Final Structure Foundation Exploration Report

BEL-TR428-0.30

Belmont County, OH
May 29, 2024

Prepared for:
Belmont County Engineer's Office
101 W. Main St.
St. Clairsville, OH 43950

By:

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

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EXECUTIVE SUMMARY

This report summarizes the results of the structure foundation exploration program performed in support of the replacement of Bridge No. BEL T0428 00300 (SFN 0733385) carrying Coleman Road, Township Road 428 (TR 428), over Wheeling Creek in Wheeling Township, Belmont County, Ohio.

The report includes the geotechnical information obtained from the borings and laboratory testing performed under this study. The exploration findings, 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 an overlying layer of cohesive soil underlain by granular soils extending to bedrock. The encountered bedrock consists of siltstone. Further discussion on the encountered subsurface conditions is in Section 4.

Although the depth to bedrock is relatively shallow (approximately 9.5 to 15 feet below the existing ground surface at the boring locations), the use of shallow foundations may be prohibitive based on the size of the excavation footprints required and the additional cost for temporary shoring and site dewatering. As such, it is anticipated that drilled shafts or prebored piles socketed into competent bedrock will be utilized to support the new bridge structure. (The selected design consultant will determine the appropriate foundation type.) As such, parameters are provided for the design of both foundation types 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. BEL T0428 00300 (SFN 0733385) carrying Coleman Road, Township Road 428 (TR 428) over Wheeling Creek. The BEL-TR428-0.30 project is located in Wheeling Township of Belmont County, Ohio, approximately 3.3 miles north of St. Clairsville and roughly 2.3 miles south of the Belmont and Harrison County line as shown on the Site Vicinity Map (Exhibit No. 1) in Appendix A. The work includes the complete removal of the existing 70-foot bridge structure and its replacement with either a single-span steel beam or adjacent prestressed concrete box beams with composite reinforced concrete deck on new reinforced concrete abutments. (An abbreviated structure type study will be performed by others to determine the most appropriate superstructure type.) The proposed bridge structure is to include a minimum of 25 feet approach pavement beyond the proposed bridge limits (per side), and to be built on the existing alignment and profile with profile adjustments as needed. The anticipated project length is 200 feet.

This geotechnical study was authorized by the Ohio Department of Transportation (ODOT) on January 9, 2024, under the VAR-STW Geotechnical Engineering Services CEAO 2023-2 contract. The geotechnical services performed under this task order were conducted 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 January 2024. The scope of work relative to this exploration report included:

- A literature search and field 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 and rock 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 development of the plans and design of the bridge structure by the selected design consultant.

2 GEOLOGY AND OBSERVATIONS

2.1 Project Setting

This project is located within the north-central region of Belmont County, Ohio in a rural setting surrounded by wooded hillsides and agricultural parcels, as well as a residential property to the northwest. The project site itself is located within the floodplain of the meandering Wheeling Creek. Elevations along the project site range from about El. 888 outside of the bridge limits to approximately El. 883 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 Little Switzerland Plateau of the Allegheny Plateau region of the Appalachian Plateaus province (Exhibit No. 2 in Appendix A). The Little Switzerland Plateau region is characterized by highly dissected, high-relief plateaus (generally 888 feet at the project area). Elevations in this region generally range from 540 to 1,400 feet above sea level. Soils in the Little Switzerland Plateau generally consist of red and brown silty-clay loam colluvium over Pennsylvanian-aged Upper Conemaugh Group through Permian-age Dunkard Group cyclic sequences of red and gray shales, siltstones, sandstones, limestones, and coal. According to the Quaternary Geology of Ohio map from the Ohio Department of Natural Resources (ODNR) Division of Geological Survey (Exhibit No. 3 in Appendix A), surficial soils at the site primarily consist of Cenozoic aged colluvium (Cc) derived from the local bedrock and includes scattered areas of residuum, weathered material, landslides, and bedrock outcrops.

The north-central region of Belmont County and the project site itself is drained by Wheeling Creek. Wheeling Creek enters the Ohio River approximately 10 miles southwest of the project site, near the town of Bridgeport, Ohio.

2.2.1 Project Soils

The USDA Soil Survey of Belmont County indicates that the prevalent surficial soil types within the project limits are the silt loams of the Chargin silt loam (Cg) and Lowell silt loam (LeF) units as shown in Exhibit No. 4a.

Soils of the Chargin silt loam (0 to 3 percent slopes) consist of 85 percent Chargin and similar soils, and 15 percent minor components. The occasionally flooded Chargin soils generally consist of loam, silt loam, and fine sandy loam resulting from fine-loamy alluvium that was derived from sedimentary rock. These well drained soils are typically located in flood plains with a moderately high to high water capacity.

Soils of the Lowell silt loam (40 to 70 percent slopes) consist of 85 percent Lowell and similar soils, and 15 percent minor components. The Lowell soils generally consist of silty clay, silt loam, silty clay loam, gravelly silty clay loam, and unweathered bedrock derived from residuum. These well drained soils are typically located on hills with a very low to moderately 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 moderate risk of corrosion to concrete, a low to high risk of corrosion to steel, and have a pH level of 6.0.

2.2.2 Bedrock Geology

As shown on Exhibit No. 5 (Bedrock Geology Map), the geology mapped within the project area is the Upper Pennsylvanian-age bedrock of the Conemaugh Group, with the overlying Pennsylvanian-age Monongahela Group and Permian-Pennsylvanian-age Dunkard Group located on hillsides surrounding the site. Bedrock of the Conemaugh Group (IPc) generally consists of shale, siltstone, mudstone, sandstone, non-marine limestone, and coal. The coal beds within the Conemaugh Group are generally thin, but may be very locally thick, suitable as economic coal beds, and contain plant fossils. The Monongahela Group (IPm) generally consists of shale, siltstone, sandstone, mudstone, limestone, and coal. The Dunkard Group (PIPd) generally consists of shale, siltstone, mudstone, sandstone, limestone, and coal.

Based on review of the ODNR Mine Maps as shown in Exhibit No. 6 (Mines of Ohio Map), historical deep and surficial coal mining was heavily performed in northern Belmont County and into neighboring Harrison and Jefferson Counties. While no mining was mapped within the immediate project area located along the bottom of the creek valley, significant mining was performed along and within the hillsides surrounding the project area. Based on information provided by the ODNR, these mines were located as close as roughly 500 to 1500 feet of the project site and are primarily associated with the Pittsburgh No. 8 coal seam of the overlying Monongahela Group. The coal elevations as presented in the available mine documentation varied from 890 to 970 feet. Additionally, one active surface mine (Meigs Creek No. 9 coal bed) was noted in the area approximately 1.1 miles north of the project site.

3 EXPLORATION

3.1 Site Reconnaissance

A visual reconnaissance of the project site and surrounding area was performed by an HDR geotechnical engineer on December 13, 2023, to mark the preliminary boring locations, and by this same engineer during the drilling activities on January 29, 2024. The project site is located within a rural wooded valley, with a pasture and residential property located to the west of the creek. The existing bridge conveys two-way traffic along TR 428 over Wheeling Creek. This bridge is comprised of a four-span, corrugated steel arch and concrete structure with a 9-inch thick concrete slab deck. Each corrugated steel arch is supported by concrete footings shared with the adjacent arch, except at the rear and forward ends of the structure. The two corrugated steel arches at the ends of the bridge measure approximately 12 feet in width at the waterline between the concrete foundation supports. The center two corrugated steel arches measure approximately 23 feet across at the waterline between the concrete foundations. The depth of the north flowing creek could not be determined during the site reconnaissance and drilling activities, but was in excess of 1 to 2 feet.

The guardrail along the north and south sides of the bridge consists of approximately 2-foot high, formed concrete railings, with the exception of the middle third of the south railing which has been replaced with steel guardrail. In addition, a section at the westernmost end of the north guardrail is damaged to the point where a 2-foot by 2-foot section of concrete railing remains attached only by the reinforcing bars.

3.2 Subsurface Exploration

Two borings were drilled as part of the geotechnical exploration program to assess the subsurface conditions within the BEL-TR428-0.30 project limits. The locations of the test borings are shown on the Boring Location Plan (Exhibit No. 7) in Appendix A. The test borings were located and marked in the field during the initial visual reconnaissance. These as-drilled locations are reflected on the boring plan, the boring logs in Appendix B, and Table 3-1.

Table 3-1. Summary of Bridge Structure Borings

Boring Number	Boring Type[1]	Alignment	Station[2]	Offset[2]	Surface (El., ft)[3]	Top of Bedrock (El., ft.)[3]	Bottom of Borehole (El., ft.)[3]
B-001-0-24	E1	TR 428	3+77	12 ft RT	~887.0	~877.5	~858.0
B-002-0-24	E1	TR 428	2+59	12 ft LT	~885.0	~870.0	~853.8

1. ODOT Boring Designations: Bridge Structure (E1)
2. Based on adopted station and offsets as shown on the boring location plan. Survey and alignments were not available at the time this report was written.
3. Approximated based on existing topographic maps and LiDAR obtained from OGRIPS.

The borings were drilled by Central Star Drilling on January 29, 2024, under the supervision of an HDR geotechnical engineer, with a CME 55 track rig (SN 393565). The rig was calibrated on March 7, 2022, and has an energy ratio of 83.4%. All borings were drilled in general accordance with the *Specifications for Geotechnical Explorations* (ODOT revised January 2024) utilizing 3.25-inch internal diameter hollow stem augers to advance the borings to the top of bedrock. The sampling of the soils and weathered bedrock was accomplished in accordance with the *Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils*, ASTM D 1586. 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.

Sampling of the underlying siltstone 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 samples selected for laboratory testing to confirm the field classification and to assess the various engineering properties of the earth materials. Soil index testing performed by HDR included 15 natural moisture content tests (per ASTM D 2216), 9 Atterberg limit determinations (per ASTM D 4318), and 9 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, 4 unconfined compression tests (ASTM D 7012 – Method C) and 1 Slake Durability (ASTM D 4644) 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 two test borings consists of cohesive silts and clays overlying granular soils extending to bedrock. Siltstone was encountered beneath the soil overburden at a relatively shallow depth of approximately 9.5 to 15 feet below the existing ground surface at the boring locations.

The overlying layer of cohesive soils was encountered from the ground surface to an approximate depth of 8.5 feet in both boring locations. These soils generally consisted of soft Sandy Silt (A-4a) and medium stiff to stiff Silt and Clay (A-6a). The underlying granular soils consisted of medium dense to dense Gravel with Sand (A-1-b) and loose to dense Gravel with Sand and Silt (A-2-4).

Siltstone bedrock was encountered in both borings at depths of about 9.5 to 15 feet (El. 877.5 to 870.0) below existing grade. The uppermost 1.2 to 4.5 feet was weathered and described as very weak. The siltstone extended to the termination depth in each boring. The siltstone bedrock was described as strong with recorded Stratum Rock Quality Designations (SRQDs) from 39% to 59%. Zones of sandstone laminations were also noted in both borings.

Groundwater was encountered in both borings at depths ranging from 9.5 to 10 feet (El. 877.5 to 875.0) below existing grade during drilling. Water levels upon completion were not obtained as water was introduced into the boreholes during the rock coring process. Delayed water readings were also not obtained as the borings were sealed immediately upon completion given their locations in proximity to the TR 428 travel lanes. Groundwater levels at the site are expected to vary depending upon precipitation, the water elevation within Wheeling Creek, and other seasonal variations.

5 ANALYSES AND RECOMMENDATIONS

5.1 Bridge Foundations

The project involves the replacement of an existing bridge structure carrying TR 428 over Wheeling Creek. Providing a recommended foundation type for the anticipated replacement structure (single-span steel beam or prestressed concrete box beams with composite reinforced concrete deck on new reinforced concrete abutments) is outside the scope of this study. However, the use of shallow foundations at the site may be prohibitive based on the expected size and depth of the excavation footprints and the additional cost for temporary shoring and the required site dewatering given the proximity of the creek as well as saturated granular layers encountered above the top of rock. As such, it is anticipated that deeper foundations (prebored piles or drilled shafts) will be utilized for foundation support.

5.2 Determination of Soil and Rock Parameters

Soil parameters were developed primarily from published correlations with SPT data and plasticity indices, recorded pocket penetrometer readings, and our engineering experience and judgement. A summary of the recommended soil strength parameters and design profile elevations are provided in Table 5-1. Details of the parameter development are located in Appendix D.

Table 5-1: Recommended Soil Strength Parameters

Recommended Design Profile[1]		Material	Unit Wt.[2]		Undrained Shear Strength		Drained Shear Strength	
Top Elevation (ft)	Bottom Elevation (ft)		γ_T (pcf)	γ_{eff} (pcf)	S_u (psf)	ϕ' (°)	c' (psf)	ϕ' (°)
887.0	879.0	Cohesive Soil	120	57.6	1200	0	105	22
879.0	876.5	Cohesive Soil	110	47.6	350	0	50	20
876.5	870.0	Granular Soil	135	72.6	0	35	0	35
870.0	868.8	Shale Bedrock (Modeled as Cohesive Soil)	140	77.6	4000	0	250	28

1. Layer breaks based on Boring B-002-0-24.
2. Effective unit weights to be used below groundwater (assumed at El. 875.0 in the recommended design soil profile).

The recommended design parameters for design of the bridge foundations in the underlying siltstone bedrock are provided in the sections and tables below. The details of the parameter development for both soil and rock are located in Appendix D.

Table 5-2: Recommended Bedrock Design Parameters (Drilled Shaft Foundations)

Rock Type	Unconfined Compressive Strength Qu (psi)	Slake Durability Index SDI (%)	Rock Quality Designation RQD (%)	Unit Weight (pcf)	Rock Mass Rating, RMR (dim)	Unfactored Unit Side Resistance (psf)[1]	Unfactored Unit Tip Resistance (psf)[1]
Siltstone	9,000	96	50	160	38	4,360	22,500

1. Calculated based on AASHTO Equation 10.8.3.5.4c-1 (per ODOT GDM) for Drilled Shafts in rock.

Given the relatively shallow depth to bedrock at the project site, the use of pile foundations will require the placement of the piles into prebored holes extending a minimum 5 feet into bedrock, as discussed in the ODOT BDM 305.3.5.7. In addition to this minimum 5 feet, the ODOT BDM and GDM requires a minimum socket length of 10 feet for bedrock with a strength less than 1500 psi. While the compressive strength of the siltstone is greater than 1500 psi, the augers were able to penetrate through the upper 4.5 feet of weak siltstone and the rock sampled with SPT methods at Boring B-001-0-24. Therefore, it is recommended that the prebored holes extend a minimum of 10 feet below the top of the siltstone. For piles placed in such prebored holes and not subjected to driving stresses or potential driving damages, a structural resistance factor of 0.95 may be applied in determining the factored axial resistance for the respective pile section per the ODOT BDM and GDM. The factored axial resistance for selected HP Sections are listed in Table 5-3 below.

Table 5-3: Factored Structural Resistance for Selected Piles

Pile Section	Cross-Sectional Area of Steel Section (in^2)	Factored Axial Reisitance[1] (kips)
HP 10x42	12.4	585
HP 12x53	15.5	735
HP 14x73	21.4	1,015

1. Based on 50 ksi steel and a structural resistance factor, φ_c = 0.95, for piles placed in prebored holes in accordance with ODOT BDM 305.3.5.7 and ODOT GDM 1305.1.

As the piles will be installed within prebored holes and socketed in bedrock, consideration could be given to neglect the contribution of the soil overburden for lateral resistance given the limited thickness of soil anticipated to remain below the bottom of the new bridge abutments and the top of bedrock. However, if needed, Table 5-4 provides a summary of the recommended design parameters for lateral analyses performed using the LPILE software program by Ensoft. Any piles spaced closer than five (5) pile widths must also consider group effects.

Table 5-4. Recommended Lateral Design Parameters[1]

Recommended Design Profile[2]		Material	Unit Wt.		E50[1]	K (pci)[3]	
Top Elevation (ft)	Bottom Elevation (ft)		γ_T (pcf)	γ_{Eff} (pcf)		Above Groundwater	Below Groundwater
887.0	879.0	Cohesive Soil	120	-	0.007	-	-
879.0	876.5	Cohesive Soil	110	-	0.02	-	-
876.5	870.0	Granular Soil	135	72.6	-	225	125
870.0	868.7	Siltstone Bedrock (Modeled as Cohesive Soil)	140	77.6	0.005	-	-

1. Any piles spaced closer than five (5) pile widths must also consider group effects.
2. Layer breaks based on Boring B-002-0-24.
3. ε50 and k values per LPile Technical Manual.

5.3 Scour Evaluation Parameters

Continuous sampling of the soil overburden was conducted starting at the approximate elevation of the ground surface at the face of the existing abutments as measured in both borings to assist with the determination of the scour analysis parameters per Section 1302 of the GDM. However, the 6 feet of continuous sampling per SGE Section 303.7.1 was not obtained in Boring B-001-0-24 as sampler refusal was encountered along the soil-bedrock interface prior to penetrating the full 6 feet. In addition, review of LiDAR data available on the Ohio Geographically Referenced Information Program's website after the subsurface exploration program was complete, indicated a streambed elevation of approximately 880 feet. As such, the split-spoon sample collected in the 2.5-foot interval immediately above the continuous zone was also included. Table 5-5 and Table 5-6 below summarize the sampling depths and respective scour analysis parameters to be utilized in determining the predicted scour depth for the encountered soils and bedrock, respectively. The determination of the scour analysis parameters are provided in Appendix D.

Table 5-5: Soil Scour Analysis Parameters

Boring	Sample	Elevation (ft)	D50 Value (mm)	Critical Shear Stress, Tc (psf)	D50, equivalent (mm)[1]	Erosion Category, EC (dim)
B-001-0-24	SS-3	881.0 – 879.5	0.019	0.099	4.729	3.26
	SS-4	878.5 – 877.0	0.284	0.006	N/A	1.54
B-002-0-24	SS-3	879.0 – 877.5	0.061	0.006	0.276	2.36
	SS-4	876.5 – 875.0	4.774	0.100	N/A	3.01
	SS-5	875.0 – 873.5	2.298	0.048	N/A	2.63
	SS-6	873.5 – 872.0	5.240	0.109	N/A	3.06
	SS-7	872.0 – 870.5	3.912	0.082	N/A	2.91

1. Not applicable for granular materials (GDM Section 1302.1)

Table 5-6: Rock Scour Analysis Parameters

Boring	Material	Elevation (ft)	Critical Shear Stress, Tc (psf)	D50, equivalent (mm)	Erosion Category, EC (dim)
B-001-0-24	Augered Siltstone	877.0 – 873.0	0.370	17.701	3.06
	Cored Siltstone	873.0 – 858.0	144.253	6906.866	4.12
B-002-0-24	Augered Siltstone	870.0 – 868.8	0.370	17.701	3.06
	Cored Siltstone	868.8 – 853.8	117.782	5639.433	3.97

5.4 Additional 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 the removal of the existing bridge structure and possible relocation of existing utilities.

5.4.2 Settlement

- Modifications to the vertical roadway alignment within the project area are expected to be minor and as such, minimal settlement is anticipated to occur. In addition, any settlement of the bridge structure itself would be limited as the bridge foundations are anticipated to bear within siltstone bedrock as encountered below the stream bed. However, additional analyses to estimate the magnitude of any drag forces acting on the foundations as outlined in Section 305.3.2.2 of the ODOT BDM using the neutral plane method may need to be conducted if the roadway profile is raised.

6 LIMITATIONS

This report documents the findings and conclusions of HDR Engineering, Inc., for the geotechnical aspects related to the planning and design of the BEL-TR428-0.30 project in Belmont County, Ohio. The report has been prepared for the use of the Belmont County Engineer’s Office 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 variations 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 January 2024); "*Specifications for Geotechnical Explorations.*"

State of Ohio Department of Transportation (Updated January 2024); "*Geotechnical Design Manual.*"

State of Ohio Department of Transportation (Updated January 2024); "*Bridge Design Manual.*"

State of Ohio Department of Transportation (Updated January 2024); "*Location and Design Manual, Volume 2 – Drainage Design.*"

United States Department of Agriculture: Natural Resources Conservation Service (2024); "Web Soil Survey". *http://websoilsurvey.nrcs.usda.gov/app/*

Ohio Department of Natural Resources, Division of Geologic Survey (2024); "Ohio Geology Interactive Map". *https://ohiodnr.gov/business-and-industry/services-to-business-industry/gismapping-services/ohio-geology-interactive-map*

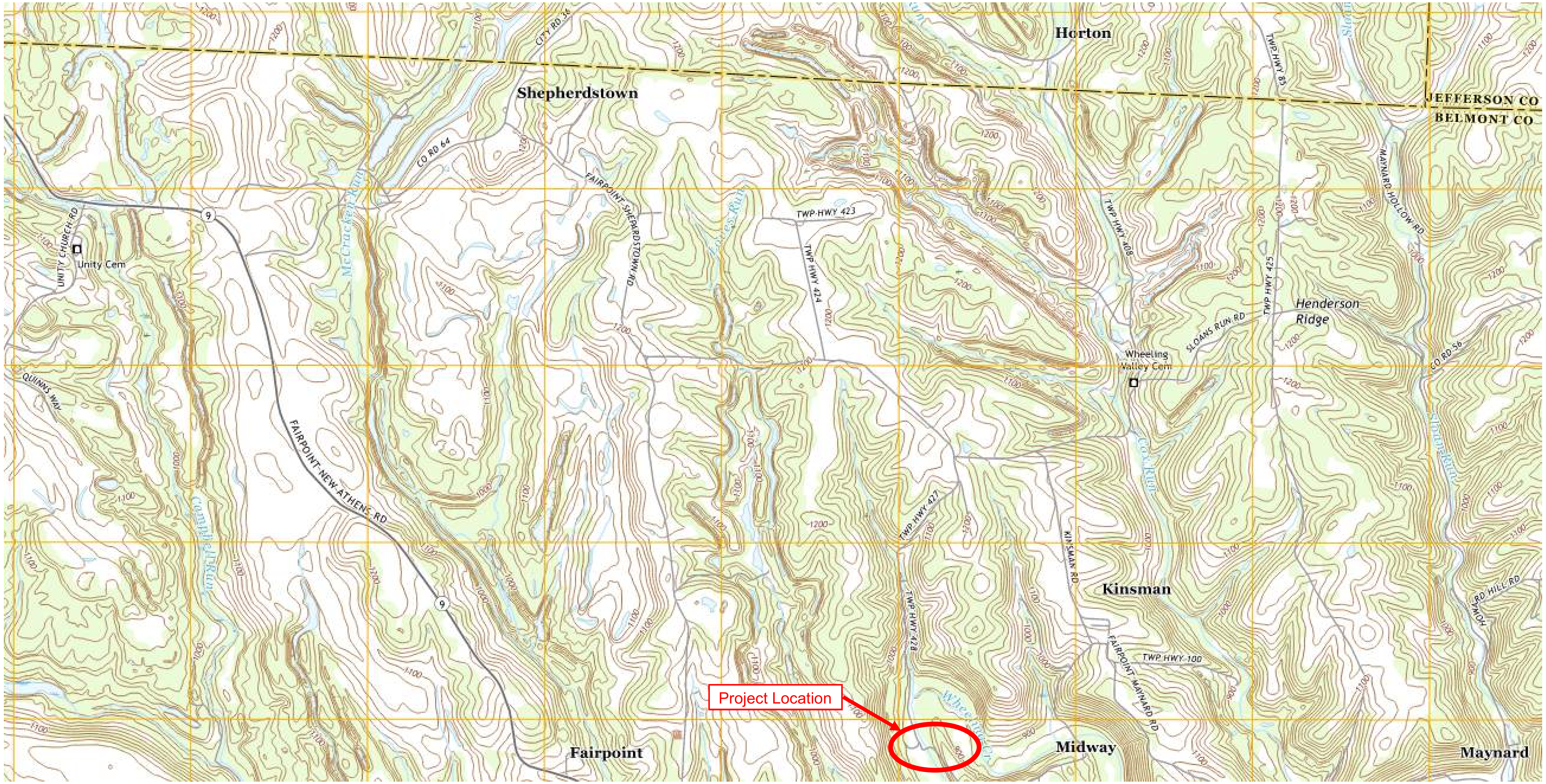
Ohio Department of Natural Resources, Division of Geologic Survey and Division of Mineral Resources (2024); "Mines of Ohio*". https://gis.ohiodnr.gov/MapViewer/?config=OhioMines#*

Ohio Department of Natural Resources, Division of Geologic Survey, (1998) "Physiographic Regions of Ohio*".*

Appendix A. Exhibits

Calculated: MM
Checked: AKB

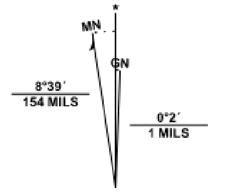
Exhibit No. 1 : Site Vicinity and Topographic Map



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 17T

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.

