fail. Stress, psi		20.7	27.8	37.7
Excess Pore Pr., psi		-0.7	1.0	7.3
Ult. Stress, psi		37.7	32.6	38.8
Excess Pore Pr., psi		-7.6	-2.1	5.5
$\bar{\sigma}_1$ Failure, psi		26.4	36.8	50.5
$\bar{\sigma}_3$ Failure, psi		5.7	9.0	12.7

#### Type of Test:

CU with Pore Pressures

**Sample Type:** Remolded

**Description:** Clayey Sand (SC)

**LL=** 33

**PL=** 23

**PI=** 10

**Specific Gravity=** 2.7

**Remarks:** Specimens were remolded to approximately 95% MDD at optimum water content.

**Figure** \_\_\_\_\_

**Client:** HNTB North Carolina PC

**Project:** S-23-102 (Keeler Mill Road) BRO Armstrong Creek

**Source of Sample:** S-23-102-2 Offset **Depth:** 0-5'

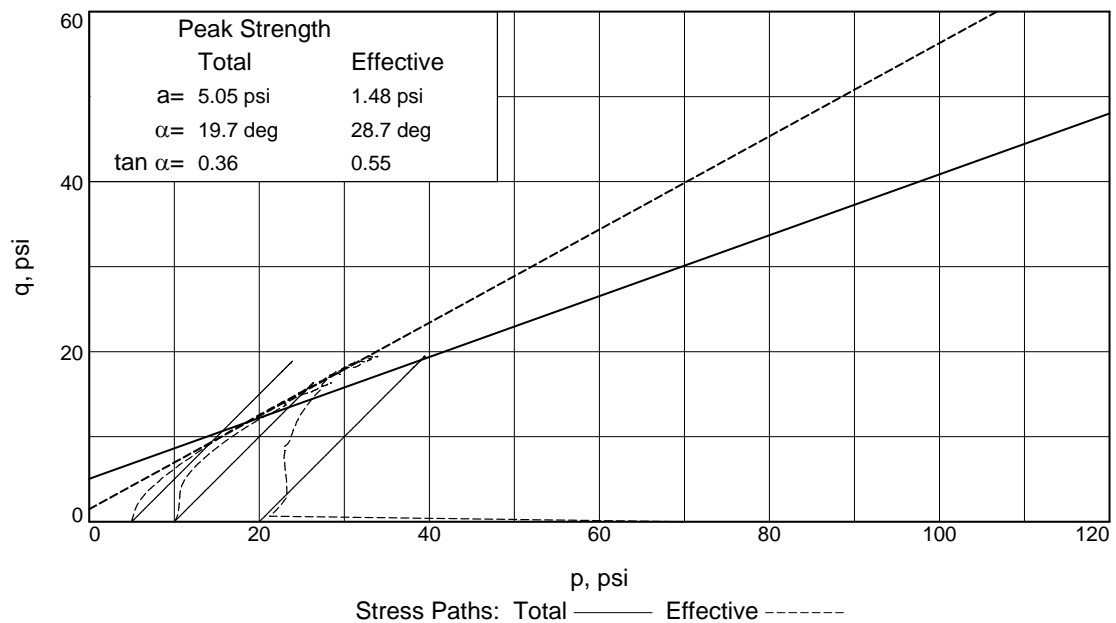
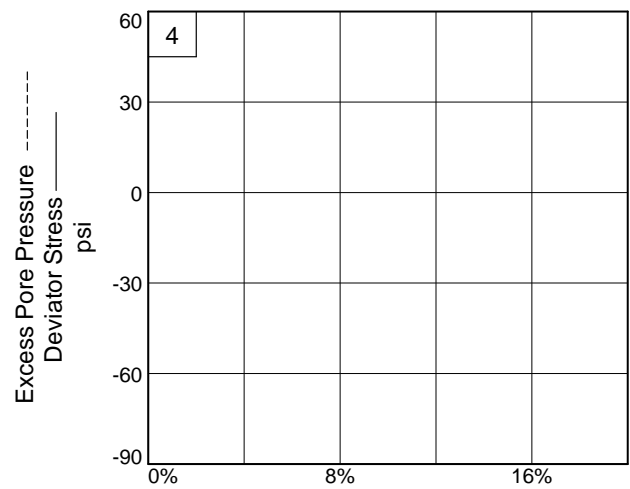
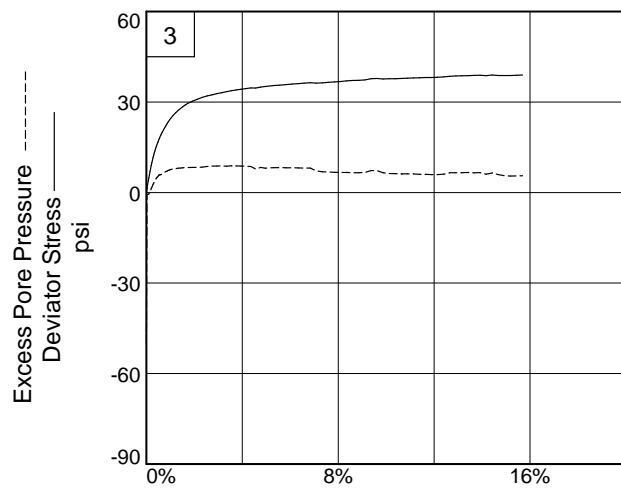
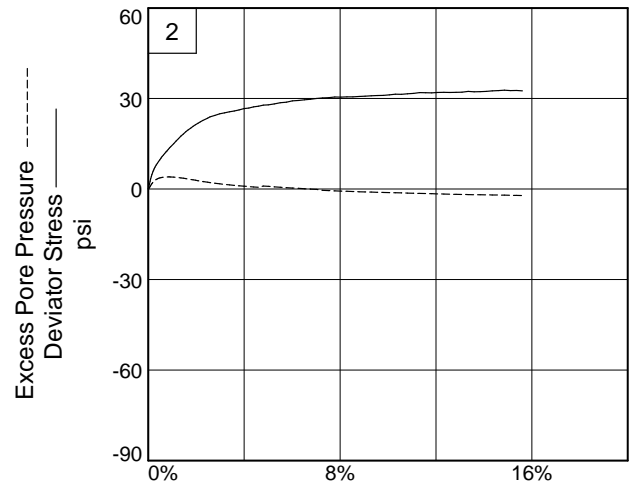
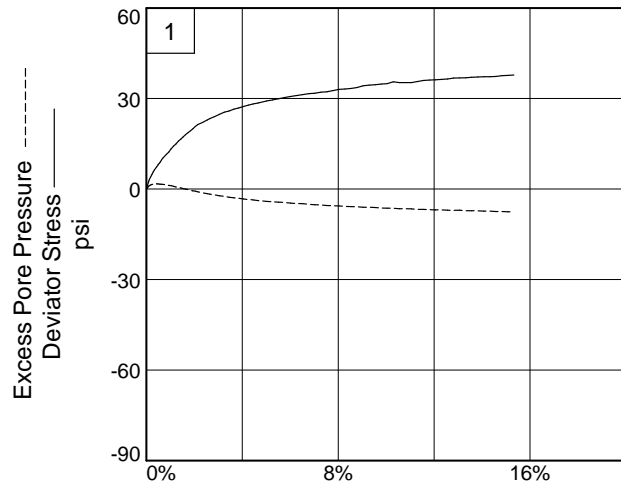
**Proj. No.:** 8623P180

**Date Sampled:** N/A

TRIAXIAL SHEAR TEST REPORT

Terracon Consultants, Inc.

