SOILS AND FOUNDATIONS
REPORT NO. 02-25

PROJECT: WV NP NERI 107(3)
LANDSLIDES REPAIRS

CUNARD RIVER ACCESS ROAD
FAYETTE COUNTY, WEST VIRGINIA

US DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
EASTERN FEDERAL LANDS HIGHWAY DIVISION
22001 LOUDOUN COUNTY PARKWAY, BUILDING E-2, SUITE 200
ASHBURN, VIRGINIA 20147

NOVEMBER 2025

TABLE OF CONTENTS

1. INTRODUCTION 3
1.1. General 3
1.2. Project Location 3
1.3. Background 3
2. GEOLOGY 3
2.1. Regional Geology 3
3. SUBSURFACE EXPLORATION PROGRAM 4
3.1. Drilling, Sampling, Equipment, and Testing 4
3.2. Laboratory Testing 4
4. SUBSURFACE CONDITIONS 4
4.1. General Stratification 4
4.2. Groundwater 4
5. DESIGN ANALYSIS AND RECOMMENDATIONS 5
5.1. Design Alternatives 5
5.2. Design Analysis 6
5.3. Recommendations 7
6. CONSTRUCTION 8
7. REFERENCES 9
8. DISCLAIMER/LIMITATIONS CLAUSE 10
APPENDICES 11
Appendix I – Figures 12
Appendix II – Geotechnical Data Report 14
Appendix III – Design Analysis 77
Appendix IV – Site Photographs 126

Note: ***Design changes subsequent to publication of this report and prior to the project's advertisement will be documented by a memo attached after the title page.***

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CUNARD RIVER ACCESS ROAD
FAYETTE COUNTY, WEST VIRGINIA

1. INTRODUCTION

1.1. General

This report presents the results of the subsurface exploration, laboratory testing, geotechnical analysis, and evaluations and recommendations for the repair of one (1) landslide along Cunard River Access Road (Route 107) in West Virginia.

1.2. Project Location

The site is located within New River Gorge National Park and Preserve. Table No. 1 includes a summary of the sites locations. Vicinity maps and sites location are shown in Figures No. 1 through No. 2 in Appendix I.

Table No. 1: Field Data

WV NP NERI 107(3) Site List		
Site ID		Description
Route	Station	
107	100+93 to 121+90	Landslide/Embankment Failure

1.3. Background

Cunard Access Road experienced damage from severe storm events. The damage included landslides and embankment failures. This project aims to repair the storm-related damages at the subject site. Site photographs are included in Appendix IV – Site Photographs.

2. GEOLOGY

2.1. Regional Geology

Available geologic information indicates the project sites are located within the Pocahontas, Bluestone and Princetone Formations. The geologic map of the project area is included in Appendix II – Geotechnical Data Report.

3. SUBSURFACE EXPLORATION PROGRAM

3.1. Drilling, Sampling, Equipment, and Testing

A subsurface exploration program consisting of soil borings and rock cores was conducted to characterize subsurface conditions at the subject site. Drilling was performed by Terracon on September 8, 2022. The program consisted of drilling the total of two (2) borings. Detail information of the subsurface exploration, borings location plan, boring logs, and rock cores are included in Appendix II – Geotechnical Data Report.

3.2. Laboratory Testing

A laboratory testing program was conducted on representative soil and rock core samples recovered during the subsurface exploration. The primary purpose of the testing program was to aid in the classification and evaluation of the engineering properties of soils and rock present at the site. Laboratory tests included natural moisture content (AASHTO T-265), Atterberg limits (AASHTO T-89 & T-90), particle size analysis (AASHTO T-88), and classification (AASHTO M-145) on soil samples, and Unconfined Compressive Strength (UCS) Test (ASTM D 7012) of intact rock core samples. All tests were conducted in accordance with applicable AASHTO/ASTM standard test methods. The results of the laboratory testing program are included in Appendix II – Geotechnical Data Report

4. SUBSURFACE CONDITIONS

4.1. General Stratification

In general, the soil borings encountered three layers. These were Layer 1 – Existing Fill, Layer 2 – Native Soil, and Layer 3 – Bedrock. A brief description of the soils encountered is presented in Appendix II – Geotechnical Data Report.

It should be noted that the stratification lines designating the interfaces between soil and rock types on the boring logs, represent approximate boundaries. The transition between materials may be gradual. One or more of the units may be absent at specific locations.

Site observations reveal the presence of bedrock outcrops at differents locations along Cunard River Access Road. Coubles, Boulders and shallow Bedrock may be encountered at different depths and locations along and at the site. See Section 6 of the report.

4.2. Groundwater

Groundwater was not encountered in any of the two (2) soil borings. Additional detailed information can be found in Appendix II – Geotechnical Data Report. It must be noted that, changes in groundwater levels could be expected due to seasonal variations, precipitation, evaporation, and surface water runoff.

5. DESIGN ANALYSIS AND RECOMMENDATIONS

5.1. Design Alternatives

Landslides occur as a result of unbalanced pressures along the sloping ground. The presence of water, works as a trigger mechanism by increasing the driving forces and/or reducing the shear strength of the in-situ materials. To mitigate slope stability problems, two general approaches can be used. One approach is to reduce the driving forces and increasing shear strength by lowering the groundwater table by improving the surface and subsurface drainage systems. The second approach is to increase the resisting forces by buttressing the slope, adding a retaining structure, or by reinforcing the embankment fill.

Three alternatives were considered given its feasibility and effectiveness for landslides stabilization, subsurface conditions, constructability, cost, project requirements, and our experience with similar projects. A brief discussion of each alternative is presented below.

- Alternative No. 1 – MSE (Mechanically Stabilized Earth) Retaining Wall with Welded Wire Mesh Facing

This alternative consists of re-establishing the roadway and stabilize the slope by constructing a retaining wall with geosynthetic reinforced soil. MSE walls are constructed using common construction materials, and conventional equipment and techniques, providing an economical and durable structure. It is cost-effective, self-draining, and can tolerate larger differential settlements compared to other repair alternatives. This alternative will require road closure at all times. These structures can be constructed with a Battered vegetated system that provides the opportunity for vegetation to grow and mimic the surrounding landscape.

- Alternative No. 2 – Anchored Soldier Pile Wall

This alternative consists of re-establishing the roadway and stabilize the slope by constructing an Anchored Soldier Pile Wall. This structure is a non-gravity cantilvered wall that relies on permanent ground anchors for additional lateral support and slope stability mitigation measures. This type of wall requires a specialized contractor, equipment and techniques which will be a more costly approach in comparison to MSE and RSS structures.

- Alternative No. 3 – Reinforced Soil Slope (RSS)

Reinforced Soil Slope systems are composed of continuoes layers of geogrid laid down alternatively with horizontal layers of compacted select granular backfill or granular backfill (AASHTO # 57 Stone) with a face no steeper than 70° from horizontal. These types of systems are constructed using common construction materials, conventional equipment and techniques, providing an economical and durable structure. It is cost-effective, self-draining, and can tolerate larger differential settlements compared to other repair alternatives. These structures can be constructed with a vegetated system that provides the opportunity for vegetation to grow and mimic the surrounding landscape.

It should be noted that both alternatives No. 1 and No. 3 will require a significantly much larger footprint for construction.

Our recommendation is listed below:

- Alternative No. 2 - Anchored Soldier Pile Wall.

Alternative No. 1 and No 3 are not recommended due to constructability challenges (excavation), environmental impact (excessive LOD), substantial negative effects on the park's aesthetics, which would persist until trees and vegetation are able to grow.

5.2. Design Analysis

The design of the structures was conducted using limit equilibrium methodology, in general accordance with the design concepts and procedures presented in FHWA Publication FHWA-IF-99-015, "Geotechnical Engineer Circular No. 4 – Ground Anchors and Anchored Systems", and following "AASHTO LRFD Bridge Design Specifications, 9th Ed." (2020) November 2021 Errata design requirements. A summary of soil engineering parameters assumed in the external, internal, and global stability analyses are presented in Table No. 2 and Table No. 3.

Table No. 2: Summary of assumed engineering properties for analysis and design of structures.

Material Type	Unit Weight (pcf)	Cohesion (psf)	Internal Friction Angle ϕ (°)
Aggregate Base Course	120 – 130	0.0	34 – 38
Layer 1	95 – 120	0.0	28 – 34
Layer 2	100 – 120	0.0	22 – 36
Bedrock	155 – 165	500 – 1,000	38 – 45

Table No. 3: Presumptive ultimate unit bond strength of gravity grouted permanent ground anchors.

Material Type	q_{Bond} (ksf)
Silty Sand and Gravel soils	1.5 – 3.0
Silstone and Sandstone	14.0 – 28.0

The selected load factors and combinations are presented in Table No. 4. The factors follow (AASHTO-LRFD, 2020). The resistance factor used for design are presented inTable No. 5.

Table No. 4: Retaining walls design load factors and combinations.

Load Combination	EH	EV	ES	LS
Strength I (Max)	1.50	1.35	1.50	1.75
Strength I (Min)	0.90	1.00	0.75	1.75
Service I	1.00	1.00	1.00	1.00
Extreme Event I	1.00	1.00	1.00	0.00 or 0.50

Table No. 5: Anchored Soldier Pile wall design resistance factors.

Analysis	Resistance Factor
Axial Compressive Resistance of Vertical Elements	Φ: 0.50
Side Resistance in Sand β-method	Φ: 0.55
Passive Resistance of Vertical Elements	Φ: 0.75
Anchor Pullout Resistance	Φ: 0.65
Anchor Tensile Resistance	Φ: 0.80
Pile Shear Resistance	Φ: 1.00
Overall/Global	Φ: 0.65 (FS:1.5)

Analysis	Resistance Factor
Overall/Global Extreme Event I	Φ: 0.9 (FS:1.1)

A uniform distributed live surcharge load of 250 psf was applied along the travelway to account for traffic loading following (AASHTO-LRFD, 2020)– Section 3.11.6.4 requirements.

External and internal stability analysis computations were performed using PTC Mathcad Prime v. 10.0 software program by Computer Software Company (PTC) Inc, and global/overall stability analysis using the computer program SLIDE2 v. 9.038 and RSPile v. 3.022 by Rocscience, Inc. Design calculations and computer output files are included in Appendix III – Design Analysis.

According to AASHTO 11.5.4.2, a seismic design shall not be considered mandatory for walls located in Seismic Zones 1 through 3, or for walls at Sites where the site adjusted peak ground acceleration is less than or equal to 0.4g, unless one or more of the following is true:

- Liquefaction induced lateral spreading or slope failure, or seismically induced slope failure, due to the presence of sensitive clays that lose strength during the seismic shaking, may impact the stability of the wall for the design earthquake.
- The wall supports another structure that is required, based on the applicable design code or specification for the supporting structure, to be designed for seismic loading and poor seismic performance of the wall could impact the seismic performance of that structure.

In addition, according to C11.5.4.2, paragraph 7, a seismic analysis should be considered mandatory if the wall is located in seismic zone 2 or higher, and if either of the following is greater than 30 feet:

- The exposed wall height plus the average depth over the width of the wall of any soil surcharge present.
- For tiered walls, the sum of the exposed height of all the tiers plus the average soil surcharge depth.

Based on the above listed criteria, it was concluded that the retaining structure along Route 107 do not require an external or internal seismic evaluation, as applicable, due to an adjusted PGA less than 0.4g, and the retaining structures are in Seismic Zone 1 to 3. However, an Extreme Event I Overall Stability Analysis is required. For this analysis, it was assumed an allowable lateral deformation based on the flexible nature of the types of structure. See the evaluation calculations in Appendix III – Design Analysis for details.

5.3. Recommendations

The Anchored Soldier Pile wall system must have a maximum wall height of 19 feet, minimum drilled shaft embedment depth of 27 feet, with H-Pile spaced horizontally by 6.0 feet, and with H-Pile tip elevation of 1065 feet or deeper. A minimum of three (3) rows of permanent ground anchores is required. The anchors must have a minimum unbonded and bonded lengths of 20 feet and 30 feet respectively, and a minimum anchors tensile and pullout resistance of 45,000 lb. The maximum embankment height behind the wall must be 5.0 ft with a slope no steeper than 1V:2H.

5.3.1. Underdrain System

The Anchored Soldier Pile Wall must include a subsurface water drainage system composed of granular backfill and a minimum 6 inch diameter pipe. The drainage pipes must be surrounded by a filter fabric to prevent the migration of fines. The perforated pipe will drain subsurface water into a minimum 6 inch non-perforated outlet pipe located at the lowest point in front of the wall and at a maximum spacing of 75 feet. To keep wildlife out of the retaining wall drainage system a 1/4" mesh should be installed to cover the non-perforated pipe outlet.

6. CONSTRUCTION

The contractor attention is drawn to the fact, site observations and the subsurface exploration reveal the presence of bedrock at the site location. Coubles, Boulders and **Shallow Bedrock** shall be anticipated at different depths and locations**. It is responsibility of the contractor to determine the means and methods of, but not limited to, drilled shaft construction, permanent ground anchor drilling and installation, and excavation.**

7. REFERENCES

AASHTO-LRFD. (2020). *AASHTO LRFD Bridge Design Specification* (9th ed.). Washington, D.C.: American Association of State Highway and Transportation Officials.

Berg, R., Christopher, B., & Samtani, N. (2009). *Design of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes* (Vol. I & II). Washington, D.C.: National Highway Institute (NHI), Federal Highway Administration (FHWA), U.S. DOT.

FHWA. (2024). *Standard Specifications For Construction of Roads and Bridges on Federal Highway Projects (FP-24).* US Department of Transportation. Washington D.C.: US Department of Transportation.

FHWA. (2015). *Strength Characterization of Open-Graded Aggregates for Structural Backfills - FHWA-HRT-15-034.* McLean: FHWA.

8. DISCLAIMER/LIMITATIONS CLAUSE

The subsurface explorations and tests described in this report have been conducted in accordance with standard practices and procedures (except as specifically noted). The results of these exploration and tests represent conditions at the specific locations and dates indicated. Subsurface conditions between these locations may vary. The Geotechnical Design Analyses and Recommendations Sections of this report are based on subsurface exploration data and subsurface profiles provided by others, and include interpretations and recommendations developed by the Government in the process of preparing the design. These interpretations are not intended as a substitute for the personal investigation, independent interpretation, and judgment of the Contractor.

JONATHAN HERRERA-ROLDAN
Digitally signed by JONATHAN HERRERA-ROLDAN
Date: 2025.11.18 10:59:55 -05'00'

Prepared by:
Jonathan Herrera-Roldán, P.E.
Sr. Geotechnical Engineer

MOUNIR A ABOUZAKHM
Digitally signed by MOUNIR A ABOUZAKHM
Date: 2025.11.18 11:20:29 -05'00'

Reviewed by:
Mounir Abouzakhm, P.E.
Division Geotechnical Engineer

APPENDICES

Appendix I – Figures

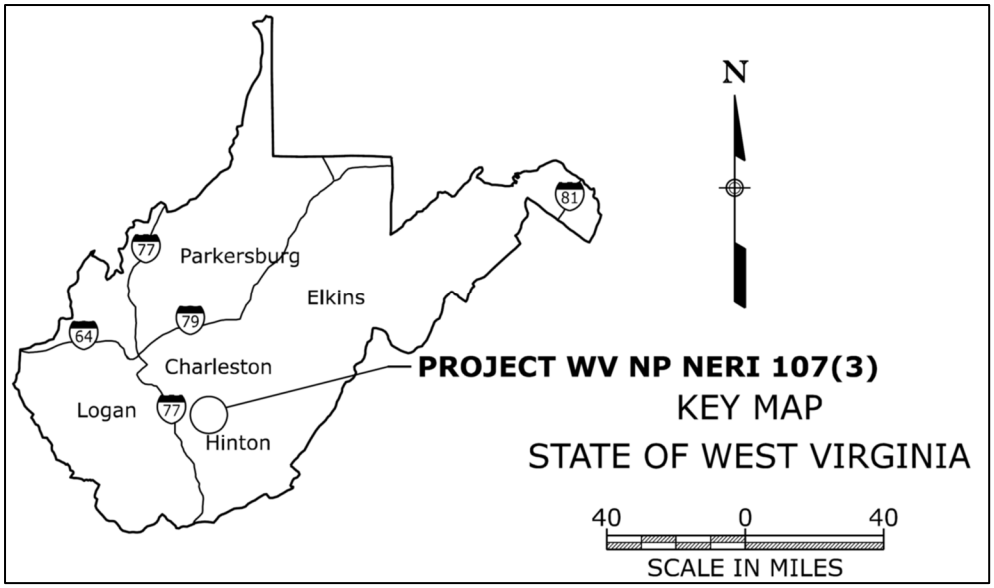

Figure No. 1

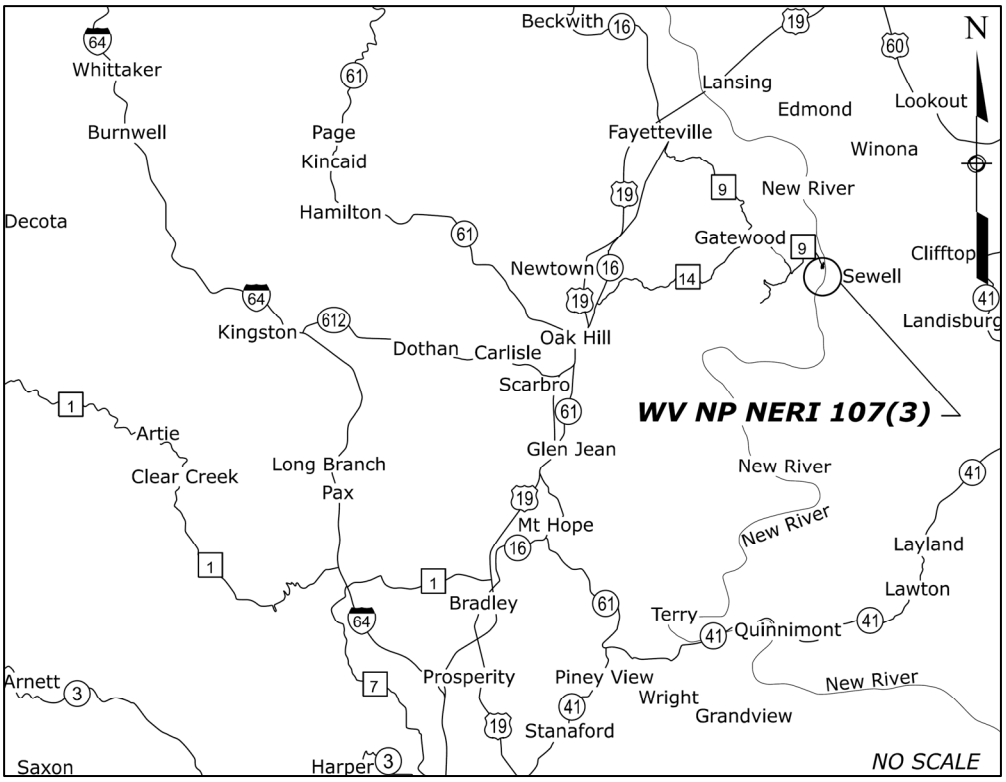

Figure No. 2

Appendix II – Geotechnical Data Report

AECOM
150 Clay Street, Suite 430
Morgantown, WV 26501
aecom.com

December 1, 2022

Your Reference
Contract No. 693C7321D000003,
Task Order 693C7322F00101N

Our Reference
60691052 EFL New River
Geotech

Mr. Jonathan Herrera-Roldan
Contractoing Officers Representative
Eastern Federal Lands Highway Divisi
220001 Loudoun County arkway
Building E-2, Suite 200
Ashburn, Virginia 20147

RE: NERI 107(2) Subsurface Exploration and Laboratory Testing in New River Gorge National Park Fayette County, West Virginia

Dear Mr. Herrera-Roldan

We are pleased to submit the attached final geotechnical report (Revision 1, dated 01 DEC 2022) and review comment status in accordance with; Contract No. 693C7321D000003, Task Order 693C7322F00101N, Highway and/or Bridge Design and Engineering Services Indefinite Delivery, Indefinite Quantity Contracts (IDIQC), Project: NERI 107(2) - Subsurface Exploration and Laboratory Testing in New River Gorge National Park Fayette County, West Virginia.

The AECOM team, AECOM and partner Terracon, completed eight (8) borings in the New River Gorge National Park, six (6) along Cunard Road and two (2) along Glade Creek Road and laboratory testing to assist EFLHD in development of engineering parameters for the remediation of subsurface conditions at the site. All borings were advanced with a track-mounted, rotary drill rig using continuous flight hollow stem augers. A split-barrel sampling spoon was utilized to collect samples and to provide the data for the Standard Penetration Test (SPT).

All bore holes were observed by a Geotechnical Inspector and logs maintained. Samples were transported to the laboratory where the Moisture Content, Grain Size Distribution, Unconfined Compression, and Atterberg Limits were determined. The attached final Geotechnical Report provides the in-depth information for this project for your use.

Thank you for the opportunity. Please feel free to reach out with any questions or concerns.

Kind regards,

Chris Channell, PE
Project Manager
AECOM
T: 304-381-9267
M: 304-290-8127
E: Brian.Channell1@AECOM.com

NERI 107(2) Subsurface Exploration and Laboratory Testing in New River Gorge

Geotechnical Final Data Report

Prepared for:

AECOM
150 Clay Street Suite 430
Morgantown, WV 26501

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November 8, 2022

AECOM
150 Clay Street Suite 430
Morgantown, WV 26501

Attn: Brian "Chris" Channell
P: 304.381.9267
E: brian.channell1@aecom.com

Re: Geotechnical Data Report
NERI 107(2) Subsurface Exploration and Laboratory Testing in New River Gorge
Fayette County
West Virginia
Terracon Project No. N2225050

Dear Mr. Channell:

We have completed the scope of Geotechnical Data services for the above referenced project in general accordance with Terracon Proposal No. PN2225050 dated July 22, 2022. This report presents the findings of the subsurface exploration and laboratory testing for the proposed project.

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

Sincerely,

Terracon

Todd A. Griffith, P.E.
Geotechnical Department Manager

Kevin M. Ernst, P.E.
Principal, Regional Manager

TODD A. GRIFFITH
REGISTERED
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STATE OF
WEST VIRGINIA
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Table of Contents

Report Summary i
Introduction 1
Project Description 1
Site Conditions 2
Geotechnical Characterization 4
General Comments 6

Figures

Subsurface Profiles

Attachments

Exploration and Testing Procedures
Photography Log (Rock Core Photographs and Boring Locations)
Site Location and Exploration Plans
Exploration and Laboratory Results
Supporting Information

Note: This report was originally delivered in a web-based format. **Blue Bold** text in the report indicates a referenced section heading. The PDF version also includes hyperlinks which direct the reader to that section and clicking on the terracon logo will bring you back to this page. For more interactive features, please view your project online at **client.terracon.com**.

Refer to each individual Attachment for a listing of contents.

Report Summary

Topic [1]	Overview Statement [2]
Project Description	The project is in at the New River Gorge National Park in Fayette County, West Virginia. As stated in Section C of the Statement of work, engineering parameters of the subsurface soils are required to evaluate remediation recommendations for the landslides that are observed at Cunard and Glade Creek Roads. The purpose of the project is to perform subsurface exploration and laboratory testing for the delivery of boring logs, laboratory test results, and soil profiles for the Federal Highway Administration, Eastern Federal Lands Highway Division (EFLHD).
Geotechnical Characterization	In general, the borings encountered existing fill material likely placed during development of the original roadways, underlain by colluvial material associated with the downslope movement of soil and rock. Below the colluvial material some residual material was encountered in several borings before bedrock was encountered.
General Comments	This section contains important information about the limitations of this geotechnical engineering report.

1. This summary is for convenience only. It should be used in conjunction with the entire report for design purposes.

Introduction

This geotechnical data report presents the results of the subsurface exploration and laboratory testing services performed for NERI 107(2) project located along Cunard and Glade Creek Roads in the New River Gorge National Park in Fayette County, West Virginia. The purpose of these services was to provide information relative to:

- Subsurface soil conditions
- Laboratory testing results
- Groundwater conditions

The Scope of Services for this project included the advancement of test borings, laboratory testing, development of boring logs, development of subsurface profiles, and preparation of this data report.

Drawings showing the site and boring locations are shown on the **Site Location** and **Exploration Plan**, respectively. The results of the laboratory testing performed on soil samples obtained from the site during the field exploration are included on the boring logs and subsurface profiles as well as on separate graphs in the **Exploration Results** section.

Project Description

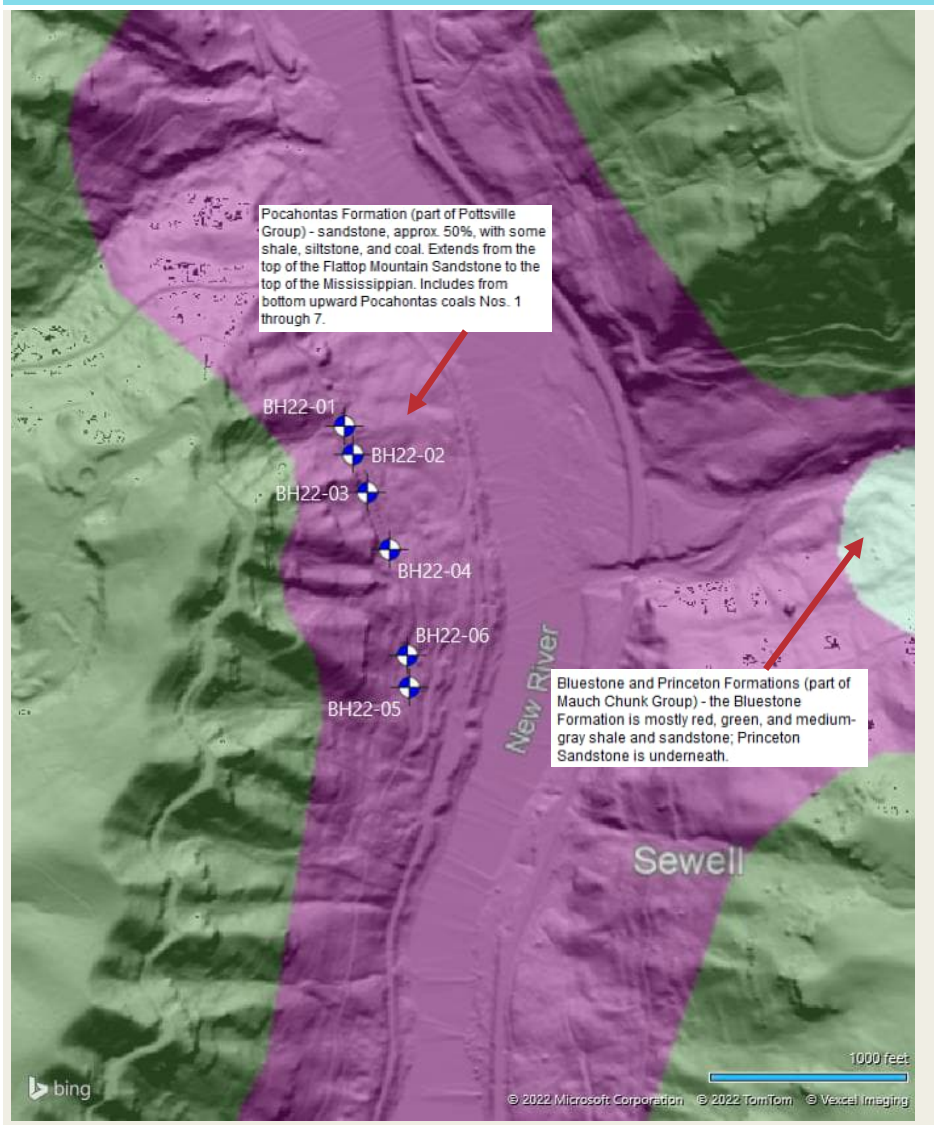
A summary of the project conditions and description is below and is based on the information provided in the Scope of Work as well as discussions and phone calls with the project team during the project execution.

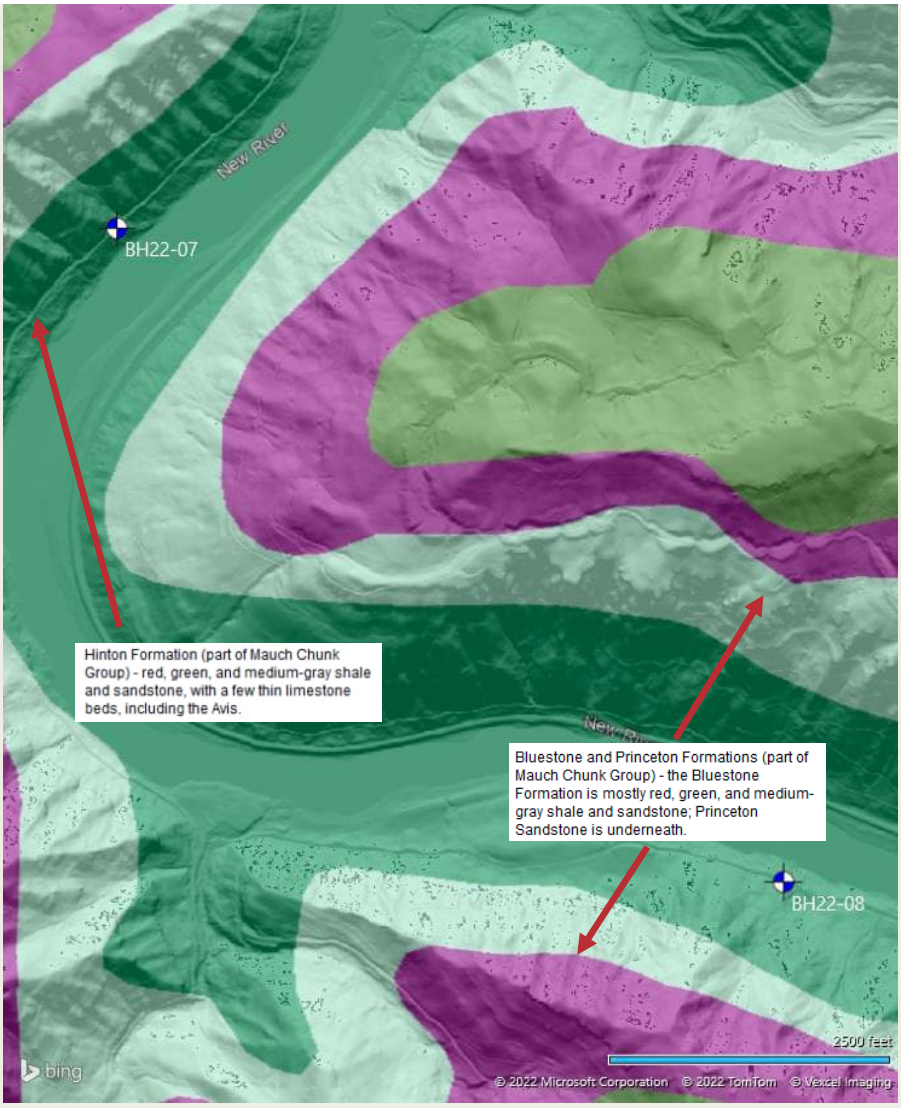
Item	Description
Information Provided	Information was provided in the RFP Section C provided by email.
Project Description	We understand that the downslope sides of Cunard Road and Glade Creek Road within the New River Gorge National Park in Fayette County, West Virginia, has shown signs of instability. Remediation efforts are planned by Federal Highway Administration, Eastern Federal Lands Highway Division (EFLHD) and the purpose of this project is to perform borings and laboratory testing to assist in development of engineering parameters for the subsurface conditions at the site.