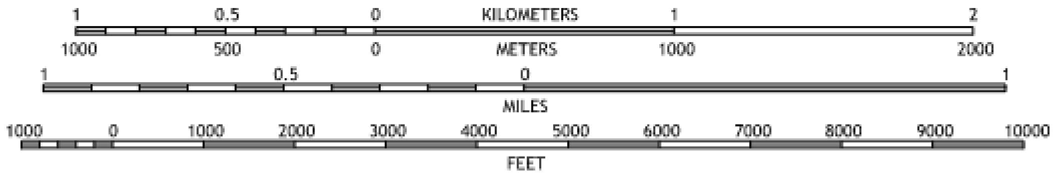
Imagery..NAIP, July 2015 - October 2015
Roads... U.S. Census Bureau, 2016
Names...GNIS, 1979 - 2019
Hydrography...............................National Hydrography Dataset, 1899 - 2019
Contours...National Elevation Dataset, 2010
Boundaries..............Multiple sources; see metadata file 2017 - 2018
Public Land Survey System...BLM, 2017
Wetlands.................FWS National Wetlands Inventory 2004 - 2007



UTM GRID AND 2019 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

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

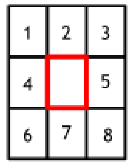
SCALE 1:24 000



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



ADJOINING QUADRANGLES

1 Jewett
2 Cadiz
3 Smithfield
4 Flushing
5 Dillonvale
6 Bethesda
7 Saint Clairsville
8 Lansing

ROAD CLASSIFICATION

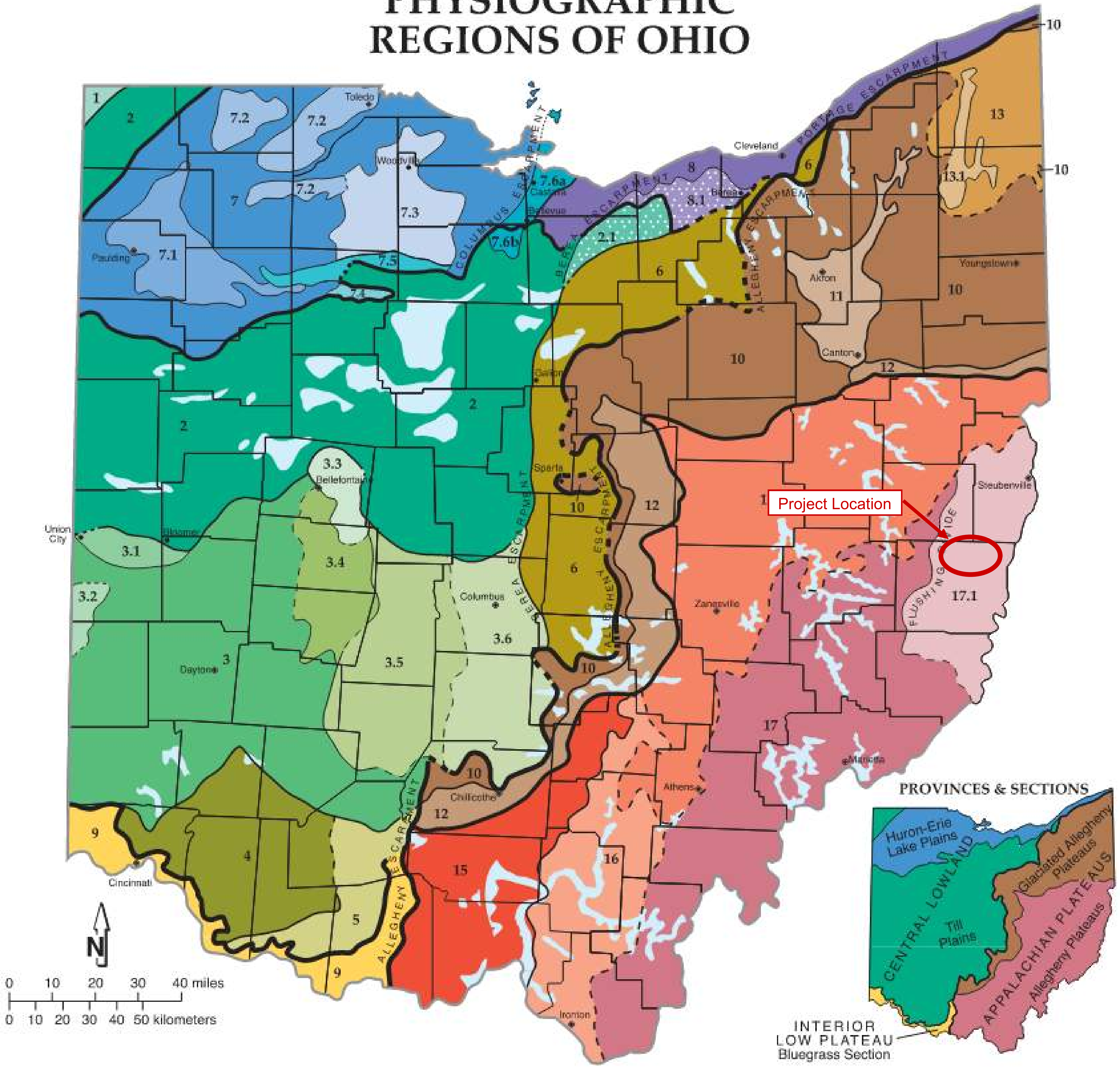
Expressway
Secondary Hwy
Ramp
Local Connector
Local Road
4WD
Interstate Route
US Route
State Route

HARRISVILLE, OH
2019

Project: BEL-TR428-0.30
PID: 119483

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: MM

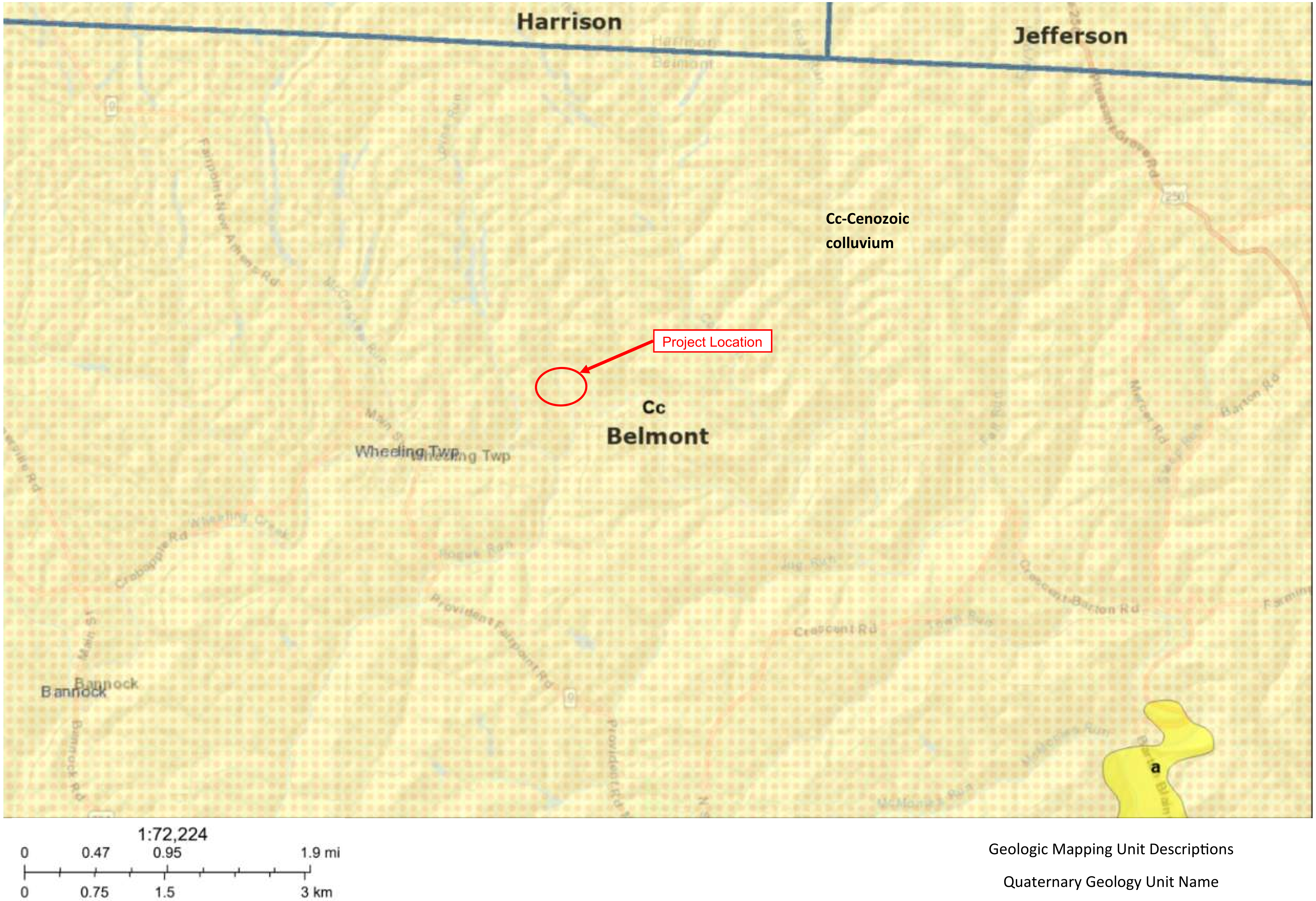
Checked: AKB

Exhibit No. 2 : Physiographic Regions of Ohio

Project: BEL-TR428-0.30

PID: 119483

Exhibit No. 3 : Surficial Geology



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

Geologic Mapping Unit Descriptions

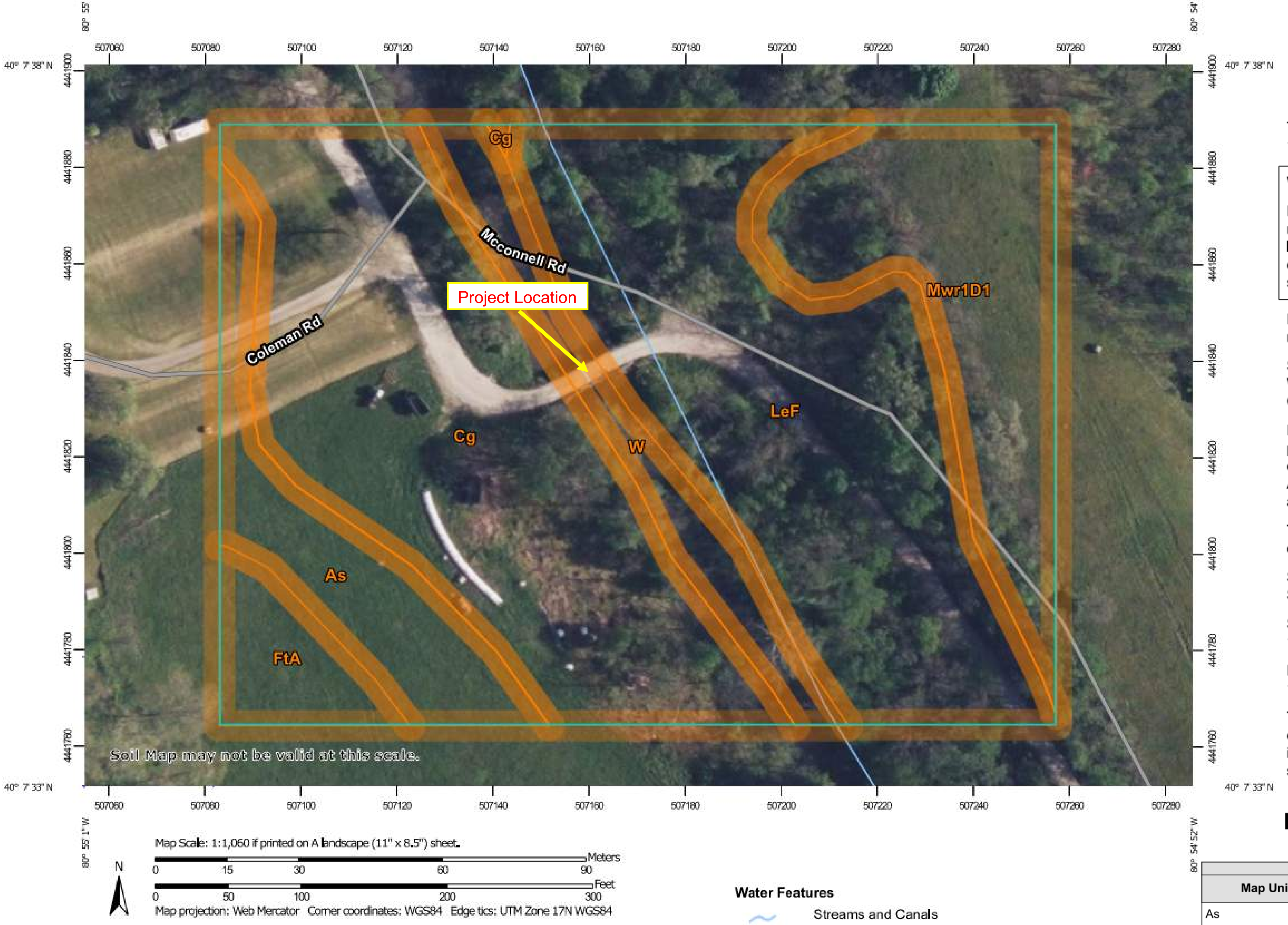
Quaternary Geology Unit Name

a	Alluvium and alluvial terraces, deposited in present and former floodplains; ranges from silty clay in areas of fine-grained deposits to coarse sand, gravel, or cobbles in areas of shallow bedrock
Cc	Colluvium derived from local bedrock in unglaciated areas; includes scattered areas of residuum, weathered material, landslides, and bedrock outcrop

Calculated: MM
Checked: AKB

Project: BEL-TR428-0.30
PID: 119483

Soil Map—Belmont County, Ohio



Map Scale: 1:1,060 if printed on A landscape (11" x 8.5") sheet.

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 17N WGS84

Source: USDA Natural Resources Conservation Services
https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

Area of Interest (AOI)

☐	Area of Interest (AOI)

Soils

☐	Soil Map Unit Polygons
〰	Soil Map Unit Lines
■	Soil Map Unit Points

Water Features

〰	Streams and Canals

Transportation

+++	Rails
〰	Interstate Highways
〰	US Routes
〰	Major Roads
〰	Local Roads

Background

▨	Aerial Photography

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: Belmont County, Ohio
Survey Area Data: Version 21, Aug 31, 2023

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

Date(s) aerial images were photographed: May 19, 2021—Sep 19, 2021

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.

Map Unit Legend

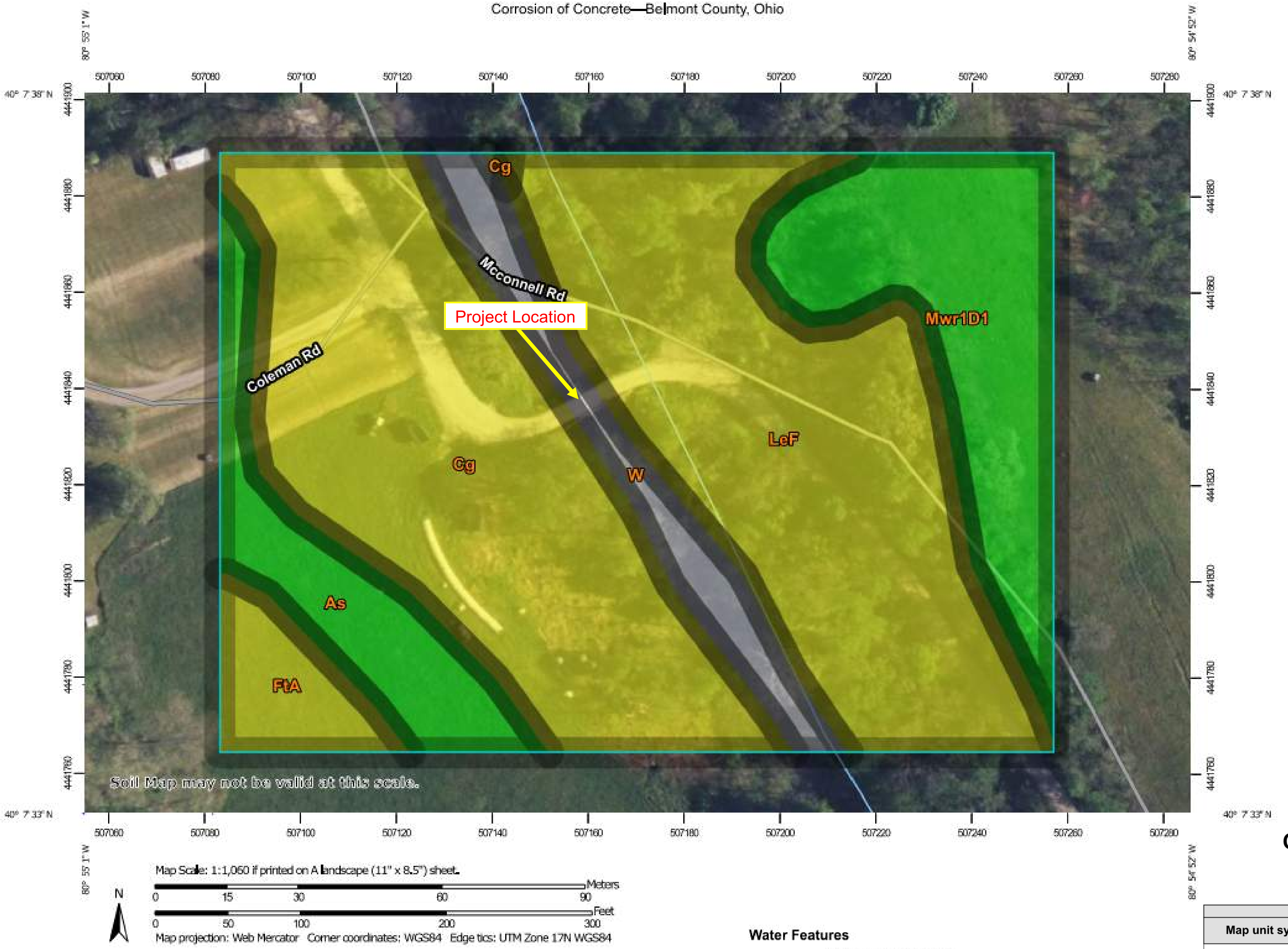
Map Unit Symbol	Map Unit Name	Acres in AOI
As	Ashton silt loam, occasionally flooded	0.5
Cg	Chagrin silt loam, 0 to 3 percent slopes, occasionally flooded	1.7
FtA	Fitchville silt loam, 0 to 3 percent slopes	0.2
LeF	Lowell silt loam, 40 to 70 percent slopes	1.7
Mwr1D1	Morristown silt loam, 8 to 25 percent slopes, reclaimed	0.8
W	Water	0.4
Totals for Area of Interest		**5.4**

Calculated: MM
Checked: AKB

Exhibit No. 4a : Soil Survey Map
Soil Types

Project: BEL-TR428-0.30
PID: 119483

Corrosion of Concrete—Belmont County, Ohio



Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

Source: USDA Natural Resources Conservation Services
https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

Area of Interest (AOI)
⬜ Area of Interest (AOI)

Soils

Soil Rating Polygons
🟥 High
🟨 Moderate
🟩 Low
⬜ Not rated or not available

Water Features
～ Streams and Canals

Transportation
┼┼┼ Rails
～ Interstate Highways
～ US Routes
～ Major Roads
～ Local Roads

Background
🟩 Aerial Photography

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)

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

Soil Survey Area: Belmont County, Ohio
Survey Area Data: Version 21, Aug 31, 2023

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

Date(s) aerial images were photographed: May 19, 2021—Sep 19, 2021

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.

Corrosion of Concrete

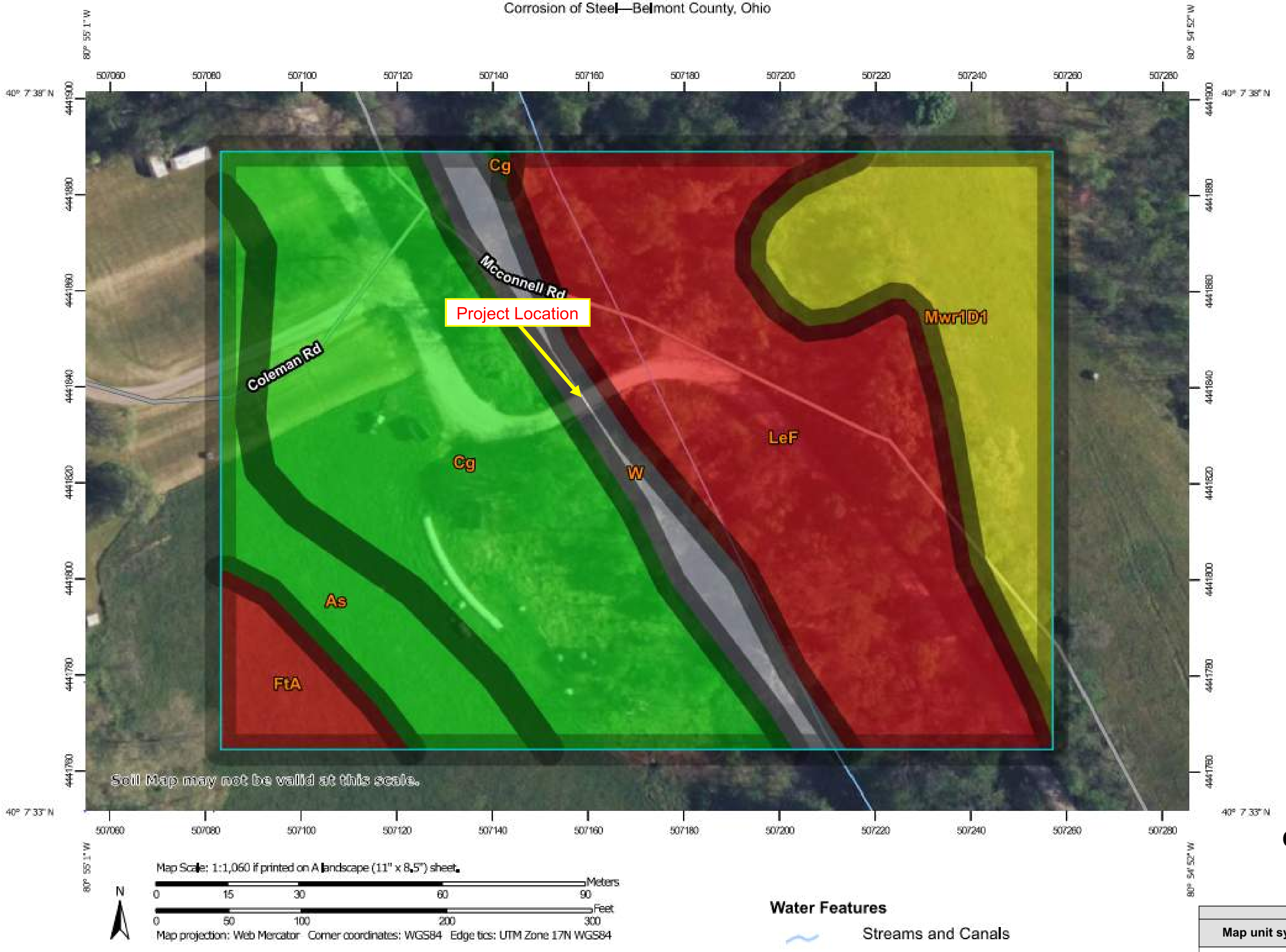
Map unit symbol	Map unit name	Rating	Acres in AOI
As	Ashton silt loam, occasionally flooded	Low	0.5
Cg	Chagrin silt loam, 0 to 3 percent slopes, occasionally flooded	Moderate	1.7
FtA	Fitchville silt loam, 0 to 3 percent slopes	Moderate	0.2
LeF	Lowell silt loam, 40 to 70 percent slopes	Moderate	1.7
Mwr1D1	Morristown silt loam, 8 to 25 percent slopes, reclaimed	Low	0.8
W	Water		0.4
Totals for Area of Interest			**5.4**

Calculated: MM
Checked: AKB

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

Project: BEL-TR428-0.30
PID: 119483

Corrosion of Steel—Belmont County, Ohio



Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

Source: USDA Natural Resources Conservation Services
https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

Area of Interest (AOI)

- ⬜ Area of Interest (AOI)

Soils

Soil Rating Polygons

- 🟥 High
- 🟨 Moderate
- 🟩 Low
- ⬜ Not rated or not available

Water Features

- 〰 Streams and Canals

Transportation

- ┿┿ Rails
- 〰 Interstate Highways
- 〰 US Routes
- 〰 Major Roads
- 〰 Local Roads

Background

- ▨ Aerial Photography

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: Belmont County, Ohio
Survey Area Data: Version 21, Aug 31, 2023

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

Date(s) aerial images were photographed: May 19, 2021—Sep 19, 2021

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.

