REPORT OF GEOTECHNICAL EXPLORATION (FINAL)
WOO-23-20.83 CULVERT REPLACEMENT

PID: 101335
WOOD COUNTY, OHIO

May 20, 2026

Prepared for:

Ohio Department of Transportation, District 2

Bowling Green, Ohio

Prepared by:

Stantec Consulting Services Inc.

Cincinnati, Ohio

Project/File:

175578434

Stantec

Revision Schedule

Revision	Description	Author	Date	Quality Check	Date	Independent Review	Date
01	Draft	J. Samples	1/13/26	J. Swindler	1/27/26	E. Kistner	1/28/26
02	Final	J. Samples	5/13/26	J. Swindler	5/19/26	E. Kistner	5/18/26

Disclaimer

The conclusions in the Report titled WOO-23-20.83 Culvert Replacement are Stantec's professional opinion, as of the time of the Report, and concerning the scope described in the Report. The opinions in the document are based on conditions and information existing at the time the scope of work was conducted and do not take into account any subsequent changes. The Report relates solely to the specific project for which Stantec was retained and the stated purpose for which the Report was prepared. The Report is not to be used or relied on for any variation or extension of the project, or for any other project or purpose, and any unauthorized use or reliance is at the recipient's own risk.

Stantec has assumed all information received from Ohio Department of Transportation, District 2 (the "Client") and third parties in the preparation of the Report to be correct. While Stantec has exercised a customary level of judgment or due diligence in the use of such information, Stantec assumes no responsibility for the consequences of any error or omission contained therein.

This Report is intended solely for use by the Client in accordance with Stantec's contract with the Client. While the Report may be provided by the Client to applicable authorities having jurisdiction and to other third parties in connection with the project, Stantec disclaims any legal duty based upon warranty, reliance or any other theory to any third party, and will not be liable to such third party for any damages or losses of any kind that may result.

Prepared by: _________________________
Signature
James A. Samples, EI

Reviewed by: _________________________
Signature
James R. Swindler Jr., PE

Approved by: _________________________
Signature
Eric M. Kistner, PE

Table of Contents

Executive Summary .... **ii**
Acronyms / Abbreviations .... **iii**
1 INTRODUCTION **1**
2 GEOLOGY AND OBSERVATIONS OF THE PROJECT **2**
2.1 GENERAL 2
2.2 SOIL GEOLOGY 2
2.3 BEDROCK GEOLOGY 2
2.4 HYDROLOGY 3
2.5 HYDROGEOLOGY 3
2.6 SEISMIC 3
2.7 SITE RECONNAISSANCE 3

3 EXPLORATION **4**
3.1 HISTORIC EXPLORATION PROGRAMS 4
3.2 PROJECT EXPLORATION PROGRAM 4

4 FINDINGS **6**
4.1 CULVERT BORINGS 6
4.2 ROADWAY BORING 6

5 ANALYSIS AND RECOMMENDATIONS **7**
5.1 GENERAL 7
5.2 CULVERT 7
5.2.1 FOUNDATION DESIGN 7
5.2.2 LATERAL EARTH PRESSURE 8
5.3 SUBGRADE 9

List of Tables

Table 1. Boring Summary 5
Table 2. Lateral Earth Pressure Parameters 9

List of Figures

Figure 1: Site Vicinity (from ODOT Traffic Information Mapping System (TIMS, 2025)) 1

List of Appendices

Appendix A Geotechnical Profile
Appendix B Culvert Foundation Calculations
Appendix C Subgrade Analysis

Executive Summary

The Ohio Department of Transportation plans to replace an existing culvert for Martin Ditch along U.S. Route 23 near Woodville, Ohio, approximately 0.25 miles south of its intersection with U.S. Route 20. Stantec Consulting Services Inc. was contracted to perform geotechnical exploration and provide design recommendations for the proposed culvert replacement.

Site Conditions and Geology
The project site lies within the Woodville Lake-Plain Reefs of the Huron-Erie Lake Plains. Overburden soils consist primarily of clay till from the Late Wisconsinan era, underlain by Lockport Dolomite bedrock. The site is generally flat with low relief and poorly drained soil.

Exploration and Findings
Three borings were advanced: two at the culvert location and one for subgrade evaluation. Borings revealed asphalt pavement over aggregate base, underlain by fine-grained soils (silt and clay) and, in one location, a coarse-grained layer of gravel and sand. Fine-grained soils exhibited medium stiff to hard consistency with low to moderate plasticity. Coarse-grained soils were loose to medium dense. Dolomite bedrock was encountered at depths ranging from 10.6 to 11.0 feet, and groundwater was encountered between 7.4 and 10.5 feet.

Design Recommendations
The existing culvert will be replaced with a precast, reinforced concrete three-sided flat-topped culvert with a 23-foot span and 9-foot rise at SLM 20.83. Spread footings for precast culvert sections and wingwalls will be placed at an approximate elevation of 621 feet on dolomite bedrock. The requirements to utilize ODOT SCD HWDD-1, Type A Headwall for foundation design are met for this site with the exception that the cutoff wall is not required for bearing on dolomite bedrock. The factored bearing resistance of the bedrock at the site is 60 kips per square foot (ksf) using a resistance factor of 0.45.

The recommended D50 particle size for the bedrock at the site is 0.8 millimeters. Since the bedrock is not considered scour resistant, an erodibility index of 488, critical shear stress of 117 pounds per square foot, and erosion category of 2.5 are also recommended for scour analysis.

Soils classify as OSHA Type B, requiring sloped excavations at 1:1 (horizontal to vertical) per OSHA standards. Groundwater was encountered above footing elevation; therefore, dewatering will be necessary. The contractor should implement stream diversion and use temporary barriers or berms with sump pumps to manage groundwater and stream infiltration during construction.

Subgrade analysis indicates an average N_{60L} of 11 blows per foot and a design CBR of 5. No unsuitable or unstable soils are present along the alignment, therefore no subgrade stabilization is required.

Acronyms / Abbreviations

Acronym / Abbreviation	Full Name
ASTM	American Society for Testing and Materials
BPF	Blows Per Foot
CMS	Construction and Materials Specifications
ER	Energy Ratio
GDM	Geotechnical Design Manual
KSF	Kips Per Square Foot
ODNR	Ohio Department of Natural Resources
ODOT	Ohio Department of Transportation
PSI	Pounds Per Square Inches
SGE	Specifications for Geotechnical Explorations
SPT	Standard Penetration Test
SR	State Route
TIMS	Traffic Information Mapping System
US	United States
USDA	United States Department of Agriculture

1 INTRODUCTION

The Ohio Department of Transportation (ODOT) is planning to replace a culvert for Martin Ditch on United States (US) Route 23 (N. Fostoria Rd.) northwest of Woodville in Wood County, approximately 0.25 miles south of the intersection of US Route 23 with US Route 20 (W. Main St.).

Stantec Consulting Services Inc. (Stantec) was contracted to perform the geotechnical exploration and provide design recommendations for the project. Figure 1 shows the site vicinity.

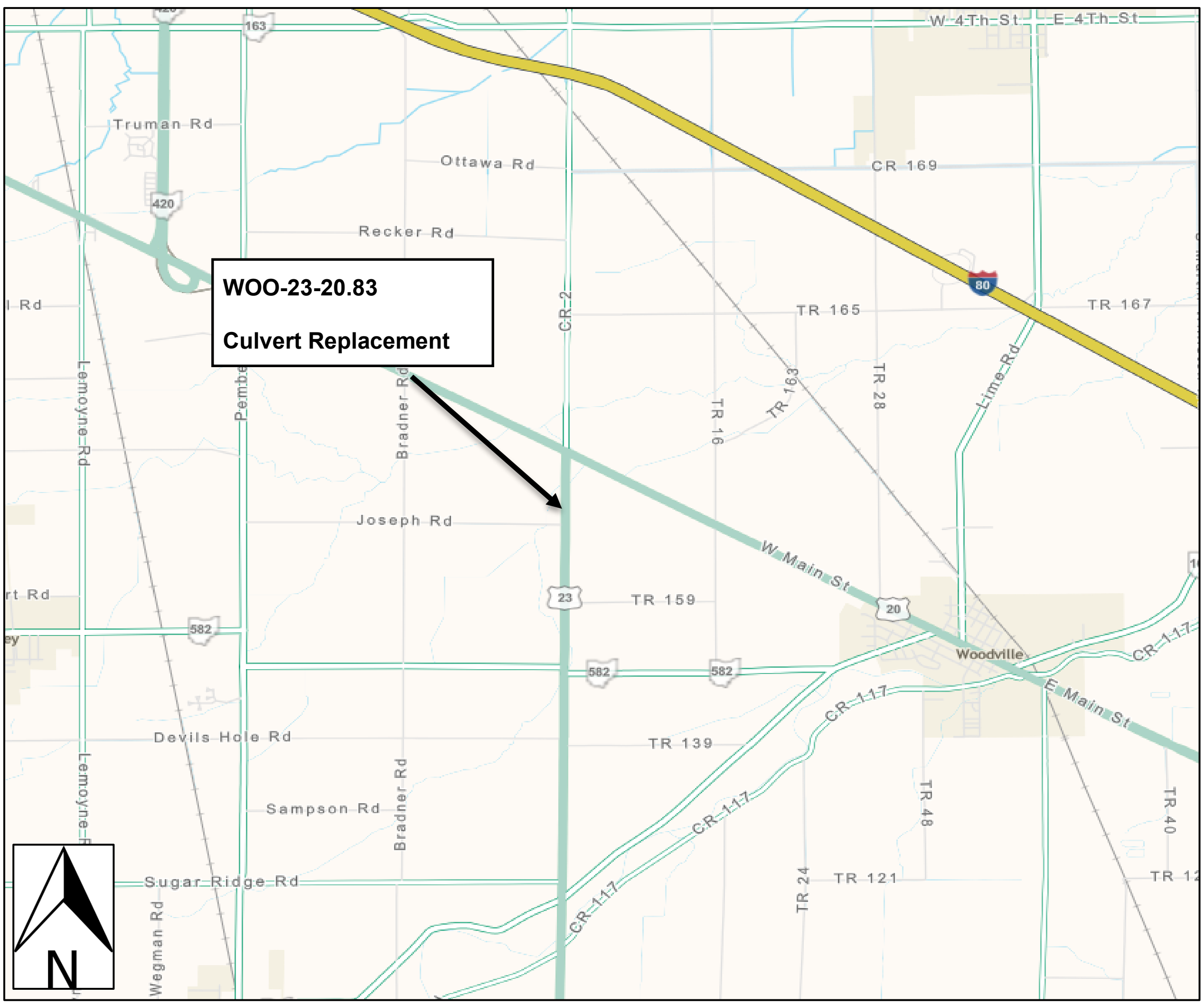


Figure 1: Site Vicinity (from ODOT Traffic Information Mapping System (TIMS, 2025))

2 GEOLOGY AND OBSERVATIONS OF THE PROJECT

2.1 GENERAL

The *Physiographic Regions of Ohio Map* (Ohio Department of Natural Resources (ODNR), 1998) indicates that the project is located within the Woodville Lake-Plain Reefs of the Huron-Erie Lake Plains. The Woodville Lake-Plain Reefs are described as lacustrine plain with low dunes and lake margin features, punctuated by more than 75 ancient bedrock reefs rising 10 to 40 feet above the level of the plain and ranging from 0.1 to 3.0 square miles. It also consists of oblong reefs that are highly draped with drift. The region has a very low relief (generally about 10 feet) with elevations of 600 to 775 feet.

2.2 SOIL GEOLOGY

According to the *Quaternary Geology of Ohio Map* (ODNR, 1999), the project site is underlain by clay till (Hiram, Yorkshire, Lake tills) from Late Wisconsinan era. These soils are lake-planed moraine, very flat, planed by waves in glacial lakes and consist of small patches of sand, silt, or clay on the surface in many areas. The soil survey (*Web Soil Survey of Wood County, Ohio*, United States Department of Agriculture [USDA], 2025) indicates that the project site is underlain by soils from the Hoytville clay loam. These soils are typically clay and clay loam. The soil is described as very poorly drained with very low capacity of transmitting water. The *Ohio Geology Interactive Map* (ODNR, 2025) indicates that the project site consists of 0 to 20 feet of glaciated till.