Site Conditions

The following description of site conditions is derived from the site visits in association with the field exploration, laboratory testing and review of publicly available geologic and topographic maps.

Item	Description
Site Information	The project is located along two separate roadways within the New River Gorge National Park. Borings BH22-01 to BH22-06 were drilled along Cunard Road and Borings BH22-07 and BH22-08 were drilled along Glade Creek Road. The as drilled boring locations were surveyed by a subcontracted survey crew from Allegheny Surveys See **Site Location**
Existing Improvements	Cunard Road is currently a two-lane, asphalt paved, roadway that allows for access to put-in and take-out areas for personal and commercial white-water rafting. Glade Creek Road is a single lane gravel roadway that allows access to campgrounds along the New River and Glade Creek.
Current Ground Cover	Asphalt and gravel paved roadways
Existing Topography (Google Earth)	The walls of the New River Gorge are very steep, and the upslope and downslope portions of the roadways are steep which causes slope instability.
Geology – Cunard Road Borings	Borings BH-22-01 through BH22-06 are mapped within the new River Gorge and the underlying bedrock is the Pennsylvanian aged Pocahontas Formation and the Mississippian aged Bluestone formation. The Pocahontas Formation contains sandstone, siltstone, shale, mudstone, and coal. The mapped coal beds include the Pocahontas No. 6 and the Pocahontas No. 3 in this area. The Pocahontas No. 3 coal bed exists at approximate elevation 1032 feet and is 1.0 ft. thick. The Pocahontas No. 6 seam outcrops just above the roadway at the boring locations and is less than 1 ft. thick. The Bluestone formation contains mudstone, shale, siltstone, and sandstone. A few thin impure discontinuous coal beds are present as well.

Item	Description
Geologic Map – Cunard Road Borings	
Geology – Glade Creek Borings	Borings BH22-07 and BH22-08 are mapped within the New River Gorge and the underlying bedrock at these locations is the Mississippian aged Upper Hinton Member. This member consists of a variable succession of mudstone, sandstone with limited occurrences of coal. The limestones can contain marine shell beds. Sandstones are generally very fine to medium grained and can contain conglomeratic lenses. Coals found within this member are usually centimeter scale and impure.

Item	Description
Geology Map – Glade Creek Borings	

Geotechnical Characterization

A general characterization of the subsurface conditions has been developed based upon review of the subsurface exploration, laboratory data, geologic setting and provided project information. Conditions observed at each exploration point are indicated on the individual logs. The borings were surveyed after completion of drilling to determine the GPS coordinates and the elevations of each boring. This information is presented in the table below and also on the boring logs and subsurface profiles The individual logs can be found in the **Exploration Results** and the Subsurface Profiles can be found in the **Figures** attachment of this report.

Location	Boring	As Drilled Northing, Easting	As Drilled Elevation (feet)
Cunard Road	BH22-01	365171.292, 1961346.275	1237.1
	BH22-02	365029.138, 1961388.596	1222.7
	BH22-03	364838.560, 1961461.347	1209.5
	BH22-04	364522.462, 1961590.082	1165.1
	BH22-05	363859.677, 1961673.025	1108.6
	BH22-06	364020.063, 1961663.196	1111.3
Glade Creek Road	BH22-07	308364.212, 1952327.949	1305.9
	BH22-08	302570.094, 195825.054	1272.2

As part of the general characterization the following layers within the subsurface profiles for each site were identified. For a more detailed view of the model layer depths at each boring location, refer to the Boring Logs and Subsurface Profiles.

Cunard Road Borings (BH22-01 to BH22-06)

Layer	Range of Depths to bottom of layer [1]	Layer Name	General Description
1	**2.5 to 8 feet in**	**Existing Fill**	Gravel and sand including base aggregate for pavement. Fill was likely placed as part of development of the original roadway and as part of attempted slope instability remediations.
2	**11 to 33 feet in**	**Native Soil**	Predominantly granular material ranging from silty clay gravel and sand to silty sand with cobbles and boulders throughout
3	**Undetermined**	**Bedrock [2]**	Sandstone interbedded with siltstone and shale

1. Depth referenced from existing ground surface
2. All borings terminated in this stratum

Glade Creek Road Borings (BH22-07 to BH22-08)

Layer	Range of Depths to bottom of layer [1]	Layer Name	General Description
1	Unknown	Native Soil [2]	Predominantly granular material ranging from silty clay gravel and sand to silty sand with cobbles and boulders throughout
2	Undetermined in Boring BH22-07, not encountered in Boring BH22-08	Bedrock [3]	Sandstone interbedded with siltstone and shale

1. Depth referenced from existing ground surface
2. Boring BH22-08 terminated within this stratum
3. Boring BH22-07 terminated in this stratum

The boreholes were observed while drilling and immediately after completion for the presence and level of groundwater. Groundwater was not encountered in any of the borings during drilling. It should be noted that water was introduced in each boring where coring was performed either for bedrock sampling, as in Borings BH22-02 through BH22-06, or to penetrate boulders within the subsurface profile, as in Borings BH22-05 and BH22-08. Remnants of this introduced water was observed at 23 feet, 5 feet, 20.5 feet, and 2.3 feet, and 28 feet in Borings BH22-02, BH22-04, BH22-05, BH22-06, and BH22-08 respectively.

Groundwater conditions may be different at the time of construction. Groundwater conditions may change because of seasonal variations in rainfall, runoff, and other conditions not apparent at the time of drilling. Long-term groundwater monitoring was outside the scope of services for this project.

The results of field and laboratory testing are presented in the **Exploration Results**. The **General Comments** section provides an understanding of the report limitations.

General Comments

Analysis and opinions are based upon Terracon's understanding of the project, the geotechnical conditions in the area, and the data obtained from the site exploration. Variations will occur between exploration point locations or due to the modifying effects of construction or weather. The nature and extent of such variations may not become evident until during or after construction.

The Scope of Services does not include either specifically or by implication any environmental or biological (e.g., mold, fungi, bacteria) assessment of the site or identification or prevention of pollutants, hazardous materials or conditions. If the owner is concerned about the potential for such contamination or pollution, other studies should be undertaken.

The services and any correspondence are intended for the sole benefit and exclusive use of the client for specific application to the project discussed and are accomplished in accordance with generally accepted geotechnical engineering practices with no third-party beneficiaries intended. Any third-party access to services or correspondence is solely for information purposes to support the services provided by Terracon to the client. Reliance upon the services and any work product is limited to the client and is not intended for third parties. Any use or reliance of the provided information by third parties is done solely at their own risk. No warranties, either express or implied, are intended or made.

Site characteristics as provided are for design purposes and not to estimate excavation cost. Any use of the report in that regard is done at the sole risk of the excavating cost estimator as there may be variations on the site that are not apparent in the data that could significantly effect excavation cost. Any parties charged with estimating excavation costs should seek their own site characterization for specific purposes to obtain the specific level of detail necessary for costing. Site safety and cost estimating including excavation support and dewatering requirements/design are the responsibility of others.

Figures

Contents:

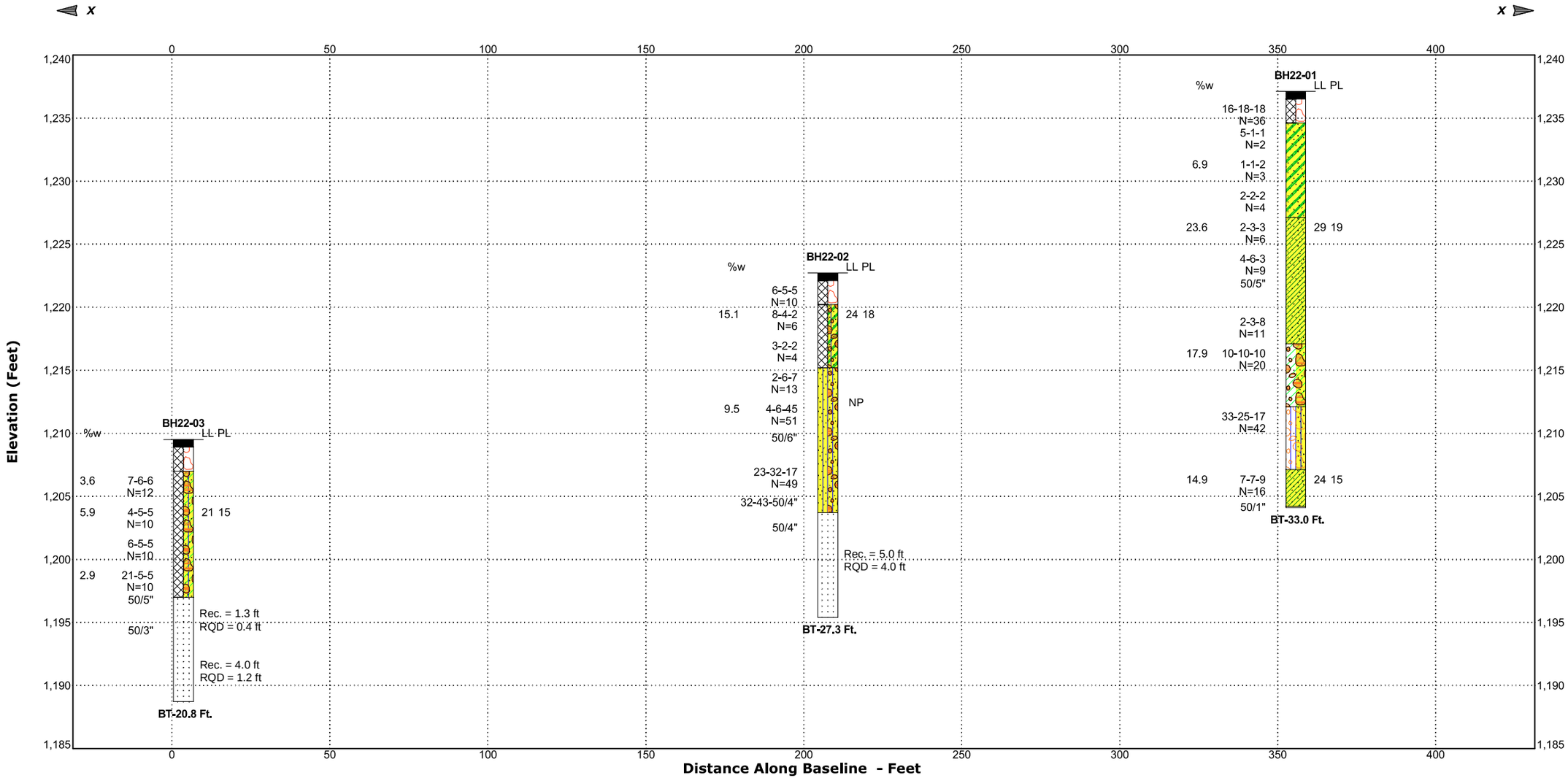
Subsurface Profiles

NERI 107(2) New River Gorge National Park
Cunard River Access and Glade Creek Road | Fayetteville, West Virginia
Terracon Project No. N2225050

Subsurface Profile

Borings BH22-01 through BH22-03

Terracon
912 Morris St
Charleston, WV



Notes	Water Level Observations	Explanation	Material Legend
See General Notes in Supporting Information for symbols and soil classifications. Soils profile provided for illustration purposes only. Soils between borings may differ AR - Auger Refusal BT - Boring Termination	Water Level Reading at time of drilling. Water Level Reading after drilling.	BH22-01 — Borehole Number Moisture Content — %w LL PL — Liquid and Plastic Limits Sampling (See General Notes) Borehole Lithology AR BT — Borehole Termination Type	Asphalt Aggregate Base Course Clayey Sand Sandy Lean Clay Clayey Gravel with Sand Silty Gravel with Sand Sandstone Silty Clayey Sand with Gravel Silty Sand with Gravel Silty Clayey Gravel with Sand

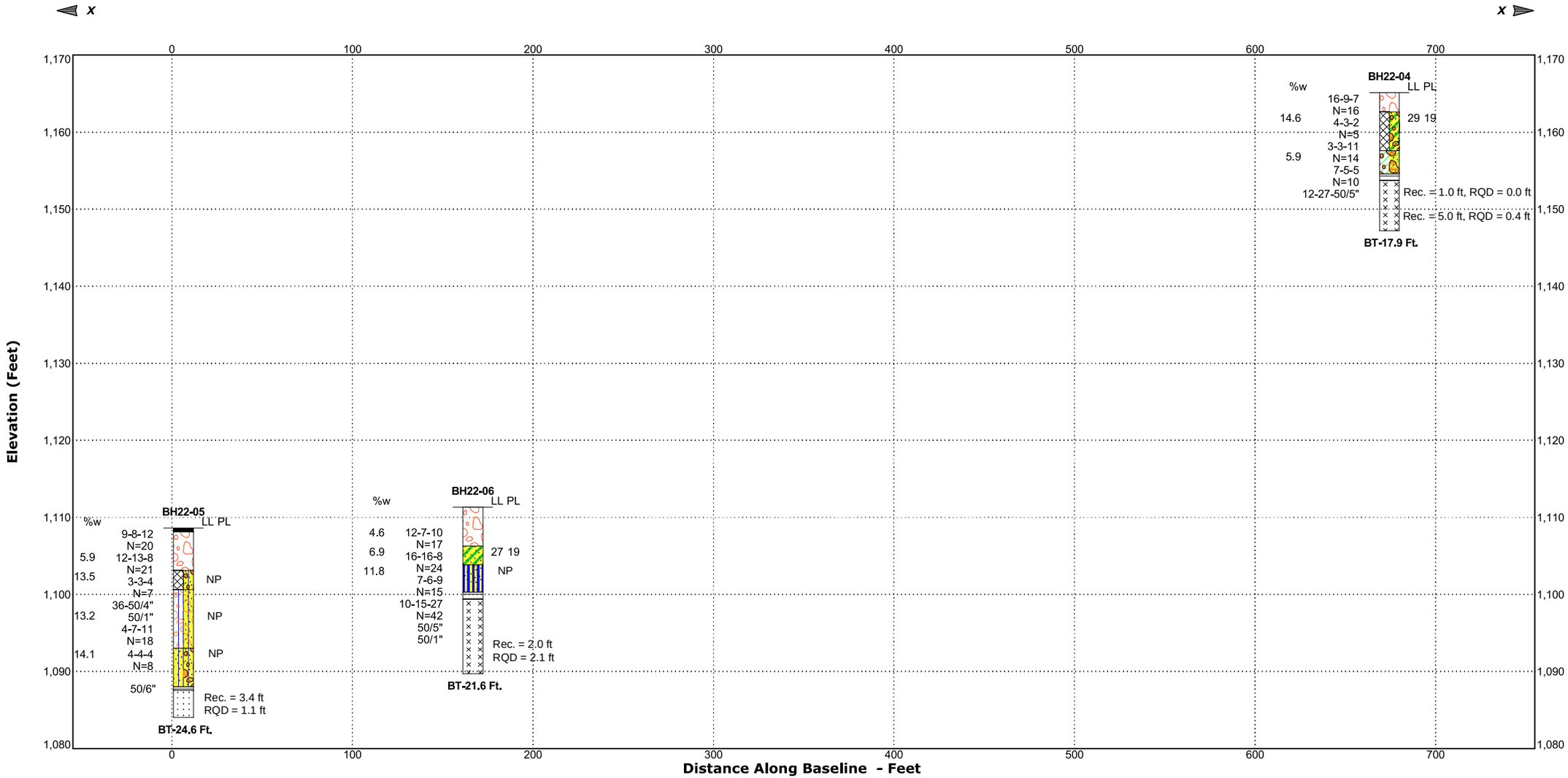
Facilities | Environmental | Geotechnical | Materials

NERI 107(2) New River Gorge National Park
Cunard River Access and Glade Creek Road | Fayetteville, West Virginia
Terracon Project No. N2225050

Subsurface Profile

Borings BH22-04 through BH22-06

Terracon
912 Morris St
Charleston, WV



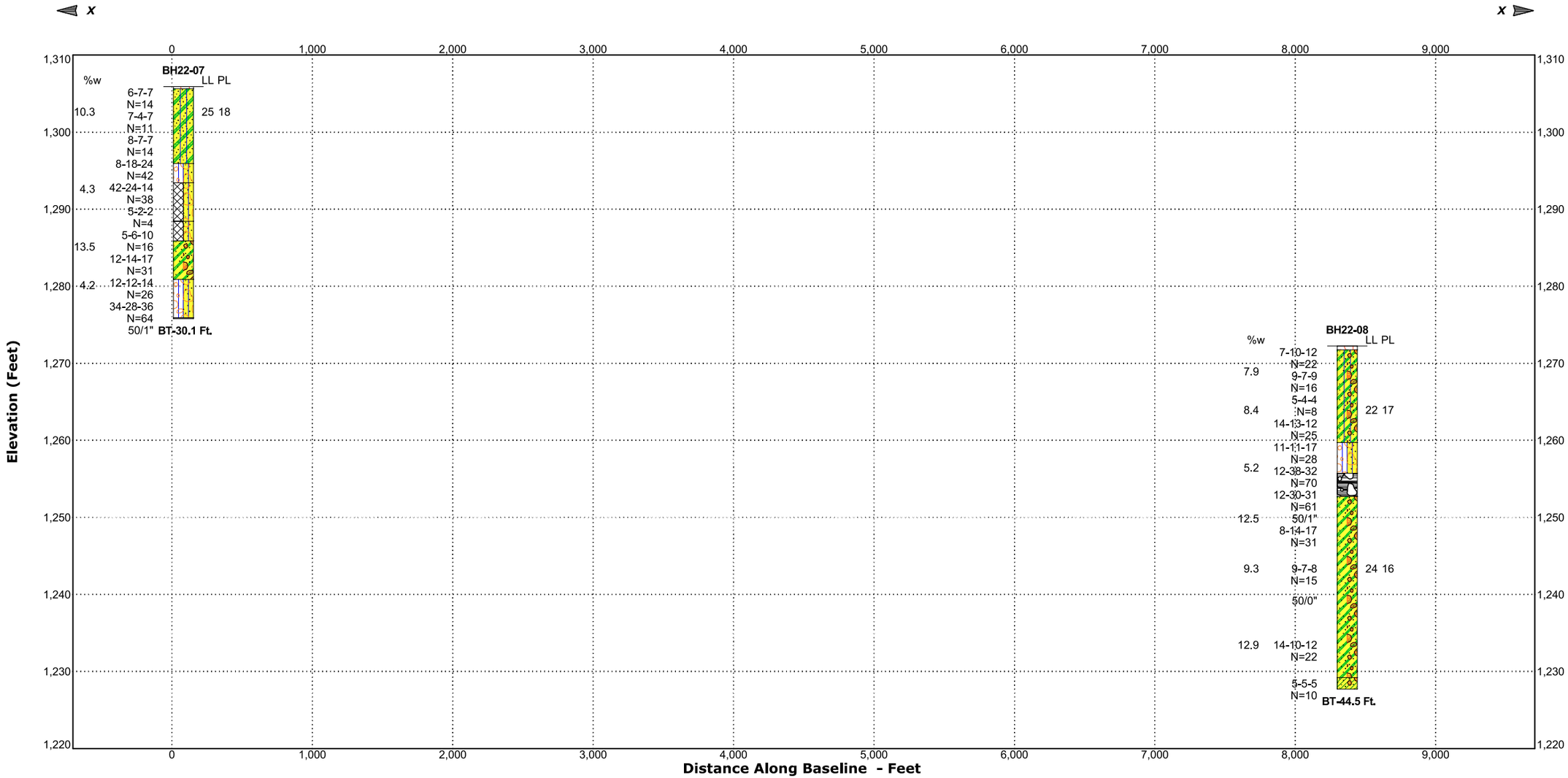
Notes	Water Level Observations	Explanation	Material Legend
See General Notes in Supporting Information for symbols and soil classifications. Soils profile provided for illustration purposes only. Soils between borings may differ AR - Auger Refusal BT - Boring Termination	Water Level Reading at time of drilling. Water Level Reading after drilling.	BH22-04 — Borehole Number Moisture Content — %w LL PL — Liquid and Plastic Limits Sampling (See General Notes) Borehole Lithology AR BT — Borehole Termination Type	Aggregate Base Course; Clayey Sand with Gravel; Clayey Gravel with Sand; Shale; Siltstone; Asphalt; Silty Sand with Gravel; Silty Gravel with Sand; Sandstone; Clayey Sand

NERI 107(2) New River Gorge National Park
Cunard River Access and Glade Creek Road | Fayetteville, West Virginia
Terracon Project No. N2225050

Subsurface Profile

Borings BH22-07 and BH22-08

Terracon
912 Morris St
Charleston, WV



Notes	Water Level Observations	Explanation	Material Legend
See General Notes in Supporting Information for symbols and soil classifications. Soils profile provided for illustration purposes only. Soils between borings may differ AR - Auger Refusal BT - Boring Termination	Water Level Reading at time of drilling. Water Level Reading after drilling.	BH22-07 — Borehole Number Moisture Content — %w LL PL — Liquid and Plastic Limits Sampling (See General Notes) Borehole Lithology AR BT — Borehole Termination Type	Aggregate Base Course; Silty Clayey Sand; Silty Gravel with Sand; Clayey Sand with Gravel; Shale; Silty Clayey Sand with Gravel; Boulders and Cobbles; Sandy Lean Clay with Gravel

Attachments

Exploration and Testing Procedures

Field Exploration

Number of Borings	Approximate Boring Depth (feet)	Location
6 (BH22-01 to BH22-06)	17.9 to 33.0	Cunard Road
2 (BH22-07 and BH22-08)	30.1 to 44.5	Glade Creek Road

Boring Layout and Elevations: Terracon personnel provided the boring layout using handheld GPS equipment (estimated horizontal accuracy of about ±10 feet) and referencing existing site features. The as-drilled locations were surveyed by a subcontracted survey crew to provide accurate coordinates and elevations for the boring logs. These locations and elevations are shown on the boring logs and subsurface profiles.

Subsurface Exploration Procedures: The borings were advanced with a track-mounted, rotary drill rig using continuous flight hollow stem augers. In the split-barrel sampling procedure, a standard 2-inch outer diameter split-barrel sampling spoon was driven into the ground by a 140-pound automatic hammer falling a distance of 30 inches. The number of blows required to advance the sampling spoon the last 12 inches of a normal 18-inch penetration is recorded as the Standard Penetration Test (SPT) resistance value. Where bedrock or refusal-to-drilling conditions were encountered prior to reaching a depth of 30 feet below existing ground surface, rock coring was performed using NQ2 sized rock coring equipment to confirm bedrock or to penetrate the encountered boulders and cobbles. The drill rig used for this project uses and automatic hammer that was calibrated on October 26, 2021. At that time the Energy Transfer Ratio (ETR) for the automatic hammer was 92.8% with a Hammer Efficiency Correction (C_E) of 1.55

The SPT resistance values, also referred to as N-values, are indicated on the boring logs at the test depths and recovery and RQD of the rock core samples are also indicated on the boring logs. Groundwater levels were observed and recorded during drilling and sampling. For safety purposes, all borings were backfilled with auger cuttings after their completion. Pavements were patched with cold-mix asphalt and/or pre-mixed concrete, as appropriate.

The boreholes were also observed at the completion of drilling for the presence of groundwater. The groundwater levels are shown on the attached boring logs.

A boring inspector was on site during the drilling and recorded the sampling depths, penetration distances, and other sampling information on the field boring logs. The

samples were placed in appropriate containers and taken to the Terracon soil laboratory for testing and classification by a Geotechnical Engineer. The boring inspector prepared field boring logs that included visual classifications of the materials observed during drilling and the interpretation of the subsurface conditions between samples by the inspector. Final boring logs were prepared from the field logs. The final boring logs represent the Geotechnical Engineer's interpretation of the field logs and include modifications based on observations and test results of the samples in our laboratory.

Laboratory Testing

The project engineer reviewed the field data and assigned laboratory tests. The laboratory testing program included the following types of tests:

- Moisture Content
- Grain size distribution
- Rock Unconfined Compression
- Atterberg Limits

The laboratory testing program often included examination of soil samples by an engineer. Based on the results of the field and laboratory programs, the soil samples have been described in accordance with the Unified Soil Classification System.

Rock classification was conducted using locally accepted practices for engineering purposes; petrographic analysis may reveal other rock types. Rock core samples typically provide an improved specimen for this classification. Boring log rock classification was determined using the Description of Rock Properties.

Photography Log

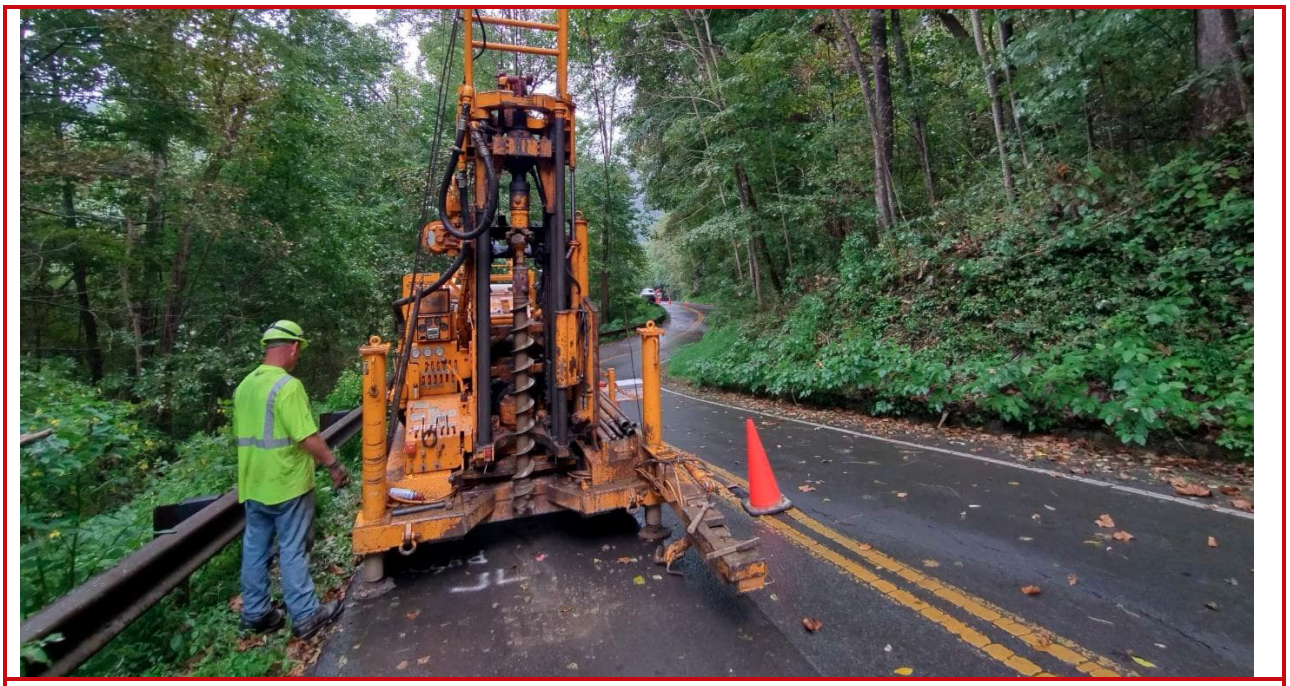
Boring BH22-02 Rock Core

Boring BH22-03 Rock Core

Boring BH22-04 Rock Coring

Boring BH22-05 Rock Coring

Boring BH22-06 Rock Core



Boring BH22-01 Prior to Drilling

Boring BH22-01 After Drilling

Boring BH22-02 Prior to Drilling

Boring BH22-02 After Drilling

Boring BH22-03 Prior to Drilling

Boring BH22-03 After Drilling

Boring BH22-04 Prior to Drilling

Boring BH22-04 After Drilling

Boring BH22-05 Prior to Drilling

Boring BH22-05 After Drilling

Boring BH22-06 Prior to Drilling

Boring BH22-06 After Drilling

Boring BH22-07 Prior to Drilling

Boring BH22-07 After Drilling

Boring BH22-08 Prior to Drilling

Boring BH22-08 After Drilling

Site Location and Exploration Plans

Contents:

Site Location Plan
Exploration Plan

Note: All attachments are one page unless noted above.

Site Location

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

MAP PROVIDED BY MICROSOFT BING MAPS

Exploration Plan

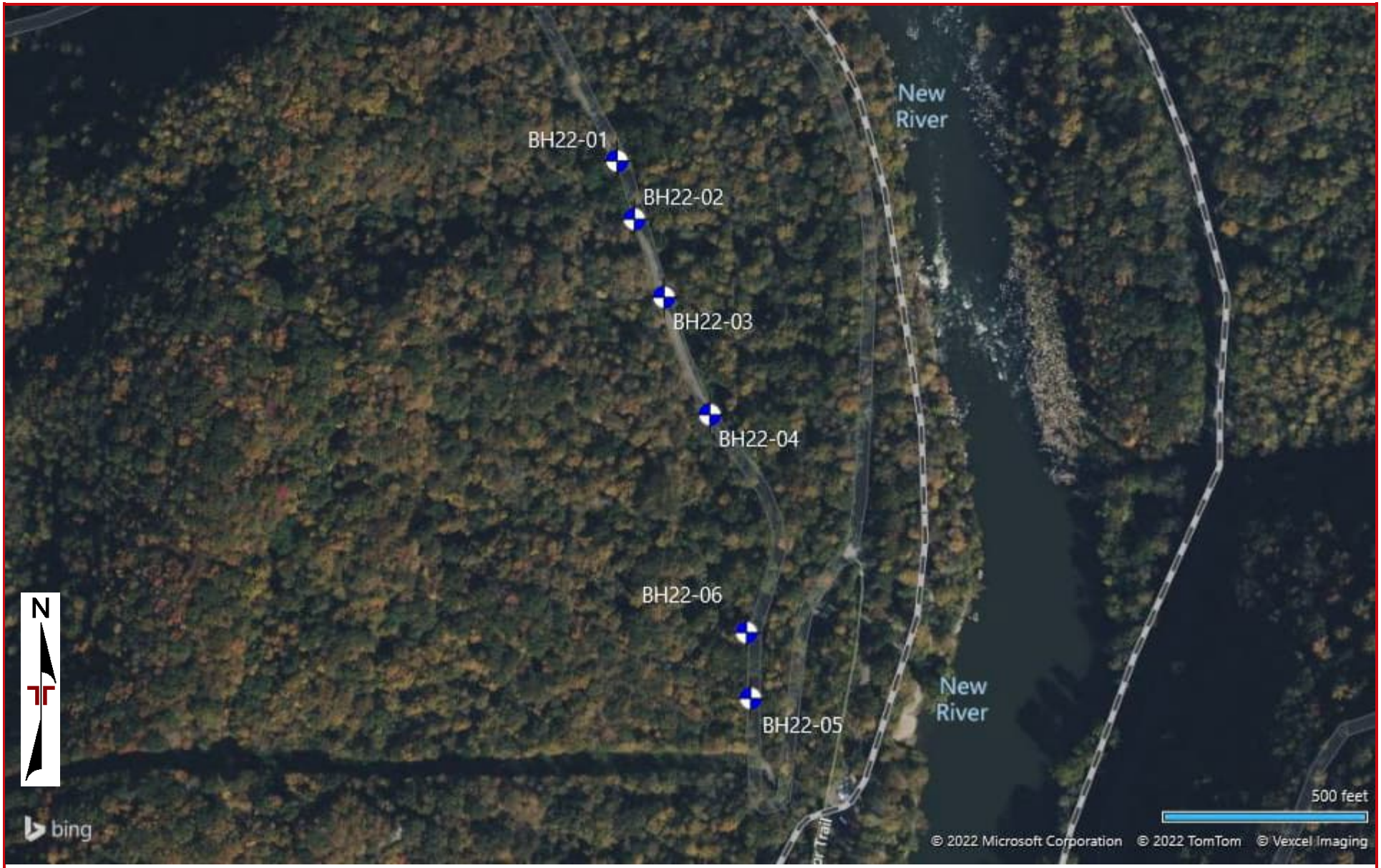


DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

MAP PROVIDED BY MICROSOFT BING MAPS

Exploration Plan

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

MAP PROVIDED BY MICROSOFT BING MAPS

Exploration and Laboratory Results

Contents:

Boring Logs (BH22-01 through BH22-08) (12 pages)
Water Contents
Atterberg Limits
Grain Size Distribution (4 pages)
Rock Core Unconfined Compression Tests (5 pages)

Note: All attachments are one page unless noted above.