Corrosion of Steel

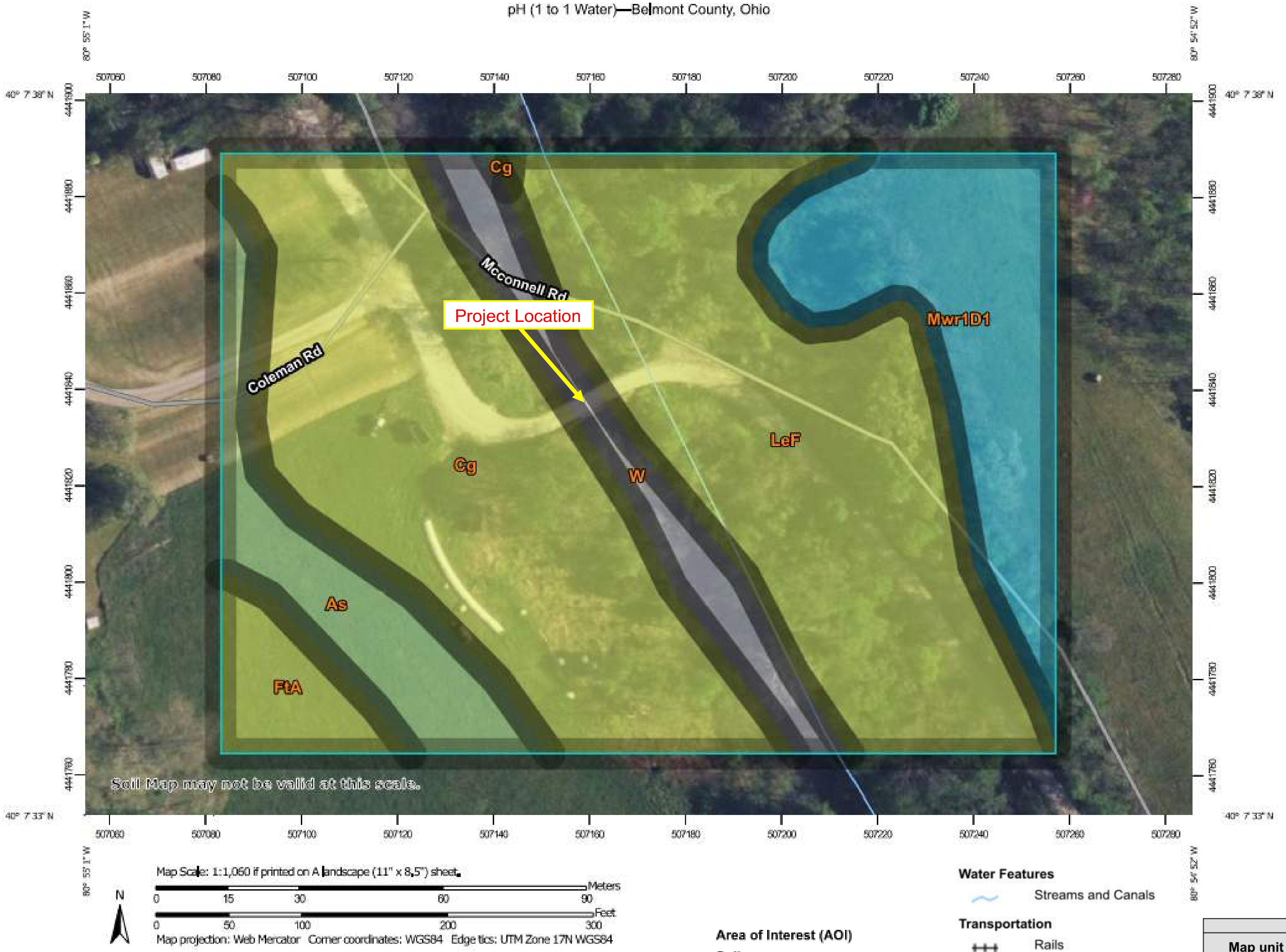
Map unit symbol	Map unit name	Rating	Acres in AOI
As	Ashton silt loam, occasionally flooded	Low	0.5
Cg	Chagrin silt loam, 0 to 3 percent slopes, occasionally flooded	Low	1.7
FtA	Fitchville silt loam, 0 to 3 percent slopes	High	0.2
LeF	Lowell silt loam, 40 to 70 percent slopes	High	1.7
Mwr1D1	Morristown silt loam, 8 to 25 percent slopes, reclaimed	Moderate	0.8
W	Water		0.4
Totals for Area of Interest			**5.4**

Calculated: MM
Checked: AKB

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

Project: BEL-TR428-0.30
PID: 119483

pH (1 to 1 Water)—Belmont County, Ohio



Map Scale: 1:1,060 if printed on A landscape (11" x 8.5") sheet.

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 17N WGS84

Area of Interest (AOI)

Soils

⬜ Soil Survey Areas

Soil Rating Polygons

- 🟥 Ultra acid (ph < 3.5)
- 🟧 Extremely acid (pH 3.5 - 4.4)
- 🟧 Very strongly acid (pH 4.5 - 5.0)
- 🟨 Strongly acid (pH 5.1 - 5.5)
- 🟨 Moderately acid (pH 5.6 - 6.0)
- 🟩 Slightly acid (pH 6.1 - 6.5)
- 🟩 Neutral (pH 6.6 - 7.3)
- 🟦 Slightly alkaline (pH 7.4 - 7.8)
- 🟦 Moderately alkaline (pH 7.9 - 8.4)
- 🟪 Strongly alkaline (pH 8.5 - 9.0)
- 🟪 Very strongly alkaline (pH > 9.0)
- ⬜ Not rated or not available

Water Features

〰 Streams and Canals

Transportation

- +++ Rails
- 〰 Interstate Highways
- 〰 US Routes
- 〰 Major Roads
- 〰 Local Roads

Water Features

〰 Streams and Canals

Transportation

- +++ Rails
- 〰 Interstate Highways
- 〰 US Routes
- 〰 Major Roads
- 〰 Local Roads

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: Belmont County, Ohio
Survey Area Data: Version 21, Aug 31, 2023

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

Date(s) aerial images were photographed: May 19, 2021—Sep 19, 2021

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.

pH (1 to 1 Water)

Map unit symbol	Map unit name	Rating	Acres in AOI
As	Ashton silt loam, occasionally flooded	6.5	0.5
Cg	Chagrin silt loam, 0 to 3 percent slopes, occasionally flooded	6.0	1.7
FtA	Fitchville silt loam, 0 to 3 percent slopes	5.9	0.2
LeF	Lowell silt loam, 40 to 70 percent slopes	6.0	1.7
Mwr1D1	Morristown silt loam, 8 to 25 percent slopes, reclaimed	7.6	0.8
W	Water		0.4
Totals for Area of Interest			**5.4**

Rating Options

Aggregation Method: Dominant Component
Component Percent Cutoff: *None Specified*
Tie-break Rule: Higher
Interpret Nulls as Zero: No
Layer Options (Horizon Aggregation Method): All Layers (Weighted Average)

Source: USDA Natural Resources Conservation Services
https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

Calculated: MM
Checked: AKB

Exhibit No. 4d : Soil Survey Map
pH Levels

Project: BEL-TR428-0.30
PID: 119483

Exhibit No. 5 : Bedrock Geology Map

Calculated: MM
Checked: AKB

Project: BEL-TR428-0.30
PID: 119483

Geologic Unit

🟧 PIPd - Dunkard Group (Permian-Pennsylvanian)

🟩 IPm - Monongahela Group

🟨 IPc - Conemaugh Group

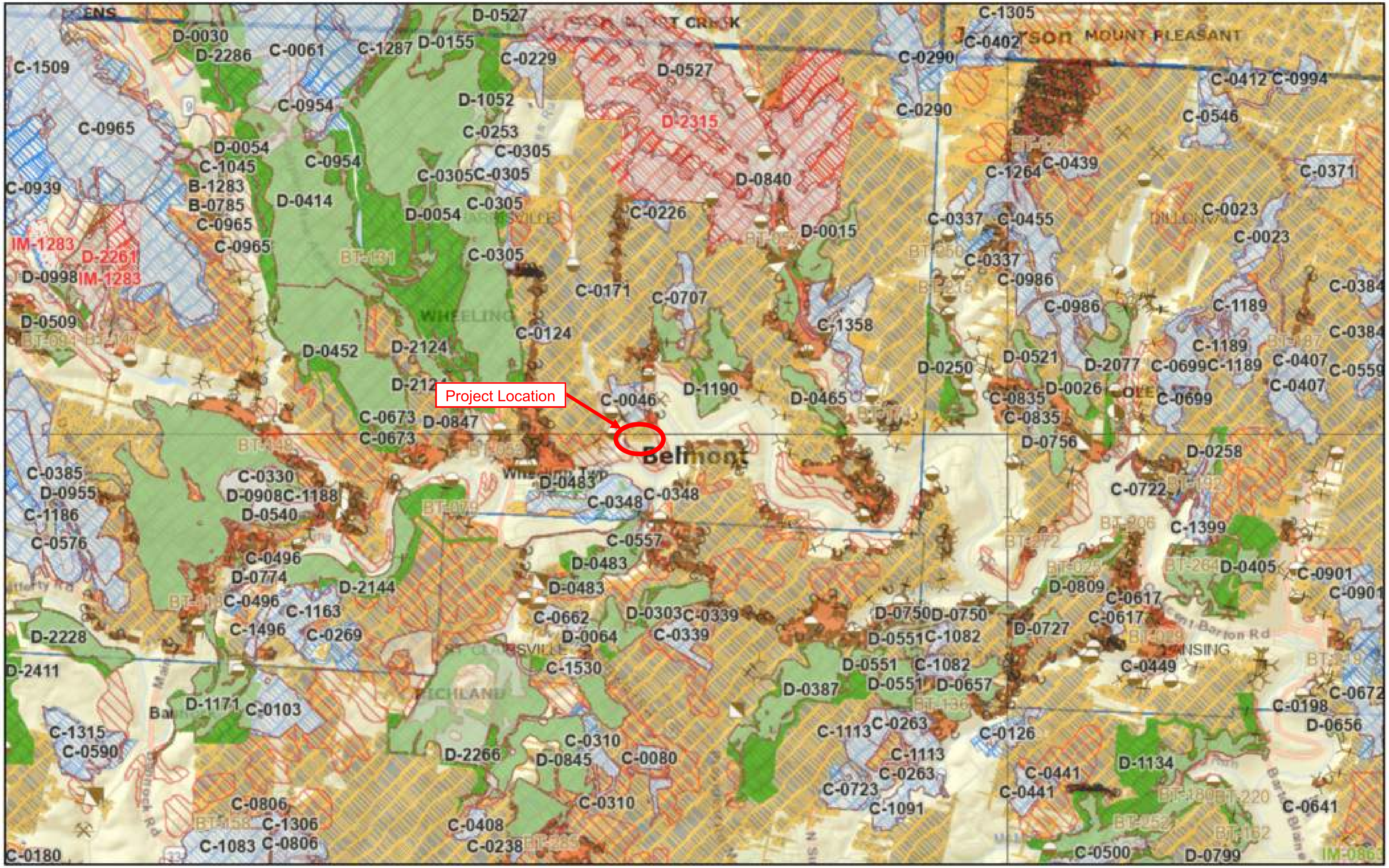
☐ Counties

Source: ODNR Division of Geological Survey

https://gis.ohiodnr.gov/website/dgs/geologyviewer/#

1:72,224

0	0.47	0.95	1.9 mi
0	0.75	1.5	3 km



February 7, 2024

☐ Quadrangle 24K (7.5 min)
▨ Past
▨ Current
▨ Known

▨ Partially Known
▨ Current
▨ Historic - From Topo Maps
Past
▨ B Law (1972 - 1975)

▨ C Law (1976 - 1981)
🟩 D Law (1982 - Present)
▨ Current
☐ Surface Affected Area

✕ Locations
✕ Locations
Past
● Air Shaft
Drift Entry

Vertical Mine Shaft
Slope Entry

1:72,224
0 0.47 0.95 1.9 mi
0 0.75 1.5 3 km
Esri, HERE, Garmin, NGA, USGS, NPS

Source: ODNR Division of Geological Survey, Mines of Ohio Interactive Map
https://gis.ohiodnr.gov/MapViewer/?config=OhioMines

Calculated: MM
Checked: AKB

Exhibit No. 6 : Mines of Ohio Map

Project: BEL-TR428-0.30
PID: 119483

MODEL: TR428 - Plan 1 [Sheet] PAPERSIZE: 34x22 (in.) DATE: 3/28/2024 TIME: 10:20:53 AM USER: SKIRK
pw:\\pwhdruseas01:HDR_US_East_01\Documents\SME_-_OH\SME-ODOT_37647_CEAO_Geotech\ODT_SME-_BEL-TR428-0.30\6.0_CAD_BIM\6.2_WIP\01_Design\10392314\400-Engineering\Geotechnical\Sheets\Boring Location Plan

EXHIBIT NO. 7: BORING LOCATION PLAN

HORIZONTAL
SCALE IN FEET
0 10 20 40

DESIGN AGENCY

HDR

DESIGNER
AKB

REVIEWER
DMV 03/28/24

PROJECT ID
119483

SHEET	TOTAL
P.1	1

Appendix B. Boring Logs and Rock Core Photos

PROJECT: BEL-TR428-00.30
TYPE: BRIDGE
PID: 119483 SFN: 733385
START: 1/29/24 END: 1/29/24

DRILLING FIRM / OPERATOR: CENTRAL STAR / MJ
SAMPLING FIRM / LOGGER: HDR / DM
DRILLING METHOD: 3.25" HSA / NQ2
SAMPLING METHOD: SPT / NQ2

DRILL RIG: CME 55 TRACK
HAMMER: CME AUTOMATIC
CALIBRATION DATE: 3/7/22
ENERGY RATIO (%): 83.4

STATION / OFFSET: 3+77, 12' RT.
ALIGNMENT: TR 428
ELEVATION: 887.0 (MSL) EOB: 29.0 ft.
LAT / LONG: 40.126853, -80.915745

EXPLORATION ID B-001-0-24
PAGE 1 OF 1

MATERIAL DESCRIPTION AND NOTES	ELEV. 887.0	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, BROWN TO DARK BROWN, **SILT AND CLAY**, SOME SAND, LITTLE GRAVEL, MOIST			2 4 4	11	78	SS-1	1.50	-	-	-	-	-	-	-	-	27	A-6a (V)	
	881.0		2 5 3	11	100	SS-2	1.00	19	10	11	41	19	36	21	15	25	A-6a (7)	
MEDIUM STIFF, BROWNISH-GRAY TO GRAY-BROWN, **SILT AND CLAY**, LITTLE SAND, TRACE GRAVEL, NOTED ROOTS AND WOOD FRAGMENTS, MOIST	878.5		1 3 3	8	100	SS-3	0.50	4	3	12	58	23	35	22	13	31	A-6a (9)	
LOOSE TO MEDIUM DENSE, BROWNISH-GRAY TO GRAY-BROWN, **GRAVEL WITH SAND AND SILT**, TRACE CLAY, DRY	877.5	W 877.5 TR	5 6 50/5"	-	47	SS-4	-	0	44	27	21	8	26	17	9	4	A-2-4 (0)	
SILTSTONE, DARK GRAY TO GRAY, VERY WEAK. @ 11.5' - 11.6' : Trace Limestone Fragments			50/5"	-	60	SS-5	-	-	-	-	-	-	-	-	-	13	Rock (V)	
			50/2"	-	100	SS-6	-	-	-	-	-	-	-	-	-	3	Rock (V)	
	873.0		46 50/3"	-	100	SS-7	-	-	-	-	-	-	-	-	-	8	Rock (V)	
SILTSTONE, DARK GRAY TO BLACK, SLIGHTLY WEATHERED, STRONG, LAMINATED TO VERY THIN BEDDED, CARBONACEOUS, ARENACEOUS, JOINT AND BEDDING DISCONTINUITIES, FRACTURED TO MODERATELY FRACTURED, NARROW TO OPEN APERTURE, SLICKENSIDED, LAMINATED TO VERY BLOCKY, FAIR SURFACE CONDITIONS; RQD 59%, REC 100%. @ 14.5' - 16': SDI = 96% @ 16.3' - 16.7': qu = 9,178 psi, γ = 159 pcf @ 17.3' - 19.3': Irregularly Interbedded Sandstone Laminations			55		100	NQ2-1											CORE	
			65		100	NQ2-2											CORE	
@ 23.8' - 24.8': Noted Increase in Core Barrel Advancement Rate (weak/soft layer)			60		100	NQ2-3											CORE	
	858.0	EOB 29	52		100	NQ2-4											CORE	

NOTES: NONE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 25 LB. BENTONITE POWDER; 45 LB. CEMENT; 40 GAL. WATER

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 3/24/24 12:51 - C:\PWWORKING\EAST01\D3694593\20240131_BEL-TR428-0.30_BORINGLOGS.GPJ

PROJECT: BEL-TR428-00.30	DRILLING FIRM / OPERATOR: CENTRAL STAR / MJ	DRILL RIG: CME 55 TRACK	STATION / OFFSET: 2+59, 12' LT.	EXPLORATION ID B-002-0-24
TYPE: BRIDGE	SAMPLING FIRM / LOGGER: HDR / DM	HAMMER: CME AUTOMATIC	ALIGNMENT: TR 428	
PID: 119483 SFN: 733385	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 3/7/22	ELEVATION: 885.0 (MSL) EOB: 31.2 ft.	PAGE 1 OF 2
START: 1/29/24 END: 1/29/24	SAMPLING METHOD: SPT / NQ2	ENERGY RATIO (%): 83.4	LAT / LONG: 40.126800, -80.916156	

MATERIAL DESCRIPTION AND NOTES	ELEV. 885.0
MEDIUM STIFF TO STIFF, BROWN, **SILT AND CLAY**, SOME SAND, WET @ 1.0' - 1.5': Limestone cobble	879.0
SOFT, GRAY, **SANDY SILT**, LITTLE CLAY, NOTED LEAVES AND WOOD FRAGMENTS, WET	876.5
MEDIUM DENSE TO DENSE, GRAY, **GRAVEL WITH SAND**, LITTLE TO TRACE SILT, TRACE CLAY, MOIST TO WET	872.0
DENSE, GRAY, **GRAVEL WITH SAND AND SILT**, TRACE CLAY, MOIST @ 14.5': Auger Grinding	870.0
SILTSTONE, DARK GRAY, VERY WEAK. @ 15.0' - 15.5': Sandstone, Brown	868.8
SILTSTONE, DARK GRAY TO BLACK, SLIGHTLY WEATHERED, STRONG, LAMINATED TO VERY THIN BEDDED, CARBONACEOUS, ARENACEOUS, JOINT AND BEDDING DISCONTINUITIES, FRACTURED TO MODERATELY FRACTURED, NARROW APERTURE, SLICKENSIDED, LAMINATED TO VERY BLOCKY, FAIR SURFACE CONDITIONS; RQD 39%, REC 100%. @ 16.2' - 19.1': Highly Fractured @ 19.0' - 21.4': Irregularly Bedded Sandstone Laminations @ 20.2' - 21.2': Noted Increase in Core Barrel Advancement Rate (weak/soft layer) @ 24.7' - 25.1': qu = 9,397 psi, γ = 162 pcf @ 25.6' - 26.0': qu = 8,288 psi, γ = 161 pcf	

DEPTHS: W 875.0 (at 9–10); TR (at 15)

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
24 4 3	10	67	SS-1	0.50	-	-	-	-	-	-	-	-	32	A-6a (V)	
3 2 2	6	67	SS-2	0.50	0	2	20	60	18	33	20	13	44	A-6a (9)	
1 2 1	4	100	SS-3	0.25	0	7	39	40	14	31	26	5	46	A-4a (4)	
8 11 10	29	56	SS-4	-	68	8	8	9	7	21	16	5	11	A-1-b (0)	
11 18 14	44	56	SS-5	-	53	17	10	11	9	24	18	6	15	A-1-b (0)	
12 14 14	39	67	SS-6	-	65	10	9	8	8	24	18	6	13	A-1-b (0)	
11 12 17	40	78	SS-7	-	61	13	8	8	10	31	21	10	16	A-2-4 (0)	
22 50/4"	-	100	SS-8	-	-	-	-	-	-	-	-	-	11	Rock (V)	
0		100	NQ2-1											CORE	
27		100	NQ2-2											CORE	
58		100	NQ2-3											CORE	
42		100	NQ2-4											CORE	

PID: 119483	SFN: 733385	PROJECT: BEL-TR428-00.30	STATION / OFFSET: 2+59, 12' LT.	START: 1/29/24	END: 1/29/24	PG 2 OF 2	B-002-0-24

MATERIAL DESCRIPTION AND NOTES	ELEV. 855.0	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	HOLE SEALED
								GR	CS	FS	SI	CL	LL	PL	PI			
@ 30.5' - 30.9': qu = 9,549 psi, γ = 162 pcf	853.8	EOB 31																

NOTES: NONE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 25 LB. BENTONITE POWDER; 45 LB. CEMENT; 40 GAL. WATER

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 3/24/24 12:51 - C:\PWWORKING\EAST01\D3694593\20240131_BEL-TR428-0.30_BORINGLOGS.GPJ

B-001-0-24

Run #	Depth (ft)		Recovery		RQD	
NQ2-1	14.0	16.8	33 in. / 33 in.	100%	18 in. / 33 in.	55%
NQ2-2	16.8	21.8	60 in. / 60 in.	100%	39 in. / 60 in.	65%

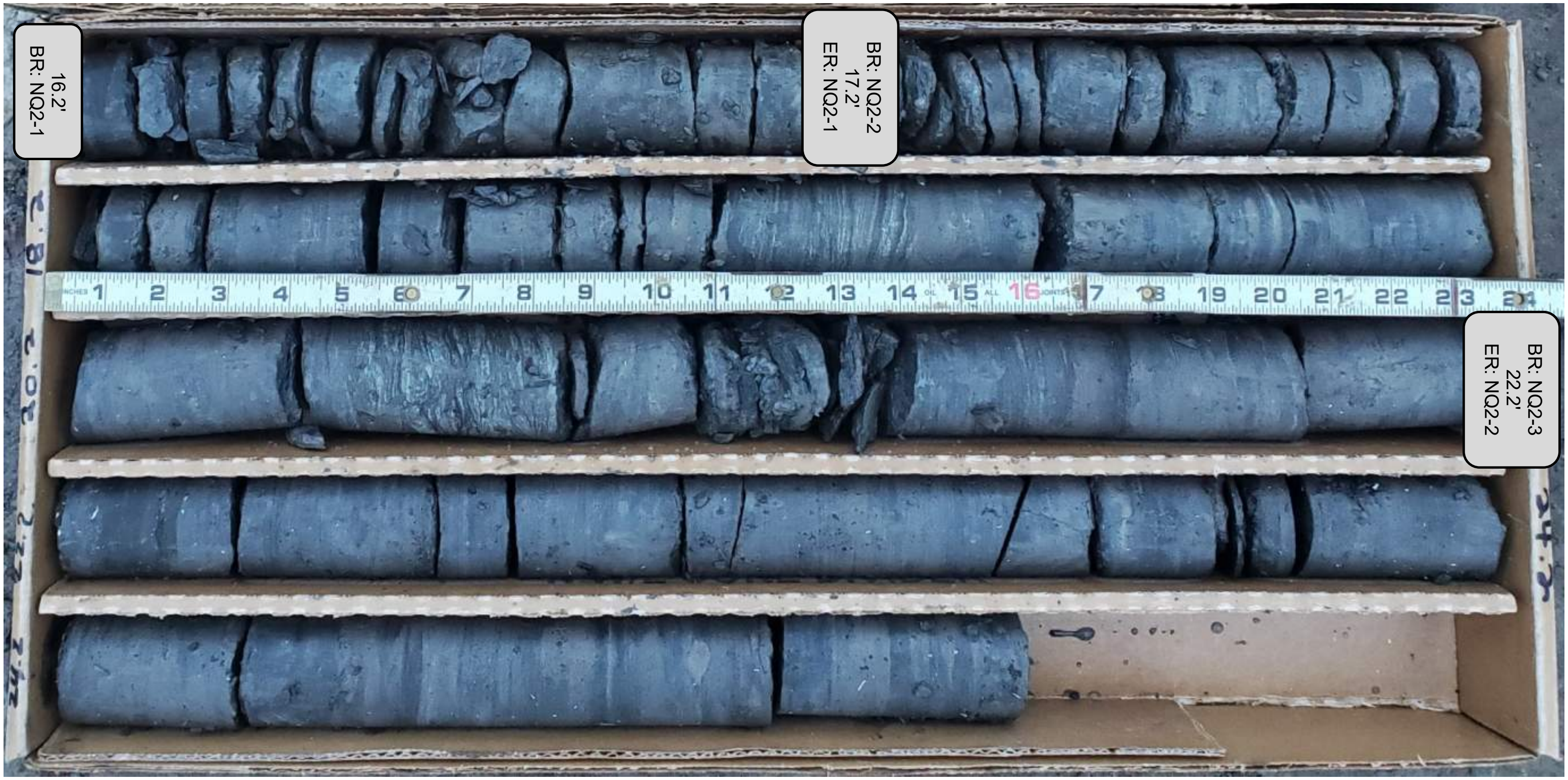
BEL-TR428-0.30, PID 119483

B-001-0-24

Run #	Depth (ft)		Recovery		RQD	
NQ2-3	21.8	26.8	60 in. / 60 in.	100%	36 in. / 60 in.	60%
NQ2-4	26.8	29.0	27 in. / 27 in.	100%	14 in. / 27 in.	52%

