Final Structure Foundation Exploration Report

MOE-TR2001-0.13

Monroe County, OH
March 7, 2023

Prepared for:
Office of the Monroe County Engineer
47134 Moore Ridge Road
Woodsfield, OH 43793

By:

HDR
9999 Carver Road, Suite 210
Blue Ash, OH 45242

Contents

Tables

Appendices

This page is intentionally left blank.

EXECUTIVE SUMMARY

This report summarizes the results of the structure foundation exploration program performed in support of the replacement of Bridge No. MOE-TR2001-0.13 (SFN5630290) carrying Wehr Road, Township Road 2001 (TR 2001), over the Seneca Fork Wills Creek in Seneca Township in northwestern Monroe County.

The report includes the geotechnical information obtained from borings and laboratory testing performed under this study. The exploration, along with the laboratory test results are presented in more detail in Section 3 as well as in Appendices B and C of this report.

Based on HDR's assessment of the borings, the generalized soil profile consists of silt and clay deposits with interbedded granular layers overlying cohesive residual soils. The underlying bedrock consists of interbedded shale, sandstone, and claystone. Further discussion on the encountered subsurface conditions is located in Section 4.

Given the depth to bedrock (< 50 feet), it is anticipated that deep foundations will be utilized to support the new bridge structure. The selected design build team will determine the appropriate foundation type. However, given the proximity of the Seneca Fork Wills Creek, shallow groundwater, and the interbedded soft to loose interbedded cohesive and granular layers within the upper 16 to 21 feet of the soil profile, pile foundations are anticipated to be the preferred foundation option. The recommended design parameters for the foundation analyses to be performed by the design build team are provided in Section 5 and in Appendix D.

1 INTRODUCTION

This report summarizes the results of the structure foundation exploration program performed in support of the replacement of Bridge No. MOE-TR2001-0.13 (SFN 5630290) carrying Wehr Road (TR 2001) over the Seneca Fork Wills Creek. The MOE-TR2001-0.13 project is located in Seneca Township in northwest Monroe County as shown on the Site Vicinity Map (Exhibit No. 1) in Appendix A. The work includes removal of the existing 36-foot bridge structure and its replacement with a presumed single span box beam structure using the design-build contracting method. The new bridge structure is to be located immediately upstream of the existing bridge location, with a total project length of 200 feet. The project limits start at Straight Line Mileage (SLM) 0.13 and extends to approximate SLM 0.17.

This geotechnical study was authorized by the Ohio Department of Transportation (ODOT) on October 12, 2022, under the VAR-STW Geotechnical Engineering Services CEAO 2023-2 contract. The geotechnical services performed under this task order were carried out in general accordance with ODOT's *Specifications for Geotechnical Explorations* (SGE) *Geotechnical Design Manual* (GDM), *Bridge Design Manual* (BDM), and the *Location and Design Manual, Volume 2*. All four documents are dated July 2022. The scope of work relative to this exploration report included:

- a visual reconnaissance of the project site,
- review of available soil and geologic information within the project area,
- the development and performance of a subsurface exploration program to evaluate the existing subsurface conditions at the bridge location,
- laboratory testing on selected soil and rock samples in accordance with the requirements of the SGE,
- characterization of a generalized soil profile along with recommended design strength parameters, and
- preparation of this Structure Foundation Exploration report.

This report presents the descriptions and interpretations of the encountered subsurface conditions at the site and provides general geotechnical recommendations to assist in the design of the replacement bridge structure by the selected design build team.

2 GEOLOGY AND OBSERVATIONS

2.1 Project Setting

This project is located within the northwest portion of Monroe County, Ohio in a rural setting surrounded by agricultural parcels. A residential structure, barn and other associated outbuildings are located to the southwest of the bridge structure. Elevations along the project site range from about El. 860 at the bridge limits to approximately El. 855 at the stream crossing itself.

2.2 Soil and Geologic Setting

A review of the Physiographic Regions of Ohio map (Ohio Division of Geological Survey, 1998) indicates that the project site is located within the Marietta Plateau region of the Allegheny Plateaus section of the Appalachian Plateaus province (Exhibit No. 2 in Appendix A). The Marietta Plateau region is characterized by highly dissected, high relief valleys of generally 350 to 600 feet near the Ohio River. Elevations in this region generally range from 515 to 1,400 feet above sea level. Soils in the Marietta Plateau typically consist of red and brown silty-clay loam colluvium, as well as Pleistocene (Teays)-age Minford clay over Pennsylvanian-age upper Conemaugh group through Permian-age Dunkard group cyclic sequences of red and gray shales, and siltstones, sandstones, limestones, and coals.

Drainage in the northwestern part of Monroe County is generally accommodated by the Seneca Fork Wills Creek and its tributaries. The project site itself is directly drained by the Seneca Fork Wills Creek, which in turn drains into Senecaville Lake approximately 3½ miles downstream of the project site.

According to the Surficial Geology data from the Ohio Department of Natural Resources (ODNR) Division of Geological Survey (Exhibit No. 3 in Appendix A), surficial soils at the site consist of primarily Holocene-aged alluvial deposits (a) overlying silt and clay with occasional sand and gravel interbeds of unspecified age (LC). These surficial deposits are underlain by Pennsylvanian bedrock including sandstone, shale, siltstone, clay, limestone, and coal (P). The alluvium develops in floodplains of modern streams with soils ranging from silt to clay to boulders, commonly including organic materials. The silt and clay with occasional sand and gravel interbed deposits are likely the result of backwater lake deposits, but may also be deltaic deposits, outwash, and deposits in upland depressions.

2.2.1 Project Soils

The USDA Soil Survey of Perry County indicates the most prevalent surficial soil type within the project limits are the Kinnick-Lindside silt loams (KnL1AF) as shown in Exhibit No. 4a.

Soils of the Kinnick-Lindside silt loam (0 to 3 percent slopes) consist of 70 percent Kinnick and similar soils, 20 percent Lindside and similar soils, and 10 percent minor components. The Kinnick soils generally consist of silt loam derived from silty alluvium. The well drained soils are typically located in flood plains with a moderately high to high water capacity. Lindside soils generally consist of silt loam overlying stratified gravelly sandy loam to silty clay loam derived from alluvium. The well drained soils are typically located in floodplains with a moderately high to high water capacity.

As shown on Exhibit Nos. 4b through 4d in Appendix A, the soil survey indicates the soils within the project area are considered to have a low risk of corrosion to concrete, a moderate risk of corrosion to steel, and a pH level of 6.5.

2.2.2 Bedrock Geology

As shown on Exhibit No. 5 (Bedrock Geology Map), the bedrock geology mapped within the project area is the Upper Pennsylvanian age Conemaugh Group (IPc). The Upper Pennsylvanian age Monongahela Group (IPm) is located at higher elevations on the valley walls and ridges outside the project area. Bedrock elevations in the project area are estimated at roughly El. 800 as shown on Exhibit No. 6 (Bedrock Topography Map), and quickly climb upon the valley walls to approximately El 880 and higher.

The Upper Pennsylvanian age Conemaugh Group generally consists of shale, siltstone, mudstone, sandstone, limestone, and coal. General features include lenticular, planar, nodular, irregular, and cross bedding. The mudstone, shale and siltstone are described as argillaceous to sandy, non-bedded to thinly bedded, locally calcareous and may contain marine fossils in lower half of the unit. The sandstones are described as fine to medium grained, locally conglomeratic, thin to massive to cross bedded, and micaceous. Limestone is described as micritic to coarse grained, thin to medium bedded with marine fossils common in the lower part of the unit. Coals are impure, bituminous, thin to bedded, and discontinuous.

No previous surface or deep mining was mapped at the project site itself. However, as shown on the ODNR Mine of Ohio Map (Exhibit No. 7), several abandoned mine entrances are located approximately 2.5 miles east of the project site. These mine openings are associated with the Meigs Creek No. 9 coal seam of the overlying Monongahela Group. This seam ranged from roughly El. 990 to El. 1022 based on the available historic mining information provided by the ODNR. Additional surface mines were also mapped approximately 3 miles northwest of the project site in neighboring Noble County. The elevation of these mines is estimated from El. 1040 to El. 1060, based on the mine boundaries and existing topographic data. However, a specific coal seam and elevation was not indicated in the available information from the ODNR.

3 EXPLORATION

3.1 Site Reconnaissance

A visual reconnaissance of the project site and surrounding area was performed by an HDR geotechnical engineer during the drilling activities on October 20, 2022. The project site is located within a relatively wide valley containing the Seneca Fork Wills Creek. The existing bridge is a one lane structure carrying TR 2001 over the creek, with the roadway ending soon after the crossing at a homestead. This single span structure is supported by two approximately 24-inch deep by 9-inch wide, steel sections spanning between the two bridge abutments. The bridge structure appears to have been previously supported on stacked stones. These stone abutments are still in place, but appear to no longer be the primary support for the structure. The east abutment has been reinforced with a 12-inch deep by 12-inch wide steel beam spanning the width of the bridge and supported by three 12-inch deep by 12-inch wide piles driven in front of the stacked stone. Guardrail lagging has been placed behind the lower half of the piles. At the west abutment, the bridge structure extends beyond the stacked stone abutment and is supported on a 12-inch deep by 12-inch wide steel grade beam placed upon the ground immediately behind the abutment.

The existing bridge deck consists of wood planks, placed perpendicular to the alignment, supported on five evenly spaced 3.5-inch wide by 7-inch deep steel sections positioned parallel to the alignment. Several steel plates have also been placed over wood planks near the center of the structure. The bridge deck is supported by 7 approximately 8-inch wide and 8-inch deep steel sections spanning perpendicular to the alignment and connected to the two 24-inch deep by 9-inch wide steel sections on either side of the bridge.

3.2 Subsurface Exploration

Two borings were drilled as part of the geotechnical exploration program to assess the subsurface conditions within the MOE-TR2001-0.13 project limits. The locations of the test borings are shown on

the Boring Location Plan (Exhibit No. 8) in Appendix A. These as-drilled locations are reflected on the boring plan, boring logs and Table 3-1.

Table 3-1. Summary of Bridge Structure Borings

Boring Number	Boring Type[1]	Alignment	Station	Offset	Surface (El., feet)	Bottom of Borehole (El., feet)
B-001-0-22	E1	TR 2001	9+66	15 RT	861.3	802.3
B-002-0-22	E1	TR 2001	10+31	17 RT	861.6	807.6

[1] ODOT Boring Designations: Bridge Structure (E1)

The borings were drilled by Central Star Drilling under the supervision of an HDR geotechnical engineer on October 20, 2022, with a Diedrich D-50 track rig. The rig was calibrated on March 7, 2022, with an energy ratio of 86.8%. All borings were drilled in general accordance with the *Specifications for Geotechnical Explorations* (ODOT revised July 2022) utilizing 3.25-inch internal diameter hollow stem augers to advance the borings to the top of bedrock. The sampling of the soils was accomplished in accordance with the *Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils*, ASTM D 1586. In the split-barrel sampling procedure, a standard 2-inch outside diameter split-barrel sampling spoon is driven into the ground with a 140-pound hammer falling a distance of 30 inches. The number of blows required to advance the sampling spoon the last 12 inches of a typical 18-inch penetration is recorded as the standard penetration test (SPT) resistance or N_{SPT}-value. The N_{SPT}-value is then corrected to an energy ratio of 60%, termed N_{60}, which is used for design. Two undisturbed soil samples were collected in Boring B-001-0-22 and one was collected in Boring B-002-0-22 in accordance with the *Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes*, ASTM D 1587. The depth of these samples was determined by the HDR geotechnical engineer after review of the encountered subsurface conditions above the undisturbed samples.

Sampling of the underlying bedrock was performed in accordance with the *Standard Practice for Rock Core Drilling and Sampling of Rock for Site Investigation*, ASTM D 2113, using an NQ2-size double tube-swivel barrel with a diamond bit. Boring logs and photographs of the recovered rock core samples are provided in Appendix B.

3.3 Laboratory Testing

The obtained soil and rock samples were visually examined by an HDR geotechnical engineer, and representative soil samples selected for laboratory testing to confirm the field classification and to assess the various engineering properties of the soils. Soil index testing performed by HDR included 34 natural moisture content tests (per ASTM D 2216), 18 Atterberg limit determinations (per ASTM D 4318), and 18 grain size analyses (per ASTM D 422). The results of the soil index tests are presented on the final boring logs located in Appendix B. In addition to the soil index testing, 3 soil unconfined compression tests (per ASTM D 2166) were performed on the undisturbed Shelby tube samples and two point load strength index of rock tests (ASTM D 5731) were performed on bedrock samples. Results of these tests are presented on the individual laboratory sheets included in Appendix C.

4 FINDINGS

The generalized soil profile as encountered in the borings consists of silt and clay deposits with interbedded granular layers overlying cohesive residual soils. The underlying bedrock consists of interbedded shale, sandstone, and claystone.

The silt and clay deposits generally consist of an overlying roughly 6-foot thick layer of medium stiff to stiff Silt and Clay (A-6a) underlain by interbedded very soft Clay (A-7-6), very soft Silt (A-4b), very soft to soft Sandy Silt (A-4a), loose Fine Sand (A-3), loose Coarse and Fine Sand (A-3a), and loose to medium dense Gravel and Stone Fragments with Sand, Silt, and Clay (A-2-6) to about 21.5 feet below the existing ground surface (bgs) (El 839.8) in Boring B-001-0-22 and 16.5 feet bgs (El 845.1) in Boring B-002-0-22. The silt and clay deposits become more competent below these depths, with the respective borings encountering medium stiff to stiff Clay (A-7-6), stiff to very stiff Silt and Clay (A-6a), and stiff Silt (A-4b) to a depth of 36.5 feet bgs (El 824.8) and 38.5 feet bgs (El 823.1).

Residual soils were encountered in each of the borings below these depths. Boring B-001-0-22 encountered a 12-foot layer of very stiff Clay (A-7-6) with noted stone fragments from a depth of 36.5 feet bgs (El 824.8) to the top of rock at El 812.8. At Boring B-002-0-22, hard Sandy Silt (A-4a) exhibiting relic rock structure was encountered at a depth of 38.5 feet bgs (El 823.1) to the top of rock at 43 feet bgs (El 818.6).

The underlying bedrock as encountered in Borings B-001-0-22 and B-002-0-22 consisted of interbedded shale, sandstone, and claystone. Shale was encountered from a depth of 48.5 to 49.0 feet (El. 812.8 to El. 812.3) and 53.0 to 55.5 feet (El. 808.3 to El. 805.8) in Boring B-001-0-22 and from 43 to 46.5 feet (El. 818.6 to El. 815.1) in Boring B-002-0-22. The shale was characterized as slightly to moderately weathered and weak to very weak in strength. The shale which was cored had a stratum rock quality (SRQD) of 60%. Claystone was encountered underlying the shale in Boring B-001-0-22 at a depth of 55.5 feet to termination at 59.0 feet bgs (El. 805.8 to El. 802.3). The claystone was characterized as slightly to moderately weathered and very weak with a SRQD of 77%. Sandstone was encountered from 49 feet (El 812.3) to 53 feet (El 808.3) in Boring B-001-0-22, and from a depth of 46.5 feet (El 815.1) to boring termination at 54.0 feet (El. 807.6) in Boring B-002-0-22. The sandstone was characterized as slightly to moderately weathered and weak to slightly strong. The sandstone as encountered in Boring B-001-0-22 had a SRQD of 0%, and a B-002-0-22, the SRQD was 56%.

Groundwater was encountered in both borings during drilling. As water was introduced during drilling activities to perform rock coring, water levels upon completion were not obtained. Furthermore, the borings were sealed immediately upon completion as the borings were performed in close proximity to the traveled lane, and delayed water readings were not obtained. Groundwater depths and elevations encountered in the borings are tabulated in Table 4-1 and included on the boring logs in Appendix B.

Table 4-1. Summary of Groundwater Levels

Boring	Depth/Elevation at Completion (ft)	Notes
B-001-0-22	6.5/854.8	Water added at 49.0 feet, Boring completed same day
B-002-1-22	16/845.6	Water added at 43.0 feet. Boring completed same day

5 ANALYSES AND RECOMMENDATIONS

5.1 Determination of Soil Parameters

Soil parameters were developed primarily from laboratory tests, supplemented by published correlations with SPT data and plasticity indices, recorded pocket penetrometer readings, and our engineering experience and judgement. A summary of the recommended strength parameters for the various layers are provided in Table 5-1. Details of the parameter development are located in Appendix D.

Table 5-1. Recommended Soil Strength Parameters

Material	Unit Wt.[1]		Undrained Shear Strength		Drained Shear Strength	
	γ_T (pcf)	γ_{eff} (pcf)	S_u (psf)	ϕ' (°)	c' (psf)	ϕ' (°)
1 - Medium Stiff to Stiff Cohesive	130	67.6	1050	0	105	22
2 - Very Loose Granular	115	52.6	0	27	0	27
3 - Very Soft to Soft Cohesive	115	52.6	400	0	20	16
4 - Loose to Medium Dense Granular	125	62.6	0	29	0	29
5 - Very Stiff Cohesive	130	67.6	1200	0	165	25
6 - Hard Residuum	140	77.6	4000	0	250	28

1. Effective unit weights to be used below groundwater (assumed at El 850.5 in recommended design soil profile).

5.2 Bridge Foundations

The project involves the replacement of an existing single-span structure carrying Wehr Road (TR 2001) over Seneca Fork Wills Creek. As this will be a design-build project, providing a recommended foundation type is outside the scope of this study. However, given the roughly 16 feet to 21 feet of soft and/or loose interbedded soils overlying the site, and the depth to competent bedrock (approximately 43 to 48.5 feet bgs), it is anticipated that deep foundations will be utilized to support the bridge abutments. With the adjacent creek, shallow groundwater, and granular soil layers encountered within the soil profile, driven or cast-in-place pile foundations rather than drilled shafts are anticipated to be the preferred foundation type to avoid potential complications related to seepage and potential caving of the shaft walls during excavation. As such, Table 5-2 below provides the recommended design profile and a summary of recommended design parameters for use by the selected design build team for axial and lateral pile analyses using both APILE and LPILE software programs by Ensoft. Any piles spaced closer than five (5) pile widths must consider group effects.

Table 5-2. Recommended Axial and Lateral Pile Design Parameters

Recommended Design Profile		Material	Unit Wt.[1]		E50	k
Top Elevation (ft)	Bottom Elevation (ft)		γ_T (pcf)	γ_{Eff} (pcf)		
861.5	855.5	1 - Medium Stiff to Stiff Cohesive	130	130	0.007	N/A
855.5	850.5	3 - Very Soft to Soft Cohesive	115	115	0.02	N/A
850.5	847	4 - Loose to Medium Dense Granular	115	52.6	N/A	20
847	840	3 - Very Soft to Soft Cohesive	115	52.6	0.02	N/A
840	823	1 - Medium Stiff to Stiff Cohesive	130	67.6	0.007	N/A
823	813	5 - Very Stiff Cohesive	130	67.6	0.007	N/A

[1] Effective unit weights to be used below groundwater (assumed at El 850.5 in recommended design soil profile).

5.3 Scour Evaluation Parameters

Continuous sampling of the soils was conducted within each boring for a length of 6 feet beginning from the approximate elevation of the stream bed for Seneca Fork Wills Creek to assist with the determination of the scour analysis parameters per Section 1302 of the GDM. Table 5-3 below summarizes the sampling depths and respective scour analysis parameters to be utilized by the selected design build team in determining the predicted scour depth.