Terracon
912 Morris St
Charleston, WV

Boring Log No. BH22-01

Location: See Exploration Plan

Northing: 365171.292 Easting: 1961346.275

Depth (Ft.)	Description	Elevation.: 1237.1 (Ft.)
0.6	**ASPHALT**	1236.5
	FILL - AGGREGATE BASE COURSE	
2.5		1234.6
	CLAYEY SAND (SC), colluvial, trace gravel, gray to brown, very loose to loose	
10.0		1227.1
	SANDY LEAN CLAY (CL), varying amount of gravels, brown, medium stiff to stiff, boulders/cobbles noted	
	-boulder/cobbles encountered at 15 ft	
20.0		1217.1
	CLAYEY GRAVEL WITH SAND (GC), brown, medium dense	
25.0		1212.1
	SILTY GRAVEL WITH SAND (GM), brown, very dense	

Depth (Ft.)	Sample Type	Recovery (In.)	Field Test Results	Water Content (%)	Atterberg Limits LL-PL-PI
		12	16-18-18 N=36		
		0	5-1-1 N=2		
5		10	1-1-2 N=3	6.9	
		3	2-2-2 N=4		
10		13	2-3-3 N=6	23.6	29-19-10
		3	4-6-3 N=9		
15		1	50/5"		
		1	2-3-8 N=11		
20		10	10-10-10 N=20	17.9	
25		10	33-25-17		

Graphic Log | Water Level Observations | RECOVERY (ft) | RQD (ft) | RQD (%)

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.

Water Level Observations
Groundwater not encountered

Notes

Advancement Method
3.25" Hollow Stem Auger

Abandonment Method
Boring backfilled with auger cuttings and surface capped with asphalt

Drill Rig
CME 585

Hammer Type
Automatic

Driller
L.Slate

Logged by
J.Tower

Boring Started
09-12-2022

Boring Completed
09-12-2022

Terracon
912 Morris St
Charleston, WV

Boring Log No. BH22-01

Location: See Exploration Plan

Northing: 365171.292 Easting: 1961346.275

Elevation.: 1237.1 (Ft.)

Graphic Log	Depth (Ft.)	Water Level Observations	Sample Type	Recovery (In.)	Field Test Results	RECOVERY (ft)	RQD (ft)	Water Content (%)	Atterberg Limits LL-PL-PI	RQD (%)
	SILTY GRAVEL WITH SAND (GM), brown, very dense *(continued)*				N=42					
	30.0 1207.1									
	SANDY LEAN CLAY (CL), trace gravel, gray, stiff to very stiff			9	7-7-9 N=16			14.9	24-15-9	
	32.9 1204.2									
	33.0 **SANDSTONE**, brown, dense, completely weathered 1204.1			1	50/1"					
	Boring Terminated at 33 Feet									

30

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.

Water Level Observations

Groundwater not encountered

Drill Rig
CME 585

Hammer Type
Automatic

Driller
L.Slate

Logged by
J.Tower

Boring Started
09-12-2022

Boring Completed
09-12-2022

Notes

Advancement Method
3.25" Hollow Stem Auger

Abandonment Method
Boring backfilled with auger cuttings and surface capped with asphalt

Terracon
912 Morris St
Charleston, WV

Boring Log No. BH22-02

Location: See Exploration Plan

Northing: 365029.138 Easting: 1961388.596

Depth (Ft.)	Description	Elevation (Ft.)
0.6	**ASPHALT**	1222.1
2.5	**FILL - AGGREGATE BASE COURSE**, dense graded aggregate	1220.2
7.5	**FILL - SILTY CLAYEY SAND WITH GRAVEL**, brown to reddish brown, loose	1215.2
19.0	**SILTY SAND WITH GRAVEL (SM)**, brown, medium dense, boulders cobbles noted throughout boulders/cobbles at 12.5 ft boulders/cobbles at 15 ft	1203.7
	SANDSTONE, gray, fine-grained, close to moderate fracture spacing, medium bedding, moderately to highly weathered, medium strong, iron staining throughout, discontinuity ranging from 30 deg to 60 deg -rock vertically fractured from 22.6 to 22.9 ft 23.8 ft: Unconfined compressive strength = 11,474 psi 25.2 ft: Unconfined compressive strength = 7,927 psi	

Depth (Ft.)	Sample Type	Recovery (In.)	Field Test Results	RECOVERY (ft)	RQD (ft)	Water Content (%)	Atterberg Limits LL-PL-PI	RQD (%)
		13	6-5-5 N=10					
		16	8-4-2 N=6			15.1	24-18-6	
5		0	3-2-2 N=4					
		12	2-6-7 N=13					
10		14	4-6-45 N=51			9.5	NP	
		1	50					
15		0	23-32-17 N=49					
		14	32-43-50/4"					
20		2	50/4"					
25				5.0	4.0			80

Water Level Observations: 23 ft: at completion of drilling

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

Advancement Method
3.25" Hollow Stem Auger/NQ2

Abandonment Method
Boring backfilled with auger cuttings and surface capped with asphalt

Drill Rig
CME 585

Hammer Type
Automatic

Driller
L.Slate

Logged by
J.Tower

Boring Started
09-12-2022

Boring Completed
09-12-2022

Terracon
912 Morris St
Charleston, WV

Boring Log No. BH22-02

Location: See Exploration Plan

Northing: 365029.138 Easting: 1961388.596

Graphic Log	Depth (Ft.)	Elevation.: 1222.7 (Ft.)	Depth (Ft.)	Water Level Observations	Sample Type	Recovery (In.)	Field Test Results	RECOVERY (ft)	RQD (ft)	Water Content (%)	Atterberg Limits LL-PL-PI	RQD (%)
	27.3 -carbonaceous shale encountered at 26.8 ft	1195.4										
	Boring Terminated at 27.3 Feet											

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.

Water Level Observations

23 ft: at completion of drilling

Notes

Advancement Method
3.25" Hollow Stem Auger/NQ2

Abandonment Method
Boring backfilled with auger cuttings and surface capped with asphalt

Drill Rig
CME 585

Hammer Type
Automatic

Driller
L.Slate

Logged by
J.Tower

Boring Started
09-12-2022

Boring Completed
09-12-2022

Terracon
912 Morris St
Charleston, WV

Boring Log No. BH22-03

Location: See Exploration Plan

Northing: 364838.56 Easting: 1961461.347

Depth (Ft.)	Description	Elevation.: 1209.5 (Ft.)
0.6	**ASPHALT**	1208.9
	FILL - AGGREGATE BASE COURSE	
2.5		1207
	FILL - SILTY CLAYEY GRAVEL WITH SAND, gray, loose to medium dense	
12.5		1197
	SANDSTONE, brown, fine-grained, very close to close fracture spacing, medium to thick bedding, highly to moderately weathered, medium strong, iron staining throughout	
	20 ft: Unconfined compressive strength = 13,646 psi	
20.8		1188.7
	Boring Terminated at 20.8 Feet	

Depth (Ft.)	Sample Type	Recovery (In.)	Field Test Results	RECOVERY (ft)	RQD (ft)	Water Content (%)	Atterberg Limits LL-PL-PI	RQD (%)
		18	7-6-6 N=12			3.6		
5		10	4-5-5 N=10			5.9	21-15-6	
		12	6-5-5 N=10					
10		10	21-5-5 N=10			2.9		
		2	50/5"					
15		2	50/3"					
				1.3	0.4			20
				4.0	1.2			30
20								

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.

Water Level Observations

Groundwater not encountered

Notes

Advancement Method
3.25" Hollow Stem Auger/NQ2

Abandonment Method
Boring backfilled with auger cuttings and surface capped with gravel

Drill Rig
CME 585

Hammer Type
Automatic

Driller
L.Slate

Logged by
J.Tower

Boring Started
09-09-2022

Boring Completed
09-09-2022

Terracon
912 Morris St
Charleston, WV

Boring Log No. BH22-04

Location: See Exploration Plan

Northing: 364522.462 Easting: 1961590.082

Depth (Ft.) Elevation.: 1165.1 (Ft.)

Graphic Log	Description	Depth (Ft.)	Water Level Observations	Sample Type	Recovery (In.)	Field Test Results	RECOVERY (ft)	RQD (ft)	Water Content (%)	Atterberg Limits LL-PL-PI	RQD (%)
	AGGREGATE BASE COURSE 2.5 / 1162.6				12	16-9-7 N=16					
	FILL - CLAYEY SAND WITH GRAVEL, gray to brown, loose to medium dense 7.5 / 1157.6				6	4-3-2 N=5			14.6	29-19-10	
		5	▽		12	3-3-11 N=14					
	CLAYEY GRAVEL WITH SAND (GC), brown, loose 10.5 / 1154.6				12	7-5-5 N=10			5.9		
		10			15	12-27-50/5"					
	SILTY SHALE, brown, very dense, highly weathered 11.4 / 1153.7										
	SILTSTONE, gray, extremely to moderately fractured, thin to medium bedding, moderately weathered, medium strong						1.0	0.0			0
	-vertical fractures at 15 ft 17.9 / 1147.2	15					5.0	0.4			8
	Boring Terminated at 17.9 Feet										

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.

Water Level Observations

▽ 5 ft: at completion of drilling

Notes

Advancement Method
3.25" Hollow Stem Auger/NQ2

Abandonment Method
Boring backfilled with auger cuttings and surface capped with gravel

Drill Rig
CME 585

Hammer Type
Automatic

Driller
L.Slate

Logged by
J.Tower

Boring Started
09-09-2022

Boring Completed
09-09-2022

Terracon
912 Morris St
Charleston, WV

Boring Log No. BH22-05

Location: See Exploration Plan

Northing: 363859.677 Easting: 1961673.025

Depth (Ft.)	Description	Elevation.: 1108.6 (Ft.)
0.5	**ASPHALT**	1108.1
	AGGREGATE BASE COURSE	
5.5		1103.1
	FILL - SILTY SAND WITH GRAVEL, brown, loose	
8.0		1100.6
	SILTY GRAVEL WITH SAND (GM), brown, medium dense to dense, boulders encountered throughout	
15.6		1093
	SILTY SAND WITH GRAVEL (SM), brown, loose, cobbles and boulders encountered throughout	
20.6		1088
21.1	**SANDY SHALE**, brown, dense	1087.5
	SANDSTONE, brown, moderately fractured, close to moderate spacing, medium bedding, moderately weathered, medium strong 23 ft: Unconfined compressive strength = 13,583 psi	
24.6		1084
	Boring Terminated at 24.6 Feet	

Depth (Ft.)	Sample Type	Recovery (In.)	Field Test Results	RECOVERY (ft)	RQD (ft)	Water Content (%)	Atterberg Limits LL-PL-PI	RQD (%)
		8	9-8-12 N=20					
		13	12-13-8 N=21			5.9		
5		9	3-3-4 N=7			13.5	NP	
		5	36-50/4"					
		1	50/1"	1.2				
10		7	4-7-11 N=18			13.2	NP	
				1.1				
15		4	4-4-4 N=8			14.1	NP	
				1.3				
20		0.5	50					
				3.4	1.1			31

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.

Water Level Observations

20.5 ft: at completion of drilling

Notes

Rock coring was required to penetrate boulders from 11.1 feet after aurger refusal was encountered

Advancement Method
3.25" Hollow Stem Auger/NQ2

Abandonment Method
Boring backfilled with auger cuttings and surface capped with asphalt

Drill Rig
CME 585

Hammer Type
Automatic

Driller
L.Slate

Logged by
J.Tower

Boring Started
09-08-2022

Boring Completed
09-08-2022

Terracon
912 Morris St
Charleston, WV

Boring Log No. BH22-06

Location: See Exploration Plan

Northing: 364020.063 Easting: 1961663.196

Elevation.: 1111.3 (Ft.)

Graphic Log	Depth (Ft.)	Description	Depth (Ft.)	Water Level Observations	Sample Type	Recovery (In.)	Field Test Results	RECOVERY (ft)	RQD (ft)	Water Content (%)	Atterberg Limits LL-PL-PI	RQD (%)
		AGGREGATE BASE COURSE, silty sand with gravel, dense graded aggregate										
				▽	X	14	12-7-10 N=17			4.6		
	5.0	1106.3	5									
		CLAYEY SAND (SC), brown, medium dense			X	12	16-16-8 N=24			6.9	27-19-8	
	7.5	1103.8										
		SANDY SILT (SM), brown, very stiff			X	12	7-6-9 N=15			11.8	NP	
			10									
	11.0	1100.3			X	18	10-15-27 N=42					
	12.0	**SILTY SHALE**, with sand, gray, medium dense to dense 1099.3										
		SILTSTONE, extremely to moderately fractured, close to moderate fracture spacing, medium bedding, highly to moderately weathered, medium strong, highly fractured from 15.1 ft to 18.2 ft discontinuity angle ranging from 45 deg to 60 deg			X	5	50/5"					
			15		X	0	50/1"	1.5				
		18 ft: Unconfined compressive strength = 3,702 psi -clay interbedded with at 18.3 ft						5.0	2.1			42
			20									
	21.6	1089.7										
		Boring Terminated at 21.6 Feet										

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.

Water Level Observations

▽ 3.4 ft: at completion of drilling

Notes

Advancement Method
3.25" Hollow Stem Auger/NQ2

Abandonment Method
Boring backfilled with auger cuttings and surface capped with gravel

Drill Rig
CME 585

Hammer Type
Automatic

Driller
L.Slate

Logged by
J.Tower

Boring Started
09-08-2022

Boring Completed
09-08-0202

Terracon
912 Morris St
Charleston, WV

Boring Log No. BH22-07

Location: See Exploration Plan

Northing: 308364.212 Easting: 1952327.949

Depth (Ft.)	Elevation.: 1305.9 (Ft.)
0.3	**AGGREGATE LAYER** 1305.6
	SILTY CLAYEY SAND (SC-SM), brown, medium dense to dense
	-cobbles encountered at 5 ft
10.0	1295.9
	SILTY GRAVEL WITH SAND (GM), brown, dense
12.5	1293.4
	SILTY GRAVEL WITH SAND (GM), brown, loose to medium dense
17.5	1288.4
	SILTY GRAVEL WITH SAND (GM), brown, dense
20.0	1285.9
	CLAYEY SAND WITH GRAVEL (SC), brown, medium dense
25.0	1280.9
	SILTY GRAVEL WITH SAND (GM), reddish brown, very dense

Depth (Ft.)	Sample Type	Recovery (In.)	Field Test Results	Water Content (%)	Atterberg Limits LL-PL-PI
		12	6-7-7 N=14		
		11	7-4-7 N=11	10.3	25-18-7
5		3	8-7-7 N=14		
		5	8-18-24 N=42		
10		10	42-24-14 N=38		
		3	5-2-2 N=4	4.3	
15		4	5-6-10 N=16		
		5	12-14-17 N=31		
20		13	12-12-14 N=26	13.5	
25		9	34-28-36	4.2	

Graphic Log | Water Level Observations | RECOVERY (ft) | RQD (ft) | RQD (%)

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.

Water Level Observations
Groundwater not encountered

Notes

Advancement Method
3.25" Hollow Stem Auger

Abandonment Method
Boring backfilled with auger cuttings upon completion.

Drill Rig
CME 585

Hammer Type
Automatic

Driller
L.Slate

Logged by
J.Tower

Boring Started
09-07-2022

Boring Completed
09-07-2022

Terracon
912 Morris St
Charleston, WV

Boring Log No. BH22-07

Location: See Exploration Plan

Northing: 308364.212 Easting: 1952327.949

Elevation.: 1305.9 (Ft.)

Graphic Log	Depth (Ft.)	Description	Depth (Ft.)	Water Level Observations	Sample Type	Recovery (In.)	Field Test Results	RECOVERY (ft)	RQD (ft)	Water Content (%)	Atterberg Limits LL-PL-PI	RQD (%)
		SILTY GRAVEL WITH SAND (GM), reddish brown, very dense *(continued)*					N=64					
	30.0											
	30.1	**SILTY SHALE**, brown, dense, completely weathered	30			1	50/1"					
	1275.9	***Boring Terminated at 30.1 Feet***										

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.

Water Level Observations

Groundwater not encountered

Drill Rig
CME 585

Hammer Type
Automatic

Driller
L.Slate

Logged by
J.Tower

Boring Started
09-07-2022

Boring Completed
09-07-2022

Notes

Advancement Method
3.25" Hollow Stem Auger

Abandonment Method
Boring backfilled with auger cuttings upon completion.

Terracon
912 Morris St
Charleston, WV

Boring Log No. BH22-08

Location: See Exploration Plan

Northing: 302570.094 Easting: 1958254.054

Depth (Ft.)	Elevation.: 1272.2 (Ft.)
0.5	**AGGREGATE** 1271.7
	SILTY CLAYEY SAND WITH GRAVEL (SC-SM), brown, loose to medium dense
12.5	1259.7
	SILTY GRAVEL WITH SAND (GM), brown, very dense, weathered sandstone rock fragments
16.5	1255.7
	BOULDERS & COBBLES, brown, dense, weathered sandstone rock fragments
19.5	1252.7
	CLAYEY SAND WITH GRAVEL (SC), brown, medium dense to dense, boulders throughout

Depth (Ft.)	Sample Type	Recovery (In.)	Field Test Results	Water Content (%)	Atterberg Limits LL-PL-PI	RQD (%)
		18	7-10-12 N=22			
		18	9-7-9 N=16	7.9		
5		16	5-4-4 N=8			
		14	14-13-12 N=25	8.4	22-17-5	
10		14	11-11-17 N=28			
		13	12-38-32 N=70			
15		14	12-30-31 N=61	5.2		
		0	50/1"			
20		6	8-14-17 N=31	12.5		
25						

Water Level Observations: Water Level Observations (column) — 28 ft: at completion of drilling

RECOVERY (ft) | RQD (ft)

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

Rock coring was required to penetrate boulders from 16.6 feet after aurger refusal was encountered

Advancement Method
3.25" Hollow Stem Auger/NQ2

Abandonment Method
Boring backfilled with auger cuttings and bentonite chips upon completion.

Drill Rig
CME 585

Hammer Type
Automatic

Driller
L.Slate

Logged by
J.Tower

Boring Started
09-07-2022

Boring Completed
09-07-2022

Terracon
912 Morris St
Charleston, WV

Boring Log No. BH22-08

Location: See Exploration Plan

Northing: 302570.094 Easting: 1958254.054

Depth (Ft.) Elevation.: 1272.2 (Ft.)

Graphic Log	Depth (Ft.)	Water Level Observations	Sample Type	Recovery (In.)	Field Test Results	RECOVERY (ft)	RQD (ft)	Water Content (%)	Atterberg Limits LL-PL-PI	RQD (%)
CLAYEY SAND WITH GRAVEL (SC), brown, medium dense to dense, boulders throughout *(continued)*										
				6	9-7-8 N=15			9.3	24-16-8	
	30									
				0	50/0"					
	35									
				8	14-10-12 N=22			12.9		
	40									
43.0 1229.2										
SANDY LEAN CLAY WITH GRAVEL (CL), brown, stiff				12	5-5-5 N=10					
44.5 1227.7										
Boring Terminated at 44.5 Feet										

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.

Water Level Observations

28 ft: at completion of drilling

Drill Rig
CME 585

Hammer Type
Automatic

Driller
L.Slate

Logged by
J.Tower

Boring Started
09-07-2022

Boring Completed
09-07-2022

Notes

Rock coring was required to penetrate boulders from 16.6 feet after aurger refusal was encountered

Advancement Method
3.25" Hollow Stem Auger/NQ2

Abandonment Method
Boring backfilled with auger cuttings and bentonite chips upon completion.

Summary of Laboratory Results

BORING ID	Depth (Ft.)	Water Content (%)
BH22-01	5-6.5	6.9
BH22-01	10-11.5	23.6
BH22-01	20-21.5	17.9
BH22-01	30-31.5	14.9
BH22-02	2.5-4	15.1
BH22-02	10-11.5	9.5
BH22-03	2.5-4	3.6
BH22-03	5-6.5	5.9
BH22-03	10-11.5	2.9
BH22-04	2.5-4	14.6
BH22-04	7.5-9	5.9
BH22-05	3-4.5	5.9
BH22-05	5.5-7	13.5
BH22-05	10.6-12.1	13.2
BH22-05	15.6-17.1	14.1
BH22-06	2.5-4	4.6
BH22-06	5-6.5	6.9
BH22-06	7.5-9	11.8
BH22-07	2.5-4	10.3
BH22-07	12.5-14	4.3
BH22-07	20-21.5	13.5
BH22-07	25-26.5	4.2
BH22-08	2.5-4	7.9
BH22-08	7.5-9	8.4
BH22-08	15-16.5	5.2
BH22-08	21.6-23.1	12.5
BH22-08	28.1-29.6	9.3
BH22-08	38-39.5	12.9

PROJECT: NERI 107(2) New River Gorge National Park

SITE: Cunard River Access and Glade Creek Road
Fayetteville, West Virginia

Terracon
912 Morris St
Charleston, WV

PROJECT NUMBER: N2225050

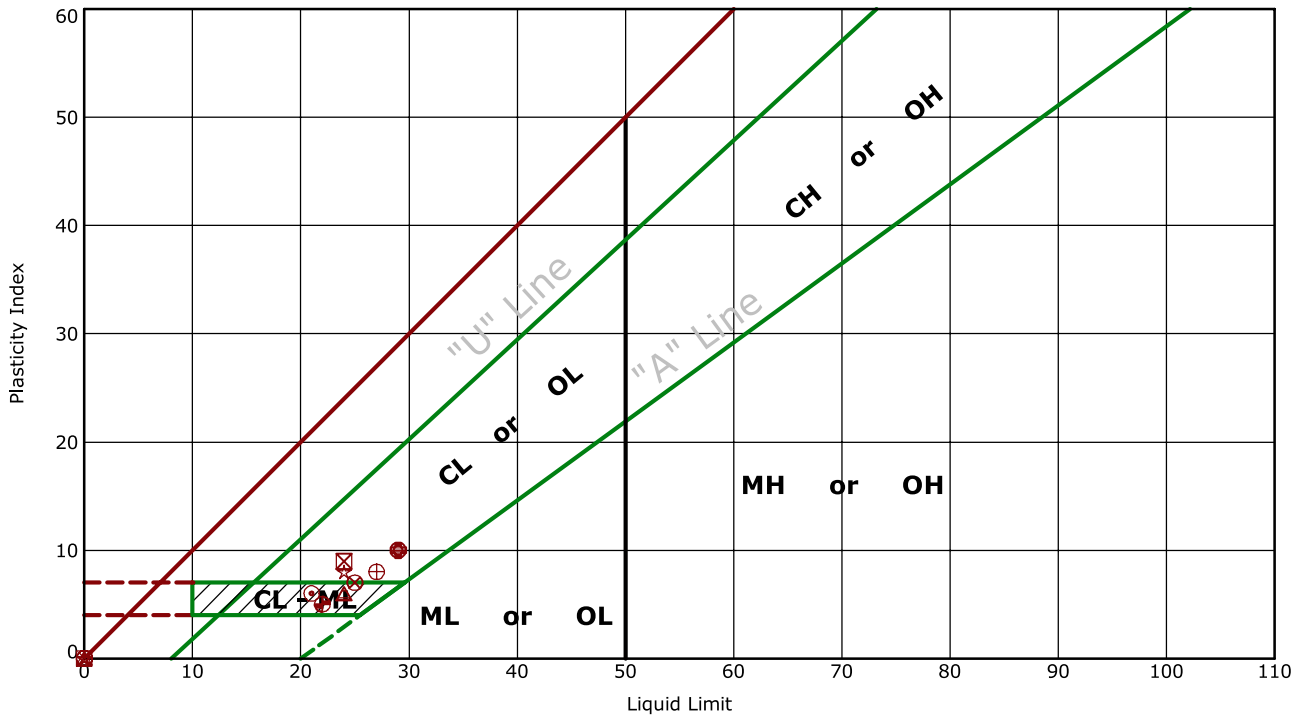
CLIENT: AECOM Design
Morgantown, WV

LABORATORY TESTS ARE NOT VALID IF SEPARATED FROM ORIGINAL REPORT. SMART LAB SUMMARY-PORTRAIT N2225050 FHWA EFLHD_WV FLT-.GPJ TERRACON_DATATEMPLATE.GDT 11/4/22

Terracon
912 Morris St
Charleston, WV

Atterberg Limit Results

ASTM D4318

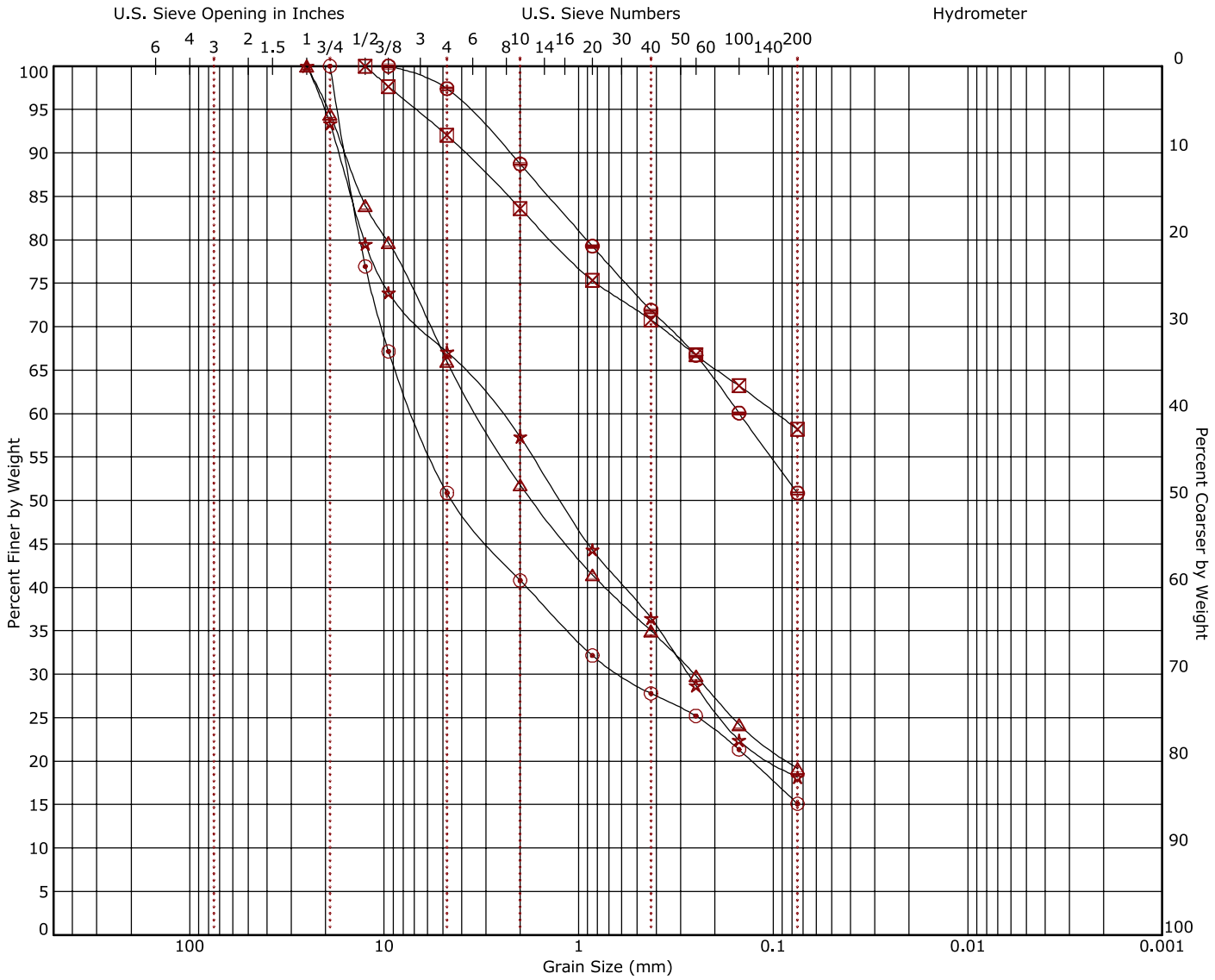


	Boring ID	Depth (Ft)	LL	PL	PI	Fines	USCS	Description
⊖	BH22-01	10 - 11.5	29	19	10	50.9	CL	SANDY LEAN CLAY
⊠	BH22-01	30 - 31.5	24	15	9	58.2	CL	SANDY LEAN CLAY
▲	BH22-02	2.5 - 4	24	18	6	19.2	SC-SM	SILTY, CLAYEY SAND with GRAVEL
★	BH22-02	10 - 11.5	NP	NP	NP	18.2	SM	SILTY SAND with GRAVEL
⊙	BH22-03	5 - 6.5	21	15	6	15.1	GC-GM	SILTY, CLAYEY GRAVEL with SAND
✿	BH22-04	2.5 - 4	29	19	10	35.7	SC	CLAYEY SAND with GRAVEL
○	BH22-05	5.5 - 7	NP	NP	NP	26.6	SM	SILTY SAND with GRAVEL
△	BH22-05	10.6 - 12.1	NP	NP	NP	13.3	GM	SILTY GRAVEL with SAND
⊗	BH22-05	15.6 - 17.1	NP	NP	NP	26.9	SM	SILTY SAND with GRAVEL
⊕	BH22-06	5 - 6.5	27	19	8	35.4	SC	CLAYEY SAND
□	BH22-06	7.5 - 9	NP	NP	NP	50.9	ML	SANDY SILT
⊗	BH22-07	2.5 - 4	25	18	7	52.1	CL-ML	SANDY SILTY CLAY
◓	BH22-08	7.5 - 9	22	17	5	30.8	SC-SM	SILTY, CLAYEY SAND with GRAVEL
☆	BH22-08	28.1 - 29.6	24	16	8	28.6	SC	CLAYEY SAND with GRAVEL