BEL-TR428-0.30, PID 119483

B-002-0-24



Run #	Depth (ft)		Recovery		RQD	
NQ2-1	16.2	17.2	12 in. / 12 in.	100%	0 in. / 12 in.	0%
NQ2-2	17.2	22.2	60 in. / 60 in.	100%	16 in. / 60 in.	27%
NQ2-3	22.2	27.2	60 in. / 60 in.	100%	35 in. / 60 in.	58%

BEL-TR428-0.30, PID 119483

B-002-0-24

Run #	Depth (ft)		Recovery		RQD	
NQ2-3	22.2	27.2	60 in. / 60 in.	100%	35 in. / 60 in.	58%
NQ2-4	27.2	31.2	48 in. / 48 in.	100%	20 in. / 48 in.	42%

BEL-TR428-0.30, PID 119483

Appendix C. Laboratory Testing

Unconfined Compression Test of Rock (ASTM D 7012)

ASTM: D7012-Method C

UNCONFINED COMPRESSION TEST (ROCK CORE)

PROJECT NAME : BEL-428-0.30
PROJECT NO. : 10392314
PROJECT COUNTY : Belmont
PROJECT STATE : Ohio
LABORATORY NO. : PID 119483
SUBMITTED BY : HDR

SAMPLE NO. : RC-3
SAMPLE LOC. : B-001-0-24
SAMPLE DEPTH : 16.3' to 16.7'
DATE TESTED : 3/4/2024
DATE REPORTED : 3/4/2024

ROCK DESCRIPTION : Shale
Machine Used : ELE CT-7250
Diameter : 1.96 in
Height : 3.99 in
Area : 3.02 in²
Volume : 0.0070 ft³

RESULTS :

Air Dry Moisture:	1.5	%
Air-Dry Density :	159.4	lbs/ft.³
Maximum Stress :	9,178	psi
Elapsed Time :	9:48	min.
Rate of Loading :	50	lb/sec

Comments :

Approved By : Kevin E. Walker

ASTM: D7012-Method C

UNCONFINED COMPRESSION TEST (ROCK CORE)

PROJECT NAME : BEL-428-0.30
PROJECT NO. : 10392314
PROJECT COUNTY : Belmont
PROJECT STATE : Ohio
LABORATORY NO. : PID 119483
SUBMITTED BY : HDR

SAMPLE NO. : RC-4
SAMPLE LOC. : B-002-0-24
SAMPLE DEPTH : 24.7' to 25.1'
DATE TESTED : 3/4/2024
DATE REPORTED : 3/4/2024

ROCK DESCRIPTION : Shale
Machine Used : ELE CT-7250
Diameter : 1.96 in
Height : 4.32 in

Area : 3.02 in²
Volume : 0.0076 ft³

RESULTS :

Air Dry Moisture:	1.6	%
Air-Dry Density :	162.0	lbs/ft.³
Maximum Stress :	9,397	psi
Elapsed Time :	9:54	min.
Rate of Loading :	50	lb/sec

Comments :

Approved By : Kevin E. Walker

ASTM: D7012-Method C

UNCONFINED COMPRESSION TEST (ROCK CORE)

PROJECT NAME : BEL-428-0.30
PROJECT NO. : 10392314
PROJECT COUNTY : Belmont
PROJECT STATE : Ohio
LABORATORY NO. : PID 119483
SUBMITTED BY : HDR

SAMPLE NO. : RC-1
SAMPLE LOC. : B-002-0-24
SAMPLE DEPTH : 25.6' to 26.0'
DATE TESTED : 3/4/2024
DATE REPORTED : 3/4/2024

ROCK DESCRIPTION : Shale
Machine Used : ELE CT-7250
Diameter : 1.96 in
Height : 4.02 in
Area : 3.01 in²
Volume : 0.0070 ft³

RESULTS :

Air Dry Moisture:	1.7	%
Air-Dry Density :	160.8	lbs/ft.³
Maximum Stress :	8,288	psi
Elapsed Time :	8:40	min.
Rate of Loading :	50	lb/sec

Comments :

Approved By : Kevin E. Walker

ASTM: D7012-Method C

UNCONFINED COMPRESSION TEST (ROCK CORE)

PROJECT NAME : BEL-428-0.30
PROJECT NO. : 10392314
PROJECT COUNTY : Belmont
PROJECT STATE : Ohio
LABORATORY NO. : PID 119483
SUBMITTED BY : HDR

SAMPLE NO. : RC-2
SAMPLE LOC. : B-002-0-24
SAMPLE DEPTH : 30.5' to 30.9'
DATE TESTED : 3/4/2024
DATE REPORTED : 3/4/2024

ROCK DESCRIPTION : Shale
Machine Used : ELE CT-7250
Diameter : 1.96 in
Height : 4.30 in
Area : 3.03 in²
Volume : 0.0075 ft³

RESULTS :

Air Dry Moisture:	1.7	%
Air-Dry Density :	162.4	lbs/ft.³
Maximum Stress :	9,549	psi
Elapsed Time :	9:54	min.
Rate of Loading :	50	lb/sec

Comments :

Approved By : Kevin E. Walker

Slake Durability Index (ASTM D 4644)

SLAKE DURABILITY INDEX
KENTUCKY METHOD 64-513-79 or ASTM D 4644

COUNTY: Belmont PROJECT NO.: 10392314

PROJECT NAME: BEL-428-0.30 / PID# 119483

BORING NO.: B-001-0-24 STATION & OFF-SET: NA

SAMPLE DEPTH: 14.5-16.0' SAMPLE ELEVATION: NA

SAMPLE DESCRIPTION: NA

BEAKER NO.: 30 WEIGHT OF BEAKER: 77.04 gm

INITIAL WEIGHT OF SAMPLE (USE 10 PIECES (Approx. 40 to 50 gm/piece))

SAMPLE + BEAKER 550.71 gm DATE: 02/29/2024 TIME: 10:32 AM

OVEN DRY INITIAL WEIGHT (After 12 Hrs. Drying (Min.))

Note: IF TEST IS NOT A KENTUCKY METHOD, INTIAL MOISTURE CONTENT IS DETERMINED BY WEIGHING SAMPLE AND DRUM AND PLACING DRUM IN OVEN.
A PHOTOGRAPH OF THE SAMPLE MUST BE TAKEN PRIOR TO BEING PLACED IN DRUM.

SAMPLE & BEAKER/DRUM 537.66 gm **minus** BEAKER/DRUM 77.04 gm (W1) = 460.62 gm

FIRST 10 MINUTE CYCLE: DATE: 03-1-24 TIME: 4:45:00 AM Temp.: 20.8 ° C

SECOND 10 MINUTE CYCLE: DATE: 03-2-24 TIME: 7:10:00 AM Temp. : 20.8 ° C

OVEN DRY FINAL WEIGHT (12 Hrs. Drying (Min.) After Second Cycle)

SAMPLE & BEAKER 517.04 gm **minus** BEAKER 77.04 gm (W2) = 440.00 gm

SLAKE DURABILITY INDEX = $\frac{(W2)}{(W1)}$ X 100 SDI = 95.5

Moisture Content = 2.8 % Avg. Temp.= 20.8 ° C

TESTED BY: Mike Garrison

Appendix D. Analyses

Design Profile

PROJECT: BEL-TR428-00.30	DRILLING FIRM / OPERATOR: CENTRAL STAR / MJ	DRILL RIG: CME 55 TRACK	STATION / OFFSET: 3+77, 12' RT.	EXPLORATION ID B-001-0-24	
TYPE: BRIDGE	SAMPLING FIRM / LOGGER: HDR / DM	HAMMER: CME AUTOMATIC	ALIGNMENT: TR 428		
PID: 119483 SFN: 733385	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 3/7/22	ELEVATION: 887.0 (MSL) EOB: 29.0 ft.	PAGE 1 OF 1	
START: 1/29/24 END: 1/29/24	SAMPLING METHOD: SPT / NQ2	ENERGY RATIO (%): 83.4	LAT / LONG: 40.126853, -80.915745		

MATERIAL DESCRIPTION AND NOTES	ELEV. 887.0	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, BROWN TO DARK BROWN, **SILT AND CLAY**, SOME SAND, LITTLE GRAVEL, MOIST Layer 1		1 2 3	2 4 4	11	78	SS-1	1.50	-	-	-	-	-	-	-	-	27	A-6a (V)	
	881.0	4 5 6	2 5 3	11	100	SS-2	1.00	19	10	11	41	19	36	21	15	25	A-6a (7)	
MEDIUM STIFF, BROWNISH-GRAY TO GRAY-BROWN, **SILT AND CLAY**, LITTLE SAND, TRACE GRAVEL, NOTED ROOTS AND WOOD FRAGMENTS, MOIST Layer 3	878.5	7 8	1 3 3	8	100	SS-3	0.50	4	3	12	58	23	35	22	13	31	A-6a (9)	
LOOSE TO MEDIUM DENSE, BROWNISH-GRAY TO GRAY-BROWN, **GRAVEL WITH SAND AND SILT**, TRACE CLAY, DRY	877.5	W 877.5 TR 9	5 6 50/5"	-	47	SS-4	-	0	44	27	21	8	26	17	9	4	A-2-4 (0)	
SILTSTONE, DARK GRAY TO GRAY, VERY WEAK. @ 11.5' - 11.6' : Trace Limestone Fragments MODELED AS A HARD CLAY Layer 4		10 11	50/5"	-	60	SS-5	-	-	-	-	-	-	-	-	-	13	Rock (V)	
		12	50/2"	-	100	SS-6	-	-	-	-	-	-	-	-	-	3	Rock (V)	
	873.0	13	46 50/3"	-	100	SS-7	-	-	-	-	-	-	-	-	-	8	Rock (V)	
SILTSTONE, DARK GRAY TO BLACK, SLIGHTLY WEATHERED, STRONG, LAMINATED TO VERY THIN BEDDED, CARBONACEOUS, ARENACEOUS, JOINT AND BEDDING DISCONTINUITIES, FRACTURED TO MODERATELY FRACTURED, NARROW TO OPEN APERTURE, SLICKENSIDED, LAMINATED TO VERY BLOCKY, FAIR SURFACE CONDITIONS; RQD 59%, REC 100%. @ 14.5' - 16': SDI = 96% @ 16.3' - 16.7': qu = 9,178 psi, γ = 159 pcf @ 17.3' - 19.3': Irregularly Interbedded Sandstone Laminations		14 15 16	55		100	NQ2-1											CORE	
		17 18 19 20 21	65		100	NQ2-2											CORE	
@ 23.8' - 24.8': Noted Increase in Core Barrel Advancement Rate (weak/soft layer)		22 23 24 25 26	60		100	NQ2-3											CORE	
	858.0	27 28 EOB 29	52		100	NQ2-4											CORE	

NOTES: NONE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 25 LB. BENTONITE POWDER; 45 LB. CEMENT; 40 GAL. WATER

PROJECT:	BEL-TR428-00.30	DRILLING FIRM / OPERATOR:	CENTRAL STAR / MJ	DRILL RIG:	CME 55 TRACK	STATION / OFFSET:	2+59, 12' LT.
TYPE:	BRIDGE	SAMPLING FIRM / LOGGER:	HDR / DM	HAMMER:	CME AUTOMATIC	ALIGNMENT:	TR 428
PID: 119483	SFN: 733385	DRILLING METHOD:	3.25" HSA / NQ2	CALIBRATION DATE:	3/7/22	ELEVATION: 885.0 (MSL)	EOB: 31.2 ft.
START: 1/29/24	END: 1/29/24	SAMPLING METHOD:	SPT / NQ2	ENERGY RATIO (%):	83.4	LAT / LONG:	40.126800, -80.916156

EXPLORATION ID
B-002-0-24

PAGE
1 OF 2

MATERIAL DESCRIPTION AND NOTES	ELEV. 885.0	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**, SOME SAND, WET @ 1.0' - 1.5': Limestone cobble Layer 1		1 2	24 4 3	10	67	SS-1	0.50	-	-	-	-	-	-	-	-	32	A-6a (V)	
	879.0	3 4 5 6	3 2 2	6	67	SS-2	0.50	0	2	20	60	18	33	20	13	44	A-6a (9)	
SOFT, GRAY, **SANDY SILT**, LITTLE CLAY, NOTED LEAVES AND WOOD FRAGMENTS, WET Layer 2	876.5	7 8	1 2 1	4	100	SS-3	0.25	0	7	39	40	14	31	26	5	46	A-4a (4)	
MEDIUM DENSE TO DENSE, GRAY, **GRAVEL WITH SAND**, LITTLE TO TRACE SILT, TRACE CLAY, MOIST TO WET Layer 3		W 875.0 9 10	8 11 10	29	56	SS-4	-	68	8	8	9	7	21	16	5	11	A-1-b (0)	
		11	11 18 14	44	56	SS-5	-	53	17	10	11	9	24	18	6	15	A-1-b (0)	
	872.0	12	12 14 14	39	67	SS-6	-	65	10	9	8	8	24	18	6	13	A-1-b (0)	
DENSE, GRAY, **GRAVEL WITH SAND AND SILT**, TRACE CLAY, MOIST @ 14.5': Auger Grinding	870.0	13 14 TR	11 12 17	40	78	SS-7	-	61	13	8	8	10	31	21	10	16	A-2-4 (0)	
SILTSTONE, DARK GRAY, VERY WEAK. @ 15.0' - 15.5': Sandstone, Brown Layer 4	868.8	15 16	22 50/4"	-	100	SS-8	-	-	-	-	-	-	-	-	-	11	Rock (V)	
SILTSTONE, DARK GRAY TO BLACK, SLIGHTLY WEATHERED, STRONG, LAMINATED TO VERY THIN BEDDED, CARBONACEOUS, ARENACEOUS, JOINT AND BEDDING DISCONTINUITIES, FRACTURED TO MODERATELY FRACTURED, NARROW APERTURE, SLICKENSIDED, LAMINATED TO VERY BLOCKY, FAIR SURFACE CONDITIONS; RQD 39%, REC 100%. @ 16.2' - 19.1': Highly Fractured @ 19.0' - 21.4': Irregularly Bedded Sandstone Laminations @ 20.2' - 21.2': Noted Increase in Core Barrel Advancement Rate (weak/soft layer)		17	0		100	NQ2-1											CORE	
		18 19 20 21 22	27		100	NQ2-2											CORE	
@ 24.7' - 25.1': qu = 9,397 psi, γ = 162 pcf @ 25.6' - 26.0': qu = 8,288 psi, γ = 161 pcf		23 24 25 26 27	58		100	NQ2-3											CORE	
		28 29	42		100	NQ2-4											CORE	

MODELED AS A HARD CLAY

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 3/24/24 12:51 - C:\PWWORKING\EAST01\D3694593\20240131_BEL-TR428-0.30_BORINGLOGS.GPJ

PID: 119483	SFN: 733385	PROJECT: BEL-TR428-00.30	STATION / OFFSET: 2+59, 12' LT.	START: 1/29/24	END: 1/29/24	PG 2 OF 2	B-002-0-24

MATERIAL DESCRIPTION AND NOTES	ELEV. 855.0	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	HOLE SEALED
								GR	CS	FS	SI	CL	LL	PL	PI			
@ 30.5' - 30.9': qu = 9,549 psi, γ = 162 pcf	853.8	EOB 31																

NOTES: NONE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 25 LB. BENTONITE POWDER; 45 LB. CEMENT; 40 GAL. WATER

SUBSURFACE DIAGRAM

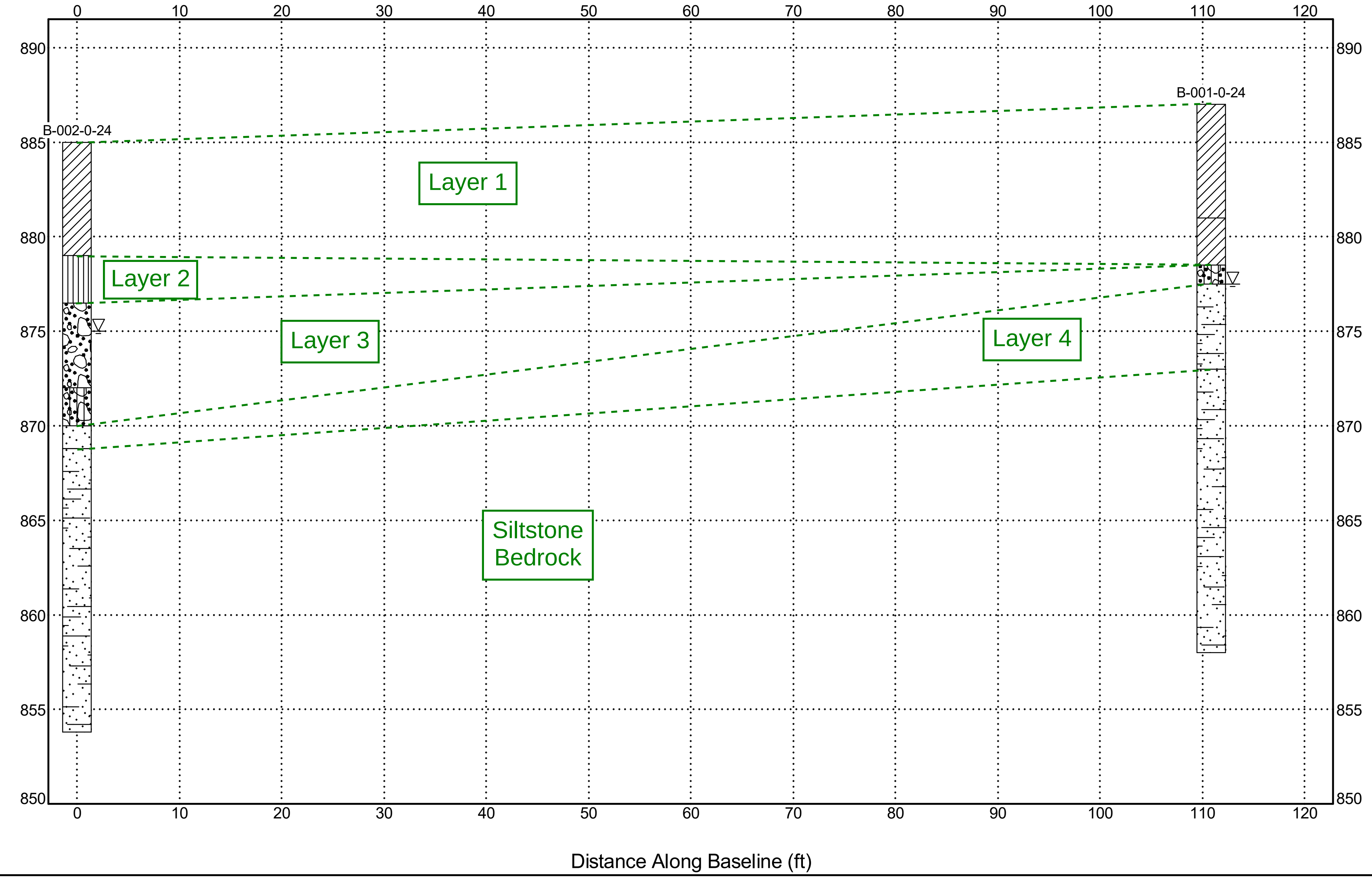
OHIO DEPARTMENT OF TRANSPORTATION
OFFICE OF GEOTECHNICAL ENGINEERING

CLIENT

PROJECT NUMBER 119483

PROJECT NAME

PROJECT LOCATION 111111



STRATIGRAPHY & GW - A SIZE - OH DOT.GDT - 3/24/24 12:52 - C:\PWWORKING\EAST01\D3694593\20240131_BEL-TR428-0.30_BORINGLOGS.GPJ

Soil and Rock Strength Parameter Determination

Belmont County Engineer
BEL-TR248-0.30

Soil Strength Parameter Determination

Computed By = TJW
Checked By = DCM

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
		PPR	N-values		Tested							N_{60} Value	ODOT GB-7 Correlations		Tested		
			Sowers	T and P	Values	Correlation	Tested	Correlation	Tested				Cohesion (psf)	phi (deg)	Cohesion (psf)	phi (deg)	
	Max	1500	1925	1463		100		120			**Max**	11	121	23			
	Min	500	1050	798		95		110		S_u= **1200** psf	**Min**	6	75	21			c' = **105** psf
Layer 1	**Average**	800	1610	1224		98		118		Φ = **0** deg	**Average**	9	106	22			Φ' = **22** deg
	Std Dev	447	379	288		3		4			**Std Dev**	2	19	1			
MEDIUM STIFF TO STIFF COHESIVE										Y_{dry} = 100 pcf							Y_{dry} = 100 pcf
	Avg + Std	1247	1989	1512		101		122		Y_{moist} = **120** pcf	**Avg + Std**	11	126	23			Y_{moist} = **120** pcf
	Avg - Std	353	1231	935		95		114			**Avg - Std**	7	87	21			
	Max	250	300	532		90		110			**Max**	4	50	20			
	Min	250	300	532		90		110		S_u = **350** psf	**Min**	4	50	20			c' = **50** psf
Layer 2	**Average**	250	300	532		90		110		Φ = **0** deg	**Average**	4	50	20			Φ' = **20** deg
	Std Dev	N/A	N/A	N/A		N/A		N/A			**Std Dev**	N/A	N/A	N/A			
SOFT COHESIVE										Y_{dry} = 90 pcf							Y_{dry} = 90 pcf
	Avg + Std	N/A	N/A	N/A		N/A		N/A		Y_{moist} = **110** pcf	**Avg + Std**	N/A	N/A	N/A			Y_{moist} = **110** pcf
	Avg - Std	N/A	N/A	N/A		N/A		N/A			**Avg - Std**	N/A	N/A	N/A			
	Max	N/A	N/A	N/A		120		135			**Max**	44	N/A	35			
	Min	N/A	N/A	N/A		105		125		S_u = **0** psf	**Min**	29	N/A	34			c' = **0** psf
Layer 3	**Average**	N/A	N/A	N/A		116		133		Φ = **35** deg	**Average**	38	N/A	35			Φ' = **35** deg
	Std Dev	N/A	N/A	N/A		8		5			**Std Dev**	6	N/A	1			
MEDIUM DENSE TO DENSE GRANULAR										Y_{dry} = 115 pcf							Y_{dry} = 115 pcf
	Avg + Std	N/A	N/A	N/A		124		138		Y_{moist} = **135** pcf	**Avg + Std**	44	N/A	35			Y_{moist} = **135** pcf
	Avg - Std	N/A	N/A	N/A		109		128			**Avg - Std**	32	N/A	34			
	Max	N/A	N/A	N/A		N/A		N/A			**Max**	N/A	250	28			
	Min	N/A	N/A	N/A		N/A		N/A		S_u = **4000** psf	**Min**	N/A	250	28			c' = **250** psf
Layer 4	**Average**	N/A	N/A	N/A		N/A		N/A		Φ = **0** deg	**Average**	N/A	250	28			Φ' = **28** deg
	Std Dev	N/A	N/A	N/A		N/A		N/A			**Std Dev**	N/A	0	0			
VERY WEAK SILTSTONE (HARD COHESIVE)										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	250	28			Y_{moist} = **140** pcf
	Avg - Std	N/A	N/A	N/A		N/A		N/A			**Avg - Std**	N/A	250	28			

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
Max	11	100	1.5	19	10	20	60	23	36	22	15	44
Min	6	67	0.5	0	2	11	41	18	33	20	13	25
Average	9	82	0.8	8	5	14	53	20	35	21	14	32
Std Dev	2	17	0.4	10	4	5	10	3	2	1	1	7
Avg + Std	11	99	1.2	18	9	19	63	23	36	22	15	39
Avg - Std	7	66	0.4	-2	1	9	43	17	33	20	13	24