Table 5-3: Scour Analysis Parameters

Boring	Sample	Elevation of Top of Sample (ft)	D50 Value (mm)	Critical Shear Stress Tc (psf)	Erosion Category EC (dim)
B-001-0-22	SS-4	854.82	0.0304	0.001	0.38
	SS-5	853.32	0.0808	0.002	0.89
	SS-6	851.82	0.2168	0.003	2.21
	SS-7	850.32	0.2442	0.001	2.21
B-002-0-22	SS-4	855.15	0.2416	0.000	2.36
	SS-5	853.65	0.0849	0.006	2.21
	SS-6	852.15	0.0895	0.002	0.94
	SS-7	850.65	2.1089	0.044	2.59

5.4 Recommendations

5.4.1 Site Preparation

- Site preparation activities at the bridge should be performed in accordance with Item 201 and Item 202 of the current edition of the CMS. These activities are anticipated to include removal of the existing bridge structure and possible relocation of existing utilities.

5.4.2 Settlement

- As modifications to the roadway alignment within the project area are expected, some settlement is anticipated to occur. Settlement of the bridge structure would be limited should the bridge foundations bear on the underlying competent bedrock encountered at approximately 43 to 48.5 feet below the existing ground surface. However, analyses would need to be conducted to estimate the magnitude of drag forces, if any, acting on the piles as outlined in section 305.3.2.2 of the ODOT BDM using the neutral plane method considering 100% tip resistance mobilization if bearing on rock.

6 LIMITATIONS

This report documents the preliminary findings and conclusions of HDR Engineering, Inc., for the geotechnical aspects related to the planning and design of the MOE-TR2001-0.13 project in Monroe County, Ohio. The report has been prepared for the use of the Office of the Monroe County Engineer for specific application to this project, in accordance with generally accepted engineering practice. No warranty, expressed or implied, is made. Any analyses or recommendations submitted are based on the field explorations performed at the locations indicated, on specific laboratory tests on individual samples taken during this exploration, and information obtained from outside sources. The report and analyses do not reflect variation that could occur between borings or at other points in time. Variations in conditions, if any, may become evident during the construction period, at which time, a re-evaluation of the recommendations may become necessary. In the event of such changes, the recommendations and changes should be reviewed by HDR's geotechnical staff.

7 REFERENCES

State of Ohio Department of Transportation (Updated July 2022); "*Specifications for Geotechnical Explorations."*

State of Ohio Department of Transportation (Updated July 2022); "*Geotechnical Design Manual."*

State of Ohio Department of Transportation (Updated July 2022); "*Bridge Design Manual."*

State of Ohio Department of Transportation (July 2022); "*Location and Design Manual, Volume 2 – Drainage Design."*

United States Department of Agriculture: Natural Resources Conservation Service (2022); "Web Soil Survey". http://websoilsurvey.nrcs.usda.gov/app/"

Ohio Department of Natural Resources, Division of Geologic Survey (2022); "*Ohio Geology Interactive Map*". https://ohiodnr.gov/business-and-industry/services-to-business-industry/gis-mapping-services/ohio-geology-interactive-map

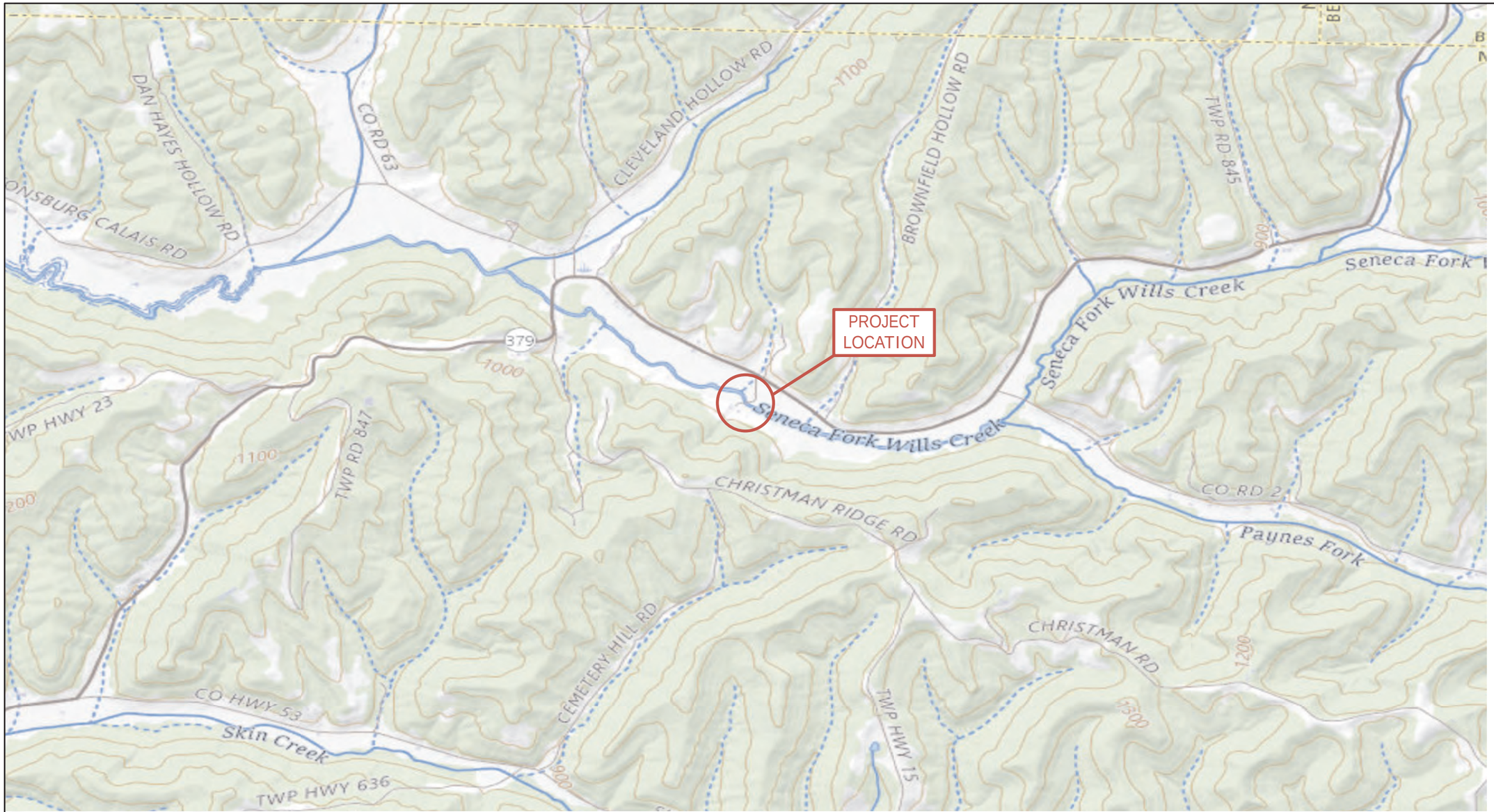
Ohio Division of Geological Survey, (1998); *Physiographic regions of Ohio: Ohio Department of National Resources*, Division of Geological Survey, scale 1:2,100,000.

Ohio Department of Natural Resources Division of Geological Survey (2013); "*Ohio's Geology in Core and Outcrop: A Field Guide for Citizens and Environmental and Geotechnical Investigators*", Information circular 63.

United States Geological Survey Topographic Map, (2019); "*Cameron Quadrangle, Ohio."*

Ohio Department of Natural Resources, Division of Geologic Survey and Division of Mineral Resources (2022); *"Mines of Ohio". https://gis.ohiodnr.gov/MapViewer/?config=OhioMines#*

Appendix A. Exhibits



Produced by the United States Geological Survey
North American Datum of 1983 (NAD83)
World Geodetic System of 1984 (WGS84). Projection and
1 000-meter grid:Universal Transverse Mercator, Zone 17S
This map is not a legal document. Boundaries may be generalized for this map scale. Private lands within government reservations may not be shown. Obtain permission before entering private lands.

Imagery	NAIP,	August 2015 - October 2015
Roads	U.S. Census Bureau,	2016
Roads within US Forest Service Lands	FSTopo Data with limited Forest Service updates,	2016
Names	GNIS,	1979 - 2019
Hydrography	National Hydrography Dataset,	1899 - 2019
Contours	National Elevation Dataset,	2010
Boundaries	Multiple sources; see metadata file	2017 - 2018
Public Land Survey System	BLM,	2017
Wetlands	FWS National Wetlands Inventory	2004 - 2007

MN
GN
8°19'
148 MILS
0°12'
4 MILS
UTM GRID AND 2019 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

U.S. National Grid
100,000 - m Square ID
ME
Grid Zone Designation
17S

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
NORTH AMERICAN VERTICAL DATUM OF 1988

This map was produced to conform with the National Geospatial Program US Topo Product Standard, 2011. A metadata file associated with this product is draft version 0.6.18

QUADRANGLE LOCATION

1	2	3
4		5
6	7	8

1 Senecaville
2 Quaker City
3 Barnesville
4 Sarahsville
5 Lewisville
6 Macksburg
7 Stafford
8 Graysville
ADJOINING QUADRANGLES

ROAD CLASSIFICATION

Expressway	Local Connector
Secondary Hwy	Local Road
Ramp	4WD
Interstate Route	US Route
State Route	
FS Primary Route	FS Passenger Route
FS High Clearance Route	

Check with local Forest Service unit for current travel conditions and restrictions.

SUMMERFIELD, OH
2019

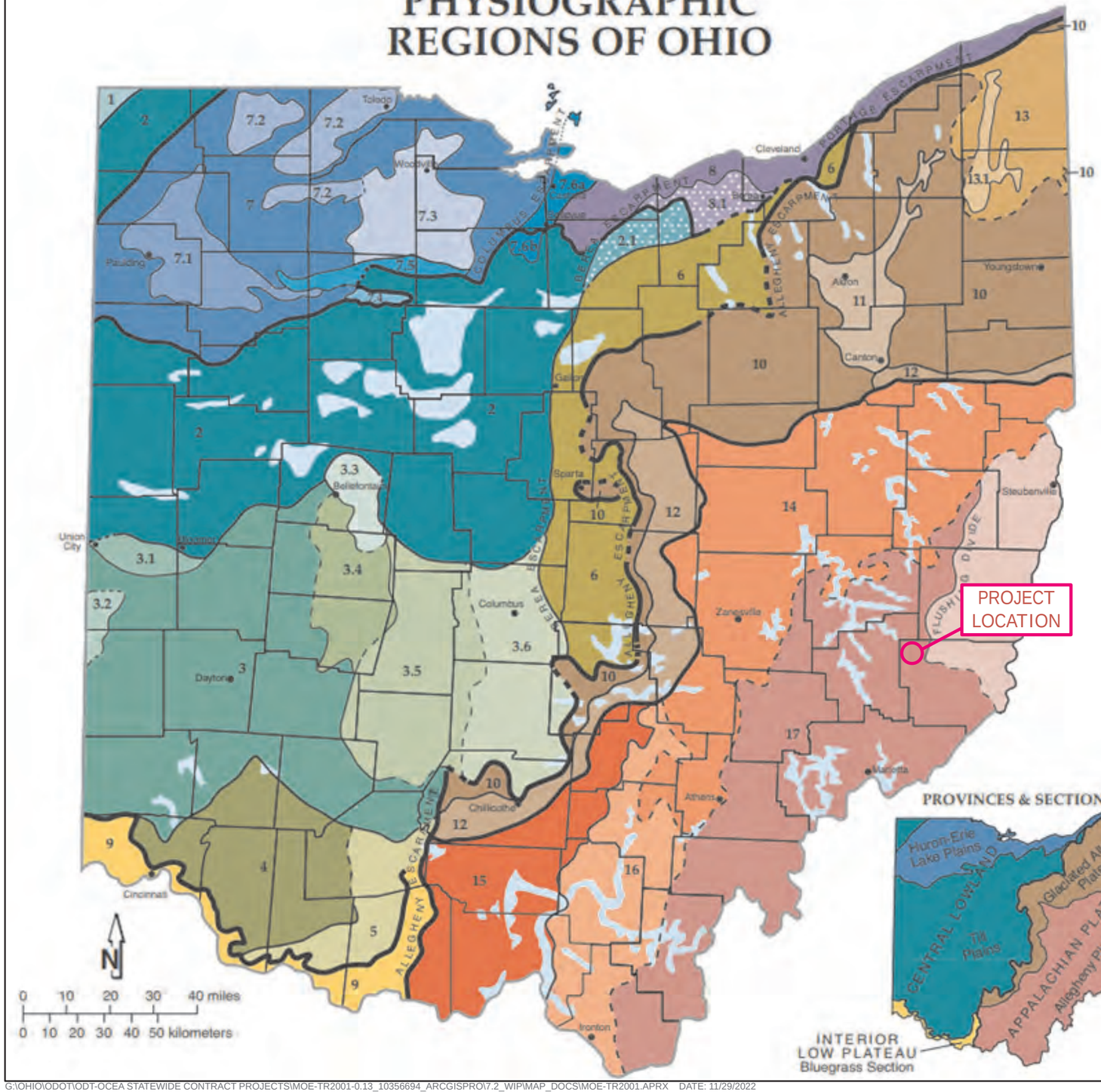
Calculated: LSH
Checked: DMV

Exhibit No. 1: Site Vicinity and Topographic Map

Project: MOE-TR2001-0.13
PID: 117522

STATE OF OHIO • DEPARTMENT OF NATURAL RESOURCES • DIVISION OF GEOLOGICAL SURVEY

PHYSIOGRAPHIC REGIONS OF OHIO



Till Plains

- 1. Steuben Till Plain
- 2. Central Ohio Clayey Till Plain
  - 2.1. Berea Headlands of the Till Plain
- 3. Southern Ohio Loamy Till Plain
  - 3.1. Union City-Bloomer Transitional Terrain
  - 3.2. Whitewater Interlobate Plain
  - 3.3. Bellefontaine Upland
  - 3.4. Mad River Interlobate Plain
  - 3.5. Darby Plain
  - 3.6. Columbus Lowland
- 4. Illinoian Till Plain
- 5. Dissected Illinoian Till Plain
- 6. Galion Glaciated Low Plateau

Huron-Erie Lake Plains

- 7. Maumee Lake Plains
  - 7.1. Paulding Clay Basin
  - 7.2. Maumee Sand Plains
  - 7.3. Woodville Lake-Plain Reefs
  - 7.4. Findlay Embayment
  - 7.5. Fostoria Lake-Plain Shoals
  - 7.6a and 7.6b. Bellevue-Castalia Karst Plain
- 8. Erie Lake Plain
  - 8.1. Berea Headlands of the Erie Lake Plain

Bluegrass Section

- 9. Outer Bluegrass Region

Glaciated Allegheny Plateaus

- 10. Killbuck-Glaciated Pittsburgh Plateau
- 11. Akron-Canton Interlobate Plateau
- 12. Illinoian Glaciated Allegheny Plateau
- 13. Grand River Low Plateau
  - 13.1 Grand River Finger-Lake Plain

Allegheny Plateaus

- 14. Muskingum-Pittsburgh Plateau
- 15. Shawnee-Mississippian Plateau
- 16. Ironton Plateau
- 17. Marietta Plateau
  - 17.1. Little Switzerland Plateau

Transitional boundary

Lake basin/deposits outside Huron-Erie Lake Plains

Reference:

Ohio Division of Geological Survey, 1998

Physiographic Regions of Ohio,

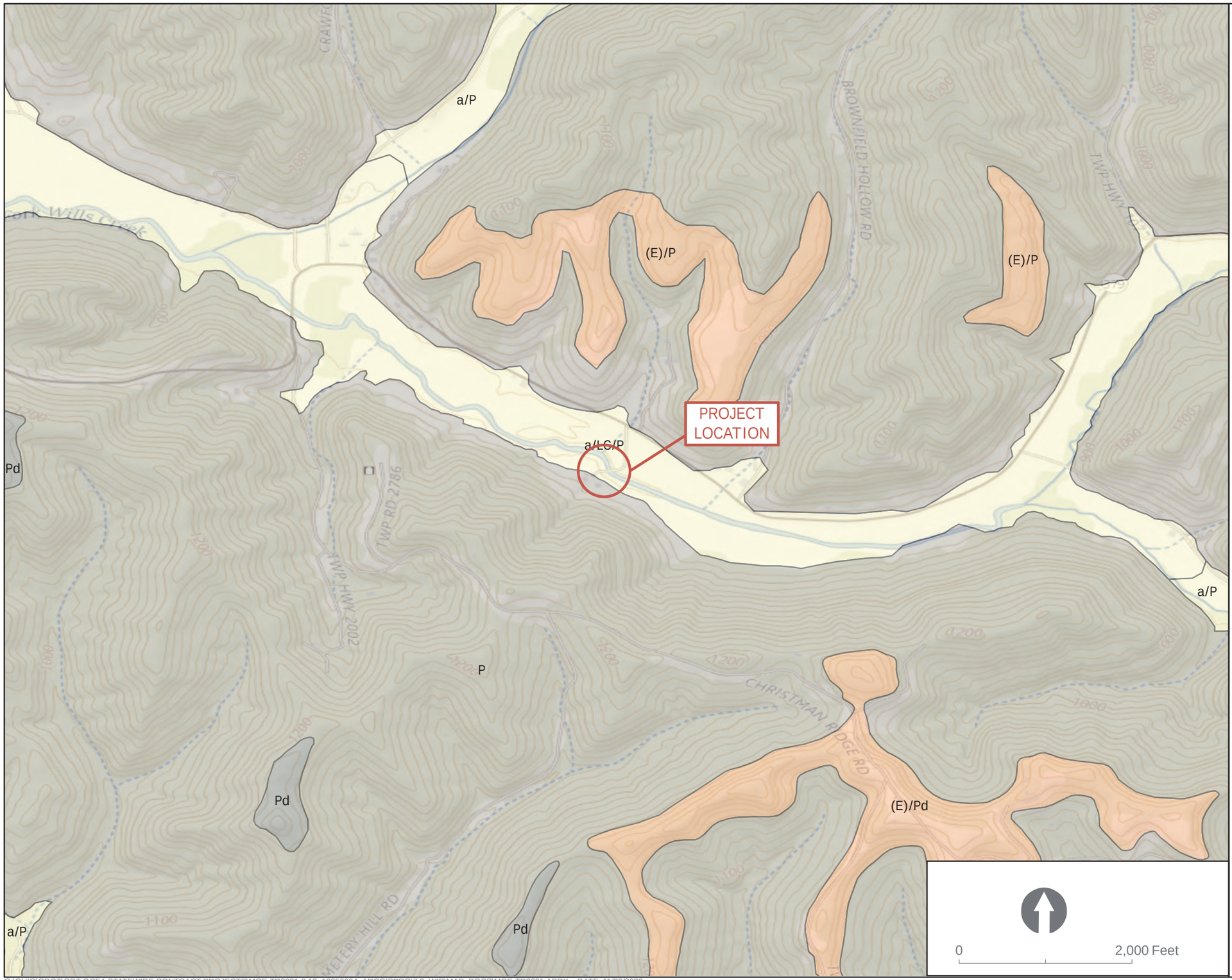
Ohio Dept. of Natural Resources, Division of Geological Survey

Calculated: LSH
Checked: DMV

Exhibit No. 2: Physiographic Regions of Ohio

Project: MOE-TR2001-0.13
PID: 117522

G:\OHIO\ODOT\ODT-OCEA STATEWIDE CONTRACT PROJECTS\MOE-TR2001-0.13_10356694_ARCGISPRO\7.2_WIP\MAP_DOCS\MOE-TR2001.APRX DATE: 11/29/2022



Geologic Mapping Unit Descriptions
Surficial Units

- Quarry
- Pit
- **a** — Alluvium (Holocene) -Includes a wide variety of textures from silt to clay to boulders. Commonly includes organic material; generally, not compact. Occurs in floodplains of modern streams and mapped only where areal extent and thickness are noteworthy. Also includes alluvial terraces, old floodplain remnants that are positioned tens of feet above modern floodplains.
- **E** — Eolian silt (loess) and fine sand - Deposited by wind, generally on bedrock and Illinoian till-capped ridges. Mapped where thickness and areal extent noteworthy.
- **SG** — Sand and gravel (predominantly Wisconsinan) - Intermixed and interbedded sand and gravel commonly containing thin, discontinuous layers or silt, clay, and till. Grains well to moderately sorted, moderately to well rounded; finely stratified to massive, may be cross bedded; locally, may contain organic material. Widespread fluvial deposits in terraces and buried valleys. May be older in deep buried valleys.
- **L** — Silt (predominantly Wisconsinan) - Massive or laminated, commonly contains thin sand partings. May contain localized clay, sand, or gravel layers. Clay content commonly increases with depth. Frequently occurs in lowland surface deposits, in terraces, and as deposits of glacial lakes.
- **LC** — Silt and clay with occasional sand-and-gravel interbeds (unspecified age). Present as deltaic deposits, outwash, deposits in upland depressions, intermorainal lake deposits, and backwater lake deposits.
- **P** — Sandstone, Siltstone, shale, clay, limestone, and coal- Sandstone nonbedded to massive, medium to coarse grained with abundant rounded quartz pebbles; quartz pebble conglomerate present. Interbeds of shale, sandstone, siltstone, clay, coal, and limestone common in upper portions of unit. Common horizontal and vertical changes in rock type.
- **Pd** — Sandstone, siltstone, shale, and clay (predominantly Permian). Sandstone fine grained to conglomeratic; thin to massive, crossbedding present. Limestone and coal beds present in lower part of unit.