Chattanooga, TN



**Client:** HNTB North Carolina PC

**Project:** S-23-102 (Keeler Mill Road) BRO Armstrong Creek

**Source of Sample:** S-23-102-2 Offset **Depth:** 0-5'

**Project No.:** 8623P180

**Figure** \_\_\_\_\_

**Terracon Consultants, Inc.**

750 Pilot Road, Suite F  
Las Vegas, Nevada 89119  
(702) 597-9393



**Client**

HNTB North Carolina PC

**Project**

S-23-102 (Keeler Mill Road) BRO Armstrong Creek

**Sample Submitted By:** Terracon (86)

**Date Received:** 8/16/2024

**Lab No.:** 24-0279

**Results of Corrosion Analysis**

<b>Sample Number</b>	S-23-102-2
<b>Sample Location</b>	--
<b>Sample Depth (ft.)</b>	2.0-12.0
pH Analysis, AASHTO T289	6.60
Water Soluble Sulfate (SO4), AASHTO T290 (mg/kg)	87
Chlorides, AASHTO T291, (mg/kg)	127
Saturated Minimum Resistivity, AASHTO T288, (ohm-cm)	1746

**Analyzed By**

A handwritten signature in black ink, appearing to read 'N. Campo'.

Nathan Campo  
Laboratory Coordinator

The tests were performed in general accordance with applicable ASTM and AWWA test methods. This report is exclusively for the use of the client indicated above and shall not be reproduced except in full without the written consent of our company. Test results transmitted herein are only applicable to the actual samples tested at the location(s) referenced and are not necessarily indicative of the properties of other apparently similar or identical materials.



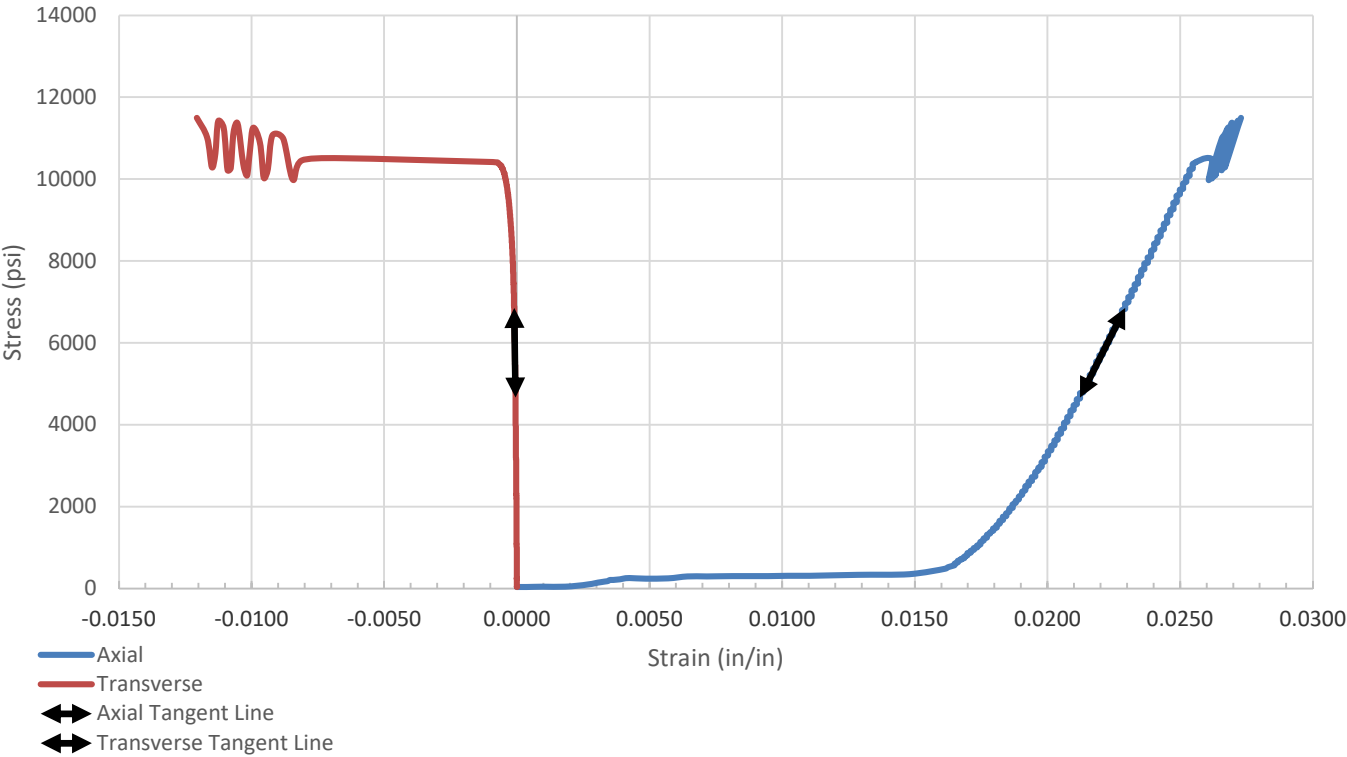
PROJECT ID P041161 PROJECT NAME S-23-102 BRO Armstrong Creek  
PROJECT COUNTY Greenville

Borehole	Core Run Number	Core Run Top Depth	REC (%)	RQD (%)	q <sub>u</sub> (psi)	Poisson's Ratio	Secant Modulus (ksi)	Unit Weight (pcf)	RMR	GSI
S-23-102-1	NQ-1	49.0	72	63	11497	0.03	1290	169	60	60
S-23-102-1	NQ-2	54.0	100	97						75
S-23-102-1	NQ-3	59.0	100	86	8566	0.01	1052	170	74	75
S-23-102-2	NQ-1	33.5	100	100	12281	0.07	1358	169	77	90
S-23-102-2	NQ-2	38.5	93	93	13547	0.07	1310	164	77	85



<b>Client</b> HNTB North Carolina PC Attn: Spencer Franklin 343 E Six Forks Rd Ste 200 Raleigh, NC 27609	<b>Project</b> S-23-102 (Keeler Mill Road) BRO Armstrong Creek  Project No. 8623P180
--	---

ASTM D7012 Stress/ Strain Curve



SAMPLE LOCATION			
Site:	S-23-102 (K eeler Mill Road)		
Description:	Gneiss		
Boring:	S-23-102-1	Depth (feet):	53.2-54.0
SPECIMEN INFORMATION			
Sample No.:	R1	Mass (g):	546.26
Length (in.):	4.13	Diameter (in.):	1.95
L/D Ratio:	2.12	Density (pcf):	168.72
TEST RESULTS			
Failure Load (lbs):		34337	
Failure Strain (%):		2.78	
Unconfined Compressive Strength (psi):		11,497	
Elastic Modulus, E, (ksi):		1290	
Poisson's Ratio, u:		0.029	
Time of Failure (min):		01:39	
Rate of Loading (psi/sec):		0.041	
Moisture Content Post-break:		0.008	



Client	Project
HNTB North Carolina PC Attn: Spencer Franklin 343 E Six Forks Rd Ste 200 Raleigh, NC 27609	S-23-102 (Keeler Mill Road) BRO Armstrong Creek
	Project No. 8623P180

Equipment:	TICCS ID:
Calipers	W-54522
Scale	B-71466
Dial Indicator	C-70608
Compression (spherically seated)	C-48999

Samples were prepared and tested in accordance with ASTM D4543 and D7012. Deviations, if any, are noted below:

Notes:

Per ASTM D4543, this specimen has not met the requirements for perpendicularity, by exceeding 0.250°.