2.3 BEDROCK GEOLOGY

Bedrock mapping (*Ohio Geology Interactive Map*, ODNR, 2025) and *Descriptions of Geologic Map Units* (ODNR, 2011) indicate that the overburden soils at the project site are underlain by sedimentary rock of the Lockport Dolomite formation from the Silurian age. The Lockport Dolomite group consists of dolomite with minor limestone, chert and shale. The bedrock from this formation is described as bluish gray to gray and weathers reddish gray to gray. The diagnostic feature consists of fossiliferous dolomite and distinct planar to irregular bedding.

According to the *Ohio Oil and Gas Well Viewer* map (ODNR, 2025), there are no oil and gas wells within a 5-mile radius of the project site.

According to the *Ohio Mine Locator* (ODNR, 2025), there are seven mines within a 4-mile radius of the project site. One historical industrial quarry lies about 4 miles southeast, and the other six surface mines, producing limestone, are located about 3 to 4 miles east of the project site.

The *Karst Interactive Map* (ODNR, 2025) indicates the area is underlain by Silurian or Devonian-age carbonate bedrock that is overlain by less than 20 feet of glacial drift. There are four suspected karst features within a 5-mile radius of the project site, two are within the same Lockport Dolomite formation that underlies the project site and the other two are within the Greenfield Dolomite formation

2.4 HYDROLOGY

Drainage from the site flows to an unnamed tributary of Toussaint Creek located approximately 0.5 miles west of the project site. The tributary runs 0.5 miles north before joining Toussaint Creek. The Toussaint Creek flows approximately 25 miles northeast and outlets into Lake Erie.

2.5 HYDROGEOLOGY

According to the *Ohio Geology Interactive Map*, the site is underlain by the Lake Maumee Lacustrine Aquifer (sand and gravel aquifer), which has a yield of less than 5 gallons per minute. Bedrock aquifers in the area tend to yield 25 to 100 gallons of water per minute. It is likely that the primary aquifer at the site is through bedrock due to the low amount of soil encountered. According to the Groundwater Resources of Wood County map (ODNR, 2025), the project site is in an area where wells with yields of 9 to 48 gallons per minute can be achieved.

A search was performed using the ODNR *Ohio Water Wells Map* (2025) to review the geology recorded on logs of water wells located near the project site. According to the map, five water wells have been drilled within a 1500-foot radius of the project site. The well logs indicate that bedrock depth ranges from 6 to 26 feet. The bedrock encountered at these wells were described as limestone. The logs also indicate that static water depth in the area ranges from 5 to 9 feet.

2.6 SEISMIC

A review of the seismic data available in the project vicinity was completed using the ODNR *Ohio Earthquake Epicenters Map* (2025). Overall, Ohio has a relatively limited amount of seismic activity. Within a 8-mile radius of the project, there have been four earthquake epicenters with magnitudes of 1.3 to 2.6. The available data reviewed included events that occurred in Ohio from 1886 to present day.

2.7 SITE RECONNAISSANCE

Stantec representatives visited the site on May 13, 2025, to record observations and mark borehole locations. The land surrounding the project site was described as primarily rural with some resident and business locations nearby. Minor pavement cracks were observed on both lanes along US 23. Deterioration in the form of concrete spalling was observed on the culvert wingwalls. Little water was observed in the creek at the time of field explorations, but flow was noted to be travelling from west to east.

3 EXPLORATION

3.1 HISTORIC EXPLORATION PROGRAMS

The ODOT Transportation Information Maps System (TIMS) website provides documentation for two geotechnical explorations performed near the culvert replacement project.

SAN, WOO-20-(0.00) (12.36) was an exploration project for the roadway and bridge structures over Toussaint Creek along US 20 in Sandusky and Wood Counties located approximately 0.5 miles northwest of the current project location. A crossing for Martin Ditch located approximately 0.25 miles north of the project was also evaluated in this historic project. The project consisted of 45 shallow subgrade borings and four borings for the bridge drilled to depths of 10 to 44 feet. The overburden soils were classified as sandy silt (A-4a), silt and clay (A-6a), silty clay (A-6b), and clay (A-7-6). Bedrock was encountered at depths of 20 to 25 feet and described as limestone.

WOO-199-12.05 was an exploration for an existing roadway alignment drilled in 1959 passing through the project site. The project consisted of 91 borings drilled up to depths of 10 feet. The overburden soils were classified as gravel and/or stone fragments with sand (A-1-b), gravel and/or stone fragments with sand and silt (A-2-4), gravel and/or stone fragments with sand, silt and clay (A-2-6), coarse and fine grained sand (A-3a), sandy silt (A-4a), silt (a-4b), silt and clay (A-6a), silty clay (A-6b), elastic clay (A-7-5) and clay (A-7-6). Bedrock information was not available in the logs since the borings were terminated upon refusal.

3.2 PROJECT EXPLORATION PROGRAM

Stantec advanced three borings to obtain geotechnical data for the proposed culvert replacement. Two borings were advanced for the culvert at diagonally opposite ends, one in the northbound lane and the other in the southbound lane. In addition, one subgrade boring was performed in the southbound lane north of the culvert, with continuous sampling to a depth of 7.5 feet below the existing ground elevation.

These borings were marked with white paint using the approximate locations provided by District 2. No survey was performed for the boring locations, so GPS coordinates for each boring location were determined using phone GPS capabilities. Elevations, stations, and offsets were determined using the existing topographic contour maps and basemaps provided by the ODOT. A summary of these borings is shown in Table 1. Boring locations are shown on the geotechnical profile in Appendix A.

Table 1. Boring Summary

Boring No.	Station (feet)	Offset (feet)	Alignment	Ground surface Elevation (feet)	Bottom of Boring Elevation (feet)	Boring Type
B-001-0-25	1097+88	10 Rt.	US 23	633.5	617.0	Culvert
B-002-0-25	1098+24	16 Lt.	US 23	633.4	615.5	Culvert
B-003-0-25	1098+68	16 Lt.	US 23	633.4	626.5	Subgrade

The borings were performed with a CME 45 track-mounted drill rig using 3¼-inch inside diameter (ID) hollow stem augers to advance the borings through soil. Standard Penetration Test (SPT) sampling was performed continuously for 7.5 feet in the subgrade boring or at 2.5-foot intervals until reaching coreable bedrock in the culvert borings. The energy ratio (ER) of the CME 45 automatic hammer and drill rod system was measured to be over 90 percent on December 22, 2022. The depths and elevations of the SPTs with the corresponding N_{60}-values are shown on the boring logs in Appendix A.

The materials encountered were logged by a geotechnical engineer, with attention given to soil type, consistency, and moisture. The borings were checked for the presence of groundwater during drilling with the depth of water recorded, if encountered. The borings were sealed with bentonite grout, then capped with asphalt cold patch for the culvert borings. The subgrade boring was backfilled with auger cuttings and bentonite chips, then capped with asphalt cold patch.

The soil samples obtained from the borings were returned to Stantec's geotechnical laboratory for visual classification and tested for water content. Engineering classification testing was performed on samples taken near proposed subgrade and samples reflecting each of the main soil horizons. The engineering classification tests conducted on the samples were sieve and hydrometer analysis (ASTM D 422) and Atterberg limits (ASTM D 4318). The samples were classified according to the ODOT classification method.

Two undisturbed Shelby tube samples were extruded in the laboratory, for which one Unconsolidated Undrained (UU) triaxial compression test (ASTM D 2850) and one Unconfined Compression (UC) test (ASTM D 2166) were performed. Two rock core samples were subjected to unconfined compressive strength of rock core (UCR) testing (ASTM D 7012). Results from Stantec's laboratory program are shown on the boring logs and detailed laboratory reports are provided in Appendix A.

4 FINDINGS

4.1 CULVERT BORINGS

The surface material encountered included approximately 10 to 11 inches of asphalt underlain by approximately 0 to 6 inches of aggregate base. Below the surface materials, fine-grained soils were encountered in boring B-001-0-25 and coarse-grained soil underlain by fine-grained soils were encountered in boring B-002-0-25.

The fine-grained soils were classified as silt and clay (A-6a), silty clay (A-6b), and clay (A-7-6). The soils were described as brown to gray, medium stiff to hard (SPT N_{60} values ranging from 5 to 45 bpf with an average of 17 bpf), damp to moist (moisture content of 4 to 30 percent with an average of 15 percent), and having low to moderate plasticity (PI of 7 to 22 percent with an average of 15 percent). A 6-foot-thick coarse-grained soil layer was encountered in boring B-002-0-25 and classified as gravel and stone fragments with sand (A-2-4). The coarse-grained soils were described as red to brown, loose to medium dense (SPT N_{60} values ranging from 6 to 15 bpf with an average of 11 bpf), moist (moisture content of 17 to 18 percent with an average of 18 percent), and having low plasticity (PI of 7 percent).

Bedrock was encountered at depths of 10.6 to 11.0 feet and augered to depths of 11.0 to 12.5 feet. After encountering the coreable bedrock, 5.5 to 6.0 feet coring was performed in borings B-001-0-25 and B-002-0-25, respectively. The bedrock was classified as dolomite and described as light brown to gray, highly to slightly weathered, strong, fine-grained, thin bedded, and moderately fractured. The recovery ranged from 73 to 100 percent and RQD ranged from 45 to 89 percent. Two unconfined compressive strength of rock tests were completed on the dolomite specimens from borings B-001-0-25 and B-002-0-25, resulting in compressive strengths of 7,450 and 5,240 pounds per inches (psi).

Borings B-001-0-25 and B-002-0-25 were terminated at depths of 16.5 and 18.5 feet, respectively. Groundwater was encountered at depths of 9.0 and 10.5 feet.

4.2 ROADWAY BORING

A roadway boring, B-003-0-25, was drilled to depth of 7.5 feet, approximately 40 feet north of the culvert in the southbound lane to obtain data for the existing pavement build-up. The surface material encountered included approximately 24 inches of asphalt with no apparent aggregate base. Below the surface materials, fine-grained soil was encountered in the boring.

The fine-grained soil was classified as silty clay (A-6b). The soil was described as dark brown to gray, stiff to very stiff (SPT N_{60} values ranging from 11 to 23 bpf with an average of 15 bpf), damp to moist (moisture content of 4 to 27 with an average of 17 percent), and having plasticity (PI of 17 to 19 percent with an average of 18 percent). Groundwater was encountered at a depth of 7.4 feet.

5 ANALYSIS AND RECOMMENDATIONS

5.1 GENERAL

The recommendations that follow are based on the information discussed in this report and the interpretation of the subsurface conditions encountered at the site during the fieldwork and project information currently available from the designer. If future design changes are made, Stantec should be notified so that such changes can be reviewed, and the recommendations amended as necessary. Recommendations will also be updated once design is finalized.

These conclusions and recommendations are based on data and subsurface conditions from the borings advanced during this exploration using the degree of care and skill ordinarily exercised under similar circumstances by competent members of the engineering profession. No warranties can be made regarding the continuity of conditions.

5.2 CULVERT

5.2.1 FOUNDATION DESIGN

The existing culvert is planned to be replaced by a precast, reinforced concrete three-sided flat-topped culvert with a 23-foot span and 9-foot rise. Bearing resistance calculations were performed at the inlet and outlet for the culvert utilizing information obtained from borings B-001-0-25 (inlet) and B-002-0-25 (outlet) and laboratory testing. The spread footings are planned to be at an approximate elevation of 621 feet. The spread footing widths for the culvert and wingwalls are 6 feet and 7 feet respectively. At elevation 621 feet, the foundation material is expected to be dolomite bedrock. Rock compression test results were used to estimate the cohesion and friction angle of dolomite as outlined in section 1303.3.3 of the ODOT Geotechnical Design Manual (GDM). A cohesion value of 4,700 pounds per square foot (psf) and a friction angle of 28 degrees were selected based on the relationships. Bedrock properties follow recommended properties of ODOT SCD HWDD-1, Type A Headwall with the exception that the cutoff wall is not required for bearing on bedrock. The approximate thalweg elevation is 623.8 feet.

Methods outlined in section 1303.3.3 were also used to determine the bearing resistance of the dolomite bedrock encountered at the site. The recommended factored bearing resistance is 60 kips per square foot utilizing a resistance factor of 0.45 for footings bearing on rock (from Table 10.5.5.2.2-1 of the 2024 AASHTO LRFD). Bearing resistance calculations for bedrock are provided in Appendix B.