Source: ODNR Division of Geological Survey
https://gis.ohiodnr.gov/website/dgs/geologyviewer/#

Calculated: LSH
Checked: DMV

Exhibit No. 3: Surficial Geology

Project: MOE-TR2001-0.13
PID: 117522

G:\OHIO\ODOT\ODT-OCEA STATEWIDE CONTRACT PROJECTS\MOE-TR2001-0.13_10356694_ARCGISPRO\7.2_WIP\MAP_DOCS\MOE-TR2001.APRX DATE: 11/29/2022

Map Unit Legend

KnL1AF, 0 to 30 percent slopes, frequently flooded

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:15,800.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Perry County, Ohio
Survey Area Data: Version 19, Sep 9, 2022

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Oct 8, 2020—Nov 7, 2020

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Source:Web Soil Survey 11/2022
https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

Calculated: LSH
Checked: DMV

Exhibit No. 4a: Soil Survey Map
Soil Type

Project: MOE-TR2001-0.13
PID: 117522

Corrosion of Concrete

Map Unit Legend

KnL1AF, 0 to 30 percent slopes, frequently flooded, Low rating

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:15,800.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Perry County, Ohio
Survey Area Data: Version 19, Sep 9, 2022

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Oct 8, 2020—Nov 7, 2020

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Source:Web Soil Survey 11/2022
https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

Calculated: LSH
Checked: DMV

Exhibit No. 4b: Soil Survey Map
Corrosion of Concrete

Project: MOE-TR2001-0.13
PID: 117522

Corrosion of Steel

Map Unit Legend

KnL1AF, 0 to 30 percent slopes, frequently flooded, Moderate rating

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:15,800.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Perry County, Ohio
Survey Area Data: Version 19, Sep 9, 2022

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Oct 8, 2020—Nov 7, 2020

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Source:Web Soil Survey 11/2022
https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

Calculated: LSH
Checked: DMV

Exhibit No. 4c: Soil Survey Map
Corrosion of Steel

Project: MOE-TR2001-0.13
PID: 117522

pH (1 to 1 Water)

Map Unit Legend

KnL1AF, 0 to 30 percent slopes, frequently flooded, pH rating 6.5

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:15,800.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Perry County, Ohio
Survey Area Data: Version 19, Sep 9, 2022

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Oct 8, 2020—Nov 7, 2020

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Source:Web Soil Survey 11/2022
https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

Calculated: LSH
Checked: DMV

Exhibit No. 4d: Soil Survey Map
pH Levels

Project: MOE-TR2001-0.13
PID: 117522

G:\OHIO\ODOT\ODT-OCEA STATEWIDE CONTRACT PROJECTS\MOE-TR2001-0.13_10356694_ARCGISPRO\7.2_WIP\MAP_DOCS\MOE-TR2001.APRX DATE: 11/29/2022

GEOLOGIC UNIT

- IPc - Conemaugh Group
- IPm - Monongahela Group
- PIPd - Dunkard Group, Permian-Pennsylvanian

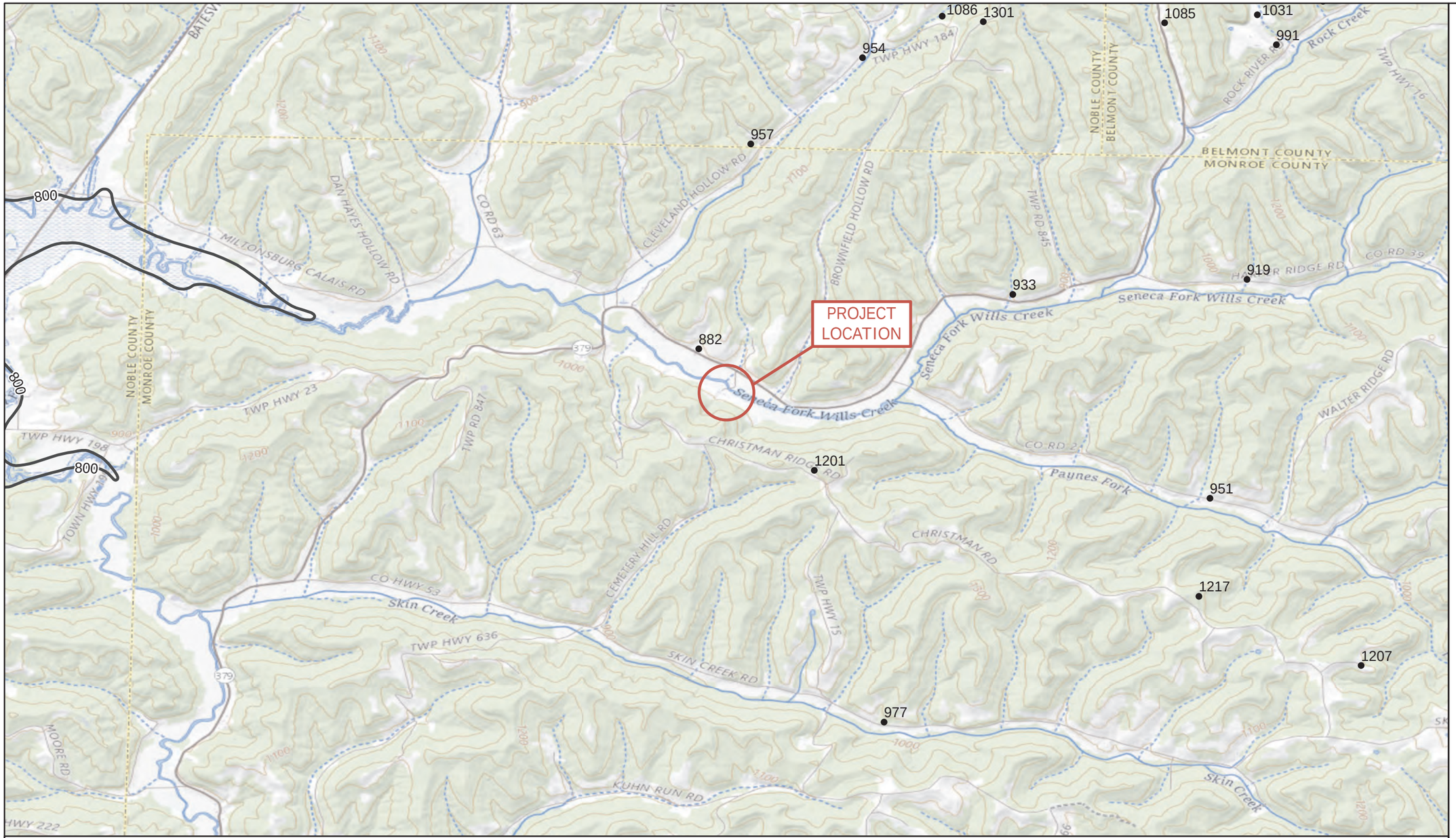
0 4,000 Feet

Source: ODNR Division of Geological Survey, 500K Generalized bedrock map of Ohio.
https://gis.ohiodnr.gov/website/dgs/geologyviewer/#

Calculated: LSH
Checked: DMV

Exhibit No. 5: Bedrock Geology Map

Project: MOE-TR2001-0.13
PID: 117522



Bedrock contour (ft)

Bedrock Elevation (ft)

0 6,000 Feet

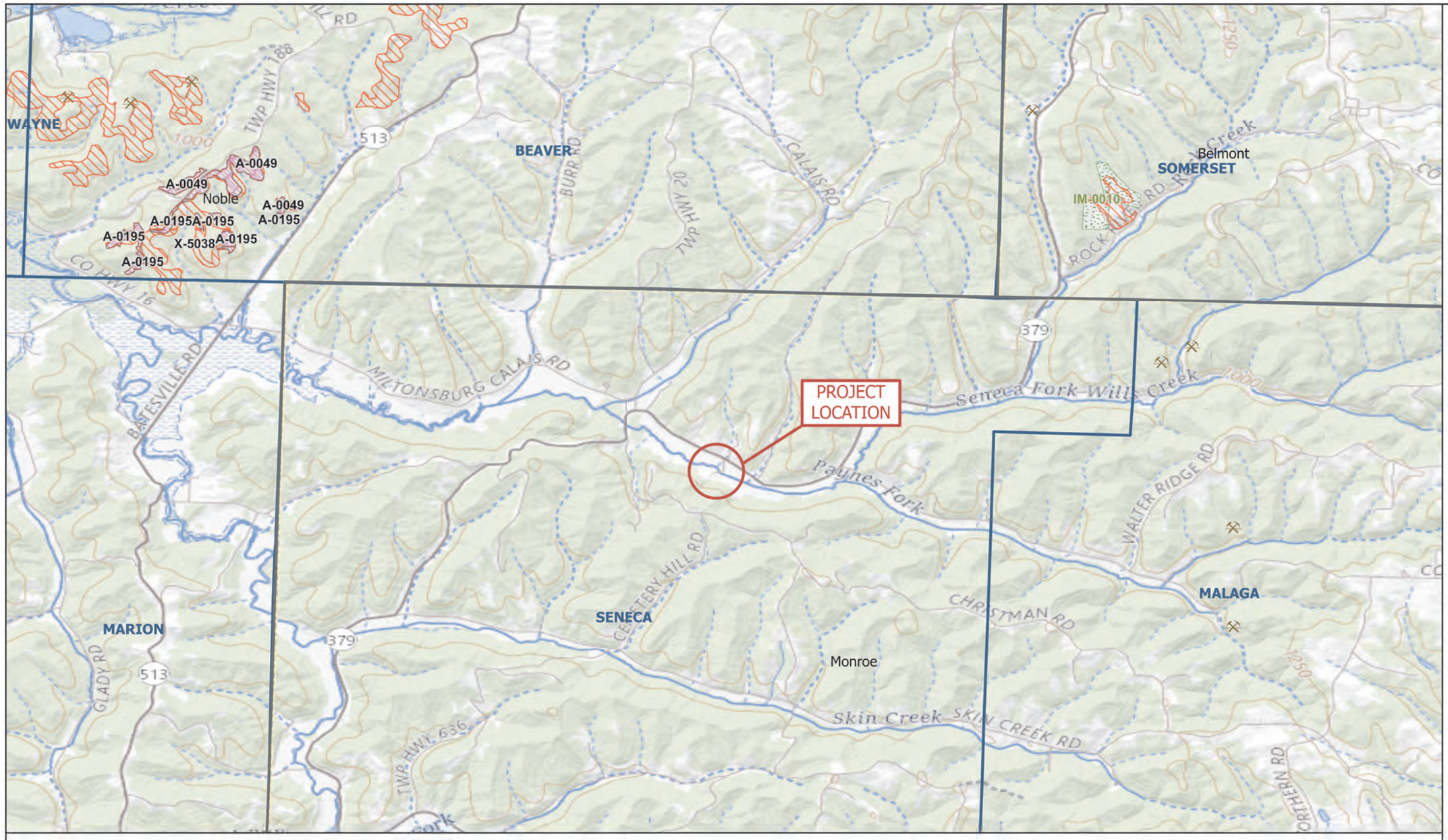
Source: ODNR Division of Geological Survey, Bedrock Topography 24K
https://gis.ohiodnr.gov/website/dgs/geologyviewer/#

Calculated: LSH
Checked: DMV

Exhibit No. 6: Bedrock Topography Map

Project: MOE-TR2001-0.13
PID: 117522

G:\OHIO\ODOT\ODT-OCEA STATEWIDE CONTRACT PROJECTS\MOE-TR2001-0.13_10356694_ARCGISPRO\7.2_WIP\MAP_DOCS\MOE-TR2001.APRX DATE: 11/29/2022



G:\OHIO\ODOT\ODT-OCEA STATEWIDE CONTRACT PROJECTS\PER-CR25-2.00_10354468_ARCGISPRO\7.2_WIP\MAP_DOCS\HDR_PROJECT.APRX DATE: 11/29/2022

Calculated: LSH
Checked: DMV

Exhibit No. 7: Mines of Ohio Map

Project: MOE-TR2001-0.13
PID: 117522

MODEL: CLX_RW_2001 - Plan 1 [Sheet] PAPERSIZE: 17x11 (in.) DATE: 12/1/2022 TIME: 8:11:01 PM USER: CWAHLBRI

EXHIBIT NO. 8: BORING LOCATION PLAN

HORIZONTAL SCALE IN FEET
0 20
10 40

SHEET	TOTAL
1	1

PROJECT ID: 117522

REVIEWER: DMV 12/02/22

DESIGNER: DCM

DESIGN AGENCY: HDR

Appendix B. Boring Logs and Rock Core Photos

PROJECT: MOE-TR2001-00.13	DRILLING FIRM / OPERATOR: CENTRAL STAR / TS	DRILL RIG: DIEDRICH D-50 TRACK	STATION / OFFSET: 9+66, 15' RT.
TYPE: BRIDGE	SAMPLING FIRM / LOGGER: HDR / DCM	HAMMER: AUTOMATIC HAMMER	ALIGNMENT: TR 2001
PID: 117522 SFN: 5630290	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 3/7/22	ELEVATION: 861.3 (MSL) EOB: 59.0 ft.
START: 10/20/22 END: 10/20/22	SAMPLING METHOD: SPT / ST / NQ2	ENERGY RATIO (%): 86.8	LAT / LONG: 39.849175, -81.267229

EXPLORATION ID B-001-0-22

MATERIAL DESCRIPTION AND NOTES	ELEV. 861.3	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
MEDIUM STIFF TO STIFF, BROWN, **SILT AND CLAY**, TRACE SAND, TRACE GRAVEL, MOIST			2 2 3	7	44	SS-1	1.00	-	-	-	-	-	-	-	-	29	A-6a (V)	
			3 4 5	13	100	SS-2	2.00	1	1	4	62	32	36	25	11	27	A-6a (8)	
	855.3		2 2 3	7	78	SS-3	1.00	-	-	-	-	-	-	-	-	26	A-6a (V)	
VERY SOFT TO SOFT, GRAY, **SANDY SILT**, LITTLE TO SOME CLAY, TRACE GRAVEL, WET		W 854.8	1 2 1	4	100	SS-4	-	0	1	43	35	21	21	15	6	34	A-4a (4)	
	851.8		WOH WOH 1	1	33	SS-5	-	4	13	35	31	17	24	19	5	37	A-4a (3)	
LOOSE, GRAY, **COARSE AND FINE SAND**, LITTLE SILT, LITTLE TO TRACE CLAY, LITTLE GRAVEL, WET			2 3 2	7	78	SS-6	-	16	19	39	15	11	22	18	4	24	A-3a (0)	
	847.3		2 3 3	9	89	SS-7	-	20	16	45	11	8	16	16	NP	23	A-3a (0)	
VERY SOFT, GRAY, **CLAY**, SOME SAND, WET			1 1 1	3	78	SS-8	0.25	-	-	-	-	-	-	-	-	51	A-7-6 (V)	
	844.3		2 3 1	6	78	SS-9A	0.25	-	-	-	-	-	-	-	-	46	A-7-6 (V)	
LOOSE, GRAY, **FINE SAND**, WET	842.8					SS-9B	-	-	-	-	-	-	-	-	-	40	A-3 (V)	
VERY SOFT, GRAY, **SILT**, "AND" CLAY, TRACE SAND, WET			1 1 1	3	100	SS-10	-	0	0	4	57	39	29	20	9	31	A-4b (8)	
	839.8				75	ST-11	1.00	5	3	7	49	36	41	20	21	29	A-7-6 (13)	
MEDIUM STIFF TO STIFF, BROWN, **CLAY**, "AND" SILT, TRACE SAND, TRACE GRAVEL, MOIST @ 22.5' - 23.0' : qu = 2,130 psf			2 2 4	9	67	SS-12	0.50	-	-	-	-	-	-	-	-	30	A-7-6 (V)	
	832.8																	
VERY STIFF, GRAY, **SILT AND CLAY**, SOME GRAVEL, LITTLE SAND, DAMP			5 4 7	16	22	SS-13	1.00	-	-	-	-	-	-	-	-	21	A-6a (V)	

PID: 117522	SFN:	PROJECT: MOE-TR2001-00.13	STATION / OFFSET: 9+66, 15' RT.	START: 10/20/22	END: 10/20/22	PG 2 OF 3	B-001-0-22

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
@ 28.5' - 30.0' : Drove 3-inch SPT Sampler to recover addtional sample for SS-13 VERY STIFF, GRAY, **SILT AND CLAY**, SOME GRAVEL, LITTLE SAND, DAMP *(continued)*	831.3	31 32 33																
@ 33.5' - 35.0 : Trace Brown and Red-Brown		34 35 36	4 6 9	22	78	SS-14	2.50	34	8	6	23	29	37	22	15	19	A-6a (5)	
VERY STIFF, RED-BROWN AND GRAY, **CLAY**, "AND" SILT, TRACE SAND, TRACE STONE FRAGMENTS, DAMP	824.8	37			58	ST-15	1.50	3	1	3	59	34	41	26	15	21	A-7-6 (10)	
@ 38.0' - 38.5' : qu = 2,320 psf		38 39	5 7 9	23	100	SS-16	2.00	-	-	-	-	-	-	-	-	34	A-7-6 (V)	
		40 41 42 43																
@ 44.5' - 45.0' : Red-brown, fine sand, some clay		44 45 46 47	3 5 6	16	100	SS-17	-	-	-	-	-	-	-	-	-	25	A-7-6 (V)	
	812.8	48																
SHALE, GRAY, SLIGHTLY TO MODERATELY WEATHERED, WEAK.	812.3	TR 49	50/1"	-	100	SS-18	-	-	-	-	-	-	-	-	-	22	Rock (V)	
SANDSTONE, GRAY, SLIGHTLY TO MODERATELY WEATHERED, WEAK TO SLIGHTLY STRONG, FINE TO MEDIUM GRAINED, VERY THIN BEDDED, PYRITIC, BEDDING DISCONTINUITIES, FRACTURE TO MODERATELY FRACTURED, NARROW TO OPEN APERTURE, SLICKENSIDED TO SLIGHTLY ROUGH, LAMINATED, POOR TO FAIR SURFACE CONDITION; RQD 0%, REC 100%. @ 49.0' - 53.0' : Interbedded shale partings 1/4 inch to 1 inch in thickness	808.3	50 51 52 53	38		100	NQ2-1											CORE	
SHALE, GRAY, SLIGHTLY TO MODERATELY WEATHERED, VERY WEAK, THIN TO MEDIUM BEDDED, BEDDING AND JOINT DISCONTINUITIES, FRACTURE TO MODERATELY FRACTURED, SLICKENSIDED, LAMINATED, FAIR TO POOR SURFACE CONDITIONS; RQD 60%, REC 100%. @ 53.7' - 53.9' : Interbedded Sandstone @ 54.6' - 54.8' : Interbedded Sandstone	805.8	54 55 56 57																
CLAYSTONE, GRAY, SLIGHTLY TO MODERATELY WEATHERED, VERY WEAK, MEDIUM BEDDED, JOINT DISCONTINUITIES, SLIGHTLY FRACTURED, TIGHT APERTURE, SLICKENSIDED, LAMINATED, FAIR TO POOR SURFACE CONDITION; RQD 77%, REC 100%.	802.3	EOB 58 59	58		100	NQ2-2											CORE	