Per ASTM D4543, this specimen has not met the requirements for flatness, by exceeding 0.001 inches.

Per ASTM D4543, this specimen has not met the requirements for parallelism, by exceeding 0.25°.

According to ASTM D7012 Section 8.2.1, this specimen, although not meeting all requirements of ASTM D4543 is acceptable for testing. However, the results reported may differ from results obtained from a test specimen that meets the requirements of D4543.

Client

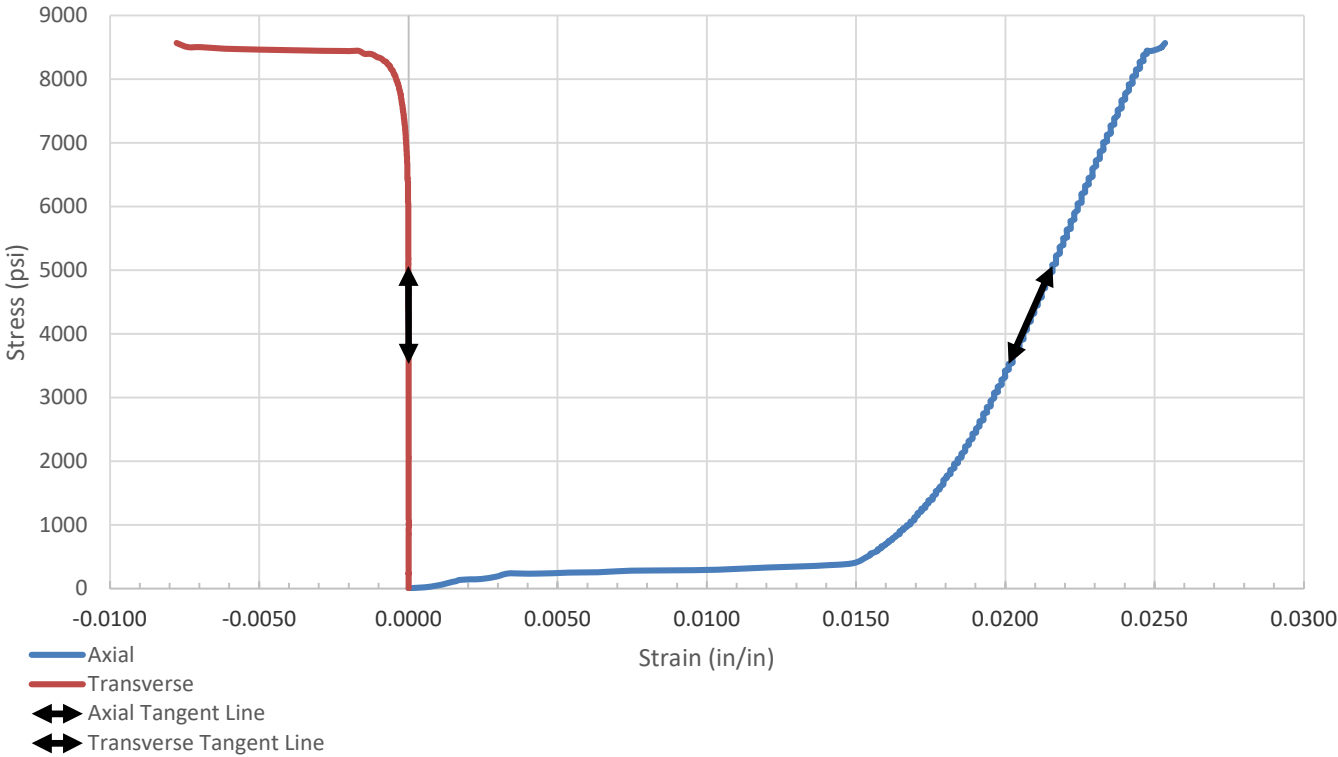
HNTB North Carolina PC  
Attn: Spencer Franklin  
343 E Six Forks Rd Ste 200  
Raleigh, NC 27609

Project

S-23-102 (Keeler Mill Road) BRO Armstrong Creek

Project No. 8623P180

ASTM D7012 Stress/ Strain Curve



SAMPLE LOCATION

Site:	S-23-102 (K eeler Mill Road)		
Description:	Gneiss		
Boring:	S-23-102-1	Depth (feet):	62.7-64.0

SPECIMEN INFORMATION

Sample No.:	R3	Mass (g):	546.64
Length (in.):	4.11	Diameter (in.):	1.95
L/D Ratio:	2.11	Density (pcf):	169.66

TEST RESULTS

Failure Load (lbs):	25583
Failure Strain (%):	2.57
Unconfined Compressive Strength (psi):	8,566
Elastic Modulus, E, (ksi):	1052
Poisson's Ratio, u:	0.006
Time of Failure (min):	01:18
Rate of Loading (psi/sec):	0.041
Moisture Content Post-break:	0.0019



Client	Project
HNTB North Carolina PC Attn: Spencer Franklin 343 E Six Forks Rd Ste 200 Raleigh, NC 27609	S-23-102 (Keeler Mill Road) BRO Armstrong Creek
	Project No. 8623P180

Equipment:	TICCS ID:
Calipers	W-54522
Scale	B-71466
Dial Indicator	C-70608
Compression (spherically seated)	C-48999

Samples were prepared and tested in accordance with ASTM D4543 and D7012. Deviations, if any, are noted below:

Notes:

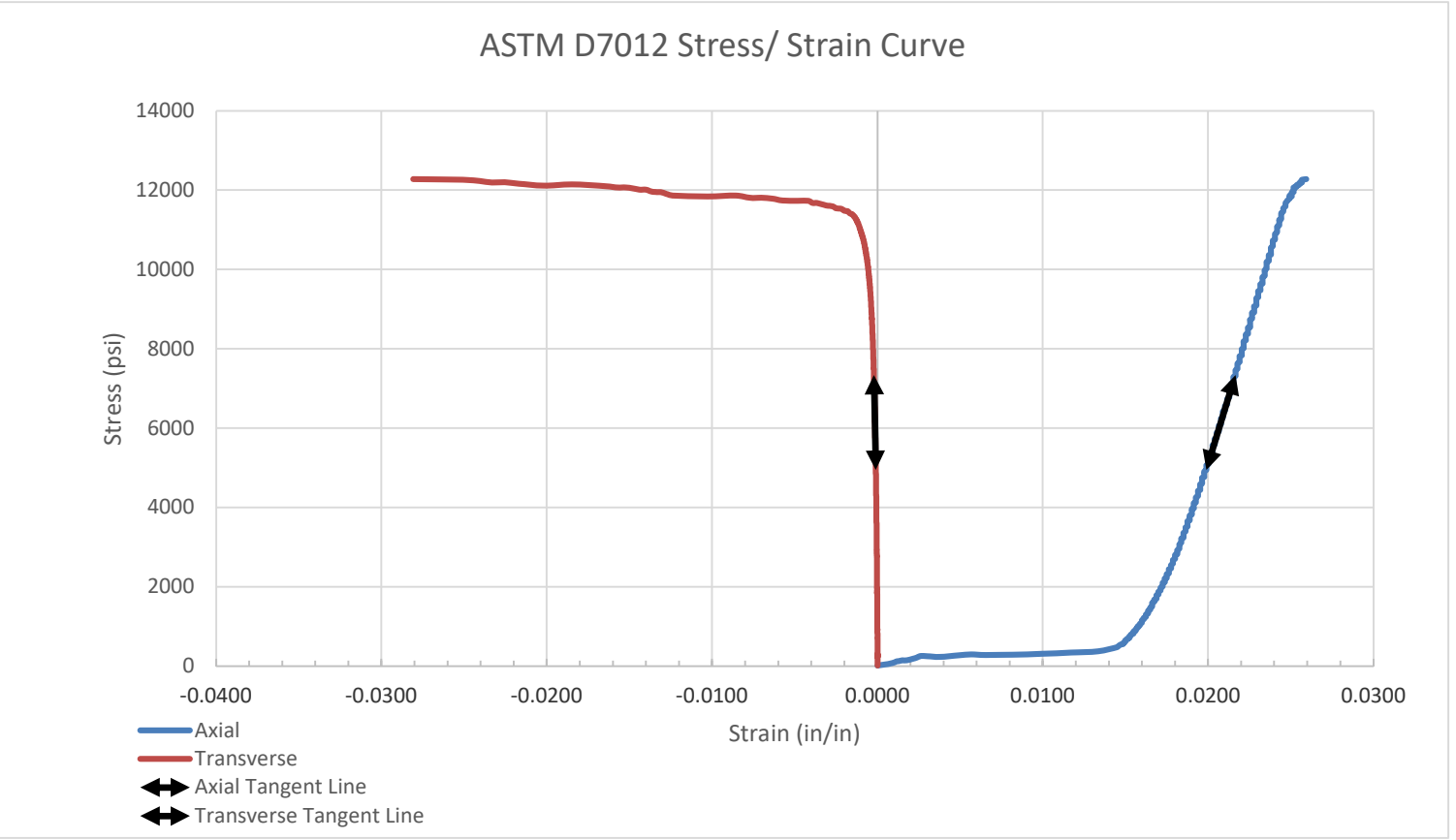
Per ASTM D4543, this specimen has not met the requirements for perpendicularity, by exceeding 0.250°.

Per ASTM D4543, this specimen has not met the requirements for flatness, by exceeding 0.001 inches.

Per ASTM D4543, this specimen has not met the requirements for parallelism, by exceeding 0.25°.

According to ASTM D7012 Section 8.2.1, this specimen, although not meeting all requirements of ASTM D4543 is acceptable for testing. However, the results reported may differ from results obtained from a test specimen that meets the requirements of D4543.

Client	Project
HNTB North Carolina PC	S-23-102 (Keeler Mill Road) BRO Armstrong Creek
Attn: Spencer Franklin	
343 E Six Forks Rd Ste 200	
Raleigh, NC 27609	Project No. 8623P180



SAMPLE LOCATION			
Site:	S-23-102 (Keeler Mill Road)		
Description:	Granite		
Boring:	S-23-102-2	Depth (feet):	34.5-35.6
SPECIMEN INFORMATION			
Sample No.:	R1	Mass (g):	521.4
Length (in.):	3.98	Diameter (in.):	1.94
L/D Ratio:	2.05	Density (pcf):	168.84
TEST RESULTS			
Failure Load (lbs):		36302	
Failure Strain (%):		3.05	
Unconfined Compressive Strength (psi):		12,281	
Elastic Modulus, E, (ksi):		1358	
Poisson's Ratio, u:		0.066	
Time of Failure (min):		01:52	
Rate of Loading (psi/sec):		0.040	
Moisture Content Post-break:		0.0014	



Client	Project
HNTB North Carolina PC Attn: Spencer Franklin 343 E Six Forks Rd Ste 200 Raleigh, NC 27609	S-23-102 (Keeler Mill Road) BRO Armstrong Creek
	Project No. 8623P180

Equipment:	TICCS ID:
Calipers	W-54522
Scale	B-71466
Dial Indicator	C-70608
Compression (spherically seated)	C-48999

Samples were prepared and tested in accordance with ASTM D4543 and D7012. Deviations, if any, are noted below:

Notes:

Per ASTM D4543, this specimen has not met the requirements for straightness, by exceeding 0.02 inches.

Per ASTM D4543, this specimen has not met the requirements for perpendicularity, by exceeding 0.250°.

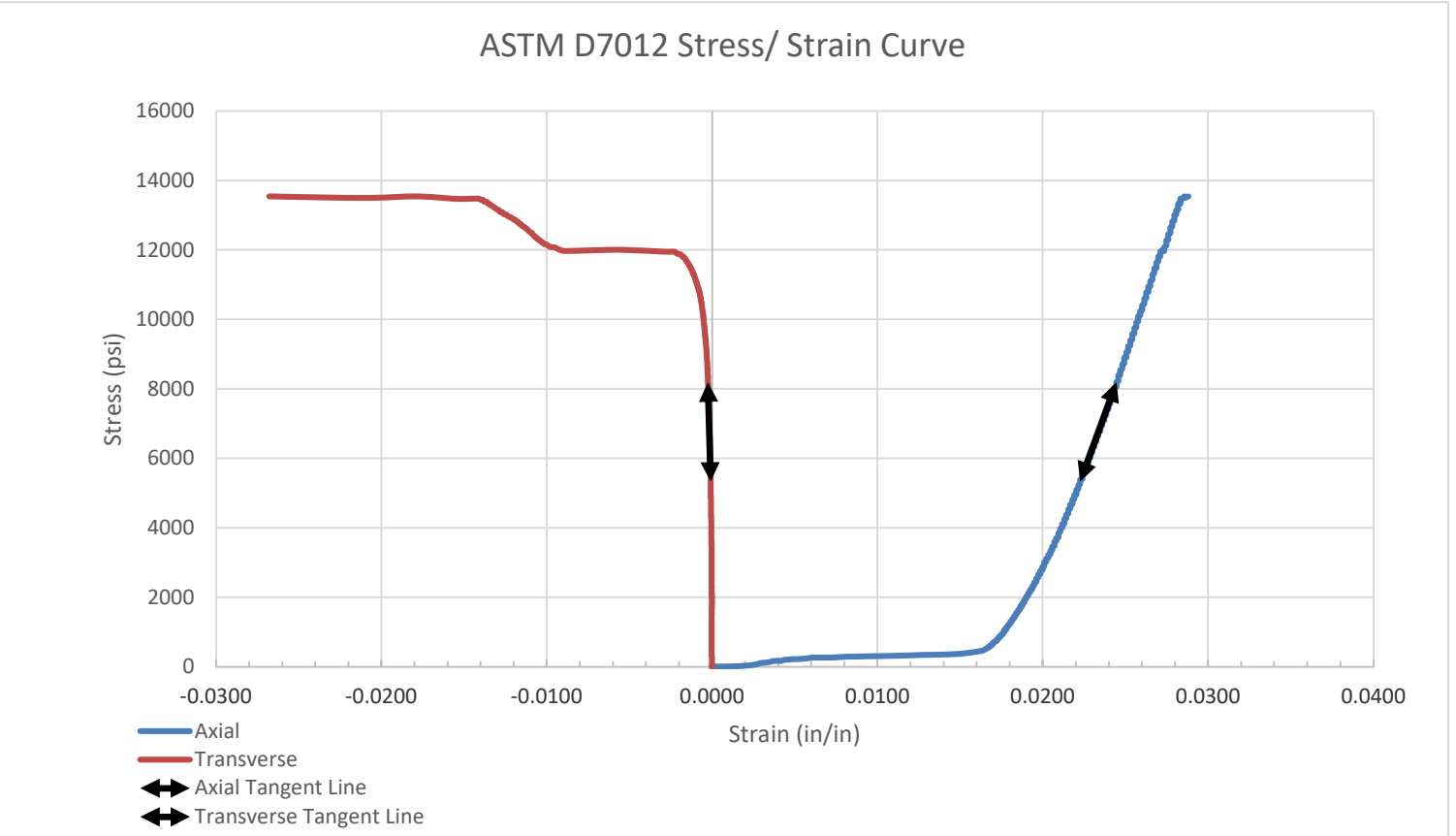
Per ASTM D4543, this specimen has not met the requirements for flatness, by exceeding 0.001 inches.