Terracon
912 Morris St
Charleston, WV

Grain Size Distribution

ASTM D422 / ASTM C136



Cobbles	Gravel		Sand			Silt or Clay
	coarse	fine	coarse	medium	fine	

Boring ID	Depth (Ft)	Description		LL	PL	PI	Cc	Cu
BH22-01	10 - 11.5	SANDY LEAN CLAY		29	19	10		
BH22-01	30 - 31.5	SANDY LEAN CLAY		24	15	9		
BH22-02	2.5 - 4	SILTY, CLAYEY SAND with GRAVEL		24	18	6		
BH22-02	10 - 11.5	SILTY SAND with GRAVEL		NP	NP	NP		
BH22-03	5 - 6.5	SILTY, CLAYEY GRAVEL with SAND		21	15	6		

Boring ID	Depth (Ft)	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Fines	%Silt	%Clay
BH22-01	10 - 11.5	9.5	0.149			0.0	2.6	46.5	50.9		
BH22-01	30 - 31.5	12.5	0.096			0.0	8.0	33.9	58.2		
BH22-02	2.5 - 4	25	3.292	0.254		0.0	34.0	46.9	19.2		
BH22-02	10 - 11.5	25	2.535	0.273		0.0	32.9	48.9	18.2		
BH22-03	5 - 6.5	19	7.005	0.604		0.0	49.1	35.8	15.1		

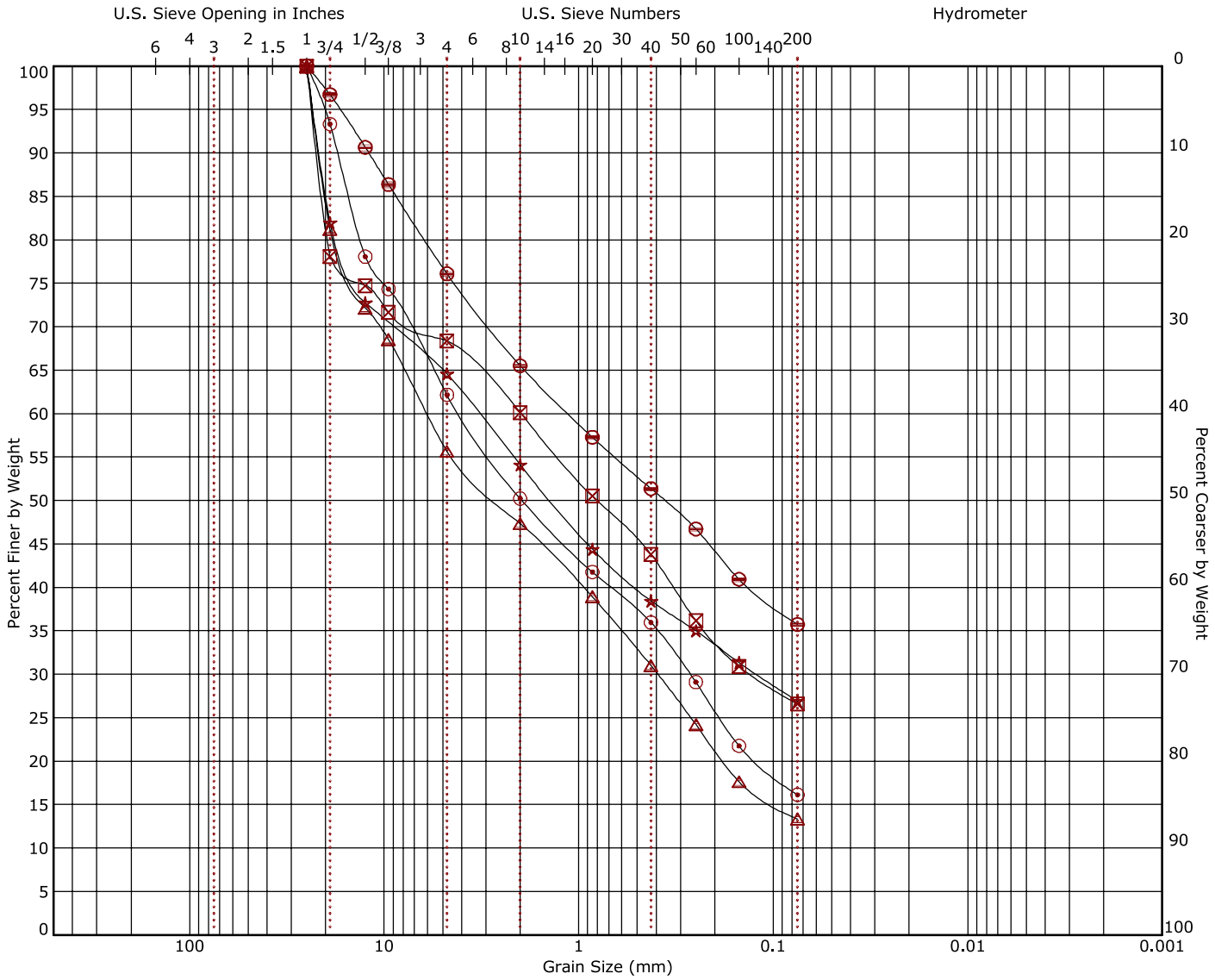
Laboratory tests are not valid if separated from original report.

Facilities | Environmental | Geotechnical | Materials

Terracon
912 Morris St
Charleston, WV

Grain Size Distribution

ASTM D422 / ASTM C136



Cobbles	Gravel		Sand			Silt or Clay
	coarse	fine	coarse	medium	fine	

Boring ID	Depth (Ft)	Description		LL	PL	PI	Cc	Cu
BH22-04	2.5 - 4	CLAYEY SAND with GRAVEL		29	19	10		
BH22-05	5.5 - 7	SILTY SAND with GRAVEL		NP	NP	NP		
BH22-05	10.6 - 12.1	SILTY GRAVEL with SAND		NP	NP	NP		
BH22-05	15.6 - 17.1	SILTY SAND with GRAVEL		NP	NP	NP		
BH22-06	2.5 - 4							

Boring ID	Depth (Ft)	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Fines	%Silt	%Clay
BH22-04	2.5 - 4	25	1.128			0.0	23.9	40.4	35.7		
BH22-05	5.5 - 7	25	1.976	0.13		0.0	31.6	41.8	26.6		
BH22-05	10.6 - 12.1	25	5.997	0.393		0.0	44.3	42.3	13.3		
BH22-05	15.6 - 17.1	25	3.252	0.122		0.0	35.4	37.7	26.9		
BH22-06	2.5 - 4	25	4.061	0.268		0.0	37.8	46.0	16.1		

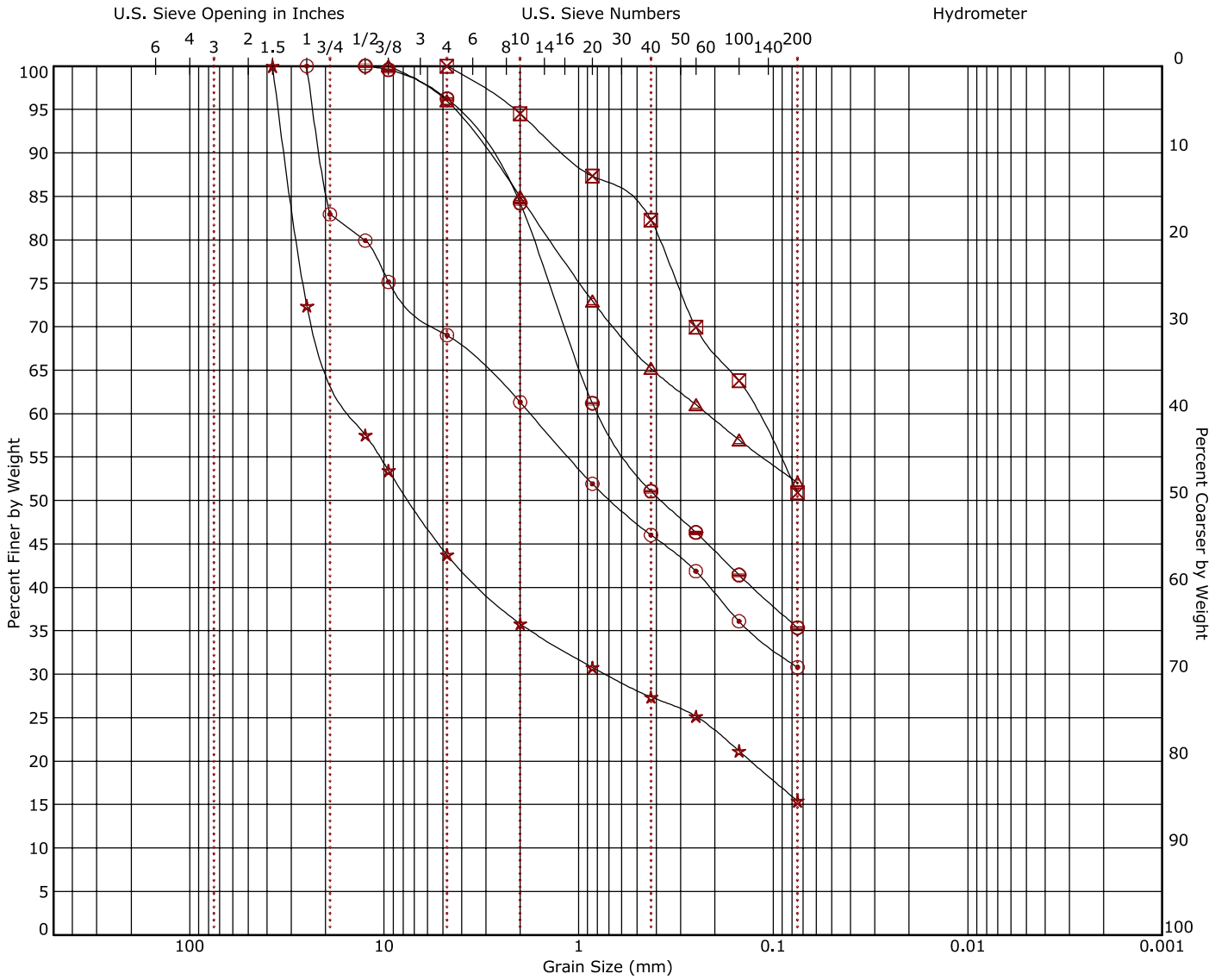
Laboratory tests are not valid if separated from original report.

Facilities | Environmental | Geotechnical | Materials

Terracon
912 Morris St
Charleston, WV

Grain Size Distribution

ASTM D422 / ASTM C136



Cobbles	Gravel		Sand			Silt or Clay
	coarse	fine	coarse	medium	fine	

Boring ID	Depth (Ft)	Description		LL	PL	PI	Cc	Cu
BH22-06	5 - 6.5	CLAYEY SAND		27	19	8		
BH22-06	7.5 - 9	SANDY SILT		NP	NP	NP		
BH22-07	2.5 - 4	SANDY SILTY CLAY		25	18	7		
BH22-07	12.5 - 14							
BH22-08	7.5 - 9	SILTY, CLAYEY SAND with GRAVEL		22	17	5		

Boring ID	Depth (Ft)	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Fines	%Silt	%Clay
BH22-06	5 - 6.5	12.5	0.783			0.0	3.8	60.9	35.4		
BH22-06	7.5 - 9	4.75	0.122			0.0	0.0	49.1	50.9		
BH22-07	2.5 - 4	9.5	0.219			0.0	4.0	43.9	52.1		
BH22-07	12.5 - 14	37.5	14.017	0.722		0.0	56.2	28.3	15.4		
BH22-08	7.5 - 9	25	1.772			0.0	31.0	38.2	30.8		

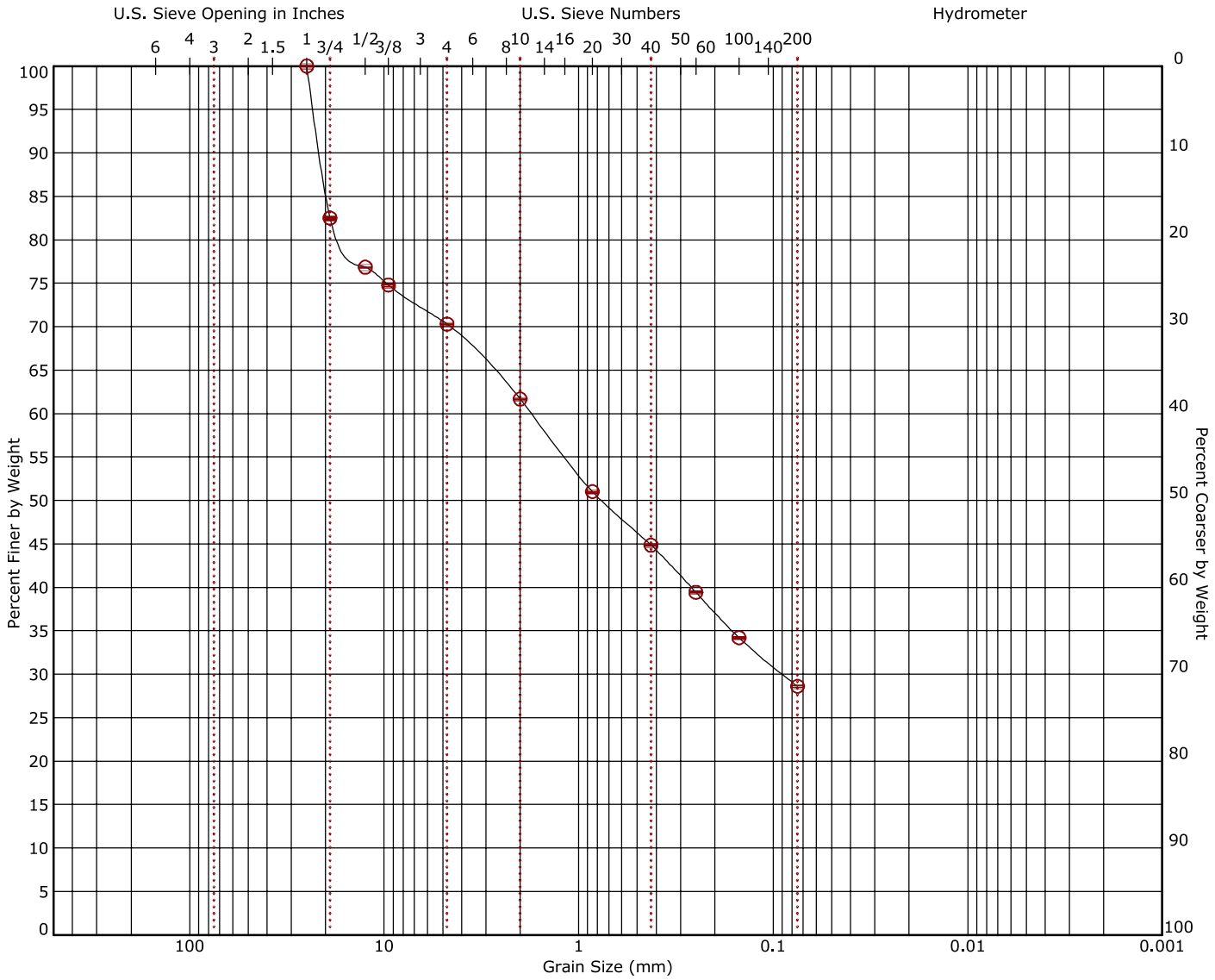
Laboratory tests are not valid if separated from original report.

Facilities | Environmental | Geotechnical | Materials

Terracon
912 Morris St
Charleston, WV

Grain Size Distribution

ASTM D422 / ASTM C136



Cobbles	Gravel		Sand			Silt or Clay
	coarse	fine	coarse	medium	fine	

Boring ID	Depth (Ft)	Description		LL	PL	PI	Cc	Cu
BH22-08	28.1 - 29.6	CLAYEY SAND with GRAVEL		24	16	8		

Boring ID	Depth (Ft)	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Fines	%Silt	%Clay
BH22-08	28.1 - 29.6	25	1.747	0.089		0.0	29.7	41.7	28.6		

Laboratory tests are not valid if separated from original report.

Terracon
912 Morris Street
Charleston, WV 25301
(304) 344-0821

Unconfined Compression Test of Intact Rock Core Report
ASTM D 7012 Method C

Client: AECOM Design Morgantown, WV
Project: NERI 107(2) New River Gorge National Park
Project No: N2225050

Boring No: BH22-02
Depth (ft): 23.8

Test Date: 10/13/2022

Avg. Specimen Diameter (in.): 1.960
Area (in.²): 3.02
Avg. Specimen Length (in.): 3.980
L/D Ratio: 2.0
Natural Density, lb/ft³ 157.1

Total Load (lbf.): 34650
Rate of Loading (lbs/sec): 80
Rate of Deformation (in/min): 0.006
Break Time (minutes): 10.00

Compressive Strength (psi): 11474
Compressive Strength (psf): 1652185
Compressive Strength (tsf): 826

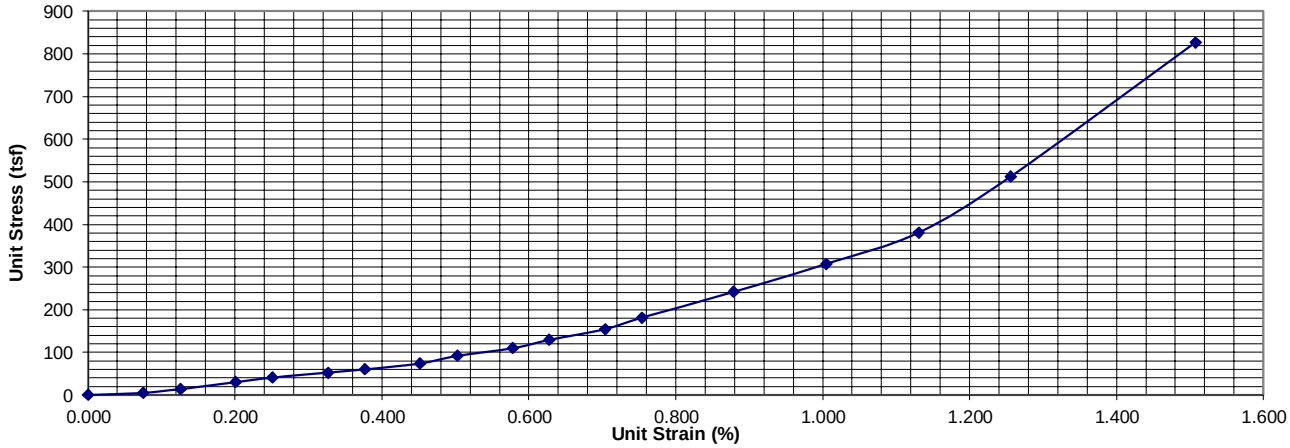
Moisture Content (%): 0.02

Deformation (in.)	Load (lbs.)	Strain (%)	Stress (psi)	Strength (tsf)
0.000	0	0.000	0	0
0.003	190	0.075	63	5
0.005	600	0.126	199	14
0.008	1240	0.201	411	30
0.010	1700	0.251	563	41
0.013	2180	0.327	722	52
0.015	2500	0.377	828	60
0.018	3100	0.452	1026	74
0.020	3840	0.503	1272	92
0.023	4600	0.578	1523	110
0.025	5400	0.628	1788	129
0.028	6450	0.704	2136	154
0.030	7600	0.754	2517	181
0.035	10150	0.879	3361	242
0.040	12870	1.005	4262	307
0.045	16000	1.131	5298	381
0.050	21480	1.256	7113	512
0.060	34650	1.508	11474	826

Failure Photograph:

Test sample prepared in general accordance to ASTM D4543

Straightness: Procedure S1 Parallelism: Procedure FP2
Flatness: Procedure FP2 Perpendicularity: Procedure P2



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

912 Morris Street
Charleston, WV 25301
(304) 344-0821

Unconfined Compression Test of Intact Rock Core Report
ASTM D 7012 Method C

Client: AECOM Design Morgantown, WV
Project: NERI 107(2) New River Gorge National Park
Project No: N2225050

Boring No: BH22-02
Depth (ft): 25.2

Test Date: 10/13/2022

Avg. Specimen Diameter (in.): 1.960
Area (in.²): 3.02
Avg. Specimen Length (in.): 4.000
L/D Ratio: 2.0
Natural Density, lb/ft³ 165.7

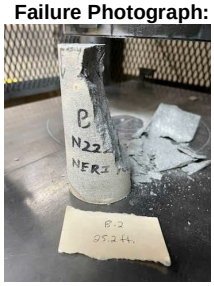
Total Load (lbf.): 23940
Rate of Loading (lbs/sec): 80
Rate of Deformation (in/min): 0.005
Break Time (minutes): 10.00

Compressive Strength (psi): 7927
Compressive Strength (psf): 1141510
Compressive Strength (tsf): 571

Moisture Content (%): 0.03

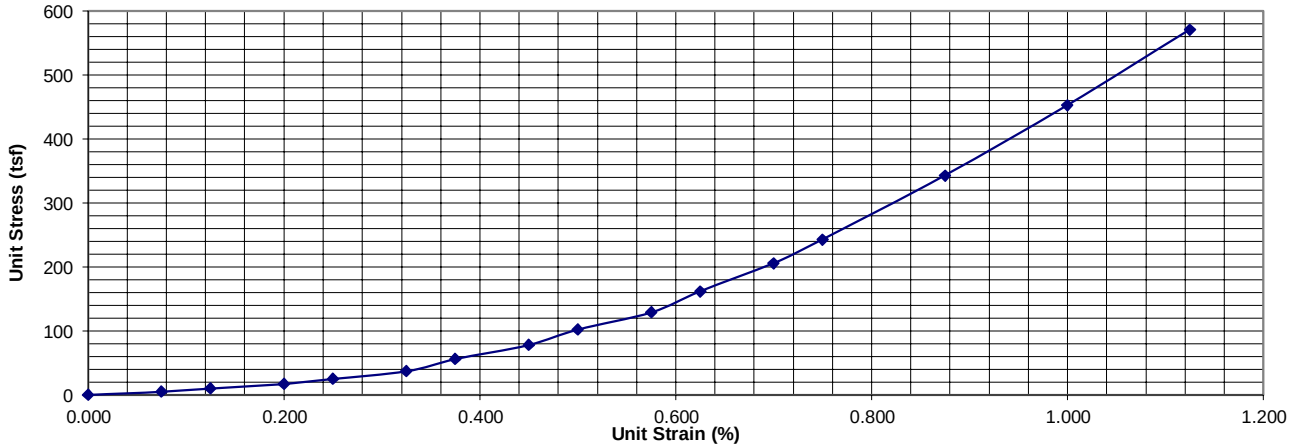
Deformation (in.)	Load (lbs.)	Strain (%)	Stress (psi)	Strength (tsf)
0.000	0	0.000	0	0
0.003	190	0.075	63	5
0.005	410	0.125	136	10
0.008	700	0.200	232	17
0.010	1070	0.250	354	25
0.013	1570	0.325	520	37
0.015	2350	0.375	778	56
0.018	3280	0.450	1086	78
0.020	4270	0.500	1414	102
0.023	5430	0.575	1798	129
0.025	6780	0.625	2245	162
0.028	8650	0.700	2864	206
0.030	10180	0.750	3371	243
0.035	14380	0.875	4762	343
0.040	19000	1.000	6291	453
0.045	23940	1.125	7927	571

Failure Photograph:



Test sample prepared in general accordance to ASTM D4543

Straightness: Procedure S1 Parallelism: Procedure FP2
Flatness: Procedure FP2 Perpendicularity: Procedure P2



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

912 Morris Street
Charleston, WV 25301
(304) 344-0821

Unconfined Compression Test of Intact Rock Core Report
ASTM D 7012 Method C

Client: AECOM Design Morgantown, WV
Project: NERI 107(2) New River Gorge National Park
Project No: N2225050

Boring No: BH22-03
Depth (ft): 20

Test Date: 10/13/2022

Avg. Specimen Diameter (in.): 1.960
Area (in.²): 3.02
Avg. Specimen Length (in.): 3.990
L/D Ratio: 2.0
Natural Density, lb/ft³ 165.7

Total Load (lbf.): 41210
Rate of Loading (lbs/sec): 110
Rate of Deformation (in/min): 0.009
Break Time (minutes): 7.00

Compressive Strength (psi): 13646
Compressive Strength (psf): 1964980
Compressive Strength (tsf): 983

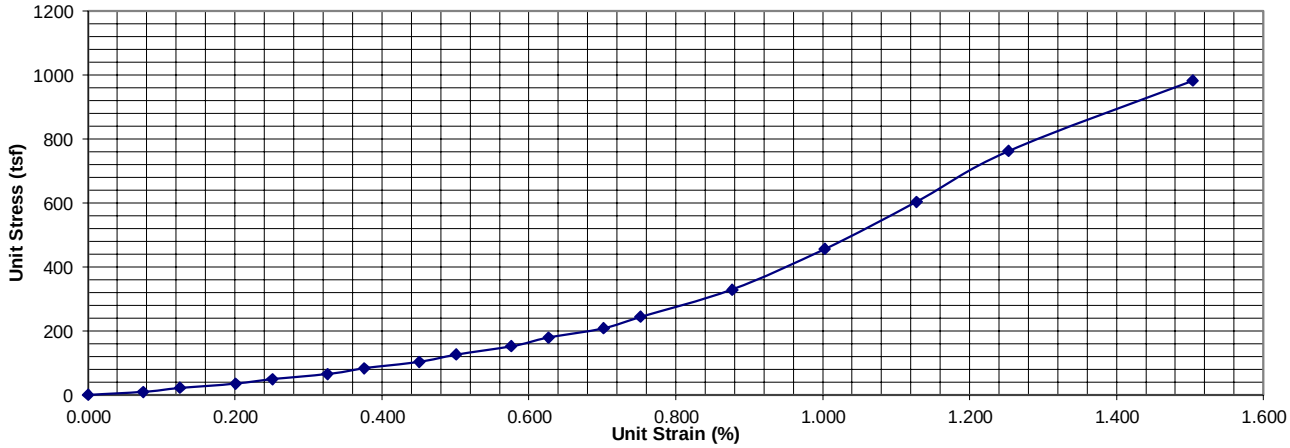
Moisture Content (%): 0.01

Failure Photograph:

Deformation (in.)	Load (lbs.)	Strain (%)	Stress (psi)	Strength (tsf)
0.000	0	0.000	0	0
0.003	390	0.075	129	9
0.005	910	0.125	301	22
0.008	1460	0.201	483	35
0.010	2040	0.251	675	49
0.013	2730	0.326	904	65
0.015	3500	0.376	1159	83
0.018	4310	0.451	1427	103
0.020	5300	0.501	1755	126
0.023	6390	0.576	2116	152
0.025	7500	0.627	2483	179
0.028	8740	0.702	2894	208
0.030	10250	0.752	3394	244
0.035	13780	0.877	4563	329
0.040	19150	1.003	6341	457
0.045	25350	1.128	8394	604
0.050	31990	1.253	10593	763
0.060	41210	1.504	13646	983

Test sample prepared in general accordance to ASTM D4543

Straightness: Procedure S1 Parallelism: Procedure FP2
Flatness: Procedure FP2 Perpendicularity: Procedure P2



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

912 Morris Street
Charleston, WV 25301
(304) 344-0821

Unconfined Compression Test of Intact Rock Core Report
ASTM D 7012 Method C

Client: AECOM Design Morgantown, WV
Project: NERI 107(2) New River Gorge National Park
Project No: N2225050

Boring No: BH22-05
Depth (ft): 23

Test Date: 10/13/2022

Avg. Specimen Diameter (in.): 1.960
Area (in.²): 3.02
Avg. Specimen Length (in.): 4.000
L/D Ratio: 2.0
Natural Density, lb/ft³ 171.4

Total Load (lbf.): 41020
Rate of Loading (lbs/sec): 110
Rate of Deformation (in/min): 0.008
Break Time (minutes): 6.10

Compressive Strength (psi): 13583
Compressive Strength (psf): 1955921
Compressive Strength (tsf): 978

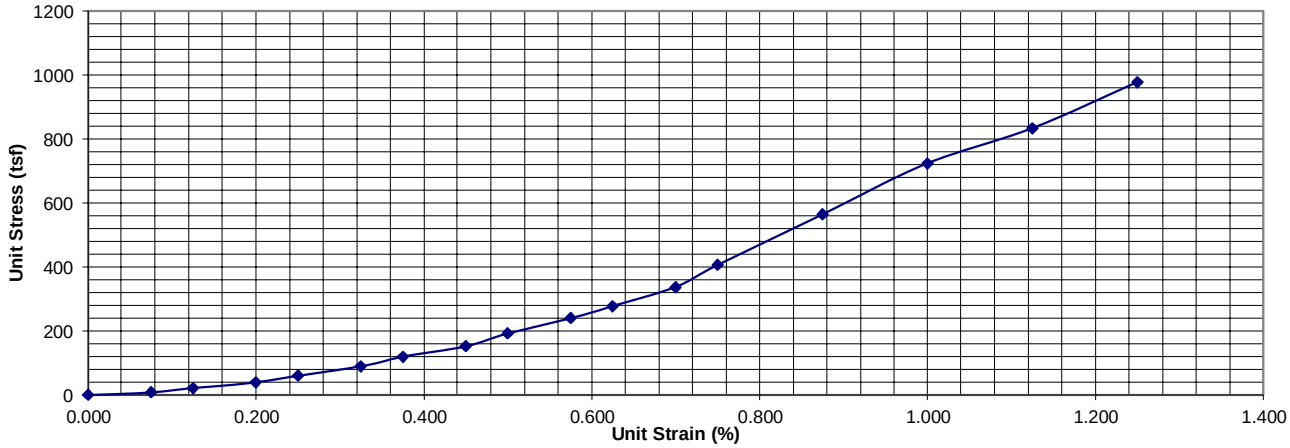
Moisture Content (%): 0.02

Deformation (in.)	Load (lbs.)	Strain (%)	Stress (psi)	Strength (tsf)
0.000	0	0.000	0	0
0.003	320	0.075	106	8
0.005	900	0.125	298	21
0.008	1650	0.200	546	39
0.010	2500	0.250	828	60
0.013	3730	0.325	1235	89
0.015	4990	0.375	1652	119
0.018	6380	0.450	2113	152
0.020	8050	0.500	2666	192
0.023	10080	0.575	3338	240
0.025	11620	0.625	3848	277
0.028	14150	0.700	4685	337
0.030	17070	0.750	5652	407
0.035	23700	0.875	7848	565
0.040	30380	1.000	10060	724
0.045	35000	1.125	11589	834
0.050	41020	1.250	13583	978

Failure Photograph:

Test sample prepared in general accordance to ASTM D4543

Straightness: Procedure S1 Parallelism: Procedure FP2
Flatness: Procedure FP2 Perpendicularity: Procedure P2



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Terracon
912 Morris Street
Charleston, WV 25301
(304) 344-0821

Unconfined Compression Test of Intact Rock Core Report
ASTM D 7012 Method C

Client: AECOM Design Morgantown, WV
Project: NERI 107(2) New River Gorge National Park
Project No: N2225050

Boring No: BH22-06
Depth (ft): 18

Test Date: 10/13/2022

Avg. Specimen Diameter (in.): 1.960
Area (in.²): 3.02
Avg. Specimen Length (in.): 4.010
L/D Ratio: 2.1
Natural Density, lb/ft³ 171.4

Total Load (lbf.): 11180
Rate of Loading (lbs/sec): 110
Rate of Deformation (in/min): 0.019
Break Time (minutes): 3.15

Compressive Strength (psi): 3702
Compressive Strength (psf): 533086
Compressive Strength (tsf): 267

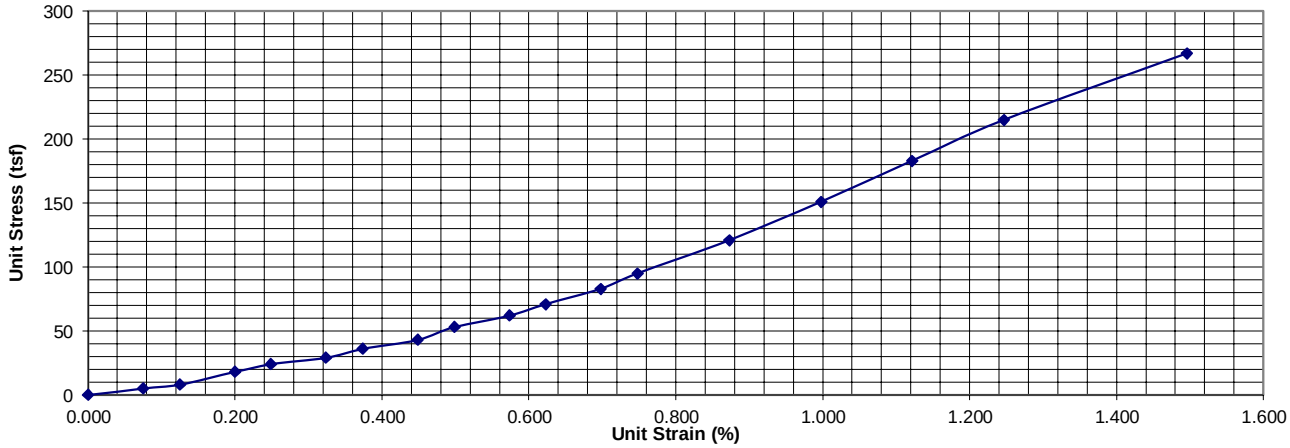
Moisture Content (%): 0.02

Deformation (in.)	Load (lbs.)	Strain (%)	Stress (psi)	Strength (tsf)
0.000	0	0.000	0	0
0.003	220	0.075	73	5
0.005	350	0.125	116	8
0.008	770	0.200	255	18
0.010	990	0.249	328	24
0.013	1200	0.324	397	29
0.015	1500	0.374	497	36
0.018	1800	0.449	596	43
0.020	2230	0.499	738	53
0.023	2600	0.574	861	62
0.025	3000	0.623	993	71
0.028	3470	0.698	1149	83
0.030	4000	0.748	1325	95
0.035	5090	0.873	1685	121
0.040	6350	0.998	2103	151
0.045	7670	1.122	2540	183
0.050	9020	1.247	2987	215
0.060	11180	1.496	3702	267

Failure Photograph:

Test sample prepared in general accordance to ASTM D4543

Straightness: Procedure S1 Parallelism: Procedure FP2
Flatness: Procedure FP2 Perpendicularity: Procedure P2



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Supporting Information

Contents:

General Notes
Unified Soil Classification System

Note: All attachments are one page unless noted above.