	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	1500	1925	1463	121	23	7.0	-2.0	100	120	0.234	2.72	0.787
Min	500	1050	798	75	21	2.0	-7.0	95	110	0.207	2.72	0.697
Average	800	1610	1224	106	22	3.8	-3.8	98	118	0.222	2.72	0.733
Std Dev	447	379	288	19	1	2.0	2.0	3	4	0.014	0.00	0.049
Avg + Std	1247	1989	1512	126	23	5.8	-1.8	101	122	0.236	2.72	0.782
Avg - Std	353	1231	935	87	21	1.8	-5.8	95	114	0.208	2.72	0.684

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 428		B-001-0-24	1	2.5	SS-1	11	78	1.5	-	-	-	-	-	-	-	-	27	A-6a	Cohesive	1	1500	1925	1463	121	23	2.0	-2.0	100	120		2.72	0.697
TR 428		B-001-0-24	3.5	5	SS-2	11	100	1	19	10	11	41	19	36	21	15	25	A-6a	Cohesive	1	1000	1925	1463	121	23	4.0	-4.0	100	120	0.234	2.72	0.697
TR 428		B-001-0-24	6	7.5	SS-3	8	100	0.5	4	3	12	58	23	35	22	13	31	A-6a	Cohesive	1	500	1400	1064	100	22	7.0	-7.0	95	120	0.225	2.72	0.787
TR 428		B-002-0-24	1	2.5	SS-1	10	67	0.5	-	-	-	-	-	-	-	-	32	A-6a	Cohesive	1	500	1750	1330	114	23	2.0	-2.0	100	120		2.72	0.697
TR 428		B-002-0-24	3.5	5	SS-2	6	67	0.5	0	2	20	60	18	33	20	13	44	A-6a	Cohesive	1	500	1050	798	75	21	4.0	-4.0	95	110	0.207	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 2

	N_{60}	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC
Max	4	100	0.3	0	7	39	40	14	31	26	5	46
Min	4	100	0.3	0	7	39	40	14	31	26	5	46
Average	4	100	0.3	0	7	39	40	14	31	26	5	46
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

	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	250	300	532	50	20	7.0	-7.0	90	110	0.189	2.72	0.886
Min	250	300	532	50	20	7.0	-7.0	90	110	0.189	2.72	0.886
Average	250	300	532	50	20	7.0	-7.0	90	110	0.189	2.72	0.886
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

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
TR 428		B-002-0-24	6	7.5	SS-3	4	100	0.25	0	7	39	40	14	31	26	5	46	A-4a	Cohesive	2

Exploration ID	Sample ID	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)
B-002-0-24	SS-3	250	300	532	50	20	7.0	-7.0	90	110	0.189	2.72	0.886

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	44	78	N/A	68	17	10	11	10	31	21	10	16	**Max**	N/A	N/A	N/A	N/A	35	14.0	-9.0	120	135	0.189	2.71	0.611
Min	29	56	N/A	53	8	8	8	7	21	16	5	11	**Min**	N/A	N/A	N/A	N/A	34	9.0	-14.0	105	125	0.099	2.71	0.409
Average	38	64	N/A	62	12	9	9	9	25	18	7	14	**Average**	N/A	N/A	N/A	N/A	35	11.5	-11.5	116	133	0.135	2.71	0.460
Std Dev	6	11	N/A	7	4	1	1	1	4	2	2	2	**Std Dev**	N/A	N/A	N/A	N/A	1	2.1	2.1	8	5	0.038	0.00	0.101
Avg + Std	44	75	N/A	68	16	10	10	10	29	20	9	16	**Avg + Std**	N/A	N/A	N/A	N/A	35	13.6	-9.4	124	138	0.173	2.71	0.560
Avg - Std	32	54	N/A	55	8	8	8	7	21	16	5	12	**Avg - Std**	N/A	N/A	N/A	N/A	34	9.4	-13.6	109	128	0.097	2.71	0.359

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 428		B-002-0-24	8.5	10	SS-4	29	56	-	68	8	8	9	7	21	16	5	11	A-1-b	Granular	3	N/A				34	9.0	-9.0	105	125	0.099	2.71	0.611
TR 428		B-002-0-24	10	11.5	SS-5	44	56	-	53	17	10	11	9	24	18	6	15	A-1-b	Granular	3	N/A				35	11.0	-11.0	120	135	0.126	2.71	0.409
TR 428		B-002-0-24	11.5	13	SS-6	39	67	-	65	10	9	8	8	24	18	6	13	A-1-b	Granular	3	N/A				35	12.0	-12.0	120	135	0.126	2.71	0.409
TR 428		B-002-0-24	13	14.5	SS-7	40	78	-	61	13	8	8	10	31	21	10	16	A-2-4	Granular	3	N/A				35	14.0	-14.0	120	135	0.189	2.71	0.409

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	Short-Term Cohesion (psf) N-values Sowers	Short-Term Cohesion (psf) N-values 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	N/A	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	13	**Max**	N/A	N/A	N/A	250	28	15.0	-10.0	N/A	N/A	N/A	N/A	N/A
Min	N/A	60	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3	**Min**	N/A	N/A	N/A	250	28	10.0	-15.0	N/A	N/A	N/A	N/A	N/A
Average	N/A	90	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	9	**Average**	N/A	N/A	N/A	250	28	12.5	-12.5	N/A	N/A	N/A	N/A	N/A
Std Dev	N/A	20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4	**Std Dev**	N/A	N/A	N/A	0	0	2.1	2.1	N/A	N/A	N/A	N/A	N/A
Avg + Std	N/A	110	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	13	**Avg + Std**	N/A	N/A	N/A	250	28	14.6	-10.4	N/A	N/A	N/A	N/A	N/A
Avg - Std	N/A	70	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4	**Avg - Std**	N/A	N/A	N/A	250	28	10.4	-14.6	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	Short-Term Cohesion (psf) N-values Sowers	Short-Term Cohesion (psf) N-values 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 428		B-001-0-24	10	10.42	SS-5	Refusal	60	-	-	-	-	-	-	-	-	-	13	Rock		4	N/A	N/A	N/A	250	28	10.0	-10.0					
TR 428		B-001-0-24	11.5	11.67	SS-6	Refusal	100	-	-	-	-	-	-	-	-	-	3	Rock		4	N/A	N/A	N/A	250	28	12.0	-12.0					
TR 428		B-001-0-24	13	13.75	SS-7	Refusal	100	-	-	-	-	-	-	-	-	-	8	Rock		4	N/A	N/A	N/A	250	28	13.0	-13.0					
TR 428		B-002-0-24	15	15.8	SS-8	Refusal	100	-	-	-	-	-	-	-	-	-	11	Rock		4	N/A	N/A	N/A	250	28	15.0	-15.0					

Project: BEL-TR428-00.30
Client: Belmont County Engineer
Task: **Generalized LPILE Parameters**

Calculated By: TJW **Date:** 3/15/2024
Checked By: DCM **Date:** 3/18/2024

Soil Lateral Design Profile - B-001-0-24

		Elevation				Unit Wt (pcf)				
	Soil Type	Top (ft)	Bottom (ft)	Cohesion (psf)	Phi (deg)	Total	Effective[1]	ε50	k (pci)	
	Layer 1 - Medium Stiff to Stiff Cohesive	887.0	878.5	1200	0	120	120	0.007	N/A	
1	Layer 3 - Medium Dense to Dense Granular	878.5	877.5	0	35	135	135	N/A	225	
2	Layer 4 - Very Weak Siltstone (Hard Cohesive)	877.5	873.0	4000	0	140	77.6	0.005	N/A	GW
3	Bedrock									

1. Effective unit weights to be applied below groundwater table (assumed at El. 877.5 feet in recommended design profile)

2. Top of Pile assumed at El. 876.5

ε50 tables from LPile Technical Manual

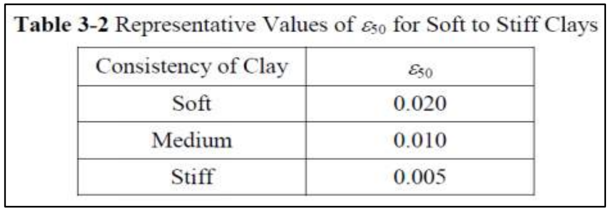


Table 3-2 Representative Values of ε_{50} for Soft to Stiff Clays

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

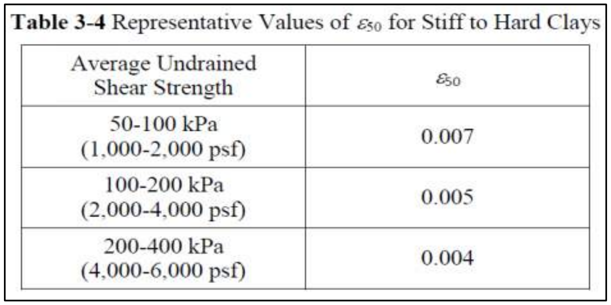


Table 3-4 Representative Values of ε_{50} for Stiff to Hard Clays

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

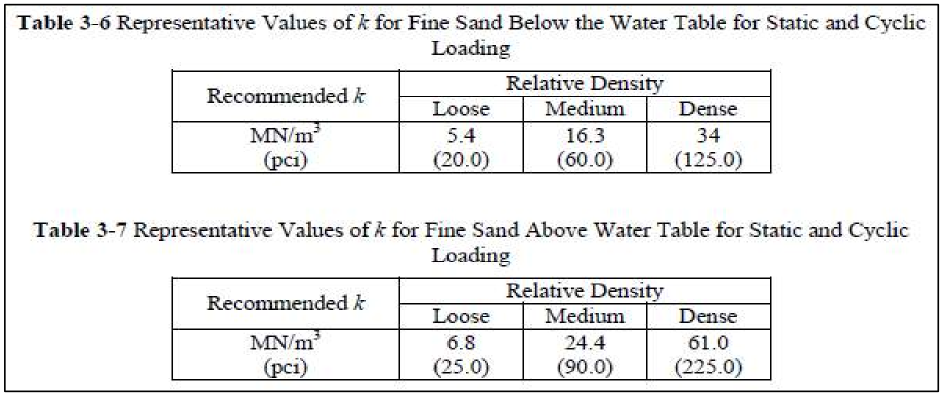


Table 3-6 Representative Values of *k* for Fine Sand Below the Water Table for Static and Cyclic Loading

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)

Project: BEL-TR428-00.30	**Calculated By:** TJW	**Date:** 3/15/2024
Client: Belmont County Engineer	**Checked By:** DCM	**Date:** 3/18/2024
Task: **Generalized LPILE Parameters**		

Soil Lateral Design Profile - B-002-0-24

		Elevation				Unit Wt (pcf)				
	Soil Type	Top (ft)	Bottom (ft)	Cohesion (psf)	Phi (deg)	Total	Effective[1]	ε50	k (pci)	
	Layer 1 - Medium Stiff to Stiff Cohesive	885.0	879.0	1200	0	120	**120**	**0.007**	**N/A**	
	Layer 2 - Soft Cohesive	879.0	876.5	350	0	110	**110**	**0.02**	**N/A**	
1	Layer 3 - Medium Dense to Dense Granular	876.5	875.0	0	35	135	**135**	**N/A**	**225**	
2	Layer 3 - Medium Dense to Dense Granular	875.0	870.0	0	35	135	**72.6**	**N/A**	**125**	GW
3	Layer 4 - Very Weak Siltstone (Hard Cohesive)	870.0	868.7	4000	0	140	**77.6**	**0.005**	**N/A**	
4	Bedrock									

1. Effective unit weights to be applied below groundwater table (assumed at El. 875 feet in recommended design profile)

2. Top of Pile assumed at El. 876.5

ε50 tables from LPile Technical Manual

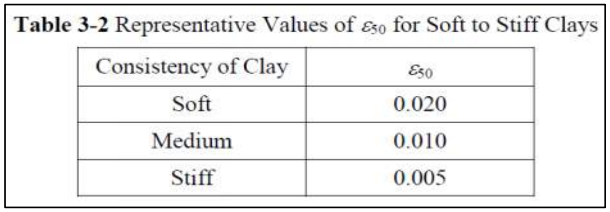


Table 3-2 Representative Values of ε_{50} for Soft to Stiff Clays

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

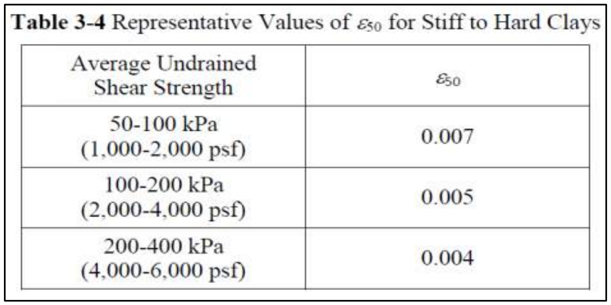


Table 3-4 Representative Values of ε_{50} for Stiff to Hard Clays

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

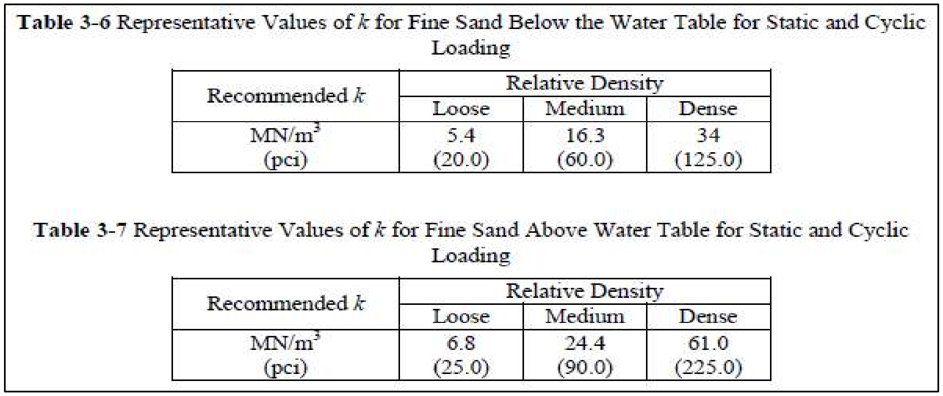


Table 3-6 Representative Values of k for Fine Sand Below the Water Table for Static and Cyclic Loading

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)

Belmont County Engineer
BEL-TR428-00.30

Rock Strength Parameter Determination

Computed By = AKB
Checked By = DMV

BEDROCK TESTING (CORED BEDROCK)

Project	Exploration ID	Sample Depth (ft)	Sample ID	Rock Type	Color	Moist Unit Weight (pcf)	Compressive Strength		Er Modulus		GSI		Em (Hoek & Brown) Modulus		Lesser of Er vs Em	Em (Yang) Modulus	
							(psi)	(MPa)	(psi)	(MPa)	Range	USE	(GPa)	(psi)	(psi)	(MPa)	(psi)
BEL-TR428-00.30	B-001-0-24	16.3	NQ2-1	Siltstone	Dark Gray to Black	159.4	9178	63.3		0	30-35	30	2.5	364850	364850	0.0	0
BEL-TR428-00.30	B-002-0-24	24.7	NQ2-3	Siltstone	Dark Gray to Black	162.0	9397	64.8		0	30-35	30	2.5	369177	369177	0.0	0
BEL-TR428-00.30	B-002-0-24	25.6	NQ2-3	Siltstone	Dark Gray to Black	160.8	8288	57.1		0	30-35	30	2.4	346709	346709	0.0	0
BEL-TR428-00.30	B-002-0-24	30.5	NQ2-4	Siltstone	Dark Gray to Black	162.4	9549	65.8		0	30-35	30	2.6	372151	372151	0.0	0
				Siltstone	**Maximum**	162.4	9549						Siltstone	**Maximum**	372151		
					Minimum	159.4	8288							**Minimum**	346709		
					Average	161.2	9103							**Average**	363222		
					Std Dev	1.4	564							**Std Dev**	11409		
					Adopted Value	160	9000							**Adopted Value**	363000		

krm 0.0005

BEDROCK CORRELATION (AUGERED BEDROCK)

Hammer Efficiency (%) 83.4

Project	Exploration ID	Sample Depth (ft)	Sample ID	Rock Type	Color	Blow Count	Penetration Depth (in)	N83.4 (bpf)	N90 (bpf)	Qu (ksf)	Qu (psi)
BEL-TR428-00.30	B-001-0-24	10	SS-5	Siltstone	Dark Gray to Gray	50	5	120	111	10.2304	71.044
BEL-TR428-00.30	B-001-0-24	11.5	SS-6	Siltstone	Dark Gray to Gray	50	2	300	278	25.58	177.61
BEL-TR428-00.30	B-001-0-24	13	SS-7	Siltstone	Dark Gray to Gray	50	3	200	185	17.05	118.41
BEL-TR428-00.30	B-002-0-24	15	SS-8	Siltstone/Sandstone	Dark Gray	50	4	150	139	12.79	89
										Maximum	177.61
										Minimum	71.044
										Average	114
										Std Dev	47
										Adopted Value	115

N90 = Blow count adjusted to a 90% hammer efficiency
*Qu (ksf) = 0.092*N90 (bpf) per ODOT GDM Section 404.3*

BEDROCK QUALITY

Project	Exploration ID	Rock Type	Depth Range (ft.) From	To	Thickness (ft)	Layer RQD (%)	Weighted RQD*(Length / Total Length)
BEL-TR428-00.30	B-001-0-24	Siltstone	14	16.7	2.7	55	5.0
BEL-TR428-00.30	B-001-0-24	Siltstone	16.7	21.7	5	65	10.8
BEL-TR428-00.30	B-001-0-24	Siltstone	21.7	26.7	5	60	10.0
BEL-TR428-00.30	B-001-0-24	Siltstone	26.7	29.0	2.3	52	4.0
BEL-TR428-00.30	B-002-0-24	Siltstone	16.3	17.3	1	0	0.0
BEL-TR428-00.30	B-002-0-24	Siltstone	17.3	22.3	5	27	4.5
BEL-TR428-00.30	B-002-0-24	Siltstone	22.3	27.3	5	58	9.7
BEL-TR428-00.30	B-002-0-24	Siltstone	27.3	31.3	4	42	5.6
				Siltstone	30	**RQD SUM**	50
				Maximum	5	65	
				Minimum	1	0	
				Average	3.8	44.9	
				Adopted Value (Overall)			50

B-001

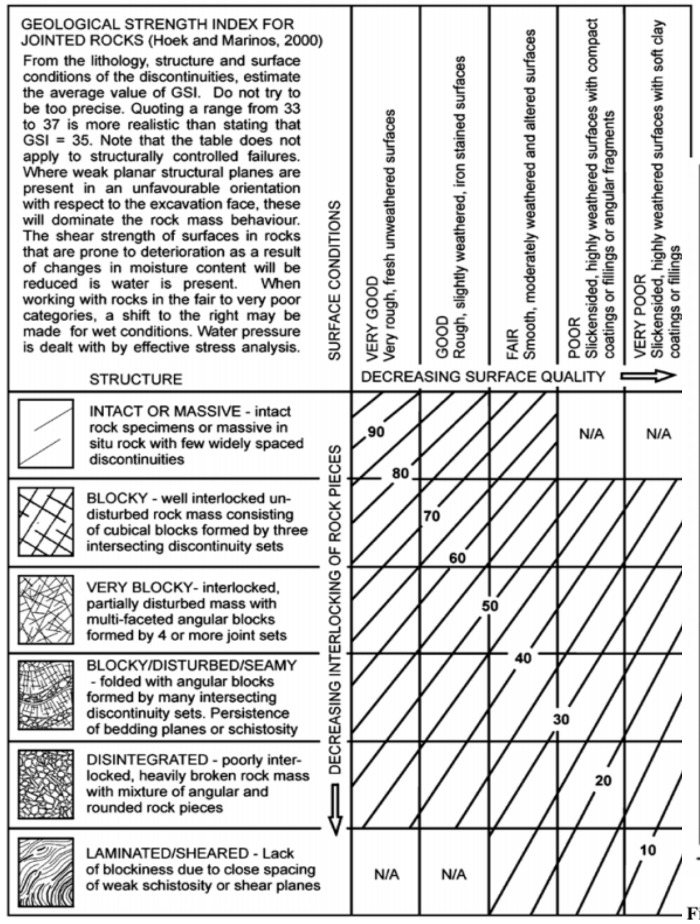
Project	Exploration ID	Rock Type	Depth Range (ft.) From	To	Thickness (ft)	Layer RQD (%)	Weighted RQD*(Length / Total Length)
BEL-TR428-00.30	B-001-0-24	Siltstone	14	16.7	2.7	55	9.9
BEL-TR428-00.30	B-001-0-24	Siltstone	16.7	21.7	5	65	21.7
BEL-TR428-00.30	B-001-0-24	Siltstone	21.7	26.7	5	60	20.0
BEL-TR428-00.30	B-001-0-24	Siltstone	26.7	29.0	2.3	52	8.0
				Siltstone	15	**RQD SUM**	60
				Maximum	5	65	
				Minimum	2.3	52	
				Average	3.8	58.0	
				Adopted Value (B-001, Scour Only)			60

B-002

Project	Exploration ID	Rock Type	Depth Range (ft.) From	To	Thickness (ft)	Layer RQD (%)	Weighted RQD*(Length / Total Length)
BEL-TR428-00.30	B-002-0-24	Siltstone	16.3	17.3	1	0	0.0
BEL-TR428-00.30	B-002-0-24	Siltstone	17.3	22.3	5	27	9.0
BEL-TR428-00.30	B-002-0-24	Siltstone	22.3	27.3	5	58	19.3
BEL-TR428-00.30	B-002-0-24	Siltstone	27.3	31.3	4	42	11.2
				Siltstone	15	**RQD SUM**	40
				Maximum	5	58	
				Minimum	1	0	
				Average	3.8	31.8	
				Adopted Value (B-002, Scour Only)			40

Table 10.4.6.5-1—Estimation of E_m Based on GSI

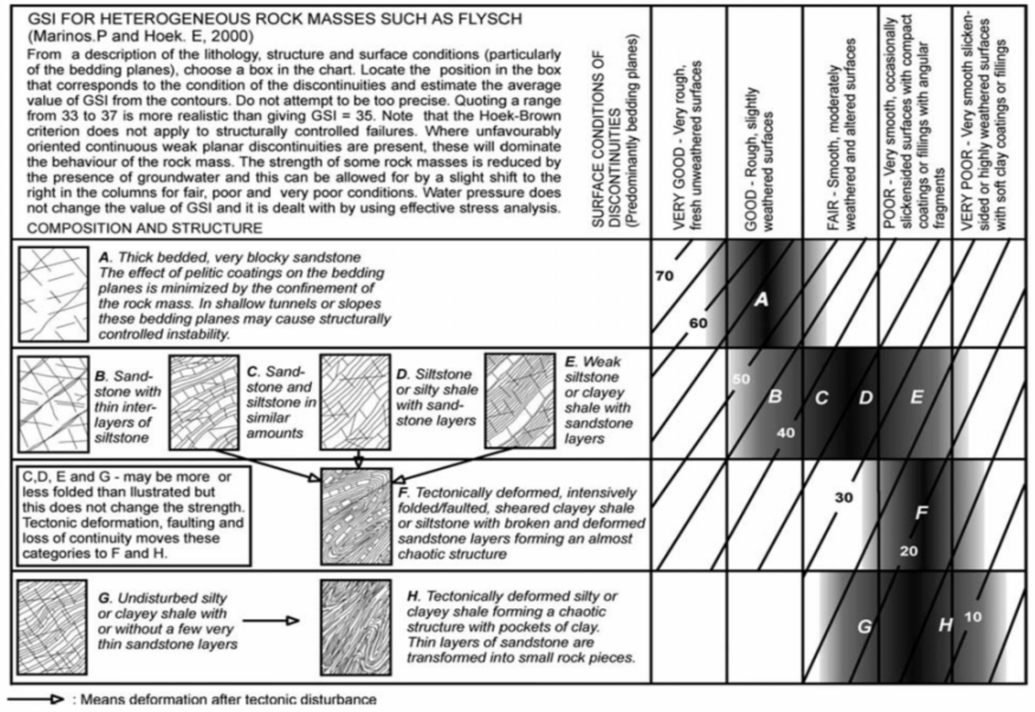
Expression	Notes/Remarks	Reference
$E_m\left(GPa\right) = \sqrt{\frac{q_u}{100}}10^{\frac{GSI-10}{40}}$ for $q_u \leq 100$ MPa $E_m\left(GPa\right) = 10^{\frac{GSI-10}{40}}$ for $q_u \leq 100$ MPa	Accounts for rocks with $q_u < 100$ MPa; notes q_u in MPa	Hoek and Brown (1997); Hoek et al. (2002)
$E_m = \frac{E_R}{100} e^{GSI/21.7}$	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.		