Per ASTM D4543, this specimen has not met the requirements for parallelism, by exceeding 0.25°.

According to ASTM D7012 Section 8.2.1, this specimen, although not meeting all requirements of ASTM D4543 is acceptable for testing. However, the results reported may differ from results obtained from a test specimen that meets the requirements of D4543.



<b>Client</b> HNTB North Carolina PC Attn: Spencer Franklin 343 E Six Forks Rd Ste 200 Raleigh, NC 27609	<b>Project</b> S-23-102 (Keeler Mill Road) BRO Armstrong Creek  Project No. 8623P180
--	---



SAMPLE LOCATION			
Site:	S-23-102 (Keeler Mill Road)		
Description:	Gneiss		
Boring:	S-23-102-2	Depth (feet):	41.5-42.5
SPECIMEN INFORMATION			
Sample No.:	R2	Mass (g):	531.66
Length (in.):	4.14	Diameter (in.):	1.95
L/D Ratio:	2.12	Density (pcf):	163.81
TEST RESULTS			
Failure Load (lbs):		40457	
Failure Strain (%):		2.88	
Unconfined Compressive Strength (psi):		13,547	
Elastic Modulus, E, (ksi):		1310	
Poisson's Ratio, u:		0.072	
Time of Failure (min):		02:06	
Rate of Loading (psi/sec):		0.041	
Moisture Content Post-break:		0.0017	





Client	Project
HNTB North Carolina PC Attn: Spencer Franklin 343 E Six Forks Rd Ste 200 Raleigh, NC 27609	S-23-102 (Keeler Mill Road) BRO Armstrong Creek
	Project No. 8623P180

Equipment:	TICCS ID:
Calipers	W-54522
Scale	B-71466
Dial Indicator	C-70608
Compression (spherically seated)	C-48999

Samples were prepared and tested in accordance with ASTM D4543 and D7012. Deviations, if any, are noted below:

Notes:

Per ASTM D4543, this specimen has not met the requirements for perpendicularity, by exceeding 0.250°.

Per ASTM D4543, this specimen has not met the requirements for flatness, by exceeding 0.001 inches.

Per ASTM D4543, this specimen has not met the requirements for parallelism, by exceeding 0.25°.

According to ASTM D7012 Section 8.2.1, this specimen, although not meeting all requirements of ASTM D4543 is acceptable for testing. However, the results reported may differ from results obtained from a test specimen that meets the requirements of D4543.

## **Appendix C – Supporting Documents**

S-23-102 Bridge Replacement over Armstrong Creek | Greenville County, SC  
Terracon Project No. 8623P180 | SCDOT Project ID: P041161



## **Appendix C**

### **Supporting Documents**

3-Point Acceleration Design Response Spectrum By SCDOT  
Rig Calibration Report – DR#554 (5 Pages)

Note: All exhibits are one page unless noted above.

### 3-Point Acceleration Design Response Spectrum

SCDOT v3.2 - 06/01/2023

Project ID:	P041161	Latitude:	34.9420
Route:	S-23-102	County:	23 - Greenville
Project:	BRO Armstrong Creek		
		Longitude:	82.4927

Designer:	D. Sapkota - Support
Date:	10/15/2024

Design EQ	PGA	S <sub>DS</sub>	S <sub>D1</sub>	M <sub>W</sub>	R	PGV	D <sub>5-95</sub>	T' <sub>o</sub>
	g	g	g	-	km	inches/sec	sec	sec
FEE	0.04	0.09	0.01	6.88	243.47	0.33	50.53	0.17
SEE	0.08	0.17	0.02	5.63	103.10	0.72	21.36	0.13

Fundamental Period of Structure, T <sub>0</sub>	Range of Interest		V <sub>s,H</sub> *	H	T <sub>NH</sub>	
	sec				sec	
sec	0.5*T <sub>0</sub>	2.0*T <sub>0</sub>	ft/sec	ft	(4*H)/V <sub>s,H</sub> *	(6*H)/V <sub>s,H</sub> *
0.00	0.00	0.00	963.26	58.00	0.19	0.36
0.00	0.00	0.00	H = B-C Boundary			

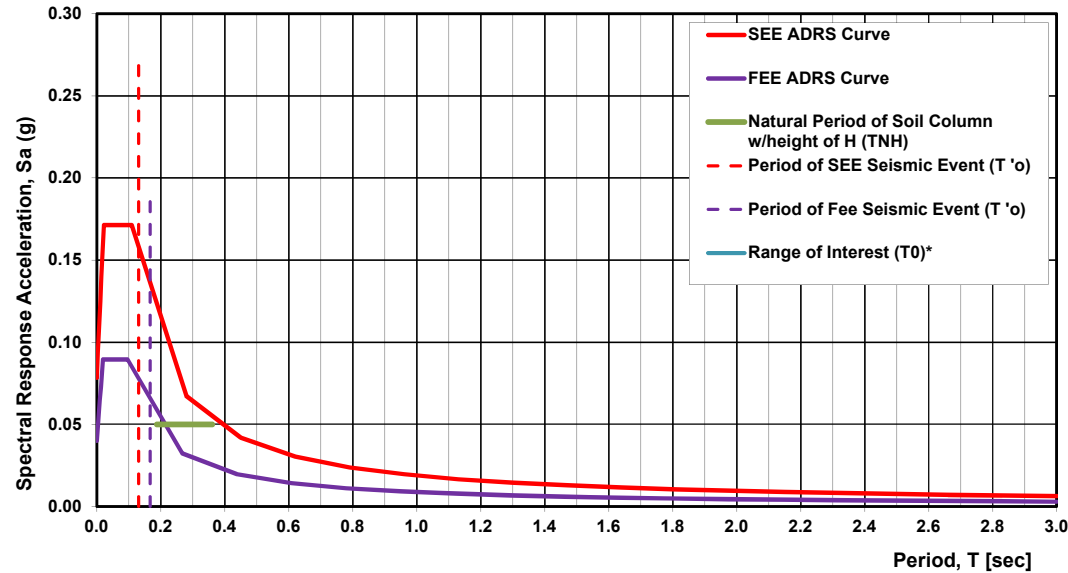
H = B-C Boundary

Damping:	5%
Geologic Condition:	Geologically Realistic (Q = 100)*
ADRS Location within Soil Column:	SCP
	At Ground Surface

South Carolina Piedmont

\*Same Geologic Condition as used in SCENARIO\_PC (2006)