A scour analysis will be performed by the culvert designer. The recommended D50 value of the bedrock to use for analysis is 0.8 mm based on guidance provided in the ODOT Geotechnical Design Manual (GDM) section 1302.1.3. The thalweg elevation is 605.3 feet.

The rock mass rating determined for the bedrock as part of the bearing resistance less than 75. Therefore, the bedrock at the site should be considered non-scour resistant according to ODOT BDM 305.2.1.2.b. The erodibility index of bedrock was determined using the method outlined in the 2012 Hydraulic Engineering Circular Number 18, Evaluating Scour at Bridges 5th Edition Section 4.7.2. Based on the strength, RQD, and joint conditions of the bedrock, the recommended Erodibility Index is 488. Using equations provided in ODOT GDM section 1302.1.3, the critical shear stress is 117 psf and the erosion category (EC) is 2.5. Calculations for the scour parameters are provided in Appendix B.

According to the Occupational Safety and Health Administration (OSHA) 1946 Subpart P App A – *Soil Classification*, on-site soils most closely fall under Type B. Sloped excavations thus require a 1:1 horizontal to vertical slope according to OSHA 1926 Subpart P App B – *Sloping and Benching*.

A review of the boring logs indicates that groundwater is contained in fine-grained soil layers at depths of 9.0 to 10.5 feet at the culvert location, which is above the foundation elevation. It should be anticipated that stream diversion and dewatering will be necessary to install the headwall footings. The dewatering plan should include temporary barriers or earth berms to isolate footing excavations from the stream flow and sump pumps to remove stream and groundwater infiltration into isolated areas.

Karst activity is not suspected at the project site; however, there are four suspected karst locations within a 5-mile radius. The ground surface should be monitored during field activities for possible subsidences or karst occurrences. If karst activity is suspected, further investigation may be warranted to determine its extent.

5.2.2 LATERAL EARTH PRESSURE

Permanent structure walls should be designed to withstand the development of lateral earth pressures and hydrostatic pressures. The magnitude of such pressures varies based on soil type, permissible wall movement, and configuration of backfill. Table 2 provides the recommended lateral earth pressure parameters for retained soil and select granular backfill. Assumed material properties for retained soil are outlined in Table 307-1 of the Bridge Design Manual. Material properties for select granular backfill are provided in the ODOT Construction and Materials Specifications (CMS).

Table 2. Lateral Earth Pressure Parameters

Soil Parameter	Retained Soil	Granular Backfill
Drained Friction Angle (degrees)	30	32
Unit Weight (pcf)		
Moist	120	120
Buoyant	58	73
Earth Pressure Coefficient		
Active Case (K_A)	0.33	0.31
Passive Case (K_P)	3.0	3.3
At-Rest Case (K_0)	0.5	0.47
Equivalent Fluid Unit Weights (pcf)		
Active Case	40	37
Passive Case	360	396
At-Rest Case	60	56

To reduce lateral earth pressures applied to structures due to hydrostatic buildup, free drainage should be provided in accordance with ODOT CMS Item 518. Placement of the granular backfill should be in accordance with ODOT CMS Item 518.05 “Porous Backfill”. Positive drainage of the granular backfill using weepholes or pipe drains is necessary to minimize the hydrostatic pressures against the structures. Providing positive drainage from the backfill will allow the use of the design parameters associated with the “drained” condition. If selected walls are capable of deflecting a distance of approximately 0.1 percent of the wall height, then an “active” condition could be used for design. If not, the “at-rest” condition should be used for design.

Backfill comprised of cohesive soils and/or granular soils with significant clay content may result in high magnitudes of lateral loads due to creep and swelling pressures. These materials are not recommended for use as backfill behind permanent structures. It is recommended that a backfill material comprised of free-draining granular material, such as the material specified under ODOT CMS Item 518.03, be used. The backfill material should be coarse angular gravel with a gradation equivalent to No. 57 aggregate, as specified under ODOT CMS Item 703, Table 703.01-1.

Backfill should be compacted in accordance with ODOT CMS Item 203.07 “Compaction and Moisture Requirements”. Overcompaction in areas directly behind structures should be avoided as this can cause damage to the structures. Appropriate equipment should be used to obtain the required compaction without causing damage.

5.3 SUBGRADE

The ODOT GDM outlines a procedure for estimating the methods and limits of subgrade treatment that will be required to stabilize pavement subgrade prior to construction of the pavement section. The procedure is based upon the results of the borings, field testing, and laboratory testing.

A subgrade analysis was completed for areas impacted by culvert construction in accordance with the ODOT GDM. The subgrade analysis results are provided in Appendix C. Cut and fill estimations could not be estimated from the information available from the designer, so it was assumed that the proposed roadway elevation would be the same as the existing elevation. Soil surrounding the culvert will be excavated to construct the new culvert and be replaced with engineered fill, so the soil from the culvert borings was not included in the subgrade analysis. An average N_{60L} of 11 bpf was calculated from the data obtained from B-003-0-25. A design California Bearing Ratio (CBR) of 5 is recommended based on the subgrade analysis. According to the subgrade analysis, there are no unstable or unsuitable soils located along the alignment. Therefore, no subgrade stabilization is required.

Appendix A Geotechnical Profile

PROJECT DESCRIPTION

THIS PROJECT, WOO-23-20.83, IS THE EXPLORATION FOR A CULVERT REPLACEMENT ON UNITED STATES (US) ROUTE 23 (N. FOSTORIA RD.), NORTHWEST OF WOODVILLE IN WOOD COUNTY, APPROXIMATELY 0.25 MILES SOUTH OF THE INTERSECTION OF US ROUTE 23 WITH US ROUTE 20 (W. MAIN ST.)

HISTORIC RECORDS

ODOT TIMS PROVIDES DOCUMENTATION FOR THREE GEOTECHNICAL EXPLORATIONS PERFORMED NEAR THE CULVERT REPLACEMENT PROJECT.

WOO-20-13.99 WAS AN EXPLORATION FOR A BRIDGE STRUCTURE DRILLED IN 1969. THE PROJECT CONSISTED OF FIVE BORINGS DRILLED TO DEPTHS OF 15 TO 20 FEET. GLACIAL TILL WAS ENCOUNTERED TO THE DEPTHS OF 4.5 TO 5 FEET. BEDROCK WAS ENCOUNTERED AT DEPTHS RANGING FROM 4.5 TO 5 FEET AND DESCRIBED AS DOLOMITE.

SAN, WOO-20-(0.00) (12.36) WAS A ROADWAY AND STRUCTURE EXPLORATION AT TOUSSAINT CREEK ALONG US 20 IN SANDUSKY AND WOOD COUNTIES. THE PROJECT CONSISTED OF 45 SHALLOW SUBGRADE BORINGS AND FOUR BORINGS FOR THE BRIDGE DRILLED TO DEPTHS OF 10 TO 44 FEET. THE OVERBURDEN SOILS WERE CLASSIFIED AS SANDY SILT (A-4A), SILT AND CLAY (A-6A), SILTY CLAY (A-6B), AND CLAY (A-7-6). BEDROCK WAS ENCOUNTERED AT DEPTHS OF 20 TO 25 FEET AND DESCRIBED AS LIMESTONE.

WOO-199-12.05 WAS AN EXPLORATION FOR AN EXISTING ROADWAY ALIGNMENT DRILLED IN 1959. THE PROJECT CONSISTED OF 91 BORINGS DRILLED UP TO DEPTHS OF 10 FEET. THE OVERBURDEN SOILS WERE CLASSIFIED AS GRAVEL AND/OR STONE FRAGMENTS WITH SAND (A-1-B), GRAVEL AND/OR STONE FRAGMENTS WITH SAND AND SILT (A-2-4), GRAVEL AND/OR STONE FRAGMENTS WITH SAND, SILT AND CLAY (A-2-6), COARSE AND FINE GRAINED SAND (A-3A), SANDY SILT (A-4A), SILT (A-4B), SILT AND CLAY (A-6A), SILTY CLAY (A-6B), ELASTIC CLAY (A-7-5), AND CLAY (A-7-6). BEDROCK INFORMATION WAS NOT AVAILABLE IN THE LOGS AND THE BORINGS WERE TERMINATED WHEN ENCOUNTERED REFUSAL.

GEOLOGY

THE PROJECT SITE IS LOCATED WITHIN THE WOODVILLE LAKE-PLAIN REEFS OF MAUMEE LAKE PLAINS IN HURON-ERIE LAKE PLAINS. THE WOODVILLE LAKE PLAIN REEF IS DESCRIBED AS LACUSTRINE PLAIN WITH LOW DUNES AND LAKE MARGIN FEATURES, PUNCTUATED BY MORE THAN 75 ANCIENT BEDROCK REEFS RISING 10 FEET TO 40 FEET ABOVE THE LEVEL OF PLAIN AND RANGING IN AREA FROM 0.1 TO 3.0 SQUARE MILES. THE OBLONG REEFS ARE THINLY DRAPED WITH DRIFT. THE REGION HAS VERY LOW RELIEF (GENERALLY ABOUT 10 FEET) WITH ELEVATIONS OF 600 TO 775 FEET. THE SOIL IS TYPICALLY DESCRIBED AS THIN TO ABSENT WISCONSINAN-AGE WAVE PLANED CLAY TILL, LACUSTRINE DEPOSITS AND SAND OVER SILURIAN-AGE REEFAL LOCKPORT DOLOMITE.

THE GEOLOGY CONSISTS OF SEDIMENTARY ROCK OF THE LOCKPORT DOLOMITE FORMATION FROM THE SILURIAN AGE. LOCKPORT DOLOMITE CONSISTS OF DOLOMITE WITH MINOR LIMESTONE, CHERT, AND SHALE. THE BEDROCK FROM THIS FORMATION IS DESCRIBED AS BLUISH GRAY TO GRAY AND WEATHERS REDDISH GRAY TO GRAY. THE DIAGNOSTIC FEATURE CONSISTS OF FOSSILIFEROUS DOLOMITE AND DISTINCT PLANAR TO IRREGULAR BEDDING.

RECONNAISSANCE

STANTEC REPRESENTATIVES VISITED THE SITE ON MAY 13, 2025 TO RECORD OBSERVATIONS AND MARK BOREHOLE LOCATIONS. THE LAND SURROUNDING THE PROJECT SITE WAS PRIMARILY DESCRIBED AS RURAL WITH SOME RESIDENTIAL AND BUSINESS LOCATIONS NEARBY. MINOR PAVEMENT CRACKS WERE OBSERVED ON BOTH LANES ALONG US 23. DETERIORATION IN THE FORM OF CONCRETE SPALLING WAS OBSERVED ON THE CULVERT WINGWALLS.

SUBSURFACE EXPLORATION

STANTEC ADVANCED THREE BORINGS TO OBTAIN GEOTECHNICAL DATA FOR THE PROPOSED CULVERT REPLACEMENT AND TO PROVIDE PAVEMENT RECOMMENDATIONS. TWO BORINGS, B-001-0-25 AND B-002-0-25, WERE ADVANCED FOR THE CULVERT AT DIAGONALLY OPPOSITE ENDS, ONE IN THE NORTHBOUND LANE AND THE OTHER IN THE SOUTHBOUND LANE. IN ADDITION, ONE SUBGRADE BORING, B-003-0-25, WAS PERFORMED IN THE SOUTHBOUND LANE NORTH OF THE CULVERT, WITH CONTINUOUS SAMPLING TO A DEPTH OF 7.5 FEET BELOW THE EXISTING GROUND.

THE BORINGS WERE PERFORMED WITH A CME 45 TRACK-MOUNTED DRILL RIG USING 3¼-INCH INSIDE DIAMETER (ID) HOLLOW STEM AUGERS. THE STANDARD PENETRATION TEST (SPT) SAMPLING WAS PERFORMED CONTINUOUSLY FOR 6 FEET IN THE SUBGRADE BORING OR AT 2.5-FOOT INTERVALS UNTIL REACHING COREABLE BEDROCK IN THE CULVERT BORINGS. THE ENERGY RATIO (ER) OF CME 45 AUTOMATIC HAMMER AND DRILL ROD SYSTEM WAS MEASURED TO BE OVER 90 PERCENT ON DECEMBER 22, 2025.