GENERAL NOTES

DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

NERI 107(2) New River Gorge National Park ■ Fayetteville, West Virginia

November 4, 2022 ■ Terracon Project No. N2225050

SAMPLING	MATERIALS	FIELD TESTS
Rock Core Split Spoon	Aggregate Base Course Asphalt Boulders and Cobbles Clayey Gravel with Sand Clayey Sand Clayey Sand with Gravel Sandstone Sandy Lean Clay Sandy Lean Clay with Gravel Sandy Silt Shale Siltstone	**N** Standard Penetration Test Resistance (Blows/Ft.) **(HP)** Hand Penetrometer **(T)** Torvane **(DCP)** Dynamic Cone Penetrometer **UC** Unconfined Compressive Strength **(PID)** Photo-Ionization Detector **(OVA)** Organic Vapor Analyzer

DESCRIPTIVE SOIL CLASSIFICATION

Soil classification is based on the Unified Soil Classification System. Coarse Grained Soils have more than 50% of their dry weight retained on a #200 sieve; their principal descriptors are: boulders, cobbles, gravel or sand. Fine Grained Soils have less than 50% of their dry weight retained on a #200 sieve; they are principally described as clays if they are plastic, and silts if they are slightly plastic or non-plastic. Major constituents may be added as modifiers and minor constituents may be added according to the relative proportions based on grain size. In addition to gradation, coarse-grained soils are defined on the basis of their in-place relative density and fine-grained soils on the basis of their consistency.

LOCATION AND ELEVATION NOTES

Unless otherwise noted, Latitude and Longitude are approximately determined using a hand-held GPS device. The accuracy of such devices is variable. Surface elevation data annotated with +/- indicates that no actual topographical survey was conducted to confirm the surface elevation. Instead, the surface elevation was approximately determined from topographic maps of the area.

STRENGTH TERMS

RELATIVE DENSITY OF COARSE-GRAINED SOILS (More than 50% retained on No. 200 sieve.) Density determined by Standard Penetration Resistance		CONSISTENCY OF FINE-GRAINED SOILS (50% or more passing the No. 200 sieve.) Consistency determined by laboratory shear strength testing, field visual-manual procedures or standard penetration resistance		
Descriptive Term (Density)	**Standard Penetration or N-Value Blows/Ft.**	**Descriptive Term (Consistency)**	**Unconfined Compressive Strength Qu, (tsf)**	**Standard Penetration or N-Value Blows/Ft.**
Very Loose	0 - 3	Very Soft	less than 0.25	0 - 1
Loose	4 - 9	Soft	0.25 to 0.50	2 - 4
Medium Dense	10 - 29	Medium Stiff	0.50 to 1.00	4 - 8
Dense	30 - 50	Stiff	1.00 to 2.00	8 - 15
Very Dense	> 50	Very Stiff	2.00 to 4.00	15 - 30
		Hard	> 4.00	> 30

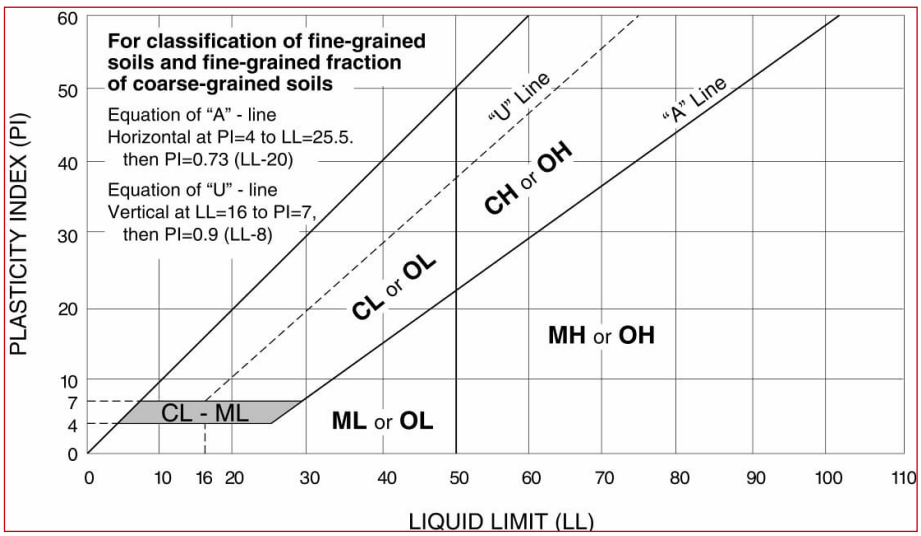
RELATIVE PROPORTIONS OF SAND AND GRAVEL		RELATIVE PROPORTIONS OF FINES	
Descriptive Term(s) of other constituents	Percent of Dry Weight	**Descriptive Term(s) of other constituents**	**Percent of Dry Weight**
Trace	<15	Trace	<5
With	15-29	With	5-12
Modifier	>30	Modifier	>12

GRAIN SIZE TERMINOLOGY		PLASTICITY DESCRIPTION	
Major Component of Sample	**Particle Size**	**Term**	**Plasticity Index**
Boulders	Over 12 in. (300 mm)	Non-plastic	0
Cobbles	12 in. to 3 in. (300mm to 75mm)	Low	1 - 10
Gravel	3 in. to #4 sieve (75mm to 4.75 mm)	Medium	11 - 30
Sand	#4 to #200 sieve (4.75mm to 0.075mm	High	> 30
Silt or Clay	Passing #200 sieve (0.075mm)		

Unified Soil Classification System

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests [A]				Soil Classification	
				Group Symbol	Group Name [B]
Coarse-Grained Soils: More than 50% retained on No. 200 sieve	**Gravels:** More than 50% of coarse fraction retained on No. 4 sieve	**Clean Gravels:** Less than 5% fines [C]	Cu≥4 and 1≤Cc≤3 [E]	GW	Well-graded gravel [F]
			Cu<4 and/or [Cc<1 or Cc>3.0] [E]	GP	Poorly graded gravel [F]
		Gravels with Fines: More than 12% fines [C]	Fines classify as ML or MH	GM	Silty gravel [F, G, H]
			Fines classify as CL or CH	GC	Clayey gravel [F, G, H]
	Sands: 50% or more of coarse fraction passes No. 4 sieve	**Clean Sands:** Less than 5% fines [D]	Cu≥6 and 1≤Cc≤3 [E]	SW	Well-graded sand [I]
			Cu<6 and/or [Cc<1 or Cc>3.0] [E]	SP	Poorly graded sand [I]
		Sands with Fines: More than 12% fines [D]	Fines classify as ML or MH	SM	Silty sand [G, H, I]
			Fines classify as CL or CH	SC	Clayey sand [G, H, I]
Fine-Grained Soils: 50% or more passes the No. 200 sieve	**Silts and Clays:** Liquid limit less than 50	**Inorganic:**	PI > 7 and plots above "A" line [J]	CL	Lean clay [K, L, M]
			PI < 4 or plots below "A" line [J]	ML	Silt [K, L, M]
		Organic:	$\frac{LL\ oven\ dried}{LL\ not\ dried} < 0.75$	OL	Organic clay [K, L, M, N]
					Organic silt [K, L, M, O]
	Silts and Clays: Liquid limit 50 or more	**Inorganic:**	PI plots on or above "A" line	CH	Fat clay [K, L, M]
			PI plots below "A" line	MH	Elastic silt [K, L, M]
		Organic:	$\frac{LL\ oven\ dried}{LL\ not\ dried} < 0.75$	OH	Organic clay [K, L, M, P]
					Organic silt [K, L, M, Q]
Highly organic soils:	Primarily organic matter, dark in color, and organic odor			PT	Peat

[A] Based on the material passing the 3-inch (75-mm) sieve.
[B] If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.
[C] Gravels with 5 to 12% fines require dual symbols: GW-GM well-graded gravel with silt, GW-GC well-graded gravel with clay, GP-GM poorly graded gravel with silt, GP-GC poorly graded gravel with clay.
[D] Sands with 5 to 12% fines require dual symbols: SW-SM well-graded sand with silt, SW-SC well-graded sand with clay, SP-SM poorly graded sand with silt, SP-SC poorly graded sand with clay.
[E] $Cu = D_{60}/D_{10}$ $\quad Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$
[F] If soil contains ≥ 15% sand, add "with sand" to group name.
[G] If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.
[H] If fines are organic, add "with organic fines" to group name.
[I] If soil contains ≥ 15% gravel, add "with gravel" to group name.
[J] If Atterberg limits plot in shaded area, soil is a CL-ML, silty clay.
[K] If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel," whichever is predominant.
[L] If soil contains ≥ 30% plus No. 200 predominantly sand, add "sandy" to group name.
[M] If soil contains ≥ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.
[N] PI ≥ 4 and plots on or above "A" line.
[O] PI < 4 or plots below "A" line.
[P] PI plots on or above "A" line.
[Q] PI plots below "A" line.



Rock Classification Notes

WEATHERING	
Term	**Description**
Fresh	Mineral crystals appear bright; show no discoloration. Features show little or now staining on surfaces. Discoloration does not extend into intact rock.
Slightly weathered	Rock generally fresh except along fractures. Some fractures stained and discoloration may extend <0.5 inches into rock.
Moderately weathered	Significant portions of rock are dull and discolored. Rock may be significantly weaker than in fresh state near fractures. Soil zones of limited extent may occur along some fractures.
Highly weathered	Rock dull and discolored throughout. Majority of rock mass is significantly weaker and has decomposed and/or disintegrated; isolated zones of stronger rock and/or soil may occur throughout.
Completely weathered	All rock material is decomposed and/or disintegrated to soil. The rock mass or fabric is still evident and largely intact. Isolated zones of stronger rock may occur locally.

STRENGTH OR HARDNESS		
Description	**Field Identification**	**Uniaxial Compressive Strength, psi**
Extremely strong	Can only be chipped with geological hammer. Rock rings on hammer blows. Cannot be scratched with a sharp pick. Hand specimens require several hard hammer blows to break.	>36,000
Very strong	Several blows of a geological hammer to fracture. Cannot be scratched with a 20d common steel nail. Can be scratched with a geologist's pick only with difficulty.	15,000-36,000
Strong	More than one blow of a geological hammer needed to fracture. Can be scratched with a 20d nail or geologist's pick. Gouges or grooves to ¼ inch deep can be excavated by a hard blow of a geologist's pick. Hand specimens can be detached by a moderate blow.	7,500-15,000
Medium strong	One blow of geological hammer needed to fracture. Can be distinctly scratched with 20d nail. Can be grooved or gouged 1/16 in. deep by firm pressure with a geologist's pick point. Can be fractured with single firm blow of geological hammer. Can be excavated in small chips (about 1-in. maximum size) by hard blows of the point of a geologist's pick;	3,500-7,500
Weak	Shallow indent by firm blow with geological hammer point. Can be gouged or grooved readily with geologist's pick point. Can be excavated in pieces several inches in size by moderate blows of a pick point. Small thin pieces can be broken by finger pressure.	700-3,500
Very weak	Crumbles under firm blow with geological hammer point. Can be excavated readily with the point of a geologist's pick. Pieces 1-in. or more in thickness can be broken with finger pressure. Can be scratched readily by fingernail.	150-700

DISCONTINUITY DESCRIPTION			
Fracture Spacing (Joints, Faults, Other Fractures)		**Bedding Spacing (May Include Foliation or Banding)**	
Description	**Spacing**	**Description**	**Spacing**
Intensely fractured	< 2.5 inches	**Laminated**	< ½-inch
Highly fractured	2.5 – 8 inches	**Very thin**	½ – 2 inches
Moderately fractured	8 inches to 2 feet	**Thin**	2 inches – 1 foot
Slightly fractured	2 to 6.5 feet	**Medium**	1 – 3 feet
Very slightly fractured	> 6.5 feet	**Thick**	3 – 10 feet
		Massive	> 10 feet

ROCK QUALITY DESIGNATION (RQD) [1]	
Description	**RQD Value (%)**
Very Poor	0 - 25
Poor	25 – 50
Fair	50 – 75
Good	75 – 90
Excellent	90 - 100

1. The combined length of all sound and intact core segments equal to or greater than 4 inches in length, expressed as a percentage of the total core run length.

Appendix III – Design Analysis

Overall Global Stability Analysis Report
WV NP NERI 107(3)
FHWA – EFLHD
SLIDE2
Software Version: 9.038

Table of Contents

Project Summary 4
Currently Open Scenarios 4
General Settings 5
Analysis Options 6
All Open Scenarios 6
Groundwater Analysis 7
All Open Scenarios 7
Random Numbers 8
All Open Scenarios 8
Surface Options 9
Site No. 5 & 6 (RSPile) - Static (C) 9
Site No. 5 & 6 (RSPile) - Static (NC) 9
Site No. 5 & 6 (RSPile) - Seismic (C) 9
Site No. 5 & 6 (RSPile) - Seismic (NC) 9
Site No. 5 & 6 (RSPile) - Ky 10
Seismic Loading 11
Site No. 5 & 6 (RSPile) - Seismic (C) 11
All other Scenarios 11
Loading 12
All other Scenarios 12
Materials 13
Materials In Use 14
Support 16
Probabilistic Input Data 17
Site No. 5 & 6 (RSPile) - Ky 17
General Settings 17
Variables 17
Global Minimums 18
Site No. 5 & 6 (RSPile) - Static (C) 18
Method: spencer 18
Site No. 5 & 6 (RSPile) - Static (NC) 18
Method: spencer 18
Site No. 5 & 6 (RSPile) - Seismic (C) 18
Method: spencer 18
Site No. 5 & 6 (RSPile) - Seismic (NC) 19
Method: spencer 19
Site No. 5 & 6 (RSPile) - Ky 19
Method: spencer 19
Global Minimum Support Data 21
Site No. 5 & 6 (RSPile) - Static (C) 21
Method: spencer 21
Site No. 5 & 6 (RSPile) - Static (NC) 21

Method: spencer 21
Site No. 5 & 6 (RSPile) - Seismic (C) 21
Method: spencer 21
Site No. 5 & 6 (RSPile) - Seismic (NC) 22
Method: spencer 22
Site No. 5 & 6 (RSPile) - Ky 22
Method: spencer 22

Slide2 Analysis Information

WV NP NERI 107(3), 95% PS&E - Overall Stability Analysis

Project Summary

File Name:	WV NP NERI 107(3), 95% PS&E - Overall Stability Analysis.slmd
Slide2 Modeler Version:	9.038
Project Title:	WV NP NERI 107(3)
Author:	J. Herrera-Roldan
Company:	FHWA - EFLHD
Date Created:	2/5/2024, 4:38:06 PM

Currently Open Scenarios

Group Name	Scenario Name	Global Minimum	Compute Time
Site No. 5 & 6 (RSPile)	Static (C)	Spencer: 1.872500	00h:00m:33.40s
	Static (NC)	Spencer: 1.597290	00h:01m:49.331s
	Seismic (C)	Spencer: 1.389510	00h:00m:35.410s
	Seismic (NC)	Spencer: 1.226220	00h:01m:37.442s
	Ky	Spencer: 1.226220	00h:01m:35.221s

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Data Output:	Standard
Failure Direction:	Right to Left

Analysis Options

All Open Scenarios

Slices Type:	Vertical
Analysis Methods Used	
	Spencer
Number of slices:	100
Tolerance:	0.001
Maximum number of iterations:	100
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Groundwater Analysis

All Open Scenarios

Groundwater Method:	Water Surfaces
Pore Fluid Unit Weight [lbs/ft3]:	62.4
Advanced Groundwater Method:	None

Random Numbers

All Open Scenarios

Pseudo-random Seed:	10116
Random Number Generation Method:	Park and Miller v.3

Surface Options

Site No. 5 & 6 (RSPile) - Static (C)

Surface Type:	Circular
Search Method:	Grid Search
Radius Increment:	10
Composite Surfaces:	Enabled
Reverse Curvature:	Invalid Surfaces
Minimum Elevation:	Not Defined
Minimum Depth:	Not Defined
Minimum Area:	Not Defined
Minimum Weight:	Not Defined

Site No. 5 & 6 (RSPile) - Static (NC)

Search Method:	Auto Refine Search
Divisions along slope:	20
Circles per division:	10
Number of iterations:	10
Divisions to use in next iteration:	50%
Number of vertices per surface:	12
Optimize Surfaces:	Enabled
Minimum Elevation:	Not Defined
Minimum Depth:	Not Defined
Minimum Area:	Not Defined
Minimum Weight:	Not Defined

Site No. 5 & 6 (RSPile) - Seismic (C)

Surface Type:	Circular
Search Method:	Grid Search
Radius Increment:	10
Composite Surfaces:	Enabled
Reverse Curvature:	Invalid Surfaces
Minimum Elevation:	Not Defined
Minimum Depth:	Not Defined
Minimum Area:	Not Defined
Minimum Weight:	Not Defined

Site No. 5 & 6 (RSPile) - Seismic (NC)

Search Method:	Auto Refine Search
Divisions along slope:	20
Circles per division:	10
Number of iterations:	10
Divisions to use in next iteration:	50%
Number of vertices per surface:	12
Optimize Surfaces:	Enabled
Minimum Elevation:	Not Defined
Minimum Depth:	Not Defined
Minimum Area:	Not Defined
Minimum Weight:	Not Defined

Site No. 5 & 6 (RSPile) - Ky

Search Method:	Auto Refine Search
Divisions along slope:	20
Circles per division:	10
Number of iterations:	10
Divisions to use in next iteration:	50%
Number of vertices per surface:	12
Optimize Surfaces:	Enabled
Minimum Elevation:	Not Defined
Minimum Depth:	Not Defined
Minimum Area:	Not Defined
Minimum Weight:	Not Defined

Seismic Loading

Site No. 5 & 6 (RSPile) - Seismic (C)

Advanced seismic analysis:	No
Staged pseudostatic analysis:	No
Seismic Load Coefficient (Horizontal):	0.071

All other Scenarios

Advanced seismic analysis:	No
Staged pseudostatic analysis:	No

Loading

All other Scenarios

Distribution:	Constant
Magnitude [psf]:	250
Orientation:	Vertical

Materials

Aggregate Base Course	
Color	
Strength Type	Mohr-Coulomb
Unit Weight	125 lbs/ft3
Cohesion	0 psf
Phi	36 °
Water Surface	Assigned per scenario
Hu Type	Custom
Hu	0
Specify alternate strength type above water surface	No

Fill - Silty Sand with Gravel (SM)	
Color	
Strength Type	Mohr-Coulomb
Unit Weight	115 lbs/ft3
Cohesion	0 psf
Phi	34 °
Water Surface	Assigned per scenario
Hu Type	Custom
Hu	1
Specify alternate strength type above water surface	No

Silty Sand with Gravel (SM) and Clayey Sand (SC)	
Color	
Strength Type	Mohr-Coulomb
Unit Weight	105 lbs/ft3
Cohesion	0 psf
Phi	26 °
Water Surface	Assigned per scenario
Hu Type	Custom
Hu	1
Specify alternate strength type above water surface	No

Silty Gravel with Sand (GM)	
Color	
Strength Type	Mohr-Coulomb
Unit Weight	115 lbs/ft3
Cohesion	0 psf
Phi	30 °
Water Surface	Assigned per scenario
Hu Type	Custom
Hu	1
Specify alternate strength type above water surface	No

Silty Sand with Gravel (SM)	
Color	
Strength Type	Mohr-Coulomb
Unit Weight	105 lbs/ft3
Cohesion	0 psf
Phi	28 °
Water Surface	Assigned per scenario
Hu Type	Custom
Hu	1
Specify alternate strength type above water surface	No

Weathered Silstone	
Color	
Strength Type	Mohr-Coulomb
Unit Weight	130 lbs/ft3
Cohesion	0 psf
Phi	36 °
Water Surface	Assigned per scenario
Hu Type	Custom
Hu	1
Specify alternate strength type above water surface	No

Interbeded Clay	
Color	
Strength Type	Mohr-Coulomb
Unit Weight	100 lbs/ft3
Cohesion	0 psf
Phi	22 °
Water Surface	Assigned per scenario
Hu Type	Custom
Hu	1
Specify alternate strength type above water surface	No

Siltstone	
Color	
Strength Type	Mohr-Coulomb
Unit Weight	165 lbs/ft3
Cohesion	500 psf
Phi	45 °
Water Surface	Assigned per scenario
Hu Type	Custom
Hu	1
Specify alternate strength type above water surface	No

Materials In Use

Material	Static (C)	Static (NC)	Seismic (C)	Seismic (NC)	Ky
Aggregate Base Course	✓	✓	✓	✓	✓
Fill - Silty Sand with Gravel (SM)	✓	✓	✓	✓	✓
Silty Sand with Gravel (SM) and Clayey Sand (SC)	✓	✓	✓	✓	✓
Silty Gravel with Sand (GM)	✓	✓	✓	✓	✓
Silty Sand with Gravel (SM)	✓	✓	✓	✓	✓
Weathered Silstone	✓	✓	✓	✓	✓
Interbeded Clay	✓	✓	✓	✓	✓
Siltstone	✓	✓	✓	✓	✓

Support

Ground Anchor	
Color	
Type	Grouted Tieback
Force Application	Active (Method A)
Force Orientation	Parallel to Reinforcement
Out-Of-Plane Spacing	6 ft
Tensile Capacity	45000 lbs
Plate Capacity	45000 lbs
Bond Strength	4000 lbs/ft
Material Dependent	No
Bond Length	30 ft

HP16X88 (RSPile)	
Color	
Type	RSPile
Force Application	Active (Method A)
Out-Of-Plane Spacing	6 ft
Apply Batter and Ground Slope Modifiers	Yes
Ground Slope and Batter Values	Calculate from Slide2 model
Soil Displacement Type	Maximum
Soil Displacement	1 in
Lateral Shear Direction	Along X' in RSPile

Probabilistic Input Data

Site No. 5 & 6 (RSPile) - Ky

General Settings

Sensitivity Analysis:	On
Probabilistic Analysis:	Off
Spatial Variability Analysis:	Off

Variables

Seismic Coefficient	Property	Distribution	Mean	Min	Max
Horizontal Seismic Coefficient		Normal	0.071	0.011	0.371
Vertical Seismic Coefficient		0			

Global Minimums

Site No. 5 & 6 (RSPile) - Static (C)

Method: spencer

FS	1.872500
Center:	-94.456, 1274.502
Radius:	212.507
Left Slip Surface Endpoint:	-129.398, 1064.887
Right Slip Surface Endpoint:	43.241, 1112.642
Resisting Moment:	2.46122e+07 lb-ft
Driving Moment:	1.3144e+07 lb-ft
Resisting Horizontal Force:	110646 lb
Driving Horizontal Force:	59089.7 lb
Active Support Moment:	-6.60467e+06 lb-ft
Active Horizontal Support Force:	-34177.3 lb
Maximum Single Support Force:	15433 lb
Total Support Force:	37933 lb
Total Slice Area:	3055.57 ft2
Surface Horizontal Width:	172.638 ft
Surface Average Height:	17.6993 ft

Site No. 5 & 6 (RSPile) - Static (NC)

Method: spencer

FS	1.597290
Axis Location:	-94.842, 1278.747
Left Slip Surface Endpoint:	-131.692, 1063.801
Right Slip Surface Endpoint:	55.006, 1120.299
Left Slope Intercept:	-131.692 1063.803
Right Slope Intercept:	55.006 1120.299
Resisting Moment:	2.37159e+07 lb-ft
Driving Moment:	1.48476e+07 lb-ft
Resisting Horizontal Force:	105331 lb
Driving Horizontal Force:	65943.8 lb
Active Support Moment:	-6.61055e+06 lb-ft
Active Horizontal Support Force:	-34720.1 lb
Maximum Single Support Force:	14056.1 lb
Total Support Force:	36556.1 lb
Total Slice Area:	2963.88 ft2
Surface Horizontal Width:	186.697 ft
Surface Average Height:	15.8754 ft

Site No. 5 & 6 (RSPile) - Seismic (C)

Method: spencer

FS	1.389510
Center:	-94.456, 1274.502
Radius:	212.507
Left Slip Surface Endpoint:	-129.398, 1064.887
Right Slip Surface Endpoint:	43.241, 1112.642
Resisting Moment:	2.35583e+07 lb-ft
Driving Moment:	1.69545e+07 lb-ft
Resisting Horizontal Force:	106317 lb
Driving Horizontal Force:	76514.2 lb
Active Support Moment:	-6.60467e+06 lb-ft
Active Horizontal Support Force:	-34177.3 lb
Maximum Single Support Force:	15433 lb
Total Support Force:	37933 lb
Total Slice Area:	3055.57 ft2
Surface Horizontal Width:	172.638 ft
Surface Average Height:	17.6993 ft

Site No. 5 & 6 (RSPile) - Seismic (NC)

Method: spencer

FS	1.226220
Axis Location:	-94.842, 1278.747
Left Slip Surface Endpoint:	-131.692, 1063.801
Right Slip Surface Endpoint:	55.006, 1120.299
Left Slope Intercept:	-131.692 1063.803
Right Slope Intercept:	55.006 1120.299
Resisting Moment:	2.3343e+07 lb-ft
Driving Moment:	1.90365e+07 lb-ft
Resisting Horizontal Force:	103588 lb
Driving Horizontal Force:	84477.1 lb
Active Support Moment:	-6.72873e+06 lb-ft
Active Horizontal Support Force:	-34702 lb
Maximum Single Support Force:	14794.7 lb
Total Support Force:	37294.7 lb
Total Slice Area:	3062.03 ft2
Surface Horizontal Width:	186.697 ft
Surface Average Height:	16.4011 ft

Site No. 5 & 6 (RSPile) - Ky

Method: spencer

FS	1.226220
Axis Location:	-94.842, 1278.747
Left Slip Surface Endpoint:	-131.692, 1063.801
Right Slip Surface Endpoint:	55.006, 1120.299
Left Slope Intercept:	-131.692 1063.803
Right Slope Intercept:	55.006 1120.299
Resisting Moment:	2.3343e+07 lb-ft
Driving Moment:	1.90365e+07 lb-ft
Resisting Horizontal Force:	103588 lb
Driving Horizontal Force:	84477.1 lb
Active Support Moment:	-6.72873e+06 lb-ft
Active Horizontal Support Force:	-34702 lb
Maximum Single Support Force:	14794.7 lb
Total Support Force:	37294.7 lb
Total Slice Area:	3062.03 ft2
Surface Horizontal Width:	186.697 ft
Surface Average Height:	16.4011 ft

Global Minimum Support Data

Site No. 5 & 6 (RSPile) - Static (C)

Method: spencer

Number of Supports: 4

Ground Anchor						
Support Type: Grouted Tieback						
Start (x, y)	**Length (ft)**	**L Inside SS (ft)**	**L Outside SS (ft)**	**Li (ft)**	**Lo (ft)**	**Force (lb)**
-24.9672, 1106.16	46	32.4819	13.5181	32.4819	13.5181	15433
-24.9672, 1096.16	50	28.1135	21.8865	8.11352	21.8865	7500
-24.9672, 1101.16	50	34.1526	15.8474	14.1526	15.8474	7500
-24.9672, 1091.16	50	22.0789	27.9211	2.0789	27.9211	7500

Site No. 5 & 6 (RSPile) - Static (NC)

Method: spencer

Number of Supports: 4

Ground Anchor						
Support Type: Grouted Tieback						
Start (x, y)	**Length (ft)**	**L Inside SS (ft)**	**L Outside SS (ft)**	**Li (ft)**	**Lo (ft)**	**Force (lb)**
-24.9672, 1106.16	46	33.2743	12.7257	33.2743	12.7257	14056.1
-24.9672, 1096.16	50	28.1135	21.8865	8.11352	21.8865	7500
-24.9672, 1101.16	50	34.1526	15.8474	14.1526	15.8474	7500
-24.9672, 1091.16	50	22.0789	27.9211	2.0789	27.9211	7500