### SC Seismic ADRS Curve



#### FEE Data

T	S <sub>a</sub>
0.00	0.040
0.00	0.048
0.01	0.056
0.01	0.065
0.01	0.073
0.02	0.081
0.02	0.089
0.03	0.089
0.03	0.089
0.04	0.089
0.05	0.089
0.05	0.089
0.06	0.089
0.06	0.089
0.07	0.089
0.08	0.089
0.08	0.089
0.09	0.089
0.09	0.089
0.10	0.089
0.10	0.089
0.27	0.032
0.44	0.020
0.61	0.014
0.78	0.011
0.95	0.009
1.12	0.008
1.29	0.007
1.46	0.006
1.63	0.005
1.80	0.005
1.98	0.004
2.15	0.004
2.32	0.004
2.49	0.003
2.66	0.003
2.83	0.003
3.00	0.003

#### SEE Data

T	S <sub>a</sub>
0.00	0.078
0.00	0.094
0.01	0.109
0.01	0.125
0.01	0.140
0.02	0.156
0.02	0.171
0.03	0.171
0.04	0.171
0.04	0.171
0.05	0.171
0.06	0.171
0.07	0.171
0.07	0.171
0.08	0.171
0.09	0.171
0.10	0.171
0.10	0.171
0.11	0.171
0.28	0.067
0.45	0.042
0.62	0.030
0.79	0.024
0.96	0.020
1.13	0.017
1.30	0.014
1.47	0.013
1.64	0.011
1.81	0.010
1.98	0.010
2.15	0.009
2.32	0.008
2.49	0.008
2.66	0.007
2.83	0.007
3.00	0.006

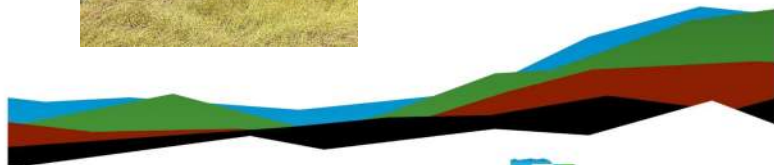
# SPT Automatic Hammer Energy Measurement Report

Drill Rig Model: GeoProbe 3126

Drill Rig Serial Number: 3126TTS52010006

Asset Number: DR#554

August 21, 2023



## Prepared for:

Terracon  
Greenville-Spartanburg, South Carolina



July 19, 2023

Terracon  
72 Pointe Circle  
Greenville, South Carolina 29607

Attn: Maggie McKenney  
E: m.mckenney@terracon.com

**Re:** SPT Automatic Hammer Energy Measurement Report  
Rig Serial Number: 3126TTS52010006  
Terracon Project Number: DYXX0500

Dear Ms. McKenney:

This report provides the Energy Transfer Ratio (ETR) for the Standard Penetration Testing (SPT) automatic hammer as summarized below:

**Table 1: Hammer Efficiency Summary**

Drill Rig Make/Model	Drill Rig Serial Number	Drill Rig Year	Asset Number	Energy Transfer Ratio (ETR)	Hammer Efficiency Correction (Ce)
GeoProbe 3126	3126TTS52010006	2021	GP#554	88.5% ± 4.2%	1.48

If you have any questions concerning this summary, or if we may be of further service, please contact us.

*James P. Smith*

James P. Smith  
National Manager of Equipment & Training

*Rob Kramer*

Rob Kramer  
Group Manager Geophysics

## Attachments:

Exhibit A: PDA SPT Analyzer Results  
Exhibit B: PDA Equipment Calibration

Facilities | Environmental | **Geotechnical** | Materials |

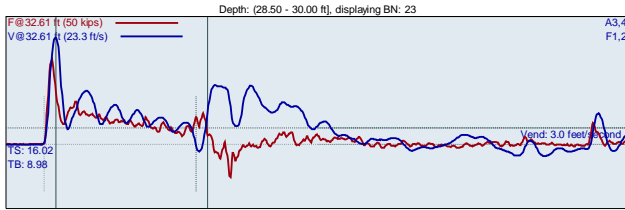
## MEASUREMENT SUMMARY

ITEM	DESCRIPTION
Drill Rig Owner	Terracon Greenville-Spartanburg - Greenville, SC
Drill Rig Operator	Brett Burnett; Terracon Exploration Services
Testing Date	08/21/2023
Testing Location	Spartanburg, SC
Boring Identification	B-1
Hammer Type	140 pounds (automatic)
Boring Method	Hollow Stem Auger
Drill Rods	<ul style="list-style-type: none"> <li>AWJ</li> <li>1-3/4" outside diameter</li> <li>3/16" wall thickness</li> </ul>
Calibration Testing Equipment	<ul style="list-style-type: none"> <li>2-foot AWJ rod instrumented w/ two strain gauges and two accelerometers</li> <li>Model SPT Analyzer™ (PDA)</li> </ul>
ASTM Methods Used	<p><b>ASTM D1586</b>, Standard Test Method for Standard Penetration Test and Split-Barrel Sampling of Soils</p> <p><b>ASTM D4633-16</b>, Standard Method for Energy Measurement for Dynamic Penetrometers</p>
SPT Calibration Personnel	Jim Smith, National Manager of Equipment and Training

## Exhibit A

### PDA SPT Analyzer Results

GP554-3126 28.5/30  
JIM SMITH Interval start: 8/21/2023  
TB-1  
AR: 1.20 in/2 SP: 0.492 k/ft3  
LE: 32.61 ft EM: 30000 ksi  
WS: 16807.9 fts



F1 : [648AWJ1] 226.21 PDICAL (1) FF1 A3 (PR): [K4483] 410.187 mv/6.4v/5000g (1) VF1  
F2 : [648AWJ2] 225.58 PDICAL (1) FF1 A4 (PR): [K10491] 421.907 mv/6.4v/5000g (1) VF1

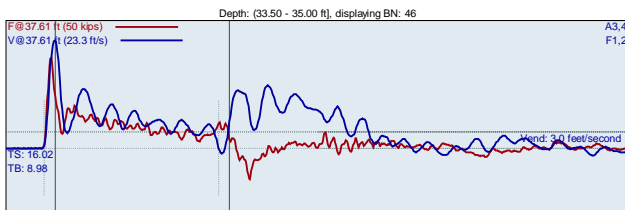
FMX: Maximum Force EFV: Maximum Energy  
VMX: Maximum Velocity ETR: Energy Transfer Ratio - Rated  
BPM: Blows/Minute

BL#	BC /6"	FMX kips	VMX ft/s	BPM bpm	EFV ft-lb	ETR %
1	6	40	19.4	1.9	234	84.1
2	6	39	19.2	51.9	292	83.4
3	6	25	16.9	52.7	274	78.2
4	6	28	17.9	52.4	273	77.9
5	6	32	19.6	52.6	294	83.9
6	6	27	17.3	53.1	268	76.5
7	8	38	19.0	52.7	289	82.5
8	8	39	19.6	52.4	305	87.2
9	8	36	19.2	52.7	290	82.8
10	8	28	18.2	52.5	292	83.4
11	8	38	19.0	53.0	293	83.8
12	8	35	19.4	52.6	282	80.4
13	8	36	19.1	52.9	299	85.3
14	8	34	19.8	52.8	307	87.7
15	11	34	19.5	52.7	307	87.6
16	11	33	19.5	52.9	299	85.6
17	11	36	19.4	52.7	308	88.1
18	11	37	18.5	52.8	320	91.4
19	11	32	19.6	52.9	301	86.1
20	11	39	18.7	52.9	301	85.9
21	11	26	17.5	52.8	277	79.1
22	11	30	19.1	52.6	306	87.4
23	11	33	19.5	52.7	298	85.1
24	11	35	19.9	52.4	303	86.5
25	11	36	19.4	53.1	313	89.6

Average	34	19.2	52.8	299	85.6
Std Dev	3	0.6	0.2	10	3.0
Maximum	39	19.9	53.1	320	91.4
Minimum	26	17.5	52.4	277	79.1
N-value: 19					

Sample Interval Time: 27.36 seconds.