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 11/30/22 17:06 - C:\PW\WORKING\EAST01\D2962291\20221020_MOE-TR2001_BORINGLOGS.GPJ

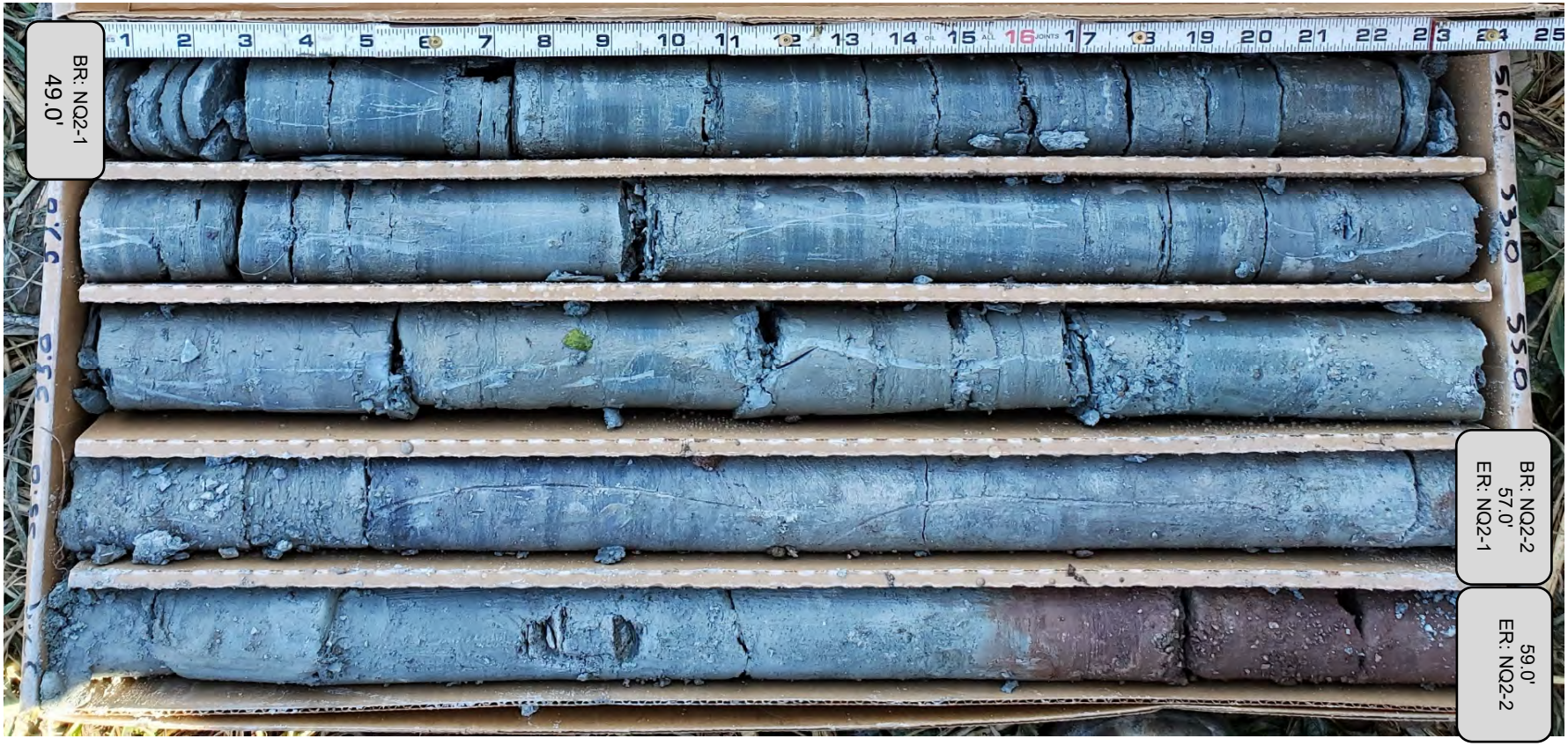
PID: 117522	SFN:	PROJECT: MOE-TR2001-00.13	STATION / OFFSET: 9+66, 15' RT.	START: 10/20/22	END: 10/20/22	PG 3 OF 3	B-001-0-22

MATERIAL DESCRIPTION AND NOTES	ELEV. 799.2	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
@ 56.2' - 56.9' : Qu = 220 psi (Point Load Test)																		

NOTES: NONE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 25 LB. BENTONITE POWDER; 94 LB. CEMENT; 50 GAL. WATER

B-001-0-22



Run #	Depth (ft)		Recovery		RQD	
NQ2-1	49	57	96 in. / 96 in.	100%	36 in. / 96 in.	38%
NQ2-2	57	59	24 in. / 24 in.	100%	14 in. / 24 in.	58%

MOE-TR2001-0.13, PID 117522

PROJECT: MOE-TR2001-00.13	DRILLING FIRM / OPERATOR: CENTRAL STAR / TS	DRILL RIG: DIEDRICH D-50 TRACK	STATION / OFFSET: 10+31, 17' RT.	EXPLORATION ID B-002-0-22
TYPE: BRIDGE	SAMPLING FIRM / LOGGER: HDR / DCM	HAMMER: AUTOMATIC HAMMER	ALIGNMENT: TR 2001	
PID: 117522 SFN: 5630290	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 3/7/22	ELEVATION: 861.6 (MSL) EOB: 54.0 ft.	PAGE 1 OF 2
START: 10/20/22 END: 10/20/22	SAMPLING METHOD: SPT / ST / NQ2	ENERGY RATIO (%): 86.8	LAT / LONG: 39.849173, -81.267472	

MATERIAL DESCRIPTION AND NOTES	ELEV. 861.6	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
MEDIUM STIFF TO STIFF, BROWN, **SILT AND CLAY**, LITTLE SAND, LITTLE GRAVEL, DAMP		1	2 2 3	7	67	SS-1	1.50	-	-	-	-	-	-	-	-	33	A-6a (V)	
		2																
		3	3 3 4	10	67	SS-2	2.00	15	10	7	45	23	37	26	11	22	A-6a (7)	
		4																
	855.6	5																
VERY LOOSE, BROWN, **COARSE AND FINE SAND**, TRACE SILT AND CLAY, WET		6	2 2 1	4	67	SS-3	0.25	-	-	-	-	-	-	-	-	27	A-6a (V)	
	853.6	7	WOH WOH WOH	0	33	SS-4	-	0	29	65	6	-	20	15	5	27	A-3a (0)	
VERY SOFT TO SOFT, BROWN, **SANDY SILT**, LITTLE CLAY, TRACE GRAVEL, WET @ 9.0' - 9.2' : Gray		8																
		9	WOH WOH WOH	0	78	SS-5	-	1	4	48	27	20	21	17	4	29	A-4a (2)	
	850.6	10	2 1 3	6	89	SS-6	-	1	4	50	25	20	22	14	8	27	A-4a (2)	
LOOSE TO MEDIUM DENSE, BROWN TRACE GRAY AND RED-BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND, SILT, AND CLAY**, WET		11																
		12	2 2 2	6	67	SS-7	-	50	13	6	13	18	38	25	13	22	A-2-6 (0)	
		13																
		14	4 4 5	13	50	SS-8	-	-	-	-	-	-	-	-	-	23	A-2-6 (V)	
	845.1	15																
	W 845.6	16																
STIFF, GRAY TO BLUE-GRAY, **SILT AND CLAY**, SOME SAND, LITTLE STONE FRAGMENTS, DAMP @ 17.0' - 17.5' : qu = 2,080 psf		17			100	ST-9	1.00	20	10	12	29	29	40	25	15	24	A-6a (7)	
		18																
		19	3 4 4	12	100	SS-10	1.50	-	-	-	-	-	-	-	-	28	A-6a (V)	
		20																
		21																
		22																
	838.1	23																
STIFF, GRAY TO BLUE-GRAY, **SILT**, SOME CLAY, LITTLE SAND, DAMP		24	2 4 5	13	100	SS-11	1.00	0	4	9	55	32	31	24	7	24	A-4b (8)	
		25																
		26																
		27																
	833.1	28																
STIFF, GRAY TO BLUE-GRAY, **CLAY**, SOME SILT, LITTLE SAND, LITTLE GRAVEL, DAMP		29	2 3 4	10	100	SS-12	1.00	12	5	4	25	54	49	28	21	27	A-7-6 (14)	

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 11/30/22 17:06 - C:\PW\WORKING\EAST01\D2962291\20221020_MOE-TR2001_BORINGLOGS.GPJ

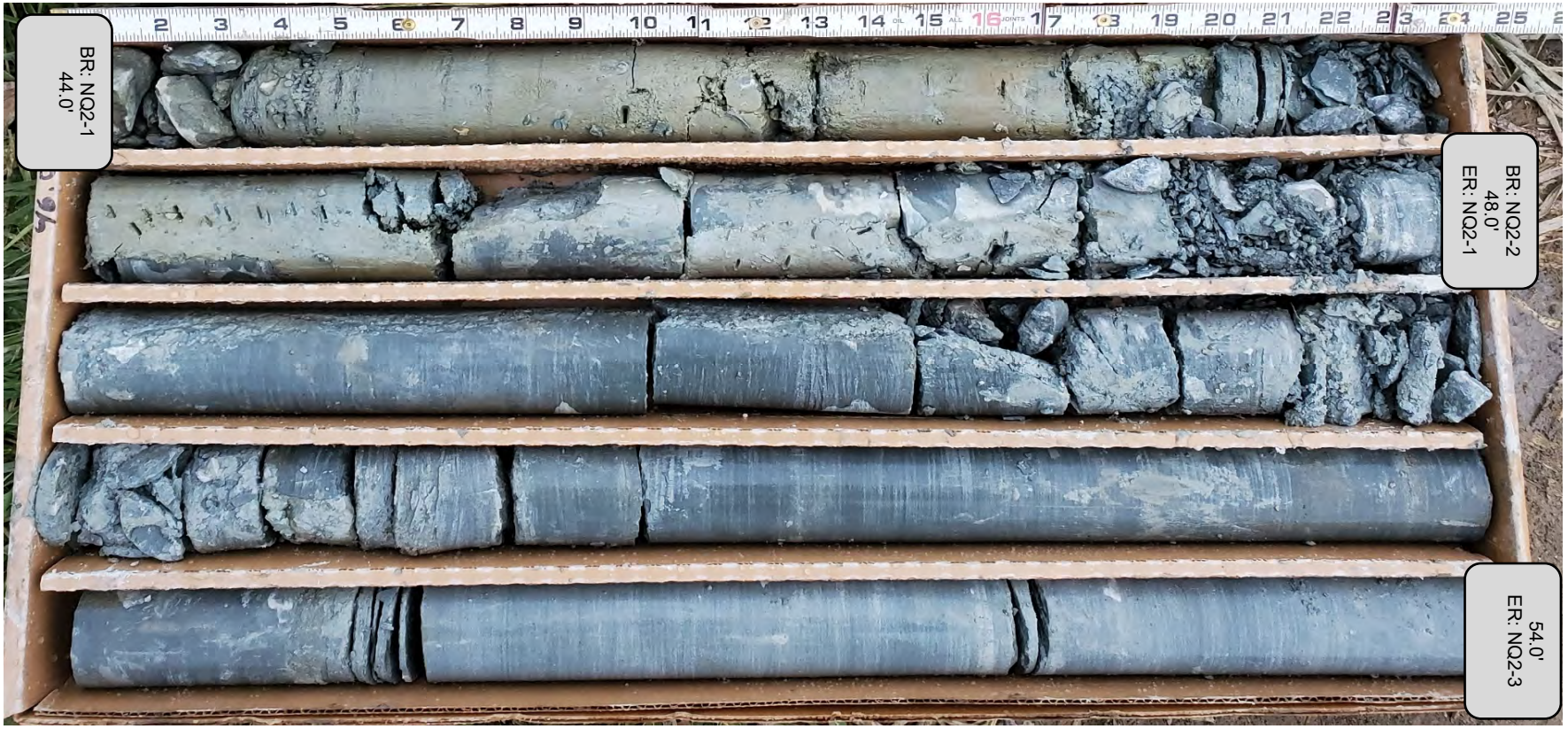
PID: 117522	SFN:	PROJECT: MOE-TR2001-00.13	STATION / OFFSET: 10+31, 17' RT.	START: 10/20/22	END: 10/20/22	PG 2 OF 2	B-002-0-22

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
STIFF, GRAY TO BLUE-GRAY, **CLAY**, SOME SILT, LITTLE SAND, LITTLE GRAVEL, DAMP *(continued)*	831.6	31 32 33 34 35 36 37 38	2 3 3	9	100	SS-13	1.00	-	-	-	-	-	-	-	-	29	A-7-6 (V)	
HARD, GRAY, **SANDY SILT**, SOME STONE FRAGMENTS, LITTLE CLAY, DAMP (Relic Rock Structure)	823.1	39 40 41 42	4 24 47	103	89	SS-14	1.00	30	15	8	34	13	27	18	9	10	A-4a (2)	
SHALE, GRAY, MODERATELY WEATHERED, VERY WEAK.	818.6	TR 43	33 50/5"	-	100	SS-15	-	-	-	-	-	-	-	-	-	13	Rock (V)	
SHALE, GRAY, MODERATELY WEATHERED, VERY WEAK, THIN BEDDED, FRIABLE, BEDDING DISCONTINUITIES, FRACTURED, NARROW TO TIGHT APERTURE, SLICKENSIDED, LAMINATED, POOR TO FAIR SURFACE CONDITION; RQD 60%, REC 100%. @ 45.5' - 46.6' : Highly Fractured @ 46.0' - 47.5' : Vertically split approximately 50% shale, 50% sandstone	817.6	44 45 46	38		100	NQ2-1											CORE	
SANDSTONE, GRAY, SLIGHTLY WEATHERED, WEAK TO SLIGHTLY STRONG, FINE GRAINED, THIN BEDDED, PYRITIC, JOINT AND BEDDING DISCONTINUITIES, MODERATELY FRACTURED, TIGHT TO NARROW APERTURE, SLIGHTLY ROUGH, VERY BLOCKY, FAIR TO GOOD SURFACE CONDITION; RQD 56%, REC 100%. @ 47.5' - 48.5' : Highly Fractured @ 51.1' - 51.8' : Qu = 469 psi (Point Load Test)	815.1	47 48 49 50 51 52 53	69		100	NQ2-2											CORE	
	807.6	EOB 54																

NOTES: SAMPLE SS-4 (6.5' - 8.0') : INSUFFICIENT AMOUNT OF FINES FOR HYDROMETER TEST

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 25 LB. BENTONITE POWDER; 94 LB. CEMENT; 50 GAL. WATER

B-002-0-22



Run #	Depth (ft)		Recovery		RQD	
NQ2-1	44	48	48 in. / 48 in.	100%	18 in. / 48 in.	38%
NQ2-2	48	54	72 in. / 72 in.	100%	50 in. / 72 in.	69%

MOE-TR2001-0.13, PID 117522

Appendix C. Laboratory Testing

Unconfined Compressive Strength of Cohesive Soils (ASTM D2166)

UNCONFINED COMPRESSION TEST

AASHTO: T-208

Project Name	: MOE-TR2001-0.13		
Project #	: 10356694	Sample #	: ST-11
Project County	: Monroe	Sample Loc.	: Boring No. B-001-0-22
Project State	: Ohio	Sample Depth	: 22.5' to 23.0'
Laboratory #	: 10356694	Date Tested	: 10/31/2022
Submitted By	: HDR	Date Reported	: 11/2/2022

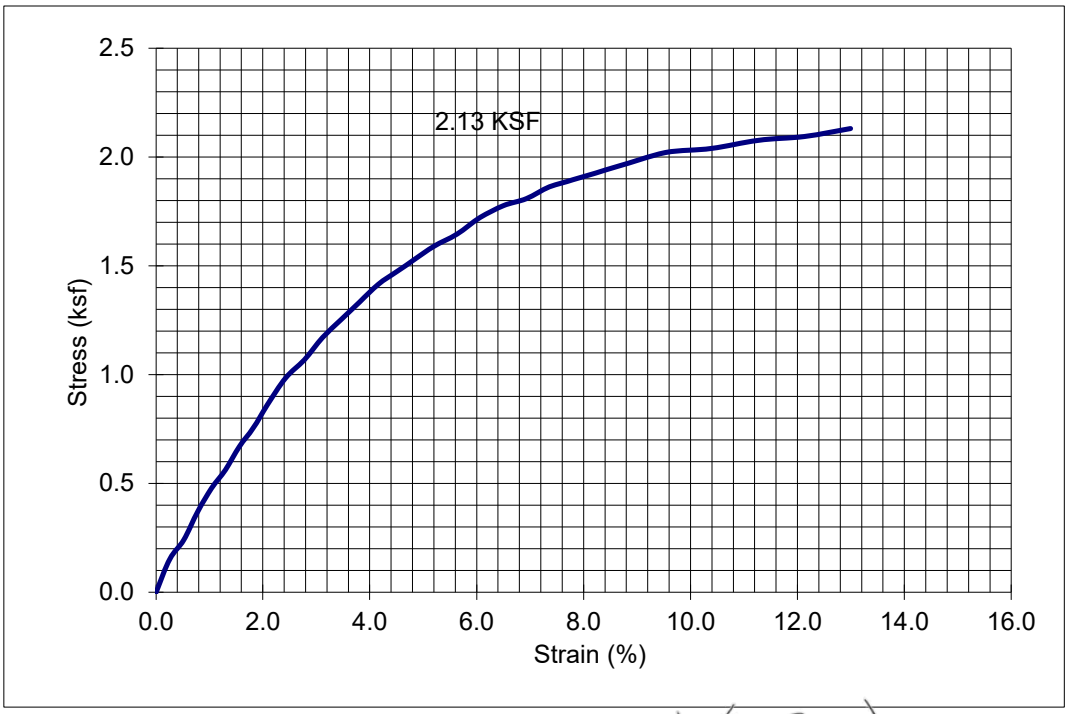
Soil Type	: A-7-6(13)				
Wet Density	: 129.7	pcf	Initial Height	: 5.77	in
Dry Density	: 104.4	pcf	Initial Diameter	: 2.85	in
Moisture	: 24.2	%	Proving Ring	: #22734	

RESULTS:

#	Axial Load lbs	Corrected Area sf	Unit Strain %	Stress Ksf
1	0.0	0.04	0.0	0.00
2	6.8	0.04	0.3	0.15
3	10.7	0.04	0.5	0.24
4	16.5	0.04	0.8	0.37
5	21.3	0.04	1.0	0.48
6	25.2	0.04	1.3	0.56
7	30.1	0.04	1.6	0.67
8	34.0	0.05	1.8	0.75
9	38.8	0.05	2.1	0.86
10	44.6	0.05	2.4	0.99
11	48.5	0.05	2.8	1.07
12	53.4	0.05	3.1	1.17
13	57.4	0.05	3.5	1.25
14	61.3	0.05	3.8	1.33
15	65.2	0.05	4.2	1.41
16	68.2	0.05	4.5	1.47
17	71.1	0.05	4.9	1.53
18	74.1	0.05	5.2	1.59
19	77.0	0.05	5.6	1.65
20	81.0	0.05	6.1	1.72
21	83.9	0.05	6.5	1.78
22	85.9	0.05	6.9	1.81
23	88.8	0.05	7.4	1.86
24	90.8	0.05	7.8	1.89
25	92.8	0.05	8.2	1.93
26	94.7	0.05	8.7	1.96
27	98.7	0.05	9.5	2.02
28	100.6	0.05	10.4	2.04
29	103.4	0.05	11.3	2.08
30	105.3	0.05	12.1	2.09
31	108.2	0.05	13.0	2.13
32	109.1	0.05	13.9	0.00

UNCONFINED COMPRESSION TEST

Project Name	: MOE-TR2001-0.13		
Project #	: 10356694	Sample #	: ST-11
Project County	: Monroe	Sample Loc.	: Boring No. B-001-0-22
Project State	: Ohio	Sample Depth	: 22.5' to 23.0'
Laboratory #	: 10356694	Date Tested	: 10/31/2022
Submitted By	: HDR	Date Reported	: 11/2/2022
Soil Type	: A-7-6(13)		
Wet Density	: 129.7 pcf	Initial Height	: 5.77 in
Dry Density	: 104.4 pcf	Initial Diameter	: 2.85 in
Moisture	: 24.2 %	Proving Ring	: #22734
Deg. of Sat.	: 100.0 %	SPECIFIC GRAVITY	: 2.660
Comments	: AASHTO: T-208		



APPROVED BY: Kevin E. Walker

hdrinc.com

4645 Village Square Drive, Suite F, Paducah, KY 42001
T 270.444.9691 F 270.538.1599

UNCONFINED COMPRESSION TEST

AASHTO: T-208

Project Name	: MOE-TR2001-0.13		
Project #	: 10356694	Sample #	: ST-15
Project County	: Monroe	Sample Loc.	: Boring No. B-001-0-22
Project State	: Ohio	Sample Depth	: 38.0' to 38.5'
Laboratory #	: 10356694	Date Tested	: 10/31/2022
Submitted By	: HDR	Date Reported	: 11/2/2022

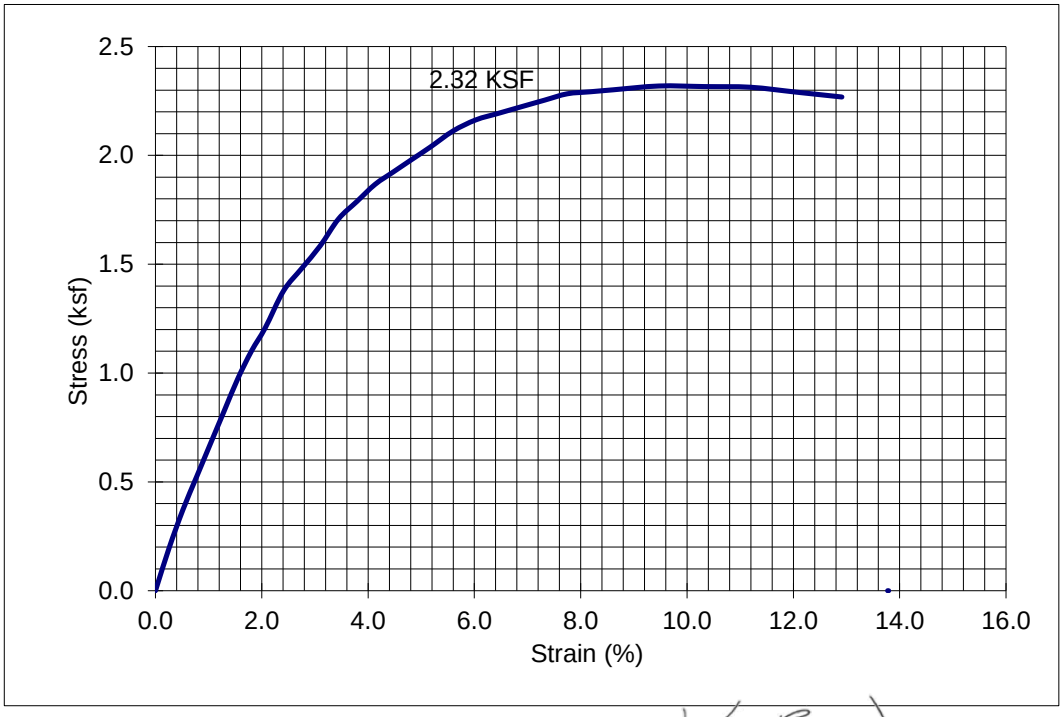
Soil Type	: A-7-6(13)				
Wet Density	: 127.7	pcf	Initial Height	: 5.81	in
Dry Density	: 101.5	pcf	Initial Diameter	: 2.84	in
Moisture	: 25.8	%	Proving Ring	: #22734	

RESULTS:

#	Axial Load lbs	Corrected Area sf	Unit Strain %	Stress Ksf
1	0.0	0.04	0.0	0.00
2	8.7	0.04	0.3	0.20
3	16.5	0.04	0.5	0.37
4	23.3	0.04	0.8	0.52
5	30.1	0.04	1.0	0.67
6	36.9	0.04	1.3	0.82
7	43.7	0.04	1.5	0.97
8	49.5	0.04	1.8	1.10
9	54.4	0.05	2.1	1.21
10	62.3	0.05	2.4	1.38
11	67.2	0.05	2.8	1.48
12	72.1	0.05	3.1	1.58
13	78.0	0.05	3.4	1.71
14	82.0	0.05	3.8	1.79
15	85.9	0.05	4.1	1.87
16	88.8	0.05	4.5	1.92
17	91.8	0.05	4.8	1.98
18	94.7	0.05	5.2	2.04
19	98.7	0.05	5.6	2.11
20	101.5	0.05	6.0	2.16
21	103.4	0.05	6.5	2.19
22	105.3	0.05	6.9	2.22
23	107.2	0.05	7.3	2.25
24	109.1	0.05	7.7	2.28
25	110.1	0.05	8.2	2.29
26	111.1	0.05	8.6	2.30
27	113.0	0.05	9.5	2.32
28	113.9	0.05	10.3	2.32
29	114.9	0.05	11.2	2.31
30	114.9	0.05	12.1	2.29
31	114.9	0.05	12.9	2.27
32	113.9	0.05	13.8	0.00

UNCONFINED COMPRESSION TEST

Project Name	: MOE-TR2001-0.13		
Project #	: 10356694	Sample #	: ST-15
Project County	: Monroe	Sample Loc.	: Boring No. B-001-0-22
Project State	: Ohio	Sample Depth	: 38.0' to 38.5'
Laboratory #	: 10356694	Date Tested	: 10/31/2022
Submitted By	: HDR	Date Reported	: 11/2/2022
Soil Type	: A-7-6(13)		
Wet Density	: 127.7 pcf	Initial Height	: 5.81 in
Dry Density	: 101.5 pcf	Initial Diameter	: 2.84 in
Moisture	: 25.8 %	Proving Ring	: #22734
Deg. of Sat.	: 100.0 %	SPECIFIC GRAVITY	: 2.750
Comments	: AASHTO: T-208		



APPROVED BY: Kevin E. Walker

UNCONFINED COMPRESSION TEST

AASHTO: T-208

Project Name	: MOE-TR2001-0.13		
Project #	: 10356694	Sample #	: ST-9
Project County	: Monroe	Sample Loc.	: Boring No. B-002-0-22
Project State	: Ohio	Sample Depth	: 17.0' to 17.5'
Laboratory #	: 10356694	Date Tested	: 10/31/2022
Submitted By	: HDR	Date Reported	: 11/2/2022

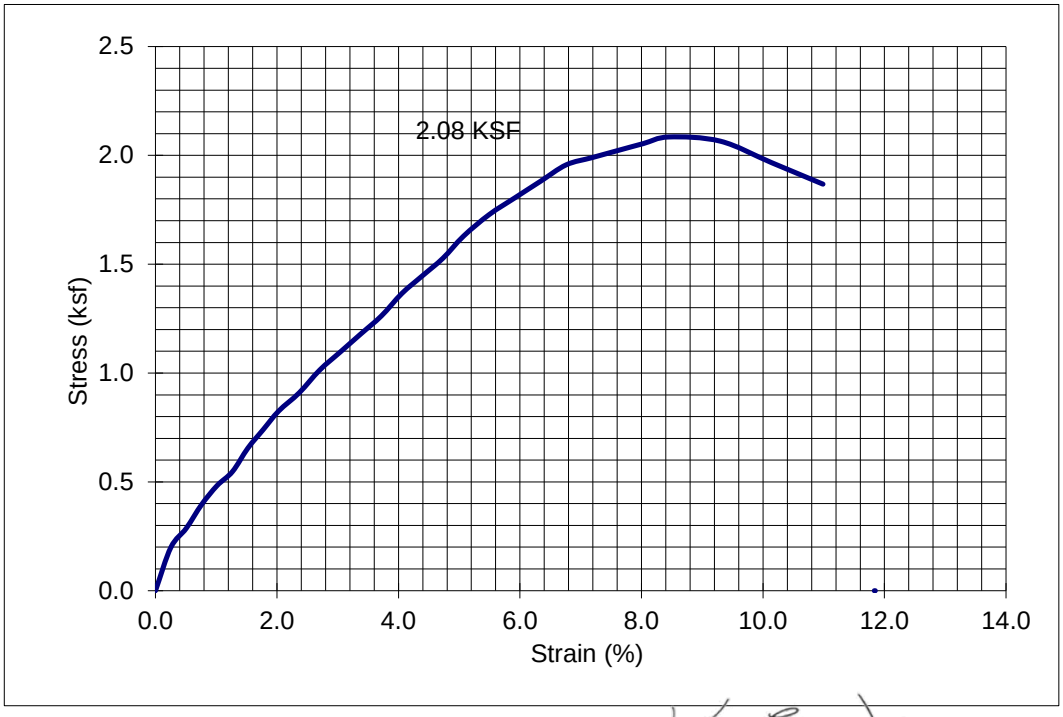
Soil Type	: A-6(7)				
Wet Density	: 132.6	pcf	Initial Height	: 5.92	in
Dry Density	: 105.8	pcf	Initial Diameter	: 2.83	in
Moisture	: 25.2	%	Proving Ring	: #22734	

RESULTS:

#	Axial Load lbs	Corrected Area sf	Unit Strain %	Stress Ksf
1	0.0	0.04	0.0	0.00
2	8.7	0.04	0.3	0.20
3	12.6	0.04	0.5	0.29
4	17.5	0.04	0.8	0.40
5	21.3	0.04	1.0	0.48
6	24.3	0.04	1.3	0.55
7	29.1	0.04	1.5	0.66
8	33.0	0.04	1.8	0.74
9	36.9	0.04	2.0	0.83
10	40.7	0.04	2.4	0.91
11	45.6	0.04	2.7	1.01
12	49.5	0.05	3.0	1.10
13	53.4	0.05	3.4	1.18
14	57.4	0.05	3.7	1.26
15	62.3	0.05	4.1	1.37
16	66.2	0.05	4.4	1.45
17	70.1	0.05	4.7	1.53
18	75.1	0.05	5.1	1.63
19	80.0	0.05	5.5	1.73
20	83.9	0.05	5.9	1.81
21	87.9	0.05	6.3	1.88
22	91.8	0.05	6.8	1.96
23	93.8	0.05	7.2	1.99
24	95.7	0.05	7.6	2.02
25	97.7	0.05	8.0	2.05
26	99.6	0.05	8.5	2.08
27	99.6	0.05	9.3	2.07
28	95.7	0.05	10.1	1.97
29	91.8	0.05	11.0	1.87
30	83.9	0.05	11.8	0.00

UNCONFINED COMPRESSION TEST

Project Name	: MOE-TR2001-0.13		
Project #	: 10356694	Sample #	: ST-9
Project County	: Monroe	Sample Loc.	: Boring No. B-002-0-22
Project State	: Ohio	Sample Depth	: 17.0' to 17.5'
Laboratory #	: 10356694	Date Tested	: 10/31/2022
Submitted By	: HDR	Date Reported	: 11/2/2022
Soil Type	: A-6(7)		
Wet Density	: 132.6 pcf	Initial Height	: 5.92 in
Dry Density	: 105.8 pcf	Initial Diameter	: 2.83 in
Moisture	: 25.2 %	Proving Ring	: #22734
Deg. of Sat.	: 100.0 %	SPECIFIC GRAVITY	: 2.740
Comments	: AASHTO: T-208		



APPROVED BY: Kevin E. Walker

Point Load Strength Index of Rock (ASTM D 5731)

ASTM D5731 Point Load Strength Index of Rock

Project Name: MOE-TR2001-0.13
Project No.: 10356694
Project County: Monroe
Project State: Ohio
Laboratory No.: 10356694
Sample Loc.: B-001-0-22

Sample No.: 56.2' to 56.9'
Date Sampled: 11/9/2022
Date Tested: 11/14/2022
Date Reported: 11/15/2022
Sample Details:

Sample Depth	Core Size	Test Type	Orientation	Width (w), in	Diameter (d), in	Length (L), in	Load (P), kip	Load (P), kN
56.2	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.040	0.18
56.3	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.061	0.27
56.4	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.038	0.17
56.5	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.038	0.17
56.6	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.029	0.13
56.7	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.031	0.14
56.8	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.029	0.13
56.9	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.031	0.14
33.5								

Note: min 10 samples required
Testing Machine Serial Number: HDR 1003

Uniaxial Compressive Strength (Bx) 220 psi

Average Uniaxial Compressive Strength: 220 psi

Point Load Strength Index	
Mean $I_{s(50)}\perp$	
Mean $I_{s(50)}$ //	9.56
$I_{s(50)}$	5.94
$I_{a(50)}$	1.00

Sampled By:

Tested By: Don Schmidt

Approved By: Kevin E. Walker

Note: ASTM D5731 applies to medium strength rock having a compresive strength over 2175 psi

hdrinc.com
ica-onramp.com
4645 Village Square Drive, Suite F, Paducah, KY 42001
T 270.444.9691 F 270.538.1599

ASTM D5731 Point Load Strength Index of Rock

Project Name: MOE-TR2001-0.13
Project No.: 10356694
Project County: Monroe
Project State: Ohio
Laboratory No.: 10356694
Sample Loc.: B-002-0-22

Sample No.: 51.1' to 51.8'
Date Sampled: 11/9/2022
Date Tested: 11/14/2022
Date Reported: 11/15/2022
Sample Details:

Sample Depth	Core Size	Test Type	Orientation	Width (w), in	Diameter (d), in	Length (L), in	Load (P), kip	Load (P), kN
51.1	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.054	0.24
51.2	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.097	0.43
51.3	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.126	0.56
51.4	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.043	0.19
51.5	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.079	0.35
51.6	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.108	0.48
51.7	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.058	0.26
51.8	Bx (1.65-1.97in)	Diametral Test	Parallel		1.98	0.1	0.074	0.33
33.5								

Note: min 10 samples required
Testing Machine Serial Number: HDR 1003

Uniaxial Compressive Strength (Bx) 469 psi

Average Uniaxial Compressive Strength: 469 psi

Point Load Strength Index	
Mean $I_{s(50)}\perp$	
Mean $I_{s(50)}$ //	20.42
$I_{s(50)}$	13.13
$I_{a(50)}$	1.00

Sampled By:

Tested By: Don Schmidt

Approved By: Kevin E. Walker

Note: ASTM D5731 applies to medium strength rock having a compresive strength over 2175 psi

hdrinc.com
ica-onramp.com
4645 Village Square Drive, Suite F, Paducah, KY 42001
T 270.444.9691 F 270.538.1599

Appendix D. Analyses

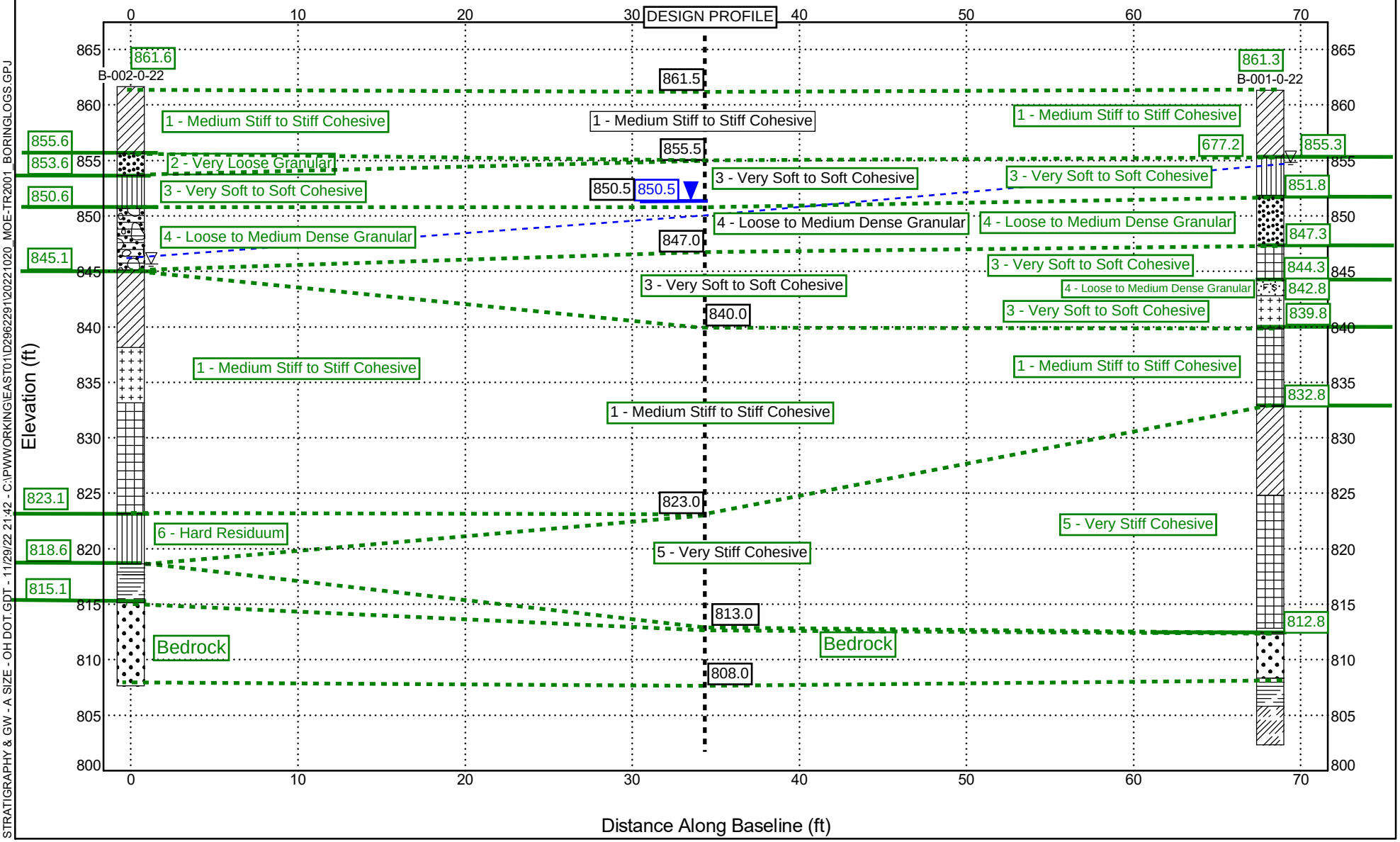
Soil Strength Parameter Determination

SUBSURFACE DIAGRAM

PROJECT NUMBER 117522

PROJECT NAME MOE - TR2001 - 0.13

PROJECT LOCATION MONROE COUNTY, OH



STRATIGRAPHY & GW - A SIZE - OH DOT.GDT - 11/29/22 21:42 - C:\PWWORKING\EAST01\D2962291\20221020_MOE-TR2001_BORINGLOGS.GPJ