EXPLORATION FINDINGS

THE SURFACE MATERIALS ENCOUNTERED INCLUDED APPROXIMATELY 10 TO 24 INCHES OF ASPHALT, UNDERLAIN BY APPROXIMATELY 0 TO 6 INCHES OF AGGREGATE BASE. BELOW THE SURFACE MATERIALS, FINE-GRAINED SOILS WERE TYPICALLY ENCOUNTERED IN BORINGS B-001-0-25 AND B-003-0-25 WHILE COARSE-GRAINED SOILS UNDERLAIN BY FINE-GRAINED SOILS WERE ENCOUNTERED IN BORING B-002-0-25.

THE FINE-GRAINED SOILS WERE CLASSIFIED AS SILT AND CLAY (A-6A), SILTY CLAY (A-6B), AND CLAY (A-7-6). THE SOILS WERE DESCRIBED AS BROWN TO GRAY, MEDIUM STIFF TO HARD, DAMP TO MOIST, AND HAVING LOW TO MODERATE PLASTICITY.

A 6-FOOT-THICK COARSE-GRAINED SOIL WAS ENCOUNTERED IN BORING B-002-0-25 AND CLASSIFIED AS GRAVEL AND STONE FRAGMENTS WITH SAND (A-2-4). THIS SOIL WAS DESCRIBED AS LOOSE TO MEDIUM DENSE, RED TO BROWN, MOIST AND HAVING LOW PLASTICITY.

WEATHERED BEDROCK WAS ENCOUNTERED AT DEPTHS OF 10.6 TO 11 FEET BELOW THE OVERBURDEN SOIL. THE BEDROCK WAS AUGERED TO DEPTHS OF 11 TO 12.5 FEET BEFORE CORING. ROCK CORING TO DEPTHS OF 5.5 AND 6 FEET WAS PERFORMED IN BORINGS B-001-0-25 AND B-002-0-25, RESPECTIVELY.THE BEDROCK WAS DESCRIBED AS LIGHT BROWN TO GRAY DOLOMITE THAT WAS HIGHLY TO SLIGHTLY WEATHERED, STRONG, FINE-GRAINED, THIN BEDDED, AND MODERATELY FRACTURED.

EXPLORATION FINDINGS (CONTINUED)

BORINGS B-001-0-25, B-002-0-25 AND B-003-0-25 WERE TERMINATED AT DEPTHS OF 16.5, 18.5, AND 7.5 FEET, RESPECTIVELY. GROUNDWATER WAS ENCOUNTERED AT DEPTHS OF 9.0, 10.5, AND 7.4 FEET, RESPECTIVELY.

SPECIFICATIONS

THIS GEOTECHNICAL EXPLORATION WAS PERFORMED IN ACCORDANCE WITH THE STATE OF OHIO, DEPARTMENT OF TRANSPORTATION, OFFICE OF GEOTECHNICAL ENGINEERING, SPECIFICATIONS FOR GEOTECHNICAL EXPLORATIONS, DATED JANUARY 2025 .

AVAILABLE INFORMATION

THE SOIL, BEDROCK, AND GROUNDWATER INFORMATION COLLECTED FOR THIS SUBSURFACE EXPLORATION THAT CAN BE CONVENIENTLY DISPLAYED ON THE SOIL PROFILE SHEETS HAS BEEN PRESENTED. GEOTECHNICAL REPORTS, IF PREPARED, ARE AVAILABLE FOR REVIEW ON THE OFFICE OF CONTRACT SALES WEBSITE.

LEGEND

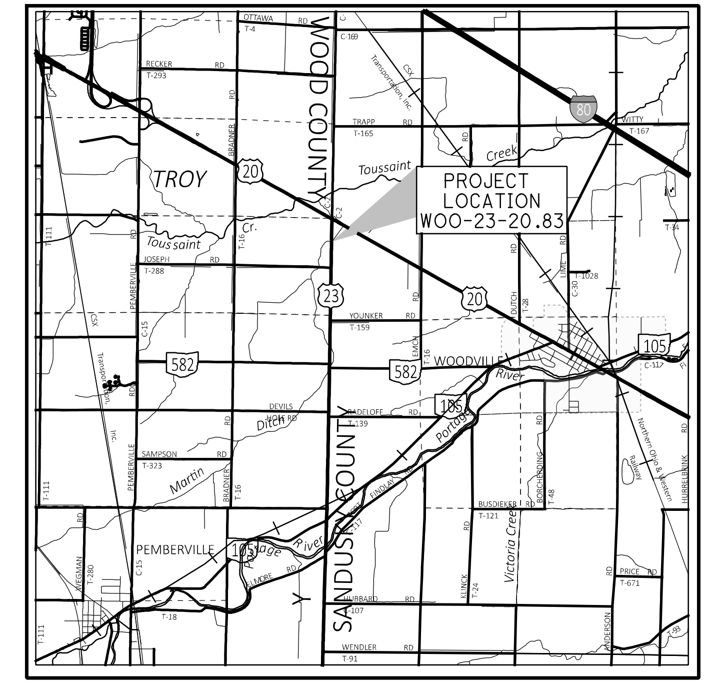
DESCRIPTION	ODOT CLASS	CLASSIFIED MECH.	CLASSIFIED VISUAL
GRAVEL AND/OR STONE FRAGMENTS WITH SAND AND SILT	A-2-4	1	1
SILT AND CLAY	A-6a	1	0
SILTY CLAY	A-6b	3	4
CLAY	A-7-6	1	2
	TOTAL	6	7
DOLOMITE	VISUAL		
PAVEMENT OR BASE = X = APPROXIMATE THICKNESS	VISUAL		

BORING LOCATION - PLAN VIEW.

DRIVE SAMPLE AND/OR ROCK CORE BORING PLOTTED TO VERTICAL SCALE ONLY. HORIZONTAL BAR INDICATES A CHANGE IN STRATIGRAPHY.

WC	INDICATES WATER CONTENT IN PERCENT.
N_{60}	INDICATES STANDARD PENETRATION RESISTANCE NORMALIZED TO 60% DRILL ROD ENERGY RATIO.
X/Y/Z	NUMBER OF BLOWS FOR STANDARD PENETRATION TEST (SPT): X= NUMBER OF BLOWS FOR FIRST 6 INCHES. Y= NUMBER OF BLOWS FOR SECOND 6 INCHES. Z= NUMBER OF BLOWS FOR THIRD 6 INCHES.
TR	INDICATES TOP OF ROCK.
SS	INDICATES A SPLIT SPOON SAMPLE.
ST	INDICATES A SHELBY TUBE SAMPLE.
UCR	UNCONFINED COMPRESSIVE STRENGTH (ROCK) SHOWN IN (PSI).
UCS	UNCONFINED COMPRESSIVE STRENGTH (SOIL) SHOWN IN (TSF).
S_u	UNDRAINED TRIAXIAL COMPRESSION SHOWN IN (TSF).
W	INDICATES FREE WATER ELEVATION.

RECON. - JS & NU 05/13/25
DRILLING - DC & JS 05/19-20/2025
DRAWN - MJ 01/2026
REVIEWED - JRS 01/27/2026



LOCATION MAP

SCALE IN MILES

0 1 2 3 4

N

PARTICLE SIZE DEFINITIONS

	12"		3"		2.0 mm		0.42 mm		0.074 mm		0.005 mm	
BOULDERS		COBBLES		GRAVEL		COARSE SAND		FINE SAND		SILT		CLAY
					No. 10 SIEVE		No. 40 SIEVE		No. 200 SIEVE			

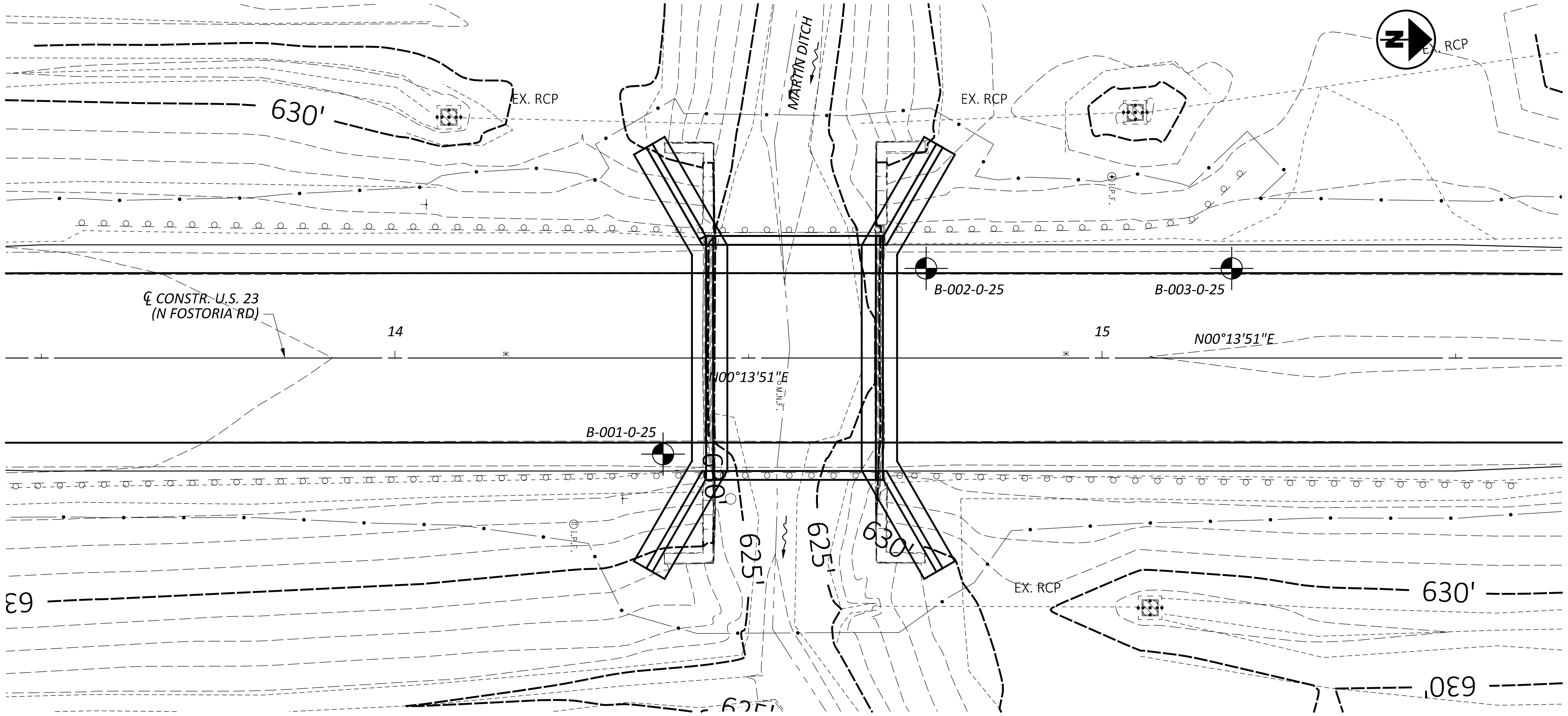
GEOTECHNICAL PROFILE - CULVERT
WOO-23-20.83 CULVERT REPLACEMENT (MARTIN CREEK)

DESIGN AGENCY
Stantec
10200 Alliance Road, Suite 300
Cincinnati, OH 45242
(513) 842-8200