GEOLOGICAL STRENGTH INDEX FOR JOINTED ROCKS (Hoek and Marinos, 2000)

From the lithology, structure and surface conditions of the discontinuities, estimate the average value of GSI. Do not try to be too precise. Quoting a range from 33 to 37 is more realistic than stating that GSI = 35. Note that the table does not apply to structurally controlled failures. Where weak planar structural planes are present in an unfavourable orientation with respect to the excavation face, these will dominate the rock mass behaviour. The shear strength of surfaces in rocks that are prone to deterioration as a result of changes in moisture content will be reduced is water is present. When working with rocks in the fair to very poor categories, a shift to the right may be made for wet conditions. Water pressure is dealt with by effective stress analysis.

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



GSI FOR HETEROGENEOUS ROCK MASSES SUCH AS FLYSCH (Marinos.P and Hoek. E, 2000)

From a description of the lithology, structure and surface conditions (particularly of the bedding planes), choose a box in the chart. Locate the position in the box that corresponds to the condition of the discontinuities and estimate the average value of GSI from the contours. Do not attempt to be too precise. Quoting a range from 33 to 37 is more realistic than giving GSI = 35. Note that the Hoek-Brown criterion does not apply to structurally controlled failures. Where unfavourably oriented continuous weak planar discontinuities are present, these will dominate the behaviour of the rock mass. The strength of some rock masses is reduced by the presence of groundwater and this can be allowed for by a slight shift to the right in the columns for fair, poor and very poor conditions. Water pressure does not change the value of GSI and it is dealt with by using effective stress analysis.

C,D, E and G - may be more or less folded than Ilustrated but this does not change the strength. Tectonic deformation, faulting and loss of continuity moves these categories to F and H.

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

Drilled Shaft Foundation Parameters

Client:	Belmont County Engineer's Office	**Calculated:** AKB	**Date:** 3/19/2024
Project:	BEL-TR428-0.30	**Checked:** MM	**Date:** 3/21/2024
Subject:	Bedrock Bearing Capacity		

Reference : Ohio DOT Bridge Design Manual (2020 Edition)
AASHTO LRFD Bridge Design Manual (2020)
Carter, J. P., and F. H. Kulhawy. *Analysis and Design of Drilled Shaft Foundations Socketed into Rock, Report No. EL-5918* . 1988

	Project Values		**Reference**	**Notes**
Unconfined Compressive Strength, Qu =	9000	psi	ASTM D7012 - Method C	See "Rock Strength Parameter Determination"
Slake Durability, SDI =	96	%	ASTM D4644	See "Rock Test Results"
Rock Quality Designation, RQD =	50	%	ODOT SGE Section 6	See "Rock Strength Parameter Determination"
Total Unit Weight, Y =	160	pcf		See "Rock Strength Parameter Determination"
Rock Mass Rating, RMR =	38			

AASHTO 10.8.3.5.4b - Side Resistance

Side Resistance, qs =	4.37	ksf		
	4368	psf		
$\frac{q_s}{p_a} = C\sqrt{\frac{q_u}{p_a}}$			AASHTO Eq. 10.8.35.4b-1	Per ODOT GDM do NOT use Eq 10.8.3.5.4b-2
Atmospheric pressure, pa =	2.12	ksf	As provided in AASHTO 10.8.3.5.4b	
Regression Coefficient, C =	1	(dim)	As provided in AASHTO 10.8.3.5.4b	
Uniaxial Compressive Strength of Rock, qu =	9	ksf	ASTM D7012 - Method C	See "Rock Strength Parameter Determination"

AASHTO 10.8.3.5.4c - Tip Resistance

$$q_p = 2.5q_u$$

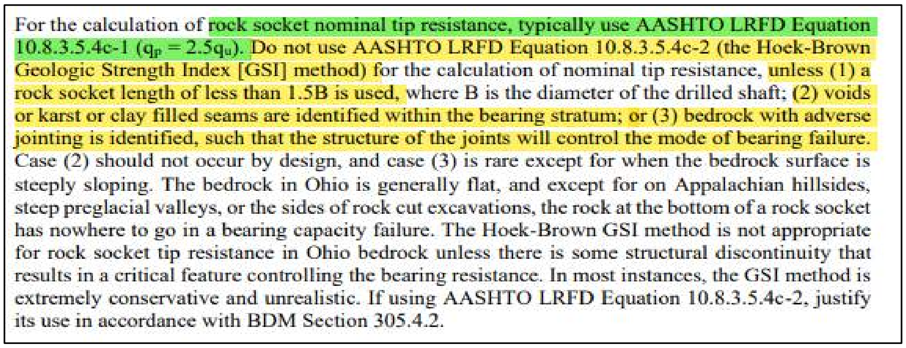
AASHTO Eq 10.8.3.5.4c-1

Assumes
1) Embedment > 1.5 B
2) No karst or clay-filled seams
3) No adverse jointing identified such that jointing will control bearing failure

Tip Resistance, qp =	22.50	ksf
	22500	psf

Uniaxial Compressive Strength of Rock, qu =	9	ksf	ASTM D7012 - Method C	See "Rock Strength Parameter Determination"

Per ODOT GDM 1306.4.2:



For the calculation of rock socket nominal tip resistance, typically use AASHTO LRFD Equation 10.8.3.5.4c-1 ($q_p = 2.5q_u$). Do not use AASHTO LRFD Equation 10.8.3.5.4c-2 (the Hoek-Brown Geologic Strength Index [GSI] method) for the calculation of nominal tip resistance, unless (1) a rock socket length of less than 1.5B is used, where B is the diameter of the drilled shaft; (2) voids or karst or clay filled seams are identified within the bearing stratum; or (3) bedrock with adverse jointing is identified, such that the structure of the joints will control the mode of bearing failure. Case (2) should not occur by design, and case (3) is rare except for when the bedrock surface is steeply sloping. The bedrock in Ohio is generally flat, and except for on Appalachian hillsides, steep preglacial valleys, or the sides of rock cut excavations, the rock at the bottom of a rock socket has nowhere to go in a bearing capacity failure. The Hoek-Brown GSI method is not appropriate for rock socket tip resistance in Ohio bedrock unless there is some structural discontinuity that results in a critical feature controlling the bearing resistance. In most instances, the GSI method is extremely conservative and unrealistic. If using AASHTO LRFD Equation 10.8.3.5.4c-2, justify its use in accordance with BDM Section 305.4.2.

Scour Analysis Parameters (Soil)

Project: BEL-TR248-0.30
Client: Belmont County Engineer
Task: **Scour Analysis**

Calculated By: AKB
Checked By: DMV

Date: 5/7/2024
Date: 5/13/2024

Reference

ODOT Geotechnical Design Manual (GDM)

Critical Shear Stress (Tc)

Cohesive Soils (GDM 1302.1.1)

$Tc = {}^{-2.0} (PI/100)^{1.3} (qu)^{0.4}$

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 (GDM 1302.1.2)

Tc (Pa) = D50 (mm)

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

Reference

Erosion Category (EC)

Cohesive Soils (GDM 1302.2)

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

PI = Plasticity index (dim)

Assume minimum PI = 4 for all soils (GDM 1302.1)

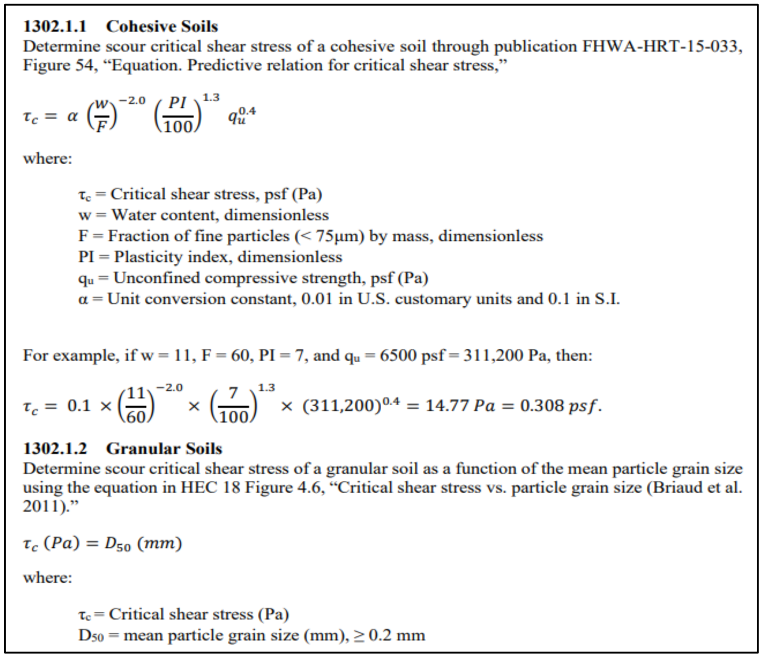
Granular Soils (GDM 1302.2)

EC = 1.2 [1.83333+log (D50)]

where $1 \leq EC \leq 6$

Boring No.	Sample	Elevation (ft)			D50	Moisture	Fines (< 75um)	Plasticiy	Unconfined Compressive Strength, Qu		Unit conversion	Tc (Pa)	Tc (psf)	D50, equivalent	EC (dim)
		Top		Bottom	(mm)	w (dim)	F (dim)	PI (dim)	Qu (psf)^{1,4}	Qu (Pa)	a (dim)			(mm)	
B-001-0-24	SS-3	881	-	879.5	0.0185	31	81	13	2000	**95739.6**	0.1	**4.729**	**0.099**	**4.729**	**3.26**
	SS-4	878.5	-	877	0.2835	4	29	9	Granular	**Granular**	0.1	**0.284**	**0.006**	**N/A**	**1.54**
B-002-0-24	SS-3	879	-	877.5	0.0608	46	54	5	2000	**95739.6**	0.1	**0.276**	**0.006**	**0.276**	**2.36**
	SS-4	876.5	-	875	4.7744	11	16	5	Granular	**Granular**	0.1	**4.774**	**0.100**	**N/A**	**3.01**
	SS-5	875	-	873.5	2.2981	15	20	6	Granular	**Granular**	0.1	**2.298**	**0.048**	**N/A**	**2.63**
	SS-6	873.5	-	872	5.2402	13	16	6	Granular	**Granular**	0.1	**5.240**	**0.109**	**N/A**	**3.06**
	SS-7	872	-	870.5	3.9118	16	18	10	Granular	**Granular**	0.1	**3.912**	**0.082**	**N/A**	**2.91**

1. See soil parameter determination sheet summary (Qu = 2(Su))
2. 1 Pa = 0.02089 psf
3. dim = dimensionless
4. Per ODOT GDM Section 1302.1, a value of Qu = 2000 psf was used for soils with Qu ≤ 1 tsf (2000 psf).



1302.1.1 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:

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

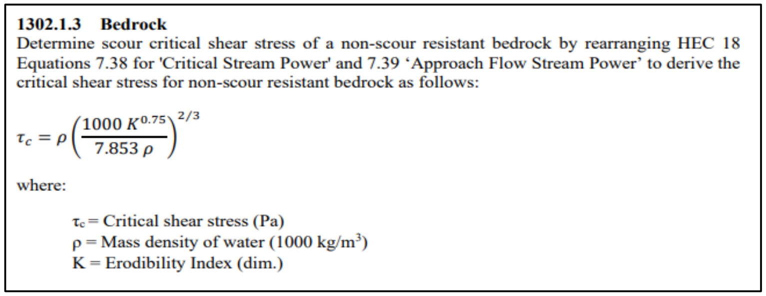
1302.1.2 Granular Soils

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



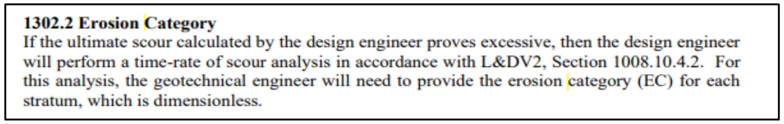
1302.1.3 Bedrock

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:

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

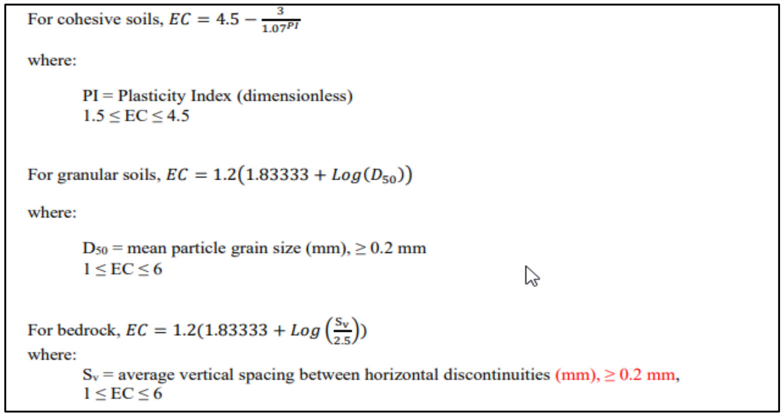
where:

τ_c = Critical shear stress (Pa)
ρ = Mass density of water (1000 kg/m^3)
K = Erodibility Index (dim.)



1302.2 Erosion Category

If the ultimate scour calculated by the design engineer proves excessive, then the design engineer will perform a time-rate of scour analysis in accordance with L&DV2, Section 1008.10.4.2. For this analysis, the geotechnical engineer will need to provide the erosion category (EC) for each stratum, which is dimensionless.



For cohesive soils, $EC = 4.5 - \frac{3}{1.07^{PI}}$

where:

PI = Plasticity Index (dimensionless)
1.5 ≤ EC ≤ 4.5

For granular soils, $EC = 1.2(1.83333 + Log(D_{50}))$

where:

D_{50} = mean particle grain size (mm), ≥ 0.2 mm
1 ≤ EC ≤ 6

For bedrock, $EC = 1.2(1.83333 + Log\left(\frac{S_v}{2.5}\right))$

where:

S_v = average vertical spacing between horizontal discontinuities (mm), ≥ 0.2 mm,
1 ≤ EC ≤ 6

Scour Analysis Parameters (Rock)

Client: Belmont County Engineer's Office
Project: BEL-TR428-0.30
Subject: HEC-18 Scour Analysis Parameters, Augered Siltstone, B-001-0-24
Reference : Ohio DOT Bridge Design Manual (2020 Edition)
AASHTO LRFD Bridge Design Manual (2020)
Page: 1

Calculated: AKB **Date:** 5/7/2024
Checked: DMV **Date:** 5/13/2024

ODOT BDM 305.2.1.2.b - Spread Footing Elevations For Foundations Inside the Limits of the 100-Yr Flood Plain

		Project Values		**Notes**	**Reference**
Unconfined Compressive Strength	Qu =	115	psi	See "Rock Strength Parameter Determination"	ASTM D7012 - Method C
	Qu =	0.8	MPa		
Intact Rock Mass Strength Parameter	Ms =	0.6	Ms = Qu	for Qu > 10 Mpa	(ODOT BDM 305.2.1.2.b)
			$Ms = (0.78)Qu^{1.05}$	for Qu < 10 Mpa	(ODOT BDM 305.2.1.2.b)
Rock Quality Designation	RQD =	0	%	Augerable bedrock	
Joint Set Number (Default value = 5)	Jn =	5		Joint Set - group of joints has the same dip angle and a strike angle	FHWA -HIF-12-003 : Evaluating Scour at Bridges
Block Size Parameter	Kb =	0.100	= RQD / Jn ≥ 0.10	- Due to lack of detailed information, assume default value	
Joint Roughness Number (Default value = 1)	Jr =	1		Small-scale features and intermediate-scale features. - Add 1.0 if mean spacing of the relevant joint set is greater than 3m, - Jr = 0.5 for planar, slickensided joints having lineation (assuming favorable orientation) - Due to lack of detailed information, assume default value	FHWA -HIF-12-003 : Evaluating Scour at Bridges
Joint Alteration Number (Default value = 5)	Ja =	5		- Due to lack of detailed information, assume default value	FHWA -HIF-12-003 : Evaluating Scour at Bridges
Shear Strength Parameter	Kd =	0.200	= Jr/Ja		
Relative Orientation Parameter (Default value = 0.4)	Js =	0.4		- Due to lack of detailed information, assume default value	FHWA -HIF-12-003 : Evaluating Scour at Bridges
Erodibility Index	K =	0.0	= (Ms)(Kb)(Kd)(Js)		FHWA-HIF-12-003 (HEC 18) - Section 4.7.2
Average Vertical Spacing Between Horizontal Discontinuities	Sv =	13	≥ 0.2 mm	- Assumed 0.5" based on fractured zone in upper cored bedrock	

Re-arrange 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:

$$\tau_c = \rho \left(\frac{1000\, K^{0.75}}{7.853\rho}\right)^{2/3} \qquad EC = 1.2\left(1.83333 + \log\left(\frac{S_v}{2.5}\right)\right)$$

Mass Density of Water	p =	1000	kg/m^3
Erodibility Index	K =	0.0	dim.
Critical Shear Stress	Tc =	17.7	Pa
	=	0.370	psf
	D50, equivalent =	17.701	mm
Erosion Category	EC =	3.06	

Client: Belmont County Engineer's Office
Project: BEL-TR428-0.30
Subject: Bedrock Parameters, Cored Siltstone, B-001-0-24
Reference : Ohio DOT Bridge Design Manual (2020 Edition)
AASHTO LRFD Bridge Design Manual (2020)
Page: 1 of 3

Calculated: AKB **Date:** 5/7/2024
Checked: DMV **Date:** 5/13/2024

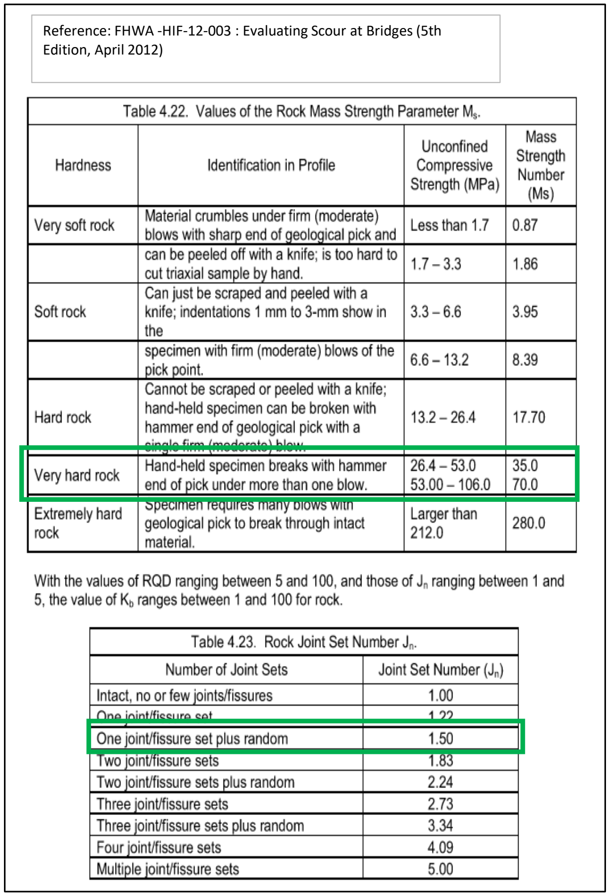
ODOT BDM 305.2.1.2.b - Spread Footing Elevations For Foundations Inside the Limits of the 100-Yr Flood Plain

NOTE: *"Scour reistant rock shall have the following properties to an elevation at least 4-ft below the Thalweg" (ODOT BDM 205.2.1.2.b-B)*

	Meets Requirement	**Project Values**		**Non-Scour requirement**			**Reference**	**Notes**
B-1 Unconfined Compressive Strength, Qu	**Yes**	9000	psi	Qu >	2500	psi	ASTM D7012 - Method C	See "Rock Strength Parameter Determination"
B-2 Slake Durability, SDI	**Yes**	96	%	SDI >	90	%	ASTM D4644	See "Rock Test Results"
B-3 Rock Quality Designation, RQD	**No**	60	%	RQD >	65	%	ODOT SGE Section 6	See "Rock Strength Parameter Determination"
B-4 Total Unit Weight, Y	**Yes**	160	pcf	Y >	150	pcf		See "Rock Strength Parameter Determination"
B-5 Rock Mass Strength	**No**							
		43		Rock Mass Rating ≥	75			
		or				or		
				Geologic Strength Index, GSI ≥	75		AASHTO LRFD 10.4.6.4	GSI not applicable to Spread footings
				with VG or Good Joint Surface Conditions				
				Massive or blocky Structure				
B-6 Erodibility Index, K	**Yes**	744.6		K ≥	100		FHWA-HIF-12-003 (HEC 18) - Section 4.7.2	
		K = (Ms)(Kb)(Kd)(Js)						
	Kb =	40.000	Kb = RQD / Jn ≥ 0.10					
	Kd =	0.750	Kd = Jr/Ja					
	Qu =	62.1	MPa					
	Ms =	62.1		Ms = Qu			for Qu ≥ 10 MPa (ODOT BDM 305.2.1.2.b)	
				$Ms = (0.78)Qu^{1.05}$			for Qu < 10 MPa (ODOT BDM 305.2.1.2.b)	
	Jn =	1.5	Joint Set Number (Default value = 5)				Joint Set - group of joints has the same dip angle and a strike angle	
	Jr =	1.5	Joint Roughness Number (Default value = 1)				Small-scale features and intermediate-scale features. - Add 1.0 if mean spacing of the relevant joint set is greater than 3m, - Jr = 0.5 for planar, slickensided joints having lineation (assuming favorable orientation)	
	Ja =	2	Joint Alteration Number (Default value = 5)					
	Js =	0.4	Relative Joint Orientation Parameter (Default value = 0.4)				- Due to lack of detailed information, assume default value	
B-7 Consider Weaker Interbedded Layers	**Yes**	Yes					ODOT BDM 305.2.1.2.b: B-7	For Interbedded rock formations, consider only weaker material
B-8 Non-Ordovician Rock Formation	**Yes**	Yes					ODOT BDM 305.2.1.2.b: B-8	No Ordovician bedrock formation may be considered as scour resistant
ALL 8 Criteria Met	6	No						

Client:	Belmont County Engineer's Office
Project:	BEL-TR428-0.30
Subject:	Bedrock Parameters, Cored Siltstone, B-001-0-24
Reference :	Ohio DOT Bridge Design Manual (2020 Edition) AASHTO LRFD Bridge Design Manual (2020)
Page:	2 of 3

ODOT BDM 305.2.1.2.b - Spread Footing Elevations For Foundations Inside the Limits of the 100-Yr Flood Plain



Reference: FHWA -HIF-12-003 : Evaluating Scour at Bridges (5th Edition, April 2012)

Table 4.22. Values of the Rock Mass Strength Parameter M_s.

Hardness	Identification in Profile	Unconfined Compressive Strength (MPa)	Mass Strength Number (Ms)
Very soft rock	Material crumbles under firm (moderate) blows with sharp end of geological pick and	Less than 1.7	0.87
	can be peeled off with a knife; is too hard to cut triaxial sample by hand.	1.7 – 3.3	1.86
Soft rock	Can just be scraped and peeled with a knife; indentations 1 mm to 3-mm show in the	3.3 – 6.6	3.95
	specimen with firm (moderate) blows of the pick point.	6.6 – 13.2	8.39
Hard rock	Cannot be scraped or peeled with a knife; hand-held specimen can be broken with hammer end of geological pick with a single firm (moderate) blow.	13.2 – 26.4	17.70
Very hard rock	Hand-held specimen breaks with hammer end of pick under more than one blow.	26.4 – 53.0 53.00 – 106.0	35.0 70.0
Extremely hard rock	Specimen requires many blows with geological pick to break through intact material.	Larger than 212.0	280.0

With the values of RQD ranging between 5 and 100, and those of J_n ranging between 1 and 5, the value of K_b ranges between 1 and 100 for rock.

Table 4.23. Rock Joint Set Number J_n.