PROJECT: MOE-TR2001-00.13	DRILLING FIRM / OPERATOR: CENTRAL STAR / TS	DRILL RIG: DIEDRICH D-50 TRACK	STATION / OFFSET: 9+66, 15' RT.
TYPE: BRIDGE	SAMPLING FIRM / LOGGER: HDR / DCM	HAMMER: AUTOMATIC HAMMER	ALIGNMENT: TR 2001
PID: 117522 SFN: 5630290	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 3/7/22	ELEVATION: 861.3 (MSL) EOB: 59.0 ft.
START: 10/20/22 END: 10/20/22	SAMPLING METHOD: SPT / ST / NQ2	ENERGY RATIO (%): 86.8	LAT / LONG: 39.849175, -81.267229

EXPLORATION ID B-001-0-22

PAGE 1 OF 3

MATERIAL DESCRIPTION AND NOTES	ELEV. 861.3	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
MEDIUM STIFF TO STIFF, BROWN, **SILT AND CLAY**, TRACE SAND, TRACE GRAVEL, MOIST			2 2 3	7	44	SS-1	1.00	-	-	-	-	-	-	-	-	29	A-6a (V)	
1- Medium Stiff to Stiff Cohesive			3 4 5	13	100	SS-2	2.00	1	1	4	62	32	36	25	11	27	A-6a (8)	
	855.3		2 2 3	7	78	SS-3	1.00	-	-	-	-	-	-	-	-	26	A-6a (V)	
VERY SOFT TO SOFT, GRAY, **SANDY SILT**, LITTLE TO SOME CLAY, TRACE GRAVEL, WET		W 854.8	1 2 1	4	100	SS-4	-	0	1	43	35	21	21	15	6	34	A-4a (4)	
3 - Very Soft to Soft Cohesive	851.8		WOH WOH 1	1	33	SS-5	-	4	13	35	31	17	24	19	5	37	A-4a (3)	
LOOSE, GRAY, **COARSE AND FINE SAND**, LITTLE SILT, LITTLE TO TRACE CLAY, LITTLE GRAVEL, WET			2 3 2	7	78	SS-6	-	16	19	39	15	11	22	18	4	24	A-3a (0)	
4 - Loose to Medium Dense Granular			2 3 3	9	89	SS-7	-	20	16	45	11	8	16	16	NP	23	A-3a (0)	
	847.3		1 1 1	3	78	SS-8	0.25	-	-	-	-	-	-	-	-	51	A-7-6 (V)	
VERY SOFT, GRAY, **CLAY**, SOME SAND, WET																		
3 - Very Soft to Soft Cohesive			2 3 1	6	78	SS-9A	0.25	-	-	-	-	-	-	-	-	46	A-7-6 (V)	
	844.3					SS-9B	-	-	-	-	-	-	-	-	-	40	A-3 (V)	
LOOSE, GRAY, **FINE SAND**, WET		F-S																
4 - Loose to Medium Dense Granular	842.8																	
VERY SOFT, GRAY, **SILT**, "AND" CLAY, TRACE SAND, WET			1 1 1	3	100	SS-10	-	0	0	4	57	39	29	20	9	31	A-4b (8)	
3 - Very Soft to Soft Cohesive	839.8																	
MEDIUM STIFF TO STIFF, BROWN, **CLAY**, "AND" SILT, TRACE SAND, TRACE GRAVEL, MOIST @ 22.5' - 23.0' : qu = 2,130 psf					75	ST-11	1.00	5	3	7	49	36	41	20	21	29	A-7-6 (13)	
			2 2 4	9	67	SS-12	0.50	-	-	-	-	-	-	-	-	30	A-7-6 (V)	
1- Medium Stiff to Stiff Cohesive	832.8																	
VERY STIFF, GRAY, **SILT AND CLAY**, SOME GRAVEL, LITTLE SAND, DAMP			5 4 7	16	22	SS-13	1.00	-	-	-	-	-	-	-	-	21	A-6a (V)	
5 - Very Stiff Cohesive																		

PID: 117522	SFN:	PROJECT: MOE-TR2001-00.13	STATION / OFFSET: 9+66, 15' RT.	START: 10/20/22	END: 10/20/22	PG 2 OF 3	B-001-0-22

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
@ 28.5' - 30.0' : Drove 3-inch SPT Sampler to recover addtional sample for SS-13 VERY STIFF, GRAY, **SILT AND CLAY**, SOME GRAVEL, LITTLE SAND, DAMP *(continued)* @ 33.5' - 35.0' : Trace Brown and Red-Brown	831.3	31 32 33 34 35 36	4 6 9	22	78	SS-14	2.50	34	8	6	23	29	37	22	15	19	A-6a (5)	
VERY STIFF, RED-BROWN AND GRAY, **CLAY**, "AND" SILT, TRACE SAND, TRACE STONE FRAGMENTS, DAMP @ 38.0' - 38.5' : qu = 2,320 psf 5 - Very Stiff Cohesive	824.8	37 38 39 40 41 42 43			58	ST-15	1.50	3	1	3	59	34	41	26	15	21	A-7-6 (10)	
			5 7 9	23	100	SS-16	2.00	-	-	-	-	-	-	-	-	34	A-7-6 (V)	
@ 44.5' - 45.0' : Red-brown, fine sand, some clay	812.8	44 45 46 47 48	3 5 6	16	100	SS-17	-	-	-	-	-	-	-	-	-	25	A-7-6 (V)	
SHALE, GRAY, SLIGHTLY TO MODERATELY WEATHERED, WEAK.	812.3	TR 49	50/1"	-	100/	SS-18	-	-	-	-	-	-	-	-	-	22	Rock (V)	
SANDSTONE, GRAY, SLIGHTLY TO MODERATELY WEATHERED, WEAK TO SLIGHTLY STRONG, FINE TO MEDIUM GRAINED, VERY THIN BEDDED, PYRITIC, BEDDING DISCONTINUITIES, FRACTURE TO MODERATELY FRACTURED, NARROW TO OPEN APERTURE, SLICKENSIDED TO SLIGHTLY ROUGH, LAMINATED, POOR TO FAIR SURFACE CONDITION; RQD 0%, REC 100%. @ 49.0' - 53.0' : Interbedded shale partings 1/4 inch to 1 inch in thickness	808.3	50 51 52 53 54 55	38		100	NQ2-1											CORE	
SHALE, GRAY, SLIGHTLY TO MODERATELY WEATHERED, VERY WEAK, THIN TO MEDIUM BEDDED, BEDDING AND JOINT DISCONTINUITIES, FRACTURE TO MODERATELY FRACTURED, SLICKENSIDED, LAMINATED, FAIR TO POOR SURFACE CONDITIONS; RQD 60%, REC 100%. @ 53.7' - 53.9' : Interbedded Sandstone @ 54.6' - 54.8' : Interbedded Sandstone	805.8	56 57 58	58		100	NQ2-2											CORE	
CLAYSTONE, GRAY, SLIGHTLY TO MODERATELY WEATHERED, VERY WEAK, MEDIUM BEDDED, JOINT DISCONTINUITIES, SLIGHTLY FRACTURED, TIGHT APERTURE, SLICKENSIDED, LAMINATED, FAIR TO POOR SURFACE CONDITION; RQD 77%, REC 100%.	802.3	EOB 59																

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 11/30/22 17:06 - C:\PWWORKING\EAST01\D2962291\20221020_MOE-TR2001_BORINGLOGS.GPJ

PID: 117522	SFN:	PROJECT: MOE-TR2001-00.13	STATION / OFFSET: 9+66, 15' RT.	START: 10/20/22	END: 10/20/22	PG 3 OF 3	B-001-0-22

MATERIAL DESCRIPTION AND NOTES	ELEV. 799.2	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
@ 56.2' - 56.9' : Qu = 220 psi (Point Load Test)																		

NOTES: NONE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 25 LB. BENTONITE POWDER; 94 LB. CEMENT; 50 GAL. WATER

PROJECT: MOE-TR2001-00.13	DRILLING FIRM / OPERATOR: CENTRAL STAR / TS	DRILL RIG: DIEDRICH D-50 TRACK	STATION / OFFSET: 10+31, 17' RT.
TYPE: BRIDGE	SAMPLING FIRM / LOGGER: HDR / DCM	HAMMER: AUTOMATIC HAMMER	ALIGNMENT: TR 2001
PID: 117522 SFN: 5630290	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 3/7/22	ELEVATION: 861.6 (MSL) EOB: 54.0 ft.
START: 10/20/22 END: 10/20/22	SAMPLING METHOD: SPT / ST / NQ2	ENERGY RATIO (%): 86.8	LAT / LONG: 39.849173, -81.267472

EXPLORATION ID B-002-0-22

PAGE 1 OF 2

MATERIAL DESCRIPTION AND NOTES	ELEV. 861.6	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
MEDIUM STIFF TO STIFF, BROWN, **SILT AND CLAY**, LITTLE SAND, LITTLE GRAVEL, DAMP 1- Medium Stiff to Stiff Cohesive		1 2	2 2 3	7	67	SS-1	1.50	-	-	-	-	-	-	-	-	33	A-6a (V)	
		2 3 4 5	3 3 4	10	67	SS-2	2.00	15	10	7	45	23	37	26	11	22	A-6a (7)	
	855.6	6	2 2 1	4	67	SS-3	0.25	-	-	-	-	-	-	-	-	27	A-6a (V)	
VERY LOOSE, BROWN, **COARSE AND FINE SAND**, TRACE SILT AND CLAY, WET 2 - Very loose Granular	853.6	7	WOH WOH WOH	0	33	SS-4	-	0	29	65	- 6 -		20	15	5	27	A-3a (0)	
VERY SOFT TO SOFT, BROWN, **SANDY SILT**, LITTLE CLAY, TRACE GRAVEL, WET @ 9.0' - 9.2' : Gray 3 - Very Soft to Soft Cohesive		8 9	WOH WOH WOH	0	78	SS-5	-	1	4	48	27	20	21	17	4	29	A-4a (2)	
	850.6	10 11	2 1 3	6	89	SS-6	-	1	4	50	25	20	22	14	8	27	A-4a (2)	
LOOSE TO MEDIUM DENSE, BROWN TRACE GRAY AND RED-BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND, SILT, AND CLAY**, WET 4 - Loose to Medium Dense Granular		12	2 2 2	6	67	SS-7	-	50	13	6	13	18	38	25	13	22	A-2-6 (0)	
		13 14 15	4 4 5	13	50	SS-8	-	-	-	-	-	-	-	-	-	23	A-2-6 (V)	
	845.1	W 845.6 16																
STIFF, GRAY TO BLUE-GRAY, **SILT AND CLAY**, SOME SAND, LITTLE STONE FRAGMENTS, DAMP @ 17.0' - 17.5' : qu = 2,080 psf 1- Medium Stiff to Stiff Cohesive		17 18			100	ST-9	1.00	20	10	12	29	29	40	25	15	24	A-6a (7)	
		19 20 21 22 23	3 4 4	12	100	SS-10	1.50	-	-	-	-	-	-	-	-	28	A-6a (V)	
	838.1																	
STIFF, GRAY TO BLUE-GRAY, **SILT**, SOME CLAY, LITTLE SAND, DAMP		24 25 26 27 28	2 4 5	13	100	SS-11	1.00	0	4	9	55	32	31	24	7	24	A-4b (8)	
	833.1																	
STIFF, GRAY TO BLUE-GRAY, **CLAY**, SOME SILT, LITTLE SAND, LITTLE GRAVEL, DAMP		29	2 3 4	10	100	SS-12	1.00	12	5	4	25	54	49	28	21	27	A-7-6 (14)	

PID: 117522	SFN:	PROJECT: MOE-TR2001-00.13	STATION / OFFSET: 10+31, 17' RT.	START: 10/20/22	END: 10/20/22	PG 2 OF 2	B-002-0-22

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
STIFF, GRAY TO BLUE-GRAY, **CLAY**, SOME SILT, LITTLE SAND, LITTLE GRAVEL, DAMP *(continued)*	831.6	31 32 33 34 35 36 37 38	2 3 3	9	100	SS-13	1.00	-	-	-	-	-	-	-	-	29	A-7-6 (V)	
HARD, GRAY, **SANDY SILT**, SOME STONE FRAGMENTS, LITTLE CLAY, DAMP (Relic Rock Structure)	823.1	39 40 41 42 43	4 24 47	103	89	SS-14	1.00	30	15	8	34	13	27	18	9	10	A-4a (2)	
6 - Hard Residuum																		
SHALE, GRAY, MODERATELY WEATHERED, VERY WEAK.	818.6 TR		33 50/5"	-	100	SS-15	-	-	-	-	-	-	-	-	-	13	Rock (V)	
SHALE, GRAY, MODERATELY WEATHERED, VERY WEAK, THIN BEDDED, FRIABLE, BEDDING DISCONTINUITIES, FRACTURED, NARROW TO TIGHT APERTURE, SLICKENSIDED, LAMINATED, POOR TO FAIR SURFACE CONDITION; RQD 60%, REC 100%. @ 45.5' - 46.6' : Highly Fractured @ 46.0' - 47.5' : Vertically split approximately 50% shale, 50% sandstone	817.6	44 45 46 47 48	38		100	NQ2-1											CORE	
SANDSTONE, GRAY, SLIGHTLY WEATHERED, WEAK TO SLIGHTLY STRONG, FINE GRAINED, THIN BEDDED, PYRITIC, JOINT AND BEDDING DISCONTINUITIES, MODERATELY FRACTURED, TIGHT TO NARROW APERTURE, SLIGHTLY ROUGH, VERY BLOCKY, FAIR TO GOOD SURFACE CONDITION; RQD 56%, REC 100%. @ 47.5' - 48.5' : Highly Fractured @ 51.1' - 51.8' : Qu = 469 psi (Point Load Test)	815.1	49 50 51 52 53	69		100	NQ2-2											CORE	
	807.6 EOB	54																

NOTES: SAMPLE SS-4 (6.5' - 8.0') : INSUFFICIENT AMOUNT OF FINES FOR HYDROMETER TEST

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 25 LB. BENTONITE POWDER; 94 LB. CEMENT; 50 GAL. WATER

Monroe County Engineer
MOE-TR2001-0.13

Soil Strength Parameter Determination

Computed By = DCM
Checked By = DMV

Layer		Undrained Shear Strength (Su) (psf)				Dry Unit Weight (pcf)		Moist Unit Wt. (pcf)		Adopted Short Term Parameters		Long-Term Strength Values				Adopted Long Term Strength Parameters (Back-Calculated from SlopeW)	
		PPR	N-values		Tested								N_{60} Value	ODOT GB-7 Correlations			
			Sowers	T and P	Values	Correlation	Tested	Correlation	Tested					Cohesion (psf)	phi (deg)		
Layer 1 MEDIUM STIFF TO STIFF COHESIVE	Max	2000	2500	1729	1065	115	106	130	133			Max	13	136	23		
	Min	250	700	532	1040	90	104	110	130	S_u=	1050 psf	Min	4	50	20	c' =	105 psf
	Average	1135	1680	1221	1053	104	105	121	131	Φ =	0 deg	Average	9	105	22	Φ' =	22 deg
	Std Dev	506	627	375	18	10	1	8	2			Std Dev	3	26	1		
										Y_{dry} =	105 pcf					Y_{dry} =	105 pcf
	Avg + Std	1641	2307	1597	1070	114	106	130	133	Y_{moist} =	130 pcf	Avg + Std	12	131	23	Y_{moist} =	130 pcf
	Avg - Std	628	1052	846	1035	94	104	113	129			Avg - Std	6	80	21		
Layer 2 VERY LOOSE GRANULAR	Max	N/A	N/A	N/A		95		115				Max	0	N/A	27		
	Min	N/A	N/A	N/A		95		115		S_u =	0 psf	Min	0	N/A	27	c' =	0 psf
	Average	N/A	N/A	N/A		95		115		Φ =	27 deg	Average	0	N/A	27	Φ' =	27 deg
	Std Dev	N/A	N/A	N/A		N/A		N/A				Std Dev	N/A	N/A	N/A		
										Y_{dry} =	95 pcf					Y_{dry} =	95 pcf
	Avg + Std	N/A	N/A	N/A		N/A		N/A		Y_{moist} =	115 pcf	Avg + Std	N/A	N/A	N/A	Y_{moist} =	115 pcf
	Avg - Std	N/A	N/A	N/A		N/A		N/A				Avg - Std	N/A	N/A	N/A		
Layer 3 VERY SOFT TO SOFT COHESIVE	Max	250	1500	798		95		120				Max	6	75	21		
	Min	250	0	0		85		105		S_u =	400 psf	Min	0	15	15	c' =	20 psf
	Average	250	471	437		91		113		Φ =	0 deg	Average	3	44	19	Φ' =	16 deg
	Std Dev	0	517	304		5		6				Std Dev	2	25	3		
										Y_{dry} =	90 pcf					Y_{dry} =	90 pcf
	Avg + Std	250	989	741		96		119		Y_{moist} =	115 pcf	Avg + Std	6	69	21	Y_{moist} =	115 pcf
	Avg - Std	250	-46	133		87		106				Avg - Std	1	19	16		
Layer 4 LOOSE TO MEDIUM DENSE GRANULAR	Max	N/A	N/A	N/A		125		130				Max	13	N/A	31		
	Min	N/A	N/A	N/A		100		120		S_u =	0 psf	Min	6	N/A	29	c' =	0 psf
	Average	N/A	N/A	N/A		109		125		Φ =	29 deg	Average	9	N/A	29	Φ' =	29 deg
	Std Dev	N/A	N/A	N/A		10		4				Std Dev	3	N/A	1		
										Y_{dry} =	110 pcf					Y_{dry} =	110 pcf
	Avg + Std	N/A	N/A	N/A		119		129		Y_{moist} =	125 pcf	Avg + Std	12	N/A	30	Y_{moist} =	125 pcf
	Avg - Std	N/A	N/A	N/A		99		121				Avg - Std	6	N/A	29		
Layer 5 VERY STIFF COHESIVE	Max	2500	4000	3059	1160	125	102	140	128			Max	23	177	25		
	Min	1000	2800	2128	1160	120	102	135	128	S_u =	1200 psf	Min	16	153	24	c' =	165 psf
	Average	1750	3663	2560	1160	121	102	136	128	Φ =	0 deg	Average	19	164	25	Φ' =	25 deg
	Std Dev	645	579	502		3		3				Std Dev	4	13	1		
										Y_{dry} =	100 pcf					Y_{dry} =	100 pcf
	Avg + Std	2395	4242	3062		124		139		Y_{moist} =	130 pcf	Avg + Std	23	177	25	Y_{moist} =	130 pcf
	Avg - Std	1105	3083	2058		119		134				Avg - Std	15	151	24		
Layer 6 HARD RESIDUUM	Max	1000	4000	4000		130		140				Max	103	250	28		
	Min	1000	4000	4000		130		140		S_u =	4000 psf	Min	103	250	28	c' =	250 psf
	Average	1000	4000	4000		130		140		Φ =	0 deg	Average	103	250	28	Φ' =	28 deg
	Std Dev	N/A	N/A	N/A		N/A		N/A				Std Dev	N/A	N/A	N/A		
										Y_{dry} =	130 pcf					Y_{dry} =	130 pcf
	Avg + Std	N/A	N/A	N/A		N/A		N/A		Y_{moist} =	140 pcf	Avg + Std	N/A	N/A	N/A	Y_{moist} =	140 pcf
	Avg - Std	N/A	N/A	N/A		N/A		N/A				Avg - Std	N/A	N/A	N/A		