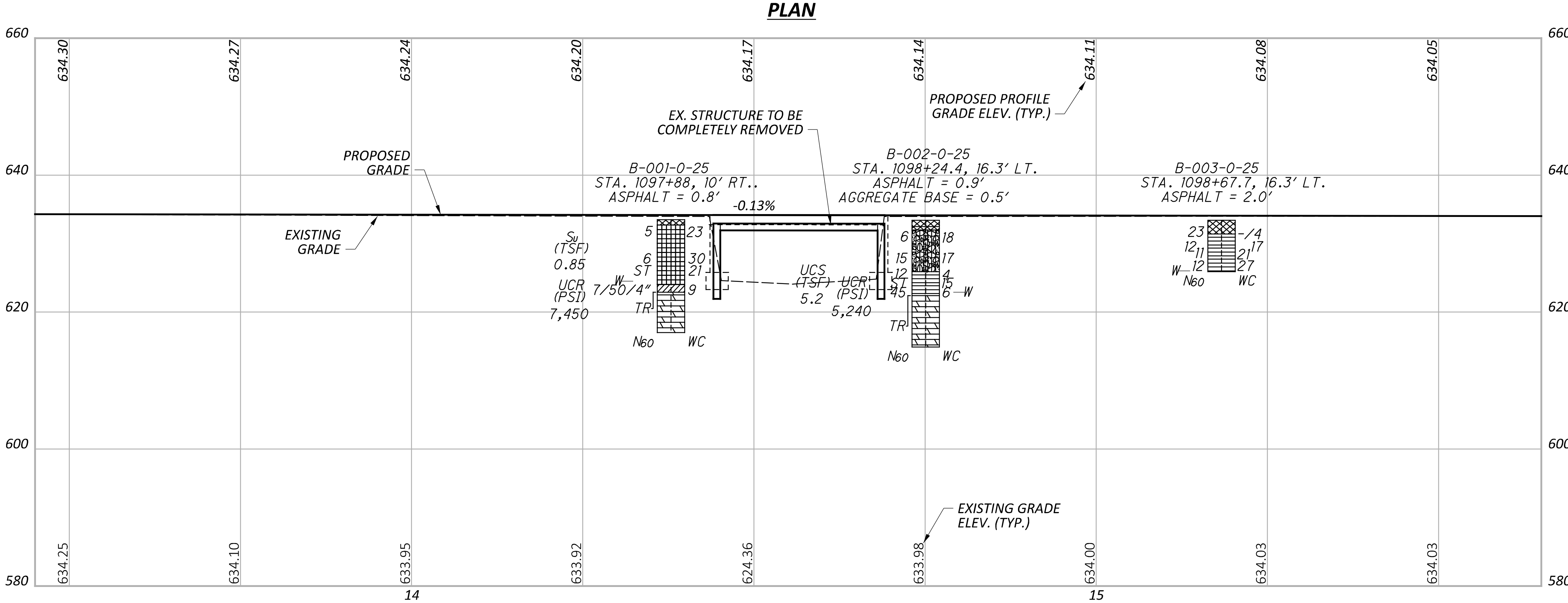
DESIGNER MSJ
REVIEWER JRS 01-27-26
PROJECT ID 101335
SUBSET 0 TOTAL 0
SHEET P.1 TOTAL 7

WOO-23-20.83

MODEL: ll0174_YC001 PAPERSIZE: 17x11 (in.) DATE: 1/28/2026 TIME: 9:44:12 AM PLTDRV: OHDOT_PDF.pltcfg PENTBL: OHDOT_Pen.tbl USER: Matt.Jennings@stantec.com WORKSPACE: OHDOTCE v02 WORKSET: 101335 PRODUCT: OpenRoadsDesigner 24.00.02.25
pw:\\ohiodot-pw.bentley.com:ohiodot-pw-02\Documents\01 Active Projects\District 02\Wood\101335\402-Engineering_Stantec\Geotechnical\Sheets\101335_ZC001.dgn



PLAN



PROFILE ALONG ℄ CONSTR. U.S. 23

HORIZONTAL SCALE IN FEET
0 5 10 20

GEOTECHNICAL PROFILE - CULVERT
U.S. 23 OVER MARTIN DITCH

DESIGN AGENCY
Stantec
10200 Alliance Road, Suite 300
Cincinnati, OH 45242
(513) 842-8200

DESIGNER
MSJ
REVIEWER
JRS 01-27-26
PROJECT ID
101335
SUBSET 0 TOTAL 0
SHEET P.2 TOTAL 7

WOO-23-20.83

MODEL: CLP_1 - Plan 1 [Sheet] PAPERSIZE: 17x11 (in.) DATE: 1/28/2026 TIME: 9:51:19 AM PLTDRV: OHDOT_PDF.pltcfg PENTBL: OHDOT_Pen.tbl USER: Matt.Jennings@stantec.com WORKSPACE: OHDOTCEv02 WORKSET: 101335 PRODUCT: OpenRoadsDesigner 24.00.02.25
pw:\\ohiodot-pw.bentley.com:ohiodot-pw-02\Documents\01 Active Projects\District 02\Wood\101335\402-Engineering_Stantec\Geotechnical\Sheets\101335_SFN_8701599_ZP001.dgn

PROJECT: WOO-23-20.83	DRILLING FIRM / OPERATOR: STANTEC / DC	DRILL RIG: CME 45#2T (814)	STATION / OFFSET: 1097+88, 10' RT.	EXPLORATION ID B-001-0-25
TYPE: STRUCTURE FOUNDATION	SAMPLING FIRM / LOGGER: STANTEC / JS	HAMMER: CME AUTOMATIC	ALIGNMENT: US 23	
PID: 101335 SFN: N/A	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 12/22/22	ELEVATION: 633.5 (MSL) EOB: 16.5 ft.	PAGE 1 OF 1
START: 5/20/25 END: 5/20/25	SAMPLING METHOD: SPT / ST / NQ2	ENERGY RATIO (%): 90*	LAT / LONG: 41.468282, -83.415030	

MATERIAL DESCRIPTION AND NOTES	ELEV. 633.5	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
ASPHALT, 10 INCHES, NO BASE OBSERVED	632.7																	
MEDIUM STIFF, BROWN TO DARK GRAY, **CLAY**, SOME GRAVEL, LITTLE SAND, SOME SILT, DAMP TO MOIST			2 1 2	5	47	SS-1	1.50	-	-	-	-	-	-	-	-	23	A-7-6 (V)	
			1 1 3	6	67	SS-2	0.50	22	5	15	22	36	45	23	22	30	A-7-6 (10)	
FROM 6.8 FT. TO 7.3 FT., UNDRAINED SU = 0.85 TSF					55	ST-1	-	-	-	-	-	-	-	-	-	21	A-7-6 (V)	
	624.0	W 624.5																
HARD, BROWN TO DARK GRAY, **SILT AND CLAY**, LITTLE GRAVEL, SOME SAND, DAMP	622.9	TR	7 50/4"	-	100		4.5+	20	8	13	26	33	29	16	13	9	A-6a (6)	
DOLOMITE, LIGHT GRAY, AUGERABLE.	622.5																	
DOLOMITE, LIGHT BROWN TO GRAY, MODERATELY TO HIGHLY WEATHERED, WEAK, FINE GRAINED, THIN BEDDED, ARENACEOUS, HIGHLY TO MODERATELY FRACTURED; RQD 53%, REC 75%.			45		75	NQ2-1											CORE	
FROM 13.8 FT. TO 14.2 FT., UCR = 7,450 PSI																		
	617.0	EOB	73		73	NQ2-2											CORE	

NOTES: BORING COORDINATE ESTIMATED USING PHONE GPS. ELEVATION ESTIMATED USING GOOGLE EARTH.
ABANDONMENT METHODS, MATERIALS, QUANTITIES: ASPHALT PATCH; TREMIED CEMENT/BENTONITE GROUT

B-001-0-25

Run #:	Depth		Recovery		RQD	
NQ2-1	11.0'	15.0'	36"/48"	75%	22"/48"	45%
NQ2-2	15.0'	16.5'	13"/18"	73%	13"/13"	73%

WOO-23-20.83 PID: 101335

MODEL: Sheet PAPERSIZE: 17x11 (in.) DATE: 1/27/2026 TIME: 2:21:51 PM PLTDRV: OHDOT_PDF.pltcfg PENTBL: OHDOT_Pen.tbl USER: Matt.Jennings@stantec.com WORKSPACE: OHDOTCEv02 WORKSET: 101335 PRODUCT: OpenRoadsDesigner 24.00.02.25
pw:\\ohiodot-pw.bentley.com:ohiodot-pw-02\Documents\01 Active Projects\District 02\Wood\101335\402-Engineering_Stantec\Geotechnical\Sheets\101335_ZL002.dgn

PROJECT: WOO-23-20.83	DRILLING FIRM / OPERATOR: STANTEC / DC	DRILL RIG: CME 45#2T (814)	STATION / OFFSET: 1098+24, 16' LT.
TYPE: STRUCTURE FOUNDATION	SAMPLING FIRM / LOGGER: STANTEC / JS	HAMMER: CME AUTOMATIC	ALIGNMENT: US 23
PID: 101335 SFN: N/A	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 12/22/22	ELEVATION: 633.4 (MSL) EOB: 18.5 ft.
START: 5/19/25 END: 5/19/25	SAMPLING METHOD: SPT / ST / NQ2	ENERGY RATIO (%): 90*	LAT / LONG: 41.468374, -83.415100

EXPLORATION ID: B-002-0-25 — PAGE 1 OF 1

MATERIAL DESCRIPTION AND NOTES	ELEV. 633.4	DEPTHS	SPT/RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)
ASPHALT, 11 INCHES	632.5																
AGGREGATE BASE, 6 INCHES	632.0																
LOOSE TO MEDIUM DENSE, RED TO BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND**, LITTLE SILT, LITTLE CLAY, MOIST			2 1 3	6	27	SS-1	1.50	-	-	-	-	-	-	-	-	18	A-2-4 (V)
SS-1 AND SS-2 ARE COMBINED FOR CLASSIFICATION	625.9		6 5 5	15	47	SS-2	1.25	24	14	28	14	20	19	12	7	17	A-2-4 (0)
STIFF TO HARD, DARK BROWN TO LIGHT GRAY, **SILTY CLAY**, TRACE GRAVEL, LITTLE SAND, DAMP			1 3 5	12	13	SS-3	-	-	-	-	-	-	-	-	-	4	A-6b (V)
FROM 9.1 FT. TO 9.6 FT., UCS = 5.2 TSF		W 622.9			100	ST-1	-	7	6	14	34	39	32	16	16	15	A-6b (10)
	622.4	TR	14 14 16	45	40	SS-4	-	-	-	-	-	-	-	-	-	6	A-6b (V)
DOLOMITE, LIGHT GRAY, AUGERABLE.	620.9																
DOLOMITE, LIGHT GRAY, MODERATELY TO SLIGHTLY WEATHERED, STRONG, FINE GRAINED, THIN BEDDED, ARGILLACEOUS, MODERATELY FRACTURED; RQD 85%, REC 97%. FROM 13.5 FT. TO 13.9 FT., UCR = 5,240 PSI			89		95	NQ2-1											CORE
	614.9	EOB	75		100	NQ2-2											CORE

NOTES: BORING COORDINATE ESTIMATED USING PHONE GPS. ELEVATION ESTIMATED USING GOOGLE EARTH.
ABANDONMENT METHODS, MATERIALS, QUANTITIES: ASPHALT PATCH; TREMIED CEMENT/BENTONITE GROUT

B-002-0-25

Run #:	Depth		Recovery		RQD	
NQ2-1	12.5'	16.9'	50"/53"	95%	47"/53"	89%
NQ2-2	16.9'	18.5'	19"/19"	100%	14"/19"	75%

WOO-23-20.83 PID: 101335

GEOTECHNICAL PROFILE - CULVERT
BORING LOG B-002-0-25

DESIGN AGENCY: Stantec, 10200 Alliance Road, Suite 300, Cincinnati, OH 45242, (513) 842-8200
DESIGNER: MSJ
REVIEWER: JRS 01-27-26
PROJECT ID: 101335
SUBSET: 0 TOTAL: 0
SHEET: P.4 TOTAL: 7

MODEL: Sheet PAPERSIZE: 17x11 (in.) DATE: 1/27/2026 TIME: 2:24:07 PM PLTDRV: OHDOT_PDF.pltcfg PENTBL: OHDOT_Pen.tbl USER: Matt.Jennings@stantec.com WORKSPACE: OHDOTCEv02 WORKSET: 101335 PRODUCT: OpenRoadsDesigner 24.00.02.25
pw:\\ohiodot-pw.bentley.com:ohiodot-pw-02\Documents\01 Active Projects\District 02\Wood\101335\402-Engineering_Stantec\Geotechnical\Sheets\101335_ZL003.dgn