Number of Joint Sets	Joint Set Number (J_n)
Intact, no or few joints/fissures	1.00
One joint/fissure set	1.22
One joint/fissure set plus random	1.50
Two joint/fissure sets	1.83
Two joint/fissure sets plus random	2.24
Three joint/fissure sets	2.73
Three joint/fissure sets plus random	3.34
Four joint/fissure sets	4.09
Multiple joint/fissure sets	5.00

psi
< 250
250 - 480
480 - 950
950 - 1900
1900 - 3800
3800 - 7600
7600 - 15300
> 30750

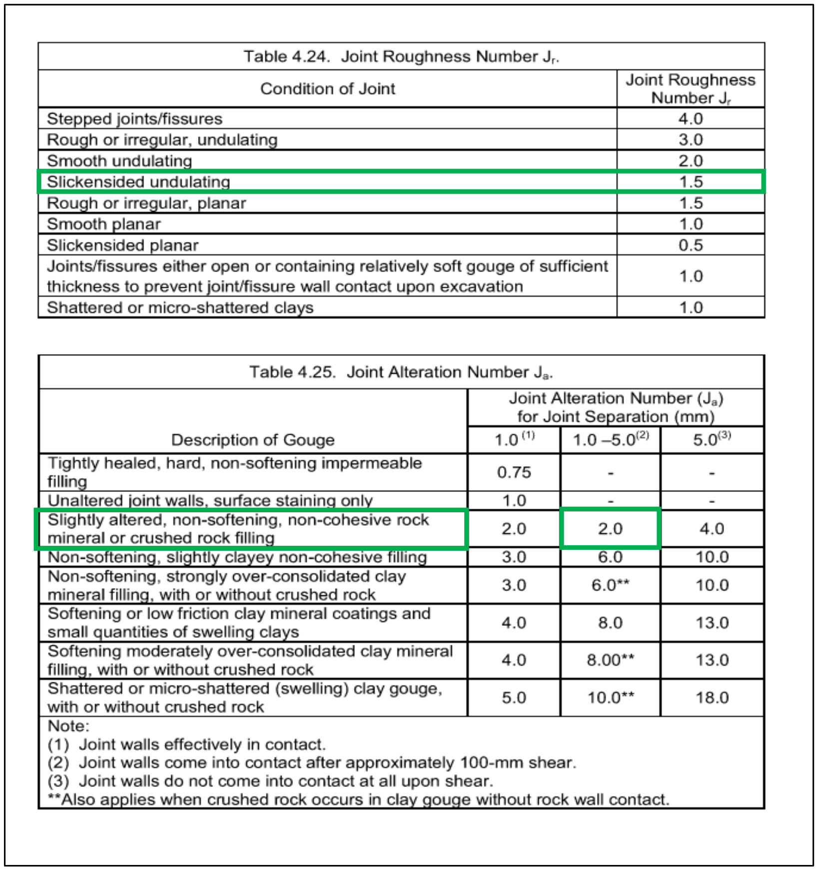


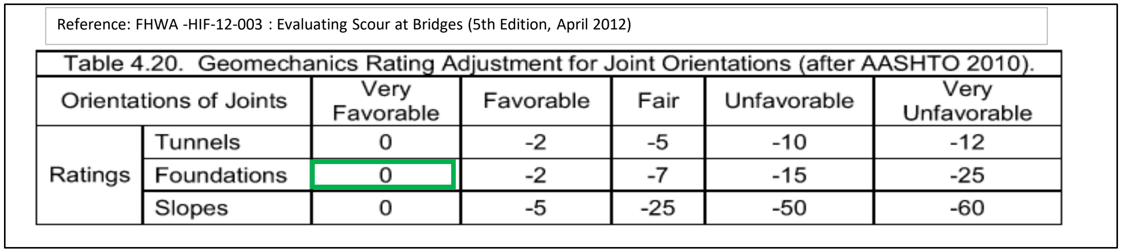
Table 4.24. Joint Roughness Number J_r.

Condition of Joint	Joint Roughness Number J_r
Stepped joints/fissures	4.0
Rough or irregular, undulating	3.0
Smooth undulating	2.0
Slickensided undulating	1.5
Rough or irregular, planar	1.5
Smooth planar	1.0
Slickensided planar	0.5
Joints/fissures either open or containing relatively soft gouge of sufficient thickness to prevent joint/fissure wall contact upon excavation	1.0
Shattered or micro-shattered clays	1.0

Table 4.25. Joint Alteration Number J_a.

Description of Gouge	Joint Alteration Number (J_a) for Joint Separation (mm)		
	1.0 $^{(1)}$	1.0 –5.0$^{(2)}$	5.0$^{(3)}$
Tightly healed, hard, non-softening impermeable filling	0.75	-	-
Unaltered joint walls, surface staining only	1.0	-	-
Slightly altered, non-softening, non-cohesive rock mineral or crushed rock filling	2.0	2.0	4.0
Non-softening, slightly clayey non-cohesive filling	3.0	6.0	10.0
Non-softening, strongly over-consolidated clay mineral filling, with or without crushed rock	3.0	6.0**	10.0
Softening or low friction clay mineral coatings and small quantities of swelling clays	4.0	8.0	13.0
Softening moderately over-consolidated clay mineral filling, with or without crushed rock	4.0	8.00**	13.0
Shattered or micro-shattered (swelling) clay gouge, with or without crushed rock	5.0	10.0**	18.0

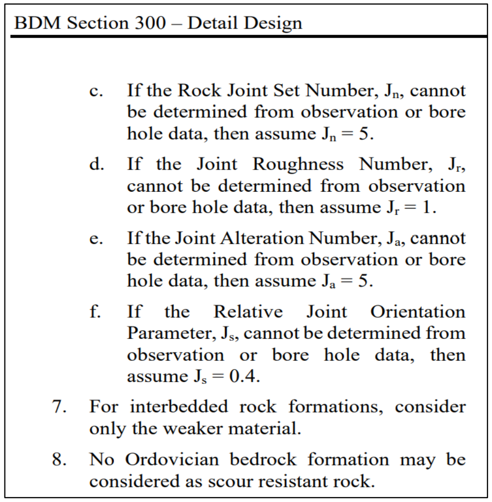
Note:
(1) Joint walls effectively in contact.
(2) Joint walls come into contact after approximately 100-mm shear.
(3) Joint walls do not come into contact at all upon shear.
**Also applies when crushed rock occurs in clay gouge without rock wall contact.



Reference: FHWA -HIF-12-003 : Evaluating Scour at Bridges (5th Edition, April 2012)

Table 4.20. Geomechanics Rating Adjustment for Joint Orientations (after AASHTO 2010).

Orientations of Joints		Very Favorable	Favorable	Fair	Unfavorable	Very Unfavorable
Ratings	Tunnels	0	-2	-5	-10	-12
	Foundations	0	-2	-7	-15	-25
	Slopes	0	-5	-25	-50	-60



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c. If the Rock Joint Set Number, J_n, cannot be determined from observation or bore hole data, then assume $J_n = 5$.

d. If the Joint Roughness Number, J_r, cannot be determined from observation or bore hole data, then assume $J_r = 1$.

e. If the Joint Alteration Number, J_a, cannot be determined from observation or bore hole data, then assume $J_a = 5$.

f. If the Relative Joint Orientation Parameter, J_s, cannot be determined from observation or bore hole data, then assume $J_s = 0.4$.

7. For interbedded rock formations, consider only the weaker material.

8. No Ordovician bedrock formation may be considered as scour resistant rock.

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ODOT BDM 305.2.1.2.b - Spread Footing Elevations For Foundations Inside the Limits of the 100-Yr Flood Plain

Relative Rating

7

13

10

6

7

RMR
43

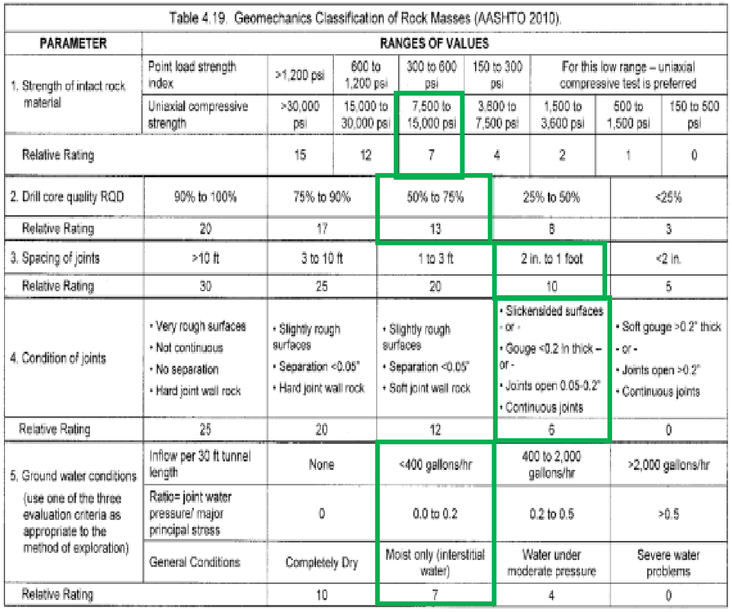

Table 4.19. Geomechanics Classification of Rock Masses (AASHTO 2010).

PARAMETER	RANGES OF VALUES								
1. Strength of intact rock material	Point load strength index	>1,200 psi	600 to 1,200 psi	300 to 600 psi	150 to 300 psi	For this low range – uniaxial compressive test is preferred			
	Uniaxial compressive strength	>30,000 psi	15,000 to 30,000 psi	7,500 to 15,000 psi	3,800 to 7,500 psi	1,500 to 3,600 psi	500 to 1,500 psi	150 to 500 psi
Relative Rating		15	12	7	4	2	1	0

PARAMETER	RANGES OF VALUES				
2. Drill core quality RQD	90% to 100%	75% to 90%	50% to 75%	25% to 50%	<25%
Relative Rating	20	17	13	8	3
3. Spacing of joints	>10 ft	3 to 10 ft	1 to 3 ft	2 in. to 1 foot	<2 in.
Relative Rating	30	25	20	10	5
4. Condition of joints	• Very rough surfaces • Not continuous • No separation • Hard joint wall rock	• Slightly rough surfaces • Separation <0.05" • Hard joint wall rock	• Slightly rough surfaces • Separation <0.05" • Soft joint wall rock	• Slickensided surfaces - or - • Gouge <0.2 in thick – or - • Joints open 0.05-0.2" • Continuous joints	• Soft gouge >0.2" thick • or - • Joints open >0.2" • Continuous joints
Relative Rating	25	20	12	6	0
5. Ground water conditions (use one of the three evaluation criteria as appropriate to the method of exploration)	Inflow per 30 ft tunnel length	None	<400 gallons/hr	400 to 2,000 gallons/hr	>2,000 gallons/hr
	Ratio= joint water pressure/ major principal stress	0	0.0 to 0.2	0.2 to 0.5	>0.5
	General Conditions	Completely Dry	Moist only (interstitial water)	Water under moderate pressure	Severe water problems
Relative Rating		10	7	4	0

Reference: FHWA -HIF-12-003 : Evaluating Scour at Bridges (5th Edition, April 2012)

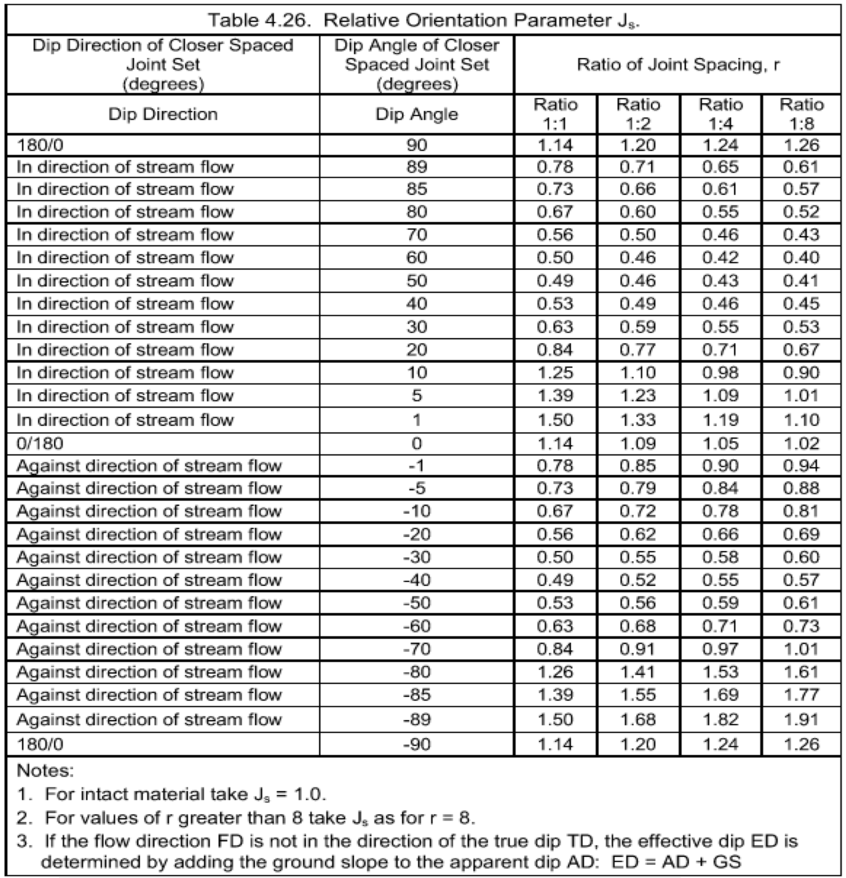

Table 4.26. Relative Orientation Parameter J_s.

Dip Direction of Closer Spaced Joint Set (degrees)	Dip Angle of Closer Spaced Joint Set (degrees)	Ratio of Joint Spacing, r			
Dip Direction	Dip Angle	Ratio 1:1	Ratio 1:2	Ratio 1:4	Ratio 1:8
180/0	90	1.14	1.20	1.24	1.26
In direction of stream flow	89	0.78	0.71	0.65	0.61
In direction of stream flow	85	0.73	0.66	0.61	0.57
In direction of stream flow	80	0.67	0.60	0.55	0.52
In direction of stream flow	70	0.56	0.50	0.46	0.43
In direction of stream flow	60	0.50	0.46	0.42	0.40
In direction of stream flow	50	0.49	0.46	0.43	0.41
In direction of stream flow	40	0.53	0.49	0.46	0.45
In direction of stream flow	30	0.63	0.59	0.55	0.53
In direction of stream flow	20	0.84	0.77	0.71	0.67
In direction of stream flow	10	1.25	1.10	0.98	0.90
In direction of stream flow	5	1.39	1.23	1.09	1.01
In direction of stream flow	1	1.50	1.33	1.19	1.10
0/180	0	1.14	1.09	1.05	1.02
Against direction of stream flow	-1	0.78	0.85	0.90	0.94
Against direction of stream flow	-5	0.73	0.79	0.84	0.88
Against direction of stream flow	-10	0.67	0.72	0.78	0.81
Against direction of stream flow	-20	0.56	0.62	0.66	0.69
Against direction of stream flow	-30	0.50	0.55	0.58	0.60
Against direction of stream flow	-40	0.49	0.52	0.55	0.57
Against direction of stream flow	-50	0.53	0.56	0.59	0.61
Against direction of stream flow	-60	0.63	0.68	0.71	0.73
Against direction of stream flow	-70	0.84	0.91	0.97	1.01
Against direction of stream flow	-80	1.26	1.41	1.53	1.61
Against direction of stream flow	-85	1.39	1.55	1.69	1.77
Against direction of stream flow	-89	1.50	1.68	1.82	1.91
180/0	-90	1.14	1.20	1.24	1.26

Notes:
1. For intact material take J_s = 1.0.
2. For values of r greater than 8 take J_s as for r = 8.
3. If the flow direction FD is not in the direction of the true dip TD, the effective dip ED is determined by adding the ground slope to the apparent dip AD: ED = AD + GS

Reference: FHWA -HIF-12-003 : Evaluating Scour at Bridges (5th Edition, April 2012)

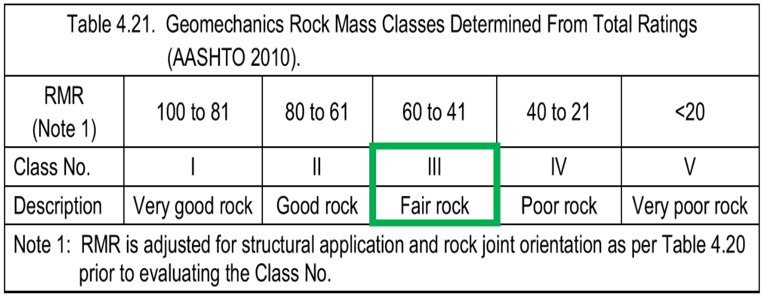

Table 4.21. Geomechanics Rock Mass Classes Determined From Total Ratings (AASHTO 2010).

RMR (Note 1)	100 to 81	80 to 61	60 to 41	40 to 21	<20
Class No.	I	II	III	IV	V
Description	Very good rock	Good rock	Fair rock	Poor rock	Very poor rock

Note 1: RMR is adjusted for structural application and rock joint orientation as per Table 4.20 prior to evaluating the Class No.

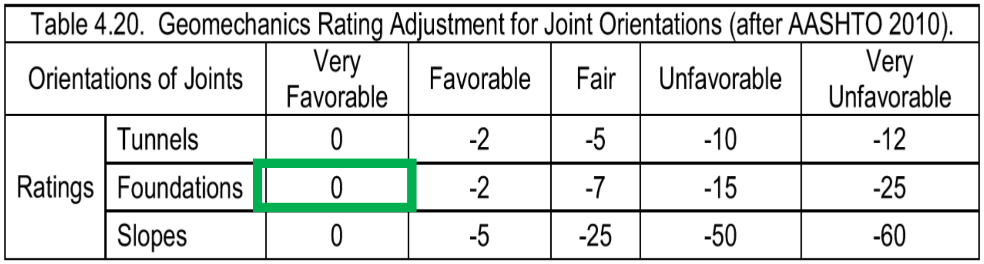

Table 4.20. Geomechanics Rating Adjustment for Joint Orientations (after AASHTO 2010).

Orientations of Joints		Very Favorable	Favorable	Fair	Unfavorable	Very Unfavorable
Ratings	Tunnels	0	-2	-5	-10	-12
	Foundations	0	-2	-7	-15	-25
	Slopes	0	-5	-25	-50	-60

Client: Belmont County Engineer's Office
Project: BEL-TR428-0.30
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Checked: DMV **Date:** 5/13/2024

ODOT BDM 305.2.1.2.b - Spread Footing Elevations For Foundations Inside the Limits of the 100-Yr Flood Plain

		Project Values		**Notes**	**Reference**
Unconfined Compressive Strength	Qu =	9000	psi	See "Rock Strength Parameter Determination"	ASTM D7012 - Method C
	Qu =	62.1	MPa		
Intact Rock Mass Strength Parameter	Ms =	62.1	Ms = Qu	for Qu > 10 Mpa	(ODOT BDM 305.2.1.2.b)
			Ms = (0.78)Qu $^{1.05}$	for Qu < 10 Mpa	(ODOT BDM 305.2.1.2.b)
Rock Quality Designation	RQD =	60	%	See "Rock Strength Parameter Determination"	ODOT SGE Section 6
Joint Set Number (Default value = 5)	Jn =	1.5		Joint Set - group of joints has the same dip angle and a strike angle	FHWA -HIF-12-003 : Evaluating Scour at Bridges
Block Size Parameter	Kb =	40.000	= RQD / Jn ≥ 0.10		
Joint Roughness Number (Default value = 1)	Jr =	1.5		Small-scale features and intermediate-scale features. - Add 1.0 if mean spacing of the relevant joint set is greater than 3m, - Jr = 0.5 for planar, slickensided joints having lineation (assuming favorable orientation)	FHWA -HIF-12-003 : Evaluating Scour at Bridges
Joint Alteration Number (Default value = 5)	Ja =	2			FHWA -HIF-12-003 : Evaluating Scour at Bridges
Shear Strength Parameter	Kd =	0.750	= Jr/Ja		
Relative Orientation Parameter (Default value = 0.4)	Js =	0.4		- Due to lack of detailed information, assume default value	FHWA -HIF-12-003 : Evaluating Scour at Bridges
Erodibility Index	K =	744.6	= (Ms)(Kb)(Kd)(Js)		FHWA-HIF-12-003 (HEC 18) - Section 4.7.2
Average Vertical Spacing Between Horizontal Discontinuities	Sv =	100	≥ 0.2 mm		

Re-arrange 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:

$$\tau_c = \rho\left(\frac{1000\,K^{0.75}}{7.853\rho}\right)^{2/3} \qquad EC = 1.2\left(1.83333 + \log\left(\frac{S_v}{2.5}\right)\right)$$

Mass Density of Water	p =	1000	kg/m^3
Erodibility Index	K =	744.6	dim.
Critical Shear Stress	Tc =	6906.9	Pa
	=	144.253	psf
	D50, equivalent =	6906.866	mm
Erosion Category	EC =	4.12	

Client:	Belmont County Engineer's Office	**Calculated:** AKB	**Date:** 5/7/2024
Project:	BEL-TR428-0.30	**Checked:** DMV	**Date:** 5/13/2024
Subject:	HEC-18 Scour Analysis Parameters, Augered Siltstone, B-002-0-24		
Reference :	Ohio DOT Bridge Design Manual (2020 Edition) AASHTO LRFD Bridge Design Manual (2020)		
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ODOT BDM 305.2.1.2.b - Spread Footing Elevations For Foundations Inside the Limits of the 100-Yr Flood Plain

		Project Values		**Notes**	**Reference**
Unconfined Compressive Strength	Qu =	115	psi	See "Rock Strength Parameter Determination"	ASTM D7012 - Method C
	Qu =	0.8	MPa		
Intact Rock Mass Strength Parameter	Ms =	0.6	Ms = Qu	for Qu > 10 Mpa	(ODOT BDM 305.2.1.2.b)
			Ms = (0.78)Qu $^{1.05}$	for Qu < 10 Mpa	(ODOT BDM 305.2.1.2.b)
Rock Quality Designation	RQD =	0	%	Augerable bedrock	
Joint Set Number (Default value = 5)	Jn =	5		Joint Set - group of joints has the same dip angle and a strike angle	FHWA -HIF-12-003 : Evaluating Scour at Bridges
Block Size Parameter	Kb =	0.100	= RQD / Jn ≥ 0.10	- Due to lack of detailed information, assume default value	
Joint Roughness Number (Default value = 1)	Jr =	1		Small-scale features and intermediate-scale features. - Add 1.0 if mean spacing of the relevant joint set is greater than 3m, - Jr = 0.5 for planar, slickensided joints having lineation (assuming favorable orientation) - Due to lack of detailed information, assume default value	FHWA -HIF-12-003 : Evaluating Scour at Bridges
Joint Alteration Number (Default value = 5)	Ja =	5		- Due to lack of detailed information, assume default value	FHWA -HIF-12-003 : Evaluating Scour at Bridges
Shear Strength Parameter	Kd =	0.200	= Jr/Ja		
Relative Orientation Parameter (Default value = 0.4)	Js =	0.4		- Due to lack of detailed information, assume default value	FHWA -HIF-12-003 : Evaluating Scour at Bridges
Erodibility Index	K =	0.0	= (Ms)(Kb)(Kd)(Js)		FHWA-HIF-12-003 (HEC 18) - Section 4.7.2
Average Vertical Spacing Between Horizontal Discontinuities	Sv =	13	≥ 0.2 mm	- Assumed 0.5" based on fractured zone in upper cored bedrock	

Re-arrange 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:

$$\tau_c = \rho \left(\frac{1000\ K^{0.75}}{7.853\rho} \right)^{2/3} \qquad EC = 1.2\left(1.83333 + \log\left(\frac{S_v}{2.5}\right)\right)$$

Mass Density of Water	p =	1000	kg/m ^{3}
Erodibility Index	K =	0.0	dim.
Critical Shear Stress	Tc =	17.7	Pa
	=	0.370	psf
	D50, equivalent =	17.701	mm
Erosion Category	EC =	3.06	

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ODOT BDM 305.2.1.2.b - Spread Footing Elevations For Foundations Inside the Limits of the 100-Yr Flood Plain

NOTE: *"Scour reistant rock shall have the following properties to an elevation at least 4-ft below the Thalweg" (ODOT BDM 205.2.1.2.b-B)*

	Meets Requirement	Project Values		Non-Scour requirement			Reference	Notes
B-1 Unconfined Compressive Strength, Qu	Yes	9000	psi	Qu >	2500	psi	ASTM D7012 - Method C	See "Rock Strength Parameter Determination"
B-2 Slake Durability, SDI	Yes	96	%	SDI >	90	%	ASTM D4644	See "Rock Test Results"
B-3 Rock Quality Designation, RQD	No	40	%	RQD >	65	%	ODOT SGE Section 6	See "Rock Strength Parameter Determination"
B-4 Total Unit Weight, Y	Yes	160	pcf	Y >	150	pcf		See "Rock Strength Parameter Determination"
B-5 Rock Mass Strength	No							
		38		Rock Mass Rating ≥	75			
		or				or		
				Geologic Strength Index, GSI ≥	75		AASHTO LRFD 10.4.6.4	GSI not applicable to Spread footings
				with VG or Good Joint Surface Conditions				
				Massive or blocky Structure				
B-6 Erodibility Index, K	Yes	496.4		K ≥	100		FHWA-HIF-12-003 (HEC 18) - Section 4.7.2	
		K = (Ms)(Kb)(Kd)(Js)						
	Kb =	26.667	Kb = RQD / Jn ≥ 0.10					
	Kd =	0.750	Kd = Jr/Ja					
	Qu =	62.1	MPa					
	Ms =	62.1		Ms = Qu			for Qu ≥ 10 MPa (ODOT BDM 305.2.1.2.b)	
				$Ms = (0.78)Qu^{1.05}$			for Qu < 10 MPa (ODOT BDM 305.2.1.2.b)	
	Jn =	1.5	Joint Set Number (Default value = 5)				Joint Set - group of joints has the same dip angle and a strike angle	
	Jr =	1.5	Joint Roughness Number (Default value = 1)				Small-scale features and intermediate-scale features. - Add 1.0 if mean spacing of the relevant joint set is greater than 3m, - Jr = 0.5 for planar, slickensided joints having lineation (assuming favorable orientation)	
	Ja =	2	Joint Alteration Number (Default value = 5)					
	Js =	0.4	Relative Joint Orientation Parameter (Default value = 0.4)				- Due to lack of detailed information, assume default value	
B-7 Consider Weaker Interbedded Layers	Yes	Yes					ODOT BDM 305.2.1.2.b: B-7	For Interbedded rock formations, consider only weaker material
B-8 Non-Ordovician Rock Formation	Yes	Yes					ODOT BDM 305.2.1.2.b: B-8	No Ordovician bedrock formation may be considered as scour resistant
ALL 8 Criteria Met	6	No						

Client: Belmont County Engineer's Office
Project: BEL-TR428-0.30
Subject: Bedrock Parameters, Cored Siltstone, B-002-0-24
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Reference: FHWA -HIF-12-003 : Evaluating Scour at Bridges (5th Edition, April 2012)

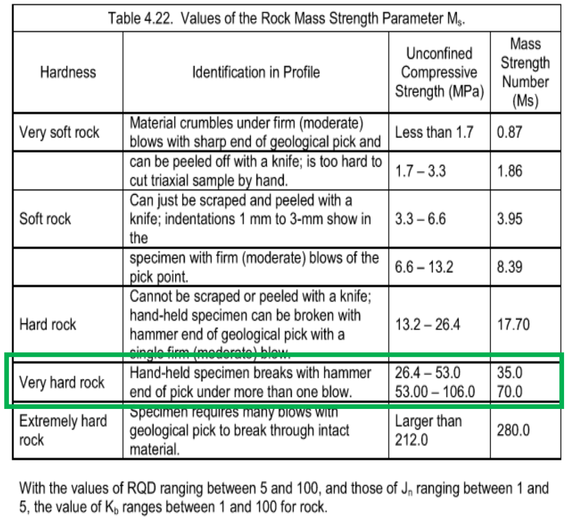


Table 4.22. Values of the Rock Mass Strength Parameter M_s.