Values for Soil Strength Correlation	
Reference	Value
HI PI (Sowers)	0.25
MD PI (Sowers)	0.175
LO PI (Sowers)	0.075
T&P	0.133

Layer 1

	N_{60}	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC		Short-Term Cohesion (psf) N-values PPR	Sowers	T & P	Correlated LT Cohesion (psf) per GB-7	phi (deg)	Midpoint Sample Depth (ft.)	Midpoint Sample Elevation (ft.)	Correlated Dry Unit Wt. (pcf) per GB-7	Correlated Moist Unit Wt. (pcf) per GB-7	Correlated C_c	Assumed Specific Gravity (G_s)	Computed Void Ratio (e)	Strength Testing: Dry Unit Wt (pcf)	Moist Unit Wt (pcf)	Qu/UU Su (psf)	CU Eff. c (psf)	CU Eff. phi (deg)	CU Total c (psf)	CU Total phi (deg)
Max	13	100	2.0	20	10	12	62	54	49	28	21	33	Max	2000	2500	1729	136	23	34.0	860.6	115	130	0.351	2.72	0.886	106	133	1065	N/A	N/A	N/A	N/A
Min	4	44	0.3	0	1	4	25	23	31	20	7	22	Min	250	700	532	50	20	1.0	827.6	90	110	0.189	2.65	0.438	104	130	1040	N/A	N/A	N/A	N/A
Average	9	82	1.1	9	6	7	44	34	39	25	14	27	Average	1135	1680	1221	105	22	14.7	846.8	104	121	0.261	2.70	0.634	105	131	1053	N/A	N/A	N/A	N/A
Std Dev	3	19	0.5	8	4	3	15	11	6	3	6	3	Std Dev	506	627	375	26	1	11.7	11.7	10	8	0.054	0.03	0.170	1	2	18	N/A	N/A	N/A	N/A
Avg + Std	12	101	1.6	17	9	10	59	45	45	27	20	30	Avg + Std	1641	2307	1597	131	23	26.4	858.5	114	130	0.315	2.73	0.804	106	133	1070	N/A	N/A	N/A	N/A
Avg - Std	6	63	0.6	1	2	4	30	24	33	22	9	24	Avg - Std	628	1052	846	80	21	3.0	835.1	94	113	0.207	2.66	0.464	104	129	1035	N/A	N/A	N/A	N/A

Alignment	Surface Elevation	Exploration ID	From		To	Sample ID	N_{60}	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC	ODOT Class.	Soil Type	Layer	Short-Term Cohesion (psf) N-values PPR	Sowers	T & P	Correlated LT Cohesion (psf) per GB-7	phi (deg)	Midpoint Sample Depth (ft.)	Midpoint Sample Elevation (ft.)	Correlated Dry Unit Wt. (pcf) per GB-7	Correlated Moist Unit Wt. (pcf) per GB-7	Correlated C_c	Assumed Specific Gravity (G_s)	Computed Void Ratio (e)	Strength Testing: Dry Unit Wt (pcf)	Moist Unit Wt (pcf)	Qu/UU Su (psf)	CU Eff. c (psf)	CU Eff. phi (deg)	CU Total c (psf)	CU Total phi (deg)
TR 2001	861.3	B-001-0-22	0	-	1.5	SS-1	7	44	1	-	-	-	-	-	-	-	-	29	A-6a	Cohesive	1	1000	1225	931	88	22	1.0	860.3	95	110		2.72	0.787							
TR 2001	861.3	B-001-0-22	2.5	-	4	SS-2	13	100	2	1	1	4	62	32	36	25	11	27	A-6a	Cohesive	1	2000	2275	1729	136	23	3.0	858.3	100	120	0.234	2.72	0.697						
TR 2001	861.3	B-001-0-22	5	-	6.5	SS-3	7	78	1	-	-	-	-	-	-	-	-	26	A-6a	Cohesive	1	1000	1225	931	88	22	6.0	855.3	95	120		2.72	0.787							
TR 2001	861.3	B-001-0-22	21.5	-	23.5	ST-11	ST	75	1	5	3	7	49	36	41	20	21	29	A-7-6	Cohesive	1	1000	N/A	N/A			23.0	838.3			0.279	2.65		104.4	129.7	1065				
TR 2001	861.3	B-001-0-22	23.5	-	25	SS-12	9	67	0.5	-	-	-	-	-	-	-	-	30	A-7-6	Cohesive	1	500	2250	1197	107	22	24.0	837.3	115	130		2.65	0.438							
TR 2001	861.6	B-002-0-22	0	-	1.5	SS-1	7	67	1.5	-	-	-	-	-	-	-	-	33	A-6a	Cohesive	1	1500	1225	931	88	22	1.0	860.6	95	110		2.72	0.787							
TR 2001	861.6	B-002-0-22	2.5	-	4	SS-2	10	67	2	15	10	7	45	23	37	26	11	22	A-6a	Cohesive	1	2000	1750	1330	114	23	3.0	858.6	100	120	0.243	2.72	0.697						
TR 2001	861.6	B-002-0-22	5	-	6.5	SS-3	4	67	0.25	-	-	-	-	-	-	-	-	27	A-6a	Cohesive	1	250	700	532	50	20	6.0	855.6	90	110		2.72	0.886							
TR 2001	861.6	B-002-0-22	16.5	-	18.5	ST-9	ST	100	1	20	10	12	29	29	40	25	15	24	A-6a	Cohesive	1	1000	N/A	N/A			18.0	843.6			0.27	2.72		105.8	132.6	1040				
TR 2001	861.6	B-002-0-22	18.5	-	20	SS-10	12	100	1.5	-	-	-	-	-	-	-	-	28	A-6a	Cohesive	1	1500	2100	1596	129	23	19.0	842.6	110	125		2.72	0.543							
TR 2001	861.6	B-002-0-22	23.5	-	25	SS-11	13	100	1	0	4	9	55	32	31	24	7	24	A-4b	Cohesive	1	1000	975	1729	136	23	24.0	837.6	115	130	0.189	2.72	0.476						
TR 2001	861.6	B-002-0-22	28.5	-	30	SS-12	10	100	1	12	5	4	25	54	49	28	21	27	A-7-6	Cohesive	1	1000	2500	1330	114	23	29.0	832.6	115	130	0.351	2.65	0.438						
TR 2001	861.6	B-002-0-22	33.5	-	35	SS-13	9	100	1	-	-	-	-	-	-	-	-	29	A-7-6	Cohesive	1	1000	2250	1197	107	22	34.0	827.6	115	130		2.65	0.438							

Values for Soil Strength Correlation	
Reference	Value
HI PI (Sowers)	0.25
MD PI (Sowers)	0.175
LO PI (Sowers)	0.075
T&P	0.133

Layer 2

	N_{60}	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC		Short-Term Cohesion (psf) N-values PPR	Sowers	T & P	Correlated LT Cohesion (psf) per GB-7	phi (deg)	Midpoint Sample Depth (ft.)	Midpoint Sample Elevation (ft.)	Correlated Dry Unit Wt. (pcf) per GB-7	Correlated Moist Unit Wt. (pcf) per GB-7	Correlated C_c	Assumed Specific Gravity (G_s)	Computed Void Ratio (e)
Max	0	33	N/A	0	29	65	N/A	N/A	20	15	5	27	Max	N/A	N/A	N/A	N/A	27	7.0	854.6	95	115	0.090	2.65	0.741
Min	0	33	N/A	0	29	65	N/A	N/A	20	15	5	27	Min	N/A	N/A	N/A	N/A	27	7.0	854.6	95	115	0.090	2.65	0.741
Average	0	33	N/A	0	29	65	N/A	N/A	20	15	5	27	Average	N/A	N/A	N/A	N/A	27	7.0	854.6	95	115	0.090	2.65	0.741
Std Dev	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Std Dev	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Avg + Std	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Avg + Std	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Avg - Std	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Avg - Std	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Alignment	Surface Elevation	Exploration ID	From		To	Sample ID	N_{60}	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC	ODOT Class.	Soil Type	Layer	Short-Term Cohesion (psf) N-values PPR	Sowers	T & P	Correlated LT Cohesion (psf) per GB-7	phi (deg)	Midpoint Sample Depth (ft.)	Midpoint Sample Elevation (ft.)	Correlated Dry Unit Wt. (pcf) per GB-7	Correlated Moist Unit Wt. (pcf) per GB-7	Correlated C_c	Assumed Specific Gravity (G_s)	Computed Void Ratio (e)
TR 2001	861.6	B-002-0-22	6.5	-	8	SS-4	0	33	-	0	29	65	-	-	20	15	5	27	A-3a	Granular	2	N/A				27	7.0	854.6	95	115	0.09	2.65	0.741

Values for Soil Strength Correlation	
Reference	Value
HI PI (Sowers)	0.25
MD PI (Sowers)	0.175
LO PI (Sowers)	0.075
T&P	0.133

Layer 3

	N_{60}	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC		Short-Term Cohesion (psf) N-values PPR	Sowers	T & P	Correlated LT Cohesion (psf) per GB-7	phi (deg)	Midpoint Sample Depth (ft.)	Midpoint Sample Elevation (ft.)	Correlated Dry Unit Wt. (pcf) per GB-7	Correlated Moist Unit Wt. (pcf) per GB-7	Correlated C_c	Assumed Specific Gravity (G_s)	Computed Void Ratio (e)
Max	6	100	0.3	4	13	50	57	39	29	20	9	51	Max	250	1500	798	75	21	19.0	854.3	95	120	0.171	2.72	0.997
Min	0	33	0.3	0	0	4	25	17	21	14	4	27	Min	250	0	0	15	15	7.0	842.3	85	105	0.099	2.65	0.741
Average	3	79	0.3	1	4	36	35	23	23	17	6	36	Average	250	471	437	44	19	12.1	849.2	91	113	0.121	2.70	0.848
Std Dev	2	23	0.0	2	5	19	13	9	3	3	2	9	Std Dev	0	517	304	25	3	4.6	4.6	5	6	0.030	0.03	0.113
Avg + Std	6	102	0.3	3	10	55	48	32	27	20	8	45	Avg + Std	250	989	741	69	21	16.7	853.9	96	119	0.151	2.73	0.960
Avg - Std	1	57	0.3	0	-1	17	22	15	20	14	4	27	Avg - Std	250	-46	133	19	16	7.6	844.6	87	106	0.090	2.67	0.735

Alignment	Surface Elevation	Exploration ID	From		To	Sample ID	N_{60}	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC	ODOT Class.	Soil Type	Layer	Short-Term Cohesion (psf) N-values PPR	Sowers	T & P	Correlated LT Cohesion (psf) per GB-7	phi (deg)	Midpoint Sample Depth (ft.)	Midpoint Sample Elevation (ft.)	Correlated Dry Unit Wt. (pcf) per GB-7	Correlated Moist Unit Wt. (pcf) per GB-7	Correlated C_c	Assumed Specific Gravity (G_s)	Computed Void Ratio (e)
TR 2001	861.3	B-001-0-22	6.5	-	8	SS-4	4	100	-	0	1	43	35	21	21	15	6	34	A-4a	Cohesive	3	N/A	300	532	50	20	7.0	854.3	90	110	0.099	2.72	0.886
TR 2001	861.3	B-001-0-22	8	-	9.5	SS-5	1	33	-	4	13	35	31	17	24	19	5	37	A-4a	Cohesive	3	N/A	75	133	15	15	9.0	852.3	85	105	0.126	2.72	0.997
TR 2001	861.3	B-001-0-22	13.5	-	15	SS-8	3	78	0.25	-	-	-	-	-	-	-	-	51	A-7-6	Cohesive	3	250	750	399	38	19	14.0	847.3	95	115		2.65	0.741
TR 2001	861.3	B-001-0-22	16	-	17	SS-9A	6	78	0.25	-	-	-	-	-	-	-	-	46	A-7-6	Cohesive	3	250	1500	798	75	21	17.0	844.3	95	120		2.65	0.741
TR 2001	861.3	B-001-0-22	18.5	-	20	SS-10	3	100	-	0	0	4	57	39	29	20	9	31	A-4b	Cohesive	3	N/A	225	399	38	19	19.0	842.3	95	115	0.171	2.72	0.787
TR 2001	861.6	B-002-0-22	8	-	9.5	SS-5	0	78	-	1	4	48	27	20	21	17	4	29	A-4a	Cohesive	3	N/A	0	0	15	15	9.0	852.6	85	105	0.099	2.72	0.997
TR 2001	861.6	B-002-0-22	9.5	-	11	SS-6	6	89	-	1	4	50	25	20	22	14	8	27	A-4a	Cohesive	3	N/A	450	798	75	21	10.0	851.6	95	120	0.108	2.72	0.787

Values for Soil Strength Correlation	
Reference	Value
HI PI (Sowers)	0.25
MD PI (Sowers)	0.175
LO PI (Sowers)	0.075
T&P	0.133

Layer 4

	N_{60}	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC		Short-Term Cohesion (psf) N-values PPR	Sowers	T & P	Correlated LT Cohesion (psf) per GB-7	phi (deg)	Midpoint Sample Depth (ft.)	Midpoint Sample Elevation (ft.)	Correlated Dry Unit Wt. (pcf) per GB-7	Correlated Moist Unit Wt. (pcf) per GB-7	Correlated C_c	Assumed Specific Gravity (G_s)	Computed Void Ratio (e)
Max	13	89	2.0	50	19	45	15	18	38	25	13	40	Max	N/A	N/A	N/A	N/A	31	17.0	851.3	125	130	0.252	2.71	0.654
Min	6	50	2.0	16	13	6	11	8	16	16	4	22	Min	N/A	N/A	N/A	N/A	29	10.0	844.3	100	120	0.054	2.65	0.323
Average	9	71	2.0	29	16	30	13	12	25	20	9	26	Average	N/A	N/A	N/A	N/A	29	13.0	848.4	109	125	0.138	2.67	0.540
Std Dev	3	17	0.0	19	3	21	2	5	11	5	6	8	Std Dev	N/A	N/A	N/A	N/A	1	2.6	2.7	10	4	0.102	0.03	0.129
Avg + Std	12	88	2.0	47	19	51	15	17	37	24	15	34	Avg + Std	N/A	N/A	N/A	N/A	30	15.6	851.1	119	129	0.240	2.71	0.669
Avg - Std	6	54	2.0	10	13	9	11	7	14	15	2	19	Avg - Std	N/A	N/A	N/A	N/A	29	10.4	845.8	99	121	0.036	2.64	0.411

Alignment	Surface Elevation	Exploration ID	From		To	Sample ID	N_{60}	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC	ODOT Class.	Soil Type	Layer	Short-Term Cohesion (psf) N-values PPR	Sowers	T & P	Correlated LT Cohesion (psf) per GB-7	phi (deg)	Midpoint Sample Depth (ft.)	Midpoint Sample Elevation (ft.)	Correlated Dry Unit Wt. (pcf) per GB-7	Correlated Moist Unit Wt. (pcf) per GB-7	Correlated C_c	Assumed Specific Gravity (G_s)	Computed Void Ratio (e)
TR 2001	861.3	B-001-0-22	9.5	-	11	SS-6	7	78	-	16	19	39	15	11	22	18	4	24	A-3a	Granular	4	N/A				29	10.0	851.3	100	120	0.108	2.65	0.654
TR 2001	861.3	B-001-0-22	11	-	12.5	SS-7	9	89	-	20	16	45	11	8	16	16	NP	23	A-3a	Granular	4	N/A				30	12.0	849.3	105	125	0.054	2.65	0.575
TR 2001	861.3	B-001-0-22	17	-	17.5	SS-9B	-	-	-	-	-	-	-	-	-	-	-	40	A-3	Granular	4	N/A					17.0	844.3	125			2.65	0.323
TR 2001	861.6	B-002-0-22	11	-	12.5	SS-7	6	67	2	50	13	6	13	18	38	25	13	22	A-2-6	Granular	4	N/A				29	12.0	849.6	105	125	0.252	2.71	0.611
TR 2001	861.6	B-002-0-22	13.5	-	15	SS-8	13	50	2	-	-	-	-	-	-	-	-	23	A-2-6	Granular	4	N/A				31	14.0	847.6	110	130		2.71	0.537

Values for Soil Strength Correlation	
Reference	Value
HI PI (Sowers)	0.25
MD PI (Sowers)	0.175
LO PI (Sowers)	0.075
T&P	0.133

Layer 5

	N_{60}	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC		Short-Term Cohesion (psf) N-values PPR	Sowers	T & P	Correlated LT Cohesion (psf) per GB-7	phi (deg)	Midpoint Sample Depth (ft.)	Midpoint Sample Elevation (ft.)	Correlated Dry Unit Wt. (pcf) per GB-7	Correlated Moist Unit Wt. (pcf) per GB-7	Correlated C_c	Assumed Specific Gravity (G_s)	Computed Void Ratio (e)	Strength Testing: Dry Unit Wt (pcf)	Moist Unit Wt (pcf)	Qu/UU Su (psf)	CU Eff. c (psf)	CU Eff. phi (deg)	CU Total c (psf)	CU Total phi (deg)
Max	23	100	2.5	34	8	6	59	34	41	26	15	34	Max	2500	4000	3059	177	25	44.0	832.3	125	140	0.279	2.72	0.414	102	128	1160	N/A	N/A	N/A	N/A
Min	16	22	1.0	3	1	3	23	29	37	22	15	19	Min	1000	2800	2128	153	24	29.0	817.3	120	135	0.243	2.65	0.323	102	128	1160	N/A	N/A	N/A	N/A
Average	19	72	1.8	19	5	5	41	32	39	24	15	24	Average	1750	3663	2560	164	25	36.8	824.5	121	136	0.261	2.68	0.382	102	128	1160	N/A	N/A	N/A	N/A
Std Dev	4	33	0.6	22	5	2	25	4	3	3	0	6	Std Dev	645	579	502	13	1	5.6	5.6	3	3	0.025	0.04	0.043	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Avg + Std	23	104	2.4	40	9	7	66	35	42	27	15	30	Avg + Std	2395	4242	3062	177	25	42.4	830.1	124	139	0.286	2.72	0.426	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Avg - Std	15	39	1.1	-3	0	2	16	28	36	21	15	18	Avg - Std	1105	3083	2058	151	24	31.2	818.9	119	134	0.236	2.64	0.339	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Alignment	Surface Elevation	Exploration ID	From		To	Sample ID	N_{60}	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC	ODOT Class.	Soil Type	Layer	Short-Term Cohesion (psf) N-values PPR	Sowers	T & P	Correlated LT Cohesion (psf) per GB-7	phi (deg)	Midpoint Sample Depth (ft.)	Midpoint Sample Elevation (ft.)	Correlated Dry Unit Wt. (pcf) per GB-7	Correlated Moist Unit Wt. (pcf) per GB-7	Correlated C_c	Assumed Specific Gravity (G_s)	Computed Void Ratio (e)	Strength Testing: Dry Unit Wt (pcf)	Moist Unit Wt (pcf)	Qu/UU Su (psf)	CU Eff. c (psf)	CU Eff. phi (deg)	CU Total c (psf)	CU Total phi (deg)
TR 2001	861.3	B-001-0-22	28.5	-	30	SS-13	16	22	1	-	-	-	-	-	-	-	-	21	A-6a	Cohesive	5	1000	2800	2128	153	24	29.0	832.3	120	135		2.72	0.414						
TR 2001	861.3	B-001-0-22	33.5	-	35	SS-14	22	78	2.5	34	8	6	23	29	37	22	15	19	A-6a	Cohesive	5	2500	3850	2926	173	25	34.0	827.3	120	135	0.243	2.72	0.414						
TR 2001	861.3	B-001-0-22	36.5	-	38.5	ST-15	ST	58	1.5	3	1	3	59	34	41	26	15	21	A-7-6	Cohesive	5	1500	N/A	N/A			38.0	823.3			0.279	2.65		101.5	127.7	1160			
TR 2001	861.3	B-001-0-22	38.5	-	40	SS-16	23	100	2	-	-	-	-	-	-	-	-	34	A-7-6	Cohesive	5	2000	4000	3059	177	25	39.0	822.3	120	135		2.65	0.378						
TR 2001	861.3	B-001-0-22	43.5	-	45	SS-17	16	100	-	-	-	-	-	-	-	-	-	25	A-7-6	Cohesive	5	N/A	4000	2128	153	24	44.0	817.3	125	140		2.65	0.323						