PROJECT: WOO-23-20.83	DRILLING FIRM / OPERATOR: STANTEC / DC	DRILL RIG: CME 45#2T (814)	STATION / OFFSET: 1098+68, 16' LT.
TYPE: STRUCTURE FOUNDATION	SAMPLING FIRM / LOGGER: STANTEC / JS	HAMMER: CME AUTOMATIC	ALIGNMENT: US 23
PID: 101335 SFN: N/A	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 12/22/22	ELEVATION: 633.4 (MSL) EOB: 7.5 ft.
START: 5/19/25 END: 5/19/25	SAMPLING METHOD: SPT	ENERGY RATIO (%): 90*	LAT / LONG: 41.468500, -83.415080

EXPLORATION ID: B-003-0-25 — PAGE 1 OF 1

MATERIAL DESCRIPTION AND NOTES	ELEV. 633.4	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
ASPHALT, 24 INCHES, NO BASE OBSERVED	631.4	1 – 2																
STIFF TO VERY STIFF, DARK BROWN TO GRAY, **SILTY CLAY**, TRACE TO LITTLE GRAVEL, SOME SAND, DAMP TO MOIST		2	32 8 7	23	33	SS-1A	-	-	-	-	-	-	-	-	-	-	UCF (V)	
		2 – 3				SS-1B	-	-	-	-	-	-	-	-	-	4	A-6b (V)	
		3 – 4	8 3 5	12	73	SS-2	2.00	-	-	-	-	-	-	-	-	17	A-6b (V)	
		5	2 3 4	11	80	SS-3	1.75	5	5	25	24	41	34	17	17	21	A-6b (9)	
	625.9	6 – 7 W 626.0 EOB	4 4 4	12	73	SS-4	1.75	12	5	16	25	42	38	19	19	27	A-6b (10)	

GRADATION (%): GR, CS, FS, SI, CL; ATTERBERG: LL, PL, PI

NOTES: BORING COORDINATE ESTIMATED USING PHONE GPS. ELEVATION ESTIMATED USING GOOGLE EARTH.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: ASPHALT PATCH; TREMIED CEMENT/BENTONITE GROUT

GEOTECHNICAL PROFILE - CULVERT
BORING LOG B-003-0-25

Unconsolidated Undrained Triaxial Compression
ASTM D 2850

Project Name 2F_WOO-23-20.83
Source B-001-0-25, 6.8'-7.3'
Description Lean Clay (CL), gray, moist, soft to firm
Specimen Type Intact

Project No. 175578434
Lab ID 844
Test ID 844-A

Date Received 06/13/2025
Date Tested 07/01/2025

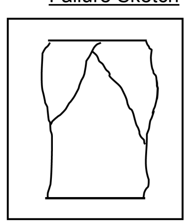
Specific Gravity 2.70
ASTM D 854, Dry

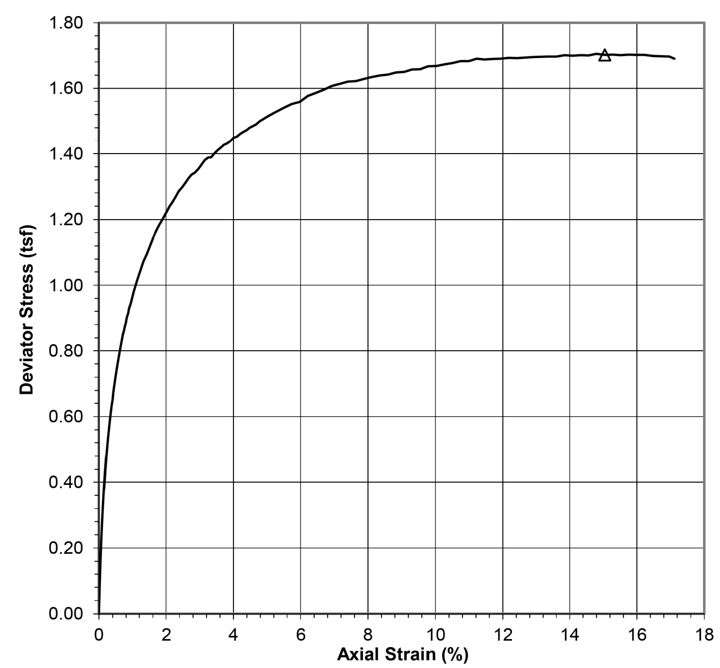
Liquid Limit
Plastic Limit
Plasticity Index

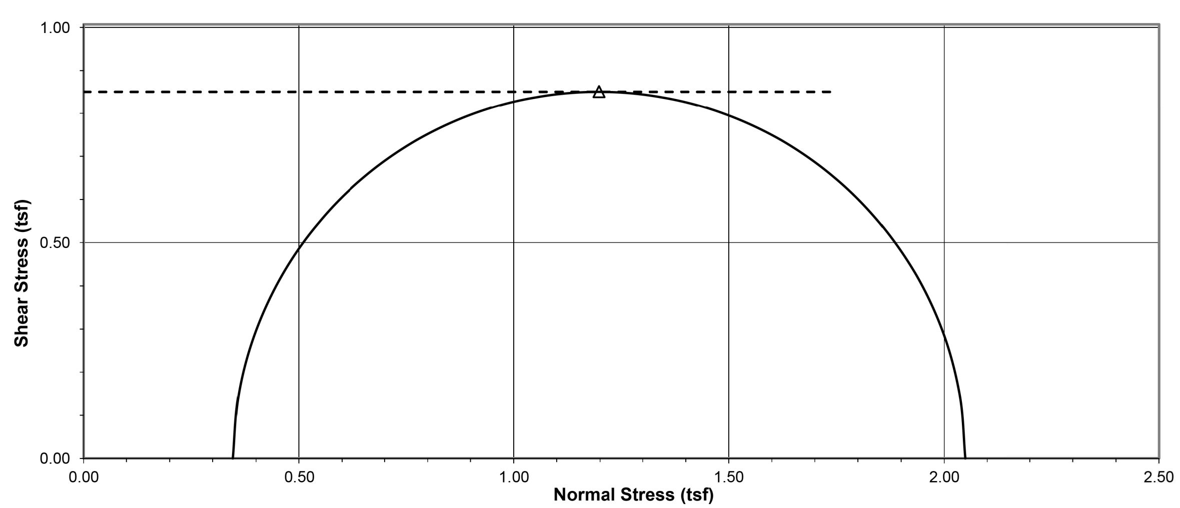
Target Test Parameters
Nominal Chamber Pressure (psi) 5
Actual Axial Strain Rate of Test (%/min) 0.952

At Unconsolidated Undrained Failure
Failure Criterion: 15% Axial Strain
Axial Strain (%) 15.05
Deviator Stress (tsf) 1.702
Minor Principal Stress, σ_3 (tsf) 0.346
Major Principal Stress, σ_1 (tsf) 2.048
Undrained Shear Strength, S_u (tsf) 0.851

Failure Sketch







Comments Classification data from B-001-0-25 SS-2:
Classification: A-7-6 (10)
%GR = 22; %CS = 5; %FS = 15; %SI =22; %CL = 36

Reviewed KG

Unconfined Compressive Strength of Cohesive Soil
ASTM D 2166

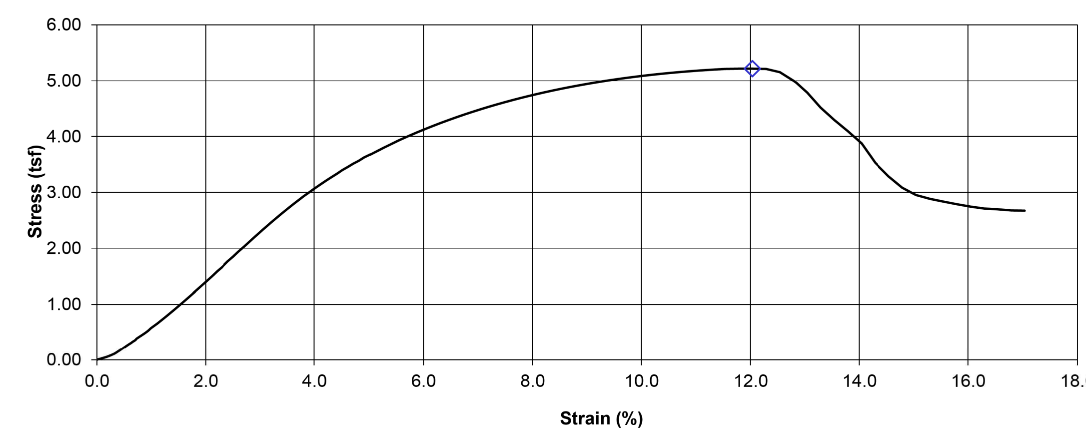
Project Name 2F_WOO-23-20.83
Project Number 175578434
Source B-002-0-25, 9.0'-9.7'
Lab ID 845
Visual Description Lean Clay with Sand (CL), brown, moist, firm
Recovered 0.7'
Test Interval 9.1' - 9.6'

Specimen Type: Undisturbed
LL 32
PL 16
PI 16
Date Extruded 06/20/2025
Date Tested 07/01/2025

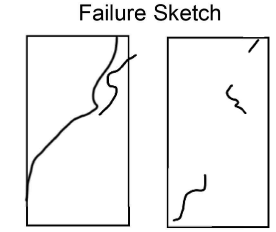
Initial Wet Density (pcf) 135.3
Initial Moisture Content (%) 15.3
Initial MC Taken Before Test, From Trimmings
Initial Dry Density (pcf) 117.4
At Test Moisture Content (%) N/A
At Test MC Taken N/A
At Test Dry Density (pcf) N/A
Specific Gravity N/A
Degree of Saturation (%) N/A
Average Height (in) 5.971
Average Diameter (in) 2.874
Height to Diameter Ratio 2.1

Unconfined Compressive Strength (tsf) 5.22
Undrained Shear Strength (tsf) 2.61
Strain at Maximum Stress (%) 12.0
Strain Rate to Failure (% / min.) 1.00

Stress vs. Strain



Failure Sketch



Pocket Penetrometer Reading (tsf) N/A
Torvane Reading (kg/cm^2) N/A

Comments
9.0'-9.6' - UW
9.6'-9.7' - saved
Classification data from same sample:
Classification: A-6b (10)
%GR = 7; %CS = 6; %FS = 14; %SI = 34' %CL = 39

Reviewed By RHB

GEOTECHNICAL PROFILE -CULVERT
LABORATORY TEST DATA

DESIGN AGENCY	Stantec, 10200 Alliance Road, Suite 300, Cincinnati, OH 45242, (513) 842-8200
DESIGNER	MSJ
REVIEWER	JRS 01-27-26
PROJECT ID	101335
SUBSET / TOTAL	0 / 0
SHEET / TOTAL	P.6 / 7

WOO-23-20.83

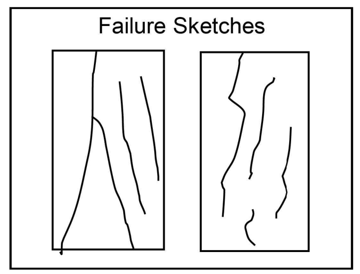
Uniaxial Compressive Strength of Intact Rock Core Specimens
ASTM D 7012, Method C

Project Name	WOO-23-20.83
Project Number	175578434
Lithology	Dolostone, gray, strong
Lab ID	UCR-1343
Hole Number	B-001-0-25
Depth (ft)	13.8'-14.2'
Date Received	08/14/2025
Temperature (°C)	22
Moisture Condition	As Prepared, Moist
Date Tested	08/29/2025
Side Planeness	N/A
Perpendicularity	N/A
End Planeness	N/A
Parallelism	N/A
Height (in)	4.585
Diameter (in)	1.972
Area (in^2)	3.054
Wet Unit Weight (pcf)	163.5
Dry Unit Weight (pcf)	N/A
Moisture Content (%)	N/A

Dimensions were not confirmed.

Loading Rate (lbf/sec)	104
Peak Load (lbf)	22740
Failure Type	Cone and Split
Compressive Strength (psi)	7450
Compressive Strength (psf)	1072800
Compressive Strength (tsf)	536

Failure Sketches



Comments Fragile nature of specimen inhibited preparation, required capping of ends with Hydro-Stone. Dimensional tolerances were not confirmed.