Site No. 5 & 6 (RSPile) - Seismic (C)

Method: spencer

Number of Supports: 4

Ground Anchor						
Support Type: Grouted Tieback						
Start (x, y)	**Length (ft)**	**L Inside SS (ft)**	**L Outside SS (ft)**	**Li (ft)**	**Lo (ft)**	**Force (lb)**
-24.9672, 1106.16	46	32.4819	13.5181	32.4819	13.5181	15433
-24.9672, 1096.16	50	28.1135	21.8865	8.11352	21.8865	7500
-24.9672, 1101.16	50	34.1526	15.8474	14.1526	15.8474	7500
-24.9672, 1091.16	50	22.0789	27.9211	2.0789	27.9211	7500

Site No. 5 & 6 (RSPile) - Seismic (NC)

Method: spencer

Number of Supports: 4

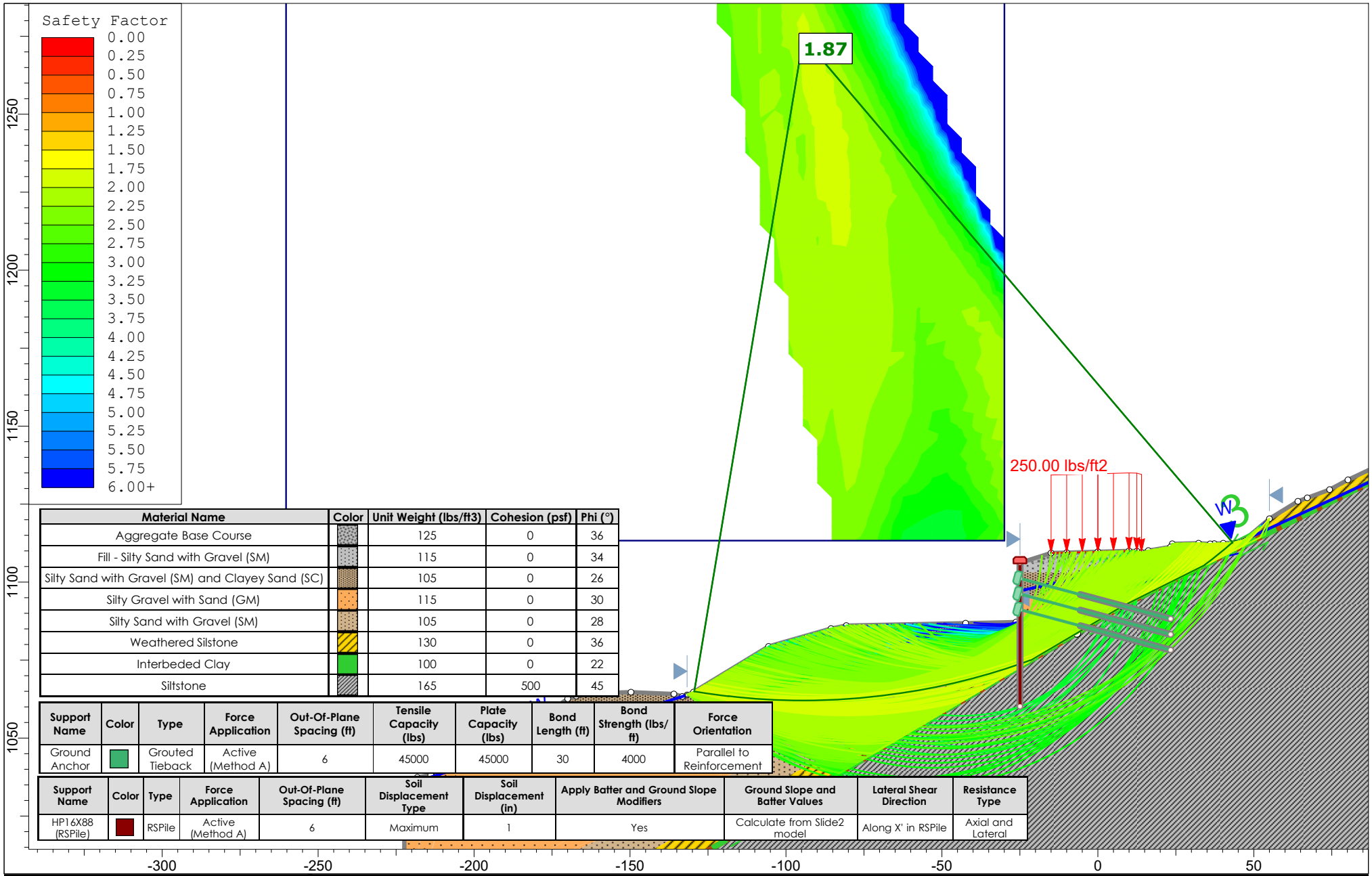
Ground Anchor						
Support Type: Grouted Tieback						
Start (x, y)	**Length (ft)**	**L Inside SS (ft)**	**L Outside SS (ft)**	**Li (ft)**	**Lo (ft)**	**Force (lb)**
-24.9672, 1106.16	46	33.285	12.715	33.285	12.715	14794.7
-24.9672, 1096.16	50	28.1135	21.8865	8.11352	21.8865	7500
-24.9672, 1101.16	50	34.1526	15.8474	14.1526	15.8474	7500
-24.9672, 1091.16	50	22.0789	27.9211	2.0789	27.9211	7500

Site No. 5 & 6 (RSPile) - Ky

Method: spencer

Number of Supports: 4

Ground Anchor						
Support Type: Grouted Tieback						
Start (x, y)	**Length (ft)**	**L Inside SS (ft)**	**L Outside SS (ft)**	**Li (ft)**	**Lo (ft)**	**Force (lb)**
-24.9672, 1106.16	46	33.285	12.715	33.285	12.715	14794.7
-24.9672, 1096.16	50	28.1135	21.8865	8.11352	21.8865	7500
-24.9672, 1101.16	50	34.1526	15.8474	14.1526	15.8474	7500
-24.9672, 1091.16	50	22.0789	27.9211	2.0789	27.9211	7500



Material Name	Color	Unit Weight (lbs/ft3)	Cohesion (psf)	Phi (°)
Aggregate Base Course		125	0	36
Fill - Silty Sand with Gravel (SM)		115	0	34
Silty Sand with Gravel (SM) and Clayey Sand (SC)		105	0	26
Silty Gravel with Sand (GM)		115	0	30
Silty Sand with Gravel (SM)		105	0	28
Weathered Silstone		130	0	36
Interbeded Clay		100	0	22
Siltstone		165	500	45

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (ft)	Tensile Capacity (lbs)	Plate Capacity (lbs)	Bond Length (ft)	Bond Strength (lbs/ft)	Force Orientation
Ground Anchor		Grouted Tieback	Active (Method A)	6	45000	45000	30	4000	Parallel to Reinforcement

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (ft)	Soil Displacement Type	Soil Displacement (in)	Apply Batter and Ground Slope Modifiers	Ground Slope and Batter Values	Lateral Shear Direction	Resistance Type
HP16X88 (RSPile)		RSPile	Active (Method A)	6	Maximum	1	Yes	Calculate from Slide2 model	Along X' in RSPile	Axial and Lateral

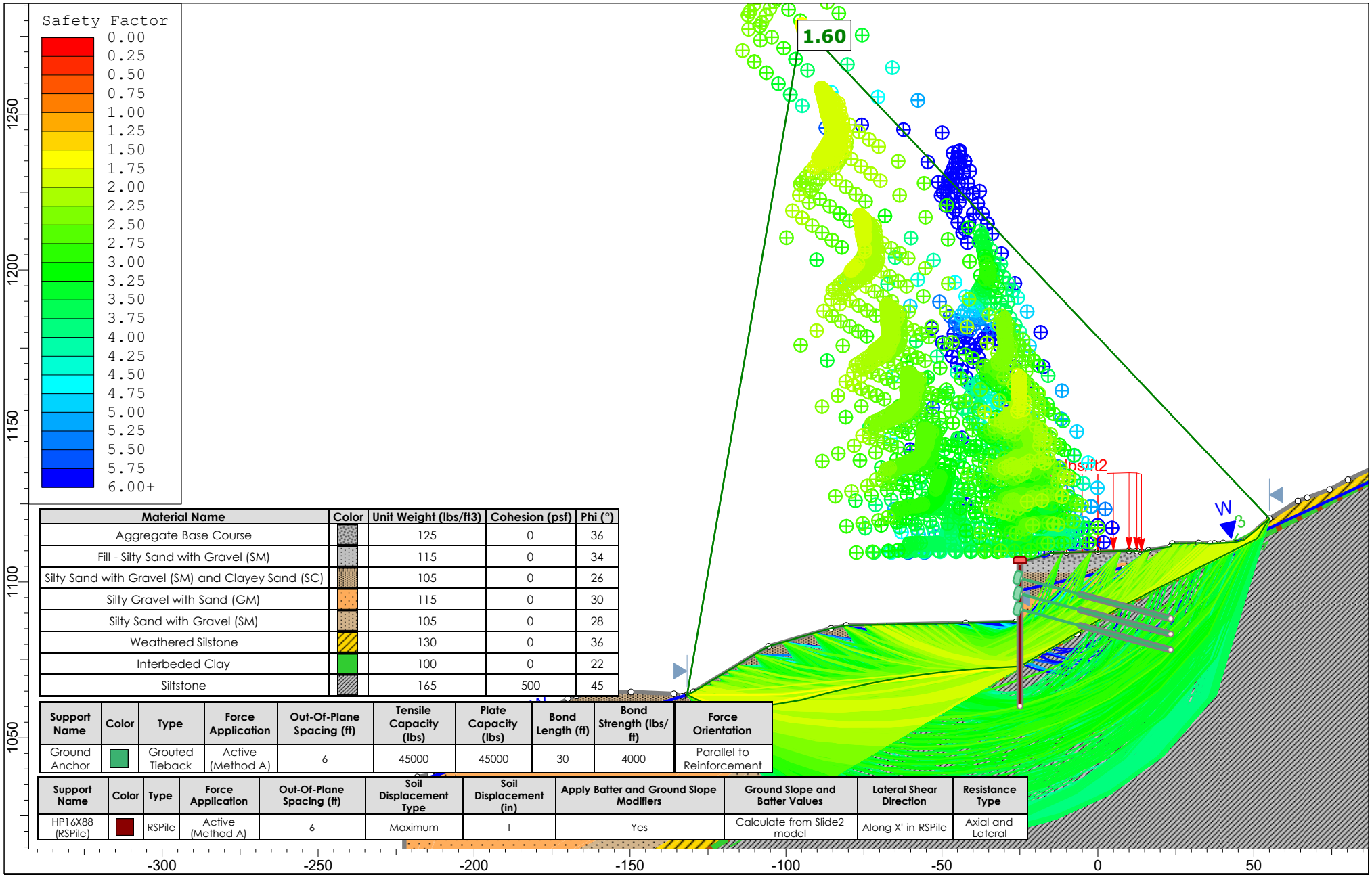
U.S. Department of Transportation
Federal Highway Administration

PROJECT: WV NP NERI 107(3)

SITE: Site No. 5 & 6 (RSPile) **SCENARIO:** Static (C)

By: J. Herrera-Roldan **DATE:** 7/25/2025

SCALE: 1:500



Material Name	Color	Unit Weight (lbs/ft3)	Cohesion (psf)	Phi (°)
Aggregate Base Course		125	0	36
Fill - Silty Sand with Gravel (SM)		115	0	34
Silty Sand with Gravel (SM) and Clayey Sand (SC)		105	0	26
Silty Gravel with Sand (GM)		115	0	30
Silty Sand with Gravel (SM)		105	0	28
Weathered Silstone		130	0	36
Interbeded Clay		100	0	22
Siltstone		165	500	45

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (ft)	Tensile Capacity (lbs)	Plate Capacity (lbs)	Bond Length (ft)	Bond Strength (lbs/ft)	Force Orientation
Ground Anchor		Grouted Tieback	Active (Method A)	6	45000	45000	30	4000	Parallel to Reinforcement

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (ft)	Soil Displacement Type	Soil Displacement (in)	Apply Batter and Ground Slope Modifiers	Ground Slope and Batter Values	Lateral Shear Direction	Resistance Type
HP16X88 (RSPile)		RSPile	Active (Method A)	6	Maximum	1	Yes	Calculate from Slide2 model	Along X' in RSPile	Axial and Lateral

U.S. Department of Transportation
Federal Highway Administration

PROJECT: WV NP NERI 107(3)

SITE: Site No. 5 & 6 (RSPile) **SCENARIO:** Static (NC)

By: J. Herrera-Roldan **DATE:** 7/25/2025

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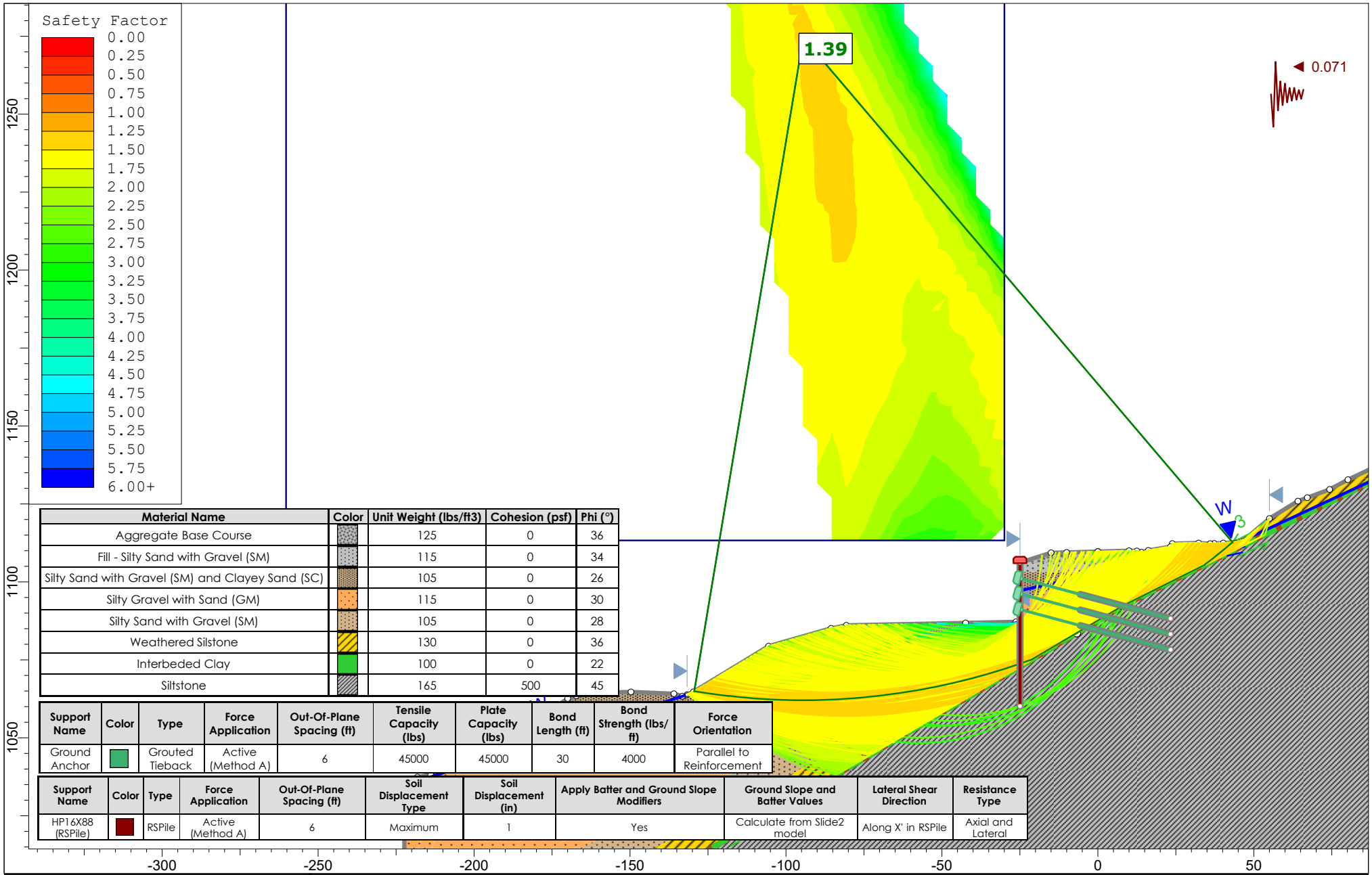

Material Name	Color	Unit Weight (lbs/ft3)	Cohesion (psf)	Phi (°)
Aggregate Base Course		125	0	36
Fill - Silty Sand with Gravel (SM)		115	0	34
Silty Sand with Gravel (SM) and Clayey Sand (SC)		105	0	26
Silty Gravel with Sand (GM)		115	0	30
Silty Sand with Gravel (SM)		105	0	28
Weathered Silstone		130	0	36
Interbeded Clay		100	0	22
Siltstone		165	500	45

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (ft)	Tensile Capacity (lbs)	Plate Capacity (lbs)	Bond Length (ft)	Bond Strength (lbs/ft)	Force Orientation
Ground Anchor		Grouted Tieback	Active (Method A)	6	45000	45000	30	4000	Parallel to Reinforcement

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (ft)	Soil Displacement Type	Soil Displacement (in)	Apply Batter and Ground Slope Modifiers	Ground Slope and Batter Values	Lateral Shear Direction	Resistance Type
HP16X88 (RSPile)		RSPile	Active (Method A)	6	Maximum	1	Yes	Calculate from Slide2 model	Along X' in RSPile	Axial and Lateral

U.S. Department of Transportation
Federal Highway Administration

PROJECT: WV NP NERI 107(3)

SITE: Site No. 5 & 6 (RSPile) **SCENARIO:** Seismic (C)

By: J. Herrera-Roldan **DATE:** 7/25/2025

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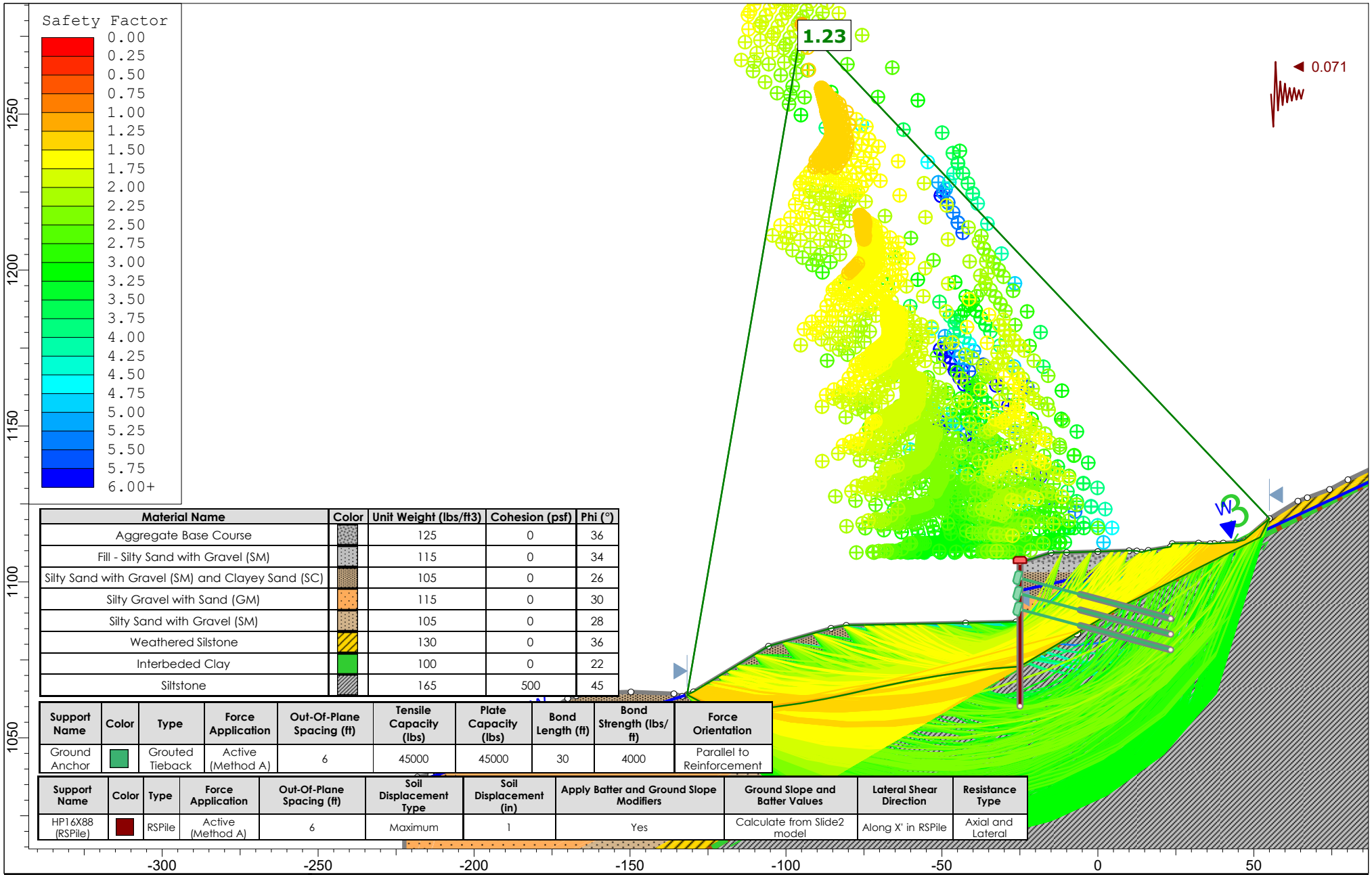

Material Name	Color	Unit Weight (lbs/ft3)	Cohesion (psf)	Phi (°)
Aggregate Base Course		125	0	36
Fill - Silty Sand with Gravel (SM)		115	0	34
Silty Sand with Gravel (SM) and Clayey Sand (SC)		105	0	26
Silty Gravel with Sand (GM)		115	0	30
Silty Sand with Gravel (SM)		105	0	28
Weathered Silstone		130	0	36
Interbeded Clay		100	0	22
Siltstone		165	500	45

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (ft)	Tensile Capacity (lbs)	Plate Capacity (lbs)	Bond Length (ft)	Bond Strength (lbs/ft)	Force Orientation
Ground Anchor		Grouted Tieback	Active (Method A)	6	45000	45000	30	4000	Parallel to Reinforcement

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (ft)	Soil Displacement Type	Soil Displacement (in)	Apply Batter and Ground Slope Modifiers	Ground Slope and Batter Values	Lateral Shear Direction	Resistance Type
HP16X88 (RSPile)		RSPile	Active (Method A)	6	Maximum	1	Yes	Calculate from Slide2 model	Along X' in RSPile	Axial and Lateral

U.S. Department of Transportation
Federal Highway Administration

PROJECT: WV NP NERI 107(3)

SITE: Site No. 5 & 6 (RSPile) | **SCENARIO:** Seismic (NC)

By: J. Herrera-Roldan | **DATE:** 7/25/2025

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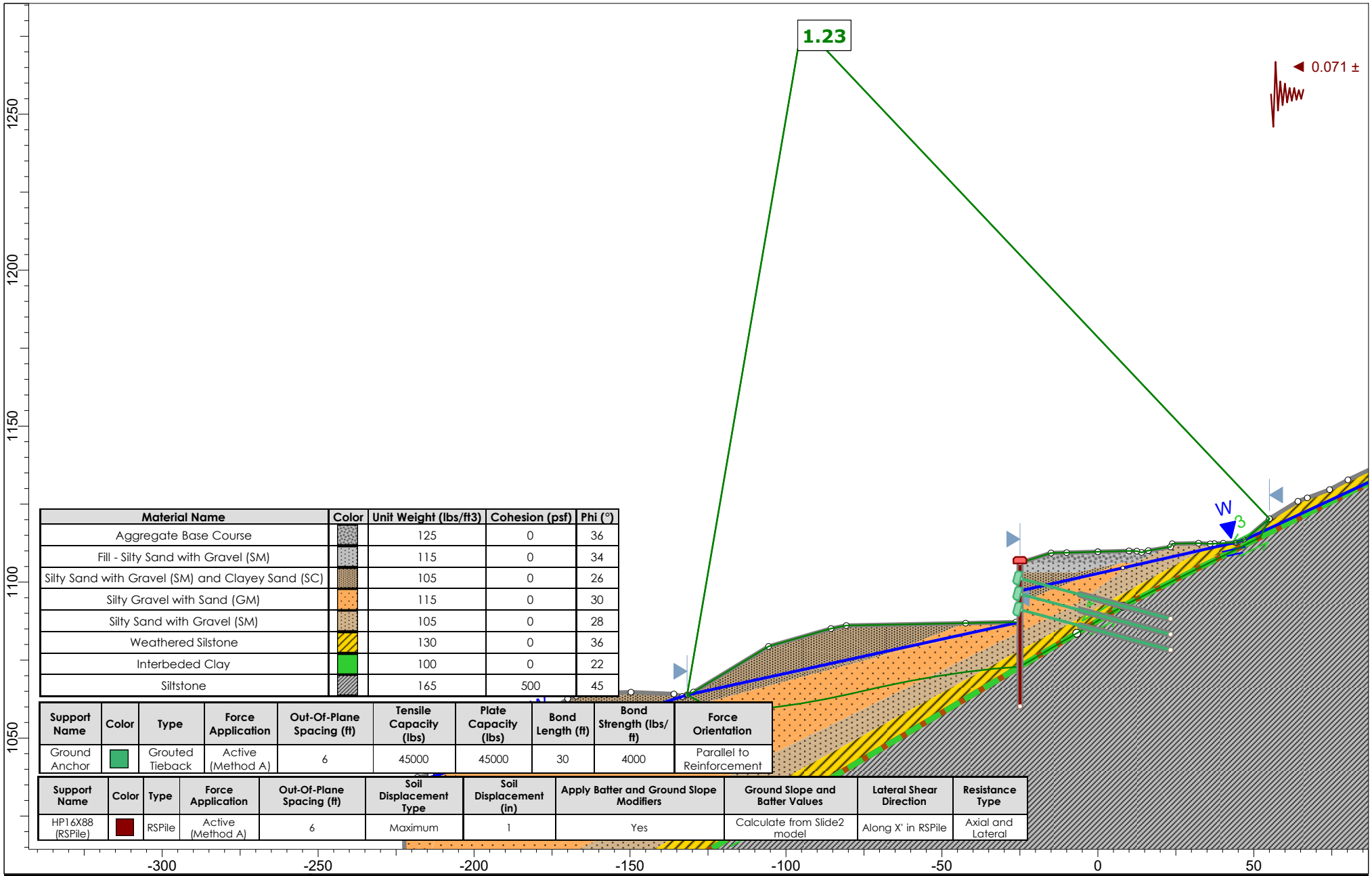


Material Name	Color	Unit Weight (lbs/ft3)	Cohesion (psf)	Phi (°)
Aggregate Base Course		125	0	36
Fill - Silty Sand with Gravel (SM)		115	0	34
Silty Sand with Gravel (SM) and Clayey Sand (SC)		105	0	26
Silty Gravel with Sand (GM)		115	0	30
Silty Sand with Gravel (SM)		105	0	28
Weathered Silstone		130	0	36
Interbeded Clay		100	0	22
Siltstone		165	500	45

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (ft)	Tensile Capacity (lbs)	Plate Capacity (lbs)	Bond Length (ft)	Bond Strength (lbs/ft)	Force Orientation
Ground Anchor		Grouted Tieback	Active (Method A)	6	45000	45000	30	4000	Parallel to Reinforcement

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (ft)	Soil Displacement Type	Soil Displacement (in)	Apply Batter and Ground Slope Modifiers	Ground Slope and Batter Values	Lateral Shear Direction	Resistance Type
HP16X88 (RSPile)		RSPile	Active (Method A)	6	Maximum	1	Yes	Calculate from Slide2 model	Along X' in RSPile	Axial and Lateral

U.S. Department of Transportation
Federal Highway Administration

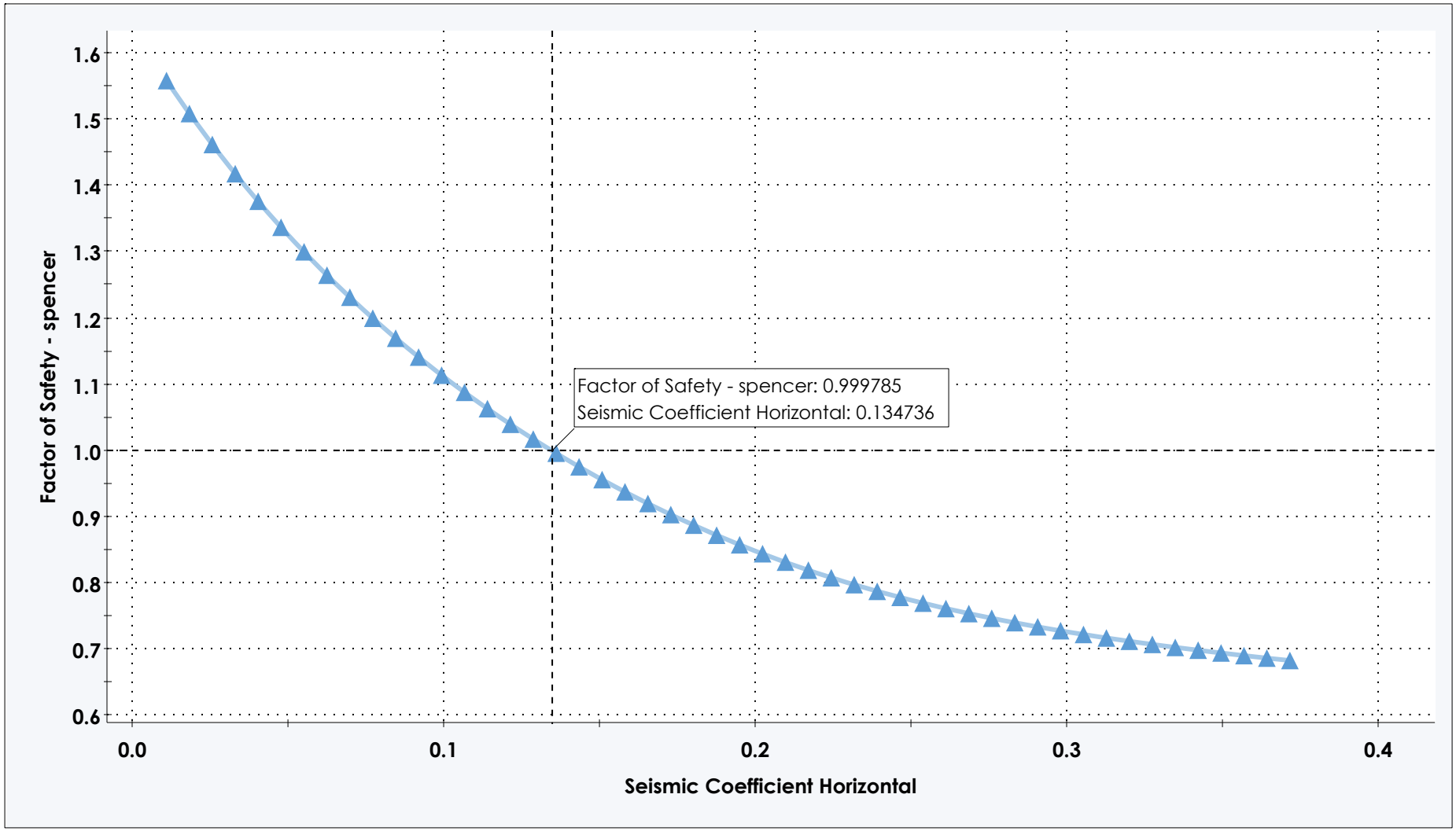
PROJECT: WV NP NERI 107(3)

SITE: Site No. 5 & 6 (RSPile) **SCENARIO:** Ky

By: J. Herrera-Roldan **DATE:** 7/25/2025

SCALE: 1:500

Yield Horizontal Seismic Coefficient



Seismic Coefficient Horizontal

U.S. Department of Transportation
Federal Highway Administration

PROJECT: WV NP NERI 107(3)	
SITE: Site No. 5 & 6 (RSPile)	**SCENARIO:** Ky
By: J. Herrera-Roldan	**DATE:** 7/25/2025
SCALE:	

Extreme Event I, No Analysis Evaluation Requirements

According to AASHTO 11.5.4.2, a seismic design shall not be considered mandatory for walls located in Seismic Zones 1 through 3, or for walls at Sites where the site adjusted peak ground acceleration is less than or equal to 0.4g, unless one or more of the following is true:

- Liquefaction induced lateral spreading or slope failure, or seismically induced slope failure, due to the presence of sensitive clays that lose strength during the seismic shaking, may impact the stability of the wall for the design earthquake.
- The wall supports another structure that is required, based on the applicable design code or specification for the supported structure, to be designed for seismic loading and poor seismic performance of the wall could impact the seismic performance of that structure.