Values for Soil Strength Correlation	
Reference	Value
HI PI (Sowers)	0.25
MD PI (Sowers)	0.175
LO PI (Sowers)	0.075
T&P	0.133

Layer 6

	N_{60}	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC		Short-Term Cohesion (psf) N-values PPR	Sowers	T & P	Correlated LT Cohesion (psf) per GB-7	phi (deg)	Midpoint Sample Depth (ft.)	Midpoint Sample Elevation (ft.)	Correlated Dry Unit Wt. (pcf) per GB-7	Correlated Moist Unit Wt. (pcf) per GB-7	Correlated C_c	Assumed Specific Gravity (G_s)	Computed Void Ratio (e)
Max	103	89	1.0	30	15	8	34	13	27	18	9	10	Max	1000	4000	4000	250	28	39.0	822.6	130	140	0.153	2.72	0.306
Min	103	89	1.0	30	15	8	34	13	27	18	9	10	Min	1000	4000	4000	250	28	39.0	822.6	130	140	0.153	2.72	0.306
Average	103	89	1.0	30	15	8	34	13	27	18	9	10	Average	1000	4000	4000	250	28	39.0	822.6	130	140	0.153	2.72	0.306
Std Dev	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Std Dev	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Avg + Std	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Avg + Std	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Avg - Std	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Avg - Std	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Alignment	Surface Elevation	Exploration ID	From		To	Sample ID	N_{60}	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC	ODOT Class.	Soil Type	Layer	Short-Term Cohesion (psf) N-values PPR	Sowers	T & P	Correlated LT Cohesion (psf) per GB-7	phi (deg)	Midpoint Sample Depth (ft.)	Midpoint Sample Elevation (ft.)	Correlated Dry Unit Wt. (pcf) per GB-7	Correlated Moist Unit Wt. (pcf) per GB-7	Correlated C_c	Assumed Specific Gravity (G_s)	Computed Void Ratio (e)
TR 2001	861.6	B-002-0-22	38.5	-	40	SS-14	103	89	1	30	15	8	34	13	27	18	9	10	A-4a	Cohesive	6	1000	4000	4000	250	28	39.0	822.6	130	140	0.153	2.72	0.306

Monroe County Engineer
MOE-TR2001-0.13

Rock Strength Parameter Determination

Computed By = DCM
Checked By = DMV

BEDROCK TESTING

Project	Exploration ID	Sample Depth (ft)	Sample ID	Rock Type	Color	Moist Unit Weight (pcf)	Compressive Strength (psi)	Compressive Strength (MPa)	Er Modulus (psi)	Er Modulus (MPa)	GSI Range	GSI USE	Em (Hoek & Brown) Modulus (GPa)	Em (Hoek & Brown) Modulus (psi)	Lesser of Er vs Em (psi)
MOE-TR2001-0.13	B-001-0-22	51.1	NQ2-2	Sandstone	Gray	-	469	3.2	NA	-	30-40	35	0.8	109983	109983
				Sandstone	Maximum	0.0	469		NA = Not Available				Sandstone	Maximum	109983
					Minimum	0.0	469							Minimum	109983
					Average	-	469							Average	109983
					Std Dev	-	-							Std Dev	-
					Recommended Value	140	500							Recommended Value	110000

BEDROCK QUALITY

Project	Exploration ID	Rock Type	Depth Range (ft.) From	Depth Range (ft.) To	Thickness (ft)	Layer RQD (%)	Weighted RQD*(Length / Total Length)
MOE-TR2001-0.13	B-001-0-22	Sandstone	49	53	4	0	0.0
MOE-TR2001-0.13	B-002-0-22	Sandstone	46.5	54	7.5	56	36.5
				Sandstone	11.5	RQD SUM	37
				Maximum	7.5	56	
				Minimum	4	0	
				Average	5.8	28.0	
				Recommended Value			37

Project	Exploration ID	Sample Depth (ft)	Sample ID	Rock Type	Color	Moist Unit Weight (pcf)	Compressive Strength (psi)	Compressive Strength (MPa)	Er Modulus (psi)	Er Modulus (MPa)	GSI Range	GSI USE	Em (Hoek & Brown) Modulus (GPa)	Em (Hoek & Brown) Modulus (psi)	Lesser of Er vs Em (psi)
								0.0		0			0.0	0	0
								0.0		0			0.0	0	0
					Maximum	0.0	0		NA = Not Available				Sandstone	Maximum	0
					Minimum	0.0	0							Minimum	0
					Average	-	-							Average	0
					Std Dev	-	-							Std Dev	0
					Recommended Value									Recommended Value	

Project	Exploration ID	Rock Type	Depth Range (ft.) From	Depth Range (ft.) To	Thickness (ft)	Layer RQD (%)	Weighted RQD*(Length / Total Length)
MOE-TR2001-0.13	B-001-0-22	Shale	53	55.5	2.5	60	30.0
MOE-TR2001-0.13	B-002-0-22	Shale	44	46.5	2.5	60	30.0
				Shale	5	RQD SUM	60
				Maximum	2.5	60	
				Minimum	2.5	60	
				Average	2.5	60.0	
				Recommended Value			60

Project	Exploration ID	Sample Depth (ft)	Sample ID	Rock Type	Color	Moist Unit Weight (pcf)	Compressive Strength (psi)	Compressive Strength (MPa)	Er Modulus (psi)	Er Modulus (MPa)	GSI Range	GSI USE	Em (Hoek & Brown) Modulus (GPa)	Em (Hoek & Brown) Modulus (psi)	Lesser of Er vs Em (psi)
MOE-TR2001-0.13	B-001-0-22	56.2	NQ2-1	Claystone	Gray	-	220	1.5	NA	-	20-30	25	0.3	42360	42360
				Claystone	Maximum	0.0	220		NA = Not Available				Sandstone	Maximum	42360
					Minimum	0.0	220							Minimum	42360
					Average	-	220							Average	42360
					Std Dev	-	-							Std Dev	-
					Recommended Value	140	200							Recommended Value	42300

Project	Exploration ID	Rock Type	Depth Range (ft.) From	Depth Range (ft.) To	Thickness (ft)	Layer RQD (%)	Weighted RQD*(Length / Total Length)
MOE-TR2001-0.13	B-001-0-22	Claystone	55.5	59	3.5	77	77.0
				Claystone	3.5	RQD SUM	77
				Maximum	3.5	77	
				Minimum	3.5	77	
				Average	3.5	77.0	
				Recommended Value			77

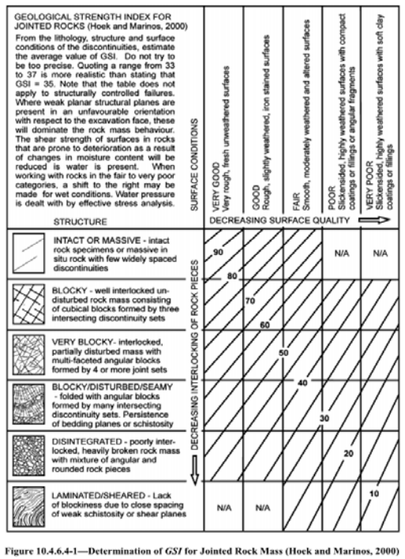


Figure 10.4.6.4-1—Determination of *GSI* for Jointed Rock Mass (Hock and Marinos, 2000)

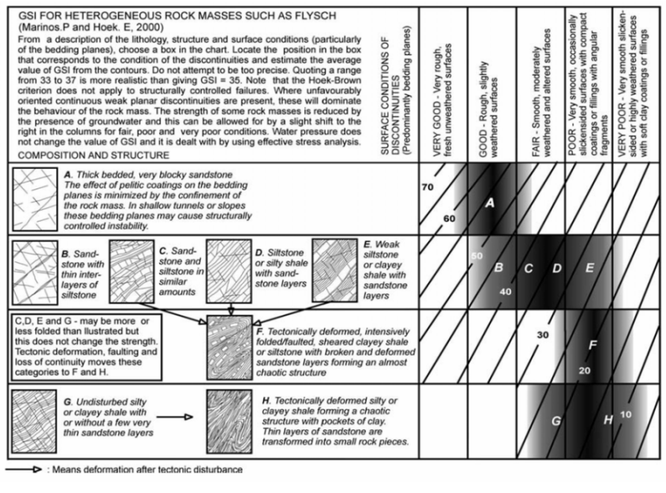


Figure 10.4.6.4-2—Determination of *GSI* for Tectonically Deformed Heterogeneous Rock Masses (Marinos and Hoek 2000)

Table 10.4.6.5-1—Estimation of E_m Based on GSI

Expression	Notes/Remarks	Reference
$E_m\left(GPa\right)=\sqrt{\frac{q_u}{100}}10^{\frac{GSI-10}{40}}$ for $q_u \le 100$ MPa $E_m\left(GPa\right)=10^{\frac{GSI-10}{40}}$ for $q_u \le 100$ MPa	Accounts for rocks with $q_u < 100$ MPa; notes q_u in MPa	Hoek and Brown (1997); Hoek et al. (2002)
$E_m=\frac{E_R}{100}e^{GSI/21.7}$	Reduction factor on intact modulus, based on *GSI*	Yang (2006)
Notes: E_r = modulus of intact rock, E_m = equivalent rock mass modulus, *GSI* = geological strength index, q_u = uniaxial compressive strength, and 1 MPa = 2.09 ksf.		

LPILE Parameters

Project: MOE-TR2001-0.13 **Calculated By:** DCM **Date:** 11/26/2022
Client: ODOT **Checked By:** DMV **Date:** 12/2/2022
Task: **Generalized LPILE Parameters**

Soil Lateral Design Profile

Soil Type	Elevation Top (ft)	Elevation Bottom (ft)	Cohesion (psf)	Phi (deg)	Unit Wt (pcf) Total	Unit Wt (pcf) Effective[1]	ε50	k (pci)
1- Medium Stiff to Stiff Cohesive	861.5	855.5	1050	0	130	130	0.007	N/A
3 - Very Soft to Soft Cohesive	855.5	850.5	400	0	115	115	0.02	N/A
4 - Loose to Medium Dense Granular	850.5	847	0	29	115	52.6	N/A	20
3 - Very Soft to Soft Cohesive	847	840	400	0	115	52.6	0.02	N/A
1 - Medium Stiff to Stiff Cohesive	840	823	1050	0	130	67.6	0.007	N/A
5 - Very Stiff Cohesive	823	813	1200	0	130	67.6	0.007	N/A
Bedrock	813							

1. Effective unit weights to be applied below groundwater table (assumed at El 850.5 in recommended design profile)

ε50 tables from LPile Technical Manual

Table 3-2 Representative Values of ε_{50} for Soft to Stiff Clays

Consistency of Clay	ε_{50}
Soft	0.020
Medium	0.010
Stiff	0.005

Table 3-4 Representative Values of ε_{50} for Stiff to Hard Clays

Average Undrained Shear Strength	ε_{50}
50-100 kPa (1,000-2,000 psf)	0.007
100-200 kPa (2,000-4,000 psf)	0.005
200-400 kPa (4,000-6,000 psf)	0.004

k tables from LPile Technical Manual

Table 3-6 Representative Values of k for Fine Sand Below the Water Table for Static and Cyclic Loading

Recommended k	Relative Density		
	Loose	Medium	Dense
MN/m^3 (pci)	5.4 (20.0)	16.3 (60.0)	34 (125.0)

Table 3-7 Representative Values of k for Fine Sand Above Water Table for Static and Cyclic Loading

Recommended k	Relative Density		
	Loose	Medium	Dense
MN/m^3 (pci)	6.8 (25.0)	24.4 (90.0)	61.0 (225.0)

Scour Analysis Parameters

Project:	MOE-TR2001-0.13	**Calculated By:**	DCM	**Date:**	11/26/2022
Client:	ODOT	**Checked By:**	DMV	**Date:**	12/2/2022
Task:	**Scour Analysis**				

Reference
ODOT Geotechnical Design Manual (GDM)

Critical Shear Stress (Tc)

Cohesive Soils (GDM 1302.1)

$Tc = a\,(w/f)^{-2.0}\,(PI/100)^{1.3}\,(qu)^{0.4}$

Tc (Pa) = Critical Shear Stress
w (dim) = Water Content
F (dim) = Fraction of Fine Particles (< 75 um)
PI (dim) = Plasticity Index (use min PI = 4)
qu (psf) = Unconfined Compressiive Test
c (psf) = 1/2 qu cohesion
a = 0.01 unit conversion
0.01 = U.S. Customary units
0.1 = S.I.

Granular Soils (GDM1302.2)

Tc (Pa) = D50 (mm)
Tc (psf) = Critical Shear Stress (Pa)
D50 mean particle grain size (mm), > or = 0.2 mm

Reference
Location and Design Manual - Volume 2 : Drainage Design (LDv2)

Erosion Category (EC)

Cohesive Soils (LDv2 C1008.10.4)

$EC = 4.5 - (3 / 1.07^{PI})$ where $1.5 \leq EC < 4.5$
PI = Plasticity index (dim)

Granular Soils (LDv2 C1008.10.4)

$EC = 1.2\,[1.83333+\log(D50)]$ where $1 \leq EC \leq 6$

Boring No.	Sample	Elevation (ft) Top		Bottom	D50 (mm)	Moisture w (dim)	Fines (< 75um) F (dim)	Plasticiy PI (dim)	Unconfined Compressive Strength Qu (psf)[1]	Qu (Pa)	Unit conversion a (dim)	Tc (Pa)	Tc (psf)	EC (dim)
B-001-0-22	SS-4	854.82	-	853.32	0.0304	34	56	6	Granular	Granular	0.1	0.030	0.001	0.38
	SS-5	853.32	-	851.82	0.0808	37	48	5	Granular	Granular	0.1	0.081	0.002	0.89
	SS-6	851.82	-	850.32	0.2168	24	26	4	800	38304.3	0.1	0.122	0.003	2.21
	SS-7	850.32	-	848.82	0.2442	23	19	4	800	38304.3	0.1	0.071	0.001	2.21
B-001-0-22	SS-4	855.15	-	853.65	0.2416	27	6	5	800	38304.3	0.1	0.007	0.000	2.36
	SS-5	853.65	-	852.15	0.0849	29	47	4	800	38304.3	0.1	0.273	0.006	2.21
	SS-6	852.15	-	850.65	0.0895	27	45	8	Granular	Granular	0.1	0.090	0.002	0.94
	SS-7	850.65	-	849.15	2.1089	22	31	13	Granular	Granular	0.1	2.109	0.044	2.59

1. See soil parameter determination sheet summary
2. 1 Pa = 0.0208854 psf
3. dim = dimensionless
4. 4 = minimum 4 PI assumed

Project:	MOE-TR2001-0.13	**Calculated By:**	DCM	**Date:**	11/26/2022
Client:	ODOT	**Checked By:**	DMV	**Date:**	12/2/2022
Task:	**Scour Analysis**				

then it must be considered cohesive for determination of critical shear stress, regardless of the tested plasticity. For soils tested as non-plastic (NP) or with PI < 4, assume PI = 4 for use in the cohesive soil critical shear stress equation.

1302.1 Cohesive Soils
Determine scour critical shear stress of a cohesive soil through publication FHWA-HRT-15-033, Figure 54, "Equation. Predictive relation for critical shear stress,"

$$\tau_c = \alpha \left(\frac{w}{F}\right)^{-2.0} \left(\frac{PI}{100}\right)^{1.3} q_u^{0.4}$$

Where:

τ_c = Critical shear stress, psf (Pa)
w = Water content, dimensionless
F = Fraction of fine particles (< 75µm) by mass, dimensionless
PI = Plasticity index, dimensionless
q_u = Unconfined compressive strength, psf (Pa)
α = Unit conversion constant, 0.01 in U.S. customary units and 0.1 in S.I.

For example, if w = 11, F = 60, PI = 7, and q_u = 6500 psf = 311,200 Pa, then:

$$\tau_c = 0.1 \times \left(\frac{11}{60}\right)^{-2.0} \times \left(\frac{7}{100}\right)^{1.3} \times (311{,}200)^{0.4} = 14.77\ Pa = 0.308\ psf.$$

1302.2 Granular Soils
Determine scour critical shear stress of a granular soil as a function of the mean particle grain size using the equation in HEC 18 Figure 4.6, "Critical shear stress vs. particle grain size (Briaud et al. 2011)."

$$\tau_c\ (Pa) = D_{50}\ (mm)$$

Where:

τ_c = Critical shear stress (Pa)
D_{50} = mean particle grain size (mm), ≥ 0.2 mm

1302.3 Bedrock
Determine scour critical shear stress of a non-scour resistant bedrock by rearranging HEC 18 Equations 7.38 for 'Critical Stream Power' and 7.39 'Approach Flow Stream Power' to derive the critical shear stress for non-scour resistant bedrock as follows:

$$\tau_c = \rho \left(\frac{1000\ K^{0.75}}{7.853\ \rho}\right)^{2/3}$$

dimensionless, where 1 ≤ EC ≤ 6

Where:

EC = Erosion Category, dimensionless

For cohesive soils:

$EC = 4.5 - \frac{3}{1.07^{PI}}$, where 1.5 ≤ EC ≤ 4.5,
PI= Plasticity Index, dimensionless

For granular soils:

$EC = 1.2\ [1.83333 + \log(D_{50})]$, where 1 ≤ EC ≤ 6,
D_{50} = mean particle grain size (mm), ≥ 0.1 mm

To estimate the erosion rate of a bedrock material, treat it as a cohesionless soil. Divide the spacing between horizontal discontinuities by a value of 2.5 to develop an equivalent D_{50} value.

Consider scour depth in the design of the substructures and the location of the bottom of footings and minimum tip elevations for piles and drilled shafts.

All major rehabilitation work requires a scour evaluation.

Provide hand calculations and/or software output along with a narrative of findings and recommended scour countermeasures in the STS. Ignore scour countermeasures in the prediction of scour depths. Include a statement regarding the susceptibility of the stream banks and flow line to scour, and the susceptibility of the piers and abutments to scour.

soil with D_{50} = 23 mm, with a bed shear stress of 53.18 Pa:

$EC = 1.2\ (1.83333 + \log(23)) = 3.83$

$\alpha = 13/3.83^{0.309} - 7.1363 = 1.45$

$\beta = 7.377777 - [(1-(3.83-4.5)^2/3.57^2)10.377777^2]^{0.5} = -2.82$

Erosion Rate, $\dot{z} = 10^{(1.45 \log(53.18) - 2.82)} = 10^{-0.3177} =$ 0.48 mm/hr = 0.019 in/hr

For example; if a material has a spacing between horizontal discontinuities of 9 inches, divide by 2.5 = 3.6 inches = 91 mm; use 91 mm as the equivalent D_{50} value.

For existing bridges, the scour evaluation may consist of determining what the bridge is founded on. For example, with bridge rehabilitation, noting that the bridge is founded on spread footings on scour resistant bedrock would constitute the scour evaluation.