CORE PREP

POST TEST

Reviewed By REL

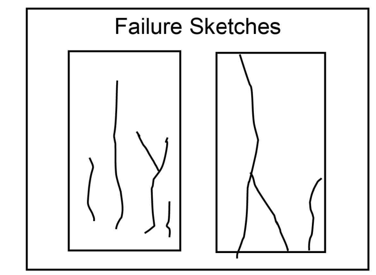
Uniaxial Compressive Strength of Intact Rock Core Specimens
ASTM D 7012, Method C

Project Name	WOO-23-20.83
Project Number	175578434
Lithology	Dolostone, gray, strong
Lab ID	UCR-1344
Hole Number	B-002-0-25
Depth (ft)	13.5'-13.9'
Date Received	08/14/2025
Temperature (°C)	22
Moisture Condition	As Prepared, Moist
Date Tested	08/29/2025
Side Planeness	N/A
Perpendicularity	N/A
End Planeness	N/A
Parallelism	N/A
Height (in)	4.785
Diameter (in)	1.957
Area (in^2)	3.007
Wet Unit Weight (pcf)	154.9
Dry Unit Weight (pcf)	N/A
Moisture Content (%)	N/A

Dimensions were not confirmed.

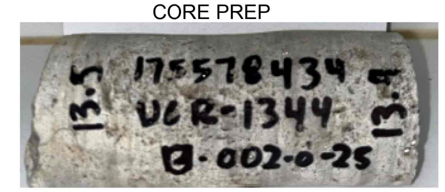
Loading Rate (lbf/sec)	71
Peak Load (lbf)	15760
Failure Type	Cone and Split
Compressive Strength (psi)	5240
Compressive Strength (psf)	754560
Compressive Strength (tsf)	377

Failure Sketches

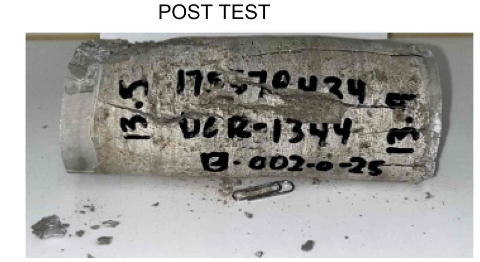


Comments Fragile nature of specimen inhibited preparation, required capping of ends with Hydro-Stone. Dimensional tolerances were not confirmed.

CORE PREP



POST TEST



Reviewed By REL

GEOTECHNICAL PROFILE -CULVERT
LABORATORY TEST DATA

DESIGN AGENCY
Stantec
10200 Alliance Road, Suite 300
Cincinnati, OH 45242
(513) 842-8200

DESIGNER MSJ
REVIEWER JRS 01-27-26
PROJECT ID 101335
SUBSET 0 TOTAL 0
SHEET P.7 TOTAL 7

WOO-23-20.83

MODEL: ll398ISheet PAPERSIZE: 17x11 (in.) DATE: 1/27/2026 TIME: 2:29:07 PM PLTDRV: OHDOT_PDF.pltcfg PENTBL: OHDOT_Pen.tbl USER: Matt.Jennings@stantec.com WORKSPACE: OHDOTCEv02 WORKSET: 101335 PRODUCT: OpenRoadsDesigner 24.00.02.25
pw:\\ohiodot-pw.bentley.com:ohiodot-pw-02\Documents\01 Active Projects\District 02\Wood\101335\402-Engineering_Stantec\Geotechnical\Sheets\101335_ZD002.dgn

Appendix B Culvert Foundation Calculations

Bearing Resistance of Rock

Using AASHTO 2024 LRFD 10.6.3.1.2a

Performed by: James Samples 5/8/2026
Reviewed by: Jim Swindler 5/19/2026

WOO-23-20.83

Using data from B-001-0-25 and B-002-0-25
RMR from AASHTO LRFD 8th edition

RMR		46	sum of relative ratings
cohesion (c)=	104*RMR	4700	psf
friction angle=	5+(RMR/2)	28	degrees
γ=		159	pcf

Nc=	25.8	Cwq=	0.82
Nq=	14.7	Cwγ=	0.5
Nγ=	16.7		

Culvert Foundation			Wingwall Foundation		
Shape factors			Shape factors		
Bearing width (B)	6	ft	Bearing width (B)	7	ft
Bearing length (L)	35	ft	Bearing length (L)	20	ft
Bearing Depth (D)	2.8	ft	Bearing Depth (D)	2.8	ft
Sc=	1.09767442		Sc=	1.199419	
Sq=	1.09115019		Sq=	1.186098	
Sγ=	0.93142857		Sγ=	0.86	
Ncm=	28.32		Ncm=	30.945	
Nqm=	16.0399078		Nqm=	17.43565	
Nγm=	15.5548571		Nγm=	14.362	
qn=	142669.426 psf	142.7 ksf	qn=	155802.9 psf	155.8 ksf

Resistance factor (2024 LRFD Table 10.5.5.2.2-1): 0.45 for footings on rock (Culvert Foundation)

Resistance factor (2024 LRFD Table 10.5.5.2.2-1): 0.45 for footings on rock (Wingwall Foundation)

Culvert Foundation			Wingwall Foundation		
qr=	64201.2418	psf	qr=	70111.28	psf
	64.2	ksf		70.1	ksf

key
- lookup from within document
- pull from bearing design
- pull from lab results
- in sheet calculation

Table 10.4.6.4-1—Geomechanics Classification of Rock Masses

	Parameter		Ranges of Values						
1	Strength of intact rock material	Point load strength index	>175 ksf	85–175 ksf	45–85 ksf	20–45 ksf	For this low range, uniaxial compressive test is preferred		
		Uniaxial compressive strength	>4320 ksf	2160–4320 ksf	1080–2160 ksf	520–1080 ksf	215–520 ksf	70–215 ksf	20–70 ksf
	Relative Rating		15	12	7	4	2	1	0

	Parameter					
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	3–10 ft	1–3 ft	2 in.–1 ft	<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 in. • Hard joint wall rock	• Slightly rough surfaces • Separation <0.05 in. • Soft joint wall rock	• Slicken-sided surfaces or • Gouge <0.2 in. thick or • Joints open 0.05–0.2 in. • Continuous joints	• Soft gouge >0.2 in. thick or • Joints open >0.2 in. • Continuous joints
	Relative Rating	25	20	12	6	0

	Parameter					
5	Groundwater conditions (use one of the three evaluation criteria as appropriate to the method of exploration)	Inflow per 30 ft tunnel length	None	<400 gal./hr.	400–2000 gal./hr.	>2000 gal./hr.
		Ratio = joint water pressure/ major principal stress	0	0.0–0.2	0.2–0.5	>0.5
		General Conditions	Completely Dry	Moist only (interstitial water)	Water under moderate pressure	Severe water problems
	Relative Rating		10	7	4	0

Bearing Capacity by AASHTO 2020 LRFD 10.6.3.1.2a

$$q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + 0.5\gamma \ BN_{\gamma m} C_{w\gamma} \quad (10.6.3.1.2a\text{-}1)$$

in which:

$$N_{cm} = N_c s_c i_c \quad (10.6.3.1.2a\text{-}2)$$

$$N_{qm} = N_q s_q d_q i_q \quad (10.6.3.1.2a\text{-}3)$$

$$N_\gamma m = N_\gamma s_\gamma i_\gamma \quad (10.6.3.1.2a\text{-}4)$$

Assume load inclination factors are equal to 1.0, based on commentary in Section 10.3.1.2a.

Assume depth correction factor, d_q, is 1.0 based on Section 10.6.3.1.2a.

Table 10.6.3.1.2a-1—Bearing Capacity Factors N_c (Prandtl, 1921), N_q (Reissner, 1924), and N_γ (Vesic, 1975)

ϕ_f	N_c	N_q	N_γ	ϕ_f	N_c	N_q	N_γ
0	5.14	1.0	0.0	23	18.1	8.7	8.2
1	5.4	1.1	0.1	24	19.3	9.6	9.4
2	5.6	1.2	0.2	25	20.7	10.7	10.9
3	5.9	1.3	0.2	26	22.3	11.9	12.5
4	6.2	1.4	0.3	27	23.9	13.2	14.5
5	6.5	1.6	0.5	28	25.8	14.7	16.7
6	6.8	1.7	0.6	29	27.9	16.4	19.3
7	7.2	1.9	0.7	30	30.1	18.4	22.4
8	7.5	2.1	0.9	31	32.7	20.6	26.0
9	7.9	2.3	1.0	32	35.5	23.2	30.2
10	8.4	2.5	1.2	33	38.6	26.1	35.2
11	8.8	2.7	1.4	34	42.2	29.4	41.1
12	9.3	3.0	1.7	35	46.1	33.3	48.0
13	9.8	3.3	2.0	36	50.6	37.8	56.3
14	10.4	3.6	2.3	37	55.6	42.9	66.2
15	11.0	3.9	2.7	38	61.4	48.9	78.0
16	11.6	4.3	3.1	39	67.9	56.0	92.3
17	12.3	4.8	3.5	40	75.3	64.2	109.4
18	13.1	5.3	4.1	41	83.9	73.9	130.2
19	13.9	5.8	4.7	42	93.7	85.4	155.6
20	14.8	6.4	5.4	43	105.1	99.0	186.5
21	15.8	7.1	6.2	44	118.4	115.3	224.6
22	16.9	7.8	7.1	45	133.9	134.9	271.8

Table 10.6.3.1.2a-3—Shape Correction Factors s_c, s_γ, s_q

Factor	Friction Angle	Cohesion Term (s_c)	Unit Weight Term (s_γ)	Surcharge Term (s_q)
Shape Factors s_c, s_γ, s_q	$\phi_f = 0$	$1+\left(\frac{B}{5L}\right)$	1.0	1.0
	$\phi_f > 0$	$1+\left(\frac{B}{L}\right)\left(\frac{N_q}{N_c}\right)$	$1-0.4\left(\frac{B}{L}\right)$	$1+\left(\frac{B}{L}\tan\phi_f\right)$

Table 10.6.3.1.2a-2—Coefficients C_{wq} and $C_{w\gamma}$ for Various Groundwater Depths

D_w	C_{wq}	$C_{w\gamma}$
0.0	0.5	0.5
D_f	1.0	0.5
$>1.5B + D_f$	1.0	1.0

Groundwater depth is between the surface and the depth of the foundation, so Cwq is interpolated at the lowest depth encountered during drilling (9 ft).

WOO-23-20.83 Bedrock Scour Parameter Determination

From HEC-18 analysis, K = 488

From ODOT GDM Section 1302.1.3:

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

Where:

τ_c = Critical shear stress (Pa)

ρ = Mass density of water (1000 kg/m^3)

K = Erodibility Index (dim.)

τc=	5591.386	Pa	psf=	0.020885 *Pa
	116.7761	psf		

Erosion Category (EC)

From ODOT GDM Section 1302.2:

For bedrock,

$$EC = 1.2(1.83333 + \text{Log}(S_v/2.5))$$

where:

S_v = average vertical spacing between horizontal discontinuities, in mm

$1 \leq EC \leq 6$

Sv = 4.5

EC= 2.506323

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 4.21. 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.					

The Erodibility Index is identical to Kirsten's excavatability index which is used to characterize rock for determining the power requirements of earth-moving equipment that can rip the subject material. The index is expressed as the product of four parameters:

$$K = (M_s)(K_b)(K_d)(J_s) \quad = 35*14*0.75*1.09 = 488.2 \tag{4.17}$$

where:

K = Erodibility Index
M_s = Intact rock mass strength parameter
K_b = Block size parameter
K_d = Shear strength parameter
J_s = Relative orientation parameter

The values of the parameters are determined by making use of tables and equations published by Annandale (1995) and Kirsten (1982) as provided in Tables 4.22 through 4.26 below. The intact rock mass strength parameter M_s is related to the unconfined compressive strength as shown in Table 4.22.