In addition, according to C11.5.4.2, paragraph 7, a seismic analysis should be considered mandatory if wall located in seismic zone 2 or higher if either of the following is greater than 30 feet:

1. The exposed wall height plus the average depth over the width of the wall of any soil surcharge present.
2. For tiered walls, the sum of the exposed height of all the tiers plus the average soil surcharge depth.

The purpose of this Extreme Event I evaluation is to determine if the retaining structure requires an external and internal seismic design.

References

- AASHTO (2020), "LRFD Bridge Design Specifications", 9th Edition, - November 2021 Errata, Washington D.C. American Association of State Highway and Transportation Officials.

Wall Location

Latitude: 37.999244° N
Longitude: 81.023706° W

Wall Height

$H = 19.00$ ft

$h_{ES} = 5.00$ ft

$H_{Wall} := H + h_{ES}$ $\therefore$ $H_{Wall} = 24.00$ ft

$\phi_f = 28$ ° Retained fill friction angle.

$\theta = 90$ ° Angle of back of wall from horizontal.

$\beta = 26.57$ ° Backslope angle from horizontal.

$\delta := \beta$ AASHTO 3.11.5.8.1

Horizontal Peak Ground Acceleration (PGA) - AASHTO Figure 3.10.2.1-1

$PGA := 0.059$ g

Horizontal Response Spectral Acceleration Coefficient at Period of 0.2 s - AASHTO Figure 3.10.2.1

$S_S := 0.127$ g

Horizontal Response Spectral Acceleration Coefficient at Period of 1.0 s - AASHTO Figure 3.10.2.1

$S_1 := 0.044$ g

Project: WV NP NERI 107(3) - Anchored Soldier Pile Wall Geotechnical Analysis and Design - STA 115+00

Site Class Definition - AASHTO Table 3.10.3.1-1

BORING ID - BH22-05

Soil Unit	Depth (ft) From	Depth (ft) To	Layer Thickness (ft)	N_i (blows/ft)												Average N (blows/ft)	d_i/N_i	$\overline{N}$
Aggregate Base	0.0	5.5	5.5	20	21											21	0.27	41
Silty Sand with Gravel	5.5	8.0	2.5	7												7	0.36	
Silty Gravel with Sand	8.0	15.6	7.6	18												18	0.42	
Silty Sand with Gravel	15.6	20.6	5.0	8												8	0.63	
Sandstone	20.6	100.0	79.4	100												100	0.79	

BORING ID - BH21-06

Soil Unit	Depth (ft) From	Depth (ft) To	Layer Thickness (ft)	N_i (blows/ft)												Average N (blows/ft)	d_i/N_i	$\overline{N}$
Aggregate Base	0.0	5.0	5.0	17												17	0.29	65
Clayey Sand	5.0	7.5	2.5	24												24	0.10	
Sandy Silt	7.5	11.0	3.5	15	12											14	0.26	
Sandstone	11.0	100.0	89.0	100												100	0.89	

$N_{Bar} = 53.00$

```
Site_Class := if N_Bar > 50
                "C"
              else
                if N_Bar > 15
                  "D"
                else
                  "E"
```

Site_Class = "C"

Site Factors - AASHTO 3.10.3.2

$PGA = 0.059$

$PGA_{_1} := 0.1 \qquad F_{pga_1} := 1.2$

$PGA_{_2} := 0.20 \qquad F_{pga_2} := 1.2$

$PGA_N := \begin{bmatrix} PGA_{_1} \\ PGA_{_2} \end{bmatrix} \qquad F_{PGA_N} := \begin{bmatrix} F_{pga_1} \\ F_{pga_2} \end{bmatrix}$

$F_{pga} := \text{linterp}\left(PGA_N, F_{PGA_N}, PGA\right) \qquad \therefore \qquad F_{pga} = 1.20$

Table 3.10.3.2-1—Values of Site Factor, F_{pga}, at Zero-Period on Acceleration Spectrum

Site Class	Peak Ground Acceleration Coefficient (*PGA*)[1]				
	PGA < 0.10	*PGA* = 0.20	*PGA* = 0.30	*PGA* = 0.40	*PGA* > 0.50
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F[2]	*	*	*	*	*

Notes:

[1]Use straight-line interpolation for intermediate values of *PGA*.

[2]Site-specific geotechnical investigation and dynamic site response analysis should be performed for all sites in Site Class F.

$S_S = 0.127$

$S_{S_1} := 0.25 \qquad F_{a_1} := 1.2$

$S_{S_2} := 0.50 \qquad F_{a_2} := 1.2$

$S_{S_N} := \begin{bmatrix} S_{S_1} \\ S_{S_2} \end{bmatrix} \qquad F_{a_N} := \begin{bmatrix} F_{a_1} \\ F_{a_2} \end{bmatrix}$

$F_a := \text{linterp}\left(S_{S_N}, F_{a_N}, S_S\right) \qquad \therefore \qquad F_a = 1.20$

Table 3.10.3.2-2—Values of Site Factor, F_a, for Short-Period Range of Acceleration Spectrum

Site Class	Spectral Acceleration Coefficient at Period 0.2 sec (S_S)[1]				
	S_S < 0.25	S_S = 0.50	S_S = 0.75	S_S = 1.00	S_S > 1.25
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F[2]	*	*	*	*	*

Notes:

[1]Use straight-line interpolation for intermediate values of S_s.

[2]Site-specific geotechnical investigation and dynamic site response analysis should be performed for all sites in Site Class F.

$S_1 = 0.044$

$S_{1_1} := 0.1 \qquad F_{v_1} := 1.7$

$S_{1_2} := 0.2 \qquad F_{v_2} := 1.7$

$S_{1_N} := \begin{bmatrix} S_{1_1} \\ S_{1_2} \end{bmatrix} \qquad F_{v_N} := \begin{bmatrix} F_{v_1} \\ F_{v_2} \end{bmatrix}$

$F_v := \text{linterp}\left(S_{1_N}, F_{v_N}, S_1\right) \qquad \therefore \qquad F_v = 1.70$

Table 3.10.3.2-3—Values of Site Factor, F_v, for Long-Period Range of Acceleration Spectrum

Site Class	Spectral Acceleration Coefficient at Period 1.0 sec (S_1)[1]				
	S_1 < 0.1	S_1 = 0.2	S_1 = 0.3	S_1 = 0.4	S_1 > 0.5
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F[2]	*	*	*	*	*

Notes:

[1]Use straight-line interpolation for intermediate values of S_1.

[2]Site-specific geotechnical investigation and dynamic site response analysis should be performed for all sites in Site Class F.

Modified Horizontal Response Spectral Acceleration Coefficients - AASHTO 3.10.4.2

$A_s := F_{pga} \cdot PGA \quad \therefore \quad A_s = 0.071\ g$

$S_{DS} := F_a \cdot S_S \quad \therefore \quad S_{DS} = 0.152\ g$

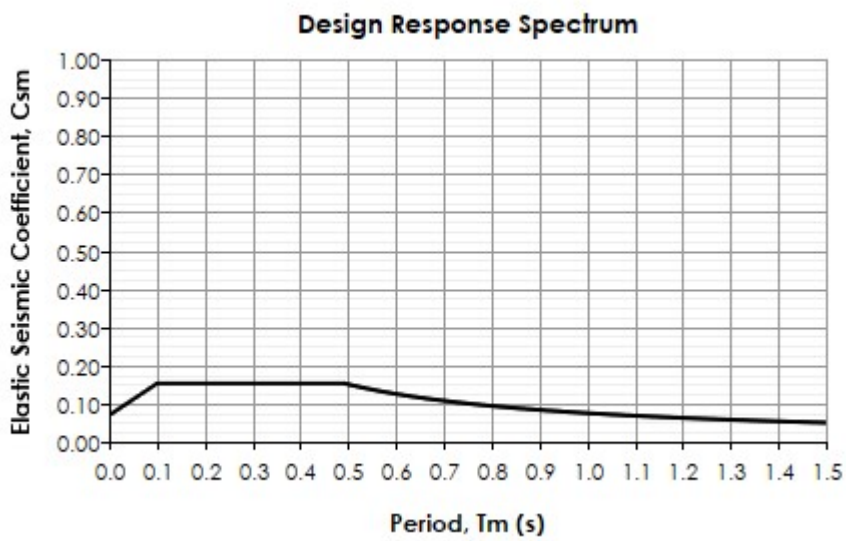
$S_{D1} := F_v \cdot S_1 \quad \therefore \quad S_{D1} = 0.075\ g$

$T_s := \frac{S_{D1}}{S_{DS}} \quad \therefore \quad T_s = 0.491\ s$

$T_o := 0.2 \cdot T_s \quad \therefore \quad T_o = 0.098\ s$

$T_m := 0.0, 0.001 .. 2.0$

Design Response Spectrum (AASHTO 3.10.4.1)



Seismic Zones - AASHTO 3.10.6

```
Seismic_Zone := if S_D1 ≤ 0.15
                  1
                else
                  if S_D1 ≤ 0.30
                    2
                  else
                    if S_D1 ≤ 0.50
                      3
                    else
                      4
```

Table 3.10.6-1—Seismic Zones

Acceleration Coefficient, S_{D1}	Seismic Zone
$S_{D1} \le 0.15$	1
$0.15 < S_{D1} \le 0.30$	2
$0.30 < S_{D1} \le 0.50$	3
$0.50 < S_{D1}$	4

$Seismic_Zone = 1.00$

Conclusion

The retaining structure located in Latitude: 37.999244° N, Longitude: 81.023706° W comply with "Extreme Event I, No Analysis" requirements. Therefore, a seismic analysis and design is not required with the exception of Overall Stability analysis.

Seismic Active Earth Pressure Coefficient - AASHTO 11.6.5.3 & A11.3.1

According to AASHTO 11.6.5.2.2, the initial horizontal seismic acceleration coefficient may be reduce to accommodate lateral deformations. Where the wall is capable of displacements of 1.0 to 2.0 or more during the design seismic event, the initial horizontal seismic acceleration coefficient may be reduce by 50%.

According to AASHTO A11.5.1 (Kavazanjian el al., 1997), the horizontal seismic acceleration coefficient may be adjusted based on a specified lateral deformation between 1.0 inches to 8.0 inches.

$k_{ho} := A_s \quad \therefore \quad k_{ho} = 0.071$ Horizontal seismic acceleration coefficient for zero lateral displacement (kmax) (AASHTO 11.6.5.2.1).

$d := 2.0\ in \quad (1.0\ in \le d \le 8.0\ in)$ Lateral wall displacement (inches).

$k_h := 0.74\ (A_s) \left(\frac{A_s}{d}\right)^{0.25} \quad \therefore \quad k_h = 0.023$ Kavazanjian et al., (1997), Equation A11.5.1-1

$k_v := 0.0$ Vertical seismic acceleration coefficient (See AASHTO 11.6.5.2.1).

$\theta_{MO} := \operatorname{atan}\left(\frac{k_h}{1 - k_v}\right) \quad \therefore \quad \theta_{MO} = 1.30\ °$

$\theta_{EA} := 90\ ° - \theta \quad \therefore \quad \theta_{EA} = 0.00\ °$ Slope of wall back face to vertical.

$$K_{AE} := \left(\frac{\cos\left(\phi_f - \theta_{MO} - \theta_{EA}\right)^2}{\cos\left(\theta_{MO}\right) \cdot \cos\left(\theta_{EA}\right)^2 \cdot \cos\left(\delta + \theta_{EA} + \theta_{MO}\right)}\right) \cdot \left(1 + \sqrt{\frac{\sin\left(\phi_f + \delta\right) \sin\left(\phi_f - \theta_{MO} - \beta\right)}{\cos\left(\delta + \theta_{EA} + \theta_{MO}\right) \cdot \cos\left(\beta - \theta_{EA}\right)}}\right)^{-2} \quad \therefore \quad K_{AE} = 0.82$$

Seismic Active Earth Pressure Coefficient - AASHTO 11.9.6

According to AASHTO C11.9.6, the initial horizontal seismic acceleration coefficient may not be reduced due to the insufficient horizontal displacement of the wall due to the anchor load contribution on the wall. AASHTO C11.9.6 states:

"During, seismic loading, the bars or strands making up the unbonded length of the anchor are able to stretch under the imposed incremental seismic loads. In most cases, the amount of elastic elongation in the strand or bar under the incremental seismic loads is sufficient to develop seismic active earth pressures but may not be sufficient to allow the horizontal seismic acceleration coefficient and associate earth pressure to be reduced to account for permanent horizontal wall displacement. The ability of the wall to deform laterally should be specifically investigated before reducing the horizontal seismic acceleration coefficient to account for horizontal wall displacement "

The horizontal seismic acceleration coefficient can be adjusted for wall height based on AASHTO A11.5.2 requirements and NCHRP Report 611 Section 7.9.2

$k_{ho} := A_s \quad \therefore \quad k_{ho} = 0.07$ Horizontal seismic acceleration coefficient for zero lateral displacement (AASHTO 11.6.5.2.1).

$$a_{Seismic} := \begin{cases} 1 + 0.01 \cdot \frac{H}{ft} \cdot \left(0.5 \cdot \left(\frac{F_v \cdot S_1}{k_{ho}}\right) - 1\right) & \text{if Site_Class} = \text{"C"} \vee \text{Site_Class} = \text{"D"} \vee \text{Site_Class} = \text{"E"} \\ \begin{cases} 1.2 \cdot \left(1 + 0.01 \cdot \frac{H}{ft} \cdot \left(0.5 \cdot \left(\frac{F_v \cdot S_1}{k_{ho}}\right) - 1\right)\right) & \text{if Site_Class} = \text{"A"} \vee \text{Site_Class} = \text{"B"} \\ \text{"Errors, Sheck Site Class"} & \text{else} \end{cases} & \text{else} \end{cases}$$

Fill height-dependent reduction factor.

$a_{Seismic} = 0.91$

$k_{h_MO} := a_{Seismic} \cdot k_{ho} \quad \therefore \quad k_{h_MO} = 0.06$ AASHTO A11.5.2 Equation A11.5.1-2

$k_v := 0.0$ Vertical seismic acceleration coefficient (See AASHTO 11.6.5.2.1).

$\theta_{MO} := \operatorname{atan}\left(\frac{k_{h_MO}}{1 - k_v}\right) \quad \therefore \quad \theta_{MO} = 3.69\ °$

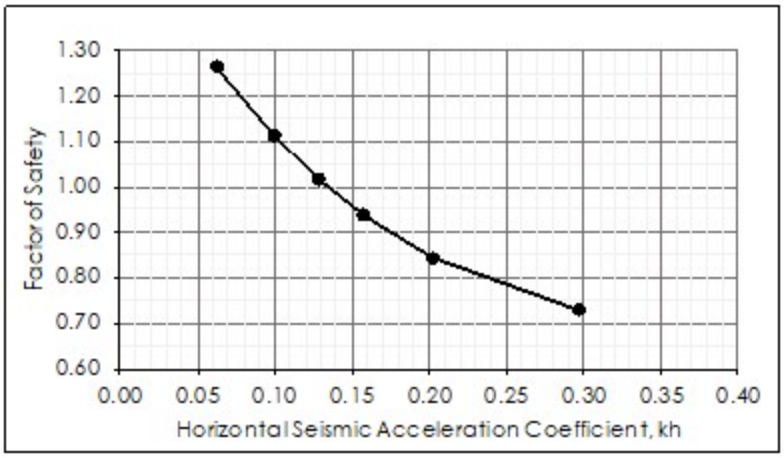
$\theta_{EA} := 90\ ° - \theta \quad \therefore \quad \theta_{EA} = 0.00\ °$ Slope of wall back face to vertical.

$$K_{AE} := \begin{cases} \left(\frac{\cos(\phi_f - \theta_{MO} - \theta_{EA})^2}{\cos(\theta_{MO}) \cdot \cos(\theta_{EA})^2 \cdot \cos(\delta + \theta_{EA} + \theta_{MO})}\right) \cdot \left(1 + \sqrt{\frac{\sin(\phi_f + \delta) \cdot \sin(\phi_f - \theta_{MO} - \beta)}{\cos(\delta + \theta_{EA} + \theta_{MO}) \cdot \cos(\beta - \theta_{EA})}}\right)^{-2} & \text{if } \phi_f \geq (\theta_{MO} + \beta) \\ \text{"The M-O method is not valid. GLE method needs to be used (See AASHTO11.6.5.3)."} & \text{else} \end{cases}$$

$K_{AE} =$ "The M-O method is not valid. GLE method needs to be used (See AASHTO11.6.5.3)."

- Determining Yield Acceleration, ky

Seismic Overall Stability Analysis Vs Seismic Yield Acelleration	
k_y	FS
0.06	1.26
0.10	1.11
0.13	1.02
0.16	0.94
0.20	0.84
0.30	0.73



$k_{y_1.0} = 0.135$ Yield acceleration for a Factor of Safety of 1.0.

$k_{y_1.1} = 0.103$ Yield acceleration for a Factor of Safety of 1.1.

$PGV := 38 \cdot F_v \cdot S_1 \quad \therefore \quad PGV = 2.84$ Peak ground velocity.

- Check Horizontal Seismic Coefficient is within required range

Horizontal_Seismic_Coefficient_Check := if $k_{y_1.0} \geq k_{ho}$
"No horizontal displacement is expected."
else
"See Below results."

Horizontal_Seismic_Coefficient_Check = "No horizontal displacement is expected."

- Determining Horizontal Wall Displacement for a Factor of Safety of 1.0

$$d_{Seismic_Mean_1.0} := \left(10^{-1.51 - 0.74 \log\left(\frac{k_{y_1.0}}{k_{ho}}\right) + 3.27 \log\left(1 - \frac{k_{y_1.0}}{k_{ho}}\right) - 0.80 \log(k_{ho}) + 1.59 \log(PGV)}\right) \text{ in}$$

$d_{Seismic_Mean_1.0} = (-0.40 - 0.45i)$ in Soldier Pile wall mean displacement for Factor of Safety of 1.0.

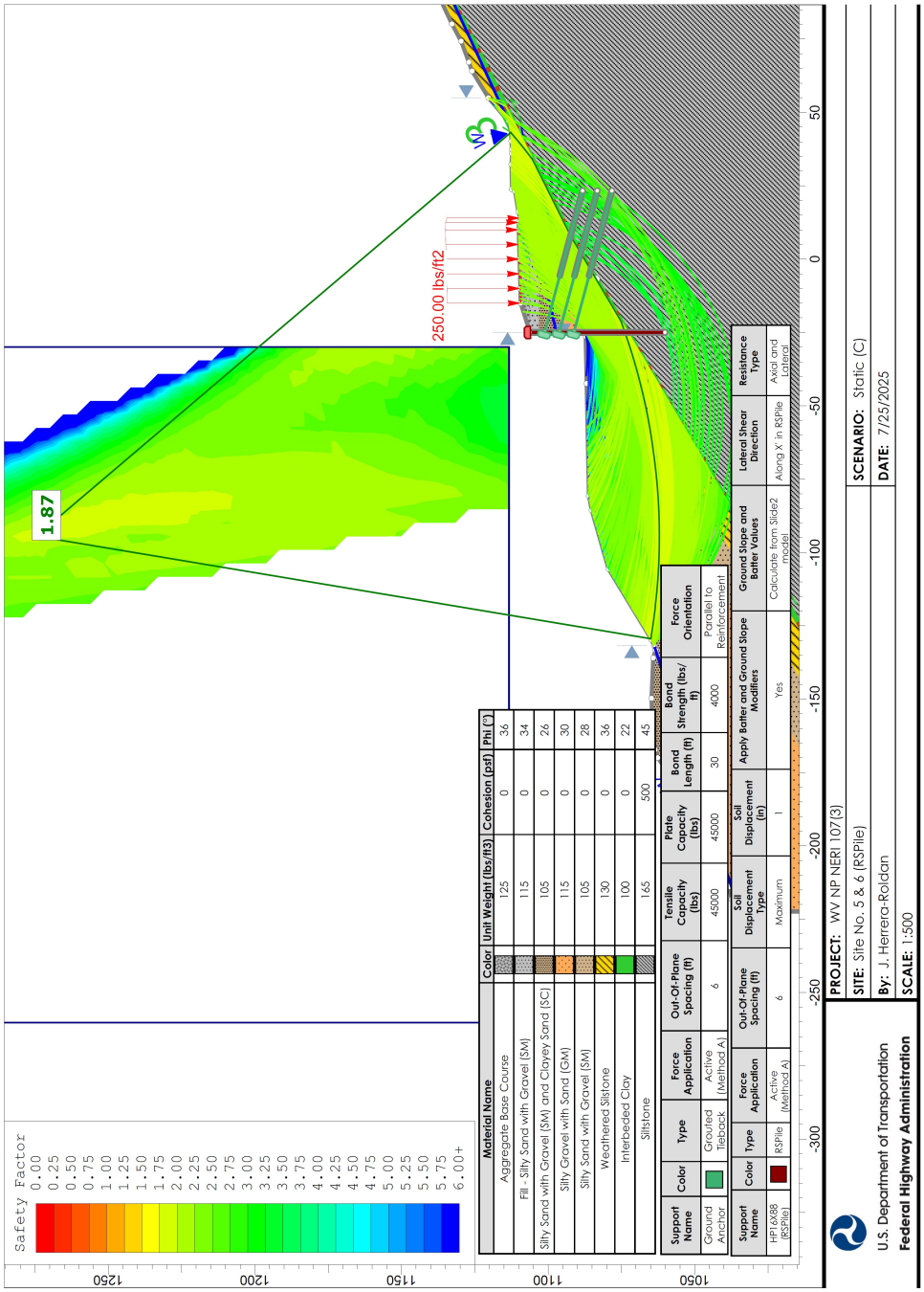
$d_{Seismic_1.0} := d_{Seismic_Mean_1.0} \cdot 2 \quad \therefore \quad d_{Seismic_1.0} = (-0.79 - 0.90i)$ in Soldier Pile wall horizontal displacement for Factor of Safety of 1.0 based on 84 % confidence (NCHRP 611, Section 7.6).

Overall Stability Analysis - AASHTO 11.9.4.4 and AASHTO 11.5.8

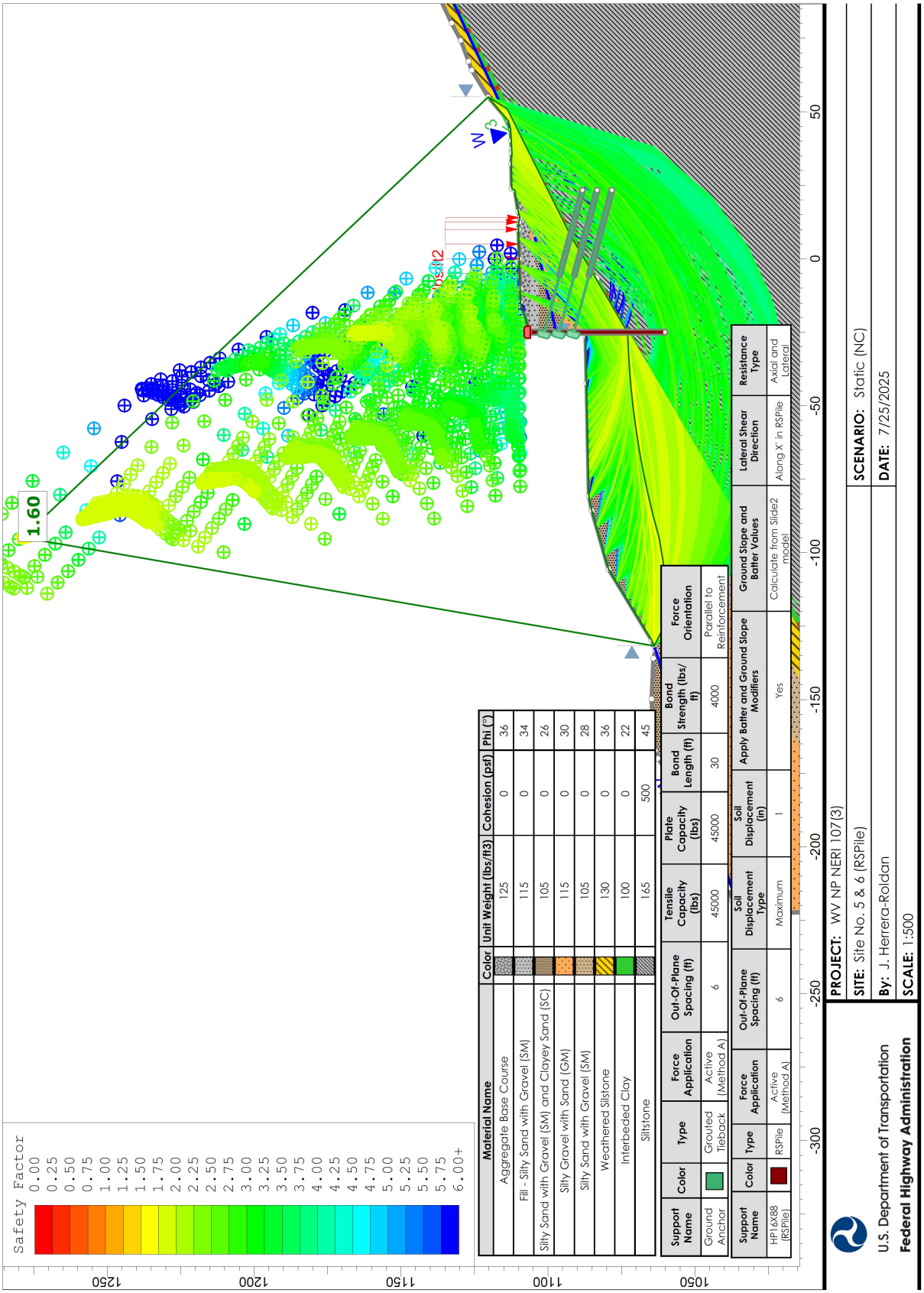
According to AASHTO 11.6.3.7, the overall stability resistance factor depends on the site specific scenario. Where the geotechnical parameter are well define, the resistance factor for overall stability is 0.75, which is equivalent to 1.3 Factor of Safety. On the other hand, where the geotechnical parameters are based on limited information, or the stratigraphy are highly variable, the resistance factor for overall stability is 0.65, which is equivalent to 1.5 Factor of Safety. This analysis complies with the second scenario. According to AASHTO 11.5.8, the resistance factor for Extreme Event I is 0.9, which is equivalent to 1.1 Factor of Safety.

The detailed overall stability report is included at the end of these calculations as an Annex.