GP554-3126 28.5/30  
JIM SMITH Interval start: 8/21/2023  
TB-1  
AR: 1.20 in/2 SP: 0.492 k/ft3  
LE: 37.61 ft EM: 30000 ksi  
WS: 16807.9 fts

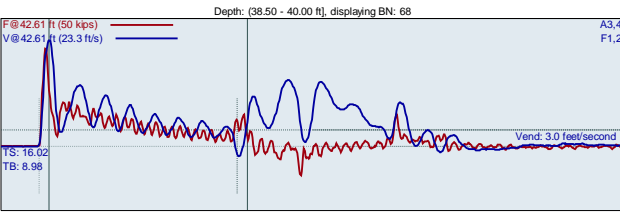


F1 : [648AWJ1] 226.21 PDICAL (1) FF1 A3 (PR): [K4483] 410.187 mv/6.4v/5000g (1) VF1  
F2 : [648AWJ2] 225.58 PDICAL (1) FF1 A4 (PR): [K10491] 421.907 mv/6.4v/5000g (1) VF1

BL#	BC /6"	FMX kips	VMX ft/s	BPM bpm	EFV ft-lb	ETR %
26	5	38	19.1	1.9	302	86.4
27	5	35	18.9	52.0	301	86.1
28	5	29	18.8	52.0	299	85.5
29	5	35	19.2	52.7	299	85.5
30	5	37	19.4	52.5	297	84.8
31	8	37	19.5	52.4	307	87.7
32	8	26	16.4	52.7	282	80.5
33	8	34	19.5	52.4	307	87.6
34	8	40	19.1	52.2	307	87.6
35	8	37	19.4	52.6	299	85.5
36	8	40	20.6	52.4	321	91.7
37	8	41	19.6	52.8	308	87.9
38	8	40	19.8	52.7	313	89.5
39	10	34	20.2	52.2	323	92.2
40	10	32	19.4	52.8	297	84.9
41	10	36	19.8	52.6	311	88.8
42	10	37	19.7	52.5	317	90.7
43	10	35	20.0	52.6	324	92.6
44	10	38	19.5	52.7	308	88.1
45	10	34	20.1	52.4	322	92.0
46	10	35	19.7	52.4	322	92.0
47	10	37	19.9	52.6	314	89.7
48	10	37	19.8	52.7	332	94.8
Average		36	19.6	52.6	312	89.1
Std Dev		3	0.8	0.2	12	3.3
Maximum		41	20.6	52.8	332	94.8
Minimum		26	16.4	52.2	282	80.5
N-value: 18						

Sample Interval Time: 25.16 seconds.

GP554-3126 28.5-30  
JIM SMITH Interval start: 8/21/2023  
TB-1  
AR: 1.20 in/2 SP: 0.492 k/ft3  
LE: 42.61 ft EM: 30000 ksi  
WS: 16807.9 ft/s



F1 : [648AWJ1] 226.21 PDICAL (1) FF1		A3 (PR): [K4483] 410.187 mm/6.4v/5000g (1) VF1				
F2 : [648AWJ2] 225.58 PDICAL (1) FF1		A4 (PR): [K10491] 421.907 mm/6.4v/5000g (1) VF1				
BL#	BC /6"	FMX kips	VMX ft/s	BPM bpm	EFV ft-lb	ETR %
49	5	34	19.6	1.9	307	87.6
50	5	34	19.3	52.0	301	86.1
51	5	27	16.5	52.7	278	79.4
52	5	33	19.9	52.5	310	88.6
53	5	29	17.7	52.7	288	82.2
54	8	29	18.6	52.5	295	84.2
55	8	23	15.6	52.9	287	82.0
56	8	34	20.1	52.6	323	92.2
57	8	28	18.1	52.8	295	84.3
58	8	38	18.8	53.1	312	89.1
59	8	35	19.2	52.6	329	94.0
60	8	36	19.3	52.9	327	93.3
61	8	40	19.7	52.8	323	92.4
62	9	35	18.8	53.0	320	91.3
63	9	37	19.1	52.7	320	91.3
64	9	35	19.9	52.9	327	93.4
65	9	29	18.8	52.7	314	89.7
66	9	35	19.7	53.0	342	97.8
67	9	36	19.9	52.8	331	94.5
68	9	38	19.3	52.8	335	95.8
69	9	36	19.9	52.5	325	92.9
70	9	39	19.5	52.9	329	94.0
Average		34	19.1	52.8	320	91.3
Std Dev		4	1.0	0.2	15	4.1
Maximum		40	20.1	53.1	342	97.8
Minimum		23	15.6	52.5	287	82.0
N-value: 17						

Sample Interval Time: 23.91 seconds.

Summary of SPT Test Results

Project: GP554-3126, Test Date: 8/21/2023				EFV: Maximum Energy ETR: Energy Transfer Ratio - Rated				
FMX: Maximum Force								
VMX: Maximum Velocity								
BPM: Blows/Minute								
Test Length ft	Blows Applied /6"	N Value	N60 Value	Average FMX kips	Average VMX ft/s	Average BPM bpm	Average EFV ft-lb	Average ETR %
32.61	6-8-11	19	28	34	19.2	52.8	299	85.6
37.61	5-8-10	18	26	36	19.6	52.6	312	89.1
42.61	5-8-9	17	25	34	19.1	52.8	320	91.3
Overall Average Values:				35	19.3	52.7	310	88.5
Standard Deviation:				4	0.8	0.2	15	4.2
Overall Maximum Value:				41	20.6	53.1	342	97.8
Overall Minimum Value:				23	15.6	52.2	277	79.1



Exhibit B

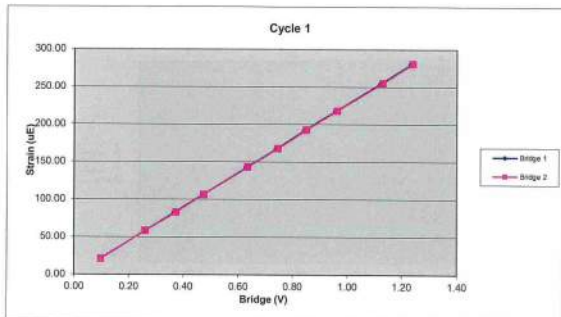
PDA Equipment Calibration



648AWJ		Cycle 1		
Sample	Force (lb)	Strain (µE)	Bridge 1 (V)	Bridge 2 (V)
1	0.00	0.00	0.00	0.00
2	799.99	21.12	0.10	0.10
3	2111.63	58.22	0.26	0.26
4	2997.39	82.70	0.37	0.37
5	3848.07	106.26	0.47	0.47
6	5131.83	143.07	0.63	0.63
7	6017.79	167.81	0.74	0.75
8	6872.07	192.74	0.85	0.85
9	7783.57	218.15	0.96	0.96
10	9136.93	255.02	1.12	1.13
11	10026.70	280.73	1.24	1.24