Joint spacing and the number of joint sets within a rock mass determines the value of K_b for rock. Joint spacing is estimated from borehole data by means of the rock quality designation (RQD) and the number of joint sets is represented by the joint set number (J_n). The values of the joint set numbers (J_n) are found in Table 4.23. As seen in the table, J_n is a function of the number of joint sets, ranging from rock with no or few joints (essentially intact rock), to rock formations consisting of one to more than four joint sets. The classification accounts for rock that displays random discontinuities in addition to regular joint sets. Random joint discontinuities are discontinuities that do not form regular patterns. For example, rock with two joint sets and random discontinuities is classified as having two joint sets plus random. Having determined the values of RQD and J_n, K_b is calculated as:

$$K_b = \frac{RQD}{J_n} \quad = 70/5 = 14 \text{ (using average RQD value from logs)} \tag{4.18}$$

Performed by: J. Samples 7/24/2023
Checkec by: Eric Kistner 7/26/2023

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 6345 psi = 43.7 MPa	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

The discontinuity or shear strength number (K_d) is the parameter that represents the relative strength of discontinuities in rock. In rock, it is determined as the ratio between joint wall roughness (J_r) and joint wall alteration (J_a), where J_r represents the degree of roughness of opposing faces of a rock discontinuity, and J_a represents the degree of alteration of the materials that form the faces of the discontinuity. Alteration relates to amendments of the rock surfaces, for example weathering or the presence of cohesive material between the opposing faces of a joint. Values of J_r and J_a can be found in Tables 4.24 and 4.25. The values of K_d calculated with the information in these tables change with the relative degree of resistance offered by the joints. Increases in resistance are characterized by increases in

Performed by: J. Samples 7/24/2023
Checkec by: Eric Kistner 7/26/2023

the value of K_d. The shear strength of a discontinuity is directly proportional to the degree of roughness of opposing joint faces and inversely proportional to the degree of alteration.

$$K_d = \frac{J_r}{J_a} = 1.5/2 = 0.75 \tag{4.19}$$

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.			
	Joint Alteration Number (J_a) for Joint Separation (mm)		
Description of Gouge	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.

Performed by: J. Samples 7/24/2023
Checkec by: Eric Kistner 7/26/2023

Relative orientation, in the case of rock, is a function of the relative shape of the rock and its dip and dip direction relative to the direction of flow. The relative orientation parameter J_s represents the relative ability of earth material to resist erosion due to the structure of the ground. This parameter is a function of the dip and dip direction of the least favorable discontinuity (most easily eroded) in the rock with respect to the direction of flow, and the shape of the material units. These two variables (orientation and shape) affect the ease by which the stream can penetrate the ground and dislodge individual material units.

Conceptually, the function of the relative orientation parameter J_s incorporating shape and orientation is as follows. If rock is dipped against the direction flow, it will be more difficult to scour the rock than when it is dipped in the direction of flow. When it is dipped in the direction of flow, it is easier for the flow to lift the rock, penetrate underneath and remove it. Rock that is dipped against the direction of flow will be more difficult to dislodge. The shape of the rock, represented by the length to width ratio *r*, impacts the erodibility of rock in the following manner. Elongated rock will be more difficult to remove than equi-sided blocks of rock. Therefore, large ratios of *r* represent rock that is more difficult to remove because it represents elongated rock shapes. Values of the relative orientation parameter J_s are provided in Table 4.26.

The material characteristics to quantify the Erodibility Index parameters are generally obtained from borehole data, field observation and testing, and laboratory testing (to obtain the unconfined compressive strength). Depending on the importance of the project, it is also possible to obtain parameter values by making use of geologic descriptions of the material [see tables of Annandale (1995)]. Larger values of the Erodibility Index value K indicate greater resistance to erosion (see Section 7.13).

4.8 SUMMARY

An understanding of soil and rock property classification is important because it provides a basis for describing common engineering properties of geomaterials and how different materials may be expected to behave under various environmental conditions and loads. As noted in Sections 4.2 and 4.3, the physical processes causing erosion of different types of soils and rock vary based on the nature of the material. Various methods for estimating and/or measuring erodibility characteristics also depend of the nature of the material being considered.

The characteristics of soils and rock (the resisting materials) are important to estimating scour and erosion under different combinations of geotechnical and hydraulic conditions. While the most widely used equations for scour assume cohesionless materials such as sand or gravel (see Chapters 6, 7, and 8), some guidance is available for estimating scour components in cohesive soils and rock. Reference is suggested to the following sections:

Section 6.7	Contraction Scour in Cohesive Materials
Section 6.8	Contraction Scour in Erodible Rock
Section 7.12	Pier Scour in Cohesive Materials
Section 7.13	Pier Scour in Erodible Rock

Performed by: J. Samples 7/24/2023
Checkec by: Eric Kistner 7/26/2023

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

Performed by: J. Samples 7/24/2023
Checkec by: Eric Kistner 7/26/2023

Appendix C Subgrade Analysis

OHIO DEPARTMENT OF TRANSPORTATION

OFFICE OF GEOTECHNICAL ENGINEERING

PLAN SUBGRADES
Geotechnical Design Manual Section 600

WOO-23-20.83
101335

Culvert Replacement at mile mark 20.83 of US 23 in Wood County, Ohio

Stantec Consulting

Prepared By: James Samples
Date prepared: Friday, May 8, 2026

Stantec Consulting
10200 Alliance Road
Suite 300
Cincinnati, OH 45242
(513) 842-8204
james.samples@stantec.com

NO. OF BORINGS: 1

NO. OF DCPS: 0

Add DCP Test Data Worksheets

#	Boring ID	Alignment	Station	Offset	Dir	Drill Rig	ER	Boring EL.	Proposed Subgrade EL	Cut Fill
1	B-003-0-25	US 23	1098+68	16	Lt	CME 45#2T (814)	90	633.4	631.4	2.0 C

OHIO DEPARTMENT OF TRANSPORTATION

Subgrade Analysis

V. 14.81 7/21/2025

#	Boring	Sample	Sample Depth		Subgrade Depth		Standard Penetration		HP (tsf)	Physical Characteristics						Moisture		Ohio DOT		Sulfate Content (ppm)	Problem		Excavate and Replace (Item 204)		Recommendation (Enter depth in inches)
			From	To	From	To	N_{60}	N_{60L}		LL	PL	PI	% Silt	% Clay	P200	M_C	M_{OPT}	Class	GI		Unsuitable	Unstable	Unsuitable	Unstable	
1	B	SS-1	1.5	3.0	-0.5	1.0	23									4	16	A-6b	16						
	003-0	SS-2	3.0	4.5	1.0	2.5	12		2							17	16	A-6b	16						
	25	SS-3	4.5	6.0	2.5	4.0	11		1.75	34	17	17	24	41	65	21	16	A-6b	9						
		SS-4	6.0	7.5	4.0	5.5	12	11	1.75	38	19	19	25	42	67	27	16	A-6b	10						

OHIO DEPARTMENT OF TRANSPORTATION

Subgrade Analysis

V. 14.81 7/21/2025

PID: 101335

County-Route-Section: WOO-23-20.83
No. of Borings: 1

Geotechnical Consultant: Stantec Consulting
Prepared By: James Samples
Date prepared: 5/8/2026

Chemical Stabilization Options		
320	Rubblize & Roll	No
206	Cement Stabilization	Option
	Lime Stabilization	Option
206	Depth	12"

Excavate and Replace Stabilization Options	
Global Geotextile Average(N60L): Average(HP):	 12" 12"
Global Geogrid Average(N60L): Average(HP):	 0" 0"

Design CBR	5

% Samples within 3 feet of subgrade			
$N_{60} \leq 5$	0%	HP ≤ 0.5	0%
$N_{60} < 12$	25%	0.5 < HP ≤ 1	0%
$12 \leq N_{60} < 15$	25%	1 < HP ≤ 2	50%
$N_{60} \geq 20$	25%	HP > 2	0%
M+	0%		
Rock	0%		
Unsuitable Soil	0%		

Excavate and Replace at Surface	
Average	0"
Maximum	0"
Minimum	0"

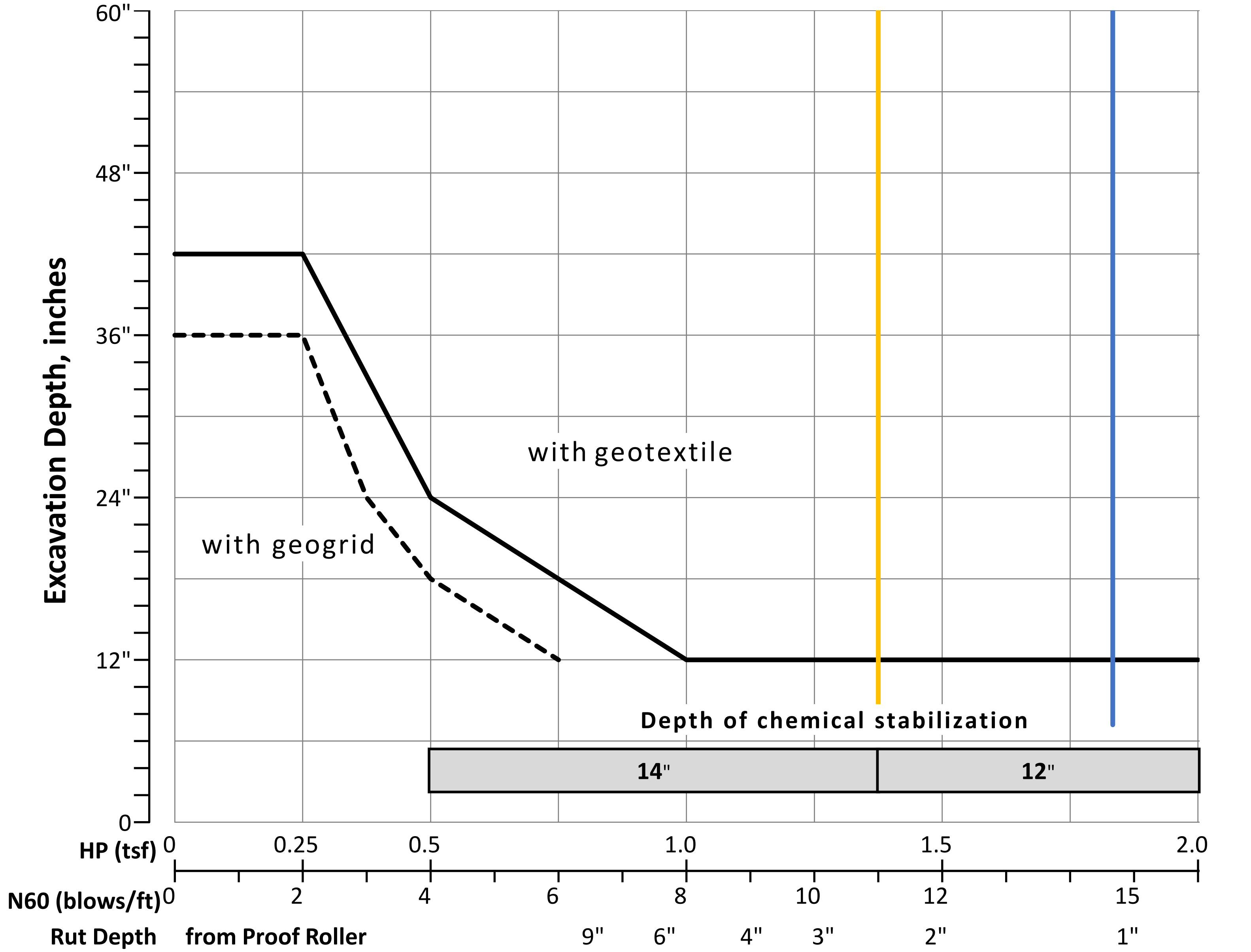
% Proposed Subgrade Surface	
Unstable & Unsuitable	0%
Unstable	0%
Unsuitable (Soil & Rock)	0%

	N_{60}	N_{60L}	HP	LL	PL	PI	Silt	Clay	P 200	M_C	M_{OPT}	GI
Average	15	11	1.83	36	18	18	25	42	66	17	16	13
Maximum	23	11	2.00	38	19	19	25	42	67	27	16	16
Minimum	11	11	1.75	34	17	17	24	41	65	4	16	9

Classification Counts by Sample

ODOT Class	UCF	Rock	A-1-a	A-1-b	A-2-4	A-2-5	A-2-6	A-2-7	A-3	A-3a	A-4a	A-4b	A-5	A-6a	A-6b	A-7-5	A-7-6	A-8a	A-8b	Totals
Count	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	4
Percent	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%
% Rock|Granular|Cohesive	0%	0%	0%									100%								100%
Surface Class Count	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	3
Surface Class Percent	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%

Fig. 600-1 – Subgrade Stabilization



OVERRIDE TABLE

Calculated Average	New Values	Check to Override
1.83	0.50	☐ HP
11.00	6.00	☐ N60L