Hardness	Identification in Profile	Unconfined Compressive Strength (MPa)	Mass Strength Number (Ms)	**psi**
Very soft rock	Material crumbles under firm (moderate) blows with sharp end of geological pick and	Less than 1.7	0.87	< 250
	can be peeled off with a knife; is too hard to cut triaxial sample by hand.	1.7 – 3.3	1.86	250 - 480
Soft rock	Can just be scraped and peeled with a knife; indentations 1 mm to 3-mm show in the	3.3 – 6.6	3.95	480 - 950
	specimen with firm (moderate) blows of the pick point.	6.6 – 13.2	8.39	950 - 1900
Hard rock	Cannot be scraped or peeled with a knife; hand-held specimen can be broken with hammer end of geological pick with a single firm (moderate) blow.	13.2 – 26.4	17.70	1900 - 3800
Very hard rock	Hand-held specimen breaks with hammer end of pick under more than one blow.	26.4 – 53.0 53.00 – 106.0	35.0 70.0	3800 - 7600 7600 - 15300
Extremely hard rock	Specimen requires many blows with geological pick to break through intact material.	Larger than 212.0	280.0	> 30750

With the values of RQD ranging between 5 and 100, and those of J_n ranging between 1 and 5, the value of K_b ranges between 1 and 100 for rock.

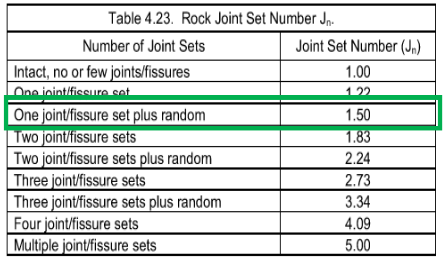


Table 4.23. Rock Joint Set Number J_n.

Number of Joint Sets	Joint Set Number (J_n)
Intact, no or few joints/fissures	1.00
One joint/fissure set	1.22
One joint/fissure set plus random	1.50
Two joint/fissure sets	1.83
Two joint/fissure sets plus random	2.24
Three joint/fissure sets	2.73
Three joint/fissure sets plus random	3.34
Four joint/fissure sets	4.09
Multiple joint/fissure sets	5.00

Reference: FHWA -HIF-12-003 : Evaluating Scour at Bridges (5th Edition, April 2012)

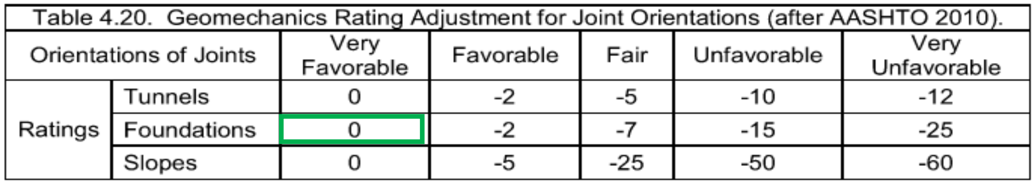


Table 4.20. Geomechanics Rating Adjustment for Joint Orientations (after AASHTO 2010).

Orientations of Joints		Very Favorable	Favorable	Fair	Unfavorable	Very Unfavorable
Ratings	Tunnels	0	-2	-5	-10	-12
	Foundations	0	-2	-7	-15	-25
	Slopes	0	-5	-25	-50	-60

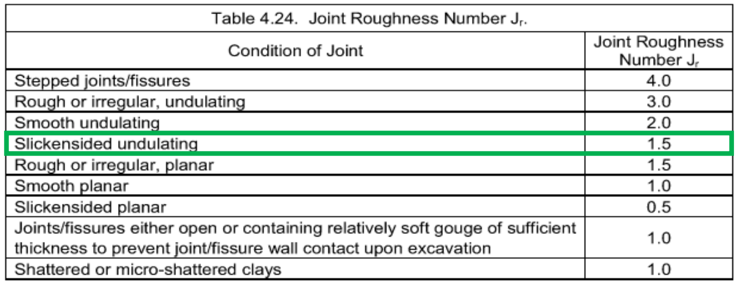


Table 4.24. Joint Roughness Number J_r.

Condition of Joint	Joint Roughness Number J_r
Stepped joints/fissures	4.0
Rough or irregular, undulating	3.0
Smooth undulating	2.0
Slickensided undulating	1.5
Rough or irregular, planar	1.5
Smooth planar	1.0
Slickensided planar	0.5
Joints/fissures either open or containing relatively soft gouge of sufficient thickness to prevent joint/fissure wall contact upon excavation	1.0
Shattered or micro-shattered clays	1.0

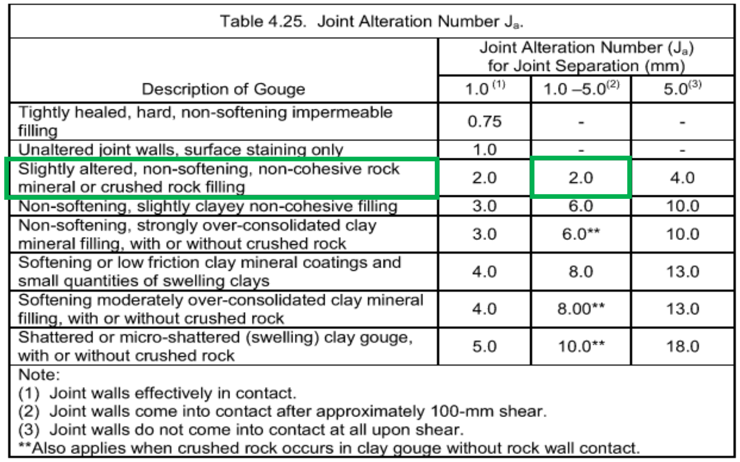
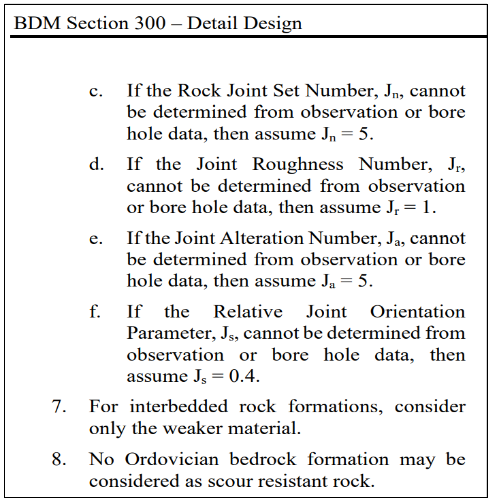


Table 4.25. Joint Alteration Number J_a.

Description of Gouge	Joint Alteration Number (J_a) for Joint Separation (mm)		
	1.0 (1)	1.0 –5.0(2)	5.0(3)
Tightly healed, hard, non-softening impermeable filling	0.75	-	-
Unaltered joint walls, surface staining only	1.0	-	-
Slightly altered, non-softening, non-cohesive rock mineral or crushed rock filling	2.0	2.0	4.0
Non-softening, slightly clayey non-cohesive filling	3.0	6.0	10.0
Non-softening, strongly over-consolidated clay mineral filling, with or without crushed rock	3.0	6.0**	10.0
Softening or low friction clay mineral coatings and small quantities of swelling clays	4.0	8.0	13.0
Softening moderately over-consolidated clay mineral filling, with or without crushed rock	4.0	8.00**	13.0
Shattered or micro-shattered (swelling) clay gouge, with or without crushed rock	5.0	10.0**	18.0

Note:
(1) Joint walls effectively in contact.
(2) Joint walls come into contact after approximately 100-mm shear.
(3) Joint walls do not come into contact at all upon shear.
**Also applies when crushed rock occurs in clay gouge without rock wall contact.



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c. If the Rock Joint Set Number, J_n, cannot be determined from observation or bore hole data, then assume $J_n = 5$.

d. If the Joint Roughness Number, J_r, cannot be determined from observation or bore hole data, then assume $J_r = 1$.

e. If the Joint Alteration Number, J_a, cannot be determined from observation or bore hole data, then assume $J_a = 5$.

f. If the Relative Joint Orientation Parameter, J_s, cannot be determined from observation or bore hole data, then assume $J_s = 0.4$.

7. For interbedded rock formations, consider only the weaker material.

8. No Ordovician bedrock formation may be considered as scour resistant rock.

Client: Belmont County Engineer's Office
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Relative Rating
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RMR
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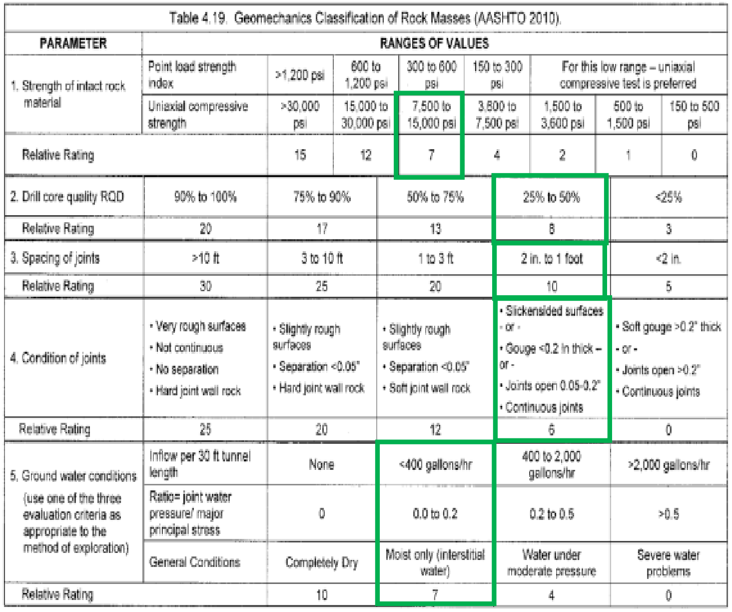

Table 4.19. Geomechanics Classification of Rock Masses (AASHTO 2010).

PARAMETER	RANGES OF VALUES							
1. Strength of intact rock material	Point load strength index	>1,200 psi	600 to 1,200 psi	300 to 600 psi	150 to 300 psi	For this low range – uniaxial compressive test is preferred		
	Uniaxial compressive strength	>30,000 psi	15,000 to 30,000 psi	7,500 to 15,000 psi	3,600 to 7,500 psi	1,500 to 3,600 psi	500 to 1,500 psi	150 to 500 psi
Relative Rating		15	12	7	4	2	1	0
2. Drill core quality RQD	90% to 100%	75% to 90%	50% to 75%	25% to 50%	<25%			
Relative Rating	20	17	13	8	3			
3. Spacing of joints	>10 ft	3 to 10 ft	1 to 3 ft	2 in. to 1 foot	<2 in.			
Relative Rating	30	25	20	10	5			
4. Condition of joints	• Very rough surfaces • Not continuous • No separation • Hard joint wall rock	• Slightly rough surfaces • Separation <0.05" • Hard joint wall rock	• Slightly rough surfaces • Separation <0.05" • Soft joint wall rock	• Slickensided surfaces - or - • Gouge <0.2 in thick – or - • Joints open 0.05-0.2" • Continuous joints	• Soft gouge >0.2" thick - or - • Joints open >0.2" • Continuous joints			
Relative Rating	25	20	12	6	0			
5. Ground water conditions (use one of the three evaluation criteria as appropriate to the method of exploration)	Inflow per 30 ft tunnel length	None	<400 gallons/hr	400 to 2,000 gallons/hr	>2,000 gallons/hr			
	Ratio= joint water pressure/ major principal stress	0	0.0 to 0.2	0.2 to 0.5	>0.5			
	General Conditions	Completely Dry	Moist only (interstitial water)	Water under moderate pressure	Severe water problems			
Relative Rating		10	7	4	0			

Reference: FHWA -HIF-12-003 : Evaluating Scour at Bridges (5th Edition, April 2012)

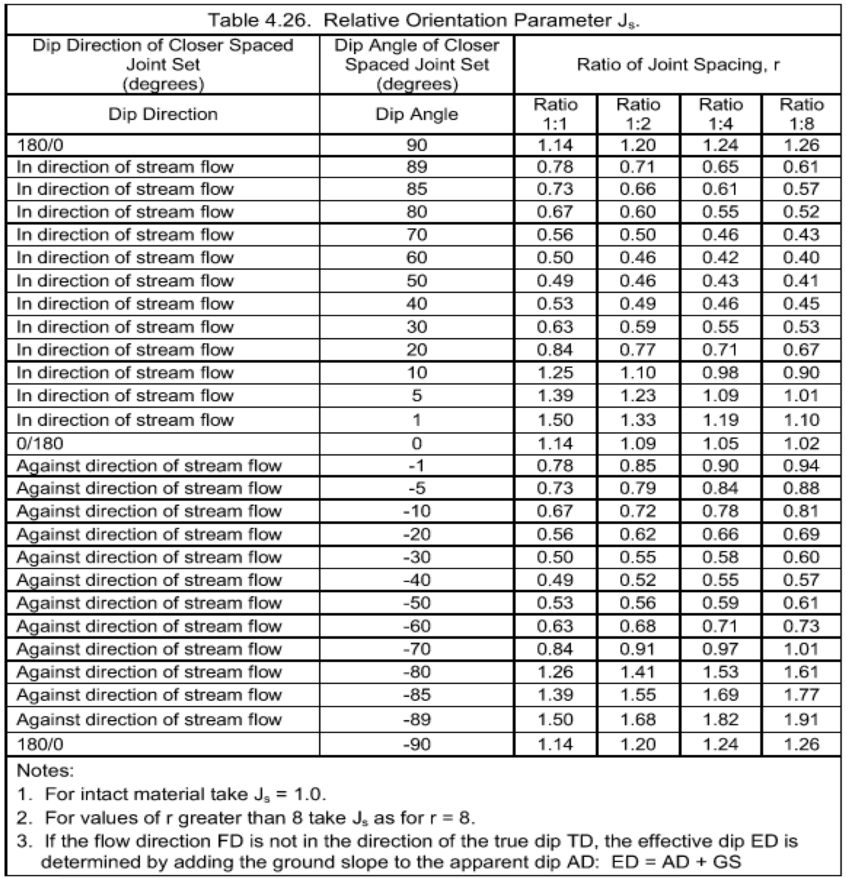

Table 4.26. Relative Orientation Parameter J_s.

Dip Direction of Closer Spaced Joint Set (degrees)	Dip Angle of Closer Spaced Joint Set (degrees)	Ratio of Joint Spacing, r			
Dip Direction	Dip Angle	Ratio 1:1	Ratio 1:2	Ratio 1:4	Ratio 1:8
180/0	90	1.14	1.20	1.24	1.26
In direction of stream flow	89	0.78	0.71	0.65	0.61
In direction of stream flow	85	0.73	0.66	0.61	0.57
In direction of stream flow	80	0.67	0.60	0.55	0.52
In direction of stream flow	70	0.56	0.50	0.46	0.43
In direction of stream flow	60	0.50	0.46	0.42	0.40
In direction of stream flow	50	0.49	0.46	0.43	0.41
In direction of stream flow	40	0.53	0.49	0.46	0.45
In direction of stream flow	30	0.63	0.59	0.55	0.53
In direction of stream flow	20	0.84	0.77	0.71	0.67
In direction of stream flow	10	1.25	1.10	0.98	0.90
In direction of stream flow	5	1.39	1.23	1.09	1.01
In direction of stream flow	1	1.50	1.33	1.19	1.10
0/180	0	1.14	1.09	1.05	1.02
Against direction of stream flow	-1	0.78	0.85	0.90	0.94
Against direction of stream flow	-5	0.73	0.79	0.84	0.88
Against direction of stream flow	-10	0.67	0.72	0.78	0.81
Against direction of stream flow	-20	0.56	0.62	0.66	0.69
Against direction of stream flow	-30	0.50	0.55	0.58	0.60
Against direction of stream flow	-40	0.49	0.52	0.55	0.57
Against direction of stream flow	-50	0.53	0.56	0.59	0.61
Against direction of stream flow	-60	0.63	0.68	0.71	0.73
Against direction of stream flow	-70	0.84	0.91	0.97	1.01
Against direction of stream flow	-80	1.26	1.41	1.53	1.61
Against direction of stream flow	-85	1.39	1.55	1.69	1.77
Against direction of stream flow	-89	1.50	1.68	1.82	1.91
180/0	-90	1.14	1.20	1.24	1.26

Notes:
1. For intact material take $J_s = 1.0$.
2. For values of r greater than 8 take J_s as for r = 8.
3. If the flow direction FD is not in the direction of the true dip TD, the effective dip ED is determined by adding the ground slope to the apparent dip AD: ED = AD + GS

Reference: FHWA -HIF-12-003 : Evaluating Scour at Bridges (5th Edition, April 2012)

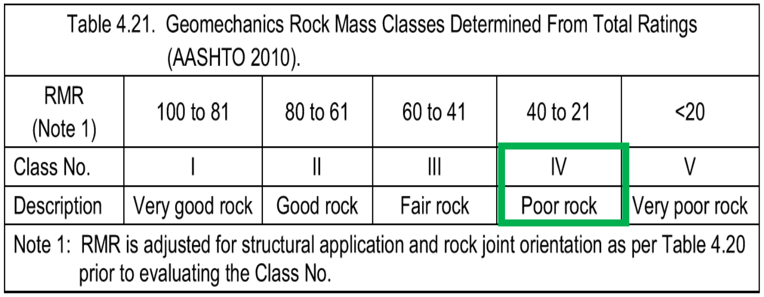

Table 4.21. Geomechanics Rock Mass Classes Determined From Total Ratings (AASHTO 2010).

RMR (Note 1)	100 to 81	80 to 61	60 to 41	40 to 21	<20
Class No.	I	II	III	IV	V
Description	Very good rock	Good rock	Fair rock	Poor rock	Very poor rock

Note 1: RMR is adjusted for structural application and rock joint orientation as per Table 4.20 prior to evaluating the Class No.

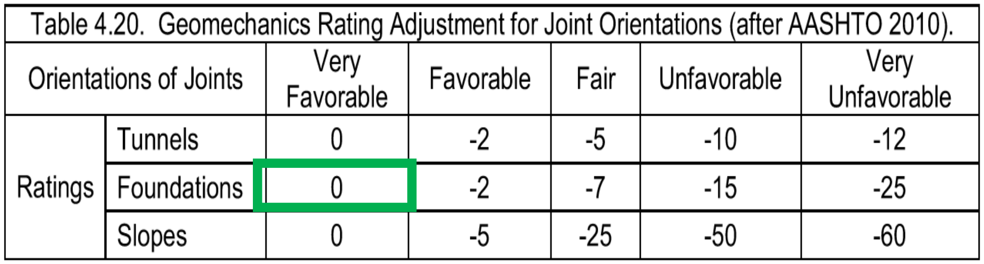

Table 4.20. Geomechanics Rating Adjustment for Joint Orientations (after AASHTO 2010).

Orientations of Joints		Very Favorable	Favorable	Fair	Unfavorable	Very Unfavorable
Ratings	Tunnels	0	-2	-5	-10	-12
	Foundations	0	-2	-7	-15	-25
	Slopes	0	-5	-25	-50	-60

Client: Belmont County Engineer's Office
Project: BEL-TR428-0.30
Subject: HEC-18 Scour Analysis Parameters, Cored Siltstone, B-002-0-24
Reference : Ohio DOT Bridge Design Manual (2020 Edition)
AASHTO LRFD Bridge Design Manual (2020)
Page: 1

Calculated: AKB **Date:** 5/7/2024
Checked: DMV **Date:** 5/13/2024

ODOT BDM 305.2.1.2.b - Spread Footing Elevations For Foundations Inside the Limits of the 100-Yr Flood Plain

		Project Values		**Notes**	**Reference**
Unconfined Compressive Strength	Qu =	9000	psi	See "Rock Strength Parameter Determination"	ASTM D7012 - Method C
	Qu =	62.1	MPa		
Intact Rock Mass Strength Parameter	Ms =	62.1	Ms = Qu	for Qu > 10 Mpa	(ODOT BDM 305.2.1.2.b)
			Ms = (0.78)Qu $^{1.05}$	for Qu < 10 Mpa	(ODOT BDM 305.2.1.2.b)
Rock Quality Designation	RQD =	40	%	See "Rock Strength Parameter Determination"	ODOT SGE Section 6
Joint Set Number (Default value = 5)	Jn =	1.5		Joint Set - group of joints has the same dip angle and a strike angle	FHWA -HIF-12-003 : Evaluating Scour at Bridges
Block Size Parameter	Kb =	26.667	= RQD / Jn ≥ 0.10		
Joint Roughness Number (Default value = 1)	Jr =	1.5		Small-scale features and intermediate-scale features. - Add 1.0 if mean spacing of the relevant joint set is greater than 3m, - Jr = 0.5 for planar, slickensided joints having lineation (assuming favorable orientation)	FHWA -HIF-12-003 : Evaluating Scour at Bridges
Joint Alteration Number (Default value = 5)	Ja =	2			FHWA -HIF-12-003 : Evaluating Scour at Bridges
Shear Strength Parameter	Kd =	0.750	= Jr/Ja		
Relative Orientation Parameter (Default value = 0.4)	Js =	0.4		- Due to lack of detailed information, assume default value	FHWA -HIF-12-003 : Evaluating Scour at Bridges
Erodibility Index	K =	496.4	= (Ms)(Kb)(Kd)(Js)		FHWA-HIF-12-003 (HEC 18) - Section 4.7.2
Average Vertical Spacing Between Horizontal Discontinuities	Sv =	75	≥ 0.2 mm		

Re-arrange 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:

$$\tau_c = \rho\left(\frac{1000\,K^{0.75}}{7.853\rho}\right)^{2/3} \qquad EC = 1.2\left(1.83333 + \log\left(\frac{S_v}{2.5}\right)\right)$$

Mass Density of Water	p =	1000	kg/m^3
Erodibility Index	K =	496.4	dim.
Critical Shear Stress	Tc =	5639.4	Pa
	=	117.782	psf
	D50, equivalent =	5639.433	mm
Erosion Category	EC =	3.97	