Bridge 1		Bridge 2	
Force Calibration (lb/V)	8120.30	Force Calibration (lb/V)	8089.75
Offset	-4.24	Offset	-2.24
Correlation	0.999998	Correlation	0.999995
Strain Calibration (µE/V)	228.56	Strain Calibration (µE/V)	227.70
Offset	-1.57	Offset	-1.51
Correlation	0.999991	Correlation	0.999983

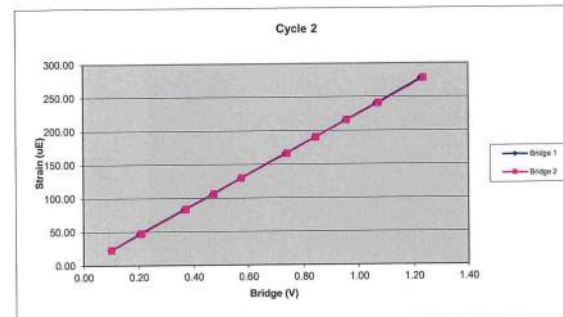
Force Strain Calibration	
EA (Kips)	35527.98
Offset	51.69
Correlation	0.999986



648AWJ		Cycle 2		
Sample	Force (lb)	Strain (µE)	Bridge 1 (V)	Bridge 2 (V)
1	0.00	0.00	0.00	0.00
2	805.54	22.23	0.10	0.10
3	1679.81	47.04	0.20	0.21
4	2989.11	83.03	0.37	0.37
5	3830.62	105.81	0.47	0.47
6	4658.00	129.50	0.57	0.58
7	5984.74	165.81	0.74	0.74
8	6848.87	189.76	0.84	0.84
9	7747.90	215.15	0.95	0.96
10	8674.21	240.08	1.07	1.07
11	9994.82	277.48	1.23	1.24

Bridge 1		Bridge 2	
Force Calibration (lb/V)	8127.14	Force Calibration (lb/V)	8103.79
Offset	10.37	Offset	-14.59
Correlation	0.999997	Correlation	0.999997
Strain Calibration (µE/V)	225.29	Strain Calibration (µE/V)	224.64
Offset	0.36	Offset	-0.33
Correlation	0.999990	Correlation	0.999992

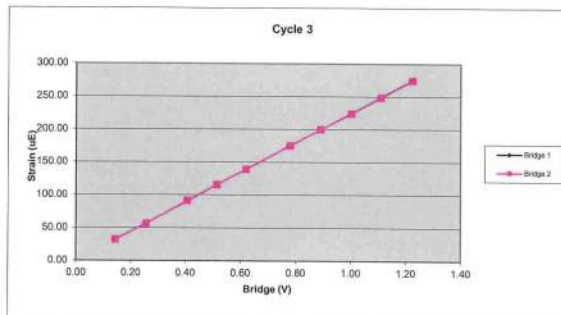
Force Strain Calibration	
EA (Kips)	36073.41
Offset	-2.66
Correlation	0.999993



648AWJ		Cycle 3		
Sample	Force (lb)	Strain (µE)	Bridge 1 (V)	Bridge 2 (V)
1	0.00	0.00	0.00	0.00
2	1153.24	31.90	0.14	0.14
3	2056.55	56.28	0.26	0.26
4	3310.19	91.18	0.41	0.41
5	4155.51	115.51	0.51	0.51
6	5035.81	139.16	0.62	0.62
7	6303.78	175.10	0.78	0.78
8	7221.91	199.87	0.89	0.89
9	8120.94	223.92	1.00	1.00
10	9001.15	246.68	1.11	1.11
11	9931.66	274.33	1.22	1.23

Bridge 1		Bridge 2	
Force Calibration (lb/V)	8132.32	Force Calibration (lb/V)	8118.57
Offset	-20.37	Offset	-15.36
Correlation	0.999998	Correlation	0.999997
Strain Calibration (µE/V)	224.79	Strain Calibration (µE/V)	224.41
Offset	-0.57	Offset	-0.43
Correlation	0.999984	Correlation	0.999985

Force Strain Calibration	
EA (Kips)	36175.62
Offset	0.42
Correlation	0.999984



Bridge Excitation (V) 5  
Shunt Resistor (ohm) 60.4k

Calibration Factors		648AWJ	
Bridge 1 (µE/V)	226.21	Bridge 2 (µE/V)	225.58
EA Factor (Kips)	35925.67	Area (in <sup>2</sup> )	1.20

Calibrated by: *Aht*  
Calibrated Date: 3/3/2022

Pile Dynamics Inc  
30725 Aurora Rd  
Solon, OH 44139

Traceable to N.I.S.T.



Accelerometer Calibration Certificate  
Pile Dynamics, Inc.



Calibrated by Pile Dynamics, Inc.  
Calibration performed on 26Oct2021

Serial No: K4483 Temperature: 22.1 °C  
Model: PR Humidity: 45%  
Calibrated on: Channel 3 on 8G 5161 LE

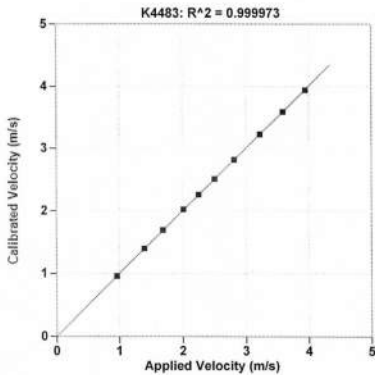
PDA CALIBRATION FACTOR  
410.2 mv/5000g  
(62.0  $\mu$ v/g)  
R<sup>2</sup>: 0.999973 [Chip programmed]

Operator: William Johnson

Signed

Ref Acc 1: 690961 Cal on: 27Jan2021  
978 g's/volt  
Ref Acc 2: 691321 Cal on: 09Feb2021  
960 g's/volt

Reference accelerometer calibrations are traceable to  
the United States National Institute of Standards and  
Technology (NIST).



Date printed: 26Oct2021, version: 2020.30.170 9.57

Accelerometer Calibration Certificate  
Pile Dynamics, Inc.



Calibrated by Pile Dynamics, Inc.  
Calibration performed on 25Jan2022

Serial No: K10491 Temperature: 19.3 °C  
Model: PR Humidity: 30%  
Calibrated on: Channel 3 on 8G 5161 LE

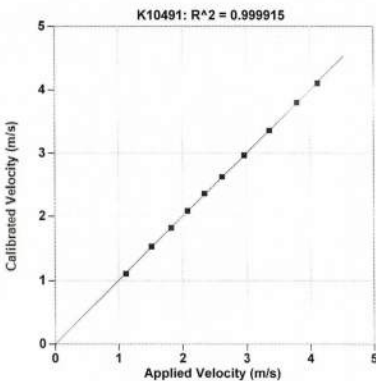
PDA CALIBRATION FACTOR  
421.9 mv/5000g  
(84.4  $\mu$ v/g)  
R<sup>2</sup>: 0.999915 [Chip programmed]

Operator: William Johnson

Signed

Ref Acc 1: 691321 Cal on: 09Feb2021  
960 g's/volt  
Ref Acc 2: 690961 Cal on: 27Jan2021  
978 g's/volt

Reference accelerometer calibrations are traceable to  
the United States National Institute of Standards and  
Technology (NIST).



Date printed: 25Jan2022, version: 2020.30.170 9.05