- Overall Stability Analysis - Static

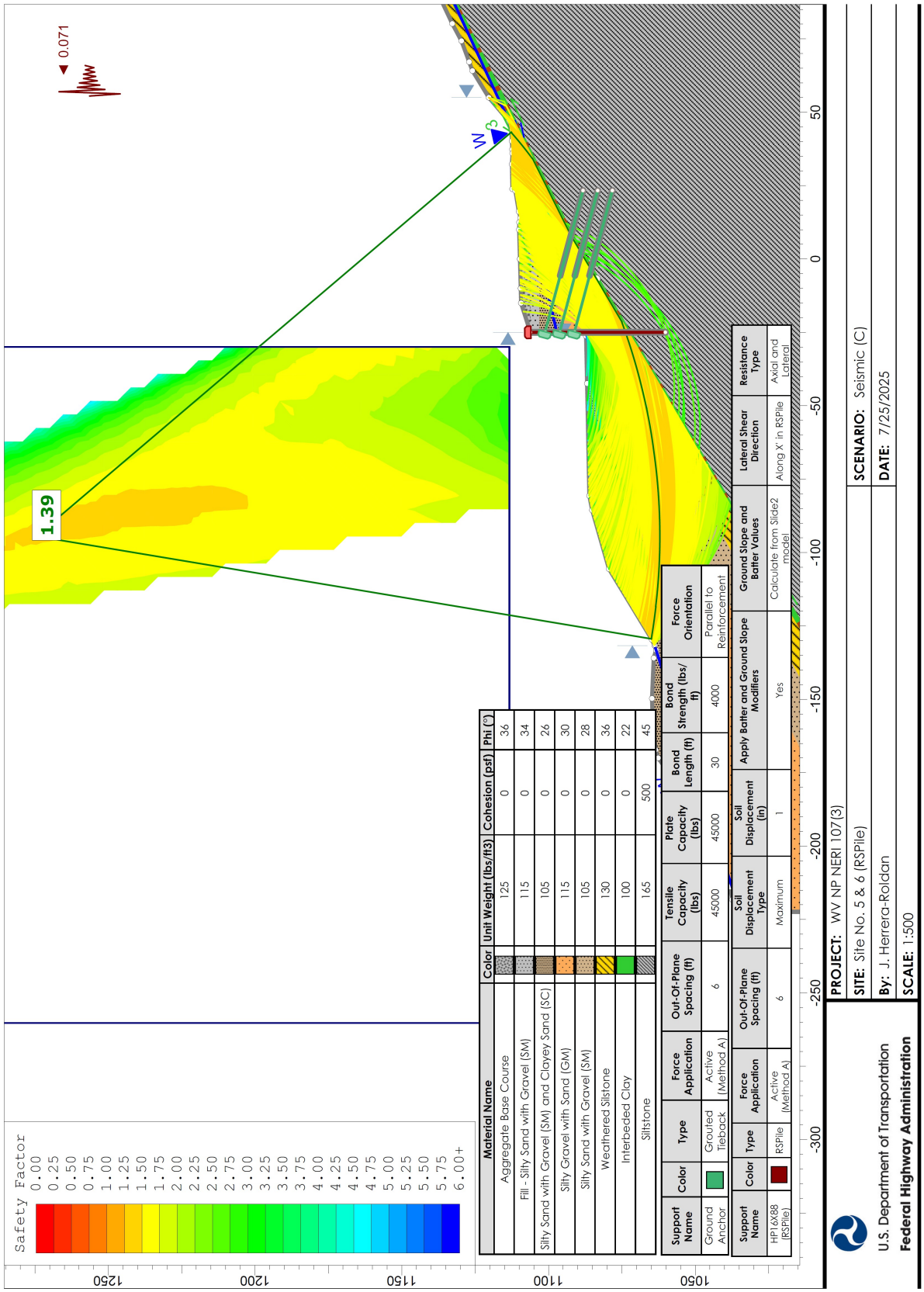


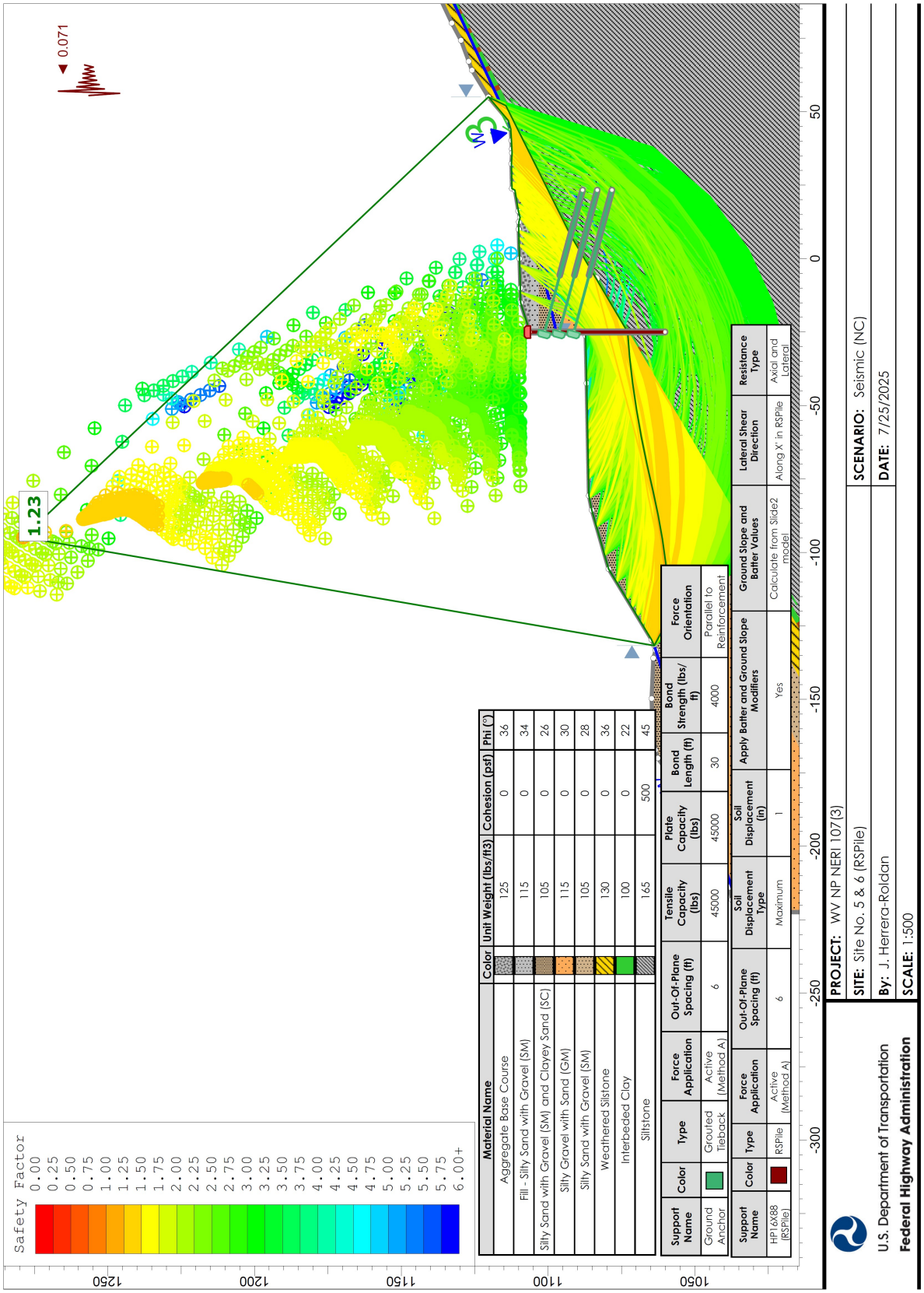
Project: WV NP NERI 107(3) - Anchored Soldier Pile Wall Geotechnical Analysis and Design - STA 115+00



Project: WV NP NERI 107(3) - Anchored Soldier Pile Wall Geotechnical Analysis and Design - STA 115+00

- Overall Stability Analysis - Extreme Event I




1.23
0.071
Safety Factor
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
2.25
2.50
2.75
3.00
3.25
3.50
3.75
4.00
4.25
4.50
4.75
5.00
5.25
5.50
5.75
6.00+
Material Name | Color | Unit Weight (lbs/ft3) | Cohesion (psf) | Phi (°)
Aggregate Base Course | 125 | 0 | 36
Fill - Silty Sand with Gravel (SM) | 115 | 0 | 34
Silty Sand with Gravel (SM) and Clayey Sand (SC) | 105 | 0 | 26
Silty Gravel with Sand (GM) | 115 | 0 | 30
Silty Sand with Gravel (SM) | 105 | 0 | 28
Weathered Siltstone | 130 | 0 | 36
Interbedded Clay | 100 | 0 | 22
Siltstone | 165 | 500 | 45
Support Name | Color | Type | Force Application | Out-Of-Plane Spacing (ft) | Tensile Capacity (lbs) | Plate Capacity (lbs) | Bond Length (ft) | Bond Strength (lbs/ft) | Force Orientation
Ground Anchor | Grouted Tieback | Active (Method A) | 6 | 45000 | 45000 | 30 | 4000 | Parallel to Reinforcement
Support Name | Color | Type | Force Application | Out-Of-Plane Spacing (ft) | Soil Displacement Type | Soil Displacement (in) | Apply Batter and Ground Slope Modifiers | Ground Slope and Batter Values | Lateral Shear Direction | Resistance Type
HP16X88 (RSPile) | RSPile | Active (Method A) | 6 | Maximum | 1 | Yes | Calculate from Slide2 model | Along X' in RSPile | Axial and Lateral
1250
1200
1150
1100
1050
-300
-250
-200
-150
-100
-50
0
50
U.S. Department of Transportation
Federal Highway Administration
PROJECT: WV NP NERI 107(3)
SITE: Site No. 5 & 6 (RSPile)
By: J. Herrera-Roldan
SCALE: 1:500
SCENARIO: Seismic (NC)
DATE: 7/25/2025

Summary of Results For Strength Limit I and Service I Stability

- Presumptive Nominal Anchor Bond Stress

$$\tau_{Anchor} = 2500 \frac{lb}{ft^2}$$

- Minimum Soldier Pile Embedment Depth

$D_{Design} = 27.00$ ft $\qquad$ $D_{Design_Check_Static} =$ "OK"

- Axial Resistance

$CDR_{Pile_Axial_max} = 2.11$ $\qquad$ $CDR_{Pile_Axial_max} =$ "OK"

$CDR_{Pile_Axial_min} = 2.93$ $\qquad$ $CDR_{Pile_Axial_min} =$ "OK"

$CDR_{Pile_Axial_Ser} = 2.79$ $\qquad$ $CDR_{Pile_Axial_Ser} =$ "OK"

- Anchor Pullout Resistance

$CDR_{Pile_Anchor_Pullout_max} = 1.24$ $\qquad$ $CDR_{Pile_Anchor_Pullout_max} =$ "OK"

$CDR_{Pile_Anchor_Pullout_min} = 1.71$ $\qquad$ $CDR_{Pile_Anchor_Pullout_min} =$ "OK"

$CDR_{Pile_Anchor_Pullout_Ser} = 1.75$ $\qquad$ $CDR_{Pile_Anchor_Pullout_Ser} =$ "OK"

- Global Stability Results

$FS_{Global} := 1.60$

$FS_{Global_Seismic} := 1.2$

Anchored Soldier Pile Wall Design Requirements

Pile AISC Manual Label: HP16 x 88

$L_{Pile} = 46.00$ ft — Total pile length.

$H = 19.00$ ft — Total height of wall.

$S_{Pile} = 6.00$ ft — Soldier pile maximum horizontal spacing.

$D_{Design} = 27.00$ ft — Soldier pile minimum embedment depth.

$H_{A1} = 5.00$ ft — Anchor spacing from top of Pile.

$H_{A2} = 5.00$ ft — Anchor spacing from first anchor two second anchor.

$H_{A3} = 5.00$ ft — Anchor spacing from second anchor two third anchor.

$H_{A4} = 0.00$ ft — Anchor spacing from third anchor.

$H_{A5} = 0.00$ ft — Anchor spacing from fourth anchor.

$H_{A6} = 4.00$ ft — Anchor spacing from fifth anchor to bottom wall lagging.

$A_{UBL} = 20.00$ ft — Minimum anchor unbonded length.

$A_{BL} = 30.00$ ft — Minimum anchor bonded length.

$\theta_{Anchor} = 15$ ° — Anchor inclination from horizontal.

$d_{Anchor} = 6.50$ in — Assumed diameter of anchor drilled hole.

Analysis Requirements

According to AASHTO LRFD 9th Ed., Section 10.8.3.5.4 Drilled Shaft Resistance in Rock, the methods used for design are based on rock geologic conditions which include joint orientations, discontinuities, weathered layered and others. For foundations in competent rock, Unconfined Compressive Strength (UCS) and Rock Quality Designation (RQD) results can be used to establish rock shear strength. However, if rock is not considered competent, the shear strength of rock shall be established taking in consideration the rock mass, which include both the nature of intact rock and the orientation and conditions of discontinuities of the overall mass.

Section 10.4.6.4 Rock Mass Strength of AASHTO LRFD 9th Ed. states the strength of intact rock should be determine using the results of unconfined compression tests on intact rock cores samples, and in the case of non-competent rocks, the rock should be classified with the geologic Strength Index (GSI) and then determine the shear strength using the Hoek-Brown failure criterion.

References

- AASHTO (2020), "LRFD Bridge Design Specifications", 9th Edition, Washington D.C. American Association of State Highway and Transportation Officials.
- Goodman, R.E. (1989) "Introduction to Rock Mechanics" 2nd Edition
- Sabatini, P.J., Bachus, R.C., Mayne, P.W., Schnedier, J.A., and Zettler, T.E. (2002), "Geotechnical Engineering Circular 5 (GEC5) - Evaluation of Soils and Rock Properties", FHWA-IF-02-0234. Federal Highway Administration, U.S Department of Transportation, Washington, D.C.
- Zhang, L. (2005), "Engineering Properties of Rock", Elsevier Science 2006

Rock Description

The rock is described as: Siltstone, extremely to moderate fractured, close to moderate fracture spacing, medium bedding, highly to moderately weathered, medium strong, highly fractured from 15.1 ft to 18.2 ft., discontinuity angle ranging from 45° to 60°.

Rock Mass Rating (RMR) - Table 40 of Sabatini (2002) - Exhibit No. 1

Parameter	Relative Rating	Description
$q_{UCS} := 3702$ psi $\therefore$ $q_{UCS} = 26$ MPa	$RR_1 := 4$	Strength of Intact Rock Material
RQD: 0% - 42%	$RR_2 := 8$	Drill Core Quality
Joint Spacing: <0.75 in to 8in	$RR_3 := 5$	Spacing of Joints
Joint Condition (Assumed): Joints open 0.04in to 0.2 in (1 mm to 5 mm) continuous joints.	$RR_4 := 6$	Joint Conditions
General Conditions: Water under moderate pressure	$RR_5 := 4$	Groundwater
Dip Orientation: 45° to 60° $\therefore$ Fair	$RR_6 := -25$	Strike and Dip Orientation

$$RMR := RR_1 + RR_2 + RR_3 + RR_4 + RR_5 + RR_6 \quad \therefore \quad RMR = 2$$

Rock Mass Class and Rating

```
RMR_Class_No._&_Description := if RMR ≤ 20
                               "Class V, Very Poor Rock"
                               else
                               if RMR ≤ 40
                               "Class IV, Poor Rock"
                               else
                               if RMR ≤ 60
                               "Class III, Fair Rock"
                               else
                               if RMR ≤ 80
                               "Class II, Good Rock"
                               else
                               "Class I, Very Good Rock"
```

$RMR_{Class_No._\&_Description} = \text{"Class V, Very Poor Rock"}$

Geologic Strength Index (GSI) - Figure 10.4.6.4-1 of AASHTO LRFD 8 - Exhibit No. 2

Rock Structure Description: Blocky/Disturbed/Seamy

Surface Quality: Very Poor $\therefore$ $GSI_{Max} := 22$ $GSI_{Min} := 15$ $GSI_{Ave.} := \frac{(GSI_{Min} + GSI_{Max})}{2} = 18.5$

Recommended m, s, and a Parameters According to AASHTO 10.4.6.4

$m_i := 7$ (Siltstone) — m_i constant (Exhibit No. 3)

$D := 1.0$ — Disturbance factor AASHTO C10.4.6.4

$m_{GSI_Min} := m_i \cdot e^{\left(\frac{GSI_{Min} - 100}{28 - (14 D)}\right)}$ $m_{GSI_Max} := m_i \cdot e^{\left(\frac{GSI_{Max} - 100}{28 - (14 D)}\right)}$ $m_{GSI_Ave} := m_i \cdot e^{\left(\frac{GSI_{Ave.} - 100}{28 - (14 D)}\right)}$

$m_{GSI_Min} = 0.02$ $m_{GSI_Max} = 0.03$ $m_{GSI_Ave} = 0.02$

$s_{GSI_Min} := e^{\left(\frac{GSI_{Min} - 100}{9 - (3 D)}\right)}$ $s_{GSI_Max} := e^{\left(\frac{GSI_{Max} - 100}{9 - (3 D)}\right)}$ $s_{GSI_Ave} := e^{\left(\frac{GSI_{Ave.} - 100}{9 - (3 D)}\right)}$

$s_{GSI_Min} = 0.0000$ $s_{GSI_Max} = 0.0000$ $s_{GSI_Ave} = 0.0000$

$a_{GSI_Min} := \frac{1}{2} + \frac{1}{6}\left(e^{\left(\frac{-GSI_{Min}}{15}\right)} - e^{\left(\frac{-20}{3}\right)}\right)$ $a_{GSI_Max} := \frac{1}{2} + \frac{1}{6}\left(e^{\left(\frac{-GSI_{Max}}{15}\right)} - e^{\left(\frac{-20}{3}\right)}\right)$ $a_{GSI_Ave} := \frac{1}{2} + \frac{1}{6}\left(e^{\left(\frac{-GSI_{Ave.}}{15}\right)} - e^{\left(\frac{-20}{3}\right)}\right)$

$a_{GSI_Min} = 0.561$ $a_{GSI_Max} = 0.538$ $a_{GSI_Ave} = 0.548$

Selection of "m", "s" and "a" parameters to determine rock shear strength

$m_{Min} := m_{GSI_Min}$ ∴ $m_{Min} = 0.02$ $m_{Max} := m_{GSI_Max}$ ∴ $m_{Max} = 0.03$ $m_{Ave} := m_{GSI_Ave}$ ∴ $m_{Ave} = 0.02$

$s_{Min} := s_{GSI_Min}$ ∴ $s_{Min} = 0.00000$ $s_{Max} := s_{GSI_Max}$ ∴ $s_{Max} = 0.00000$ $s_{Ave} := s_{GSI_Ave}$ ∴ $s_{Ave} = 0.00000$

$a_{Min} := a_{GSI_Min}$ ∴ $a_{Min} = 0.561$ $a_{Max} := a_{GSI_Max}$ ∴ $a_{Max} = 0.538$ $a_{Ave} := a_{GSI_Ave}$ ∴ $a_{Ave} = 0.548$

Hoek-Brown Shear Strength Criteria - AASHTO 10.4.6.4

- Effective Vertical Stress

$Shaft_{Elev_Top} := 2894.5$ ft — Deep foundation cap bottom elevation.

$Shaft_{Elev_Tip} := 2858$ ft — Deep foundation tip elevation.

$Layer_1_{Elev_Top} := Shaft_{Elev_Top}$ ∴ $Layer_1_{Elev_Top} = 2894.5$ ft — Layer No. 1 top elevation.

$Layer_1_{Elev_Bottom} := 2891$ ft — Layer No. 1 bottom elevation.

$\gamma_1 := 110$ pcf — Layer No. 1 unit weight.

$L_1 := Layer_1_{Elev_Top} - Layer_1_{Elev_Bottom}$ ∴ $L_1 = 3.5$ ft — Layer No. 1 length.

$\sigma_{Layer1} := \gamma_1 \cdot L_1$ ∴ $\sigma_{Layer1} = 385$ psf — Layer No. 1 total vertical stress.

$Layer_2_{Elev_Top} := Layer_1_{Elev_Bottom}$ ∴ $Layer_2_{Elev_Top} = 2891.0$ ft — Layer No. 2 top elevation.

$Layer_2_{Elev_Bottom} := 2868$ ft — Layer No. 2 bottom elevation.

$\gamma_2 := 120$ pcf — Layer No. 2 unit weight.

$L_2 := Layer_2_{Elev_Top} - Layer_2_{Elev_Bottom}$ ∴ $L_2 = 23.0$ ft — Layer No. 2 length.

$\sigma_{Layer2} := \gamma_2 \cdot L_2$ ∴ $\sigma_{Layer2} = 2760$ psf — Layer No. 2 total vertical stress.

$Layer_3_{Elev_Top} := Layer_2_{Elev_Bottom}$ ∴ $Layer_3_{Elev_Top} = 2868.0$ ft — Layer No. 3 top elevation.

$Layer_3_{Elev_Bottom} := 2858$ ft — Layer No. 3 bottom elevation.

$\gamma_3 := 145$ pcf — Layer No. 3 unit weight.

$L_3 := Layer_3_{Elev_Top} - Layer_3_{Elev_Bottom}$ ∴ $L_3 = 10.0$ ft — Layer No. 3 length.

$\sigma_{Layer3} := \gamma_3 \cdot L_3$ ∴ $\sigma_{Layer3} = 1450$ psf — Layer No. 3 total vertical stress.

$Layer_4_{Elev_Top} := Layer_3_{Elev_Bottom}$ ∴ $Layer_4_{Elev_Top} = 2858.0$ ft — Layer No. 4 top elevation.

$Layer_4_{Elev_Bottom} := 2858$ ft — Layer No. 4 bottom elevation.

$\gamma_4 := 0$ pcf — Layer No. 4 unit weight.

$L_4 := Layer_4_{Elev_Top} - Layer_4_{Elev_Bottom}$ ∴ $L_4 = 0.0$ ft — Layer No. 4 length.

$\sigma_{Layer4} := \gamma_4 \cdot L_4$ ∴ $\sigma_{Layer4} = 0$ psf — Layer No. 4 total vertical stress.

$Layer_5_{Elev_Top} := Layer_4_{Elev_Bottom}$ ∴ $Layer_5_{Elev_Top} = 2858.0\ ft$ Layer No. 5 top elevation.

$Layer_5_{Elev_Bottom} := 2858\ ft$ Layer No. 5 bottom elevation.

$\gamma_5 := 0\ pcf$ Layer No. 5 unit weight.

$L_5 := Layer_5_{Elev_Top} - Layer_5_{Elev_Bottom}$ ∴ $L_5 = 0.0\ ft$ Layer No. 5 length.

$\sigma_{Layer5} := \gamma_5 \cdot L_5$ ∴ $\sigma_{Layer5} = 0\ psf$ Layer No. 5 total vertical stress.

$GWT_{Elev} := 2858\ ft$ Ground water elevation elevation.

$Depth_{water} := GWT_{Elev} - Shaft_{Elev_Tip}$ ∴ $Depth_{water} = 0.0\ ft$ Ground water depth.

$\gamma_w := 62.4\ pcf$ Water unit weight.

$\sigma_w := \gamma_w \cdot Depth_{water}$ ∴ $\sigma_w = 0.0\ psf$ Pore water pressure.

$\sigma'_3 := \sigma_{Layer1} + \sigma_{Layer2} + \sigma_{Layer3} + \sigma_{Layer4} + \sigma_{Layer5} - \sigma_w$

$\sigma'_3 = 4595\ psf$ Effective vertical stress at drilled shaft tip elevation.

- Using Minimum "m", "s" and "a" parameters

$$\sigma'_{1_Min} := \sigma'_3 + q_{UCS} \cdot \left(m_{Min} \cdot \left(\frac{\sigma'_3}{q_{UCS}}\right) + s_{Min}\right)^{a_{Min}} \quad \therefore \quad \sigma'_{1_Min} = 8262\ psf$$

AASHTO Eq. 10.4.6.4-1

- Using Maximum "m", "s" and "a" parameters

$$\sigma'_{1_Max} := \sigma'_3 + q_{UCS} \cdot \left(m_{Max} \cdot \left(\frac{\sigma'_3}{q_{UCS}}\right) + s_{Max}\right)^{a_{Max}} \quad \therefore \quad \sigma'_{1_Max} = 10489\ psf$$

AASHTO Eq. 10.4.6.4-1

- Using Average "m", "s" and "a" parameters

$$\sigma'_{1_Ave} := \sigma'_3 + q_{UCS} \cdot \left(m_{Ave} \cdot \left(\frac{\sigma'_3}{q_{UCS}}\right) + s_{Ave}\right)^{a_{Ave}} \quad \therefore \quad \sigma'_{1_Ave} = 9310\ psf$$

AASHTO Eq. 10.4.6.4-1

- Hoek-Brown Shear Strength Criteria for Analysis and Design

$m_{HB} := m_{Ave}$ ∴ $m_{HB} = 0.021$

$s_{HB} := s_{Ave}$ ∴ $s_{HB} = 0$

$a_{HB} := a_{Ave}$ ∴ $a_{HB} = 0.548$

$q_{P_HB} := Floor(\sigma'_{1_Ave}, 100\ psf)$ ∴ $q_{P_HB} = 9300\ psf$

Exhibits

Exhibit No. 1 - Sabatini (2002) - Table 40 CSIR Classification of Joint rock mass

Table 40. CSIR classification of jointed rock mass.

A. CLASSIFICATION PARAMETERS AND THEIR RATINGS

PARAMETER			RANGES OF VALUES						
1	Strength of intact rock material	Point load strength index	>8 MPa	4 to 8 Mpa	2 to 4 MPa	1 to 2 MPa	For this low range – uniaxial compressive test is preferred		
		Uniaxial compressive strength	>200 MPa	100 to 200 MPa	50 to 100 MPa	25 to 50 MPa	10 to 25 MPa	3 to 10 MPa	1 to 3 MPa
	Relative Rating		15	12	7	4	2	1	0
2	Drill core quality RQD		90% to 100%	75% to 90%	50% to 75%	25% to 50%	<25%		
	Relative Rating		20	17	13	8	3		
3	Spacing of joints		>3 m	1 to 3m	0.3 to 1 m	50 to 300 mm	<50mm		
	Relative Rating		30	25	20	10	5		
4	Condition of joints		Very rough surfaces Not continuous No separation Hard joint wall rock	Slightly rough surfaces Separation <1mm Hard joint wall rock	Slightly rough surfaces Separation <1mm Soft joint wall rock	Slickensided surfaces or Gouge <5 mm thick or Joints open 1 to 5 mm Continuous joints	Soft gouge >5 mm thick or Joints open >5 mm Continuous joints		
	Relative Rating		25	20	12	6	0		
5	Ground water	Inflow per 10 m tunnel length	None	<25 liters/min	25 to 125 liters/min	>125 liters/min			
			OR	OR	OR	OR			
		Ratio= joint water pressure/major principal stress	0	0.0 to 0.2	0.2 to 0.5	>0.5			
			OR	OR	OR	OR			
		General Conditions	Completely Dry	Moist only (interstitial water)	Water under moderate pressure	Severe water problems			
	Relative Rating		10	7	4	0			

B. RATING ADJUSTMENT FOR JOINT ORIENTATIONS

Strike and dip orientations of joints		Very favorable	Favorable	Fair	Unfavorable	Very Unfavorable
Ratings	Tunnels	0	-2	-5	-10	-12
	Foundations	0	-2	-7	-15	-25
	Slopes	0	-5	-25	-50	-60

C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS

RMR Rating	100 to 81	80 to 61	60 to 41	40 to 21	<20
Class No.	I	II	III	IV	V
Description	Very good rock	Good rock	Fair rock	Poor rock	Very poor rock

Exhibit No. 2 - AASHTO LRFD 8 - Figure 10.4.6.4-1 Determination of GSI for Jointed Rock Mass

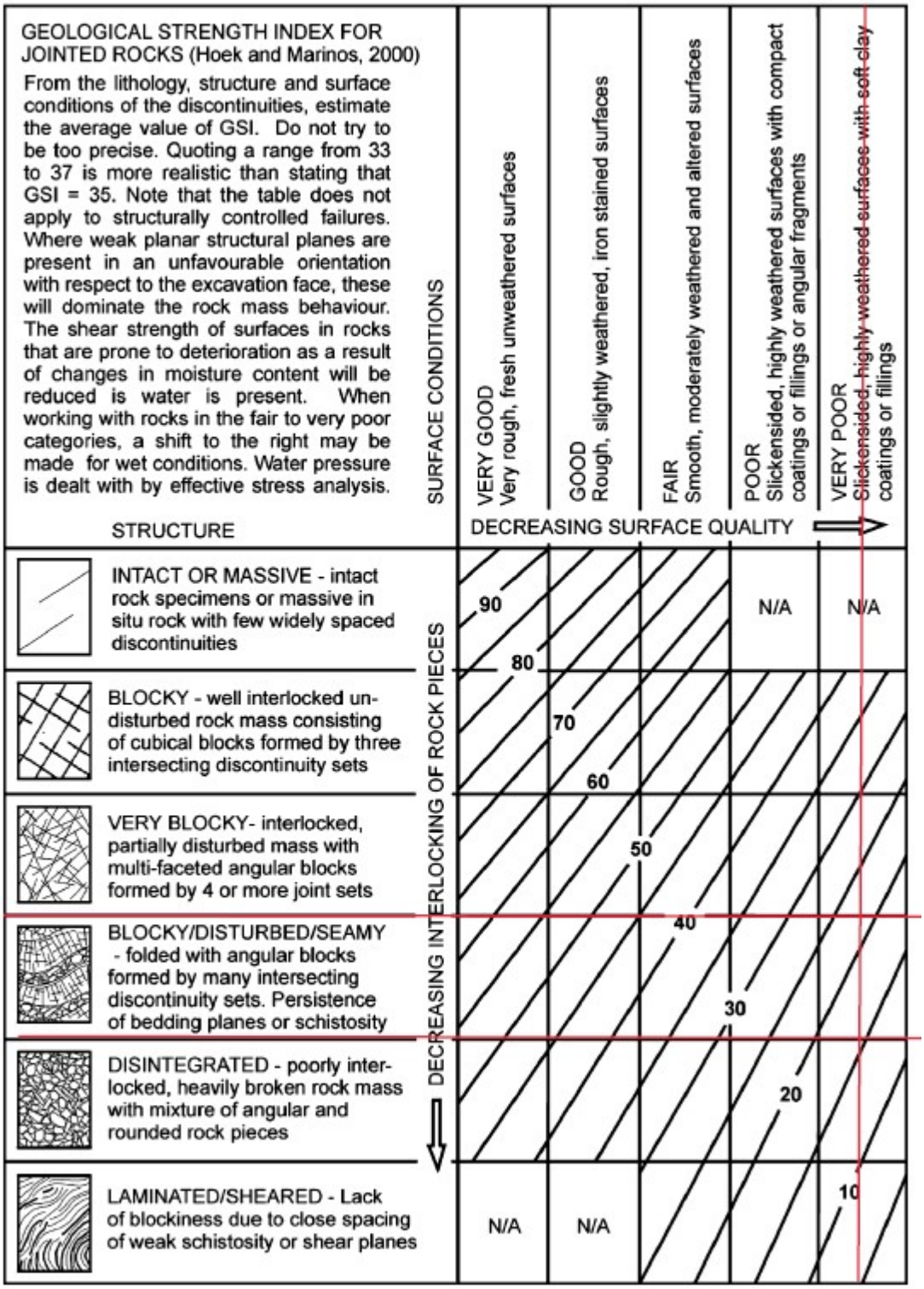


Exhibit No. 3 - AASHTO LRFD 8 - Table 10.4.6.4-1 Determination of "mi" constant

Table 10.4.6.4-1—Values of the Constant m_i by Rock Group (after Marinos and Hoek 2000; with updated values from Rocscience, Inc., 2007)

Rock type	Class	Group	Texture: Coarse	Texture: Medium	Texture: Fine	Texture: Very fine
SEDIMENTARY	Clastic		Conglomerate (21 ± 3) Breccia (19 ± 5)	Sandstone 17 ± 4	Siltstone 7 ± 2 Greywacke (18 ± 3)	Claystone 4 ± 2 Shale (6 ± 2) Marl (7 ± 2)
	Non-Clastic	Carbonates	Crystalline Limestone (12 ± 3)	Sparitic Limestone (10 ± 5)	Micritic Limestone (8 ± 3)	Dolomite (9 ± 3)
		Evaporites		Gypsum 10 ± 2	Anhydrite 12 ± 2	
		Organic				Chalk 7 ± 2
METAMORPHIC	Non Foliated		Marble 9 ± 3	Hornfels (19 ± 4)) Metasandstone (19 ± 3)	Quartzite 20 ± 3	
	Slightly foliated		Migmatite (29 ± 3)	Amphibolite 26 ± 6	Gneiss 28 ± 5	
	Foliated*			Schist (10 ± 3)	Phyllite (7 ± 3)	Slate 7 ± 4
IGNEOUS	Plutonic	Light	Granite 32 ± 3 Granodiorite (29 ± 3)	Diorite 25 ± 5		
		Dark	Gabbro 27 ± 3 Norite 20 ± 5	Dolerite (16 ± 5)		
	Hypabyssal		Porphyries (20 ± 5)		Diabase (15 ± 5)	Peridotite (25 ± 5)
	Volcanic	Lava		Rhyolite (25 ± 5) Andesite 25 ± 5	Dacite (25 ± 3)) Basalt (25 ± 5)	
		Pyroclastic	Agglomerate (19 ± 3)	Volcanic breccia (19 ± 5)	Tuff (13 ± 5)	

Appendix IV – Site Photographs

Figure No. 1: Cunard River Road Access Road – Landslide head scarp and tension cracks.

Figure No. 2: Cunard River Road Access Road. **Exposed bedrock at cutslope.**

Figure No. 3: Cunard River Road Access Road.

Figure No. 4: Cunard River Road Access Road.

Figure No. 5: Cunard River Road Access Road.

Figure No. 6: Cunard River Road Access Road.